PROJECT A: SEARCHING FOR AN EXOPLANET

Epsilo-Leidensis is a Sun-like nearby star on the Southern hemisphere which is expected to have at least one giant planet. The mass ratio between star and planet is 100:1, and the planet orbits the star in about 50 days. The orbital plane is inclined 30 degrees with respect to the line of sight. The planet is too close to the star to be imaged directly with existing techniques. Assume that t he star is bright enough to provide enough S/N in one hour. Answer the following questions:

1. What method can be used to proof its presence? Describe the general principle.
2. What feature/wavelength can be used to make the measurement?
3. What kind of instrument needs to be used to make the measurement? Give details on the instrument specifications, in particular the minimum angular and/or spectral resolution.
4. Is there a suitable telescope/instrument offered by ESO that could be used for this measurement?
5. Outline a typical observing sequence to complete this program.
6. Now assume that the star is actually fainter than expected and it would take the above equipment 50 hours of integration to get a S/N = 5. Luckily we will soon be able to use a similar instrument with improved performance on the 8m VLT. Assume the limiting noise is detector read noise and it will be 10 times less with the new instrument. How long would we have to integrate with this new instrument on the VLT to get a S/N=5?
7. In case your preferred instrument is a slit spectrograph, list some considerations for the optimum slit width of your observations.

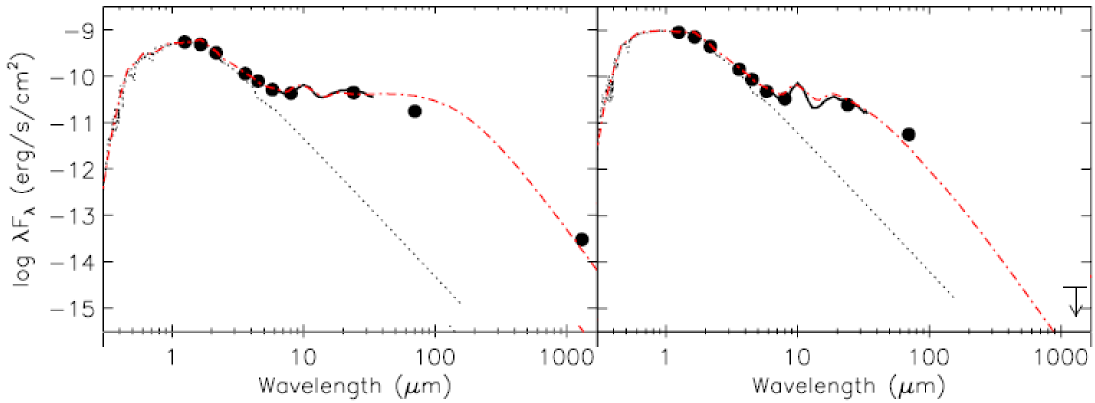
PROJECT B: MASS FUNCTION OF A STAR CLUSTER

Alpha-Sterrewachtus is a massive young star cluster in the Southern sky at a distance of about 5 kpc and an angular size of about 2 arcmin in diameter. We want to derive its stellar K-band luminosity function. Since we didn't get the 50 orbits of HST time, we will now try to observe it from the ground, using one of ESO's telescopes. Due to its high stellar density we need to use a technique that corrects for the atmospheric seeing. Answer the following questions:

1. What technique will you use to correct for the seeing? (Keep in mind that the cluster is 2 arcmin in size!)
2. Is there a suitable telescope/instrument offered by ESO that could be used for this measurement?
3. Since we want to establish the mass function from O3 stars down to the sub-solar mass range, we need to cover at least 8 magnitudes in luminosity. The brightest stars can be images at S/N=10 in only 1 second. How long do we have to integrate to get the same S/N for the sub-solar mass stars?
4. Outline a typical observing strategy. Be aware that the bright stars may cause some image artefacts that we want to mitigate, e.g. with redundant exposures.
5. The most crowded part of a star cluster is its central core of a few arcsec in diameter, and the wavefront correction provided by the above system is not sufficient to resolve the individual stars in the core. What other "flavours" of this technique do exist that could be used?
6. What is the maximum wavefront error (in nanometers at λ=2.2μm) that we can tolerate if we require that the peak brightness of a star may only be 30% less than the peak brightness of its diffraction limited PSF?

