Photocenter motion during UXor events: detecting disc structure with Gaia?

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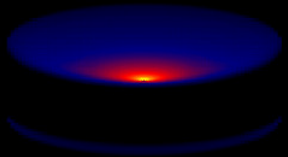
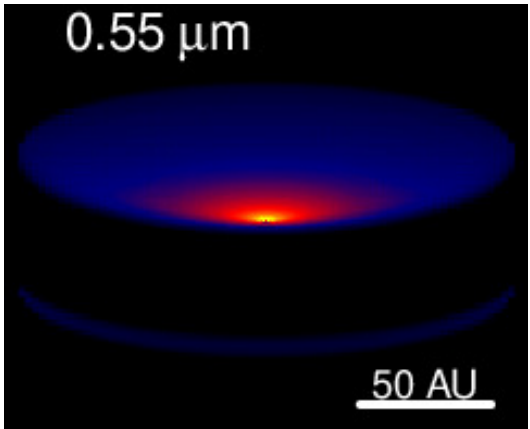
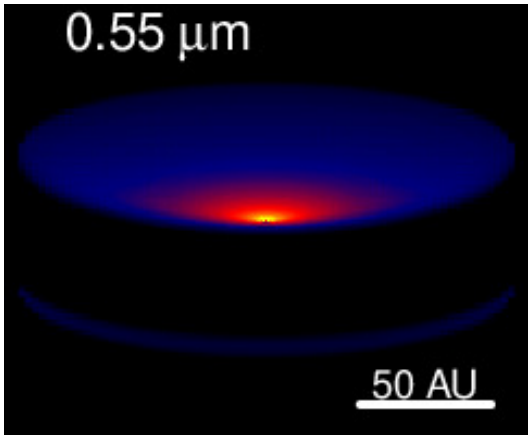




UXOR: (sporadically obscured) star
+ inclined disc

- Gaia measures photocenter of the system (T. Prusti's talk)
- Typically not coincident with the star (scattered light asymmetric)
- The displacement is related to the disc structure.
- An obscuring event will enhance the displacement.

Breaking news:
Dodin, ..., Lamzin, ..., Safonov, ...,2019:
Detected photocentre motion in scattered light of RW Aur



General principle (For a system with a unresolved spatial distribution)

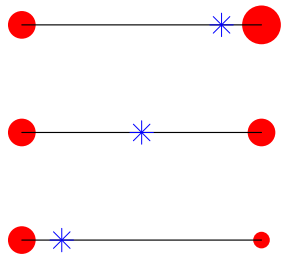
- Astrometry measures the centre of the brightness distribution (photocentre).
- Not the centre of mass (barycentre).

Apparent motion includes:

- Proper motion (barycentre)
- Motion of photocentre w.r.t barycentre
- Parallax

A standard five-parameter solution includes only proper motion and parallax.

An example of photocenter motion: "variability-induced movers" (Wielens 1996).



"Variability-induced movers" (Wielens 1996). Could be used to

- detect binary (using high-precision astrometry)
- set constraints on binary parameters.

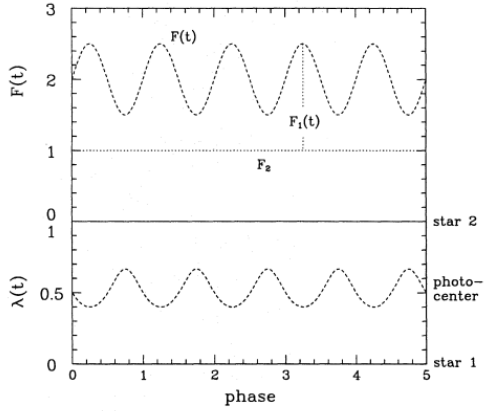


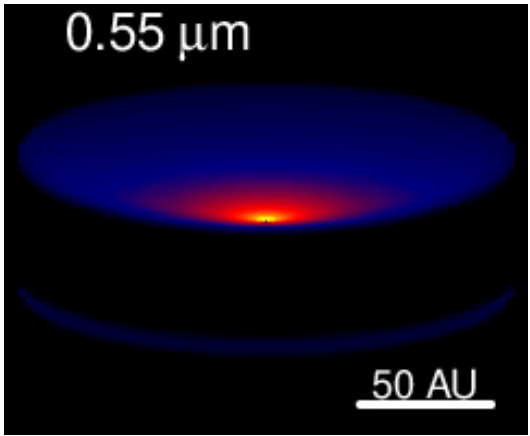
Fig. 1. Illustration of the VIM effect by a simple example. The upper panel shows the total light variation $F(t) = F_1(t) + F_2$ for $F_1(t) = 1 + 0.5 \sin \frac{2\pi}{P} t$ and $F_2 = 1 = \text{const.}$ (in arbitrary units). The lower panel shows the relative motion of the photo-center, $\lambda(t)$, defined as the distance of the photo-center from the variable star, measured in units of d, the separation of the two stars.

