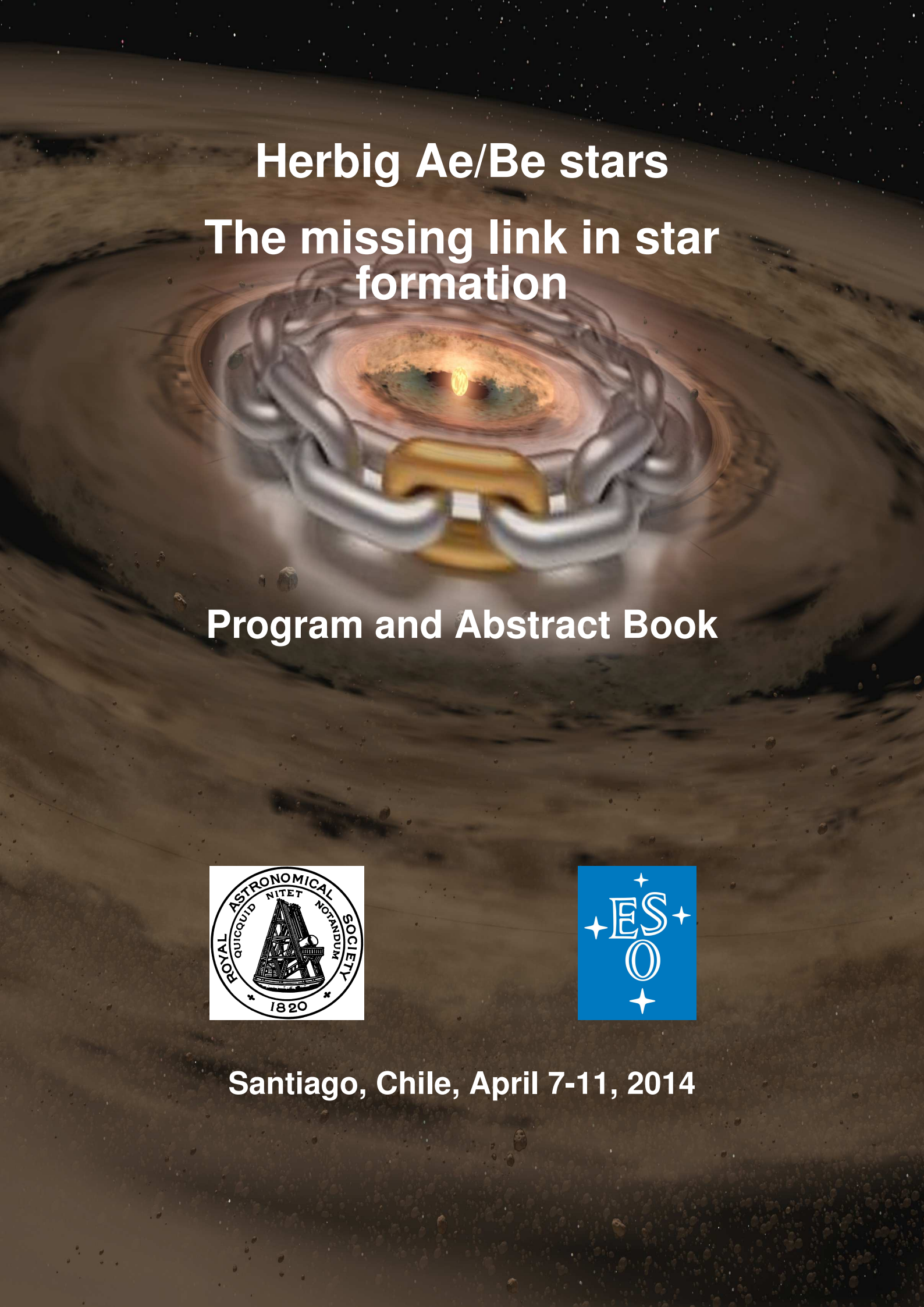
Herbig Ae/Be stars

The missing link in star formation



Program and Abstract Book

Santiago, Chile, April 7-11, 2014

The ESO 2014 Herbig Ae/Be workshop will take place in commemoration of the life and works of George H. Herbig (January 2, 1920 – October 12, 2013).

Program

Monday, April 7

Time	Speaker	Title
08:30–08:40	W.J. de Wit	Welcome
08:40–09:20	R. Waters	Herbig Ae/Be stars in perspective
"Overture": Star formation		
09:20–10:00	K. Kratter	Introduction to the theory of star formation
10:00–10:40	M. Beltran	Observational perspective of the youngest phases of intermediate mass stars
10:40–11:10	Coffee Break	
SESSION 1: Inner disk - accretion tracers dynamics		
11:10–11:50	S. Brittain	High resolution spectroscopy and spectro-astrometry of HAeBes
11:50–12:10	J. Ilee	Investigating inner gaseous discs around Herbig Ae/Be stars
12:10–12:30	J. Fairlamb	Large Spectroscopic Investigation of Over 90 Herbig Ae/Be Objects with X-Shooter
12:30–12:50	Poster presentations (1st half)	
12:50–14:30	Lunch	
14:30–15:10	C. Dougados	Accretion-ejection processes in Herbig Ae/Be stars
15:10–15:30	A. Aarnio	Herbig Ae/Be spectral line variability
15:30–15:50	P. Ábrahám	Time-variable phenomena in Herbig Ae/Be stars
15:50–16:10	Poster presentations (2nd half)	
16:10–16:40	Poster session with tea	
16:40–17:00	C. Schneider	High energy emission from the HD 163296 jet: Clues to magnetic jet launching
17:00–17:20	I. Mendigutia	Characterizing accretion of Herbig Ae/Be stars from X-Shooter/VLT
17:20–17:40	P. Woitke	A Prototype Protoplanetary Disks for Modelling: HD 163296

Tuesday, April 8

Time	Speaker	Title
SESSION 1B: Inner disk - accretion/ejection - star interaction and B-field		
09:00–09:40	S. Kraus	Interferometric view of HAeBe
09:40–10:00	J. Vink	Linear line spectropolarimetry of Herbig Ae/Be stars
10:00–10:20	R. Ramirez	A Spectro-Astrometric study of bracket gamma emission in the HAeBe star HD 100546
10:20–11:00	Poster session with coffee	
11:00–11:40	E. Alecian	Surface, rotation and interior of HAeBe stars
11:40–12:00	G. Hussain	Magnetism in intermediate mass T Tauri stars
12:00–12:20	M. Reiter	Powerful jets from intermediate-mass protostars in Carina
12:20–12:40	T. Ray	Cosmic Rays from Stellar Birth
12:40–14:30	Lunch	
SESSION 2A: Disk structure - statics		
14:30–15:10	G. Lodato	Dust dynamics in self-gravitating discs
15:10–15:30	W.F. Thi	First results of PIONIER-VLTI survey of Herbig AeBe
15:30–15:50	J. Kluska	Imaging the dust sublimation region of Herbig Ae/Be stars with VLTI/PIONIER
15:50–16:30	Poster session with tea	
16:30–17:10	R. van Boekel	Dust processing in HAeBe disks
17:10–17:30	N. Jamialahmadi	Resolving the inner disk at mid-infrared wavelengths surrounding Herbig star MWC480
17:30–17:50	J. Menu	A mid-infrared interferometric survey of the disks around intermediate-mass young stars

Wednesday, April 9

Time	Speaker	Title
SESSION 2B: Disk structure - outer disk		
09:00–09:30	Th. Henning	The life and works of George Herbig
09:30–09:50	G. Meeus	Herschel's view of the atomic and molecular gas content of Herbig Ae/Be discs
09:50–10:10	R. Bertelsen	Tracing the planet forming regions with CO
10:10–10:30	Y. Wu	Studying Circumstellar environment of intermediate–mass stars
10:30–11:10	Coffee Break	
11:10–11:30	F. Ménard	Warm gas in 12 Herbig Ae/Be disks: the CO ladder probed from 50 to 500 K
11:30–11:50	G. van der Plas	Warm CO gas as a tracer of the inner 50 AU of protoplanetary disks
11:50–12:10	K. Maaskant	Characterization of gas and dust in the gaps of Herbig Ae/Be stars
12:10–13:30	Lunch	
13:30	Departure for excursion	

Thursday, April 10

Time	Speaker	Title
09:00–09:40	C.A. Grady	The HAeBe outer disk in the UV, optical and IR
09:40–10:20	V. Piétu	Introduction to chemistry in HAeBe disks
10:20–10:40	D. Fedele	The role of photoprocesses in the chemical composition of Herbig AeBe disks
10:40–11:10	Coffee Break	
11:10–11:30	G. Sandell	LkHa 101 a Herbig B0e star with a disk
11:30–11:50	H. Zinnecker	SOFIA observations of Herbig Ae/Be stars
11:50–12:30	Poster session	
12:30–13:30	Lunch	
SESSION 3A: Transition disks - debris disks - disk lifetimes		
13:30–14:10	M. Wyatt	From primordial to debris: the evolution of HAeBe disks
14:10–14:30	A. Kóspál	ALMA observations of the gas and dust in the hybrid debris disk of the 30 Myr old star HD 21997
14:30–14:50	M. Kunitomo	Photoevaporating Disk Dispersal around Intermediate-Mass Stars
14:50–15:10	Tea Break	
15:10–15:50	G. Duchene	Herbig AeBe stars and multiplicity
15:50–16:10	C. Yasui	Rapid Evolution of the Innermost Dust Disk of Protoplanetary Disks Surrounding Intermediate-mass Stars
16:10–16:30	G. Beccari	Disk lifetimes in open clusters
16:45	Departure for conference dinner	

Friday, April 11

Time	Speaker	Title
SESSION 3B: (Signs of) Planet formation		
09:30–10:10	S. Quanz	The Herbig Ae/Be star opportunity: Deciphering planet formation around intermediate mass star with empirical data
10:10–10:30	S. Pérez	Inferring protoplanetary masses from resolved ALMA molecular gas emission
10:30–10:50	S. Casassus	Accretion flows across the protoplanetary gap of HD142527
10:50–11:20	Coffee Break	
11:20–11:40	V. Christiaens	Spiral arms in the disk of HD 142527
11:40–12:00	F. Ménard	Dust and Gas properties in the dust trap of the disk of HD 142527
12:00–12:20	N. van der Marel	Planet formation in action: the role of dust trapping in transitional disks
12:20–12:40	C. Pinte	Constraining the structure of the transition disk HD 135344B
12:40–14:30	Lunch	
"Finale": Summary		
14:30	N. Calvet	Workshop summary

Abstracts

Herbig Ae/Be spectral line variability

by Alicia Aarnio

Our group has carried out a multi-year spectroscopic survey, observing $>$50 Herbig Ae/Be stars. I will present multi-epoch spectra for $\sim$30 of these objects: these observations are separated by at least one day, but most are months or years apart. All of these objects were included in our survey due to available complementary interferometric data which we use to constrain system parameters (inclination, inner disk radii) in our radiative transfer models. In addition to multi-year observations, for two targets we have high-cadence ($\sim$minutes) time series spectra. I will summarize broad trends in our multi- epoch spectra, and then discuss in detail the two high-cadence observations and what our radiative transfer modeling results indicate is causing their observed line profile variability.

Notes:

Time-variable phenomena in Herbig Ae/Be stars

by Péter Ábrahám

Circumstellar disks around young stars have long been considered as quasi- static structures, which evolve only on the timescale of millions of years. However, more and more observations indicate that Herbig stars are variable in a wide wavelength range, from the optical to the thermal infrared. The timescale of the variability carries information on the radial location of the changing component, while its wavelength-dependence is related to the physical mechanism. One type of variability pattern, the "UXor-phenomenon", consists of random or quasi-periodic eclipse-like fadings. In UXors, passing dust clouds in a nearly edge-on circumstellar disk obscure the central star, causing time-variable extinction along the line-of-sight. We carried out a simultaneous optical-infrared monitoring program of a sample of UXor stars by combining ground-based optical/near-infrared and Spitzer mid-infrared observations. In several objects, the light curves exhibited characteristic UXor fadings, whose wavelength dependence could be determined also at 3.6 and 4.5 micrometer with high precision. Beside the UXor-type events, we also recorded annual variations, whose color variations could be compared with those of the short fadings. Another type of variability is related to changes in the thermal emission of circumstellar disks. We studied mid-infrared spectral variability on decadal timescale, by comparing low-resolution spectroscopic data obtained by ISO and by Spitzer some 10 years apart. We found that a significant fraction of our studied 33 Herbig Ae/Be stars exhibited spectral variations. The observed wavelength dependence of the infrared flux changes can be related to different physical processes causing the variability. The described projects are attempts to use variability as a direct and novel source of information on the dynamical processes in the disks of Herbig Ae/Be stars.

Notes:

Surface, rotation and interior of HAeBe stars

by Evelyne Alecian

The HAeBe stars are the pre-main sequence (PMS) progenitors of the A/B stars. As they evolve along the PMS, their interiors undergo substantial changes, while their surfaces are strongly interacting with their environment. This PMS evolution can therefore have a strong impact on the final rotation distribution and magnetic properties of the A/B stars, as well as on the development of the chemically peculiarities observed at the surface of many A/B stars. In this presentation I will review the results of the recent studies that have been conducted on the HAeBe stars that helped in improving our understanding in the surface properties of the HAeBe and A/B stars.

Notes:

Disk lifetimes in star-burst clusters

by Giacomo Beccari

Current planet formation theories are bound to comply with the observational constraint that protoplanetary disks have lifetime of $\sim$3 Myr. This timescale is based on spectroscopic studies of objects accreting matter from a circumstellar disk around pre-main sequence stars (PMS) located in low-density, nearby (d$<$1-2kpc) star forming regions. These objects do not reflect the conditions in place in the massive starburst clusters where most of star formation occurs in the universe. Using a new robust method to indentify PMS objects through their photometric excess in the Halpha band, we have studied with the HST and ground based facilities the PMS population several starburst clusters, namely NGC3603 in the Milky Way and several clusters in the Carina Nebula, 30 Doradus and the surrounding regions in the Large Magellanic Cloud and NGC 346 and NGC 602 in the Small Magellanic Cloud. We discovered there a wide spread of ages (0.5 to 20 Myr) for PMS stars, clearly showing that accretion from circumstellar disks is still going on well past 10 Myr. In addition, the age and the accreting state of many PMSs has been recenltly confirmed spectroscopically through the study of Li absorption and Halpha emission lines in the candidate PMS stars in the Carina region. This finding challenges our present understanding of protoplanetary disk evolution, and can imply a new scenario for the planet formation mechanism and of star clusters formation in general.

