Parsamian 21:

High-contrast Infrared Mapping of an Edge-on FU Ori Disc

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FU Orionis-type objects

- Low-mass ($M < 2M_{\odot}$), pre-main sequence objects
- Star + large amount of circumstellar material (disc + envelope)
- Optical outburst powered by enhanced accretion
- Many FUors were identified based on spectral characteristics

Motivation

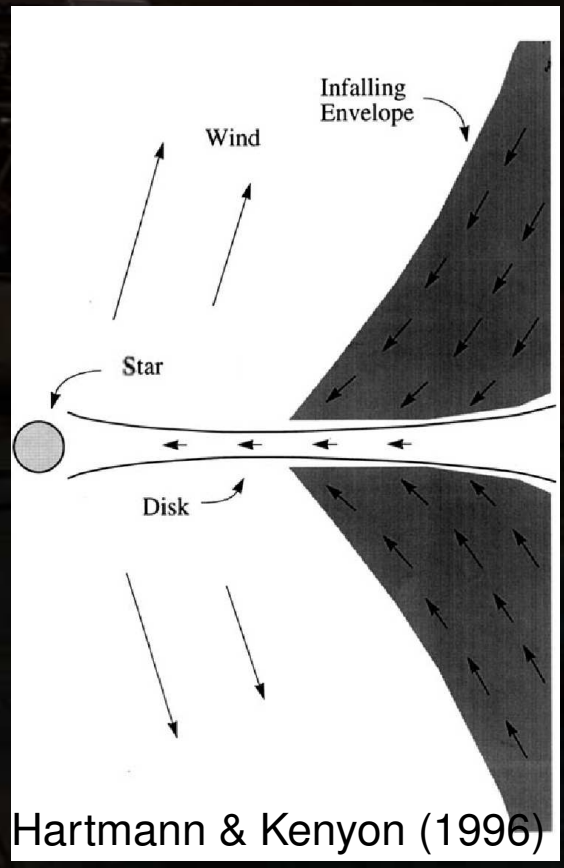
- Possibly all young stars undergo FUor-phases during their pre-main sequence evolution $\Rightarrow$ stars may collect most of their final mass during these phases

- Basic assumptions of FUor models:
  - Disc/envelope structure

    Observationally not proven
  - Trigger mechanism of the outburst

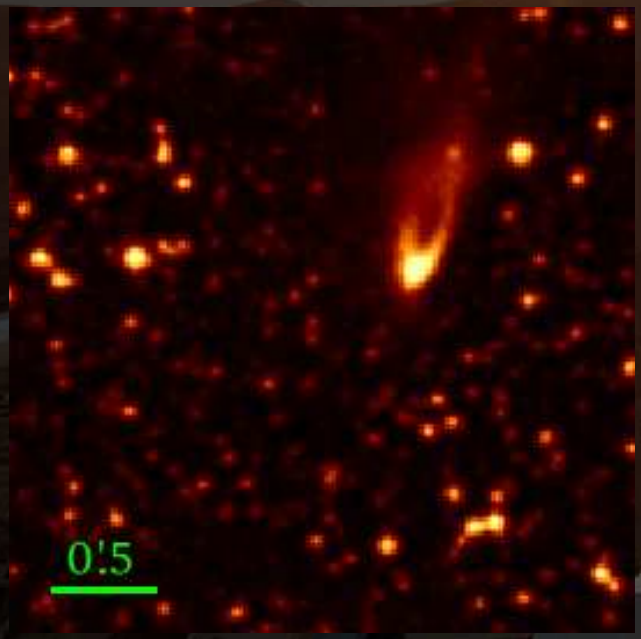
    One possible trigger mechanism: passage of a close companion