VIMs in HIPPARCUS (Bertout+ 1999)

- detect 8 binary (as VIM)
- set constraints on binary parameters.

Table 7. VIM solutions for Young Stellar Objects

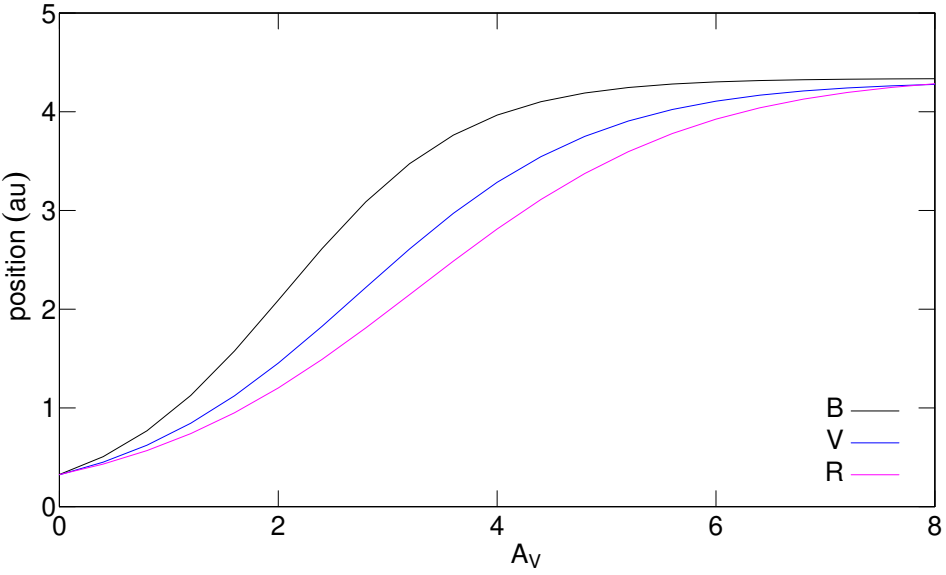
Star (1)	$\Theta_C \pm \sigma_{\Theta_C}$ (°) (2)	$\rho_{\min}$ (mas) (3)
V773 Tau	118.08 ± 9.54	119.4
RY Tau	316.61 ± 37.59	19.5
DF Tau	307.08 ± 17.70	80.2
UX Tau A	253.90 ± 5.53	204.7
UX Ori	257.42 ± 18.42	21.8
Z CMa	135.30 ± 20.27	80.1
IX Oph	244.59 ± 13.65	56.9
V1685 Cyg	22.94 ± 11.71	140.6



