The Structure and Evolution of Circumstellar Disks Revealed by Mid-Infrared Interferometry

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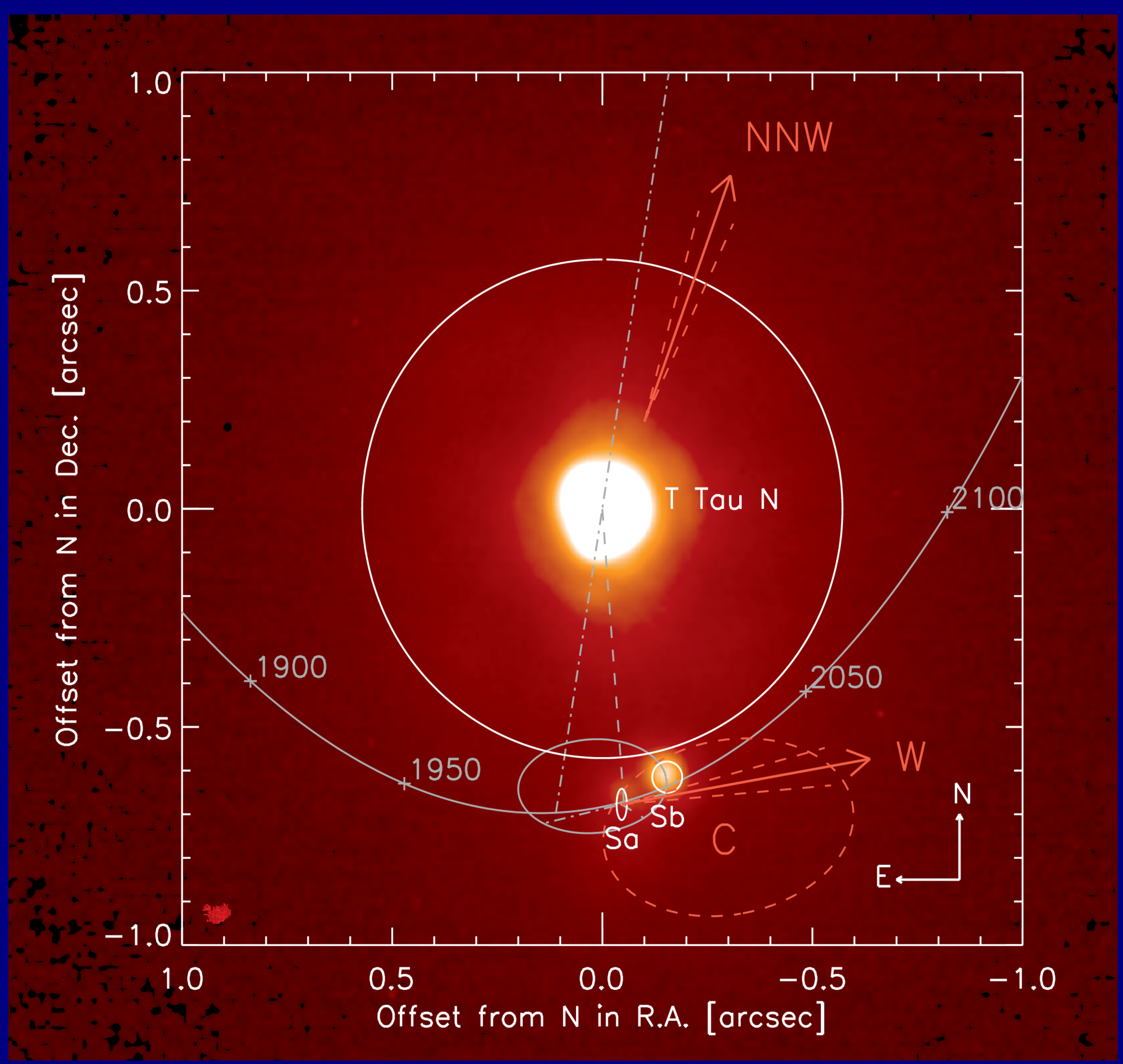
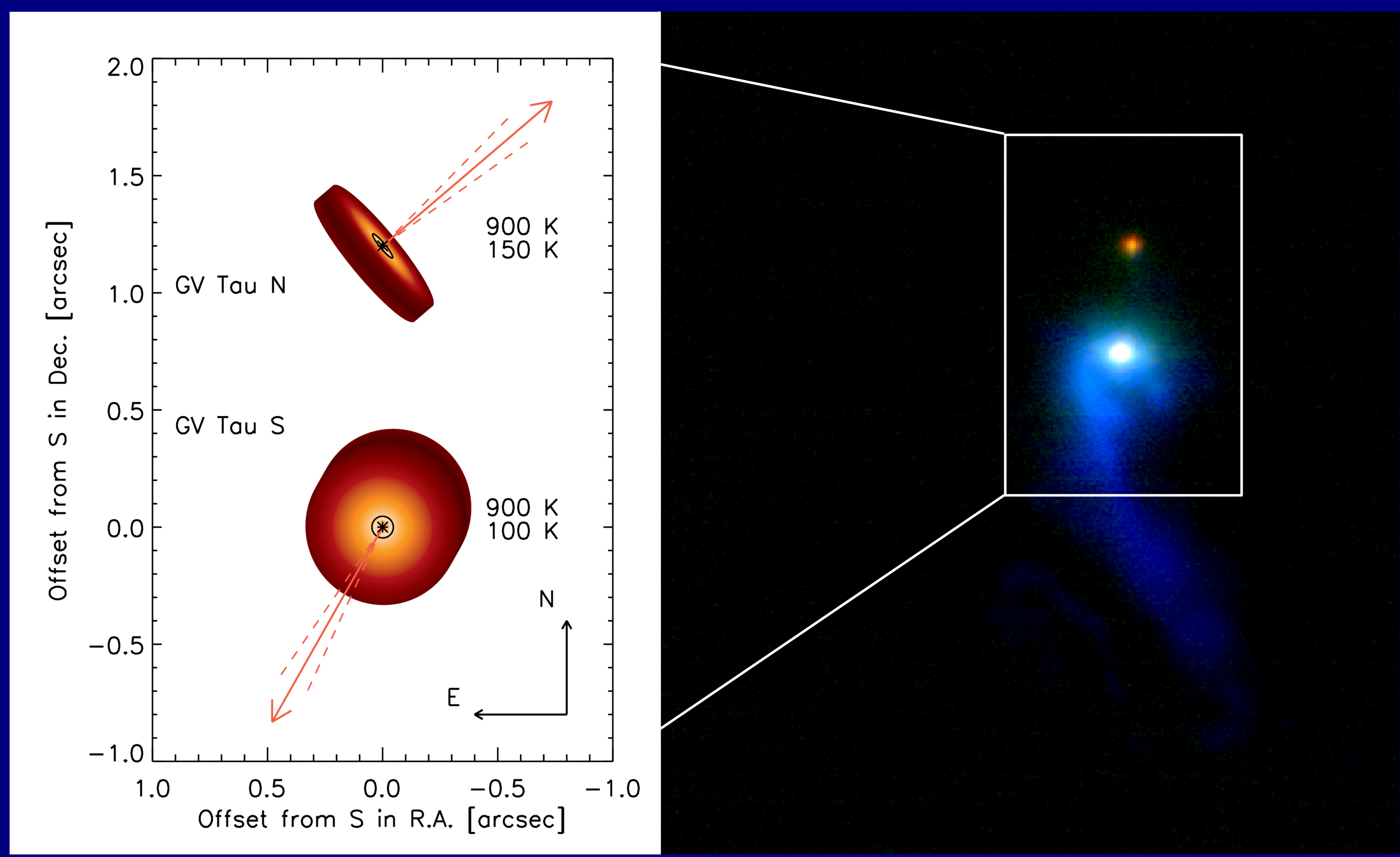
With the 10 - 20 milli-arcsec spatial resolution offered by the MID-infrared Interferometric instrument (MIDI) at the Very Large Telescope Interferometer (VLTI) we were able to resolve the circumstellar disks of several low-mass young stellar objects, e.g., T Tau, GV Tau, SVS 20, and TW Hya. The spectrally dispersed interferometric data in the wavelength range between 8 and 13 µm are also well suited to study radial changes of the dust composition and grain growth, a prerequisite for planet formation.



