Accretion/Ejection Processes in Star Formation: In Theory and in Practice

European Southern Observatory
Santiago, Chile

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Talks

Wednesday

Invited: Observational perspective of accretion in young stars

30th Nov
10:15

Ignacio Mendigutía
CAB/INTA

The mass accretion rate is a fundamental parameter to characterise young stars -and many other astrophysical sources-. It quantifies the rate at which material falls onto the central object, constraining the timescale of stellar formation and circumstellar dissipation. In turn, the way we transform from direct observations to mass accretion rates is closely related to the accepted accretion paradigm.

In this review talk I will show the evidences supporting that magnetospheric accretion is the actual paradigm that drives the derivation of mass accretion rates for the vast majority of young stars. From a practical perspective, I will summarise the ways to derive accretion rates from observable quantities. In addition, I will discuss about the massive sources for which magnetospheric accretion probably no longer applies, and the need of an alternative scenario to infer their accretion rates from observations. Last but not least, I will outline other open issues and future avenues concerning the empirical determination of mass accretion rates.

Invited: The mass accretion rate rom the Class I protostars to the Classical T Tauri stars

30th Nov
11:00

Eleonora Fiorellino
INAF - Osservatorio di Capodimonte

Stars collect most of their mass during the protostellar stage, yet the accretion luminosity and stellar parameters, which are needed to compute the mass accretion rate (Macc), are poorly constrained for the youngest sources. We computed the stellar properties and the accretion rates for a large sample of Class I protostars located in nearby (¡ 500 pc) star-forming regions, analysing their interplay, and adding these results to other Class I studied in the literature to provide a statistically significant overview of the accretion in Class I (55 objects). We used a self-consistent method to provide accretion and stellar parameters using SED modeling and veiling information from near-IR observations. We find systematically larger Macc for our

Class I sample than in Class II objects. Although the Macc we found is high, it still suggests that either stars collect most of its mass before Class I stage, or eruptive accretion is needed during the overall protostellar phase. Indeed, our results suggest that for a large number of protostars the disk can be unstable, which can result in accretion bursts and disk fragmentation in the past or in the future. We show for the first time evidence for a correlation between the mass accretion rate and the disk mass for Class I stars. We fit our sample, finding that the Class I objects relation has a slope flatter than Class II stars. Results are put in context of the disk evolution models, contraining initial conditions for planet formation.

30th Nov
12:15

Signatures of variable accretion in YSOs with optical interferometry

Aaron Labdon
European Southern Observatory

Accretion is known to be dramatically variable across many young objects, from subtle variability on long periods to rapid dramatic outbursts in EXor and FUor objects. Such changes greatly influence and sculpt the characteristics and morphology of inner disks. I present NIR interferometric results of two objects which are undergoing enhanced accretion rates. FU Ori, the archetypal outbursting star exhibiting boundary layer accretion and a viscously heated inner disk; and SU Aur, where a late infall event triggers strong disk winds from the inner disk, obscuring the central star. This work highlights the power of high angular resolution observations in diagnosing accretion and ejection processes in young stars.

30th Nov
12:35

Accretion bursts in high-mass protostars

Vardan Elbakyan
University of Leicester

Recent observations of high-mass young stellar objects (HMYSOs) with masses $M_* \geq 10M_\odot$ uncovered outbursts with accretion rates exceeding $\sim 10^{-3} M_\odot yr^{-1}$. We utilise 1D time-dependent models of protoplanetary discs around HMYSOs to study burst properties. We find that the outbursts triggered by the thermal hydrogen ionisation and magnetorotational (MRI) activation instabilities always have too low accretion rates and are one to several orders of magnitude too long compared to those observed from HMYSOs to date. On the other hand, bursts generated by tidal disruptions of gaseous giant planets formed by the gravitational instability of the protoplanetary discs yield properties commensurate with observations, provided that the clumps are in the post-collapse configuration with planet radius Rp$\geq$10 Jupiter radii.

Numerical limitations so far precluded resolving the inner tens of AU in 3D simulations. We model the disc and migrating object dynamics in this innermost region, aiming to determine their fate. We post-process results of a previous 3D

simulation of a HMYSO disc growth with a 1D code that couples migrating objects to the disc evolution self-consistently. We find that only high-density post-collapse clumps crossing the inner computational boundary may result in observable bursts. In the standard turbulent viscosity discs, migrating objects can stall at a migration trap at a few au. However, in discs powered by magnetised winds, they are able to cross the trap and produce burst.