Notes:

Observational perspective of the youngest phases of intermediate mass stars

by Maria Beltran

Intermediate-mass protostars are the long-forgotten actors in the star formation scenario. Although their pre-main sequence evolution should be similar to those of low-mass protostars, they share many characteristics with their high-mass stars counterparts. In this presentation, I will describe the observational properties of these intermediate-mass young objects and will put them in context by contrasting them to those of low-and high-mass protostars.

Notes:

First results of PIONIER-VLTI survey of Herbig AeBe

by Jean-Philippe Berger, Wing-Fai Thi

PIONIER at VLTI provides sufficient sensitivity and precision to resolve the inner disk structure (e.g astronomical unit scale) of most of the brightest Herbig AeBes. It therefore offers a remarkable overlap with current ALMA and adaptive optics Herbig AeBe samples. We will present the preliminary results of this survey that allowed us to observe 54 stars and resolve in most of cases their near-infrared emission. We are therefore in a position to study statistically the morphology and temperature of the disk inner rims and relate these to the properties of the central stars, considerations on the disk structure and dust composition and the large scale environment.

Notes:

Tracing the planet forming regions with CO

by Rosina Bertelsen

Infrared CO ro-vibrational emission lines are promising tracers of the geometry and structure of protoplanetary disks. These lines are routinely detected in ground based observations of disks around Herbig or T Tauri stars and their line profiles reveal that they originate within a few 10 AU from the central stars. At high spectral resolution, these line profiles contain a wealth of physical, chemical, and kinematic information. For example holes or gaps due to planet formation can be directly traced in the line profiles of these CO ro- vibrational transitions. Observing CO ro-vibrational emission from the disks around HAeBes there is an apparent difference between flaring (group I) and flat disks (group II). There seems to be a lack of CO emission from small radii in flaring disks. It has been speculated that this lack could be due to the presence of gaps and that flaring disks are in fact disks with gaps. Previously, the small number of observed CO ro-vibrational datasets from sources with flared disks prevented any general conclusions to be drawn. We have developed methods and tools for investigating these lines by analyzing observed CO ro-vibrational lines from a disk with an inner gap (HD 100546) in the context of a disk model (ProDiMo), which we now apply to a wider sample. With CRIRES spectra of a sample of flaring disks around Herbig Ae/Be stars, covering the wavelength region where these CO ro-vibrational lines are detected (4.5-5. micron), we investigate the geometry of flaring disks around HAeBes. We derive the radial origin of the emission for our individual sources. We discuss the general trend for the CO ro-vibrational emission from the, now expanded, sample of flaring disks within the context of the existing SEDs of the sources. Furthermore, we compare and discuss the observed trends in the context of a series of general HAeBe models (ProDiMo) with stepwise geometry (removal of the gas from the inner regions).

Notes:

Dust processing in HAeBe disks

by Roy van Boekel

The dusty material makes up only $\sim$1% of the mass of molecular clouds and circumstellar disks, but is pivotal for planet formation and the energy budget and structure of the disk. The dust originates around evolved stars and initially has diverse properties, but during the long journey through the ISM it is homogenized. Once the dust enters the molecular cloud cores and in particular the high density, and sometimes high temperature, environment of the disk, its properties once again become diverse. In this talk the processes acting on and altering the dust are discussed, with focus on the observational diagnostics available to study them, and observational evidence for dust processing in HAeBe star disks.

Notes:

High resolution spectroscopy and spectro-astrometry of HAeBes

by Sean Brittain

In this talk we describe the kinds of things that can be learned about the inner disk surrounding Herbig Ae/Be stars from the use of high resolution near infrared spectroscopy and spectro-astrometry. We will show how these tools can identify signposts of planet formation and elucidate the mechanism by which HAeBe stars accrete. We will also highlight some of the artifacts that can complicate the interpretation of the data and discuss best practices for mitigating these effects. We will conclude with a brief discussion of the value of longterm monitoring of these systems.

Notes:

Accretion flows across the protoplanetary gap of HD142527

by Simon Casassus

The largest central cavities or radial gaps in protoplantary disks are thought to be sculpted by the formation of several planets, which channel material from the outer regions and so feed stellar accretion. Hence accretion flows are predicted across the gaps. However, Nature turned out not to fit so predictably in this scenario. With ALMA Cycle0 observations of the resolved gap in HD142527, we did find gap-crossing HCO+ flows, and diffuse CO gas inside the gap. The corresponding mass inflow rate is close to the observed stellar accretion. However, as I will show in this talk with the help of CO(6-5) data, these flows correspond to a general radial accretion at all azimuth, and are not confined to narrow accretion streams. Interestingly, the observed radial velocities are comparable to the Keplerian rotation, and much faster than expected from standard hydrodynamic simulations.

Notes:

Spiral arms in the disk of HD 142527

by Valentin Christiaens

In view of both the size of its gap and the previously reported asymmetries and near-infrared spiral arms, the transition disk of the Herbig Fe star HD 142527 constitutes a remarkable case study. The talk will focus on the morphology of the outer disk through ALMA observations of 12CO J=2-1, 12CO J=3-2 and 13CO J=2-1 lines. Both 12CO J=2-1 and 12CO J=3-2 show spiral features of different sizes. The innermost spiral arm (S1) is a radio counterpart of the first near- infrared spiral observed by Fukagawa et al. (2006), but it is shifted radially outward. However, the most conspicuous CO spiral arm (S2) lies at the outskirts of the disk and had not been detected before. It corresponds to a cold density structure, with brightness temperature of 14 +- 1 K and outstanding in the 12CO J=2-1 peak-intensity map, but faint in 12CO J=3-2. There is also a faint counterarm (S3), point-symmetrical of S2 with respect to the star. These three spiral arms are modelled separately with two different formulae that approximate the loci of density maxima in acoustic waves launched by embedded planets. S1 could be fit relatively well with these formulae, compared to S2 and S3. Alternative scenarios such as external tidal interaction or gravitational instability are also discussed.

Notes:

The role of photoprocesses in the chemical composition of Herbig AeBe disks

by Davide Fedele

The intense ultraviolet (UV) radiation of an Herbig AeBe star is capable of modifying the chemical and physical structure of the associated protoplanetary disk. The energetic radiation controls the disk temperature, is responsible for the ionization of the gas, regulates the desorption of H_2O molecules from the dust grains and it can destoy the molecular bonds and lead to considerable mass loss in the form of a photoevaporative wind. This is turn has the potential to affect the dynamical evolution of the disk as well as the final chemical composition of planetary systems. I will report on our current understanding of the chemical composition of protoplanetary disks around Herbig AeBe stars obtained with a multi-wavelength survey (from near-infrared to mm, with VLT, Herschel and APEX).

Notes:

Accretion-ejection processes in Herbig Ae/Be stars

by Catherine Dougados

One of the crucial open question in star formation is to understand the link between accretion of matter onto the young star and the launching of large scale supersonic jets. In the low mass pre-main sequence T Tauri stars, magnetic fields are currently thought to play a crucial role in both processes. On one hand, stellar magnetic field lines truncate the inner disk and direct the accretion flow onto the star. This magnetospheric accretion scenario successfully accounts for most accretion and variability signatures and has gained support with the recent mapping of strong magnetic fields around these stars. On the other hand, magneto-centrifugal ejection processes best explain the high degree of collimation and ejection efficiency observed in T Tauri jets. Although the magnetic nature of the ejection process is now well established, the exact origin of the flow (disk, star or magnetosphere) is still debated. The situation for the intermediate mass Herbig Ae/Be stars is more complex.I will review in this contribution the main properties of accretion and ejection signatures from the intermediate mass Herbig Ae/Be stars and discuss their implications in the context of the scenarii developed for their lower mass counterparts. In particular these bright targets hold the promising prospect to obtain direct observational constraints on sub-AU scales which hold critical clues to the connection between accretion and ejection processes.

Notes:

Herbig AeBe stars and multiplicity

by Gaspard Duchene

Stellar multiplicity is an ubiquitous by-product of the star formation process. This particularly true for intermediate- and high-mass stars, and so one expects Herbig stars to present a high frequency of stellar companions. Besides providing key insights on the formation of these objects, the presence of a stellar companion can have dramatic effects on the circumstellar disks surrounding young stars. As is observed for disks around lower mass T Tauri stars, the dynamical influence of the companion to an Herbig star can truncate the outer regions of its disk, possibly reducing its lifetime. It can also trigger perturbations that can be directly observed, such as global spiral patterns. To fully understand the current state of an Herbig star's disk, it is therefore crucial to assess whether it has a stellar companion and, if so, to determine its main properties. In this presentation, I will summarize our current knowledge of the multiplicity of Herbig stars, building on a variety of surveys of these objects, as well as on comparison with stars of lower and higher masses.

Notes:

Large Spectroscopic Investigation of Over 90 Herbig Ae/Be Objects with X-Shooter

by John Fairlamb

Spectroscopic data observed with X-Shooter, VLT, is presented on 91 HAeBe objects making this the largest investigation into mass accretion accretion rates of HAeBe objects to date. We discuss and present trends and variations of emission lines across the whole HAeBe mass range, spanning spectral types from A9 to B0. Deriving accurate stellar parameters for the whole sample of HAeBes is discussed as they have an important role in determining accretion rates and evolutionary status. One of the key focuses here is also to determine accretion rates in the sample and we present results obtained via two independent methods: measurement of the Balmer excess under the magnetospheric accretion regime, and using established relationships between emission line strength and accretion rate. Along with this we discuss other possible accretion tracer relationships and how these compare with the lower mass T Tauri stars helping establish trends in HAeBes as a function of their mass.

Notes:

The HAeBe outer disk in the UV, optical and IR

by Carol Grady

In the mid-1990s the existence of disks around Herbig stars was controversial, but their presence is now well-established as a result of sub-millimeter, mid-IR, and optical-NIR studies. Recently, the Meeus Group I Herbig stars, intermediate-mass PMS stars with IR spectral energy distributions (SEDs) often interpreted as flared disks, have been proposed to have centrally cleared (transitional) and gapped (pre-transitional) disks, while those with simple power law IR SEDs have been interpreted as settled disks where dust grain growth dominates (Meeus Group II). Early observations with HST suggested that the Meeus Group I disks were more frequently detected in scattered light than the Meeus Group II disks. We have investigated the appearance in scattered light of both groups of disks as part of the Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS), obtaining H-band polarimetric imagery with inner working angles of 0.2" for $>$10 intermediate-mass stars with Meeus Group I disks and data for 2 Meeus Group II disks. The Meeus group II disks are preferentially detected in scattered light at epochs when the variable NIR excess is minimized. Simple geometrical arguments confirm suggestions originally due to Dullemond & Dominik that these disks are partially to largely shadowed as a result of grain growth and settling. In marked contrast, the scattered light detection rate for Meeus Group I disks approaches 100%, but these disks display a wide range of structural features including spiral arms, partially cleared wide gaps often with inner radii which differ from those seen in the sub-millimeter, and eccentric gaps. Several mechanisms have been proposed for disk clearing, including dust grain growth and settling, photo-evaporative formation of cavities, and a dynamical origin via the influence of stellar through planetary mass companions. We compare predictions for these mechanisms in terms of the imaged disks, and further consider whether the imaged disks meet expectations for the presence of companions formed through gravitational instability or core-accretion.

Grady is supported under NSF AST 1008440 and through the NASA Origins of Solar Systems program on NNG13PB64P.

Notes:

Magnetism in intermediate mass T Tauri stars

by Gaitee Hussain

There is a low incidence of magnetic fields in intermediate mass stars (2- 5Msun), with typically only 5-10% showing strong magnetic fields. Both main sequence and pre-main sequence Herbig Ae/Be stars show similar magnetic field characteristics. Here we present the results from a new study cataloguing the magnetic field properties of the intermediate mass T Tauri stars (1.5-5 Msun); PMS stars that still possess outer convective envelopes but that are presumably precursors of Herbig Ae/Be stars. I will present the first results from our survey and compare the magnetic field characteristics of our sample with lower mass T Tauri stars (0.5-1Msun) and Herbig Ae/Be stars.

Notes:

Investigating inner gaseous discs around Herbig Ae/Be stars

by John Ilee

When young stars are sufficiently massive, a significant portion of their circumstellar discs can be heated beyond the dust sublimation temperature, creating an inner gaseous disc. We use the radiation thermo-chemical disc modelling software ProDiMo to investigate the effect of these inner gaseous discs on the heating processes throughout the disc; the various global observables from these systems, such as their SEDs; and specific line tracers of these inner discs, such as CO overtone emission.

Notes:

Resolving the inner disk at mid-infrared wavelengths surrounding Herbig star MWC480

by Narges Jamialahmadi

We constrain the inner disk structure and its properties (temperature, opacity, mass of the dusts) of Herbig star MWC480 by infrared interferometry. In order to do that, we use a series of geometrical models to simulate the circumstellar around this star. On the basis of this simulations, the spectral energy distribution and multi-wavelengths intensity map of this star were calculated. The intensity map provide the basis for modeling the Keck interferometer data in the near-inferared and the Very Large Telescope Interferometer (VLTI; equipped with the mid-infrared instrument MIDI ones). We confirm that an one component optically thin disk reproduce the Keck and MIDI data and the SED for wavelengths less than 40 micron simultaneously. In order to reproduce the SED for longer wavelengths, we have attached a second disk which follows the same temperature power law and surface law of the first disk but with different masses.The mass of the first disk has assumed almost one millions time less than the second disk one. The data and simulation support the evidence of two components attached together around MWC480. Our model estimate the maximum size, temperature and mass of the dust in the first and attached second disk.