The triple system T Tau, which harbors the infrared companion Sa. The above sketch combines results of our MIDI measurements and our previous observations. The image is taken with NACO/VLT in the K_S-band.

The sizes ($r_N = 80$ AU, $r_{Sa} = 5$ AU, $r_{Sb} = 5$ AU) and the inclinations of the discs are those that we derived from our simultaneous fits of radiative transfer models to the spectral energy distributions and the visibilities. We can confirm the picture of an almost face-on ($i_N < 30^o$), comparatively massive circumstellar disc (0.04 $M_\odot$) around T Tau N and a disc seen nearly edge-on ($i_{Sb} = 72^o$) around T Tau Sa. In combination with an obscuring screen in the foreground ($A_V \sim 15$ mag) this circumstellar disc is responsible for the faintness of T Tau Sa at short wavelengths (Ratzka et al., A&A 502, 623, 2009).

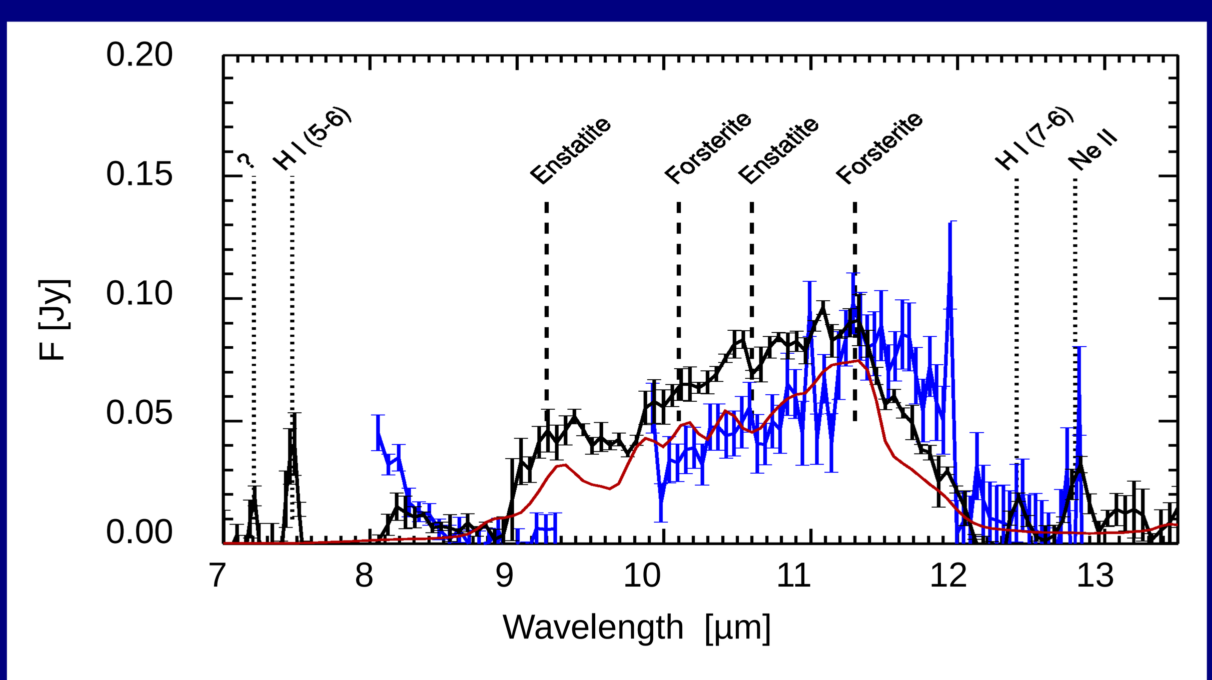
The total mass of T Tau S is rather well constrained by the orbit to 3.0 ± 0.15 $M_\odot$. The mass ratio Sb:Sa is about 0.4, corresponding to individual masses of $M_{Sa} = 2.1 \pm 0.2 M_\odot$ and $M_{Sb} = 0.8 \pm 0.1 M_\odot$ (Köhler et al., A&A 482, 929, 2008).

