Image reconstruction of circumstellar disks with MATISSE

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The Instrument

MATISSE is a mid-infrared spectro-interferometer at the VLTI that will combine beams from four Unit Telescopes (UTs) or Auxiliary Telescopes (ATs). It will measure closure phases, thus offering the capability for image reconstruction. This will allow us to obtain mid-infrared images with an unprecedented resolution, on the order of 20 milli-arcseconds, corresponding to a few AU at the distance of the next star-forming regions. MATISSE is anticipated to arrive at the telescopes in 2016.

Simulations

As input for our simulated MATISSE observations, we use simulated images of a T Tauri and an Herbig Ae star with a circumstellar disk. These are created via Monte Carlo radiative transfer calculations of hydrodynamic disk simulations (Uribe et al. 2011, ApJ 736, 85; Ruge et al. 2013, A&A 549, A97 – see also Jan Philipp's talk on Tuesday). The T Tauri star has a mass of $0.5\,M_\odot$, while the Herbig Ae star has $2.5\,M_\odot$. We simulated disks with masses between $2.7{\cdot}10^{-8}$ and $2.7{\cdot}10^{-4}\,M_\odot$. They extend from 2 AU to 9 AU from the center and are seen at an inclination of 5° (almost face-on).

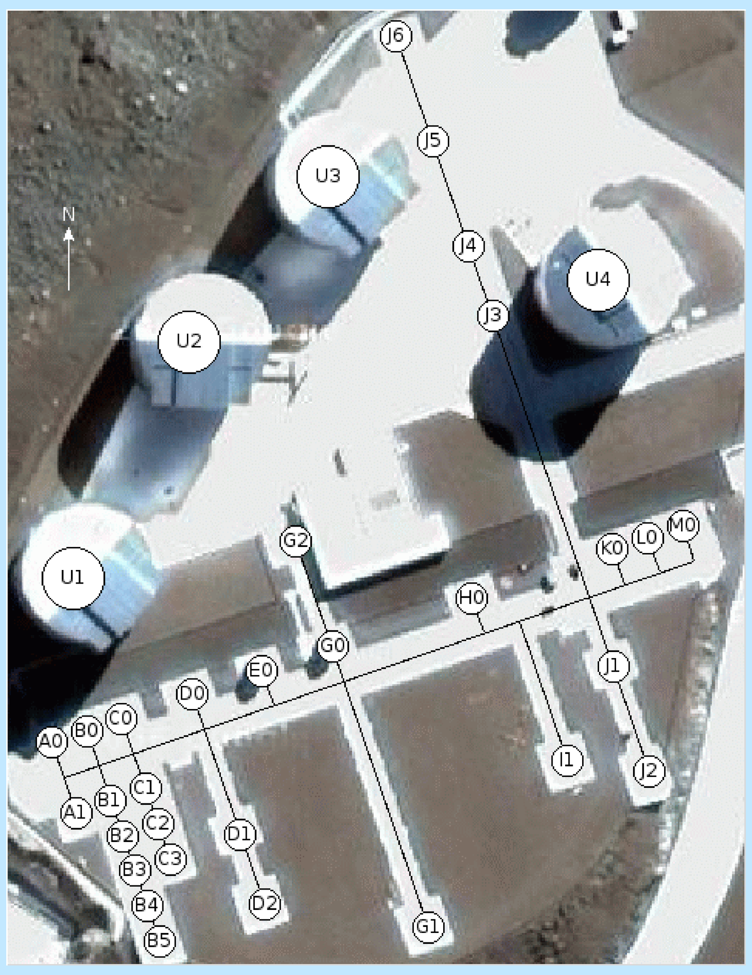


Image ©2007 DigitalGlobe / Google

Telescope Stations

The image to the left shows an aerial view of the VLTI on Cerro Paranal, Chile. The four Unit Telescopes are labeled U1 to U4, and the stations for the Auxiliary Telescopes are marked A0, A1…M0.

The VLTI offers the possibility to position the ATs at several different stations, which gives much better uv-coverage than fixed telescopes. However, we used only one telescope configuration in this study.