PROJECT C: DISK MASS OF PROTOPLANETARY DISKS

Protoplanetary disks are forming simultaneously with the protostar. These disks have a typical diameter of a few hundred AU and many are located at a distance of at least 150 pc. We can study their properties by looking at their SED (spectral energy distribution), which is the flux density multiplied by wavelength, versus wavelength, see Figure.

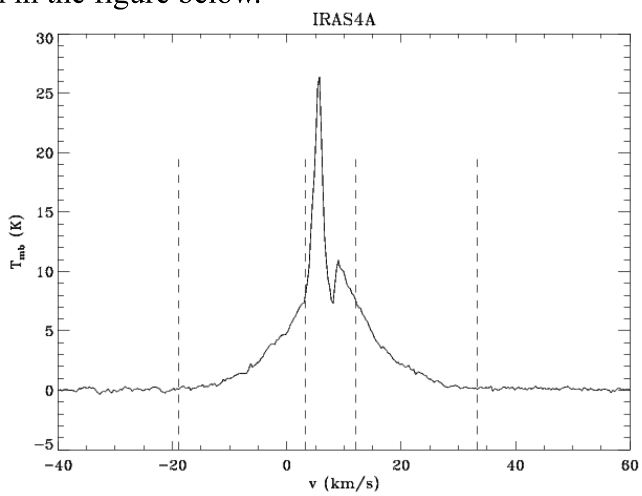


In these SEDs, the black dotted line represents the photospheric flux from the star, the excess at the longer wavelengths represent the thermal emission of the dust in the disk. We want to derive the disk mass of a number of disks, for which the SED needs one or more long wavelength fluxes.

1. Which one of the disks in the figure has a higher disk mass? So at which wavelength(s) do you need flux points to complete the SED?
2. Which ESO facility would you use to measure this flux? Which instrument? What kind of detector is this? Describe its general properties.
3. What is the spatial resolution of this telescope for these measurements? Are you diffraction or seeing limited? Can you resolve a protoplanetary disk? Is that a problem?
4. Outline a typical observing strategy for 5 disks at a declination of -77 degrees, with Spitzer MIPS-2 fluxes of 500, 800,1500, 7000 and 24000 mJy. How would you estimate the flux at longer wavelengths?
5. What is the PWV and why is it important for this kind of observations? What is the main noise contributor? What is the influence of the location of this telescope?
6. There is a similar telescope at Mauna Kea. Look up this telescope and discuss its use for these observations.
7. How would you be able to resolve these disks? Which observing facility would you use? What are the advantages and disadvantages?

