Panel C / Conclusions

What is the origin and evolution of stars and planets?

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- Science Questions
- Recommendations

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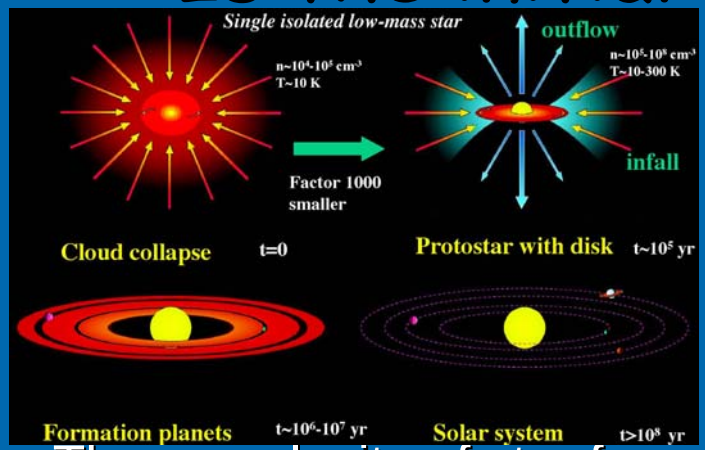
Science Questions

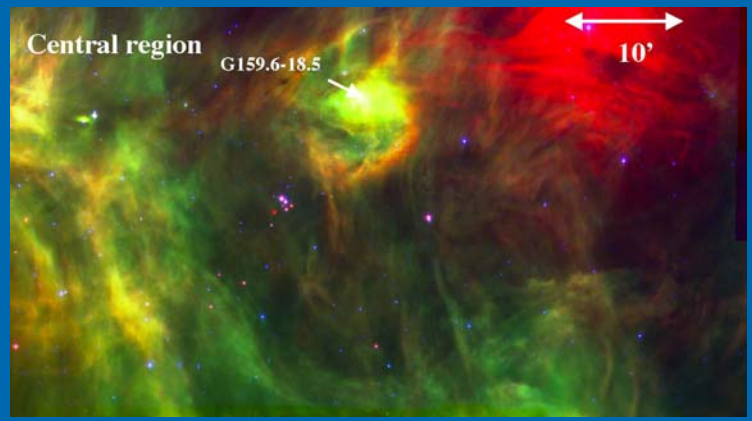
- How do stars form?
- Is the Initial Mass Function of stars universal?
- What can we learn probing stellar interiors?
- What is the life-cycle of the ISM and stars?
- How do planetary systems form and evolve?
- What are the demographics of planets in the Galaxy?
- How do we tell which planets harbour life?

How do stars form?
Is the initial mass function universal?



- The complexity of star formation: microphysics, feedback; magnetic fields, turbulence
- The modes of star formation: quasi-static vs. dynamic, clusters
- Low metallicity star formation and primordial star formation
- The role of clusters: dynamical evolution => demanding computations, evolution of binaries, impact on planet formation
- Origin of the IMF. The IMF as a global product of Star Formation across the Universe and its implication on the evolution of the Universe

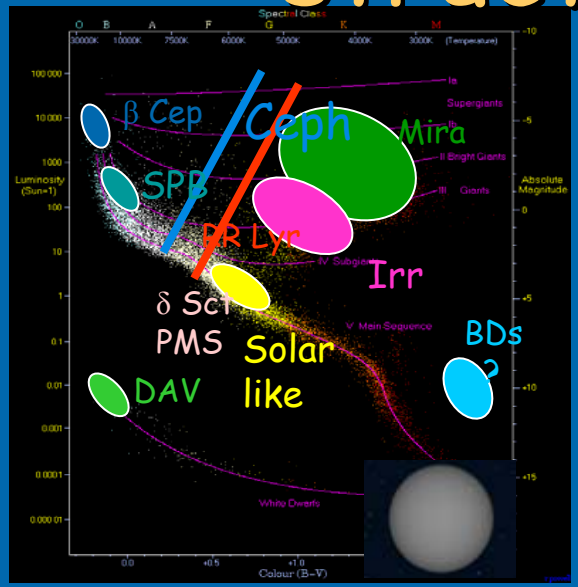
How do stars form?
Is the initial mass function universal?



Tools:

- High angular resolution observations, near and mid IR, mm and radio => resolve dense clusters, understand the structure of protoclusters, extragalactic super star clusters. Herschel, ALMA, JWST. ELT, SKA, far IR space interferometer.
- UV imaging of starbursts: the violent star formation processes in galaxies, the interaction between stellar clusters and the interstellar medium, and the variation of the IMF.
- X-ray imaging: accretion phenomena of young stars (including Class 0).

Do we understand stellar structure and evolution?