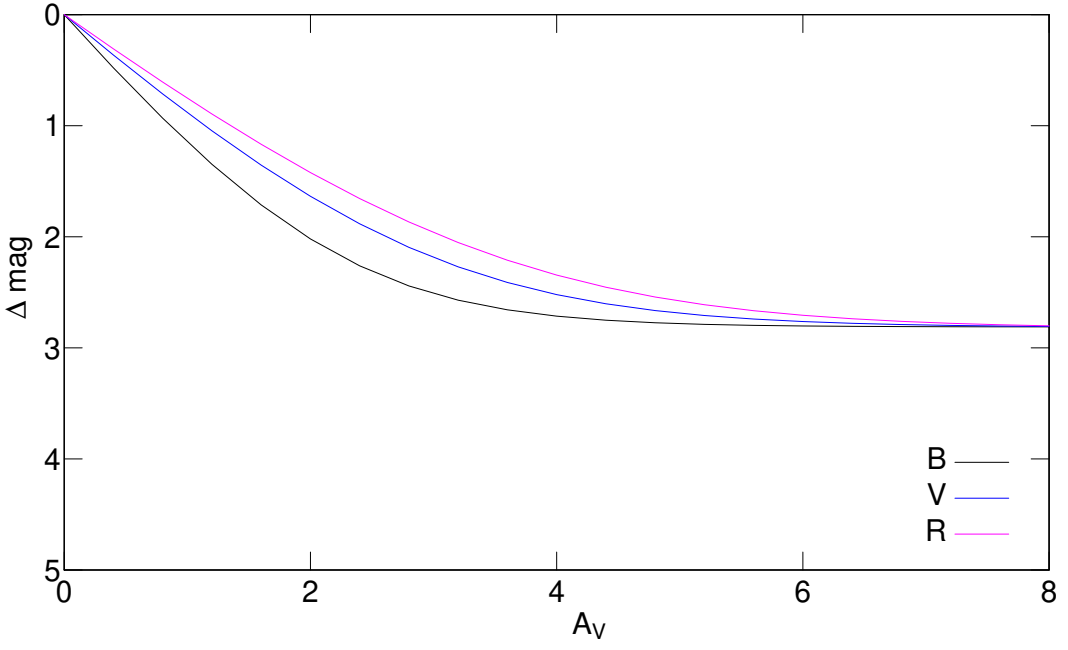
Reference model

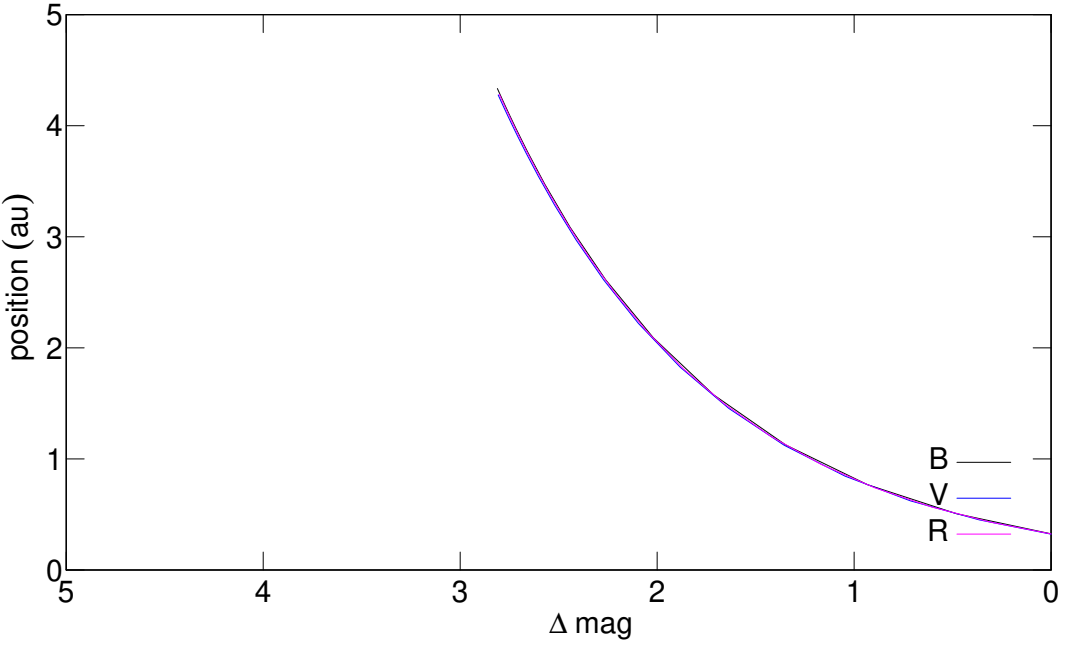
- $L_* = 5L_\odot$
- $R = [0.2, 100]$ au
- $h_{\rm in} = 0.05$
- $h_{\rm out} = 0.1$
- inclination: 70°

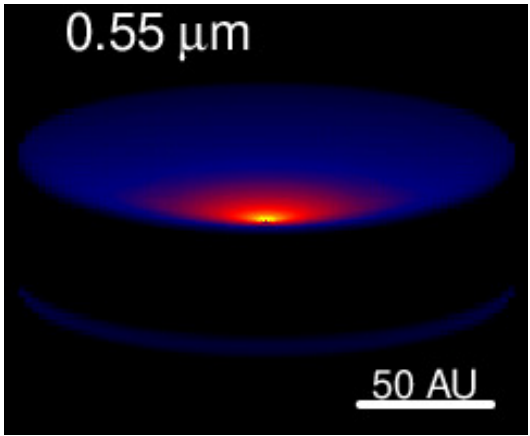
Photocentre lies at north of the star, by 0.3 au. Moves to 4.3 au from the star if the star light is blocked.



For eclipse of moderate depth, there is a wavelength-dependent displacement.

