Dichroic absorption by circumstellar dust as a possible polarigenic mechanism of RW Aur A and RY Tau

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SAI MSU

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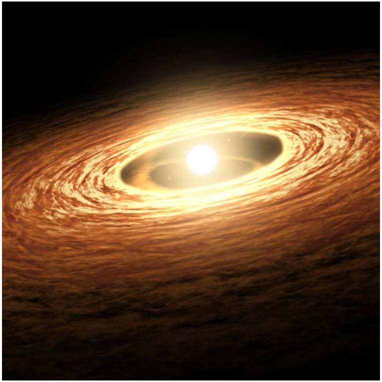
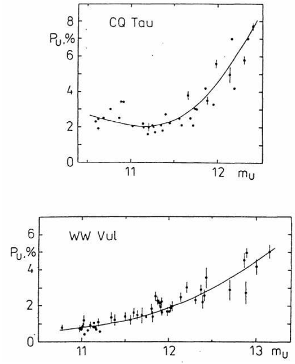
UX Ori variables

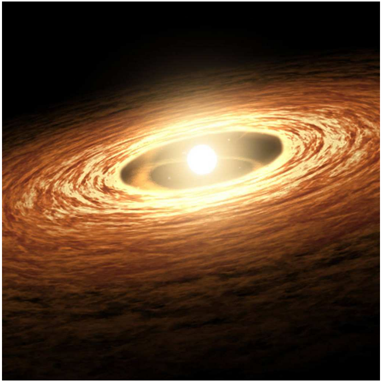


Grinin, 1991



- Polarization rises during fading. Explanation: the contribution of scattered light increases.

UX Ori variables



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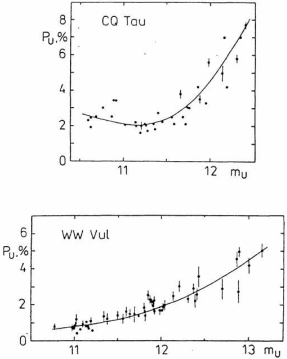
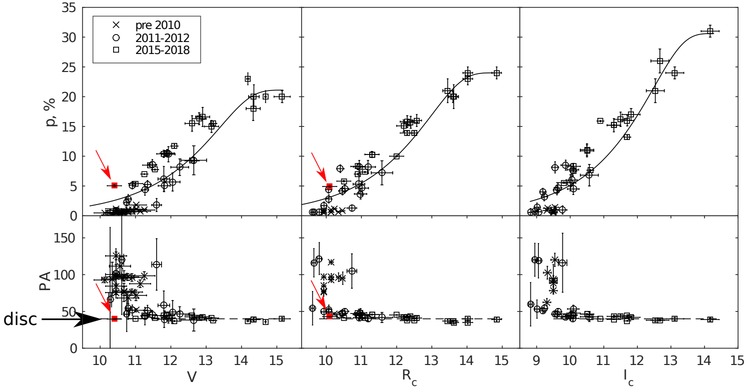


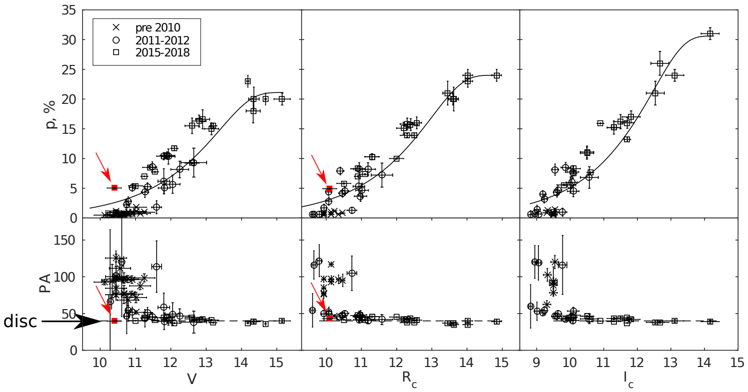
- Polarization rises during fading. Explanation: the contribution of scattered light increases.
- Exceptions: RW Aur A and RY Tau.