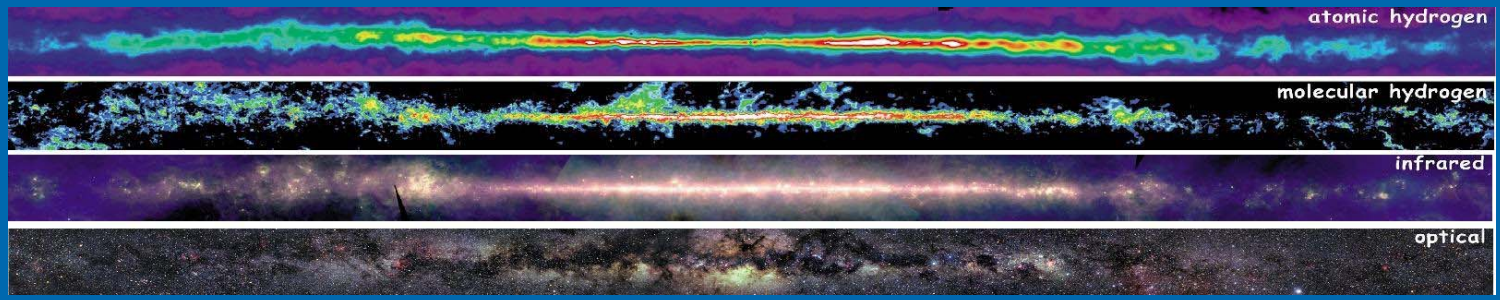


- Interior Physics: structure, magnetic fields, rotation, convection, nuclear reactions
- Physics of stellar photospheres, chromospheres and coronae: opacities, magnetic fields, winds.
- How does stellar evolution proceeds across the HR diagram?. Role of binarity.

Tools:

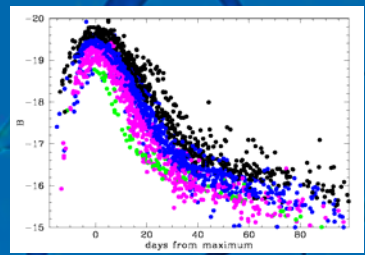
- Asteroseismology as a probe of stellar interiors. High precision photometric and radial velocity monitoring.
- Photospheric abundances as a probe of mixing and evolution. New generation of model atmospheres (3D) and radiative transfer codes. High resolution spectroscopy.
- UV and X-ray imaging and spectroscopy as a probe of chromospheres and coronae.
- Interferometry in near infrared and radio: measuring radii and resolving stellar surface

What is the life-cycle of the ISM and Stars?



ISM

- Chemical evolution of the ISM in the Universe.
- Chemistry of the local ISM and connection with Solar System bodies, Astrobiology,
- Tools: ALMA, Herschel. Laboratory studies.



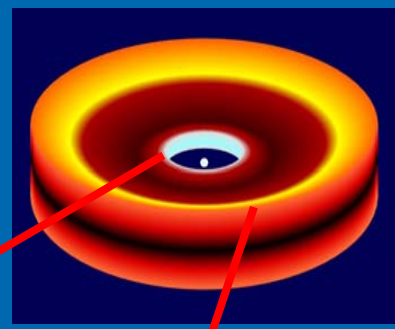
Late stages of stars

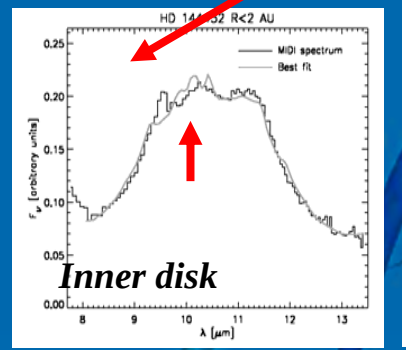
- Supernova/hypernova progenitors, explosion physics. Understanding SN Ia and CC Sne diversity. Formation of compact objects (BHs and NS).
- Yields, wind properties and mass loss history of Sne, Pne and evolved stars,
- Tools: Optical and infrared spectroscopy. ALMA. Herschel. UV and X-ray spectroscopy.

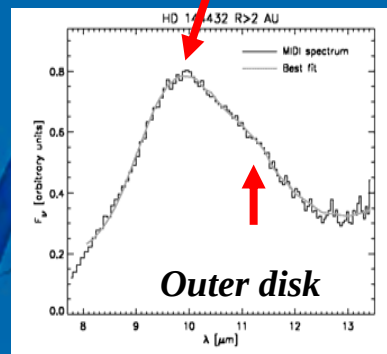
How do planetary systems form and evolve?

- Disks structure and evolution => Planets formation
- Dust evolution from ISM grains to pebbles and planetesimals
- Chemical evolution of the molecular gas
- Direct detection of forming planetary systems

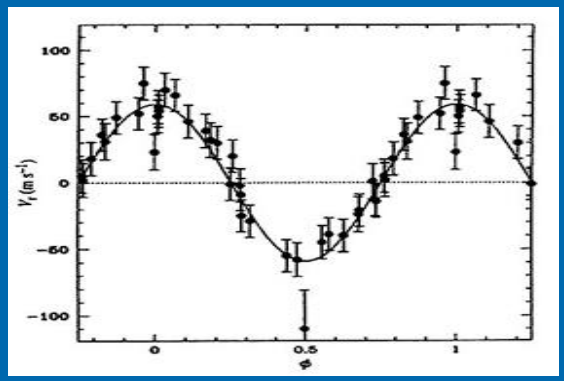
- Tools: high angular resolution observations of dust and gas (ALMA, JWST, SKA, ELT, far-infrared interferometer in space)

