# Unveiling the Early Stages of Massive Stars: high-angular and high-spectral resolution opportunities at MIR Wavelengths

Emma Bordier*[1], Lucas Labadie[1], Abigail Frost[2], Wolfgang Brandner[3], Joel Sanchez Bermudez[4], Willem-Jan De Wit[5], Rene Oudmaijer[6], and Evgenia Koumpia[7]

[1]I. Physikalisches Institut der Universität zu Köln – Germany

[2]European Southern Observatory – Chile

[3]Max Planck Institute for Astronomy – Germany

[4]Instituto de Astronomia, UNAM – Mexico

[5]European Southern Observatory – Chile

[6]University of Leeds – United Kingdom

[7]European Southern Observatory – Chile

**Abstract**

Understanding the formation mechanisms of massive stars remains a critical challenge in astrophysics, with a significant 1–2 Myr evolutionary gap persisting between the core formation stage and the onset of the main-sequence phase. During these early stages, massive young stellar objects (MYSOs) are highly luminous yet deeply embedded within molecular clouds, where their circumstellar environments deviate significantly from spherical symmetry due to processes such as disc accretion and outflow activity. A growing consensus suggesting that the disc accretion scenario can account for the formation of stars up to ∼30 M, emphasizes the crucial interplay between accretion and ejection processes, necessitating observations at small spatial scales to resolve these dynamics. Gravitational forces and radiation pressure are additional forces that shape the circumstellar environment, each playing a role in sculpting the surrounding material. To disentangle these influences and understand the role of environmental factors-such as those found in the Magellanic Clouds or the Galactic Center-spatially resolved observations are essential. Moreover, such observations can elucidate how initial conditions influence companion formation mechanisms. Our limited knowledge also stems from the limited sample sizes and it is crucial to drastically improve statistical analyses in the context of massive star formation. To move in this direction, two aspects play an important role: extending towards the mid/far-IR to access heavily embedded objects; and increasing the angular resolution to decipher the small-scale mechanisms relevant to massive star formation. Mid-infrared (MIR) wavelengths offer a critical window for probing these environments. Emission at ∼20 $\mu$m traces thermal radiation from warm dust in the inner regions of protostellar outflow cavities and provides access to numerous dust grain and molecular tracers through high-resolution spectroscopy. Despite its scientific potential, the 20$\mu$m wavelength range suffers from a lack of high-angular resolution facilities: JWST/MIRI offers exquisite sensitivity at 20 $\mu$m but at the cost of low angular resolution and saturation limits that hamper the observation of massive stars; ground-based instruments like COMICS

*Speaker

and VISIR giving access to the 20$\mu$m bands have been decommissioned or are nearing the end of their operational life without guaranteed replacements; both MATISSE and the future METIS/ELT instrument do not foresee observations beyond 10 $\mu$m.

Having access to the ~20 $\mu$m Q-band at the VLTI would bridge the gap between ALMA and the current VLTI instrumentation, bringing significant complementarity to the study of the early stages of massive star formation. A possible scope is to investigate whether the combination of ground-based high-angular resolution and ground-based high-spectral resolution across the atmospheric Q band can be enabled through a long-term planning of an infrared interferometric instrument or facility. This talk will outline the scientific objectives achievable with this facility and the observational requirements to address these critical gaps in our understanding of massive star formation, in and outside our Galaxy.