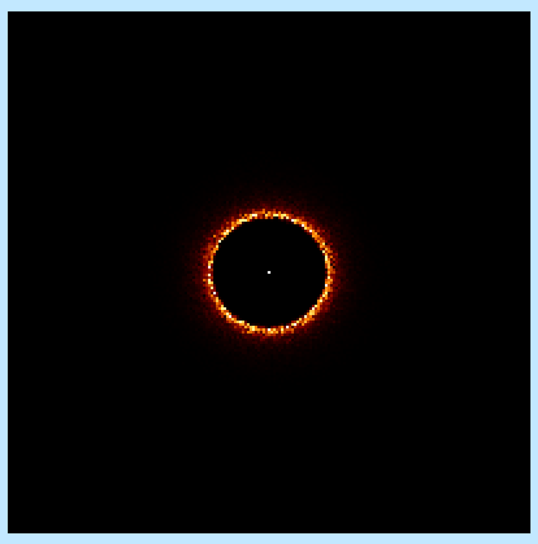
Simulated Observations

The simulated images were "observed" with the simulator of the MATISSE science group, which includes realistic instrumental noise sources. We assumed only **one night** of observations with the four Unit Telescopes, with 11 observations distributed uniformly between hour angles of -75° and $+75^\circ$. The declination of the object was set to -70°. These are somewhat idealized conditions, but serve well as starting point to find configurations that are not suitable for our science case.

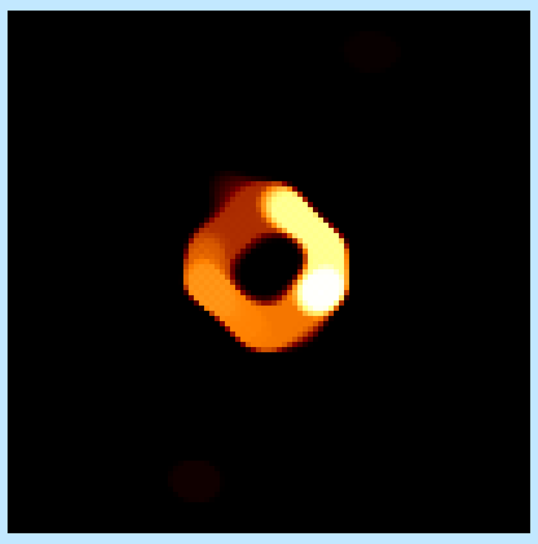
For the image reconstruction, we used the **MIRA** program (Thiébaut 2008, SPIE Conf. Series 7013) with the "total variation" regularisation.

Results – T Tauri Star

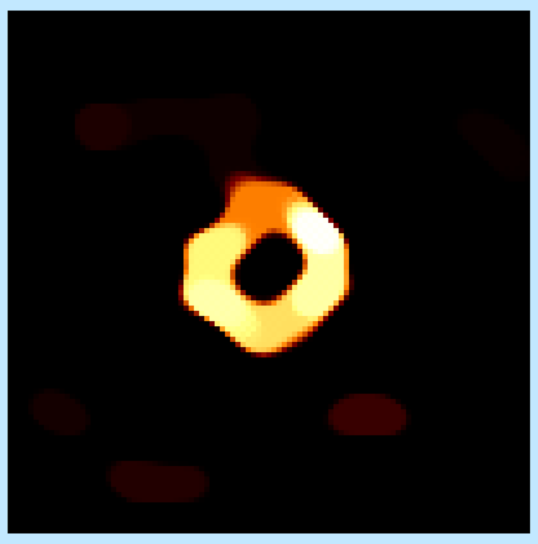
If the disk is massive (= bright) enough, then the ring caused by the inner rim is clearly visible in the reconstructed images. For fainter disks, the central hole is not resolved, or the image reconstruction fails.