Polarization of RW Aur A



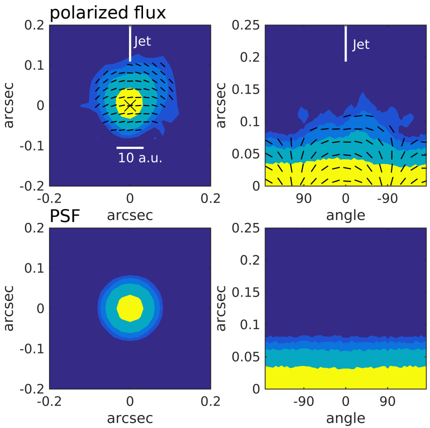
1) Polarization rises during fading
2) Plane of polarization is almost perpendicular to jet (parallel to disc).

Polarization of RW Aur A



Consider a specific date: 22-10-2016.
Magnitude is $R_c = 10.1$ (by 0.7^m fainter than pre-eclipse state).
Total polarization 5%.

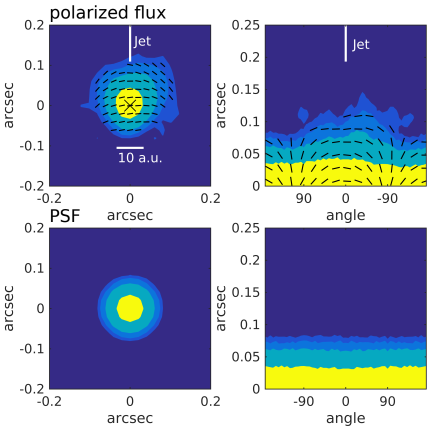
Differential Speckle Polarimetry: image in polarized flux at diffraction limited resolution (50 mas = 7 au @ 140 pc) Safonov+ 2019.



There is polarized structure shifted towards blue jet.

Resolving the polarized flux

Differential Speckle Polarimetry: image in polarized flux at diffraction limited resolution (50 mas = 7 au @ 140 pc) Safonov+ 2019.



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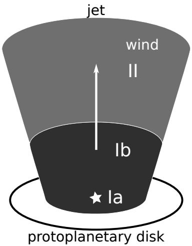
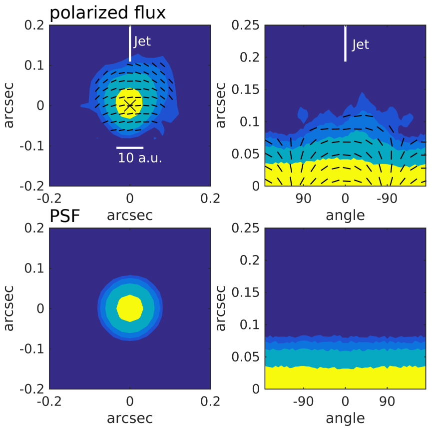


Its geometry qualitatively conforms to dusty wind hypothesis Dodin+ 2019.

Differential Speckle Polarimetry: image in polarized flux at diffraction limited resolution (50 mas = 7 au @ 140 pc) Safonov+ 2019.

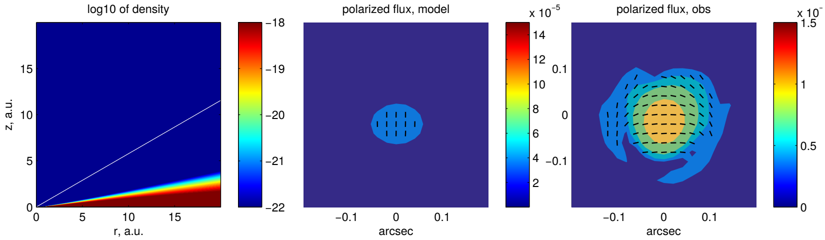


There is polarized structure shifted towards blue jet.

Summary of observational data for 2016-10-22:

- Magnitude is by 0.7^m,
- Total polarization is 5%,
- The geometry of resolved polarized flux.