Periodic accretion burst on YSOs as a results from dynamical perturbation

30th Nov
14:30am

Guo Zhen

Núcleo Milenio for Planet Formation (NPF)

The Pre-Main-Sequence stellar evolution is shaped by the mass accretion process, which is also highly unstable. The near-IR VISTA Variables in the Via Lactea (VVV) survey has successfully observed the episodic mass accretion process on embedded young star objects (YSOs). In this talk, I will present our latest investigations on periodic outbursting YSO candidates discovered from the VVV survey (Guo et al., 2022). In total, 130 candidates are identified, with periods ranging between 10 to 1500 days, likely attributed to dynamical perturbations from a (sub)stellar mass companion. The accretion nature of several objects has been confirmed by spectroscopic follow-ups. Future multi-epoch high-resolution spectroscopic observations are planned to measure the mass of the perturber. This work does not only find indirect evidence of early-stage planet formation, but also provide valuable laboratories to study the mass accretion process in young star-planet systems through both observational and theoretical approaches.

Observational evidence of episodic accretion bursts toward young embedded disks

30th Nov
14:50

Elizabeth Artur de la Villarmois

Pontificia Universidad Católica de Chile

The formation and evolution of protoplanetary disks are fundamental in the process of low mass star formation and in setting up the conditions for planet formation. In particular, Class I sources reveal the presence of Keplerian disks while still embedded in significant envelopes of dust and gas. In addition, Class I sources present infall of material (from the envelope into the disk), accretion (from the disk onto the protostar), and ejection of material through outflows, making them the perfect candidates to study the relationship between accretion and ejection.

In this work, I present an ALMA physico-chemical survey of 12 Class I sources in the Ophiuchus star-forming region. The observation of disk tracers and the high-angular resolution of the data allow us to detect Keplerian motions of the disk and infer the protostellar mass. We find a linear correlation between the protostellar

mass and the luminosity of the source, resulting in a low value for the mass accretion rate, which favors the episodic accretion scenario. In addition, we find that warm SO2 transitions are potentially tracing accretion shocks at the envelope-disk interface, increasing the local density and, therefore, the mass accretion rate.

2nd Dec
15:10

Nonthermal radio variability in protostars with the VLA, ALMA and the VLBA

Jaime Vargas González
European Southern Observatory

Low-mass protostars are known to be highly variable and magnetically active with intense magnetic fields that are responsible for high-energy processes in their stellar surface. These processes can be revealed by X-ray and radio observations, although, only with the revolutionary development of radio facilities in the last decade it has been possible to gradually narrow the gap against the extensive X-ray studies in this field. In this context, I will present a radio variability study for an unprecedented sample of Young Stellar Objects (YSOs) at centimeter and millimeter wavelengths at high spatio-temporal resolution with the VLA, ALMA and the VLBA. Radio variability in protostars at these wavelengths is associated with nonthermal (gyro-)synchrotron emission from magnetospheric activity where the centimeter range is probing gyrosynchrotron radiation from mildly relativistic electrons, and those at higher energies (MeV) are responsible for synchrotron radiation into the millimeter range. I will present the results of our systematic search for intense centimeter radio flares towards the Orion Nebula Cluster (ONC) with the VLA. These results together with the few serendipitous discoveries of strong millimeter flares reported to date has motivated us to conduct a systematic search for mm-variability in the ONC using ALMA. This later study sets the first systematic constraints on the occurrence of such events in a large YSO sample, finding a wide range of variability on timescales of hours to days, where we also present an assessment of systematic effects making use of simulated ALMA observations to find an upper limit for spurious variability. Finally, I present a multi-epoch VLBA survey for exclusively nonthermal emission from YSOs towards the ONC which represents the largest sample of VLBA light curves of protostars at high time resolution from seconds to years where we find strong variability on timescales of days and even within the individual epochs of a few hours.

Thursday

Invited: Overview of VLT/VLTI instrumentation

1st Dec
10:00

Xavier Haubois and Pascale Hibon
European Southern Observatory

Overview of the current VLT/VLTI instrumentation that is particularly suited for observing Star Formation processes.