Notes:

Imaging the dust sublimation region of Herbig Ae/Be stars with VLTI/PIONIER

by Jacques Kluska

The dust sublimation regions of Herbig stars are reachable by classical telescopes only by analyzing spectral lines without having direct information about their location. The disk inner part morphology is then not totally constrain but is known to influence strongly the amount of stellar energy received by further parts. For instance a puffed-up inner rim can create a shadow and modify the properties of the planet forming regions. The accreting gas can perturb this dust sublimation region as well as the matter ejection through winds. Having the size of the emission region is not enough to understand all the physics happening there. To probe the dust sublimation region morphology, we performed a Herbig survey with a new interferometric instrument PIONIER on the VLTI. PIONIER is a 4-beam combiner in the near infrared suitable for imaging. To analyze precisely the close surroundings of Herbig Ae/Be stars, we have adopted a new image reconstruction approach called SPARCO (Semi Parametric approach for image Reconstruction of Chromatic Objects). It consists in separating the star from its environment by using their temperature difference. That allows the image reconstruction of the targets without being polluted by their central star and therefore reveals their surroundings. Applied to the dataset of the PIONIER Large Program we are able to retrieve the morphologies of a dozen of Herbig AeBe stars. Some of them clearly reveal a dust sublimation ring while others show an unresolved component in addition at the location of the star. It indicates the presence of an additional hotter component (refractory dust grains? gaseous dusty disk?) that is confirmed by a smaller temperature difference that we detect between the star and its environment. We are comparing these images with bigger scale images when available. Also we are investigating the methods to detect signs of planet formation in the inner regions (disk instabilities such as Rossby vortices). In this presentation, we demonstrate how the PIONIER survey does its bit towards understanding the global picture of Herbig Ae/Be stars.

Notes:

Introduction to the theory of star formation

by Kaitlin Kratter

Intermediate mass stars have heavily influenced our observational understanding of the star formation process, however they are often neglected theoretically. Should stars between 2-8 solar masses be lumped in with solar-type formation models? Or do they form more like massive stars? In this review I piece together where the intermediate mass stars fit into the puzzle theoretically. I describe the continuum of multiplicity properties that can reveal important aspects of the intermediate mass star forming environment. Finally, I describe how debris-disk studies of intermediate mass stars might inform our formation models.

Notes:

Interferometric view of HAeBe stars

by Stefan Kraus

In this talk I review how optical interferometry has contributed to shaping our understanding of the class of Herbig Ae/Be stars and of their associated circumstellar disks. I will discuss the evidence for an optically-thin cavity in the inner AU and a “puffed-up rim” near the dust sublimation radius and how these observations helped to establish the current generation of irradiative disk models. Multi-wavelength interferometric observations also revealed systems with clear signatures of grain growth and dynamically-cleared disk gaps, tracing important stages of disk evolution and of ongoing planet formation. I will discuss the new opportunities provided by spectro-interferometry, which enables detailed studies on the gas distribution and velocity field on sub-AU scales, resulting in constrains on the accretion properties of the system, the disk excitation structure, and the fundamental stellar parameters. Finally, I will outline some of the open questions and loose ends in current interferometric studies, and how these might point towards new disk physics.

Notes:

ALMA observations of the gas and dust in the hybrid debris disk of the 30 Myr old star HD 21997

by Ágnes Kóspál

Circumstellar disks around stars older than 10 Myr are expected to be gas-poor. There are, however, two examples of old (30-40 Myr) debris-like disks containing a detectable amount of cold carbon monoxide (CO) gas. Here we present Atacama Large Millimeter/Submillimeter Array (ALMA) and Herschel Space Observatory observations of one of these disks, around HD 21997, and study the distribution and origin of the dust and gas in the disk. Our continuum images clearly resolve a broad ring of emission between about 55 AU and 150 AU from the central star. On the other hand, the CO brightness distribution indicates that gas can be found from less than 26 AU to 138 AU. Consequently, the gas and dust in the HD 21997 system are not entirely co-located, indicating a dust-free inner gas disk within 55 AU of the star. We explore two possible scenarios for the origin of the gas. A secondary origin, which involves gas production from colliding or active planetesimals, would require unreasonably high gas production rates and would not explain why the gas and dust are not co-located. We propose that HD 21997 is a hybrid system where secondary debris dust and primordial gas coexist. HD 21997, whose age exceeds both the model predictions for disk clearing and the ages of the oldest T Tauri-like or transitional gas disks in the literature, may be a key object linking the primordial and the debris phases of disk evolution.

Notes:

Photoevaporating Disk Dispersal around Intermediate-Mass Stars

by Masanobu Kunitomo

The disk lifetime has been investigated mainly around low-mass (LM) stars. However, recent observations have focused on the disk lifetime around intermediate-mass (IM) stars and found that the disk lifetime around IM stars measured by near-infrared bands is shorter than that around LM stars. Although this is an important observational feature, there is no theoretical study that explains it so far. In this study we investigate how the host star's mass affects the disk dispersal. We integrate the viscous evolution and the photoevaporation by X- rays and extreme ultraviolet (EUV) photons. In particular, we consider the effect of the time evolution of the X-ray luminosity because it can be important for IM stars. The X-ray luminosity of IM stars is higher than that of LM stars during the Hayashi phase, while after leaving their Hayashi tracks it becomes very small. This evolution of X-ray luminosity can affect the disk evolution because the disk lifetime around IM stars can be longer than Hayashi phase. We found that (1) the dominant source of photoevaporation around IM stars can be changed from X-ray to EUV within the disk lifetime. This feature has not been found in the disk dispersal around LM stars. (2) The disk lifetime decreases as the host star's mass becomes higher within a range of 0.5 to 2 Msun mainly due to the large X-ray luminosity. (3) However, for the stars more massive than 2 Msun, it can increase due to the rapid decrease of the X-ray luminosity. Thus, the EUV luminosity is important for the disk lifetime of high-mass stars. Finally we discuss the comparison of our results with the observational results.

Notes:

Dust dynamics in self-gravitating discs

by Giuseppe Lodato

Young protostellar discs might be massive enough so that their outer parts can be gravitationally unstable. The outcome of the instability is currently under debate. Initial simulations showed that, for the expected cooling times in protostellar discs, the instability would saturate at a finite amplitude, leading to angular momentum tranport in an otherwise “regular” disc. Only in the outermost parts of the disc the instability was predicted to be strong enough to lead to fragmentation. However, more recent calculations appear to be moving the threshold for fragmentation to progressively smaller radii, and it might be even questionable whether a non-fragmenting self-gravitating disc can exist at all. Independently on the issue of fragmentation, the spiral structure induced by the instability is likely to significantly affect the dust dynamics, as it would naturally provide pressure maxima to serve as “particle traps”. Here, I will discuss the dynamics of gas and dust in self-gravitating discs and I will also show some recent results on the possibility of detecting such structures in ALMA observations of young discs.

Notes:

Characterization of gas and dust in the gaps of Herbig Ae/Be stars

by Koen Maaskant

The evolution of young massive protoplanetary disks towards planetary systems is expected to correspond to changes in their morphology, including the formation of gaps. We have focused our attention on the depletion of dust and gas in the disk gaps seen in the disks around four key Herbig Ae/Be stars (HD97048, HD169142, HD135344B, Oph IRS 48). By modeling spatially resolved Q- band images, we find that the property responsible for the absence of mid- infrared silicate emission ($\sim$10 micron) is the depletion of dust grains in the $\sim$300-500 K temperature regime. We speculate that many, if not all Herbig disks with disk classification group I are disks with large gaps and can be characterized as (pre-)transitional. An evolutionary path from the observed group I to the observed group II sources seems no longer likely. Instead, both might derive from a common ancestor (Maaskant et al. 2013). In a follow up study targeting on the same transitional Herbig Ae/Be disks, we have characterized how the charge state of PAHs can be used as a probe of flows of gas through protoplanetary gaps. Ionized PAHs trace low-density optically thin disk regions were the UV field is high and the electron density is low. Such regions are characteristic of gas flows through the gaps of transitional disks. While in optically thick disks, PAHs are predominantly neutral. The PAH spectra of transitional disks can thus be understood as superpositions of neutral PAH emission from the optically thick disk, and ionized PAHs from the "gas flows" through the gap. In a larger sample of Herbig stars, we find a correlation between PAH ionization (traced by the 6.2/11.3 PAH feature ratio) and the disk mass (traced by the 1.3 mm luminosity). This may imply that lower-mass disks have larger gaps. Ionized PAHs in gas flows through these gaps contribute strongly to their spectra (Maaskant et al, submitted).

Notes:

Planet formation in action: the role of dust trapping in transitional disks

by Nienke van der Marel

Planet formation by dust coagulation in protoplanetary disks is one of the long standing problems in disk evolution theory. Dust grains must grow from submicron sizes to $\sim$10 MEarth rocky cores within the $\sim$10 Myr lifetime of the circumstellar disk. However, this growth process is hindered by collisional fragmentation and rapid inward radial drift. A possible solution in dust evolution theory is dust trapping in local pressure maxima in the disk, where dust particles pile up and grow. Transitional disks with large inner dust cavities have been suggested to contain these dust traps. ALMA Early Science data finally allows to address this question. One example is the Herbig Ae star Oph IRS 48, that was observed in Cycle 0 in CO(6-5), C17O(6-5) and the submillimeter continuum in the extended configuration. The gas surface density, consistent with a Keplerian disk, contains two radial density drops, at 20 and 60 AU. These density drops directly imply the presence of companions in the disk, as they lower the gas surface density along their orbit. Similar to the gas, the micrometer-sized dust grains follow a large ring-like structure. On the other hand, the ALMA continuum emission, tracing the millimeter-sized dust, reveals an unexpected huge asymmetry at 60 AU radius and steep edges in the dust distribution along the ring. The combination of the gas and dust distribution indicates that the dust trapping mechanism is at work in this disk: at the edge of the outer density drop is a pressure bump, which traps the millimeter dust. I will discuss the implications for IRS 48 and possible other dust traps in transitional disks observed with ALMA.

Notes:

Herschel's view of the atomic and molecular gas content of Herbig Ae/Be discs

by Gwendolyn Meeus

The discs around Herbig Ae/Be stars are nurseries of planets in which gas slowly gets dispersed until planets no longer can form. As an important piece of the planet-formation puzzle, both the heating & cooling processes, and the chemical composition and its evolution, as well as gas dispersing mechanisms need to be understood. In this talk, we will show Herschel results from two Key Programmes focussing on protoplanetary disc evolution, GASPS and DIGIT. Both programmes surveyed a large sample of Herbig Ae/Be stars with the spectrograph PACS, tracing the far-IR region. With the aid of emission lines of [O I], [C II], OH, H2O, CH+ and CO we can trace the disc at different vertical depths and radial distances. We look for correlations between the observed line uxes and stellar properties such as eective temperature and stellar luminosity, FUV and X-ray luminosities, accretion diagnostics, as well as with disc properties: amount of aring, PAH luminosity and (low J) CO transitions, tracing the cold gas. Our spectra cover a wide range in pure rotational transitions of CO. We analyse the CO ladder with a small model grid, and show that the amount of flaring is important in determining the line flux, as it determines the amount of warm gas. We will also present a few cases to illustrate how simultaneous modeling (using the thermo-chemical disc code ProDiMo) of the observed lines can constrain the gas properties, once the disc structure is derived.

Notes:

Dust and Gas properties in the dust trap of the disk of HD 142527

by François Ménard

Transition disks around young stars feature an inner gap mostly devoid of continuum emission and an outer rim and disk that shine brightly in scattered light in the NIR and thermal emission in the Mid and Far-IR/mm. At the disk rim, models predict that physics very relevant for planet formation is taking place. In this contribution we will discuss one of these features: the “dust traps” where dust and gas are locally concentrated, possibly for a long time. These dust traps lead to a massive enhancement of the dust concentration and may be extremely useful to rapidly grow particles to much larger sizes, on their way to the formation of planetary embryos.
The “dust trap” seen in the disk of the Herbig Ae star HD 142527 provides the best documented case so far to study them. It is well oriented, almost pole-on, and ALMA data clearly highlighting the dust trap exist in several continuum bands and in the lines of several molecular species, allowing for a good assessment of the density, temperature, and maybe motions, within the vortex. The observational gas and dust signatures of the dust trap of HD 142527 will be compared to a combination of advanced models including 3D radiative transfer and 3D multi-fluid (gas+dust) hydrodynamical simulations of Rossby Wave Instatibilities as well as thermo-chemical modelling. We will discuss how the results provide guidance toward understanding the physical and chemical processes at work within the vortex/dust trap.

Notes:

Characterizing accretion of Herbig Ae/Be stars from X-Shooter/VLT

by Ignacio Mendigutia

Understanding the way that the inner-disk gas accretes onto the stellar surface of Herbig Ae/Be (HAeBe) stars is crucial to our view of planet formation around these objects, given that the mass accretion rate tells us about the gas available to form giant planets. It is subject of debate to understand whether the accepted paradigm for lower mass T Tauri (TT) stars, magnetospheric accretion (MA), is applicable to HAeBes. Moreover, to analyse if the spectroscopic tracers used for TTs also provide valid accretion estimates for HAeBes is a previous step to carry out future accretion surveys including wide samples of these objects.

I will present a comprehensive accretion characterization from multi-epoch X- Shooter/VLT spectra of two prototypical HAeBe stars: HD 31648 and HD 163296. The wide wavelength coverage of X-Shooter has allowed us to analyse the simultaneous variability of the UV excess and several emission lines from the UV to the near-IR, providing mean accretion rates that are consistent to each other and with MA. In addition, I will present the analysis of an X-Shooter spectrum of the planet-forming candidate, intermediate-mass TT star HD 142527, showing that its stellar accretion rate is higher than previously suggested. That is however within the upper limit gas flow rate from the outer to the inner disk recently provided by Casassus et al. (2013) from ALMA observations, suggesting that almost all gas transferred between both components of the disk is not trapped by possible objects in-between but fall onto the central star.

Notes:

A mid-infrared interferometric survey of the disks around intermediate-mass young stars

by Jonathan Menu

During the past decade, the MID-infrared Interferometric instrument (VLTI/MIDI) has given us new insights in the geometry and dust composition of the disks around young stars. However, most studies focused on at most a handful of objects, which complicates the interpretation of the results of individual studies in terms of disk statistics. As an example, derived disk geometries might be model-dependent, and directly comparing geometric parameters is therefore not always possible.

The aim of this project is to investigate a statistically relevant sample of intermediate-mass young stars. We collected all archival MIDI data of more than 20 objects and reduced and calibrated the data in an automatized way.