Model: disc



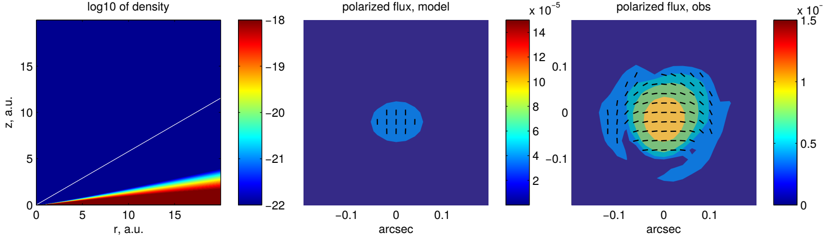
Radiation transfer modeling: MC3D, Wolf, S., 2003.
First approximation: thin disc

$$\rho(r,z) = \rho_0 (r/R_\star)^{-\alpha} \exp\left[-z^2/2h^2(r)\right], \qquad (1)$$

$$h(r) = h_0 (r/R_0)^{\beta}, \qquad (2)$$

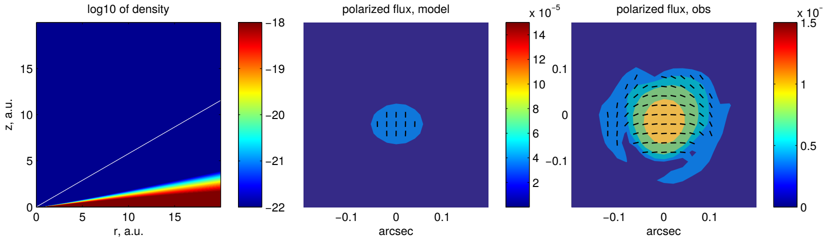
$\alpha = 2.3,\ \beta = 1.2,\ h_0 = 2.5$ au, $R_0 = 50$ au, $M = 10^{-4} M_\odot$.

Model: disc



- Resolved structure is not observable (too faint).
- Total polarization is too small: 0.7% (perpendicular to disc).
- Magnitude drop is -0.05^m.

Model: disc



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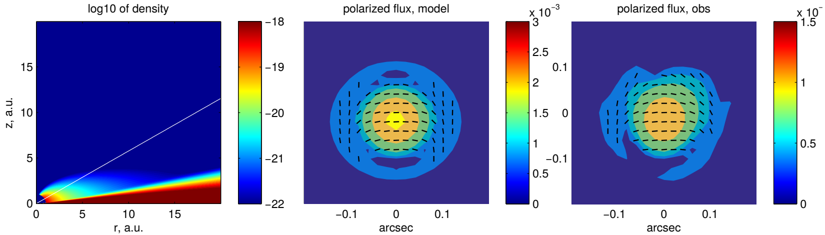
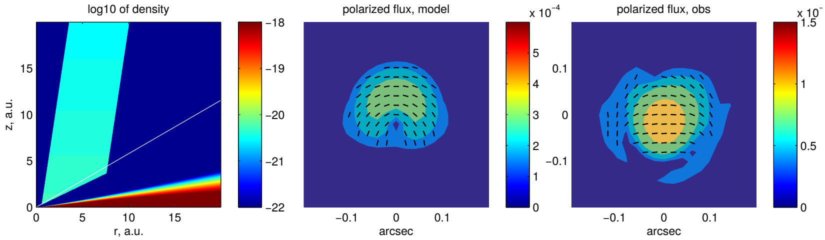
Common protoplanetary disc is thin and poorly illuminated $\rightarrow$ it scatters little light $\rightarrow$.

Model: thick disc



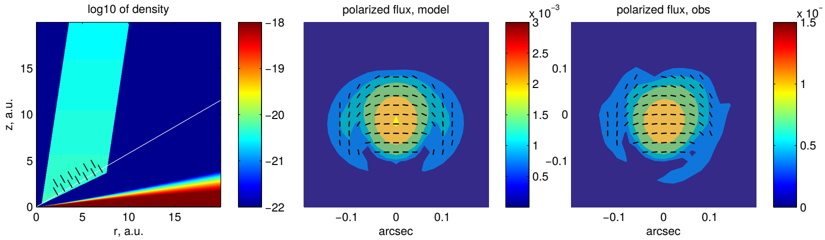
- Resolved structure is reproduced.
- Total polarization is reproduced: 6%.
- Magnitude drop is 2.4^m — more than observed.