Invited: The role of photoevaporative and MHD disk winds: a theoretical perspective on current observational evidence

1st Dec
10:45

Uma Gorti
SETI Institute

Accretion drives mass and angular momentum transport through the disk and is central to disk evolution theory, dictating the availability of material in spatial locations. Low levels of disk ionization indicate that magnetically driven disk winds likely carry away angular momentum and are responsible for the radial transport of mass. Disks are furthermore short-lived, dispersing within a few million years of star formation. Thermal or photoevaporative winds driven by heating due to X-ray and Ultraviolet photons are believed to be responsible for the dispersal process. On the observational side, gas emission lines from the optical to the sub-millimeter have indicated the presence of winds either through blue-shifted velocity profiles or via direct mapping of conical structures of outflowing material. I will summarize our current understanding of disk winds and recent advances in that direction.

Bipolar molecular outflow of the very low mass star Par-Lup3-4

1st Dec
12:00

Alejandro Santamaría Miranda
European Southern Observatory

Very low-mass stars are known to have jets and outflows, which is indicative of a scaled-down version of low-mass star formation. However, only very few outflows in very low-mass sources are well characterized. I will present the characterization of the bipolar molecular outflow of the very low-mass star Par-Lup3-4, a 0.12 $M_{\odot}$ object known to power an optical jet using ALMA Band 6 and 7 through the ^{12}CO and ^{13}CO. The properties of the outflows are consistent with those reported in other very-low mass sources and seems to be a scaled-down version of low mass stars.

Molecular Line CAMPOS: an ALMA Band 6 survey for nearby low mass Protostellar outflows

1st Dec 12:20

Aiswarya Arun
Universidad de Chile

Stars form from the gravitational contraction of dense gas within larger molecular clouds. During the contraction, the gas possibly fragments forming multiple protostars, each with a protoplanetary disk and a bipolar protostellar outflow which impacts the parent cloud. The detailed mechanisms of accretion and outflow production are not well known and are essential to understand the final stellar masses and the evolution of planets in disks. CAMPOS is an ALMA Band 6 Cycle 7 survey of 125 nearby protostars in the Chamaeleon, Ophiuchus, Aquila, Corona Australis, and Serpens molecular clouds. We selected all sources having Tbol <1900K, essentially all Class 0, I and the youngest Class II sources, with luminosities from 0.1 to 10 Lsun. We observed the sources in the continuum and in the CO, 13CO, C18O, H2CO, SiO, and N2D+. This survey allows us to study the evolution of jet and outflow morphology with age, YSO luminosity, multiplicity, diskscale dust mass, envelope mass and kinematics, and from cloud to cloud. In this talk I will show the preliminary results consisting of outflow morphology, multiplicity, and molecular line characterizations in the Chameleon star forming region.

Submillimeter water masers as excellent tools to study jet-disk like structures in high-mass protostars

1st Dec 12:40

Itziar de Gregorio-Monsalvo
European Southern Observatory

Water is one of the few molecules capable of producing maser emission in star-forming regions and it has been detected in a wide range of masses from low to massive young stellar objects (YSO). Previous studies focused on the water maser transition at 22 GHz, which constitutes a good tracer of mass-loss activity in young stars of all masses. In low-mass protostars these are mostly present during the first stages of evolution and they tend to be located close to the central protostar when the most powerful mass-loss phenomena are present. Recent studies suggest these masers trace also mass loss phenomena in intermediate and high mass sources. The water molecule shows several maser transitions at submillimeter wavelengths, which makes last generation of submillimeter telescopes like APEX and ALMA excellent facilities to follow up in the submillimeter the studies done in the past decades at 22 GHz. In this poster we present a survey of submillimeter water maser transitions at 321 and 325 GHz in a sample of YSOs with a wide range of masses, from high to low-mass. We show preliminary results of these surveys, including an analysis of the velocity structure of different maser lines, which in combination with future higher angular resolution studies could reveal if the presence of jet-like structures is something expected across all range of masses. This is particularly interesting in the case of high-mass young stars since it impacts directly in their possible formation mechanisms.

