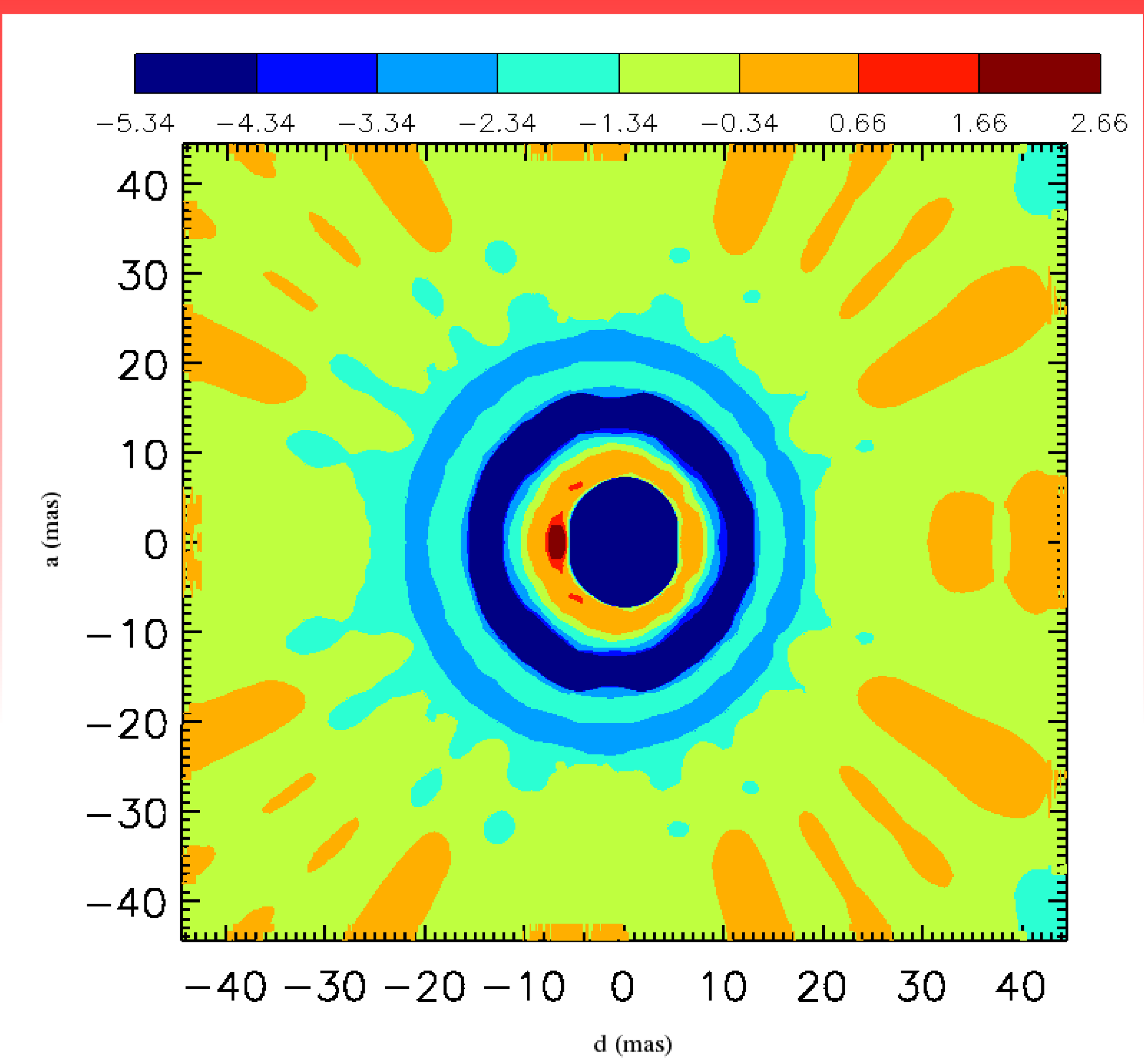
E-ELT observations of shadows, gaps, and ring-like structures in proto-planetary disks.