Model: cone wind



- Extended structure is reproduced.
- Total polarization: 0.8%, less than observed.
- Magnitude drop is reproduced: 0.7^m.

Cone wind + polarized star 5.9%

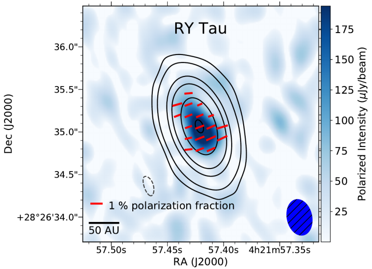


- Extended structure is reproduced ($\chi_r^2 = 1.1$).
- Total polarization is reproduced: 5%.
- Magnitude drop is reproduced: 0.7^m.

RY Tau

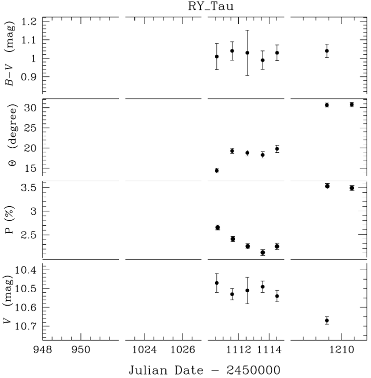
RY Tau

ALMA 3 mm, Harrison+ 2019.



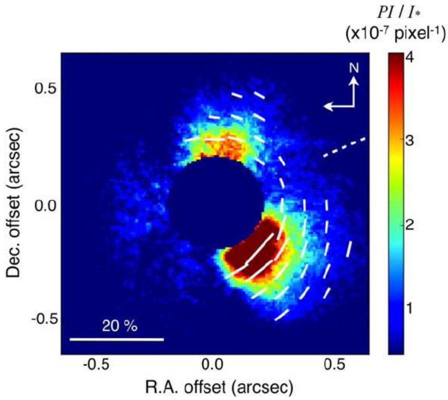
- Disc, infalling envelope, wind, jet.
- UX Ori variability, timescale 1 h – 1 yr. Sometimes quite chaotic.

Oudmaijer+ 2001. V-band polarimetry.

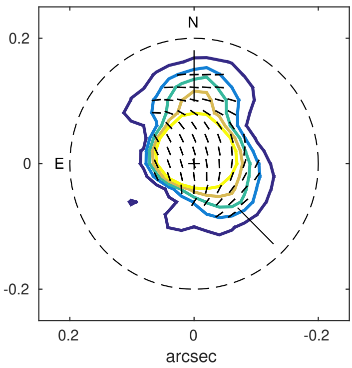


RY Tau: DSP

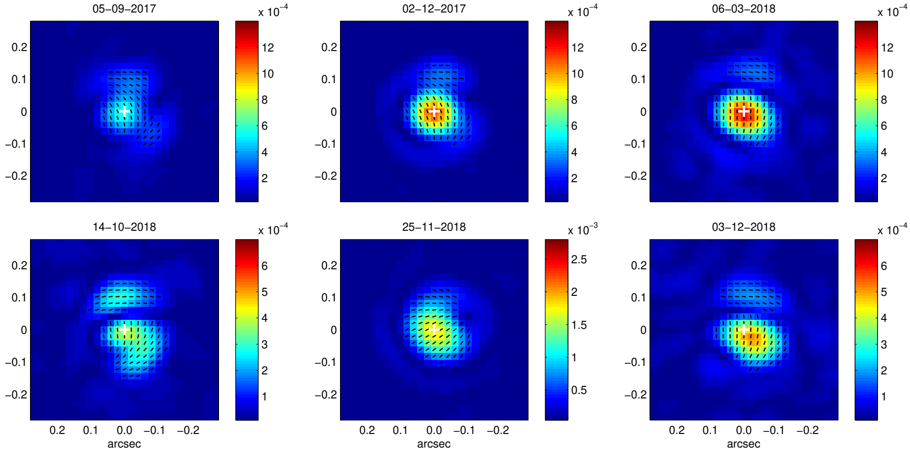
Takami+ 2013ApJ...772..145T
Subaru/HiCIAO
(AO+coronagraph), H band



Differential Speckle Polarimetry, I band.
Dashed circle corresponds to coronagraphic mask of HiCIAO.