Resolving the Binary Components of the Outbursting Protostar HBC 494 with ALMA

1st Dec
14:20

Pedro Henrique Nogueira
Universidad Diego Portal

Short contributed talk abstract: We present 1.3 mm Atacama Large Millimeter/submillimeter Array (ALMA) observations of HBC 494, an FU Ori-like object embedded in the Orion Molecular Cloud. In the previous deepest continuum ALMA observations (0.2" resolution), the unresolved disk showed asymmetric residuals when modeled as a unique gaussian disk. In this study, we present 0.028" (12 au) HBC 494 observations, which reveal that the source is a binary system with a projected separation of ∼0.18" (75 au). Radiative transfer modelling results had shown that HBC 494 N is ∼5 times brighter, ∼2 times bigger and ∼5 times more massive than the other component. We also present 12CO, 13CO, and C18O molecular line observations, which shows the large extension (∼8000 au) and dynamics of the bipolar outflows, characteristics of YSO, class 0/1 at such episodic accretion stage.

The VLTI view on massive YSOs

1st Dec
14:50

Evgenia Koumpia
European Southern Observatory

The formation of massive stars (> 8 Msun) has been a challenging topic for many decades. Our understanding of massive star formation is advancing due to new, high angular resolution observations. Here, I provide an overview of the progress made over the past decade using powerful interferometers at different wavelength regimes (e.g., VLTI, ALMA). Impressive structures and phenomena, such as discs and multiplicity, have now been observed, advancing our understanding of the nature of MYSOs, and therefore of high mass star formation.

Accretion on populations of intermediate and high-mass YSOs

1st Dec
15:10

Miguel Vioque
Joint ALMA Observatory

Historically, the study of the general properties of intermediate- to high-mass forming stars has been hampered by the lack of a well-defined, homogeneous sample, and because few and mostly serendipitously discovered sources were known. As a consequence, many open problems involving high-mass star formation suffer from biases and lack of completeness, and we know much less about these sources than about their lower mass T Tauri counterparts. Applying machine learning techniques to Gaia data we have constructed a large and homogeneous catalogue of 2226 new intermediate- to high-mass forming stars, increasing by an order of magnitude the number of known objects of the class. This unique list of new massive forming stars

is an excellent dataset to conduct research on several open problems in high-mass star formation. In the near future, this catalogue of new massive forming stars will be observed by the WEAVE multi-object survey spectrograph. This will greatly enhance and complement the Gaia data products. To exemplify this, I present the results of a spectroscopic survey that targeted 145 stars from this catalogue. These observations allowed us to derive accretion rates and to study which accretion mechanism is predominant in different stellar mass ranges. I provide further evidence to the transition from magnetospheric accretion to boundary layer accretion happening at around 4 solar masses. One long-standing problem in high-mass star formation is what is the fraction of massive forming stars in relative isolation. I conclude the talk with a Gaia-based analysis on the clustering properties of massive forming stars, using the largest sample ever considered.

Friday

Invited: Observing with ALMA and Roadmap to 2030

2nd Dec
10:00

John Carpenter

Joint ALMA Observatory

Short contributed talk abstract: ALMA's unprecedented angular resolution, sensitivity, and imaging capabilities have transformed our understanding of our cosmic origins, from the origins of galaxies to the formation of stars and planets. In this talk, I will highlight the capabilities of ALMA to study to accretion and ejection process in star formation. I will also describe the exciting new capabilities under development that will increase the bandwidth of ALMA's receivers and correlator by up to a factor of four.

Invited: Insights on Insights on Planet-forming Disks and their Evolution from ALMA Observations

2nd Dec
10:45

Laura Pérez

Universidad de Chile

During their formation, young pre-main sequence stars are generally surrounded by a gaseous accretion disk, which provides a large reservoir of material available for the eventual formation of planets. The high-resolution imaging capabilities in the sub-millimeter regime, now available thanks to ALMA, allow us to study in astonishing detail the distribution of gas and solid material in these planet-forming disks. Disk evolution and planet formation will leave an imprint on disks, resulting in a variety of substructure observed at large and small scales. In this talk, I will discuss how different disk components are traced and their properties are studied, how recent ALMA observations have characterized the underlying substructure of these protoplanetary disks, and how the evolution of protoplanetary disks can be traced by observations of their dust and gas components. All of these different avenues of research gives us new insights into planet-forming disks in the era of ALMA.

