Spatially Resolved Mid-IR Observations of the Disk Surrounding Par 21

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1. Introduction

The small group of YSOs known as FU Orionis stars provide striking evidence for the importance and irregularity of disk accretion during early stellar evolution. FU Orionis star were originally identified as a class of young stars with large (> 4 magnitudes) outbursts in optical light. All are surrounded by reflection nebulae. More recently it has been realized that the physical reason for such an FU Orionis outburst is that the accretion rate onto the central star changes, within a period of less than a month, from those commonly found around T Tauri stars into values of 10^{-3}-10^{-4} M yr^{-1}. Intriguingly, meteoritic evidence suggests that chondritic material has formed when our own proto-solar nebula went through an episode of enhanced temperatures. The study of FU Orionis objects may therefore not only constitute a crucial phase in the evolution of proto-planetary disks, but may also be directly relevant for the condensation of the protoplanetary disk into solids.

At a distance of ~ 400 pc, the object Parsamian 21 (HBC 687) is perhaps most well-known for its prominent cometary reflection nebula. On the basis of polarimetric maps Draper et al. (1985, MNRAS 212, 1P) suggested the presence of a circumstellar disk. Although no outburst has been recorded for this object, Par 21 was identified as a FU Orionis source on the basis of P Cygni line profiles indicating mass loss and double absorption lines indicating disk rotation (Staude & Neckel 1992, ApJ 400, 556).

2. Observations

Diffraction-limited images in several filters between 9.0 and 18.7 μm of the FU Orionis type object Parsamian 21 were obtained with the newly commissioned mid-infrared imager/spectrometer VISIR on the VLT in July 2005. Par 21 is clearly resolved into an elongated structure with a size of a few hundred AU (Figs. 1-2). This morphology of the region in the mid-infrared is quite distinct from that see in archive near-infrared (1.6-2.2 μm) observations, which are dominated by scattered light in the dusty envelope (Fig. 3).

