Spatially Resolved Mid-IR Observations of the Young Star Parsamian 21

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RÉSUMÉ. *Nous présentons des images du jeune objet stellaire Parsamian 21, limitées par la diffraction, obtenues en infrarouge moyen grâce à l'imageur/spectromètre VISIR récemment installé au VLT. Une structure allongée, d'un diamètre de quelques centaines d'UA, est présente sur nos images. Cette structure apparaît comme bien plus grande que ce à quoi on peut s'attendre pour des modèles simples de disques d'accrétion. Nous concluons qu'il s'agit là très probablement de la première preuve de l'existence d'un tore de poussières entourant le disque d'accrétion de Par 21.*

ABSTRACT. *We present diffraction-limited mid-infrared images of the young stellar object Parsamian 21 obtained with the newly commissioned mid-infrared imager/spectrometer VISIR at the VLT. An elongated structure with diameter of a few hundred AU is present in our images. This structure appears much larger than what may be expected for simple models for active accretion disks. We conclude that most likely we are seeing the first evidence for the presence of a dusty torus surrounding the accretion disk of Par 21.*

MOTS-CLÉS : *Étoiles: formation – Parsamian 21 – Nébuleuses par réflection*

KEYWORDS: *Stars: formation – Parsamian 21 – Reflection nebulae*

1. Introduction

The small group of Young Stellar Objects (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 (typically 10^{-6}–10^{-8} M$\odot$ yr^{-1}) into values of 10^{-3}–10^{-4} M$\odot$ yr^{-1}. Intriguingly, meteoritic evidence suggests that chondritic material has formed when our own protosolar 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 $\sim$ 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) 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).

In these *proceedings* we present new mid-infrared images of Par 21, demonstrating that its disk is surrounded by a dusty torus-like structure. We briefly discuss its properties and the implications of this discovery for theories about the evolution and structure of YSO disks.

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 *VLT Imager and Spectrometer for mid Infrared*[1] (VISIR) at the *Very Large Telescope* (VLT) in July 2005. Subtraction of the thermal emission from the sky, as well as the telescope itself, was achieved by chopping in the North-South direction with a chop throw of 15″, and nodding the telescope in the opposite direction with equal amplitude. The cosmetic quality of the images was further improved by superimposing a random jitter pattern (with maximum throw 2″) on the nodding sequence, so as to minimize the effect of bad pixels in the detector array on the final science data.

Par 21 is clearly resolved into an elongated structure with a size of a few hundred AU (Fig. 1). We note that this structure was not resolved in previous mid-IR images of Par 21 obtained with smaller telescopes (e.g. Polomski et al. 2005). The

1. http ://www.eso.org/instruments/visir/

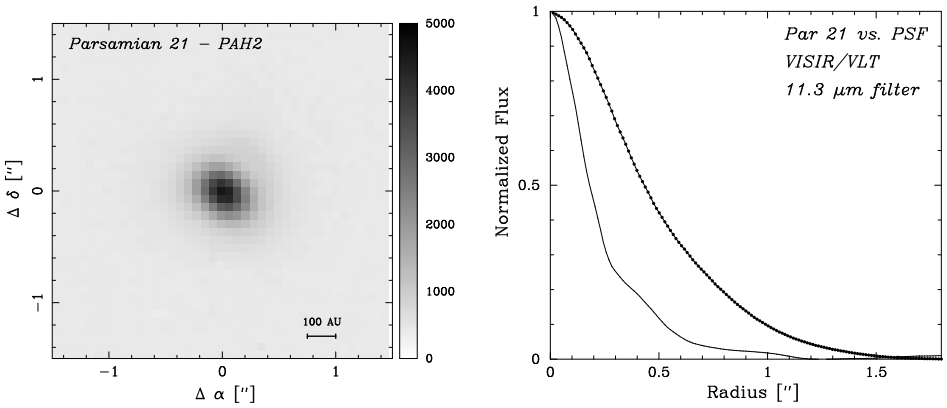

Figure 1. *VLT/VISIR image of the immediate vicinity of Par 21 at 11.3 μm (left) and the fall-off of the radially averaged intensity profile with radius compared to that of the PSF reference star (right). An extended structure with a size of a few hundred Au is visible along the NE-SW axis. The faint "ring" seen to surround Par 21, as well as the "bump" that can be seen in the profile of the PSF between 0.2 and 0.5$''$ are the first Airy ring of the diffraction pattern of the VLT.*

morphology of the region in the mid-infrared is quite distinct from that seen in archive near-infrared (1.6-2.2 μm) observations, which are dominated by scattered light in the dusty envelope (Fig. 2 ; see also the contribution by Kospal et al., these *proceedings*).

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 $\sim$ 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. 1 ; right-hand panel) can be described by a broken power-law, with $I \propto R^{-0.8}$ below 100 AU and $I \propto R^{-0.5}$ 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 an inclination of 19° to the line-of-sight (i.e. nearly edge-on) 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 $\sim$40 degrees compared to this structure. We note however, that apart from the base of the

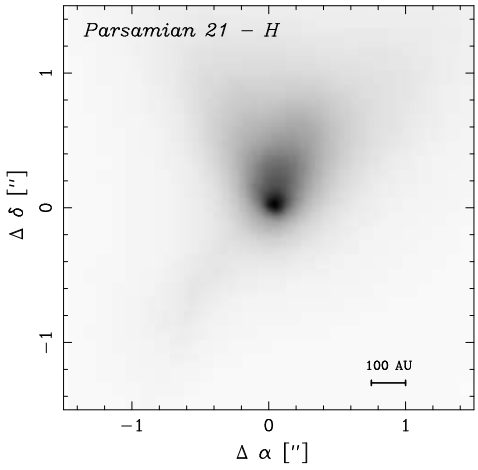

Figure 2. *VLT/NACO H-band (1.6 μm) image of the immediate vicinity of Par 21 extracted from the ESO Science Archive. The cometary nebula of which the innermost core is depicted here extends over several arcminutes on the sky. Note the "finger" of faint emission extending to the South-East.*

cometary nebula, the archive near-IR data also show a small ($\sim 1''$) linear structure extending to the South-East (Fig. 2). This structure is oriented perpendicular to the dusty torus seen in our mid-infrared images. We hypothesize that the nebula as seen is scattered light may not accurately trace the inner disk. Precession could be responsible for this difference in system orientation on small and large spatial scales.

We note that the large spatial scale of the torus detected in our new VISIR images may offer a natural explanation for the unexpectedly low visibilities displayed in interferometric data on many FU Orionis stars (Millan-Gabet et al. 2006), offering a candid illustration of the new insights that mid-infrared cameras on large-aperture ground-based telescope can bring.

4. Bibliographie

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   Visions in Infrared Astronomy, Paris, 20–22 March 2006

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3. TITRE DE L'ARTICLE :
   Spatially Resolved Mid-IR Observations of the Young Star Parsamian 21

4. TITRE ABRÉGÉ POUR LE HAUT DE PAGE MOINS DE 40 SIGNES :
   Mid-IR Observations of Par 21

5. DATE DE CETTE VERSION :
   7 avril 2006

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