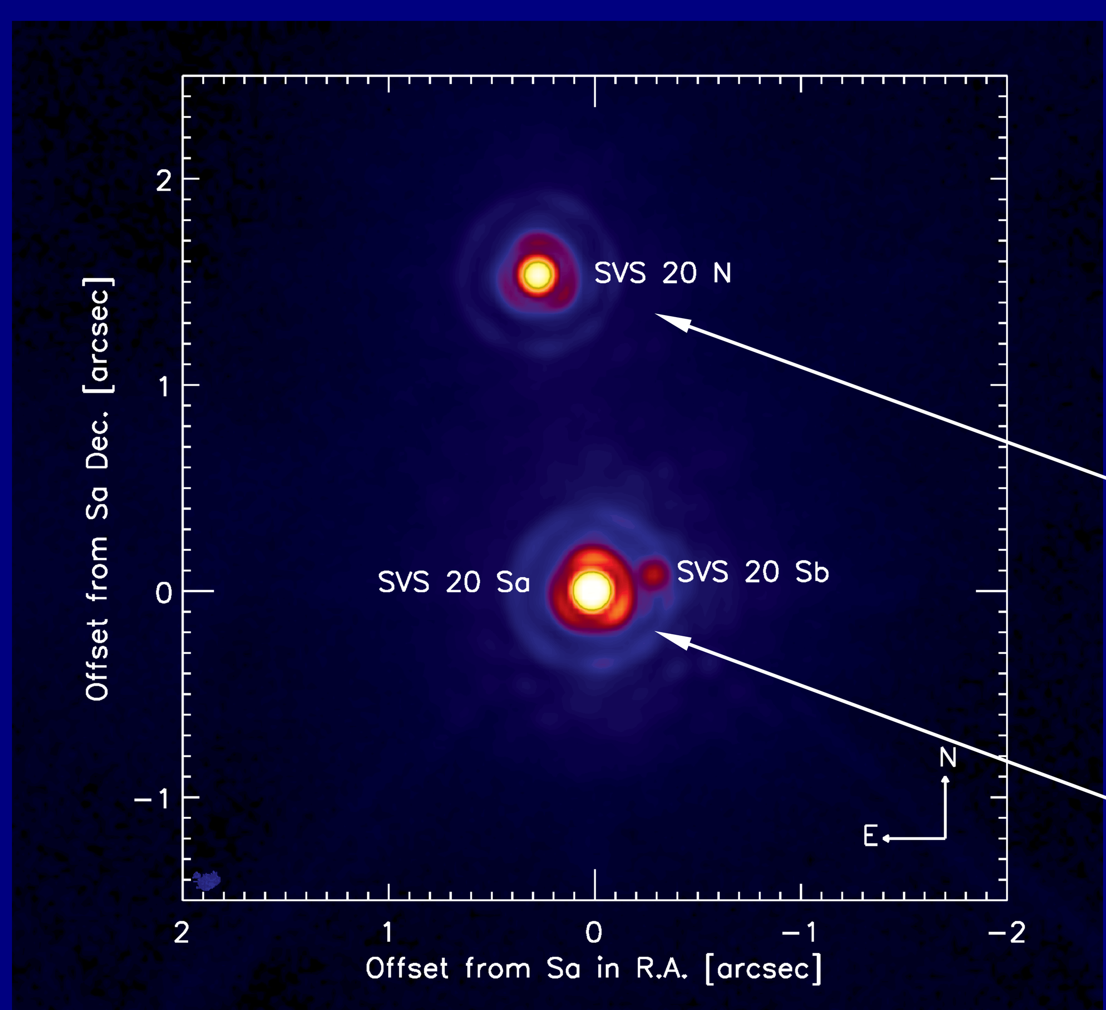


Left: Sketch of the binary system GV Tau based on the results of our MIDI/VLTI measurements (Roccatagliata et al., A&A 534, 33, 2011). Indicated are the temperatures of the fitted black-bodies and the directions of the known jets. The outer radius of the discs has been assumed to be 50 AU.

Right: Color-composite combining an archival HST-observation (blue: 606 µm) and images taken with the adaptive optics system NACO (green: H-band, red: K_S-band). The flux ratio between GV Tau N and the infrared companion GV Tau S increases from 0.003 in the visual to 0.2 in the Ks-band. The most probable formation scenario is the formation via fragmentation of two different parts of the collapsing molecular cloud combined with other dynamical processes related to the cloud or the protostars.

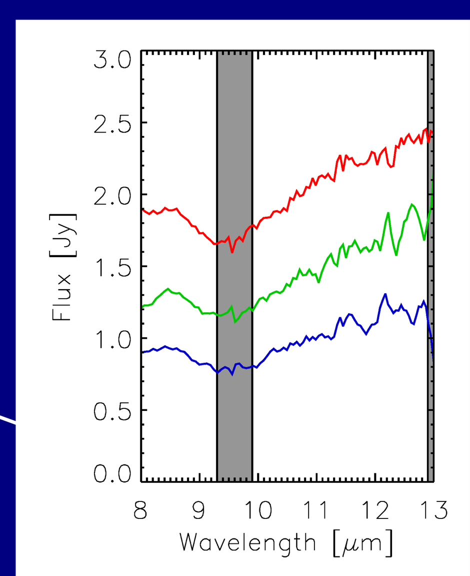
Comparison of the crystalline contribution in the spectrally dispersed correlated flux of the transitional object TW Hya (blue) with the model (red). Most of the crystalline material found in the Spitzer spectrum (black) is thus concentrated within 1 AU from the central star. The disk of TW Hya is not well mixed (Ratzka et al., A&A 471, 173, 2007).



