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High-precision polarimetry of protoplanetary disks with SPHERE/ZIMPOL

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To understand planet formation, we need to know what protoplanetary disks are made of.

- Different dust constituents of protoplanetary disks can exhibit different optical properties, e.g.:
    - icy dust grains: high albedo, low polarization
    - carbon rich material: low albedo, high polarization
- The degree of polarization of the reflected light is a good tracer for the composition of astrophysical dust (e.g. cometary dust).

Scientific goals

difficult

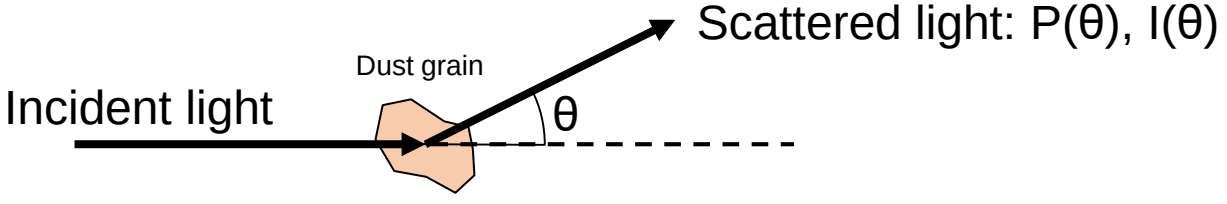
1) Determine the degree of polarization **p(θ) = P(θ)/I(θ)** of the scattered light

2) Determine the optical properties of the dust

   - asymmetry parameter: **g**
   - maximum polarization: $\mathbf{P_{max}}$
   - single scattering albedo: **ω**

"easy"

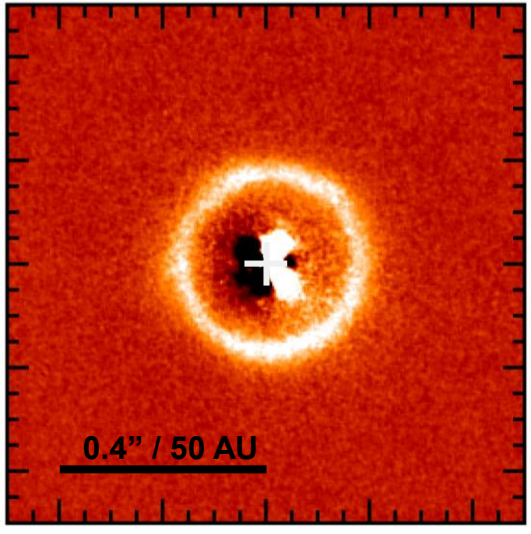
3) Constrain the physical properties of the dust (e.g. icy grains, carbon rich grains,…)



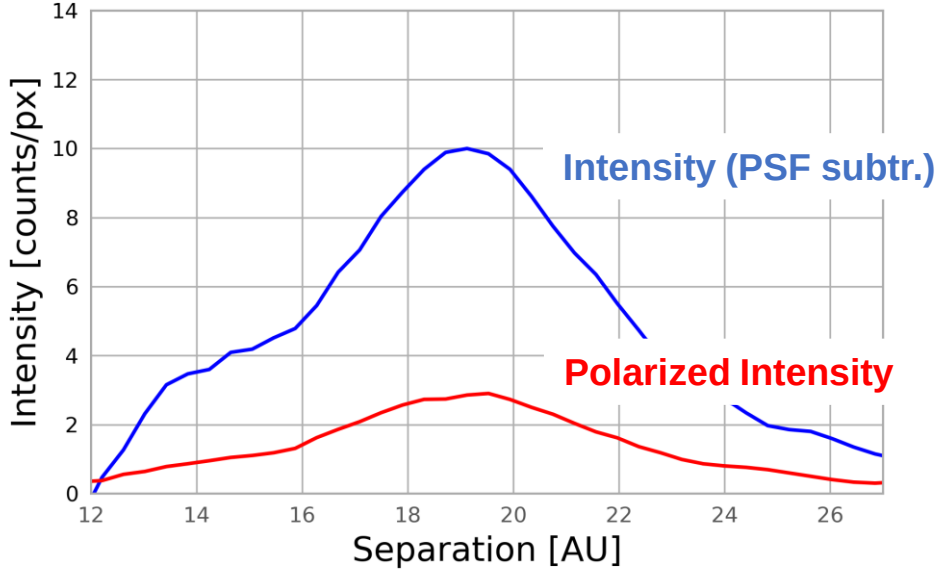
HD169142: azimuthal symmetric structure allows high SNR measurement