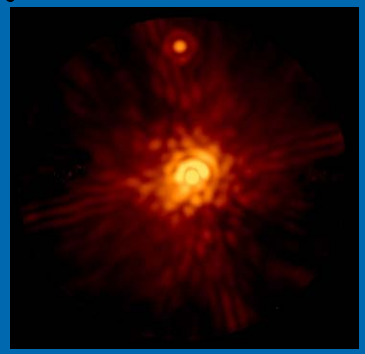






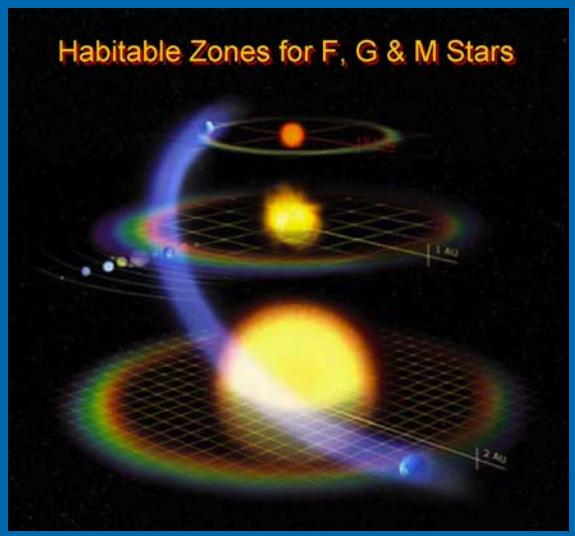
What is the diversity of planetary systems in the Galaxy?

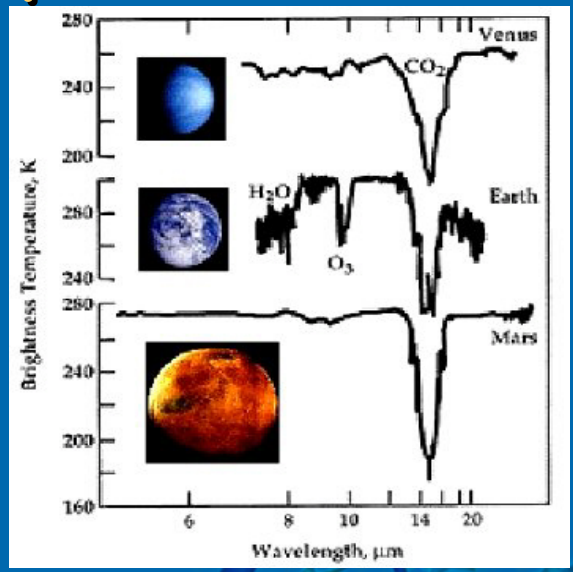




- Expand statistics of exoplanets,
- Direct imaging of giant to terrestrial planets
- Study the physical properties of exoplanets: fundamental parameters (masses, temperatures, radii), chemical composition.
- Is our Solar System a common product of the planetary formation process?
- Tools: high precision (1 cm/s) radial velocity surveys, high precision photometric monitoring for transits and microlensing, transit spectroscopy in UV to mid IR, extreme adaptive optics in near IR, mid IR imaging.

Can we find life on exoplanets?





- Search for terrestrial planets in habitable zone
- Characterization of planetary atmospheres and search for life-supporting and life-byproduct molecules.
- Tools: High contrast imaging in near IR and mid-IR. Extremely sensitive searches in radio.

Recommendations
General

- Essential role of theory and numerical simulations
  - Dedicated machines and development of mathematical tools for dynamical evolution computations
  - From microscopic to macroscopic processes in Star Formation
  - Stellar evolution and structure models. New generation of atmospheric models.
  - Planetary systems formation and evolution
  - Physics of exoplanets
- Laboratory studies
  - Needed for Astrochemistry and Astrobiology
  - Complex molecules and solids, obs. benchmarks

Recommendations
Requirements for principal facilities

- Near and mid infrared imaging and spectroscopy at high angular resolution => Fully AO ELT
- Near- to mid/Far-IR at very high spatial resolution (mas) with high contrast => IR interferometry in space
- High angular resolution and sensitivity in the mm and radio for continuum and spectroscopy => main facility ALMA and possibly SKA
- High spectral resolution in the near to far infrared.
- Long term continuous photometric monitoring with high accuracy => dedicated space platform
- High accuracy radial velocity experiments from the ground
- High accuracy astrometry from ground or space (GAIA)

Recommendations

Requirements for supporting facilities

- Measurements of velocity and magnetic fields on a broad range of scales => sensitive mm/radio large single dish telescopes and interferometers
- Wide field diffraction limited imaging and multi object spectroscopy with current generation of large telescopes
- Full exploitation of ALMA/SKA critically depend on the availability of large single dish and VLBI
- Asteroseismology and exoplanet transits will benefit from coordinated programmes on telescope networks
- Availability of UV and X-ray observatories for deep/large area surveys and spectroscopy of individual objects
- Laboratory experimental facilities for characterization of atomic and molecular species relevant to astrochemistry.