Flip-flopping pulsar model for the gamma-ray binary HESS J0632+057

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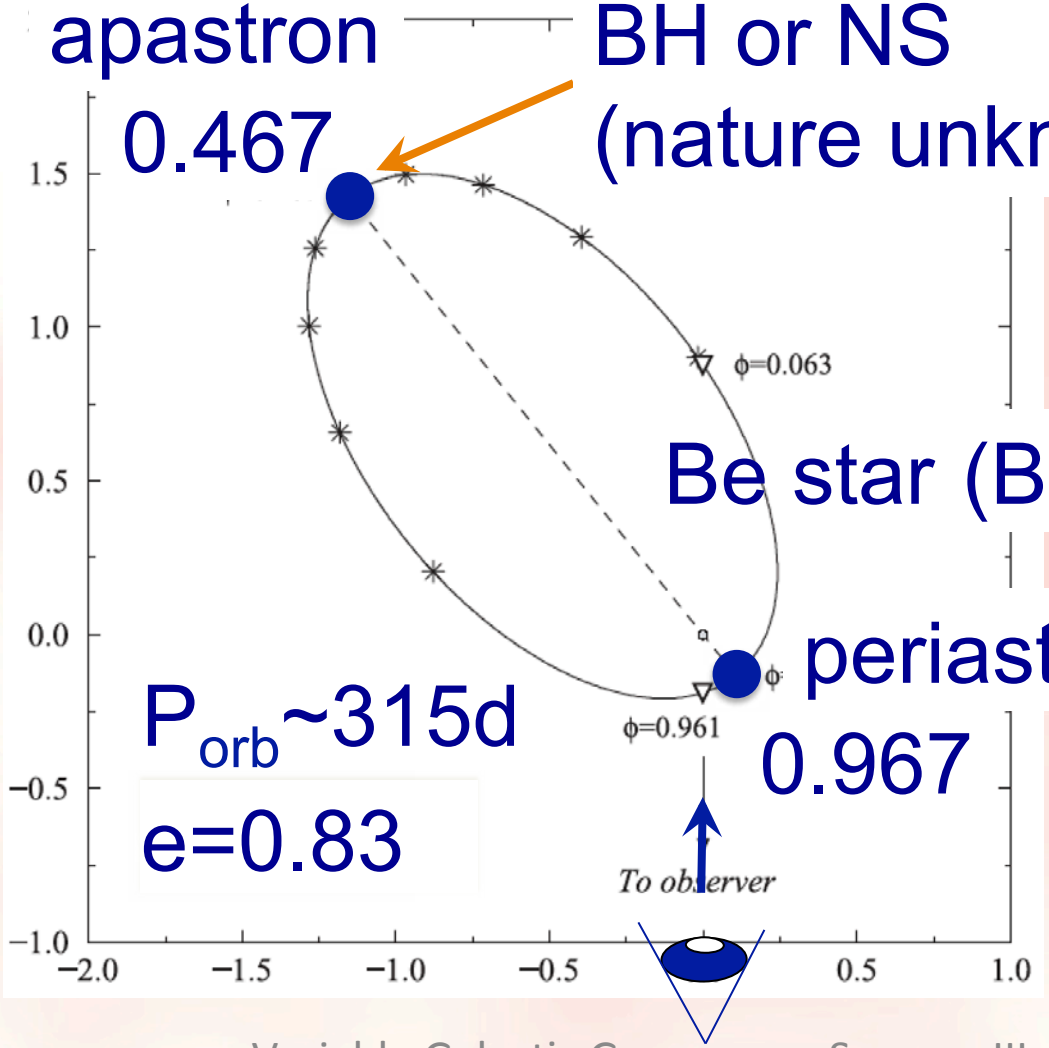
Outline

- Introduction
- Puzzling X-ray/gamma-ray light curves
- Flip-flop (ejector ⟷ propeller) scenario
- Simulation results
- Concluding remarks

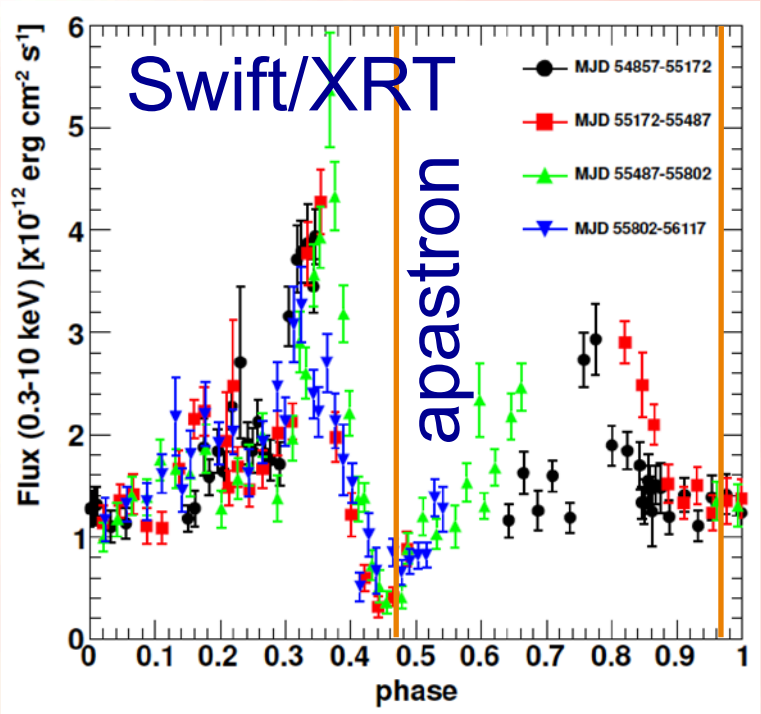
HESS J0632+057: a mysterious TeV gamma-ray binary