(Work by Ch. Tschudi)

Polarized intensity in I-band



Azimuthally averaged radial profiles



For symmetric face-on disks, we can measure the azimuthally averaged scattered light intensity:

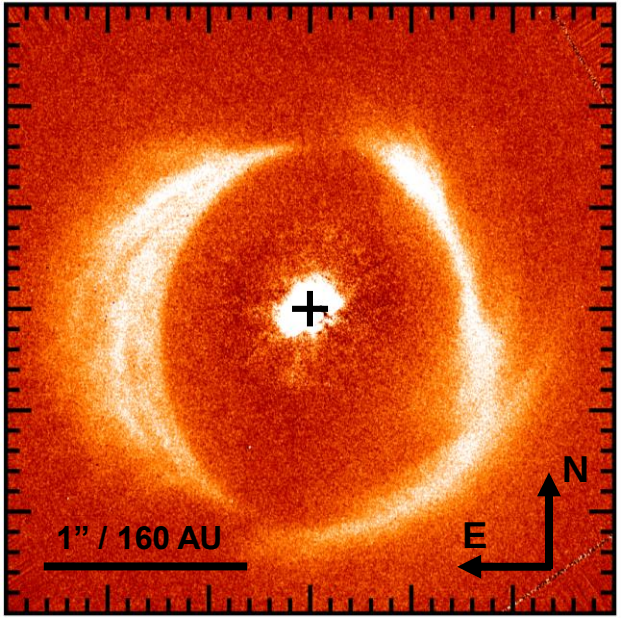
⇒ high SNR measurement of I(90°) and P(90°)

⇒ **p(90°) = 23.5% +/- 4 % polarization in R-band (626.3 nm)**

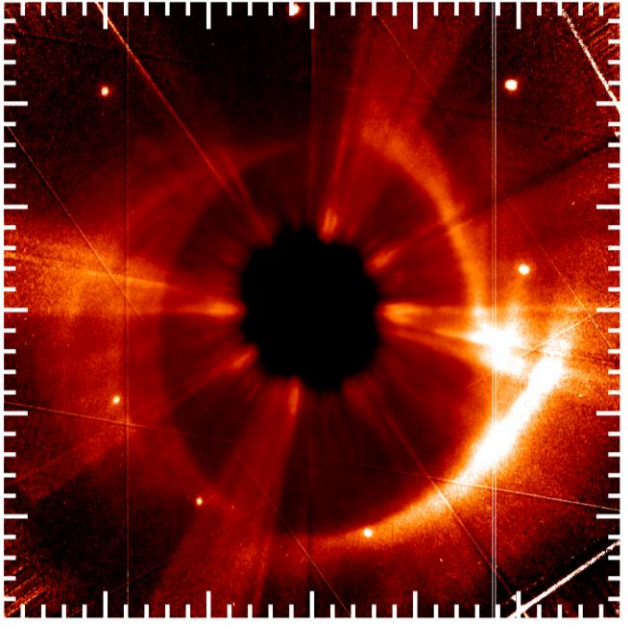
⇒ **p(90°) = 25.4% +/- 4 % polarization in I-band (789.7 nm)**

HD142527: large and bright disks allow us to measure the polarization for many different resolved structures in the disk