Essentially all observations show that the disks around these objects are resolved. As a first step, we use geometric, parametrized disk models for analyzing the data. The spectrally and spatially resolved observations allow us to constrain both the geometry and composition of the disks. We determine orientations of the disks and analyze the global and local composition of the dust grains. The model parameters are then compared to the fundamental properties of the central stars (e.g., mass, luminosity, etc.).

Here, we will present the first results of this ongoing analysis.

Notes:

Inferring protoplanetary masses from resolved ALMA molecular gas emission

by Sebastián Pérez

Inner cavities and annular gaps in circumstellar disks are thought to be signposts of the process of giant planet formation. The mass and orbits of these embedded giant planets determine the way how cavities walls are shaped. We aim to constrain the protoplanetary companion and disk parameters by comparing ALMA molecular gas images with hydrodynamical models. We want to exhaust the capabilities of 2D hydrodynamical simulations to extract planet(s) mass(es) and location(s) in transition disks. In this conference we will present the results of our efforts to couple hydro simulations with a 3D radiative transfer code and we will show the first results of comparing with ALMA data.

Notes:

Introduction to chemistry in HAeBe disks

by Vincent Piétu

In this talk, I will present the current status of our understanding of the chemistry in outer disks. I will review the detected molecules and discuss what we can learn from the analysis of their emission, in particular as observed with (sub-)millimiter arrays. Some continuum results, showing evidence of grain growth will be presented as this reduces the opacity of the disk to the starlight, influencing greatly the molecular content of circumstellar disks. Finally, I will discuss the enthusiastic perspectives offered by ALMA and NOEMA.

Notes:

Constraining the structure of the transition disk HD 135344B

by Christophe Pinte

Constraining the gas and dust structure of transition disks, particularly in the inner dust cavity, is a crucial step towards understanding the link between them and planet formation. HD 135344B is an accreting (pre-)transition disk which displays emission of warm CO extending tens of AU inside its 30 AU dust cavity. We constrain HD 135344B's disk structure from multi-instrument gas and dust observations. We employ the dust radiative transfer code MCFOST and the thermo-chemical code ProDiMo to derive the disk structure from the simultaneous modeling of the spectral energy distribution (SED), spatially resolved VLT/CRIRES CO P(10) 4.75mum, Herschel/PACS [OI] 63mum, Spitzer-IRS, and JCMT 12 CO J=3-2 spectra, VLTI/PIONIER H-band visibilities, and constraints from (sub-)mm continuum interferometry and near-IR imaging. The simultaneous modelling of current gas and dust observations provide strong constraints on the disk structure and its evolutionary status. In particular, we find that the dust cavity is filled with gas with a positive surface density profile and a gas-to-dust ratio $>$ 100, while it is lower that 10 in the outer disk detected in continuum observations. This modelling also points towards an enrichment of refractory material inside the silicate sublimation radius (R $<$ 0.2 AU). We will discuss the implications of our findings on planet formation and disk evolution theories.

Notes:

The Herbig Ae/Be star opportunity: Deciphering planet formation around intermediate mass star with empirical data

by Sascha Quanz

Planet formation studies - be they theoretical or observational in nature - are often focused on Solar-type stars, implicitly considering our Sun as a key reference point. This approach overlooks, however, that Herbig Ae/Be stars are in some sense much better targets to study planet formation empirically, with their disks generally being larger, brighter and simply easier to observe across a large wavelength range.
In this talk I will briefly review what we currently know about the occurrence rate of planets around intermediate mass stars, before discussing recent results from Herbig Ae/Be stars in the context of planet formation. Particular emphasis will be on spatially resolved scattered light images of potentially planet forming disks and how these images - in combination with other data - can be used to constrain the planet formation process. I will conclude with an outlook, what “new” science we can expect in the future with the next generation of high-contrast imagers at 8-m class telescopes.

Notes:

A Spectro-Astrometric study of bracket gamma emission in the HAeBe star HD 100546

by Ricardo Ramirez

Unlike the case of T Tauri stars, the mass accretion onto higher mass young stars (Herbig Ae/Be) and in particular the origin of the HI lines is not completely understood. The HI bracket gamma line is well correlated with accretion luminosity in T Tauri stars, and while the same relation holds for Herbig Ae stars, in Herbig Be the bracket gamma line flux often overestimates the accretion luminosity. HD 100546 is an Herbig Be star with a transitional disk. We observed it with the VLT/SINFONI integral field spectrograph in K band. We have applied the spectro-astrometric technique to the SINFONI observations of the HI bracket gamma emission line in this source. We have reached a positional accuracy (rms) of 10-30 micro arcseconds (0.01- 0.03 milli-arcseconds), corresponding to the size scale of the stellar radius. We find an asymmetric signal in RA and a S pattern in Dec of amplitude around 0.2 mas. This signal doesn't follow the expectations from a keplerian accretion disk with the same PA as the large scale disk around this source, suggesting an origin either in a stellar outflow or accretion funnels. However we show that our signal is affected by uneven slit illumination effects. Further observations will be required to confirm the origin of the detected astrometric signals.

Notes:

Cosmic Rays from Stellar Birth

by Tom Ray

Recent observations of intermediate mass young stars suggest high energy electrons can be produced in jet shocks. We explore the physics of this phenomenon and show, theoretically and observationally, how it can extend even to lower masses. Such low energy cosmic rays may be a significant contributor to ionisation of the parent molecular cloud.

Notes:

Powerful jets from intermediate-mass protostars in Carina

by Megan Reiter

The Carina nebula hosts the largest known population of powerful HH jets driven by intermediate-mass stars in a single region. These jets are externally irradiated by dozens of O-type stars in Carina that illuminate unshocked material in the jet, allowing for a more complete census of the mass-loss. Despite the strong incident ionizing radiation, portions of these jets remain neutral. Near-IR [Fe II] images reveal dense, neutral gas that was not seen in previous studies of Halpha emission. We show that near-IR [Fe II] emitting gas must be self-shielded from Lyman continuum photons, regardless of its excitation mechanism (shocks, FUV radiation, or both). High densities are required for the survival of Fe+ amid the strong Lyman continuum luminosity from Tr14, raising estimates of the mass-loss rates by an order of magnitude. New proper motion measurements using Halpha images with a $\sim$4.25 year baseline reveal tangential velocities of $>$200 km/s, in some cases exceeding velocities typical for jets from low-mass stars. In addition, these outflows are highly collimated, with opening angles of only a few degrees, similar to low-mass protostars. We propose that these jets reflect essentially the same outflow phenomenon seen in low-mass protostars, but that the collimated atomic jet core is irradiated and rendered observable. Thus, the irradiated jets in Carina constitute a new view of jets from intermediate-mass protostars that demonstrate that they are as collimated as their low-mass counterparts, but support higher densities and velocities, leading to higher mass-loss rates. This scaling of phenomena seen in low-mass star formation offers strong additional evidence that stars up to $\sim$8 Msun form by the same accretion mechanism.

Notes:

LkHa 101: a Herbig B0e star with a disk

by Goran Sandell

Disks are ubiquitous around solar mass stars and also intermediate mass Herbig Ae/Be stars of spectral type B8 or later. Disks, however, are quite rare in early B-stars. There are clear examples of proto-planetary of young high-mass protostars, which based on their bolometric luminosities appear to be early B stars like IRAS 20126+4104. Of early B stars with secure spectral classification (optical near IR) there are only a few stars which are known to have disks: MWC 349, MWC 297, HD 2007775, and LkHa 101. Here we present new results on LkHa 101 from observations with CARMA at 3 mm and archive data from the Herschel Space Observatory. LkHa 101 has long been known to have a disk, based on near and mid-IR interferometry as well as double peaked emission lines of Fe II , Ni II and Mn II, believed to originate in the inner part of a rotating Keplerian disk. Even though LkHa 101 illuminates an HII region, the star still appears to be surrounded by a cold accretion disk, since our CARMA observations show a clear dust excess even at 3 mm.

Notes:

High energy emission from the HD 163296 jet: Clues to magnetic jet launching

by Christian Schneider

I will present Chandra X-ray and HST FUV observations of the well studied Herbig Ae star HD 163296 tracing the most energetic radiation that HAeBe stars emit. In particular, the data demonstrate that HAeBe drive very high velocity jets capable of heating the outflowing plasma constantly to one million Kelvin within 30 AU from the star. In addition, I will discuss red shifted Lya emission in the forward jet direction showing that the disk (surface) irradiation is more complex than in the standard central illumination model.
This morphology of the high energy radiation shares many similarities with magnetically driven jets from fully convective T Tauri stars (TTSs). Magnetic field measurements for Herbig AeBe stars are still debated. However, the highest velocity outflow components must be driven close to the star where stellar and disk magnetic field strongly interact in classical TTSs. The observed similarities between the high velocity jet of HD 163296 and classical TTSs jets indicate that jet launching is nevertheless very similar arguing for the existence of sufficiently strong magnetic fields close to the star.

Notes:

Warm CO gas as a tracer of the inner 50 AU of proto-planetary disks

by Gerrit van der Plas

The CO molecule is a very versatile tracer that can trace many different physical regimes of Proto Planetary (PP) disks via its rotational and ro-vibrational transitions. In this talk we present observations of fundamental ro-vibrational CO emission from PP disks surrounding Herbig Ae/Be stars as a tool to study the disk surface of the inner few AU of PP disks via thermally excited CO molecules, and the inner 50 AU via CO molecules that are fluoresced by UV radiation. These observations suggest a connection between disk geometry and CO excitation conditions.

Notes:

Warm gas in 12 Herbig Ae/Be disks: the CO ladder probed from 50 to 500 K

by Matthijs van der Wiel, François Ménard

Disks around Herbig Ae/Be stars are more massive and enjoy more UV irradiation than their T Tauri counterparts. This contribution will present results from spectroscopic far-infrared/submillimeter observations of a sample of 12 Herbig disks and 6 T Tauri disks. The Herschel SPIRE spectrometer, for the first time, allows us to comprehensively probe the full 200-700 micron wavelength range. I will present new detections of ten carbon monoxide (CO) lines in the energy range $\sim$50-500 K. For two objects in our sample, observed CO ladders are compared with existing, published physical-chemical models. Results suggest that, in order to explain the optically thick 12CO ladder, the modeled gas heating balance in surface layers may need to be adjusted, for example by changing flaring geometry or PAH abundance. In addition, the total gas mass in the modeled disks is not sufficient to explain observed optically thin isotopolog lines.

Notes:

Linear line spectropolarimetry of Herbig Ae/Be stars

by Jorick Vink

Accretion is the prime mode of star formation, but the exact mode might has not yet been identified in the Herbig Ae/Be mass range. We provide evidence that the the maximum variation in mass-accretion rate is reached on a rotational timescale, which suggests that rotational modulation is the key to understanding mass accretion. We show how spectropolarimetry is uniquely capable of resolving the innermost (within 0.1 AU) regions between the star and the disk, allowing us to map the geometry of the accreting gas, and test theories of angular momentum evolution. We present Monte Carlo line-emission simulations showing how one would observe changes in the polarisation properties on rotational timescales, as accretion columns come and go into our line of sight.

Notes:

Herbig Ae/Be stars in perspective

by Rens Waters

Herbig Ae/Be stars were first recognized as a group by George Herbig, whose life achievements we celebrate at this meeting. Since the middle of the last century, a tremendous amount of progress in our theoretical and observational understanding of star- and planet formation has been made. We are now in a position to begin to quantify the connection between mature planetary systems and their birth places, the proto-planetary disks around pre main sequence stars. The Herbig Ae/Be stars have their own story to tell, and at the same time are truly intermediate between the lower mass solar type stars and the more massive early B and O type stars. Studies of Herbig Ae/Be stars and their environment, as they evolve to the main sequence and form planetary systems, can therefore provide key understanding in the physics and chemistry of that process, and impact our understanding over a much broader range of mass and luminosity.

Notes:

A Prototype Protoplanetary Disks for Modelling: HD 163296

by Peter Woitke

HD 163296 is an outstanding member of the class of protoplanetary disks around Herbig Ae/Be stars. It is one of the largest, brightest, and best studied objests known, across all wavelengths and instruments. It is also very suitable for modelling - recent ALMA science verification data show that this disk is remarkably symmetric without any signatures of holes or gaps. In this talk, I will summarise our observational knowledge about this object, based on recent publications (Tilling+2012, de Gregorio-Monsalvo+2013, Rosenfeld+2013, Mathews+2013, Klaassen+2013), and I will discuss what we understand in terms of modelling, and what we don't, based on our results in the European Framework 7 project DIANA "Analysis and Modelling of Multiwavelength Obervational Data from Protoplanetary Disks". In particular, the ALMA CO 3-2 observations show line emission from warm CO in a two-layered structure, where the CO is located at very high altitudes z/r=(0.3-0.4) over the disk midplane.

Notes:

Studying Circumstellar environment of intermediate–mass stars

by Yuefang Wu

To investigate environment evolution states and effects of intermediate-mass stars as well as the properties of the center stars themselves, we have carried out a survey with CO and 13CO lines toward 54 Herbig Ae/Be stars. So far twelve sources were mapped. Excitation temperature, column density and velocity dispersion of surrounding gas were derived. Disk mass, accretion rate and their changes with the age of the star were obtained from spectral energy distribution between 0.1 mu to 1.3 mm. Signatures of expanding, turbulence, outflow and inflow were detected. The gas motions together with the morphologies and structures revealed by maps present the effect of the center intermediate-mass stars. The spatial distribution of the associated young stellar objects also indicates possible triggered and sequential star formation.

Notes:

From primordial to debris: the evolution of HAeBe disks

by Mark Wyatt

The protoplanetary disk phase does not last much longer than 10Myr and so the disks around Herbig AeBe stars eventually dissipate leaving just a tenuous debris disk. Such debris disks are comprised of planetesimals and the dust derived from them, but may also contain gas and planets. The properties of the youngest (10-20 Myr) debris disks thus provide an important constraint on the evolution of Herbig AeBe disks, since this is their end-state. This talk looks at the properties of the youngest debris disks, both from a statistical point of view, and from detailed studies of disk structure in individual objects. This is then used to consider the implications for the evolution of Herbig AeBe disks.