typical input image

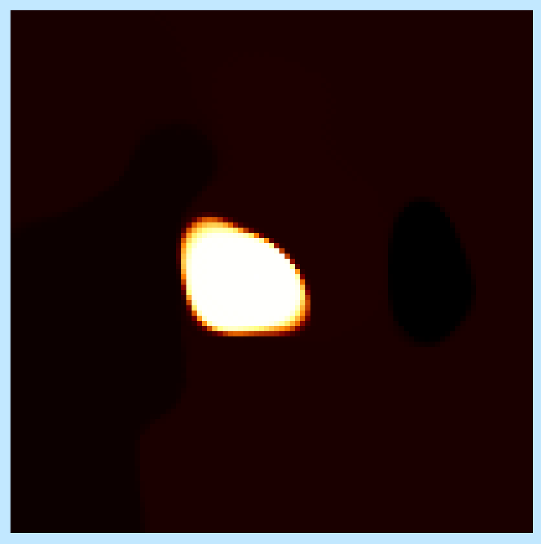


Disk mass $2.7{\cdot}10^{-4}\,M_\odot$

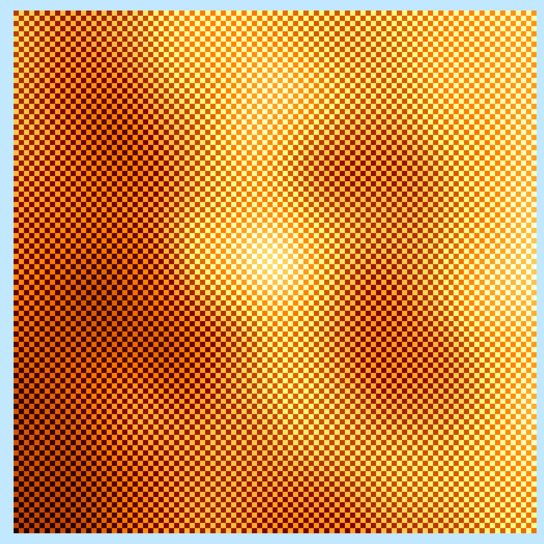


Disk mass $2.7{\cdot}10^{-5}\,M_\odot$

Disk mass $2.7{\cdot}10^{-6}\,M_\odot$



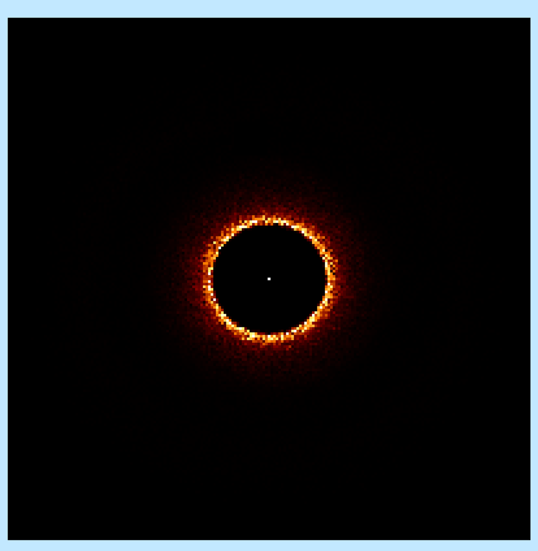
Disk mass $2.7{\cdot}10^{-7}\,M_\odot$



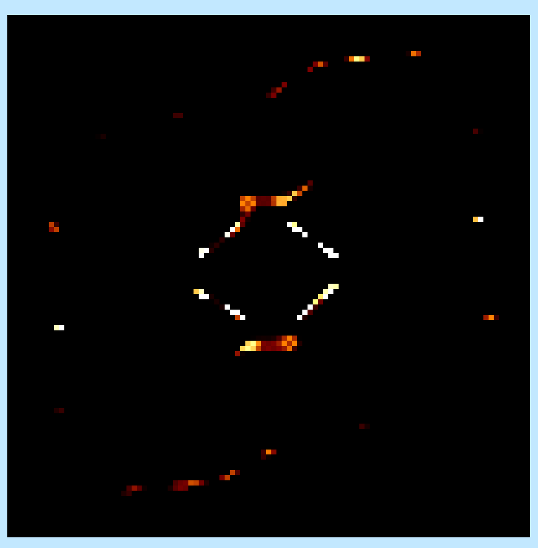
Disk mass $2.7{\cdot}10^{-8}\,M_\odot$

Results – Herbig Ae Star

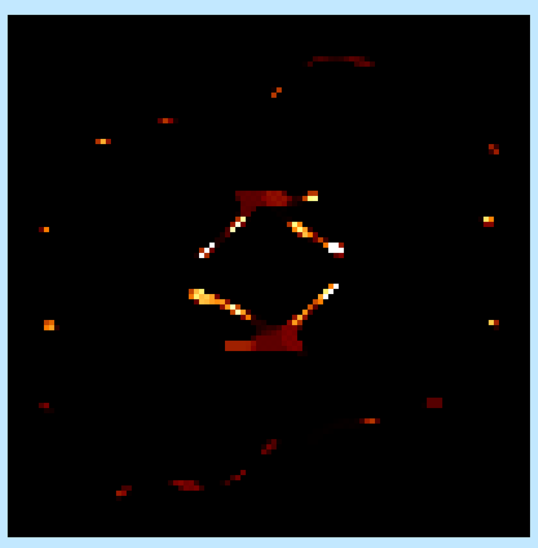
In the case of the Herbig Ae star, the disk is visible in all the reconstructed images. The image reconstruction does not "see" the central star, except in the disk with the lowest mass.