ALMAs' long baselines resolve compact discs in a wide binary

2nd Dec
12:00

James Miley
Joint ALMA Observatory

Observations using ALMA's long baselines have been instrumental in revealing sub-structures related to the mechanisms for planet formation and disc evolution. Observations with high angular resolution have revealed a plethora of different density sub-structures in young circumstellar discs related to the formation mechanisms of exoplanets. As well as these spectacular poster-children, there also exists a significant population of discs that appear radially compact for which no substructure is resolved at all. Are large numbers of "compact" discs scaled-down versions of the bright ones, meaning we require improved sensitivity and resolution to see their fine features? Or are they simply discs without sub-structures, in which different physical mechanisms dominate the evolution of disc density? Here I will present an analysis of ALMA's view of two Lupus compact discs, Sz 65 and Sz 66, that are thought to be in a wide binary system (∼1000 au separation), updated using new very high angular resolution observations (0.035", ∼5 au). We search for density sub-structure and investigate the true nature of the previously unresolved compact discs.

Massive star formation through global collapse in IRAS 15394-5358

2nd Dec
12:20

Swagat Ranjan Das
Universidad de Chile

Short contributed talk abstract: Understanding the formation mechanism of massive star formation is still not completely well comprehended. One of the processes these massive objects form is large-scale accretion. However, it requires more attention to understand this process in detail. In the present work, we study the massive clump IRAS 15394-5358 at l=326.47, b=0.70, Vlsr=-41.6 km/s using molecular line data from the ALMA Three-millimeter Observations of Massive Star-forming regions (ATOMS) survey. The massive clump with a mass of ∼1000 Msun is located at a kinematic distance of 1.82 kpc and has a bolometric luminosity of ∼10000 Lsun. The object is associated with an Extended green object (EGO), suggesting its early evolutionary stage. The ALMA 3 mm continuum image reveals six cores, suggesting ongoing fragmentation within the clump. The brightest core (C-1) has a mass of ∼300 Msun with a radius of ∼0.03 pc, which classifies it as a potential massive protostellar core. The viral analysis shows that the core is collapsing, and the mass-radius relation suggests it is harboring massive OB stars. The zeroth moment map of the H13CO+ molecule reveals a clear web of filaments extending from the massive core, creating a hub filament system. From the molecular line data, we obtain an infall velocity Vin of ∼2.5 km/s and a mass infall Min of ∼6x10^{-3} Msun/yr. The velocity gradient along the filaments towards the central core indicates an ongoing global collapse of the object.

Analysis of the gas and dust structures around Proto Brown Dwarfs in the ODISEA survey

2nd Dec
12:40

Camilo González-Ruilova

European Southern Observatory

The ODISEA survey present the largest protoplanetary disk sample in the Ophiuchus molecular cloud. From 1.3 mm ALMA observations, we analyzed the possible substructures, sizes and estimated masses of the dust around those Young Stellar Objects (YSOs). In that context, the next step was to look into the CO (2-1) line observations for the same sources. Focusing in the substellar objects, we found a variety of gaseous structures around the dusty protoplanetary disk. From 21 Proto Brown Dwarfs candidates (Class I, FT and early II), 16 show continuum emission (∼40% spatially resolved), and 11 gas emission, with large scale outflows, keplerian disks, and a combination of disk and inner outflows part. This is one of the largest substellar sample in the same molecular cloud, at early evolutionary stages.

A 3-dimensional study of molecular emission as a probe of the conditions in the massive disk around Elias 2-27

2nd Dec
14:30

Teresa Paneque-Carreño

European Southern Observatory

Elias 2-27 is a young stellar system that hosts a massive protoplanetary disk (17% of the stellar mass) . In dust continuum it displays two symmetric spiral arms and previous work suggests it is undergoing gravitational instability (GI). In this presentation I will discuss the molecular emission of CO isotopologues and CN in the source. The study of these tracers allows us to understand the environment conditions under which GI occurs and test thermochemical models of protoplanetary disks. By directly tracing the vertical profile in multiple lines it is possible to obtain the temperature structure and density conditions of the disk material. CO isotopologues show variations in the vertical extent and CN is highly asymmetric in its radial and azimuthal extension. Our results indicate that Elias 2-27 may be suffering from late-stage material infall or have a warped inner disk.

2nd Apr
14:50

Probing the multiplicity of young massive stars with NIR long baseline interferometry and high-resolution imaging.