RY Tau: multiple epochs



Two components of polarized flux distribution:

- Extended constant.
- Point–like variable.

Interstellar polarization substracted (I band):

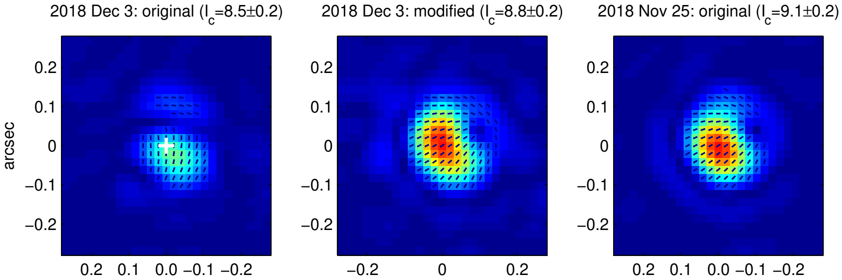
P=2.39%, $\chi = 26^\circ$, Petrov+ 1999.

RY Tau: two epochs

Apporximate data for 2018 Dec 3 by the data for 2018 Nov 25:

1) Add a point-like polarized source: $q_s, u_s, \Delta_{\mathrm{RA}}, \Delta_{\mathrm{dec}}$.
2) Change the brightness of the star by γ.

Band I_c:



band	q_s, %	u_s, %	Δ_{RA}, mas	Δ_{dec}, mas	γ	χ_r^2
I_c	2.9 ± 0.1	2.0 ± 0.2	2 ± 2	2 ± 2	0.75 ± 0.06	1.8

Conclusions

- The resolved polarimetric data for RW Aur A are difficult to explain by scattering only.
- Additional polarized flux can be generated by dichroic absorption by aligned circumstellar dust.
- RY Tau circumstellar nebula consists of stable extended component and variable uresolved point–like component (size less than 50 mas) co-located with the star (<4 mas displacement). Point–like component is probably direct stellar radiation polarized by aligned dust.

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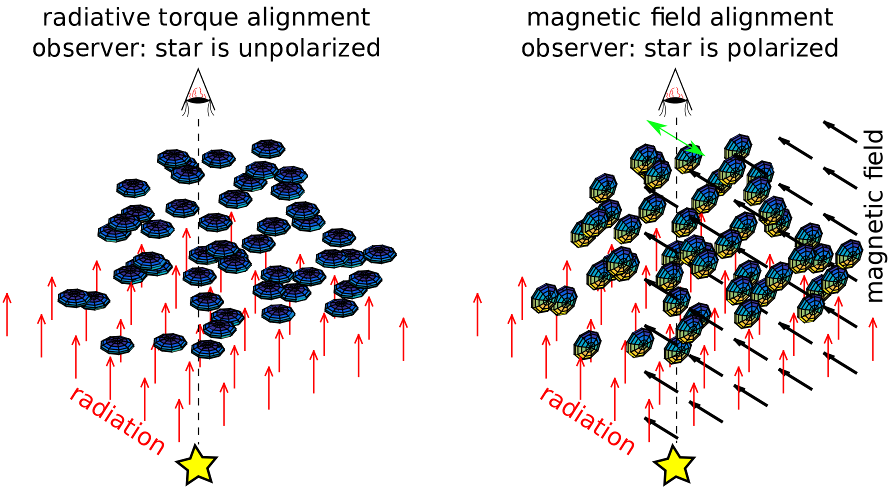
Thank you