Notes:

Rapid Evolution of the Innermost Dust Disk of Protoplanetary Disks Surrounding Intermediate-mass Stars

by Chikako Yasui

We derived the intermediate-mass ($\sim$=1.5-7 Msun) disk fraction (IMDF) in the near-infrared JHK photometric bands as well as in the mid-infrared (MIR) bands for young clusters in the age range of 0 to $\sim$10Myr. From the JHK IMDF, the lifetime of the innermost dust disk ($\sim$0.3 AU; hereafter the K disk) is estimated to be $\sim$3 Myr, suggesting a stellar mass (M_*) dependence of K-disk lifetime proportional to $M^{-0.7}$. However, from MIR IMDF, the lifetime of the inner disk ($\sim$25 AU; hereafter the MIR disk) is estimated to be $\sim$6.5 Myr, which is similar to that of the LM stars ($\sim$9 Myr), suggesting a very weak stellar mass dependence (proportional to $M^{-0.2}$). The much shorter K-disk lifetime compared to the MIR-disk lifetime for IM stars ($\sim$3-4 Myr) suggests that IM stars with transition disks, which have only MIR excess emission but no K-band excess emission, are more common than classical Herbig Ae/Be stars, which exhibit both. We suggest that this prominent early disappearance of the K disk for IM stars is due to dust settling/growth in the protoplanetary disk, and it could be one of the major reasons for the paucity of close-in planets around IM stars.

Notes:

SOFIA observations of Herbig Ae/Be stars

by Hans Zinnecker

High-spectral resolution mid-infrared observations of Herbig Ae/Be stars with SOFIA and EXES.

Notes:

Poster Abstracts

Spectrometry and Linear Spectropolarimetry of Herbig Be Stars PDS 37 and PDS 27

by Karim Ababakr

We present the results of spectropolarimetric and spectrometric observations of Herbig Be stars PDS 37 and PDS 27 both of which have not been studied in depth. Spectropolarimetry is a very powerful technique that can be used to study the circumstellar environment of stars and map their emission line regions. A change in linear polarisation across H-alpha, with depolaristion across the absorption component, is detected for both objects as an indication of a flattened region namely a disk surrounding the objects. In addition, the spectroscopic analysis shows that all visible lines are in emission. We also have discussed the accretion rates of these two objects.

Disk structure and stirring mechanism in bright debris disks

by Péter Ábrahám

A significant fraction of main-sequence stars are encircled by dusty debris disks. Dust particles of these disks are replenished by destructive collisions between unseen planetesimals whose orbits are stirred up by some mechanism. While the most commonly invoked mechanism is self-stirring, alternative solutions, such as planetary stirring, are also possible. Here we present Herschel images of eight bright debris disks whose young age and relatively large disk size hint for stirring mechanism other than self-stirring. We spatially resolved all our targets with PACS, and detected them with SPIRE as well. We determined the inclinations, position angles, and outer radii of the disks by fitting a ring-like profile to the observed brightness distributions. We used the disk sizes as input parameters for modeling the spectral energy distributions, from which we estimated the dust distribution and the total dust mass in each system. We then compared the radii of the rings and ages of the systems to the theoretical predictions for the evolution of an outward expanding dust-production zone in the self-stirring model. We found several disks in our study that are too extended to be consistent with the self- stirring scenario. This result suggests that other physical mechanisms could contribute to the dynamical stirring of these disks. Assuming that we witness the effect of planetary stirring, some of our disks are prime targets for discovering outer giant planets via direct imaging. The eight resolved disks presented here, supplemented by two additional systems from our Herschel program, the hybrid debris disk of HD 21997, and the bright debris disk of the planet-host star HD 95086 (see Kospal et al., this conference), constitute a considerable contribution to the list of debris disks successfully resolved at far-infrared wavelengths.

Modeling the water emission in protoplanetary disks

by Stefano Antonellini

The water molecule is one of the main coolants in protoplanetary disks, with rotational and ro-vibrational levels spanning from tens of K to a few thousand K in excitation energy, and lines spreading from the near-IR to the far-IR. The emission characteristic of this molecule from disks seems pretty erratic: in some objects water emission is not detected, in others, it has been detected either in the near-IR or in the far-IR. Investigating the reason of this behaviour is key for understanding fundamental physical and chemical processes in the disks involving water.
The goal of this study is to figure out through modeling which aspects of the protoplanetary disks affect the local abundances of water and hence the emission in different wavelength regions. This also helps to define potential diagnostics for future observations.
We have performed the modeling using the radiation thermo-chemical code ProDiMo, following a parametrized approach. We have produced a grid of models exploring particular directions in the multi-dimensional parameter space, computing rotational and ro-vibrational transition of both ortho and para water. We analyzed and derived the local conditions in the emitting regions, and investigated statistically (Pearson statistics) how the chemistry, properties of the emitting region and specific disk parameters correlate with the line fluxes. We simulate Spitzer

spectra for each model using simplified escape probability and we compute the ratio between Herschel HIFI lines and Spitzer lines using also detailed line radiative transfer. For a standard disk model, we found that parameters such as the dust-to-gas mass ratio, α viscosity parameter (Dubrulle), flaring parameter, dust grain size distribution, ISM radiation field, have the largest impact on the water emission. For some of them we also found a different effect on the HIFI transitions respect to the Spitzer ones.

Adaptive Optics Observations of Young Stars in Orion OB1

by Cesar Briceno

I present preliminary results from a multiplicity study of pre-main sequence stars in the Orion OB1 Association, including early type members of the 25 Orionis cluster like the HAeBe star V346 Ori. We have carried out observations of $\sim$50 young stars using the NACO instrument on VLT and the SOAR Adaptive Optics Module (SAM). Our goal is to determine population-wide multiplicity properties of low mass young stars at ages 4-10 Myr, a critical time when disks are dissipating and planetary systems have largely completed their formation process. The multiplicity fraction for single and binary systems, in disked/non-disked stars of differing ages, can provide key constraints for understanding circumstellar disk survival and evolution.

Detection of planet formation in action? A particular case in Lupus

by Claudio Caceres

Circumstellar disks are sites where giant planets are expected to form. The direct detection of forming planets still embedded in a protoplanetary disk would provide the most direct observational test for current theories of giant planet formation. Here we present Sparse Aperture Masking (NACO/VLT) and ALMA observations of a protoplanetary disk which presents evidence of planet formation in action.

A nascent Herbig Be star in a radiation-bathed globule of Cygnus X

by Fernando Comeron

The Spitzer Space Telescope has revealed the rich morphology of the gas and dust of the Cygnus X molecular complex in its interaction with the hard radiation field of the nearby Cygnus OB2 association. Many of the structures seen in the interface between Cygnus X and the bubble blown by the injection of energy by Cygnus OB2 are globules and pillars, some of them displaying clear evidence of star formation in their densest parts. Here we focus on the globule IRAS 20319+3958, which is found to host a small embedded cluster of stars. The physical conditions of the embedding gas can be studied in detail through observations ranging from near infrared to the millimeter, including those provided by Herschel and SOFIA. Furthermore, the brightest stars of the cluster are only lightly obscured and spectra in the visible can be obtained. We present spectroscopic observations of the brightest cluster member, which turns out to be a Herbig Be star with photospheric HeI lines in absorption and intense Halpha and Hbeta emission with clear P Cygni profiles. FeII multiplet lines are clearly seen in emission as well. High-resolution infrared images show this star to be a binary with a projected separation of 800 AU. The companion has much redder colors, perhaps due to a denser circumstellar envelope.

Examining young binary systems in birth by high angular resolution observations

by Gergely Csepany

The aim of this project is to carry out a survey of young T Tauri binaries, which were discovered in the early 1990s using speckle interferometry or lucky imaging techniques. The aim of the first phase of this survey is to reobserve about 30 T Tauri pairs on the northern sky using a fast Andor iXon EMCCD camera mounted on the 1 m class RCC telescope at the Piszkstet Mountain Station, Hungary, and determine whether the orbital motion of the companion could be revealed by using speckle interferometry or lucky imaging. The next phase of this project would cover more T Tauri targets, primarily targets that are available in the NACO or SINFONI archives, covering the southern sky and fainter objects.

Active asteroid belt causes the UXOR phenomenon in RZ Piscium

by Willem-Jan de Wit

RZ Psc displays dust obscuration events (UXOR behaviour) on a time scale that suggests dusty material on orbits of $\sim$0.5 AU, yet various properties of the system indicate an age older than 10Myr. We report the discovery of mid- infrared excess emission in this object.The excess constitutes $\sim$8% of its Lbol and is well fit by a single 500 K blackbody, implying a dust-free region within $\sim$0.7 AU for optically thick dust. We also report a 12.4-year cyclical photometric variability that can be interpreted as caused by perturbations in the dust distribution. We propose that the dust occultation events present a dynamical view of an active asteroid belt whose collisional products sporadically obscure the central star.

On the origin of the discrete blue–shifted absorption components in D Na I lines in the spectra of young stars

by Vladimir Grinin

The high resolution spectroscopic observations of young stars show that the matter outflow in the form of the disk wind is a highly anisotropic, non-stationary process. The sodium resonance doublet is one of the most sensitive indicator of such outflows. In several stars, the sodium D Na I lines have the P Cygni profiles with the very complex blue-shifted absorption consisting of a few narrow discrete absorption components (DACs). I argue in my talk that the most probable mechanism of formation of such DACs is the, so called, “propeller” mechanism. It is a result of interaction of circumstellar disk with the stellar magnetosphere. On the way to the Main Sequence, the efficiency of this mechanism has to increase with the mass accretion decrease.

Sub-mm studies of Herbig Ae/Be stars

by Antonio Hales

We present new sub-millimeter data of Herbig Ae/Be stars taken with single dish telescopes in Chile in order to search for continuum and gas emission around these system. We detect 12CO emission around at least two systems, as well as the 870 micron continuum. The new sub-mm data is input into the radiative transfer code MCFOST (Pinte et al. 2006) to produce disk models that fits the entire SEDs. The models reproduce well the observed CO line profiles, constraining the geometry and mass of their circumstellar disks.

A Large Scale Spectroscopic Survey of Intermediate Mass Stars with Protoplanetary Disks in the Orion region

by Luis Villarreal, Jesús Hernández

We have performed a selection of candidate intermediate mass stars (spectral types G0 or earlier) that potentially exhibit protoplanetary disks based on infrared data from the WISE and Spitzer missions. The area surveyed spans 32°x32°, including the entire Orion star forming region. Distances normally assumed for young stars located in this region range from 300 pc to 500 pc. We have initiated optical spectroscopic follow-up observations of selected candidates. Our main goal is to build a large scale census of protoplanetary disks around intermediate mass stars that will contribute to a better understanding of the star forming and disk evolution processes, as well as possible relationships between the environment and the spatial distribution of stars in this mass regime.

The HD 95086 planetary system: from discovery to structure

by Ágnes Kóspál

Before 2013, only three systems had been known where outer planets and debris disks co-exist: the ∼20-Myr-old beta Pic, the 30-Myr-old HR 8799, and the 440- Myr-old Fomalhaut. The latter two are wide separation planetary systems with giant planets significantly beyond Jupiter's orbit. Recently, analysing direct images in the L' band, members of our group have discovered a planet around HD 95086, a 17-Myr-old A8-type star belonging to the Lower Centaurus Lupus association. The planet of HD 95086 has a mass of 5 M_Jup, and a projected separation of 56 AU. The system also harbors a bright debris disk. We performed a detailed study of the debris disk using the spectral energy distribution and spatially resolved far-infrared images obtained with the Herschel Space Telescope, and found two distinct dust disk components with characteristic temperatures of 187 K and 57 K. The outer component is very extended (r_out ∼270 AU), while the minimum inner radius of the outer component, estimated from a simple assumption of black-body grains, is ∼64 AU. The mass in mm-size dust is 0.5 M_Earth and in the planetesimals is even more, making HD 95086 one of the most massive known debris disks. The good agreement between the planet's position and the characteristic radius of the outer dust belt makes HD 95086 the best target to investigate planet-disk interaction. We also present our simulations of the disk's morphology using different planet-disk interaction scenarios.

Image synthesis of HD100546 using Sparse Aperture Masking on the VLT

by Sebastian Marino

HD100546 is a system of a Herbig Ae/Be star surrounded by a circumstellar disk. From SED and line profiles observations and modeling, is expected that the disk has a zone with a decrement of the gas and dust density, what is called gap. This structure divide the disk in a inner part and a external part. The existence of this gap is probably due to planet formation and the gap has not been observed in optical images.
A observation at 3.81 [um] of HD100546, using Sparse Aperture Masking (SAM) at NAOS/CONICA on the VLT, was made in 2012. Using a software named MIRA for image reconstruction for optical interferometry, written by Éric Thiébaut, we think that we detected the gap using different regularization methods. We found a gap in the disk at a radius of ∼10 AU (consistent with the literature).

Identification of a new population of Herbig Ae/Be stars in the Large Magellanic Cloud

by Blesson Mathew

We have identified 252 emission-line stars in the sample of Reid & Parker (2012) with forbidden SII doublet 6716/6731 Å$\sim$lines in emission. From the spectral analysis we found that these stars can either be Herbig Be stars or B[e] stars rather than Classical Be stars. Some of these stars were misclassified as AGB or Post-AGB candidates from previous photometric studies. We used the photometric data in mid-infrared bands from Spitzer SAGE and WISE surveys to re-create a picture about the true nature of these stars. This information is supplemented with CMD analysis and variability studies using OGLE data to identify a new population of Herbig Ae/Be stars.

Small inner angle coronagraphy of circumstellar disks on AU scales with SPHERE and NACO

by Dimitri Mawet

This poster showcases the scientific capabilities of the coronagraph suites available on NACO in the L band, and SPHERE in the J, H and K bands. NACO will be back in operations in September 2014, and SPHERE will start its commissioning and science verification phase soon. Both instruments provide AU-scale inner working angles and high contrast imaging with complementary wavelength coverage at similar contrast levels, which is ideal for multi-wavelength investigations of circumstellar environments.

Investigating the Inner Gaseous Disk of Herbig Stars

by Parshati Patel

The structure of the inner gaseous disk of Herbig stars, where dust is thought to evaporate due to high temperature, is poorly understood. Using non-LTE radiative transfer numerical models, BEDISK and BERAY, and observational data obtained using ESPaDOnS at CFHT which ranges from $\sim$3700 to $\sim$10,500 A, we are able to constrain the physical properties of this inner gaseous region. The synthetic line profiles of hydrogen and ionized metals, along with the observed line profiles, will help understand the geometry and kinematics of the gaseous disk.