    Only 4 out of 20 FUors are confirmed binaries

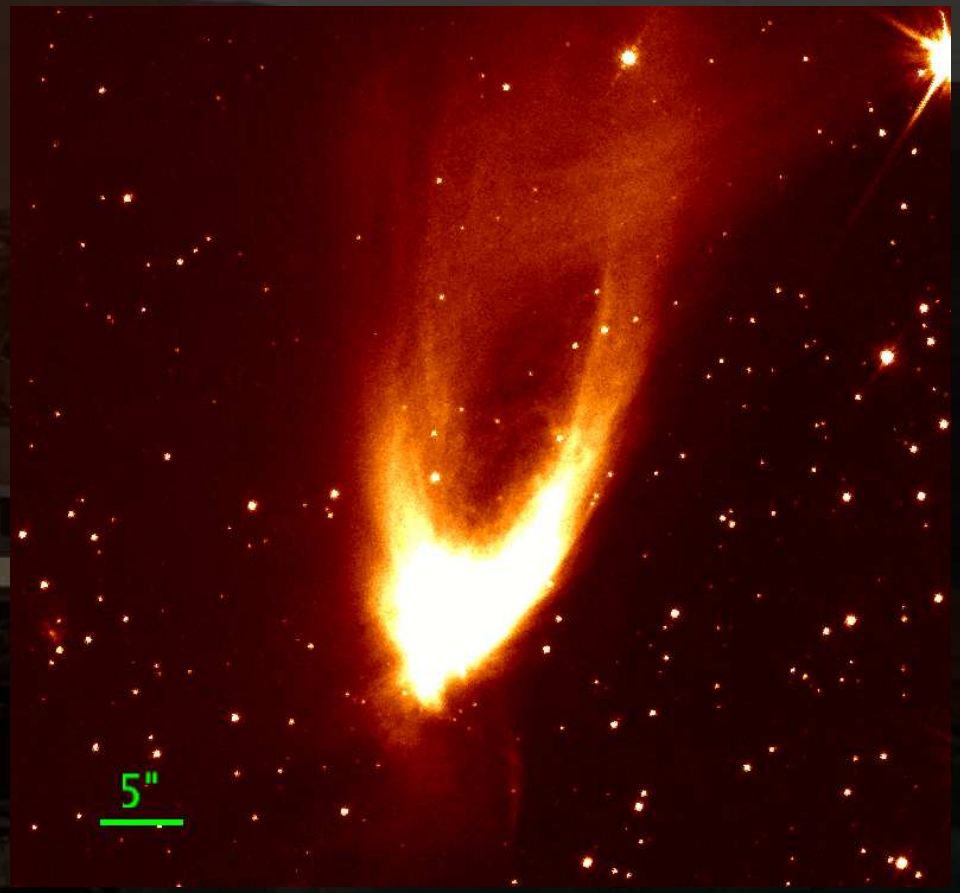


Hartmann & Kenyon (1996)