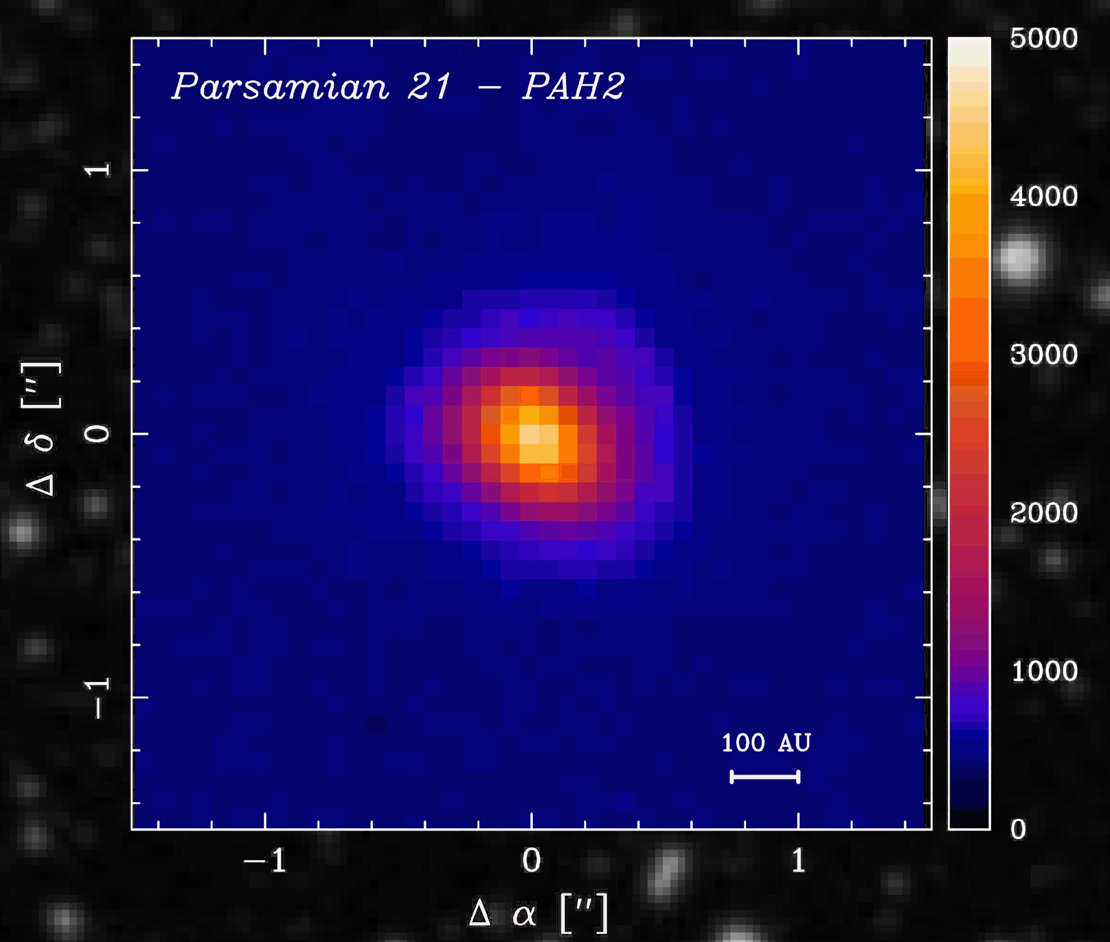

Fig. 1. VLT/VISIR image of the immediate vicinity of Par 21 in the PAH2 (11.3 μm) band. An extended structure with a size of a few hundred Au is visible along the NE-SW axis.

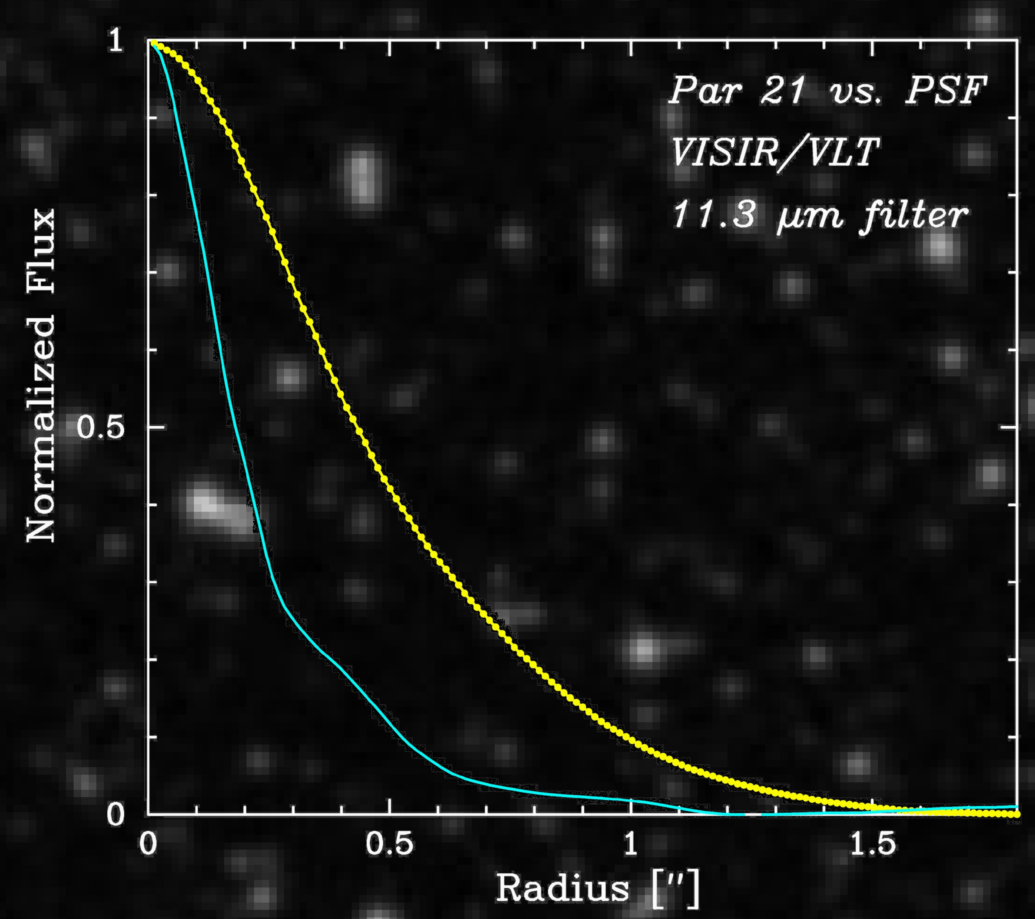

Fig. 2. Fall-off of the radially averaged intensity profile around Par 21 (yellow) with that of a PSF reference star (magenta curve). The ``bump'' that can be seen in the profile of the PSF between 0.2 and 0.5" is the first Airy ring of the diffraction pattern of the VLT.

