

# Companion search around $\beta$ Pictoris with the newly commissioned L'-band vector vortex coronagraph on VLT/NACO

D. Mawet<sup>1</sup>, O. Absil<sup>2</sup>, J. Milli<sup>1,3</sup>, P. Baudoz<sup>4</sup>, A. Boccaletti<sup>4</sup>,  
G. Chauvin<sup>3</sup>, C. Delacroix<sup>2</sup>, J. H. Girard<sup>1</sup>, A. M. Lagrange<sup>3</sup>,  
J. O'Neal<sup>1</sup>, P. Bourget<sup>1</sup>, P. Forsberg<sup>5</sup>, F. Gonte<sup>1</sup>, S. Habraken<sup>2</sup>,  
C. Hanot<sup>2</sup>, M. Karlsson<sup>5</sup>, M. Kasper<sup>6</sup>, J.-L. Lizon<sup>6</sup>, K. Muzic<sup>1</sup>,  
R. Olivier<sup>7</sup>, E. Peña<sup>1</sup>, N. Slusarenko<sup>1</sup>, L. E. Tacconi-Garman<sup>3</sup>  
and J. Surdej<sup>2</sup>

<sup>1</sup>ESO, Alonso de Cordova 3107, Casilla 19001, Vitacura, Santiago 19, Chile  
email: dmawet@eso.org

<sup>2</sup>AGO, Université de Liège, 17 Allée du Six Août, B-4000 Liège, Belgium

<sup>3</sup>IPAG, University Joseph Fourier, CNRS, BP 53, 38041, Grenoble, France

<sup>4</sup>LESIA, Observatoire de Paris, 5 pl. J. Janssen, F-92195 Meudon, France

<sup>5</sup>Ångström Laboratory, Uppsala University, Box 534, SE-751 21 Uppsala, Sweden

<sup>6</sup>ESO, Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany

<sup>7</sup>GDTech s.a., LIEGE Science Park, rue des Chasseurs Ardennais, B-4031 Liège, Belgium

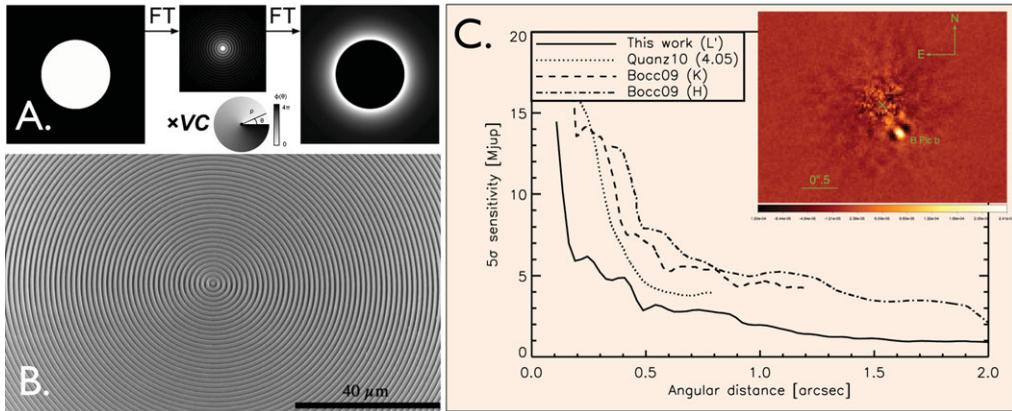
**Abstract.** Here we present the installation and successful commissioning of an L'-band Annular Groove Phase Mask (AGPM) coronagraph on VLT/NACO. The AGPM is a vector vortex coronagraph made from diamond subwavelength gratings tuned to the L' band. The vector vortex coronagraph enables high contrast imaging at very small inner working angle (here  $0''.09$ , the diffraction limit of the VLT at L'), potentially being the key to a new parameter space. During technical and science verification runs, we discovered a late-type companion at two beamwidths from an F0V star (Mawet *et al.* 2013), and imaged the inner regions of  $\beta$  Pictoris down to the previously unexplored projected radius of 1.75 AU. The circumstellar disk was also resolved from  $\simeq 1''$  to  $5''$  (see J. Milli *et al.*, these proceedings). These results showcase the potential of the NACO L-band AGPM over a wide range of spatial scales.

**Keywords.** High contrast imaging, vortex coronagraphy,  $\beta$  Pictoris b

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## 1. Introduction

High contrast imaging has thoroughly combed through the limited parameter space accessible with first-generation ground-based adaptive optics instruments and the HST. Only a few objects were discovered, and many non-detections reported and statistically interpreted. The field is now in need of a technological breakthrough (Absil & Mawet 2013). We aim at opening a new parameter space with first-generation systems such as NACO at the Very Large Telescope, by providing ground-breaking inner working angle (IWA) capabilities in the L' band. This mid-infrared wavelength range is a sweet spot for high contrast coronagraphy since the planets-to-star brightness ratio is favorable, while Strehl ratio is naturally higher.



**Figure 1.** A. Illustration of the diffraction effect of the vortex phase mask on a filled aperture (left). All of the on-axis coherent light appears outside of the downstream pupil (right). A circular aperture (Lyot stop) then blocks it all. FT stands for Fourier transform. B. Scanning electron microscope (SEM) images of the NACO AGPM made from diamond sub-wavelength gratings. C. Detection limits in terms of  $M_{Jup}$  with the L' NACO AGPM after removing  $\beta$  Pic from the data. We used the BT-Settl model assuming 12 Myr. These detection limits are the best ever presented, despite our conservative “small sample statistic” corrections to contrast at small angles. We show recent work at shorter wavelengths and with the L' band Apodized Phase Plate (APP) for comparison.

## 2. Methods and results

An annular groove phase mask (AGPM) vector vortex coronagraph (Fig. 1A) optimized for the L' band, made from diamond subwavelength gratings (Fig. 1B) has been manufactured and qualified in the lab (Delacroix *et al.* 2013). The AGPM enables high contrast imaging at very small IWA (here  $0''.09$ ), potentially being the key to a new parameter space. We present the results of the installation and successful commissioning of an L'-band AGPM on VLT/NACO (Mawet *et al.* 2013). For the science verification run (31 January 2013), we imaged the inner regions of  $\beta$  Pictoris down to the previously unexplored projected radius of 1.75 AU with unprecedented point source sensitivity. The planet was detected at very high SNR (Fig. 1C, inset), enabling precise astrometry and photometry. With the fake negative companion technique used in a multi-parametric optimization (Amoeba), we measured the following parameters:  $r = 0.448 \pm 0.01$  (first hint that the planet might be past quadrature),  $PA = 211^\circ \pm 1^\circ$ , and  $\Delta L' = 8 \pm 0.3$  mag. The disk was also clearly resolved (see J. Milli *et al.*, these proceedings).

## 3. Conclusions

No new object is detected with sufficient confidence level. There are a few hot spots close in and within the disk, to be followed up. Despite the average to mediocre conditions of the run, the NACO L' AGPM mode provides the deepest detection limits at the smallest IWA ever explored (down to 1.75 AU, see Fig. 1C).

## References

- Absil, O. & Mawet, D. 2010, *A&ARv*, 18, 317  
 Delacroix, C., Absil, O., Forsberg, P., *et al.* 2013, *A&A*, 553, 98  
 Mawet, D., Absil, O., Delacroix, *et al.* 2013, *A&AL*, 552, 13