Parsamian 21



Palomar red plate



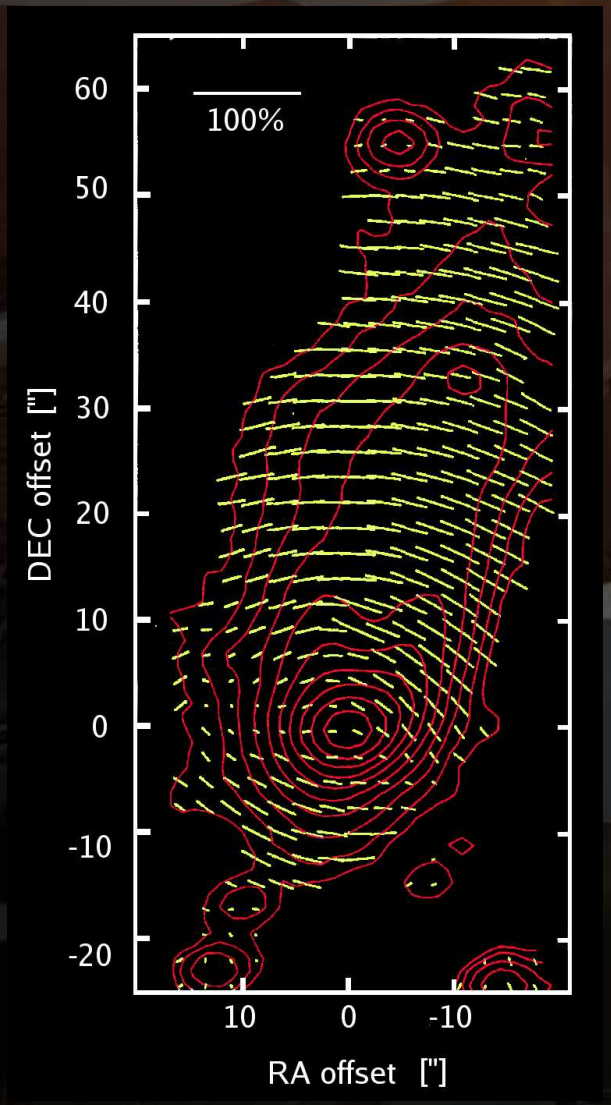
HST/WFPC2 F814W filter

Distance: 400 pc

$\Downarrow$

$1'' \leftrightarrow 400$ AU

A FUor with edge-on disc



Draper et al. (1985)

- no eruption observed; classified as a FUor based on spectral characteristics
- polarimetric observations suggest that the star is surrounded by a flattened, disc-like structure, probably seen edge-on
- multiple scattering in the disc reduces polarization

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- Our aims
  - Obtain direct evidence for the existence of the disc
  - Structure of the disc (flat/flared)