The imprint of accretion and outflow in magnetic Herbig Ae/Be stars on near-infrared spectral line variability

by Monika Petr-Gotzens

We present VLT/ISAAC medium resolution spectra of a few magnetic Herbig Ae/Be stars obtained at 1.06 - 1.1 micron. Each star was observed at several different epochs, randomly sampled and separated by a day to up to a month. This allowed us to detect clear variations in two prominent lines that probe accretion and outflow (winds) in the star-disk interacting region of Herbig Ae/Be stars, the HeI (1.083mic) line and the Pa_gamma (1.094mic) line.
First results from these observations show a distinct correlation between the equivalent width of the Pa_gamma emission and the He I emission lines, indicating that both emissions are related to the same astrophysical process, and possibly modulated by stellar rotation. Ultimately, we will use the profile variability of these lines as well as the line luminosities to analyse the complex interplay between magnetospheric accretion, outflow, stellar rotation period, and magnetic field topology.

Abundance analysis and magnetic fields measurements in a few Herbig Ae stars

by Swetlana Hubrig, Monika Petr-Gotzens

We present the most recent abundance analysis of a few Herbig Ae stars based on high-resolution UVES and HARPS spectra. The determination of their magnetic fields is carried out using HARPSpol spectra.

Herbig Ae/Be Multiple Systems: A Survey

by Bernadette Rodgers

We present results of an AO imaging search for multiplicity around ¿ 140 Herbig Ae/Be (Fe) stars. Roughly 50% are found to be likely multiple systems, many never before reported. We confirm common proper motion for a subset of these. This survey greatly expands the number of multiple HAEBE systems known, covering a broad range of primary stellar mass and distances.

Evidence for disk precession in LkHA 208

by Bringfried Stecklum

LkHA 208 is a Herbig Ae star featuring a close to edge-on circumstellar disk which is casting a shadow. It is surrounded by a bipolar reflection nebula. The object does not belong to the best-studied members of its class. It was found to be a 0.1" binary using speckle interferometry. Due to the lack of interferometric measurements the disk is poorly characterized. The present contribution provides revised stellar quantities and disk parameters, obtained by radiative-transfer modeling of a well-sampled SED. By comparing POSS I and II images striking changes of the shadow morphology were found which point to disk precession, possibly induced by the secondary.

Signatures of accretion: Pa alpha emission in HD 100546

by Mario van den Ancker

Pa alpha is one of the intrinsically most valuable diagnostics of accretion in YSOs. However, it is based in a wavelength region (1.875 microns) which is heavily affected by absorption from water vapour in the earth's atmosphere and thus generally only observed from space. We have taken advantage of the recent installation of a dedicated Particulate Water Vapour (PWV) monitor on Paranal observatory to use the CRIRES instrument at the VLT to observe the Pa alpha line in the Herbig Be star HD 100546 during an episode of particularly low PWV conditions, normally only present at much higher altitude sites. This constitutes the first detection of this line from the ground. We use the Pa alpha line to determine the accretion parameters of HD 100546 and present a comparison of this novel method to measure accretion with other methods.

The 10 micron feature of Herbig Ae/Be candidates from the Pico dos Dias Survey

by Rodrigo Vieira

Herbig Ae/Be (HAeBe) objects are intermediate mass (2-10 M_sun) stars in the pre-main sequence. Some of their properties remain not well understood to date. Only a full multi-wavelength study is able to reveal the general properties of their circumstellar material.
We propose a method of characterizing the circumstellar environment of such objects by a two-step strategy. First,

the dust chemistry is constrained by a compositional fit of the silicate feature. Once the disk opacity is determined, the spectral energy distribution (SED) is then modeled with the flared disk model proposed by Dullemond et al. (2001).

The preliminary results of the first step are shown in the present work. We have adopted the position unbiased sample of HAeBe candidates detected by the Pico dos Dias Survey (Vieira et al . 2003), to study the silicate feature from ISO observations. We have determined the dust grain fractions from fit of the 10 micron feature, with a combination of commonly adopted dust grain opacities. We have also studied its shape and correlation with the infrared spectral slope.

We conclude that the amorphous carbon can be responsible for an important fraction of the dust grain composition, in spite of being neglected in previous similar studies (van Boekel et al. 2005; Bouwman et al. 2008). Besides, the studied 10 micron features follow an evolutionary sequence (from amorphous material absorption to crystalline grain emission), as previously reported by Kessler-Silacci et al. (2005).

Our perspectives are to develop a SED automatic fitting tool, that uses the already derived dust opacities as an input. We also plan to extend our sample, in order to perform a statistical analysis of HAeBe disk properties.

Information Material

Please be aware that like in many other big cities, you have to be careful with your belongings, specially cameras and money. Wear a money belt, or cross your purse strap across your chest. Do not wear jewelry if you plan an excursion inside town, and never change money on the street, but do it in the established exchange offices or banks.

Travel to ESO Vitacura Office

The ESO offices in Chile are located in Vitacura, one of the districts of Santiago. ESO Vitacura hosts astronomers, technicians and administrative staff who contribute to the successful operations of ESO sites. ESO/Chile astronomers perform most of their research here, using the data collected at La Silla, Paranal or elsewhere. Regular talks, colloquia and seminars have turned ESO Vitacura into a very active scientific node, acting as a bridge between researchers in Europe and Chile.

The ESO Office in Santiago is located in **Alonso de Córdova 3107**, by the Mapocho River in the heart of Vitacura, a district extending over an area of 28.3 km^2 in the northeastern part of the city.

Arriving by plane: Please note that airfares to and from Chile can get quite pricey when booking shorter than 3 months in advance. The Arturo Merino Benitez Airport is located 17 km northwest of Santiago. The fastest way to get to the ESO Vitacura office from the airport is by taxi. ESO guests normally use the "Transvip" service, a private company located in the baggage claim area and also on the first floor of the airport. The average cost from the airport to the ESO Vitacura office by taxi is CLP ∼20 000 (EUR 25) and the journey takes approximately 30 minutes. A cheaper, but slower way to get to the Vitacura Office is to take a transfer bus to the Metro network. The larger transfer companies are "Tur-Bus" (https://www.turbus.cl/turbus/opencms/03_Aeropuerto) or "Centro Puerto" (http://www.centropuerto.cl/), both connecting with Line 1 of the Metro network. The estimated cost is CLP$1300 (∼2 EUR).

Public Transportation in Santiago

Metro The closer station from the ESO office in Vitacura (Santiago) is the metro station "Tobalaba" (Linea 1). Exit the Tobalaba station at Luis Thayer Ojeda street and walk until the bus stop no. 405, go off in Vitacura with Alonso de Cordova avenue and walk until the ESO office.

Buses Transantiago (http://www.transantiago.cl/es/inicio.html) is the public transport in Santiago. In order to travel by Metro and buses in Santiago, you must have the BIP card (tarjeta BIP) that can be acquired in the Metro stations.The cost of the card will be CLP$1350 (EUR 1.86) and you may load it with at least $1000 more which will cover at least two trips that do not take more than 90 minutes in total.

Taxis The black cars with their yellow roofs can be hailed anywhere. In Santiago, there is a base price of 250 pesos (USD$0.47) plus around 120 pesos for each 200 m driven (or per minute when waiting). The rates are posted on the windscreen; the meter has to be where you can see it. For longer hauls or cross-country, you can negotiate a price beforehand. Tipping is not customary.

Transport from the airport The ESO office is located in Alonso de Córdova 3107, Vitacura, Santiago. Shuttle vans run from the airport to various locations in the city door to door. Most of them have a desk in the baggage hall and on the arrivals level. About taxis, it is recommended to agree a price with the driver before using the taxi (a common fare between the airport and the Vitacura area is around 18000-22000 CLP, EUR 28.00 - 31.00).

How to get Chilean money

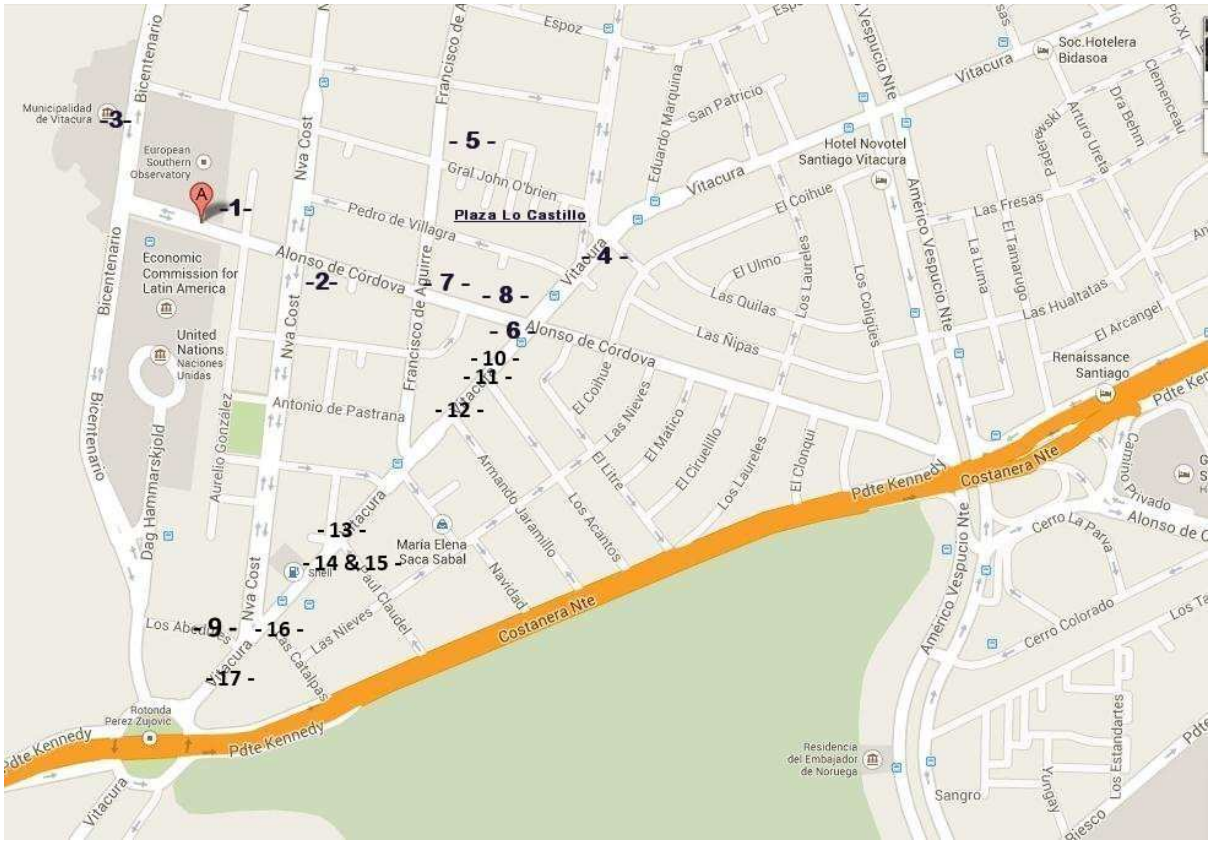
At the airport: you will find ATMs at the first and third level, International Central Hall. They accept Mastercard, Visa, Visa Electron, Cirrus, Plus and Maestro.
There is also an office of the Santander Santiago bank, located at the second level, International Central Hall. It opens from 09:00 - 14:00 hr.
Finally, the exchange office AFEX is opened 24 hours a day, and is located at the first and third level, International Central Hall.

Banks: Most internationally recognized currencies can be exchanged at commercial banks and foreign exchange agencies. Credit cards are accepted in most hotels, restaurants and shops. Banks are opened from Monday to Friday, from 9:00 to 14:00 hr.
The exchange rate for Chilean Currency is approximately (as of March 2014):

- 1 USD = 564 Chilean pesos
- 1 € (Euro) = 775 Chilean pesos

Restaurants close-by

There is a number of restaurants and small places to eat around the ESO office. There is a variety of prices to choose from rather expensive along Alonso de Cordova avenue - with a few exceptions - and others more affordable along Vitacura Avenue. The most economic would be a takeout food from **Le Fournil (4)** or the **Jumbo supermarket (5)** and the menu offered at the **Vitacura Municipality (3)**, in front of the ESO office.



- **-1- Animal**, Alonso de Cordova (just by the ESO office) Quiche, vegetarian, sandwiches, etc.
- **-2- Starbucks**, Alonso de Cordova/Nueva Costanera Sandwiches, natural juices, etc.
- **-3- Self-service restaurant at the Municipality of Vitacura** Three daily menus including vegetarian. From 13:00 - 15:00.
- **-4- Le Fournil** Sandwiches, take-out salads, natural juices, etc. In the Paseo El Mañío, there is also a number of restaurants.
- **-5- Jumbo supermarket** They sell take-out food and also have a self-service sort of cafeteria.
- **-6- Dulceria Las Bezanilla** Salads, pastries, natural juices, etc.
- **-7- Coquinaria** Restaurant and coffee-shop
- **-8- Starnberg** German food
- **-9- La Punta** - Los Abedules 3016 Empanadas, lasañas, quiche, pie, soups, etc.
- **-10- Factoria & Co.** Vitacura 3708 They sell takeout food, but you can also accommodate at the small tables looking on the street.

- **-11- Big John market** - Vitacura/Los Acantos
- **-12- OK market**
- **-13- La Fuente** Vitacura 3396 Sandwiches, pizzas, beer, etc.
- **-14 & 15- Big John** (market) and Lo Saldes (bakery) At Lo Saldes it is also possible to buy the food and use the chairs and tables in the place.
- **-16- another OK market**
- **-17- Boulangerie (bakery)** Craft shop for bread
- **- Plaza Lo Castillo -** Go down the stairs or use the elevator and located in a corner you will find the “Cafe Candelaria”. It offers vegetarian food, natural juices and pastries.

If you continue walking Vitacura avenue after Le Fournil towards Americo Vespucio avenue, you will see several more restaurants and tea rooms.