Emma Bordier

European Southern Observatory

Most main sequence massive stars (∼70%) belong to short-period binaries, a fact that does not reflect the binary parameters measured among populations of newly born massive stars. To bridge the gap between these two regimes, we need to obtain strong constrains on the origin of the pairing mechanism and the birth orbital properties. Different scenarios have been proposed to produce close binaries, such as the migration that can occur in the framework of disk fragmentation, in which massive binaries are originally formed at large separations and then harden on a time-scale of ∼2 Myr. Testing this scenario requires to detect a significant number of relatively massive companions at separations corresponding to the expected size of the accretion disk. In my talk, I will describe how optical interferometry (GRAVITY) and high-angular resolution techniques (NACO) are of great importance in characterizing multiplicity at birth, on two different datasets. From the interferometric model fitting of visibility amplitudes and closure phases, I will present some of my latest exciting results, including two important concepts: the multiplicity and companion fraction. In M17, we find a multiplicity fraction of 100% with 2.3 companions orbiting the central stars on average. Similarly, I will show a handful of preliminary multiplicity results from high-angular resolution images taken with NACO. These results will be compared to other recent studies and I will discuss the connection with the current star formation theories.

2nd Dec
15:10

Infrared variability of young solar analogs in the Lagoon Nebula

Camila Ordenes-Huanca

Pontificia Universidad Católica de Chile

T Tauri stars are intrinsically variable. Due to the intense magnetic fields they possess, they develop dark spots on their surface that, because of rotation, introduce a periodic variation of their brightness. In addition, the presence of surrounding disks can generate flux variations by variable extinction and, in some cases, by accretion. This last process usually increases the brightness of the star stochastically or periodically due to either unstable or stable hot spots, respectively. In this study, we have compiled a catalog of 379 light curves for T Tauri stars present in the Lagoon Nebula (M8) region, using data from the VVVX survey in the Ks-band. All these stars were already known and classified as pre-MS stars based on other indicators. The data presented here are spread over a period of more than eight years, which gives us a unique follow-up time for this type of sources at this wavelength. The near-IR light curves were classified according to their degree of periodicity and asymmetry, to look for the physical processes responsible for their variation. Periods were compared with the ones found in literature, on a much shorter baseline. This proved that for 126 stars, the magnetically active regions

remain stable for several years. In addition, our near-IR data were compared with the optical Kepler/K2, when available. We found that periodicity in the two bands are in good agreement, but asymmetry will depend on the bursts/dips amplitude and data cadence.

Posters

Studying the detection of interstellar objects with TESS

Rodrigo Albornoz
Universidad de Chile

The study of interstellar objects is closely related to the field of protoplanetary disks. Studying these objects is of great importance because they are direct evidence of ejection of planetesimals in early ages from other Solar Systems. The Transiting Exoplanet Survey Satellite is an instrument used to detect transits of exoplanets and has continuously observed for more than two years in the antisolar direction. This makes it particularly useful for discovering objects in orbit around the Sun. We generate different synthetic populations of interstellar objects (ISO) extracted from their galactic kinematics and simulate their trajectories throughout a month (Time in which TESS observes towards a place). We then identify and classify the objects that meet the geometric criteria of TESS , along with calculating the minimum size they should have to be detectable based on the limiting magnitude of TESS. Once the objects of the different populations have been classified, we are now able to estimate the number rate of ISO that TESS should be able to detect. With this work we will also be able to focus on other objects of a different nature, such as Long Period Comets, and compare their detection rate with that of ISOs with TESS.

The discovery of 13 new FUor-type outburst using data from VVV and XSHOOTER

Zhen Guo
Núcleo Milenio for Planet Formation (NPF)

Most of the stellar mass was gained during the protostellar stage. The episodic accretion model predicts multiple accretion bursts during the Class I stage, among which the FUor-type event has the highest amplitude (7-8 mag) and longest duration (¿ 10 yr). The mass accretion process of FUors is not controlled by the stellar magnetic field, with their near-infrared spectra dominated by broad molecular absorption bands rising from self-luminous accretion disks. In combination with the near-IR time series from the VVV survey and the near-IR spectra from XSHOOTER/VLT, we are able to identify 13 new FUor-type objects located towards the inner Galactic disk plane. Most of these newly identified FUors are severely embedded Class I object, which are optically invisible. By enlarging the population of known Class I

FUor-type objects, our discoveries provide critical observational information on the occurrence rate of episodic accretion events during the protostellar stage.

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