  - Possible companion (may trigger outburst)

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  - Structure of the disc (flat/flared)
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- Measurements needed
  - High resolution (disc is small, companion is close-by)
  - High contrast (star is bright, while both disc and companion are faint)

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Our own measurements:

- VLT/NACO images
- VLT/NACO polarimetry
- AO: $0\farcs09$ resolution (36 AU)

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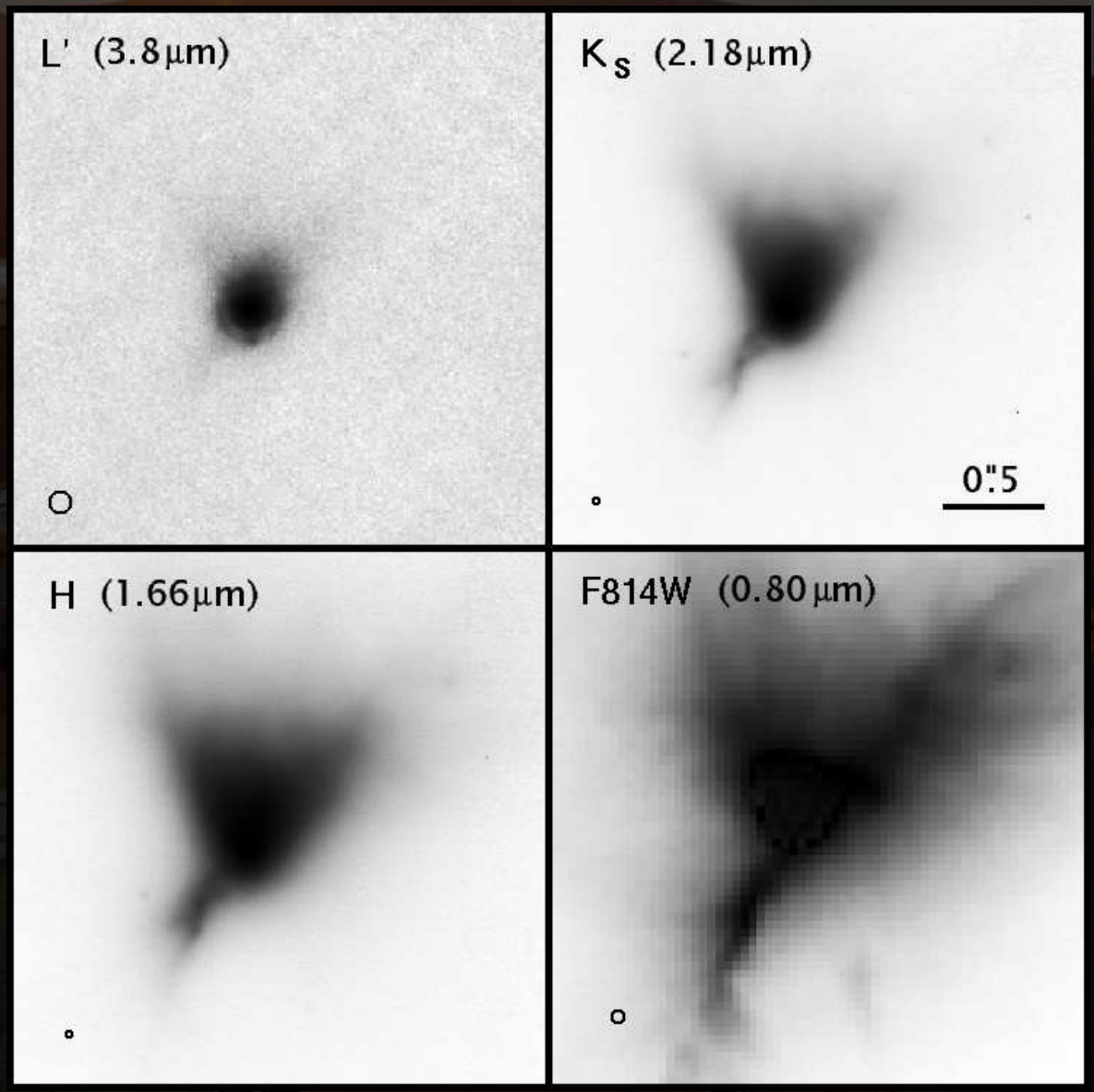
Colour composite of F814W, H and K_S images