Sightseeing

Welcome to Santiago Santiago is the capital and biggest city of Chile with over 5,000,000 people. You can find almost everything you need in this city. It has all star hotels, economical bed and breakfasts, restaurants of every ethnic background, discos, clubs, museums, universities, theaters, malls, a modern subway system which makes finding your way around Santiago a lot easier, and much more. Santiago is located at 543 m above sea level in the central zone of Chile. It is at only 100 km from the Pacific Ocean and 40 km from the Andes mountain range. If you want to venture out to other parts of Chile you can get there by bus, airline, and rental car from Santiago.

Bellavista: On the northern bank of the Mapocho, a couple of kilometres east of the Mercado Central is barrio Bellavista. Nestling at the foot of the green slopes of Cerro San Cristóbal, Bellavista is a warren of quiet, leafy streets lined with brightly coloured houses, steeped in a village-like atmosphere. It has a reputation for being the capitals bohemian quarter, thanks in part to the fact that Pablo Neruda lived here, along with several other artists, writers and intellectuals. Check it out by night when the main street, Pío Nono, becomes a colourful crafts market - and wrap up your evening with a candlelit dinner in one of the area's intimate restaurants. Theres no metro in Bellavista itself, but it is at a short walk from Baquedano metro station (Línea 1).

Cerro Santa Lucía: Climbing up the exuberantly landscaped Santa Lucía hill - via a maze of swirling stairways, turrets and fountains - is an essential part of the Santiago experience. Your reward is sweeping views over the city, impressive even when the smog is out in force. Metro: Santa Lucia station (Línea 1).

La Chascona: The former house of Pablo Neruda - Chile's Nobel Prize winning poet - is packed with bizarre and beautiful objects, from Victorian dolls and African carvings to music boxes and paperweights. Preserved as a museum, it makes for a fascinating wander. It is located in Providencia, Fernando Márquez de la Plata 0192. Open for guided tours only (02-7378712).

Barrio Bellavista

3

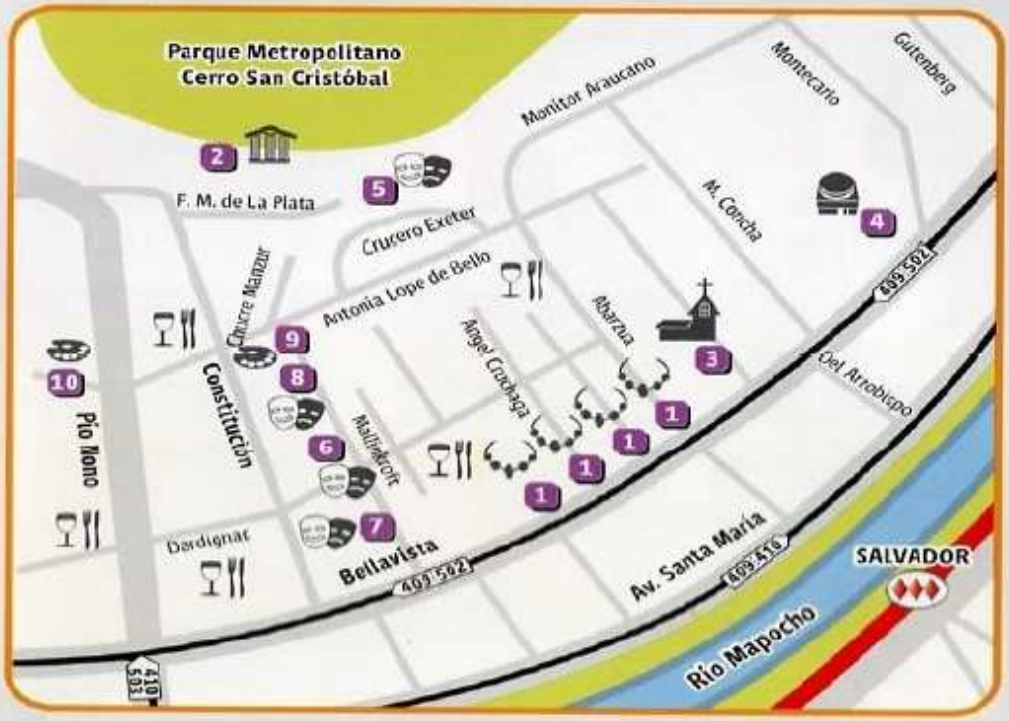
Bellavista neigborhood offers a wide range of attractions that include craftwork, art galleries, theatres and lapislázuli shops, among other activities. Intellectuals and artists consider this place as one of their favourite areas in town. For example, chilean poet Pablo Neruda built one of his houses here, "La Chascona", today a museum. The variety of restaurants, pubs, discoteques and "salsotecas" create an intense night life, turning the area into the meeting place of Santiago bohemian life.

Toda una diversidad de actividades ofrece el barrio Bellavista. Artesanías, galerías de arte, salas de teatro y joyerías de lapislázuli son algunas de las alternativas. Lugar preferido de intelectuales y artistas como el poeta Pablo Neruda donde construyó una de sus casas, hoy convertida en museo. La variada oferta de restaurantes, pubs, discotheques y salsotecas también permiten una intensa vida nocturna, siendo Bellavista uno de los puntos de encuentro favorito de la bohemia santiaguina.

1. *Artesanía Lapislázuli*
2. *Casa Museo Pablo Neruda*
3. *Iglesia Epifanía del Señor*
4. *Centro Cultural Monte Carmelo*
5. *Sala Galpón 7*
6. *Teatro Bellavista*
7. *Teatro San Ginés*
8. *Teatro Mori*
9. *Sala de Arte del Cerro*
10. *Sala de Arte La Ventana Cemicual*

Servicios que transitan por la Zona

409 410 502 503



Los Dominicos market: A good place to hunt for souvenirs is the lively Los Dominicos market, located at the end of avenida Apoquindo in Las Condes district, in a park in front of the Iglesia San Vicente Ferrer de Los Dominicos. Here you will find a huge range of beautiful handicrafts as well as antiques, books, fossils, a restaurant, and live music and dancing at weekends. Buses marked “Apoquindo” come here from the Alameda, or you can take the metro (Linea 1) out to Los Dominicos station (the last one).

Mercado Central: Santiagos distinctive market. The current wrought - iron building dates from 1872. In addition to an appealing selection of fresh fruit, vegetables and fish, the market contains a number of restaurants ranging from modest to fine dining. A nice place to eat fresh sea food. Directions: Occupies an entire block bounded by San Pablo, Puente, 21 de Mayo and Balmaceda Av. (Metro: Cal y Canto Station (Línea 2).

Palacio de la Moneda: the actual seat of the President of the Republic of Chile is located at the heart of Santiago. It was designed by Italian architect Joaquín Toesca. Construction began in 1784 and was opened in 1805, while still under construction. In 1930, a public square was built in front of the palace, the Plaza de la Constitución (Constitution Square). Metro: Moneda Station (Línea 1).

Palacio Cousiño: For a glimpse of how Santiago’s elite lived in the nineteenth century, visit the sumptuous Palacio Cousiño, a splendid 1870s mansion complete with all original furnishings, in Dieciocho No. 438, Metro: Toesca station (Línea 2).

Plaza de Armas (main square): The Plaza de Armas is the epicentre of Santiago, both literally - it is where all distances to the rest of Chile are measured from - and symbolically. Metro: Plaza de Armas station (Línea 5). Standing on the northern side of the square is the Palacio de la Real Audiencia, an immaculately preserved colonial building that today houses the Museo Histórico Nacional where military uniforms and suits of armour jostle for space with old furniture, sewing machines and womens clothes. The west side of the square is dominated by the Cathedral. A combination of Neoclassical and Baroque styles, with its orderly columns and pediment, and its ornate bell towers, the cathedral is the fifth church to be built on this site - the first was burnt down by Indians just months after it was built, and the others were destroyed by earthquakes in 1552, 1647 and 1730. Inside, take a look at the main altar, carved out of marble and richly embellished with bronze and lapislázuli. Note also the intricately crafted silver frontal, which was made by Bavarian Jesuits in the sixteenth century. Youll find more examples of the Jesuits exquisite silverwork in the Museo de Arte Sagrado tucked away behind the main body of the cathedral, along with religious paintings, sculpture and furniture.

San Cristóbal hill (Parque Metropolitano): For a gut-churning ride and matchless views of the city, take the cable car over Cerro San Cristóbal - rounded off with a plunge in the hilltop pool, Piscina Tupahue. Take the funicular from the station at the north end of Pío Nono in Bellavista which shoots up to Terraza Bellavista. From here a path leads west to the teleférico (cable car) station known as Estación Cumbre. This provides rides across to Estación Tupahue, then descends to Estación Oasis at the foot of the hill. Get off at Tupahue for the open-air Piscina Tupahue, or switch cable cars to return to Estación Cumbre. For the more energetic, the Cerro has a network of dirt trails, and a steep and winding road which goes to the top. There is a pool, zoo, giftshops, snack bars, and a fine restaurant to visit as well. The forested hill is a popular spot for running, mountain biking, and family outings. The Pedro de Valdivia Norte entrance (Metro: Pedro de Valdivia station, Line 1) is open between 8 AM and 12 midnight.

Teatro Municipal: In April, the Teatro Municipal will offer a varied program of concerts and dance.

Sightseeing – Museums

Museo Arqueológico de Santiago (MAS): Recently renovated, the museum is a center that reveals the values of the pre-Columbian cultures and the contemporary national plastic arts at the Museo de Artes Visuales. Address: José Victorino Lastarria 307, Santiago. Metro: Universidad Católica (Línea 1) or Bellas Artes station (Línea 5).

Museo de Arte Contemporáneo de Santiago, Espacio Quinta Normal: close to the Museo Nacional de Historia Natural (see below), in Matucana 464. (Metro: Quinta Normal station, Línea 5).

Museo de Arte Popular Americano: Popular Art consisting of pottery, fabric, musical instruments, religious images, painting, leather work, Mapuche silverwork, etc. from American countries, Europe and the East. Address: Compañía 2691, Santiago. (Metro: Cumming station, Línea 5)

Museo de Arte Precolombino is Santiago's finest museum, with a beautifully presented collection of pre-Hispanic art drawn from the whole South American continent. Highlights include elaborate Meso-American incense burners, Andean textiles dating back as far as 3,000 years, and Maya carvings. (See location).

Museo de Artes Decorativas: The mission of the Museo de Artes Decorativas is to offer a place for the aesthetical delight and the knowledge of artistic objects, both useful and beautiful. Located in Tabaré 654, Recoleta, Santiago. (Metro: Cerro Blanco station, Línea 2). The Museo Histórico Dominico can also be visited in the same building.

Museo Histórico Nacional: Painting, photographs, art, textiles, weapons and handicraft, among other things, are part of this Museum created in 1911, and located at the Plaza de Armas. Its goal is to preserve, to research and to spread the Chilean historical patrimony. Metro: Plaza de Armas station (Línea 5).

Museo La Merced: Two important sections can be found in the museum: one of religious art that shows paintings and silverwork of the XVII and XVIII centuries, and another section devoted to American and Easter Island archeology. Address: Mac-Iver 341, Santiago. Metro: Bellas Artes station (Línea 5).

Museo Nacional de Bellas Artes: Paintings, drawings, and sculpture by 16th- to 20th-century Chilean and European artists fill the grand National Museum of Fine Arts. The elegant, neoclassical building, which was originally intended to house the city's school of fine arts, has an impressive glass-domed ceiling that illuminates the main hall. Address: Bounded by Jose M. de la Barra and Ismael Valdés Vergara. Metro: Bellas Artes station (Línea 5).

Museo de Santiago / Casa Colorada: The Casa Colorada is half a block from the Plaza de Armas, an antique structure made of stone whose color gives it its name – "The Red House." It is widely regarded as the best-preserved colonial structure in Santiago, built between 1769 and 1779 as a residence for the first president of Chile, Mateo de Toro y Zambrano. Today, the Casa Colorada operates as the Santiago Museum, depicting the urban history of the city until the 19th century. A visitor center with information about Santiago is also located in the Casa Colorada. Metro: Plaza de Armas station (Línea 5).

Parque Quinta Normal: Located at Matucana 502 (Metro: Quinta Normal station, Línea 5), this 39-hectare (96-acre) park was first used as an animal breeding site and acclimatization park for imported trees; today, it is home to lawns, a wide variety of non-native trees, and a lagoon with boats. It is also home to the Museo Nacional de Historia Natural, (temporarily closed for repairs), which has a fairly interesting collection of stuffed animals and birds, mounted insects, plants, and anthropological exhibits. There is also the Artequín Museum at Av. Portales 3530, housed in a cast-iron building that was first used as the Chilean exhibition hall at the 1889 Parisian centenary of the French Revolution. The building was taken apart, shipped to Santiago, and reassembled here. The museum strives to introduce visitors to the art world through 120 reproductions of well-known works by artists from Picasso to Monet. Kids love the Museo de Ciencia y Tecnología for its interactive displays. Last, there is the Museo Ferroviario, with railway exhibits that include 14 steam engines and railway carriages.

Sightseeing – Shopping Malls

Alto Las Condes has 245 shops, three department stores, a multiplex, and a food court. Address: Av. Kennedy 9001, Las Condes, Santiago. The buses will usually display 'Alto Las Condes' in their boards.

Apumanque: Manquehue Sur 31, Las Condes, Santiago. You can take the metro out to Estación Manquehue (Linea 1) and you are then in front of the mall and other shopping centers.

Parque Arauco: From Metro Escuela Militar (Linea 1), buses depart to this shopping mall in Las Condes, every 20 minutes.

Sightseeing – Picturesque Quarters

Barrio Brasil: Within Agustinas, Avenida Norte Sur, Rosas and Ricardo Cumming, this is an elegant residential neighborhood dating from the 20th century, created around Plaza Brazil. At one time, this was the farthest limits of the city, but as the city grew, wealthy residents moved east in search of quieter surroundings. This barrio now is considered the Bohemian section, with the university, cultural centers, restaurants and cafes.

