Imaging Polarimetry of Eta Carinae with the Hubble Space Telescope

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Abstract. We have taken advantage of the high spatial resolution attainable with the HST to map the linear polarization in the V band across the nebulosity surrounding Eta Car. There are several new results related to polarization variations on different size scales. First, we present a two-dimensional map of the amount and position angle of the polarization across the Homunculus. Second, we provide measurements of the polarization within prominent features such as the "jet", the "paddle", the "skirt", and the "spot" in the south-eastern lobe. Third, we comment on polarization variations associated with the small-scale structure that can be seen in HST images (and which gives the lobes their cauliflower-like appearance). The new data provide insight into the three-dimensional distribution of dust about Eta Car.

1 The HST observations

The three-dimensional structure of the Homunculus has been a matter of much debate over the last few years. Polarization observations have contributed significantly to our understanding of the nature of the Homunculus. Using the HST's WFPC2, we have recently obtained a high-resolution map of the linear polarization in the V-band (F555W filter) of the Homunculus and other resolved features in the vicinity of Eta Car. The data reduction has been extremely difficult, and is discussed at length in our forthcoming AJ paper, where we also review and give reference to previous polarimetric studies of Eta Car.

2 Results

In view of the limited space for this contribution, we will immediately present our main results and conclusions:

- We confirm that the Homunculus is largely a reflection nebula in the optical (Thackeray 1956, Warren-Smith et al. 1979). The images taken in polarized light are smoother than the flux image (see Fig. 1). This is

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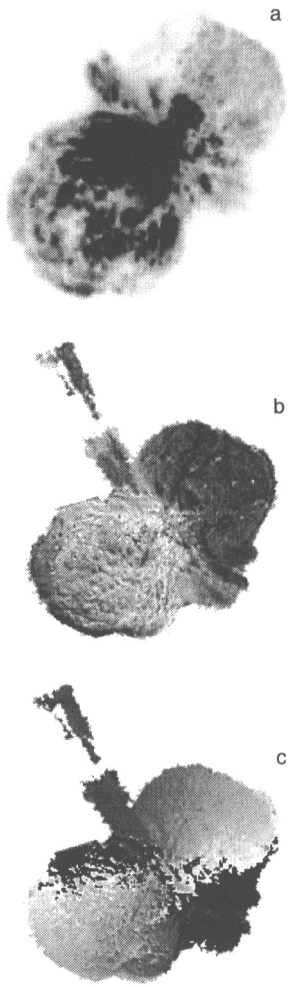

Fig. 1. The V-band image (a), percentage polarization image (b) and position angle image (c) of the Homunculus. Notice how much smoother the lobes are in the polarization images as compared to the flux image, whereas the "jet" and parts of the "skirt" appear as more pronounced features in the polarization image. Orientation of the images: N is up and E is to the left.