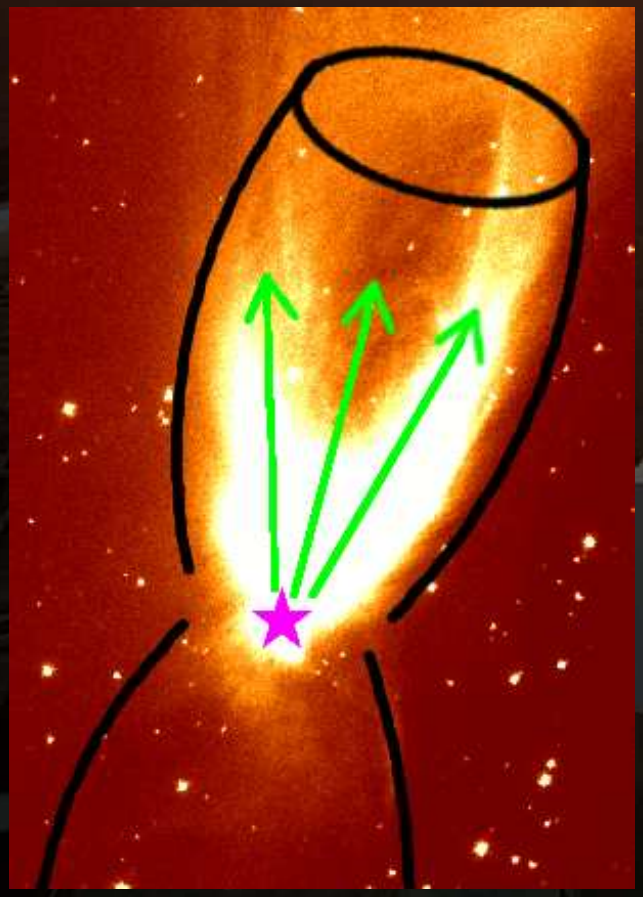
Direct images

Extended in L′ ⇒



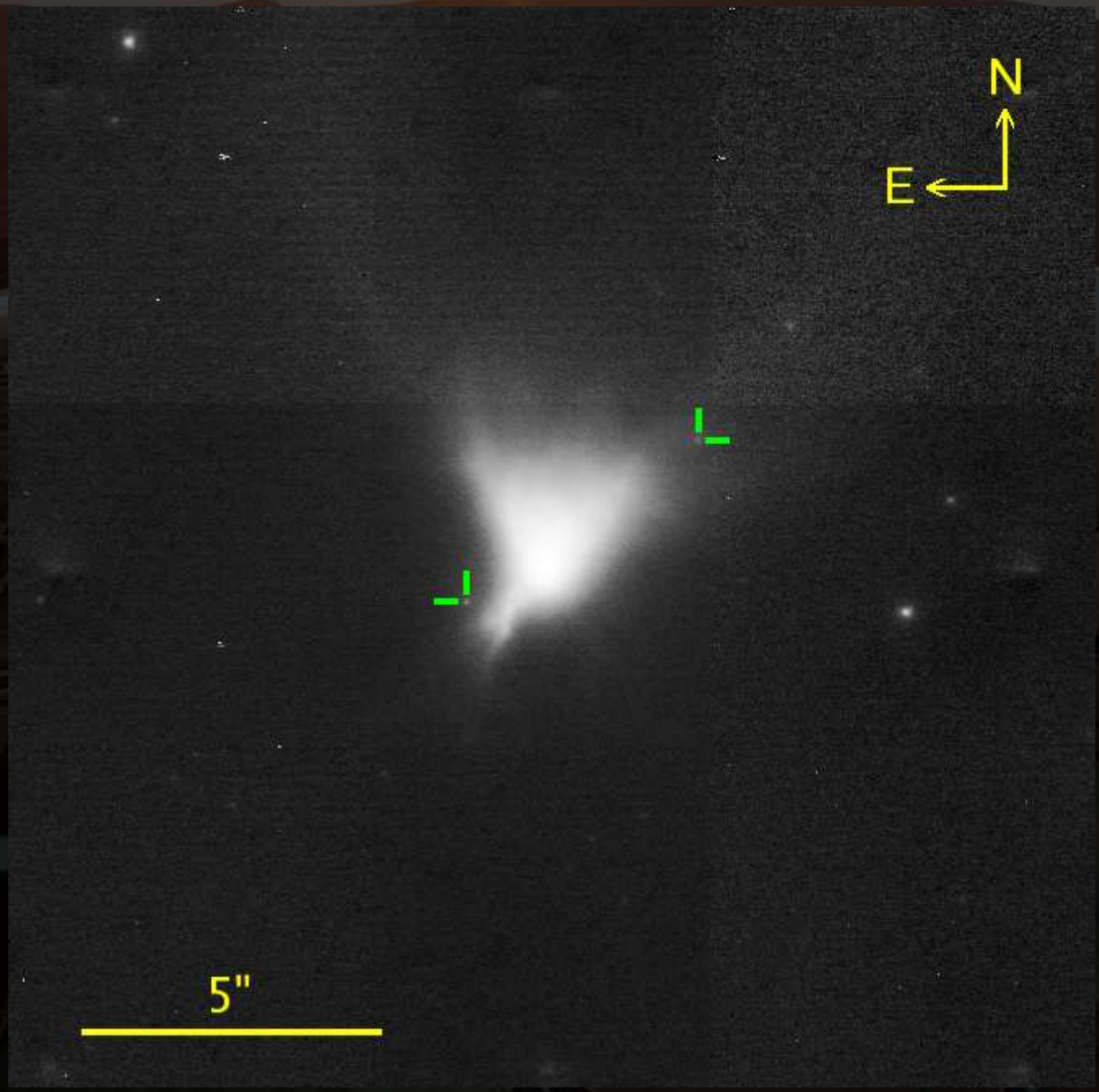
⇐ More extended at shorter wave-lengths

Morphology of the nebula



- Star drives bipolar outflow
- Outflow excavates a conical cavity
- Star illuminates this cavity
- Light is scattered towards us from the walls
- Scattering is more efficient at shorter wavelengths

Possible companion candidates



2MASS colours

Two stars can be seen in H and K_S, but not in F814W and L′

⇓

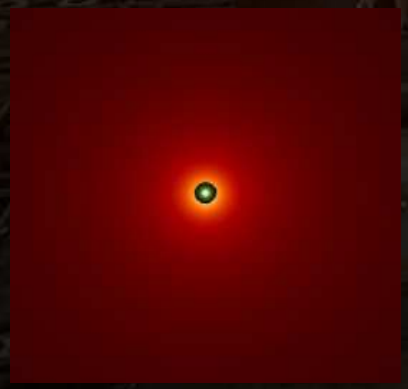
can be stars with infrared excess or heavily reddened field stars