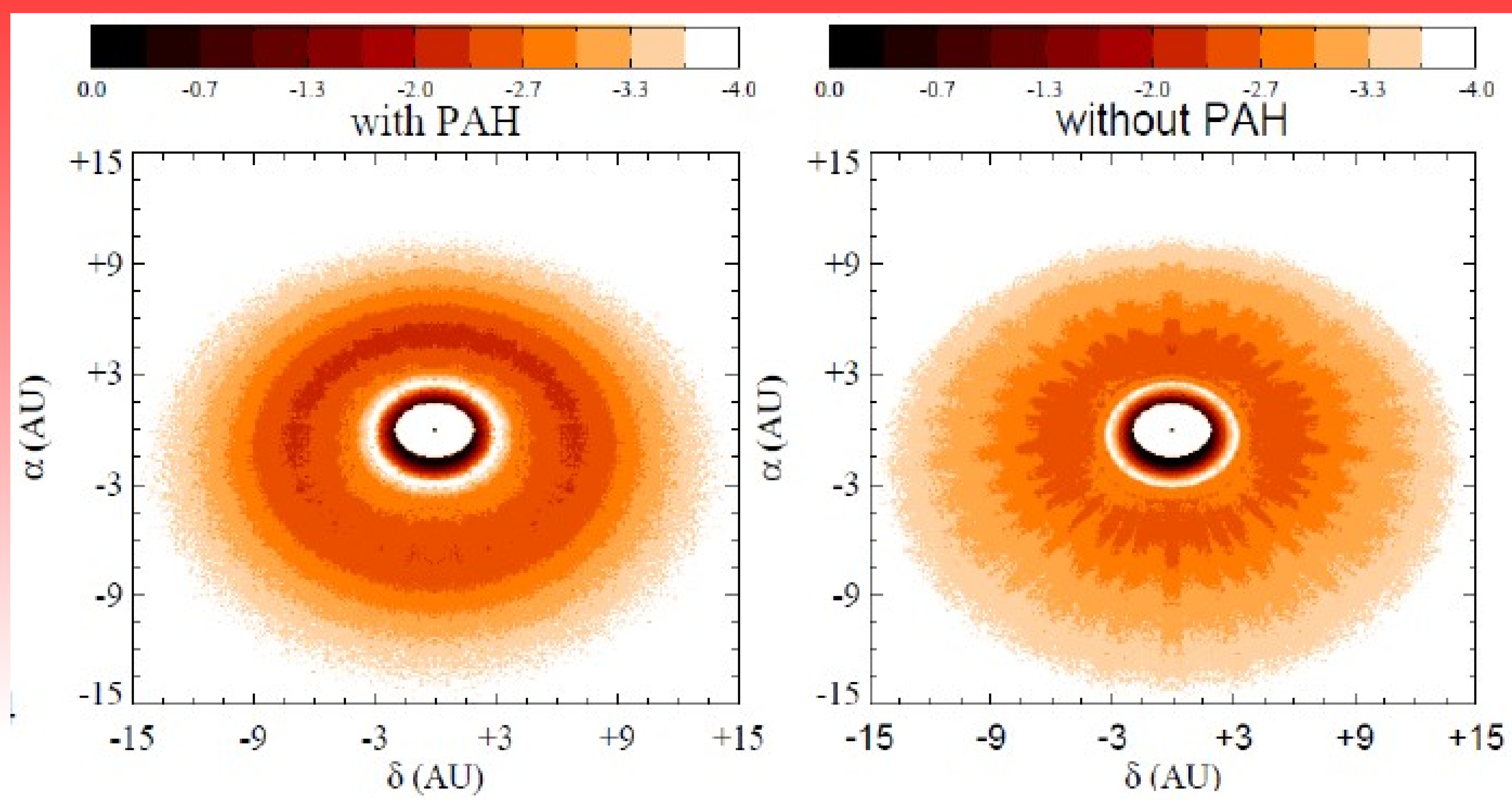
P. Scicluna[ESO, CAU Kiel], R. Siebenmorgen[ESO], F. Heymann[DLR]

The E-ELT will resolve inner structures in passively-heated disks around T Tauri and Herbig Ae stars. We simulate how an E-ELT mid-infrared instrument will detect dust emission from such disks and a near-infrared instrument the scattered light characteristics. The simulations apply a novel vectorised Monte Carlo dust radiative transfer model (Heymann & Siebenmorgen, 2012). Thanks to the vectorisation the run time is drastically reduced so that new disk-structure physics can be treated (Siebenmorgen & Heymann, 2012a).

Proto-planetary disk dust is composed of either fluffy carbon and silicate grains of various sizes or dust of the diffuse ISM. Under the assumption of hydrostatic equilibrium we find that the disk in the inner rim puffs up, followed by a shadowed region. The shadow reduces the temperature of the midplane and decreases the height of the extinction layer at the disk surface. It can be seen as a gap in the disk unless the surface is again exposed to direct stellar radiation. There the disk puffs up a second time, a third time and so forth. Therefore several gaps and ring-like structures are present in the disk surface and appear in emission images. They result from shadows in the disks and are present without the need to postulate the existence of any companion or planet. We show that to resolve such structures the resolution of the ELT is required. Compared to Herbig Ae stars, such gaps and ring-like structures are more pronounced in regions of terrestrial planets around T Tauri stars. We also show that with the high contrast and high Strehl-ratio of EPICS it will be possible to resolve these structures in near-infrared scattering, where a ripple-like pattern is observed, while current generation instruments (e.g. SPHERE) lack the required contrast.

We present an accurate treatment of PAH molecules in the MC code. Particular attention is given to the photo-dissociation of the molecules by energetic photons. Besides PAH destruction, we also consider the survival of the molecules by vertical mixing within the disk. By applying typical X-ray luminosities the model accounts for the low PAH detection probability observed in T Tauri and the high PAH detection statistics found in Herbig Ae disks (Siebenmorgen & Heymann, 2012b). We show that the destruction and survival of the molecules requires METIS in low resolution spectroscopy. Mid IR images of disks with spherical halos are presented and we show that disks are easier to resolve when PAH emission dominates.





Above: Mid-infrared (~10µm) PAH emission in Herbig Ae star discs gives rise to stronger extended emission, making it easier to resolve the disc. X-ray photodissociation of PAH molecules in T Tauri stars means this effect is not present.

Above: Near-infrared scattered light imaging of T Tauri disc surface reveals the presence of surface-brightness fluctuations of up to 4 orders of magnitude on angular scales comparable to those achievable with the E-ELT. However this requires contrast levels of 10^{-5}-10^{-9} on angular scales ≤100mas due to the proximity to the star, which is 10^4 times brighter than the scattered component. Similar structures are visible in mid-infrared emission, but the required contrast is lower, and these could be detected with METIS. Other types of disc structure, such as warps or spirals, would also be detectable with E-ELT instrumentation.

References

Heymann, F., & Siebenmorgen, R. 2012, ApJ 751, 27
Siebenmorgen, R., & Heymann, F. 2012, A&A 539, 20
Siebenmorgen, R., & Heymann, F. 2012, A&A, 543, 25