Polarized intensity at ~750nm



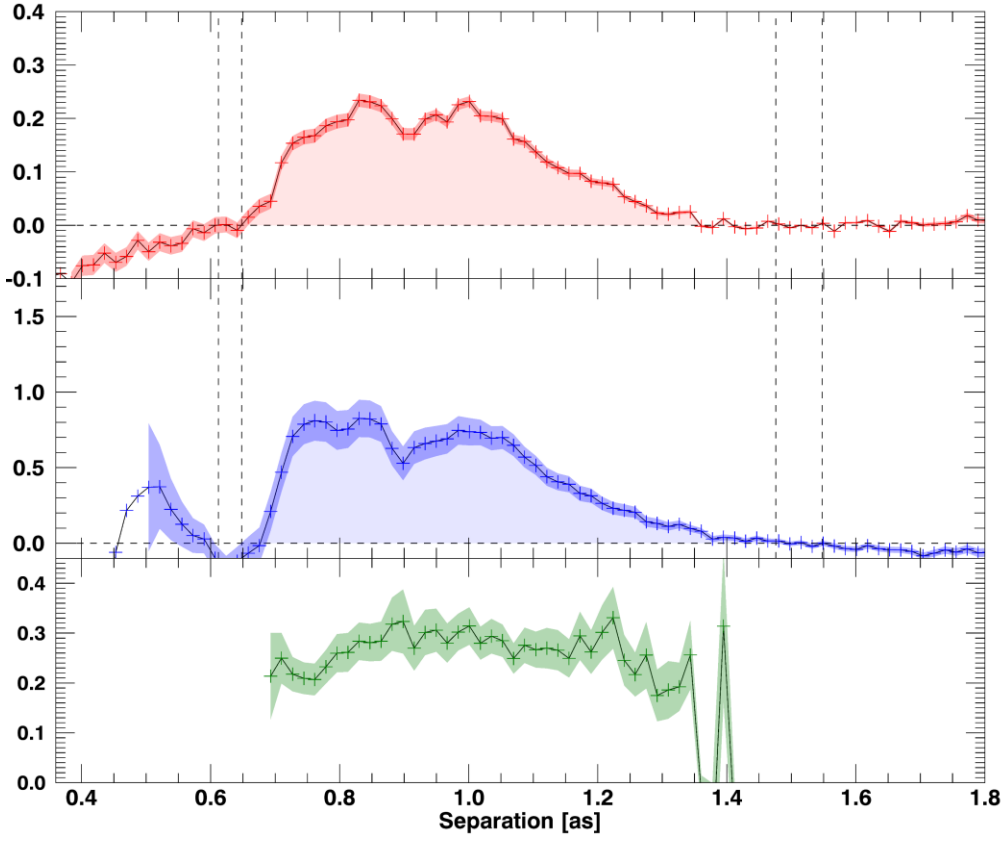
Intensity at ~750nm (scaled with $r^{2.75}$)

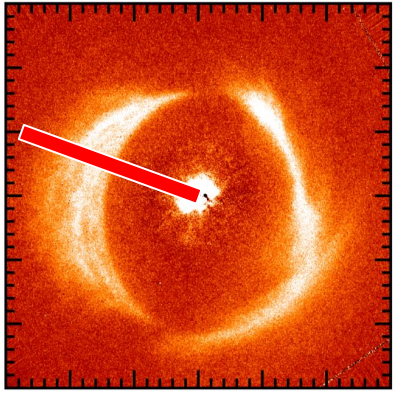


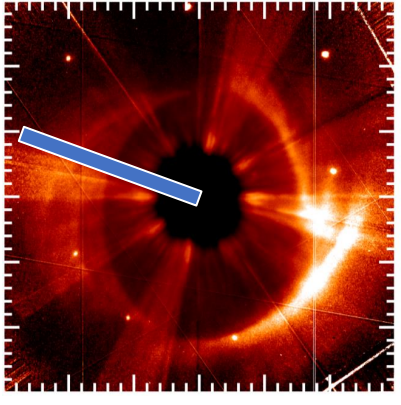
The **near side (west) is brighter than the far side (east)** in reflected intensity, a feature that is not seen in polarized intensity.

A slice through the **far side of the disk** around **HD142527** shows a consistently high polarization.

Radial profiles (polarized intensity, intensity, fractional polarization) at 70° position angle:



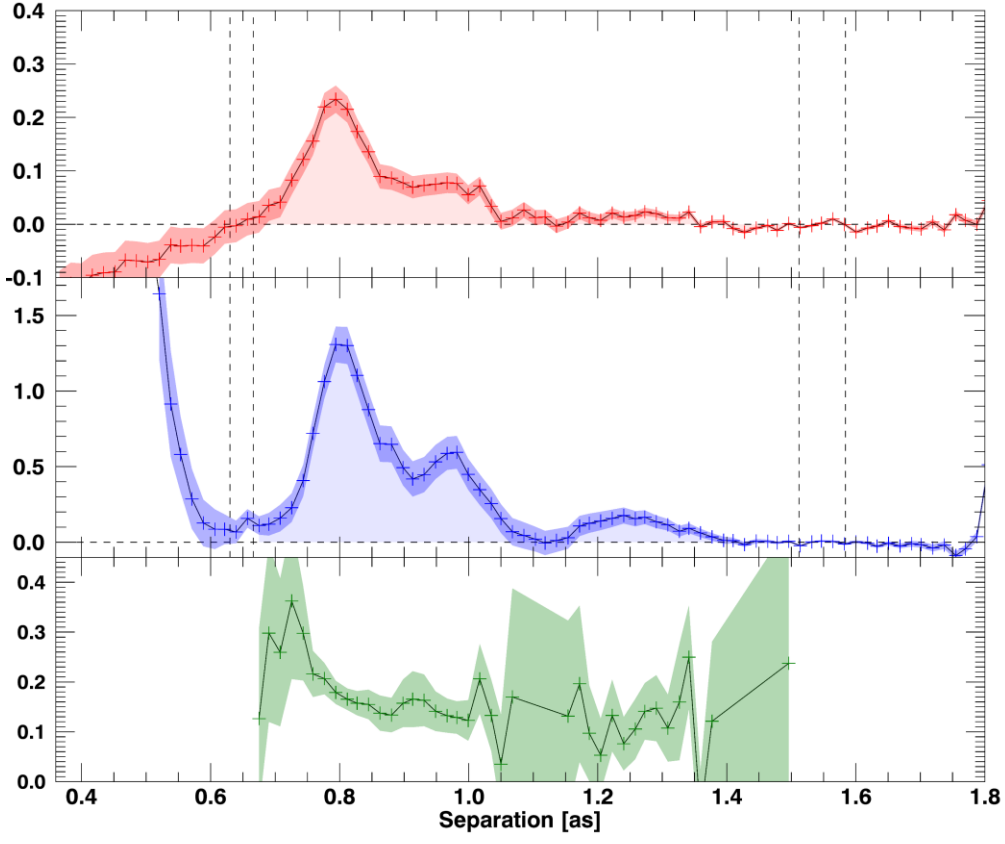


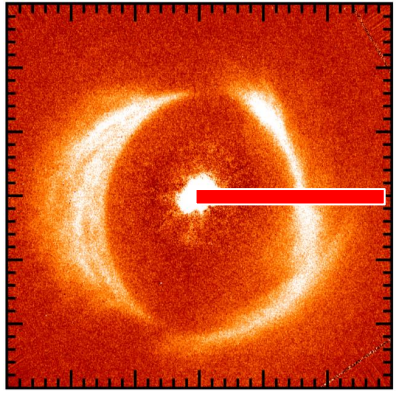


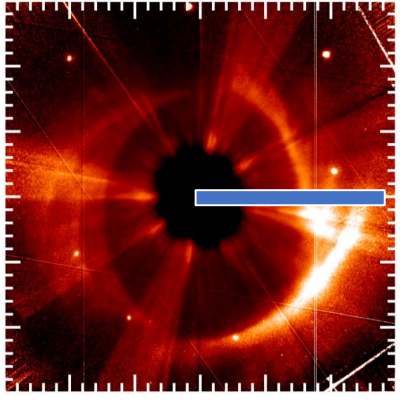
The flux weighted mean polarization is **p = 27% +/- 1 %**.

A slice through the **near side of the disk** around **HD142527** shows a significantly lower polarization.

Radial profiles (polarized intensity, intensity, fractional polarization) at 270° position angle:







The flux weighted mean polarization is **p = 16.5% +/- 1.5 %.**

Some main features of visible light scattering on **cometary dust** are:

- **forward scattering peak** (with g~0.5), which can also be seen in the HD142527 measurements and was also observed for many other circumstellar disks
- **maximum polarization of P_{max} ~30%** for the family of highly polarizing comets, which is also close to what we see in HD142527

Conclusions/Outlook

- It is possible with SPHERE/ZIMPOL to accurately measure the fractional polarization of scattered light.
- Our first comparison shows properties not unlike to cometary dust.
- We are already doing a more detailed analysis of the measurements with simulations of multiple scattering (to constrain **g, P_{max}, ω)**.
- Dedicated observations in the future will deliver for more accurate measurements and multi-wavelength information.