Differential polarimetric imaging

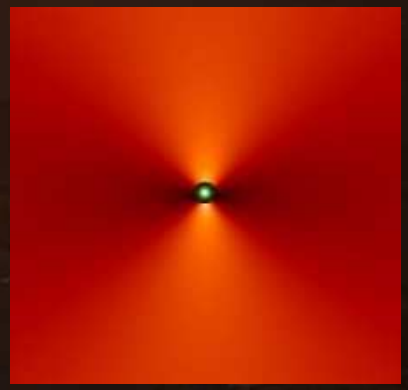
- Aim: Observation of circumstellar discs
- Problem:
  - High contrast
- Solution:
  - Light scattered by the circumstellar material is polarized
  - Light of the star itself is unpolarized
- Method:
  - Wollaston-prism $\Rightarrow$ simultaneously measure the two orthogonal polarization states $\Rightarrow$ making the difference of the two removes the unpolarized component

DPI: example face on disc

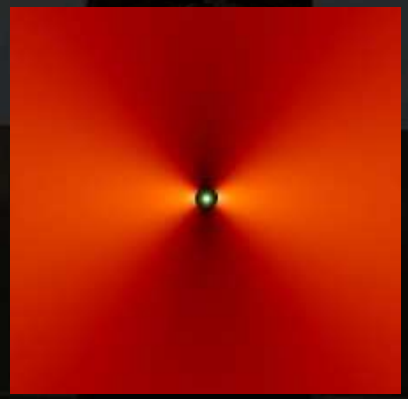
Source:
polarized +
unpolarized



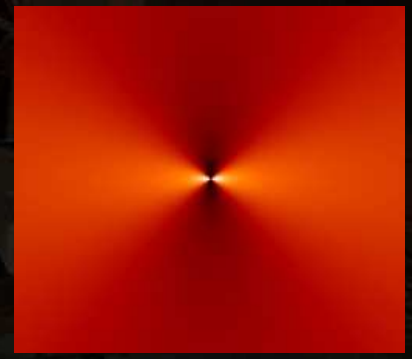
Ordinary beam



Extraordinary beam

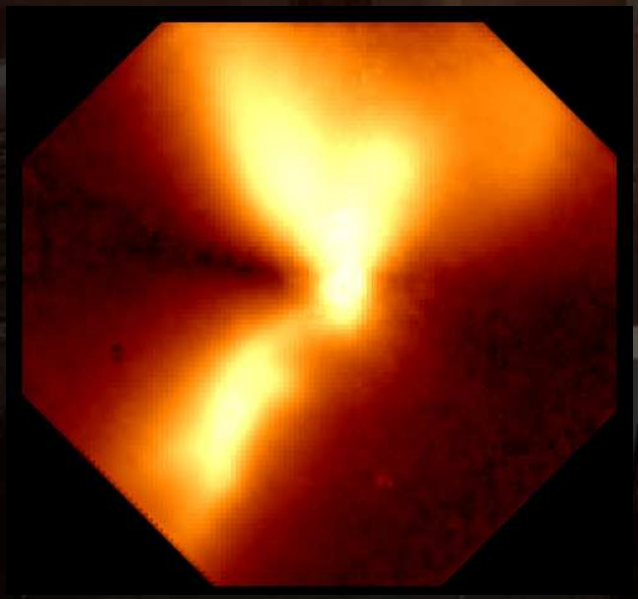


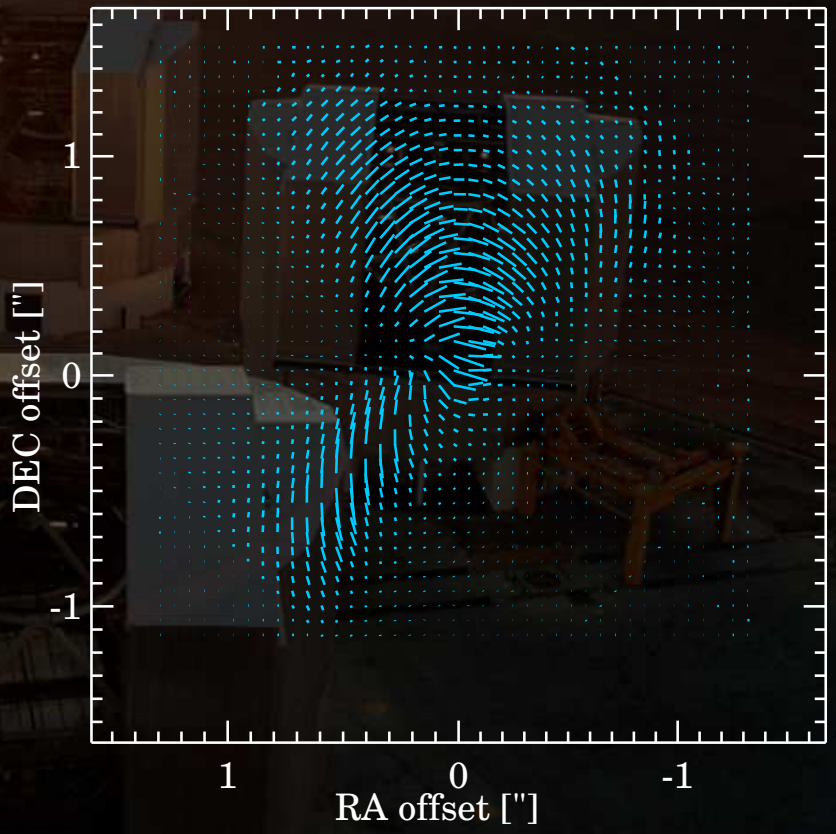
Polarized
component



NACO polarization maps

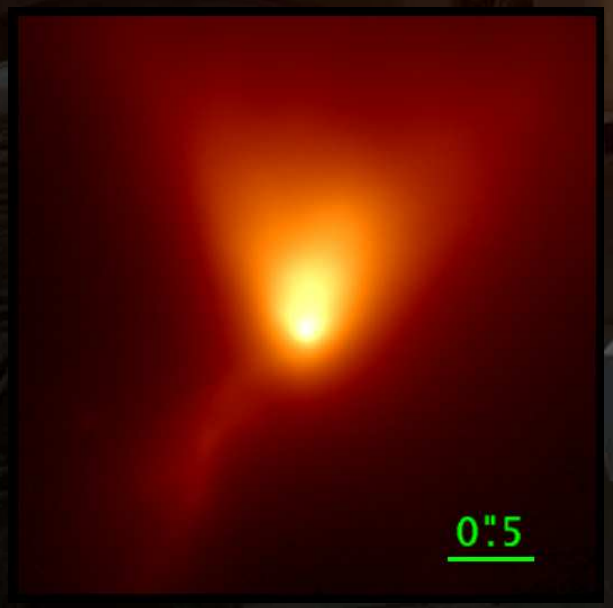
Dark band (signature of the disc)