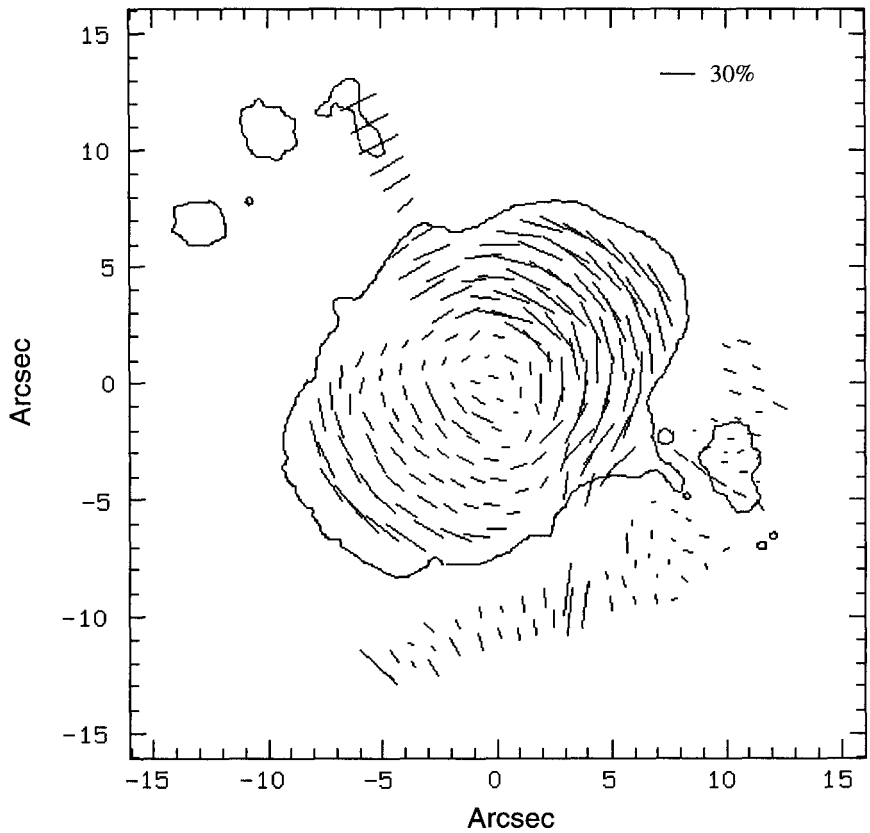

Fig. 2. A map of the polarization vectors. The overall radial distribution of polarization vectors is consistent with scattering of light from a central source by dust in the lobes. The "jet", showing vectors perpendicular to the radius vector from the center as well, clearly is a scattering feature, too. The "S ridge", on the other hand, displays predominantly radial polarization vectors, and is thus not interpreted as an area that is scattering the light from the central source.

a surprise for models which account for the small-scale structure seen in flux images with optically thick patches/thin holes. These models imply that we see the front of the lobes in some places, but the backs of the lobes in other places. Since light scattering off the front of a lobe scatters through different angles than light scattering off the back of a lobe, such "holes" or "spots" might be expected to show a different polarization from their surroundings, which does not appear to be the case.

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- The "jet" continuum is largely scattered light whereas the "S-ridge" does not show a scattered continuum (see Fig. 2). The jet is highly polarized. It is seen at a favorable viewing angle that coincides with a very advantageous phase angle of the scattering particles.
- The polarization in the "paddle" and in the streamers of the "skirt" appears to be different from its surroundings (Fig. 1). However, in quantitative measurements through circular apertures the polarization in the paddle does not stand out significantly over its sourroundings in the NW lobe. A radial cut along the minor axis does reveal elevated polarization in one of the three streamers is significant. This suggests that either the line-of-sight geometry of parts of the skirt or the geometry of the particles it contains are favorable for a high polarization.
- Qantitative modeling of the polarization map with a Monte Carlo code indicates the double-flask model is preferred over the double-bubble or bipolar-caps model for the 3-D structure of the Homunculus (see Currie et al. 1996 for the geometry of these competing models).
- Whereas the polarization map and the emission-line profiles observed across the Homunculus can be explained with the basic double-flask model, the shape of the polarized line profiles in the NW lobe remains a mystery.

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References

Currie, D.G., Dowling, D.M., Shaya, E.J., Hester, J.J., Scowen, P., Groth, E.J., Lynds, R. O'Neil, Jr., E.J., The WF/PC IDT, The WFPC2 IDT 1996: Proc. "The Role of Dust in the Formation of Stars", ESO workshop edited by H.U. Käufl & R. Siebenmorgen, p.89

Thackeray, A.D. 1956: Observatory **76**, 164

Warren-Smith, R.F., Scarrott, S.M., Murdin, P., Bingham R.G. 1979: MNRAS **187**, 761

Discussion

R. Humphreys: How do your observations compare with ground-based speckle-polarimetry of Falcke et al. (1996)?

R. Schulte-Ladbeck: Unfortunately, Falcke et al. observed in Hα. The line emission comes from many different places due to direct emission and scattering; I commented on that in the Kona proceedings. One goal of our HST observations was to check on the presence of a "polarisation disk"; however,

the exposure time splits/core saturation of the data has prevented us from doing so in the V band.

F. Vakili: With regard to the "Weigelt knots" from the speckle imaging of the central region of η Car, have you zoomed in your polarised map to see if any correlation exists between these knots and local polarisation?
R. Schulte-Ladbeck: Unfortunately, the splits of our exposures (owing to the dynamical range of the WF2 chip) are not suitable to address this question in the V band. Maybe the observations in other filters will have high S/N without overexposing the core.

N. Langer: You did not include the "skirt" in your polarisation model. Could taking it into account change your conclusions with respect to the Homunculus geometry?
R. Schulte-Ladbeck: Maybe I was too brief in explaining the conclusions. Indeed, the "skirt" is not yet included, but you can see what the implications are from the cartoon model. It appears that the polarisation in several areas belonging to the "skirt" are slightly elevated with respect to surrounding areas where the polarisation originates from the front of the NW lobes. Now, in the double-flask model, we "need" to have the front of the NW lobe close to the plane of the sky to get the high and constant polarisation. Alternatively, if we assume that the "skirt" is perpendicular to the long axis of symmetry and thus filled towards the observer, a grain population with properties different from those in the NW lobe (e.g., more forward throwing polarisation) could possibly explain the higher polarisation.

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