Barrio Lastarria: Bounded by Parque Forestal, Cerro Santa Lucía and Avenida Libertador Bernardo OHiggins, this neighborhood was established at the end of the 19th century. From the beginning, intellectuals and artists made their homes here and today it is known as a fine residential area with cultural establishments and many restaurants. Plaza Mulato Gil de Castro is an entertaining and novel cultural center found in the beautiful Parque Forestal. It is made up of an interesting and harmonious group of homes, designed by the architects Ignacio Cruz and Walter Biggeman. Everything takes place in the plaza, which includes workshops on painting, sculpture, reproductions & ceramics, as well as bookstores, theater and exhibition halls. It is recommended to visit after a good walk through the area; choose one of the small restaurants with tables outside, drink a good beer and take advantage of the latest books from the publishing houses in the Plaza. Enjoy a coffee at Emporio de la Rosa or Cafe Mosqueto.

Barrio París Londres: Bounded within San Francisco, Alonso Ovalle, Serrano and the Alameda, this neighborhood was once acres of flower and vegetable gardens maintained by Franciscan friars. Most of the houses, built in the 1920s display various architectural styles and the once narrow streets are now vehicle restricted areas with artist studios, hotels and restaurants.

Barrio Concha y Toro: Between the Alameda, Brasil, Agustinas and Ricardo Cumming (Metro República station), this is a neighborhood of narrow, short streets converging on a small plaza, once the property of doña Teresa Cazotte, the widow of Concha y Toro of wine fame. Between 1926 and 1939 a number of neoclassical, gothic and renaissance style three story homes were built, and are now a favored residence of artists and filmmakers who use the barrio in their films.

Barrio Yungay: This solidly middle class neighborhood located between the Alameda, Ricardo Cumming, Rosas and Matucana streets had its beginnings in the middle of the 19th century on what was known as the Llano de Portales. Plaza Yungay was created to honor the Chilean victory of the Battle of Yungay in the War of the Pacific. Located in the plaza is the monument to the Roto Chileno, created by Virginio Arias.

Barrio La Bolsa: The neighborhood developed in the early 20th century on land once owned by the Agustine nuns. Located between the Alameda, Bandera, Moneda and Paseo Ahumada, this barrio shows the classical influence in its buildings, notably the Stock Market, Bolsa de Comercio, the Compañía de Seguros and the Club de la Unión.

Barrio Bellas Artes / Lastarria

2

Lively cultural and gastronomic area, where coffee shops, restaurants and cultural centres are mixed with theatres, bookstores, antique shops and museums, that are set up in old houses and imposing buildings with great architectural value.

Activo núcleo cultural-gastronómico donde se mezclan cafés y restaurantes con centros culturales, teatros, librerías, anticuarios y museos, que funcionan en antiguas casonas o en imponentes edificios de gran valor arquitectónico.

1. *Posada del Corregidor*
2. *Instituto Chileno Alemán de Cultura*
3. *Museo Nacional de Bellas Artes*
4. *Instituto Chileno Francés de Cultura*
5. *Centro Cultural del Mulato Gil*
6. *Iglesia La Vera Cruz*
7. *Instituto Chileno Suizo*
8. *Palacio Bruna*
9. *El Biógrafo Cine Arte*
10. *Teatro Lastarria*
11. *Hostal Andes*
12. *Biblioteca Nacional*
13. *Castillo Hidalgo*

Servicios que transitan por la Zona

116 203 203e 204 206 207 207e 208
210 226 303 307 314 315e 401 403
403c 404 406 407 409 410 412 413
418 419 421 422 426 427 431 502
503 504 505 508 513 514 515

H13 H17 I03 I08
I09e I10 I15 I16 I17 I18
J01 J05 J09 J10 J16 J19

Barrio Brasil / Yungay

4

These traditional neighborhoods were inhabitated by chilean aristocracy and middle class people at the end of the XIX century. Today they represent a unique architectural group, where it is possible to find an interesting mix of modern buildings and antique mansions. Today in these buildings you can find universities, museums, coffee shops, pubs and restaurants.

Tradicionales barrios que habitaron la aristocracia y clase media de fines del siglo XIX hoy conforman un conjunto arquitectónico donde se intercalan modernos edificios junto a antiguas mansiones, concentrando centros culturales, universidades, museos, cafés, bares y restaurantes.

1. *Fundación Victor Jara*
2. *Teatro Novedades*
3. *Peluquería*
4. *Iglesia de San Saturnino*
5. *Museo de Arte Popular Americano*
6. *Iglesia Gratitud Nacional*
7. *Barrio Concha y Toro*
8. *Café "El Café"*
9. *Bar "Baires"*
10. *Restaurant Ocean Pacific*
11. *Restaurant Los Buenos Muchachos*

Servicios que transitan por la Zona

119 120 210 221 401 404 406 407 412 413 418 419 421 422 426 427 431 505 508 511 513

B26 B28 117 J02 J03 J05 J09 J10 J10e J19

Barrio Cívico de Santiago

1

The Civic District covers an important area of downtown Santiago. It is called this way because you can find offices and government buildings, ministries, agencies and its main landmark, Palacio de La Moneda. The main trip goes from north to south, from Plaza de La Constitución, Agustinas, La Moneda, Plaza de La Ciudadanía, Paseo Bulnes, to be completed in Parque Almagro.

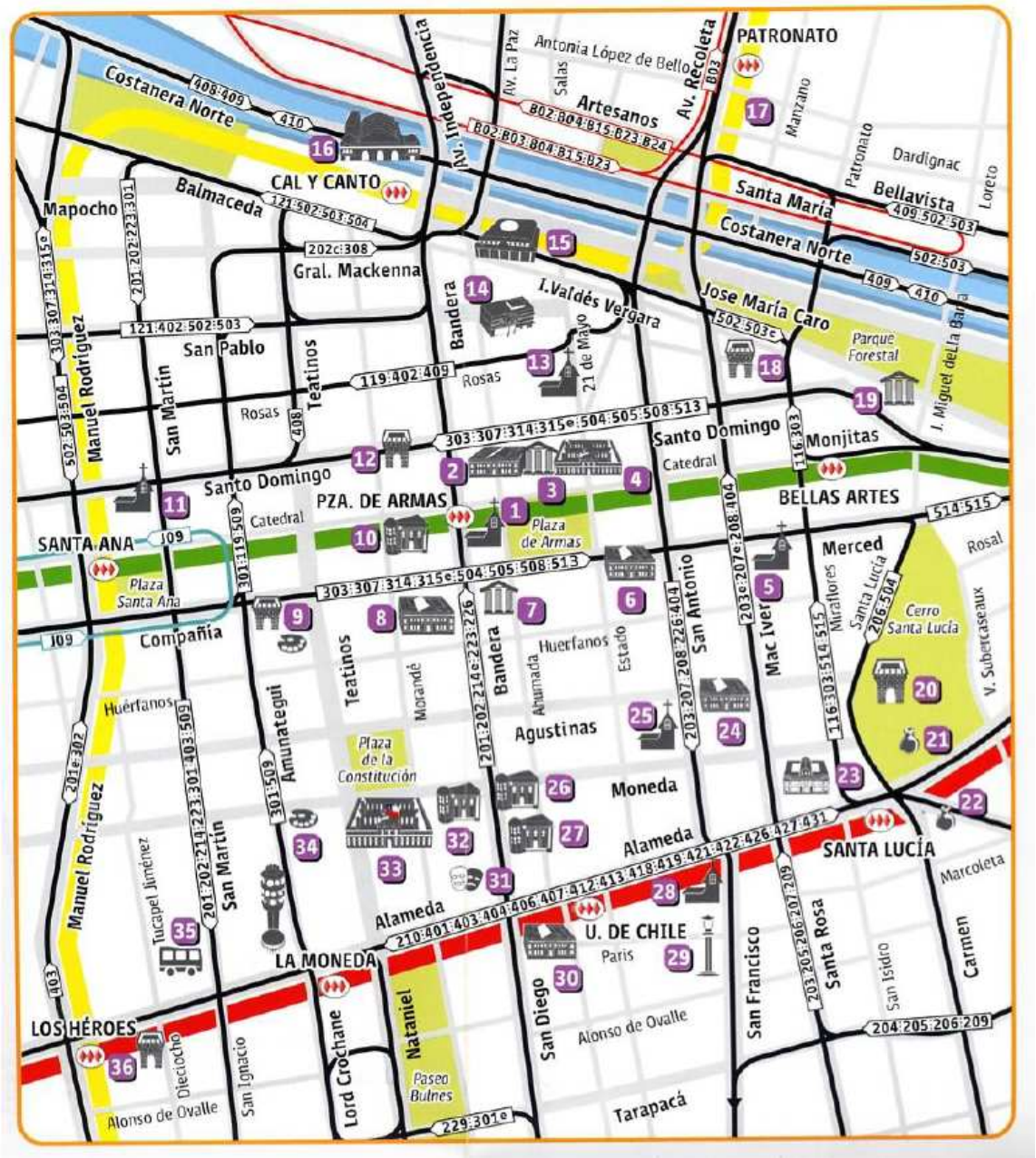
El Barrio Cívico de Santiago comprende una zona de mediana extensión en el centro de la ciudad, dentro de la comuna homónima. Se le denomina de esta manera debido a que los edificios que se encuentran dentro de él son en su gran mayoría dependencias y edificios de gobierno, tanto ministerios y organismos varios como su principal hito: el Palacio de La Moneda. El eje principal comprende de Norte a Sur, Plaza de la Constitución desde calle Agustinas, La Moneda, Plaza de la Ciudadanía, Paseo Bulnes, terminado en el Parque Almagro.

1. Metropolitan Cathedral and Sacred Art Museum / Catedral Metropolitana y Museo Arte Sagrado
2. Municipalidad de Santiago
3. National Historical Museum / Museo Histórico Nacional
4. Central Post Office Building / Correo Central
5. Basílica an Museum of La Merced / Basílica y Museo de La Merced
6. Casa Colorada Museum / Museo Casa Colorada
7. Museo Chileno de Arte Precolombino
8. Tribunales de Justicia
9. Palacio de La Alhambra
10. Building ex Congreso Nacional / Edificio ex Congreso Nacional
11. Church of Santa Ana / Iglesia de Santa Ana
12. Palacio de Velasco
13. Church of Santo Domingo / Iglesia de Santo Domingo
14. Mall del Centro
15. Mercado Central
16. Estación Mapocho
17. Barrio Comercial Patronato
18. Casa Velasco
19. National Museum of Fine Arts / Museo de Bellas Artes
20. Castillo Hidalgo
21. Centro de Arte Indígena
22. Centro Artesanal Santa Lucía
23. National Library / Biblioteca Nacional
24. Municipal Theatre / Teatro Municipal
25. Church of San Agustín / Iglesia de San Agustín
26. The Stock Exchange / Bolsa de Comercio
27. Club de la Unión
28. Church of San Francisco and Museum Arte Colonial / Iglesia de San Francisco y Museo Arte Colonial
29. Barrio Paris-Londres
30. Universidad de Chile Main Campus / Casa Central Universidad de Chile
31. Theatre Antonio Varas / Teatro Antonio Varas
32. Intendencia
33. Palacio de La Moneda – Centro Cultural
34. Galería de Arte Gabriela Mistral
35. Terminal de Buses Los Héroes
36. Palacio Errázuriz (Embajada de Brasil)

Servicios que transitan por la Zona

116 119 121 201 201e 202 202e 203 203e 204 205 206 207 207e 208 209 210 214e 223 226 229 301 301e 302 303 307 308 314 315e 401 402 403 404 406 407 408 409 410 412 413 418 419 421 422 426 427 431 502 503 503e 504 505 508 509 513 514 515

802 803 804 815 823 824 109


PATRONATO
Antonia López de Bello
Av. Recoleta
Av. La Paz
Salas
Artesanos
Manzano
Patronato
Dardignac
Bellavista
Loreto
Santa María
Costanera Norte
Av. Independencia
CAL Y CANTO
Balmaceda
Mapocho
Gral. Mackenna
Bandera
I.Valdés Vergara
Jose María Caro
Parque Forestal
J. Miguel de La Barra
San Pablo
Teatinos
Rosas
21 de Mayo
Manuel Rodríguez
San Martín
Santo Domingo
Catedral
PZA. DE ARMAS
Plaza de Armas
Monjitas
BELLAS ARTES
SANTA ANA
Plaza Santa Ana
Merced
Rosal
Cerro Santa Lucía
Compañía
Huérfanos
Amunategui
Morandé
Ahumada
Estado
San Antonio
Mac Iver
Mirallores
Santa Lucía
V. Subercaseaux
Agustinas
Plaza de la Constitución
Moneda
Alameda
SANTA LUCÍA
Marcoleta
Tucapel Jiménez
LA MONEDA
U. DE CHILE
Paris
Nataniel
Paseo Bulnes
San Diego
Alonso de Ovalle
San Francisco
Santa Rosa
San Isidro
Carmen
LOS HÉROES
Dieciocho
San Ignacio
Lord Cochrane
Tarapacá

Barrio Santiago Poniente 5

Santiago Poniente Circuit is an area that extends from Alameda to Quinta Normal Park located in Matucana street with Portales. In this circuit you can enjoy a wide range of activities of a cultural, but also scientific and technological nature, which can be of great interest for young adults but also for children.

Circuito Santiago Poniente es un área que comprende desde la Alameda hasta el Parque Quinta Normal ubicado en calle Matucana con Portales. En este circuito se pueden disfrutar de una amplia gama de panoramas de tipo cultural, pero también científico y tecnológico, lo que puede resultar de gran interés para jóvenes y adultos, pero también de los niños y niñas.

1. *Planetario USACH*
2. *Centro Cultural Matucana 100*
3. *Biblioteca de Santiago*
4. *Museo de Arte Contemporáneo*
5. *Museo Nacional de Historia Natural*
6. *Museo Artequin*
7. *Casa de Moneda*
8. *Museo Ferroviario*
9. *Centro de Extensión Balmaceda Arte Joven*
10. *Museo de Ciencia y Tecnología*
11. *Museo Infantil*
12. *Museo de La Memória*
13. *Museo de la Educación*
14. *Escuela de Artes y Oficios-Usach*
15. *Estación de Ferrocarriles*

Servicios que transitan por la Zona

105 105c 105c2 109 120 210 218e 221e 302 313e 401 404 406 407 409 410 412 413 418 419 421 422 426 427 431 505 508 511 513

B26 B28 H15 I03 I08 I09e I10 I15 I16 I17 I18 J01 J05 J09 J10 J16 J19

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