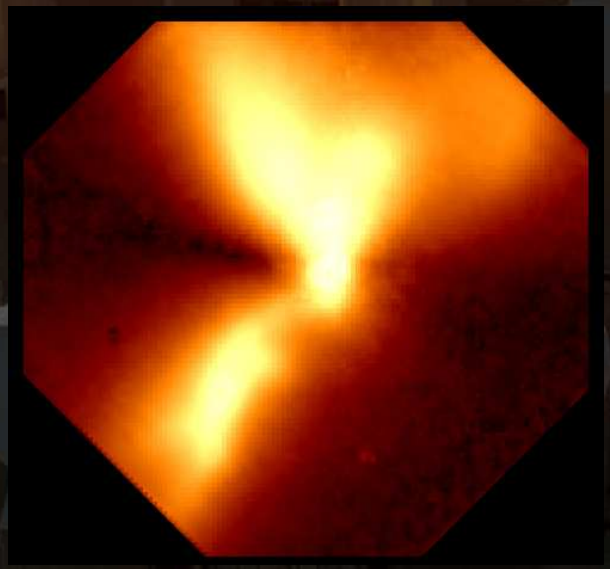


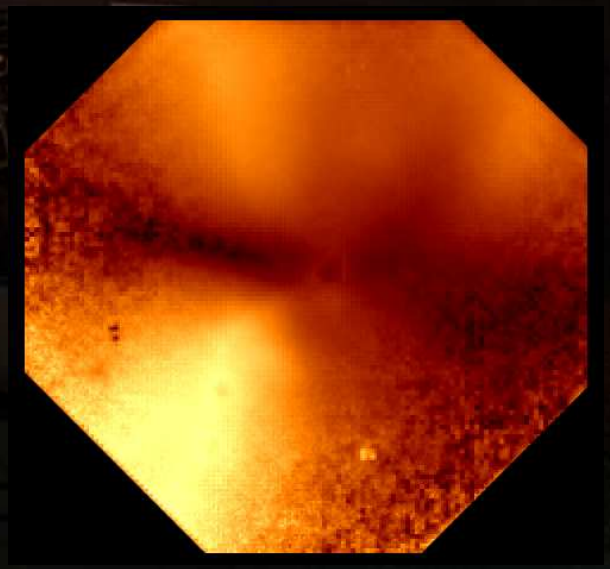


NACO polarization maps

Total intensity Polarized intensity Polarized / total intensity







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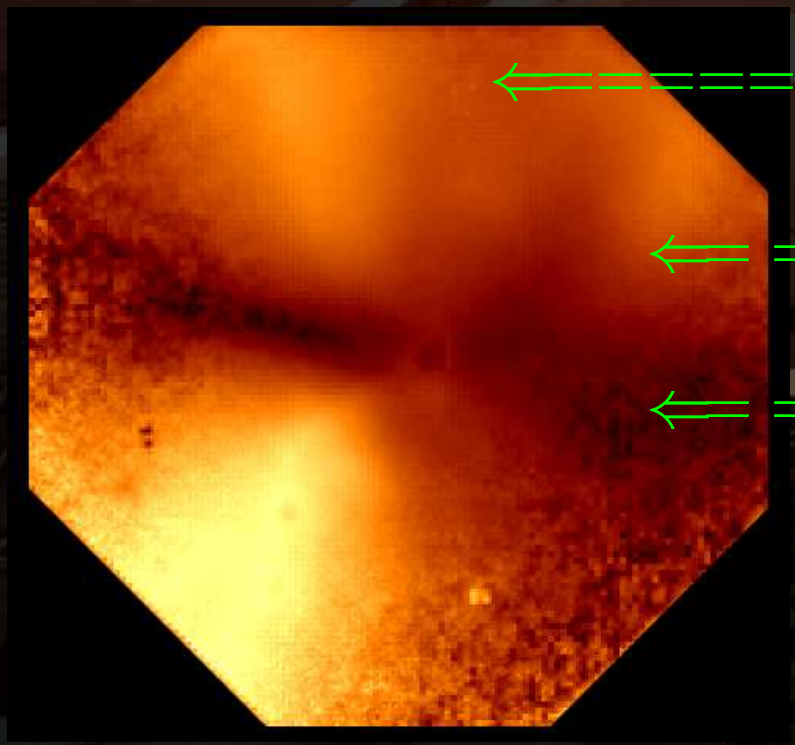


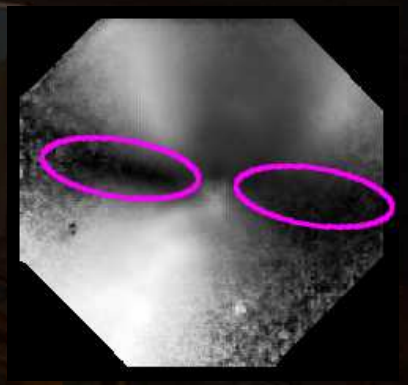
⟸⟸⟸⟸⟸ not enough scattering material inside the cavity

⟸ wall of the cavity

⟸ optically thick disk (from 40 AU to 400 AU)

Conclusions

- With the help of DPI, the different components of the circumstellar material (cavity, disc) can be distinguished (HST was not enough!);
- The circumstellar disc can be discerned from 0.″1 (40 AU) to 1.″5 (400 AU);
- The star seems to be an isolated young star; there are no close companions, although we found two possible companion candidates at 500 and 1300 AU



Future prospects

- Concerning Parsamian 21
  - Quantitative analysis of the results
  - Interpret morphology through models
  - HST/NICMOS data

- Generally
  - The example of Parsamian 21 demonstrates that adaptive optics, combined with the differential polarimetric imaging can probe the circumstellar structure close to the star.

SED of Parsamian 21