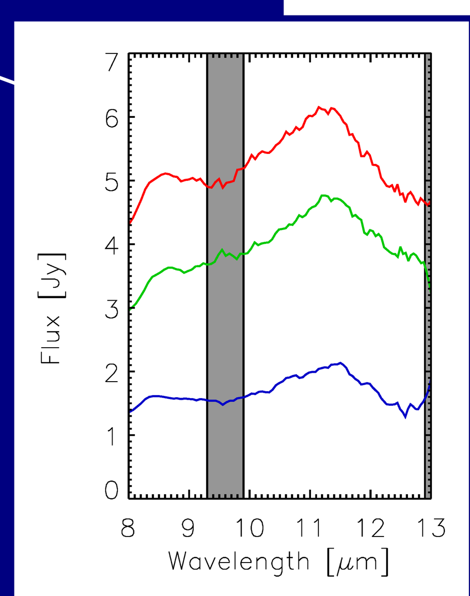


Below the total and correlated fluxes obtained with intermediate (~ 50 m) and long (~120 m) baselines are shown.

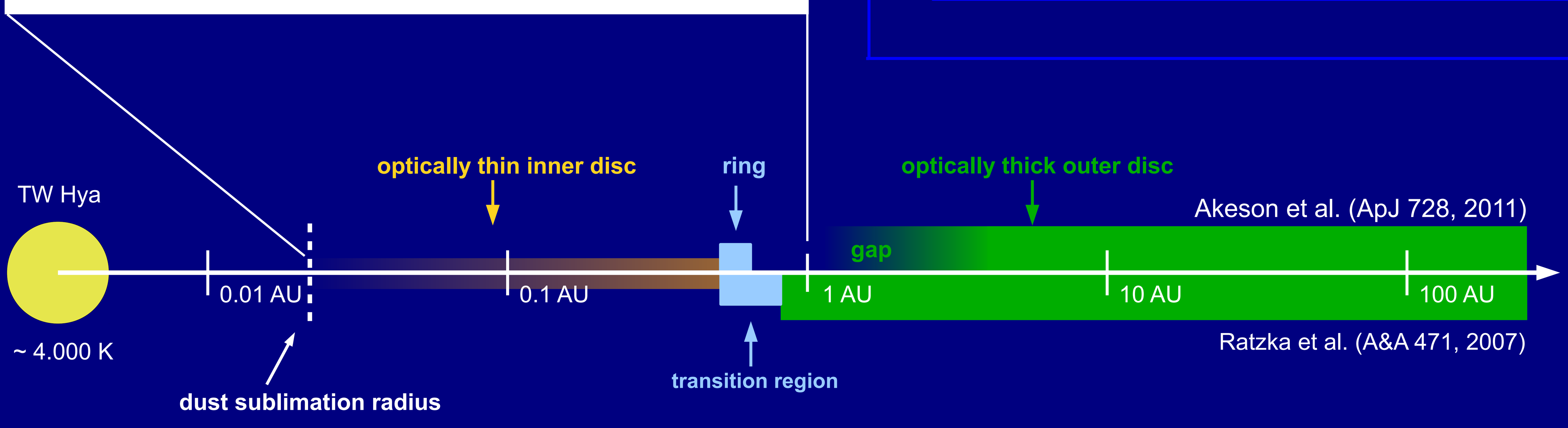
mild silicate absorption



processed dust grains



This image of the (actually) triple system SVS 20 has been taken with NACO/VLT in the Lp-band. Both SVS 20 N and Sa have been resolved with MIDI. The typical sizes of the mid-infrared emitting regions (Gaussian) are about 10 mas or 25 AU at the distance of the Serpens Core. While the size of SVS 20 Sa is independent from the PA, SVS 20 N deviates from a roundish structure (Roccatagliata et al., A&A, in preparation).



Schematic view of the two models for the disc around TW Hya. The vertical extension is not drawn to scale. The regions that can be discriminated by interferometric measurements (Keck, MIDI, and the VLA) are labeled.

Simultaneously with the MIDI measurements we modeled the spectral energy distribution (Ratzka et al., A&A 471, 2007). The data reveal a transition from an optically thin inner to an optically thick outer part between 0.5 and 0.8 AU from the central star. According to Akeson et al. (ApJ 728, 2011) this structure can be interpreted as the signature of an optically thick ring in the disc's inner hole (3-4 AU).

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