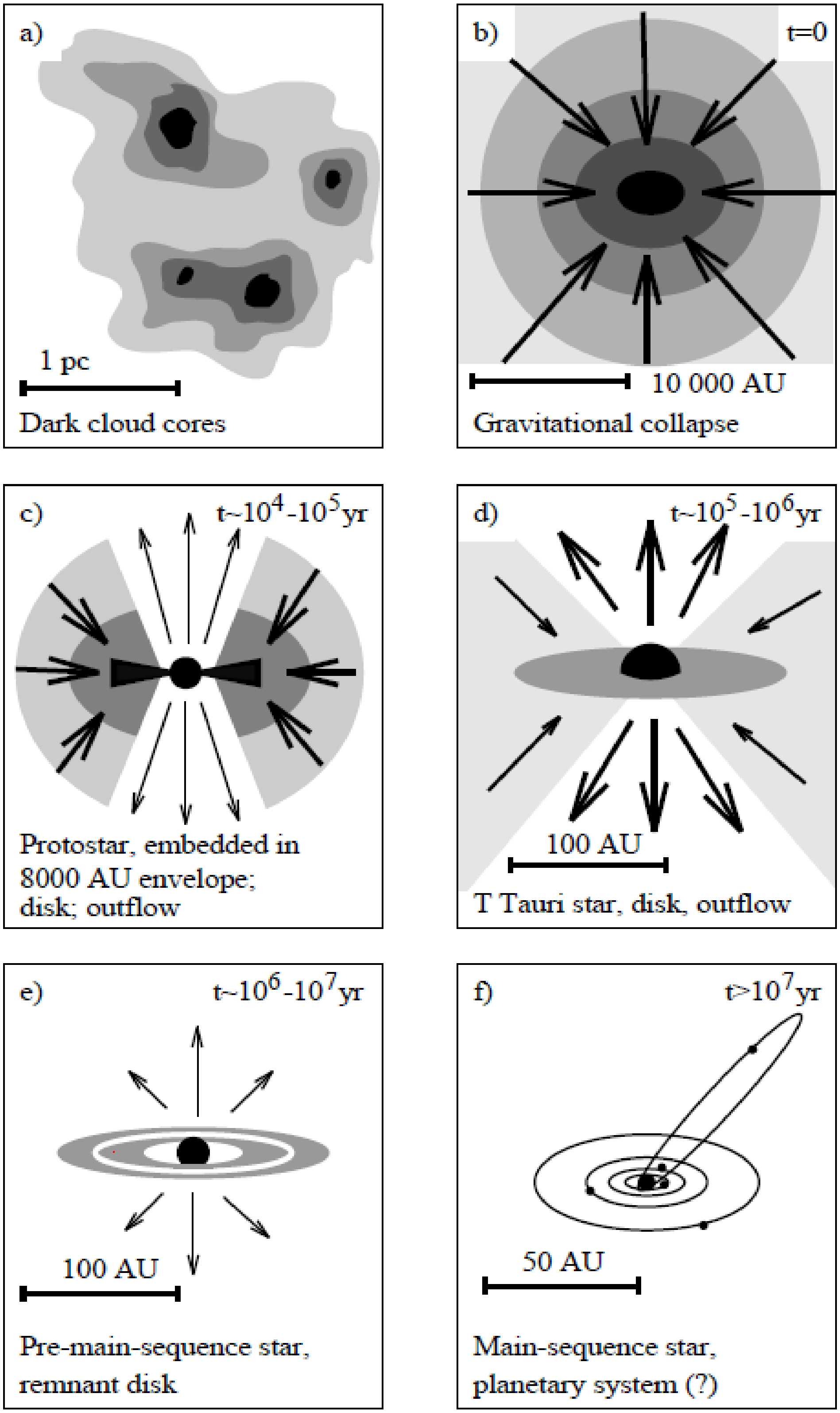
PROJECT D: MAPPING OF MOLECULAR OUTFLOWS

In the early stage of star formation, a gas cloud collapses and the material accretes on the protostar, which is growing larger and larger. At the same time, a bipolar jet starts blowing away the gas in two opposite directions of the protostar, with velocities up to 100 km/s and sizes up to 20 000 AU, and distances of at least 150 pc. This gas being blown away is called a molecular outflow. Studying the distribution of the velocities of the gas at various positions around the protostar helps to understand the underlying mechanism of the yet. The gas tracer we use is the emission line of the ^{12}CO J=3-2 transition. An example of the emission line at the central position of the protostar is shown in the figure below.



1. How can you measure the velocity of gas? Which frequency range to you need to measure typical velocities of ^{12}CO J=3-2? What is the effect of inclination? Remember the outflow is bipolar.
2. What type of instrument do you need to make these measurement? Describe its basic principle.
3. These observations have been taken for various protostars with a telescope at Mauna Kea. Which telescope is this? Which instrument would you use for mapping the outflows?
4. Why do you need a front end and a back end for this instrument? What is the purpose of each?
5. Outline a typical observing strategy for this instrument for mapping a typical outflow at a declination of -24 degrees. Require a noise level of 0.1 K in 0.4 km/s velocity bins. Describe the spatial and spectral extent you can cover and what happens to the noise if you change the velocity bin size.
6. What is the system temperature and what does it have to do with noise? Explain how a quantity in K can represent emission.

Bonus question for each project: which time and date is the best to observe your object? Assume a RA of 16h30m. For project A and B, assume a declination of -30 degrees. Useful links: http://catserver.ing.iac.es/staralt/ and http://www.briancasey.org/artifacts/astro/observability.cgi


a)
1 pc
Dark cloud cores
b)
t=0
10 000 AU
Gravitational collapse
c)
t~10⁴-10⁵yr
Protostar, embedded in
8000 AU envelope;
disk; outflow
d)
t~10⁵-10⁶yr
100 AU
T Tauri star, disk, outflow
e)
t~10⁶-10⁷yr
100 AU
Pre-main-sequence star,
remnant disk
f)
t>10⁷yr
50 AU
Main-sequence star,
planetary system (?)