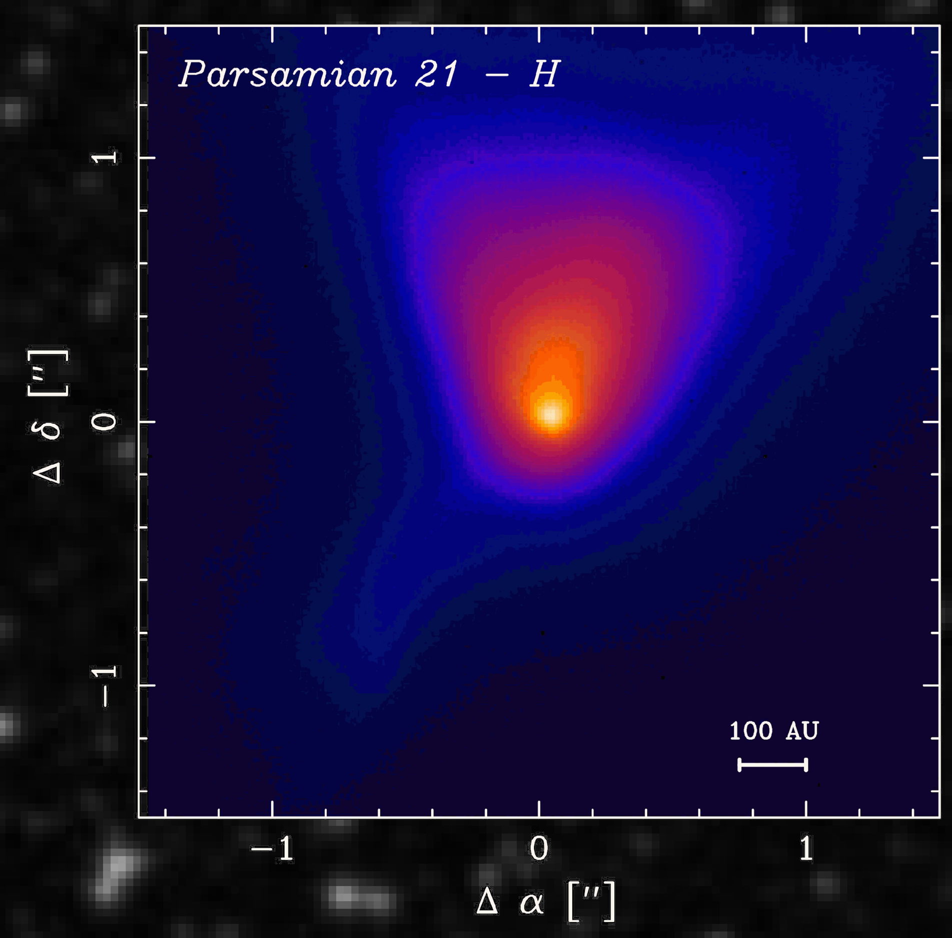

Fig. 3. VLT/NACO *H*-band (1.6 μm) image of the immediate vicinity of Par 21 extracted from the ESO Science Archive. The cometary nebula of which the innermost core is depicted here extends over several arcminutes on the sky. Note the ``finger'' of faint emission extending to the South-East.

3. Discussion and Conclusions

An elongated structure is clearly present in our new mid-infrared images of Par 21. This structure appears much larger in the mid-infrared (radius ~ 300 AU) than what may be expected for simple models for active accretion disks, which predict that the majority of the luminosity of a FU Orionis system is generated within the innermost few AU. The measured fall-off of intensity with radius from the center (Fig. 2) can be described by a broken power-law, with $I \sim R^{0.8}$ below 100 AU and $I \sim R^{0.5}$ between 100 and 300 AU. The observed structure appears to have a sharp edge, with essentially no flux coming from the area beyond 300 AU.

We conclude that most likely we are seeing evidence for the presence of a dusty torus surrounding the accretion disk of Par 21. If this structure is circularly symmetric, the axis ratio of the detected structure gives a disk inclination of 19° to the line-of-sight and a position angle -- east of north -- of 42 degrees.

Surprisingly, the observed structure is not oriented perpendicular to the polar axis of the large cometary nebula, but appears to have a relative position angle of ~40 degrees compared to this structure. We note however, that apart from the base of the cometary nebula, the archive near-IR data also show a small (~ 1") linear structure extending to the South-East (Fig. 3). This structure is oriented perpendicular to the dusty torus seen in our mid-infrared images. We hypothesize that precesion may be responsible for this difference in system orientation on small and large spatial scales.

Background Image: DSS image of the region surrounding Par21