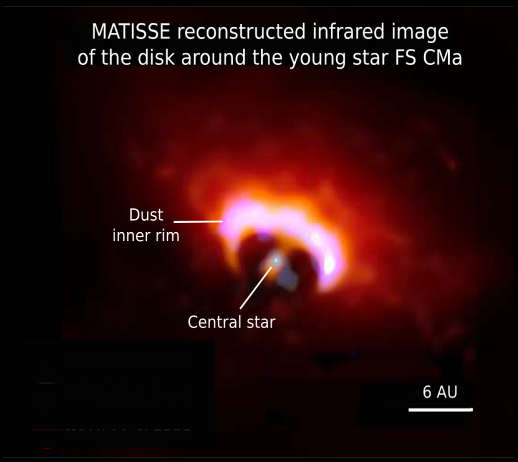
Observing the planet-forming region in protoplanetary disks



SUMMARY.
As of today, more than 4000 exoplanets have been discovered and show a great variety of characteristics (size, position) Understanding the origin of such variety requires direct observations of the primordial structures that gave birth to planets, namely the protoplanetary disks, which require very high angular resolution and a relevant wavelength coverage. MATISSE is a 2^{nd} generation instrument for the Very Large Telescope Interferometer (VLTI) of the European Southern Observatory (ESO), built by a consortium of european institutes led by the J.-L. Lagrange Laboratory at OCA. Combining 4 telescopes, this unique interferometer is able to probe the innermost regions ($\sim$ 0.1-10 au) of protoplanetary disks, expected to be the birthplace of telluric planets. Their formation remains puzzling, which requires to observe and characterize their bulding blocks (dust and gas) in disks. In this METEOR, we will explore the basics of optical interferometry and see how MATISSE works. We will then learn how to create disk models, using radiative transfer, and simulate disk observations with MATISSE.

OBJECTIVES

- Understanding optical interferometry and its applications.
- Developing knowledge and skills in radiative transfer, including the use of a radiative transfer code.
- Linking observations and constraints on the physics of disks.
- Developing a critical view on the feasibility of disk observations.

PREREQUISITES

Fourier optics; General astrophysics (radiative transfer); Dynamics and Planetology

THEORY

by A. Matter & B. Lopez

I) Optical interferometry
- Basics : temporal and spatial coherence, observables.
- the MATISSE instrument: Concept, sensitivity, accuracy, sources of noise.

II) Radiative transfer
- Basic equations of radiative transfer.
- Absorption and scattering processes by dust grains.

III) Observation of protoplanetary disks
- The inner disk regions: which wavelength and angular resolution ?
- Physical processes in disks and related spatial structures; effect on the observations.

APPLICATIONS

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The project will consist of 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., gap, inner disk rim shape) or disk physical parameter that MATISSE may be able to detect or constrain in the inner disk regions.
2) From the synthetic model images, the students will then use the tool ASPRO2 to simulate the interferometric observables that MATISSE would produce, including the expected error bars.
3) The simulated MATISSE data will then be examined to assess the feasibility of detection of the structure or physical parameter we will have focused on in the disk models.

MAIN PROGRESSION STEPS

- First 3 weeks : theoretical courses on optical interferometry (3 chapters) and radiative transfer. Exam at end term.
- First 3 weeks: bibliographic study on MATISSE and disks + familiarization with RADMC3D.
- Second half of the period : feasibility study on disks observations (radiative transfer simulations + use of ASPRO2) .
- Last week : preparation of the final oral presentation.

EVALUATION

- Type of examinations: written, project, and oral presentation.
- The written exam will essentially be a homework on optical interferometry and its applications. During the project, the students will conduct a short feasibility study, from radiative transfer disk modelling to production of simulated MATISSE observables. They will produce a report summarizing the different steps and their own critical analysis. The final oral presentation will be based on that report.
- The criteria to evaluate students' productions will be: understanding of optical interferometry basics, understanding of radiative transfer basics, ability to use the two codes (RADMC3D and ASPRO2), ability to link radiative transfer effects and disk properties, ability to analyse the effect of disk physical parameters on the MATISSE observables, critical analysis of the results, quality of the report and the oral presentation.
- Respective weights for the evaluation: written: 30%, project: 30%, oral: 40%.

BIBLIOGRAPHY & RESSOURCES

- Documentation : Link
- RADMC3D website : Link
- ASPRO2 website : Link

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