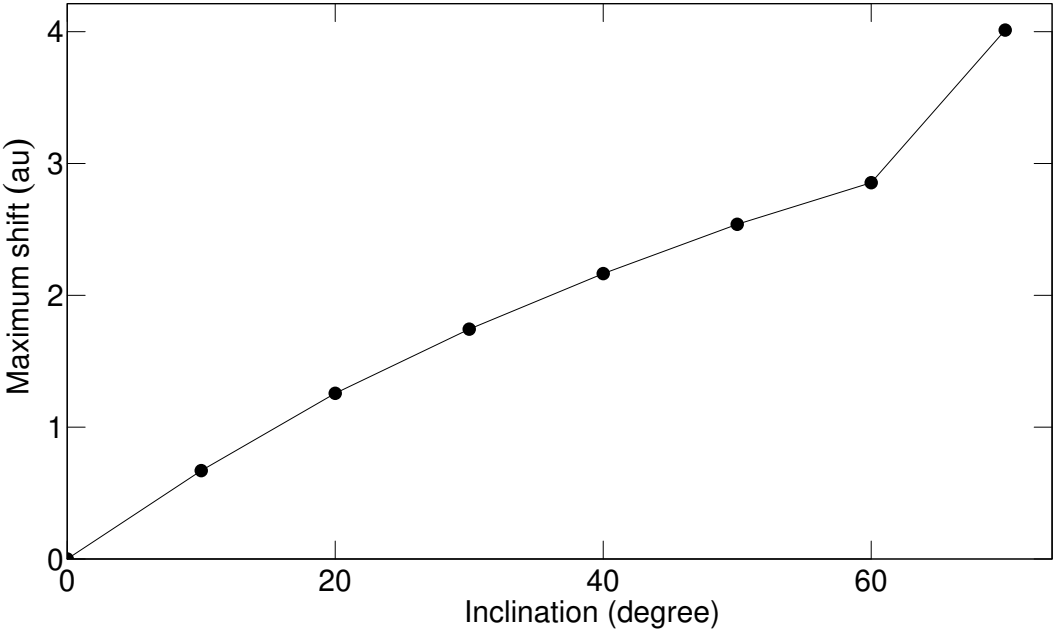

0
1
2
3
4
5
Δ mag
0
2
4
6
8
A_V
B
V
R

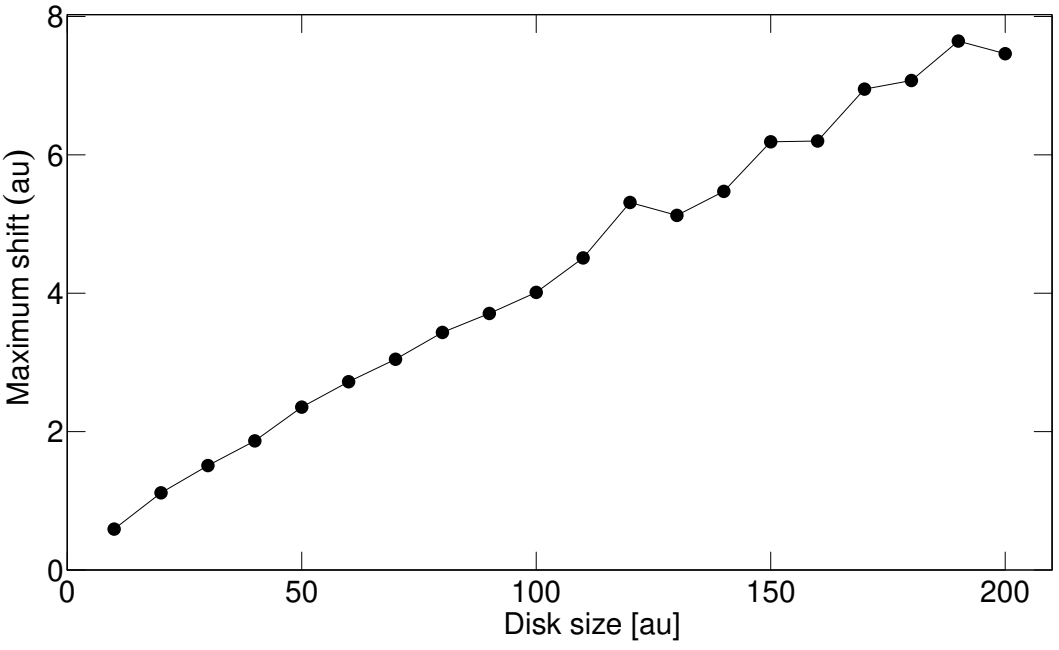

position (au)
Δ mag
B
V
R
0
1
2
3
4
5
5
4
3
2
1
0

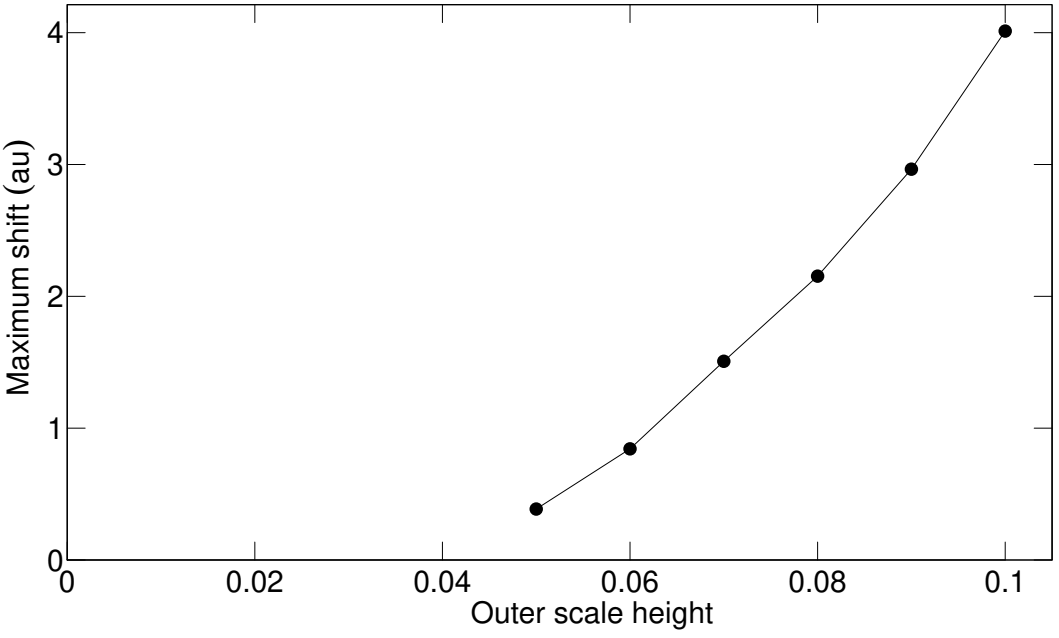


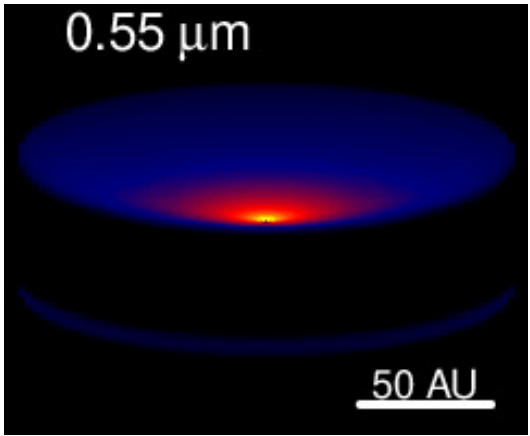
Why should we care?

- ~ 10 mas of angular shift.
- A "noise" in astrometric measurement. Parallax!
  (T. Prusti's talk: UXORs tends to have bad parallax measurements.)
- Information about disc
- Identifying UXOR events.
- Verifying UXOR theory.


Maximum shift (au)
0
1
2
3
4
0
20
40
60
Inclination (degree)


Maximum shift (au)
Disk size [au]
0
2
4
6
8
0
50
100
150
200


Maximum shift (au)
0
1
2
3
4
0
0.02
0.04
0.06
0.08
0.1
Outer scale height



Motion ↔ Disk structure

- Amplitude ↔ Disk size, inclination, flaring...
- Position angle ↔ PA of disk. (compare with other measurement)

VIMs in HIPPARCUS
(Bertout+ 1999)

- Some UXORs have VIM effects.
- UX Ori: PA$\sim 257^\circ$
- Disk major axis:
  PA$\sim 130 - -150^\circ$
  (Kreplin+ 2016)
- UX Ori in Gaia?
  (binary or not)

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Question:

- Taken into account in astrometric modelling (better parallax, proper motion)?
- Studying UXOR with: Gaia time series of photometry+astrometry?
- Considered in Gaia alert?
- With Gaia DR2, how to check whether a give star might have additional motion on top of proper motion and parallax (bad fitting with 5-parameter model)?

Thanks!