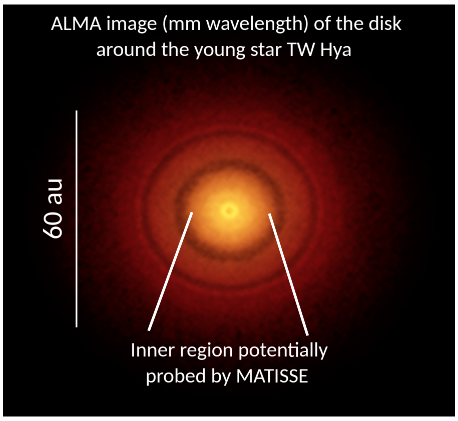
Observing the planet-forming region in protoplanetary disks



As of today, more than two thousand exoplanets have indeed been discovered, through indirect methods for most of them. These only give access to a limited amount of information on these new worlds, and especially tell us very little about the processes that led to their formation. Direct observation of the primordial structures that gave birth to the planets, namely the protoplanetary disks (see image above), require very high angular resolution and a relevant wavelength coverage. MATISSE is a second generation instrument for the Very Large Telescope Interferometer (VLTI) of the European Southern Observatory (ESO), being developed by the Lagrange Laboratory at OCA. Combining 4 telescopes, this unique interferometer will be able to probe the innermost regions (∼ 0.1-10 au) of the protoplanetary disks, expected to be the birthplace of telluric planets. Their formation and evolution processes remains puzzling and this requires to observe and characterize the dust and gas originally present in the disks, which represents the building blocks of planets. In this METEOR, we will explore the basics of optical interferometry and see how MATISSE will work. We will then learn how to create disk models, using radiative transfer, and simulate the future disk observations that MATISSE will produce.

Theory

by A. Matter

I) Optical interferometry

- Basics of optical interferometry : temporal and spatial coherence, observables (visibility, differential and closure phase).
- MATISSE in a nutshell: Concept, sensitivity, accuracy, sources of noise.

II) Radiative transfer

- Basic equations of radiative transfer.
- Absorption and scattering processes by dust grains (dependency on grain size and observing wavelength).

III) Observation of protoplanetary disks

- The inner disk regions: which wavelength and angular resolution ?
- Physical processes in disks and related spatial structures (e.g., interactions planet/disk creating gaps); effect on the observations.

Applications

by A. Matter

The students will produce simulated observations of disks with MATISSE. The work will be divided into three steps:
1) after getting familiar with the radiative transfer code RADMC3D, the students will produce a set of simple disk models including the corresponding brightness maps (synthetic images). This set of models will focus on one particular structure (e.g., gaps of different sizes) that MATISSE will aim to detect in the inner disk regions.
2) From the synthetic model images, the students will then use the tool ASPRO2 to produce the relevant interferometric observables with different configurations of the VLTI telescopes.
3) The students will then introduce these interferometric observables into a simulator of the MATISSE instrument developed here at OCA. Such a tool returns simulated MATISSE data with their corresponding error bars. The simulated MATISSE data will then be examined to assess the feasibility of detection of the structure we will have introduced in the disk models.

See also :

- 'Aspects théoriques et pratiques de la synthèse d'ouverture', Y. Rabbia: Link
- MATISSE website : Link
- 'Radiative transfer in astrophysics ? Theory, numerical methods and application', C.P. Dullemond : Link
- RADMC3D website : Link
- ASPRO2 website : Link

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