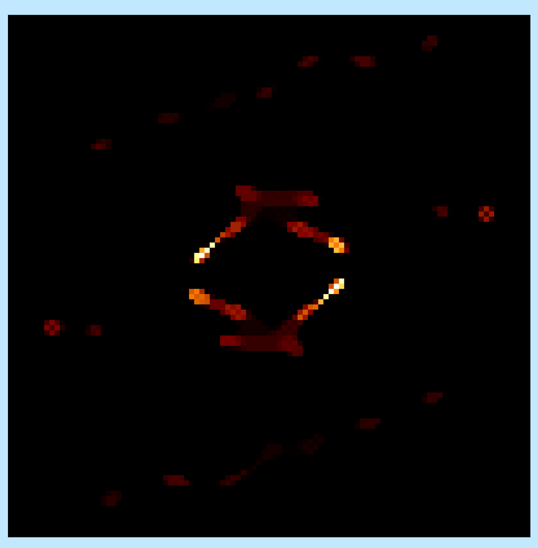
typical input image



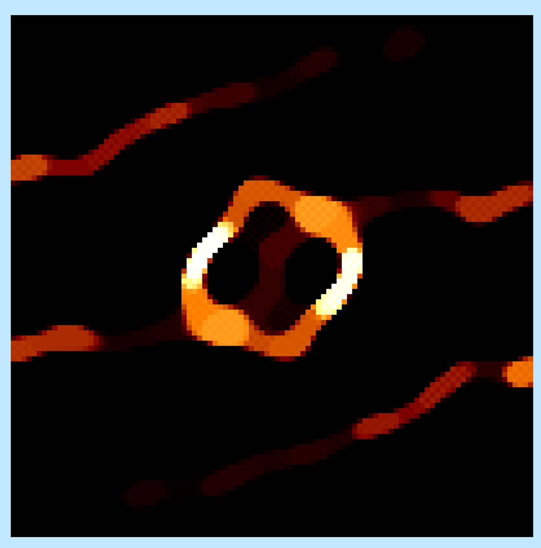
Disk mass $2.7{\cdot}10^{-4}\,M_\odot$



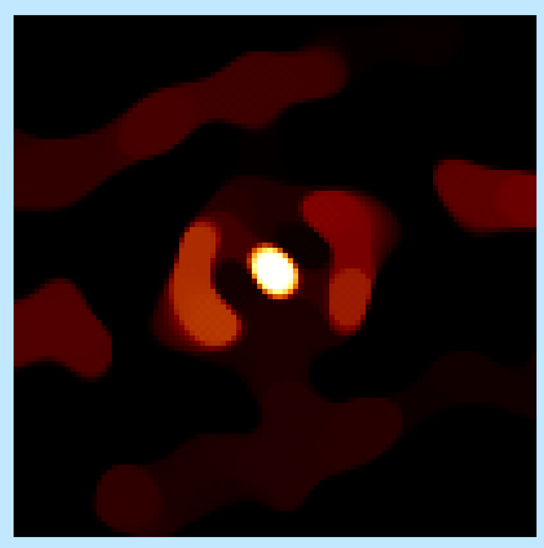
Disk mass $2.7{\cdot}10^{-5}\,M_\odot$



Disk mass $2.7{\cdot}10^{-6}\,M_\odot$



Disk mass $2.7{\cdot}10^{-7}\,M_\odot$



Disk mass $2.7{\cdot}10^{-8}\,M_\odot$

Conclusions:

We are able to reconstruct images of circumstellar disks, showing the central hole, if the signal-to-noise ratio of the simulated MATISSE observations is high enough. However, there are often artefacts in the images. Using more telescope configurations will improve the uv-coverage and therefore the quality of the reconstructed images.