Structure of the planet-forming region in circumstellar disks models confronted with high-angular resolution observations

A PhD project for the ESO Studentship Programme

Thesis Supervisor:
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Outline of the PhD project:
*The general goal of this project is to provide predictions for the observability of the potential planet-forming region of circumstellar disks and signatures of ongoing planet formation. The project is motivated by the fact that during the course of the proposed PhD project large ESO instruments will become available which are expected to provide a break-through in the spatial resolution, sensitivity, and dynamic range needed to perform these observations and to investigate potentials of ESO's Extreme Large Telesope project (***E-ELT***). The available Monte Carlo code for the modelling makes use of the modern graphical power units (GPUs).*

Sub-project A: The goal of the first project is to study the *structure* of the innermost ($\sim$ 100 AU), potentially planet-forming region in young circumstellar disks. Aiming at deriving the spatial density and temperature distribution of the dust phase, this project will provide important constraints for the physical conditions of the planet formation process. In particular the use of the disk morphology as derived from high contrast scattered light images with SPHERE/VLT will be studied. For the first time, a high spatial resolution model for the dust phase (considering the scattering phase function of individual, co-existing species of different sizes and chemical composition), the detailed structure of individual sublimation zones for the individual dust species, and the position and shape of the ice-boundary line/surface for selected volatile species will be derived in a self-consistent manner, using our state-of-the-art radiative transfer software.

Sub-project B: During recent years, numerical and analytical studies of the planet-disk interaction have shown that planets may cause characteristic large-scale signatures in the density distribution of circumstellar disks. In young circumstellar disks, with a structure dominated by gas dynamics, the most important of these signatures are gaps and spiral density waves. The importance of investigating these signatures lies in the possibility to use them in the search for embedded young planets. Therefore, these disk morphologies can provide constraints on the processes and timescales of planet formation. The goal of sub-project B is to evaluate the observability of large-scale disk inhomogeneities induced by the interaction of massive proto-planets embedded in circumstellar disks or other processes, such as the suggested local gravitiational disk collapse. This sub-project will be based on the experience in the field of circumstellar disk structure, radiative transfer modeling, and predictions of observable quantities gained in sub-project A.

Common goals of sub-projects A and B: In both sub-projects potential observables will be derived tracing the signatures of embedded giant planets in circumstellar disks, thus providing the basis for observational studies. While existing facilities can be used for the analysis of simple structures (e.g., MIDI, AMBER at the VLTI/ESO) or large-scale structures (e.g., Submillimeter Array, Plateau de Bure Interferometer, NACO and VISIR/VLT), this PhD project will primarily focus on instrumentation which will allow to study structures of higher complexity. In particular the scientific potential of following near to mid-infrared instruments which will provide sub-arsecond imaging capabilities will be evaluated: using at first priority SPHERE, and the upgraded VISIR instrument. Both projects predict first light in 2012. As a second step, the potential of the future **E-ELT** instrument projects EPICS and METIS shall be evaluated as well as 2^{nd} generation VLTI instruments (in particular MATISSE). In addition, the impact of observations with complementary instruments/observatories will be studied (e.g., the Atacama Large Millimeter

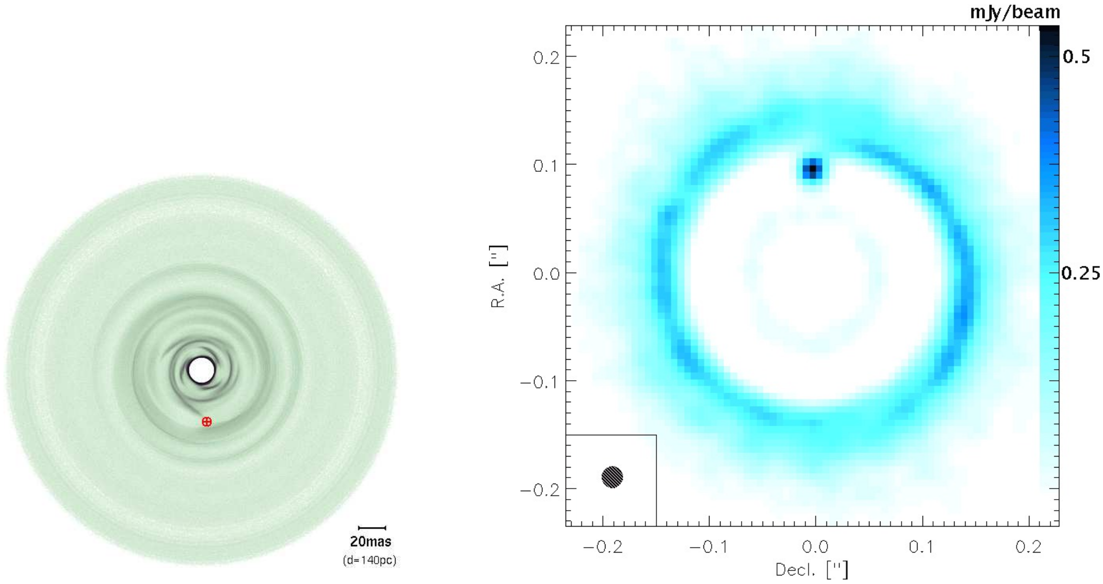

Figure 1. *[Left]* Simulated K band image of the inner region of a young circumstellar disk around a T Tauri star with an embedded Jupiter-mass planet. *[from Wolf et al. (2007), Signatures of Planets in Protoplanetary and Debris Disks, Planetary and Space Science, 55, 569]* *[Right]* Complementary simulated ALMA 900 GHz observations of the same system. The size of the synthesized beam is symbolized in the lower left edge of each image. *[from Wolf & D'Angelo (2005) On the Observability of Giant Protoplanets in Circumstellar Disks, Astrophysical Journal, 619, 1114].* For similar simulations for the METIS/E-ELT in the 11.3μm PAH band see *Siebenmorgen et al., 2010, PAH in the Universe, Toulouse, eds. Joblin&Tielens, EDP Sciences.*

Array, Herschel Space Observatory, James Webb Space Telescope, LBT in interferometic mode, and the Stratospheric Observatory for Infrared Astronomy; see Fig. 1 for illustration).
Supervisors (Siebenmorgen, Wolf): Both supervisors have profound experience in radiative transfer modeling. In addition, the experience of R. Siebenmorgen as instrument scientist/responsible for SPHERE, VISIR, HAWK-I and the METIS project for the ESO's Extreme Large Telescope (**E-ELT**) will allow to guide the numerical studies in the context of future observations. S. Wolf has a long-standing record on the analysis of multi-wavelength, spatially resolved observations of circumstellar disks. He also is the project scientist for MATISSE and is involved in further instrumentation studies (e.g., EPICS).

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