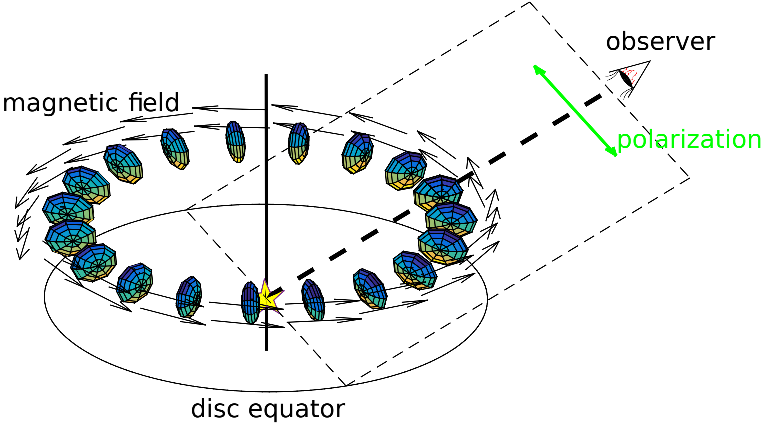
Supported by RNF (17-12-01241)

Alignment mechanisms

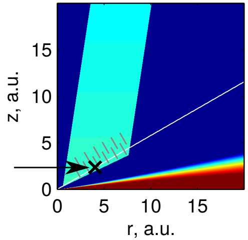


Alignment mechanisms

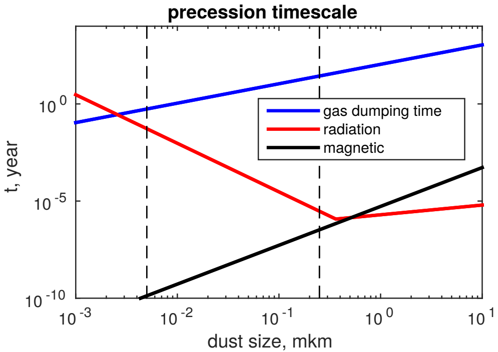
Polarization along the disc equator is consistent with torodial magnetic field.



Alignment timescales



Tazaki+ (2017)



Gas density: 5×10^{-19} g·cm^{-3}.

Gas temperature: 220 K.

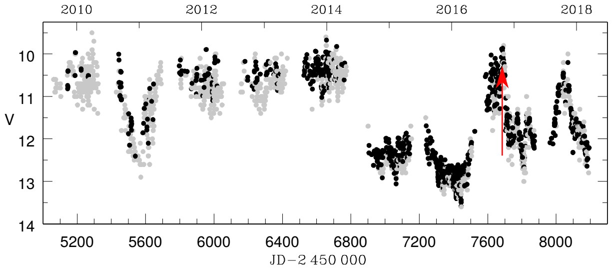
Average wavelength: 0.65 μm.

Radiation energy density: 2.7×10^{-5} erg·cm^{-3}.

Magnetic field strength: 5 mG.

smaller timescale wins

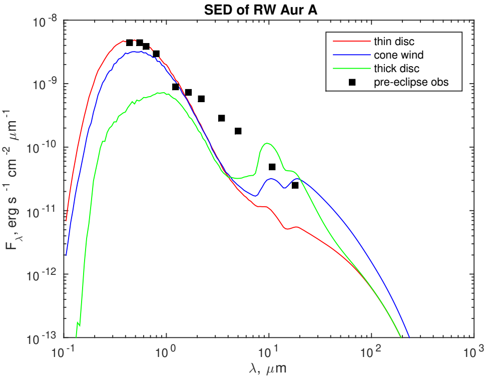
RW Aur A: 22-10-2016



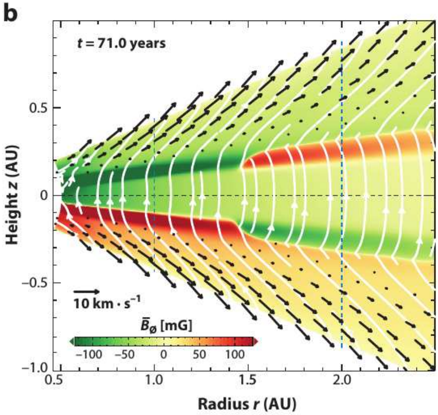
- Soon after recovery from deep eclipse. Dense wind just passed line of sight and should be visible.

RW Aur A SED

MC RT modeling.



Gressel+, 2015:



Dust can be entrained from the disc by the slow ($\lesssim$ 10 km/s) disc wind (Owen et al., 2011; Hutchinson et al., 2016), or possibly by magnetospheric wind.