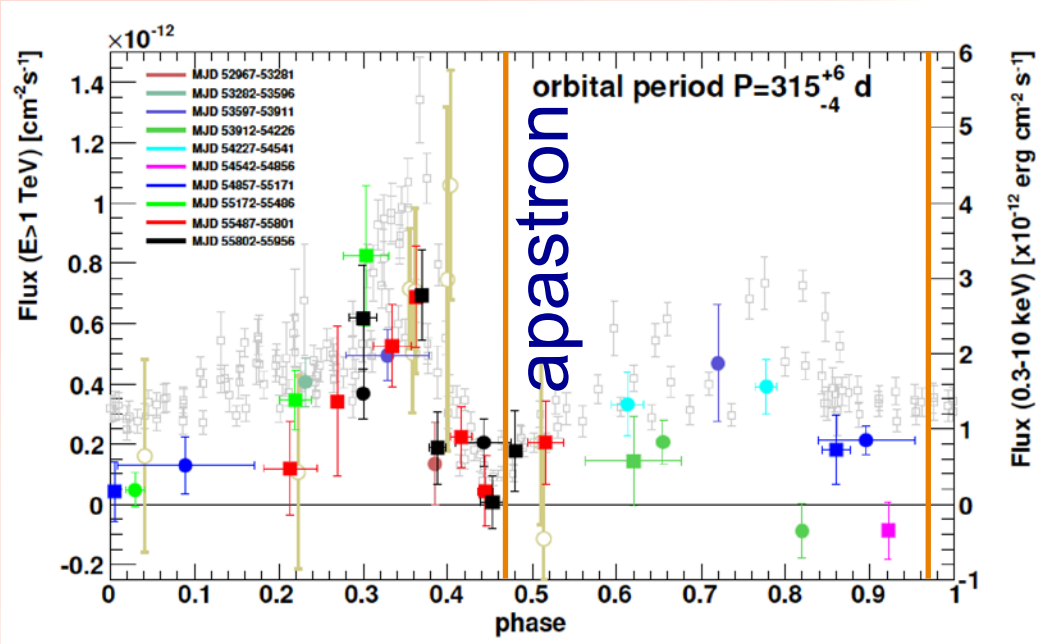
(Fig. from Casares+ 2012; P_{orb} from VERITAS 2013)

Puzzling X-ray/gamma-ray light curves

- **Double outburst near apastron**
- **Deep minimum @ apastron**
- **Quiescent @ periastron**



HESS, MAGIC, VERITAS



(VERITAS collaboration 2013)

Puzzling X-ray/gamma-ray light curves

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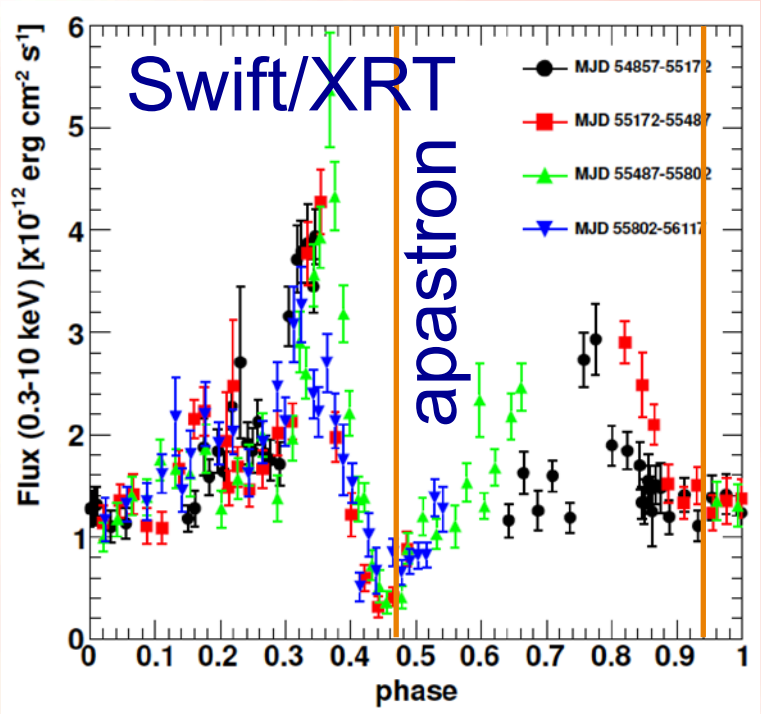
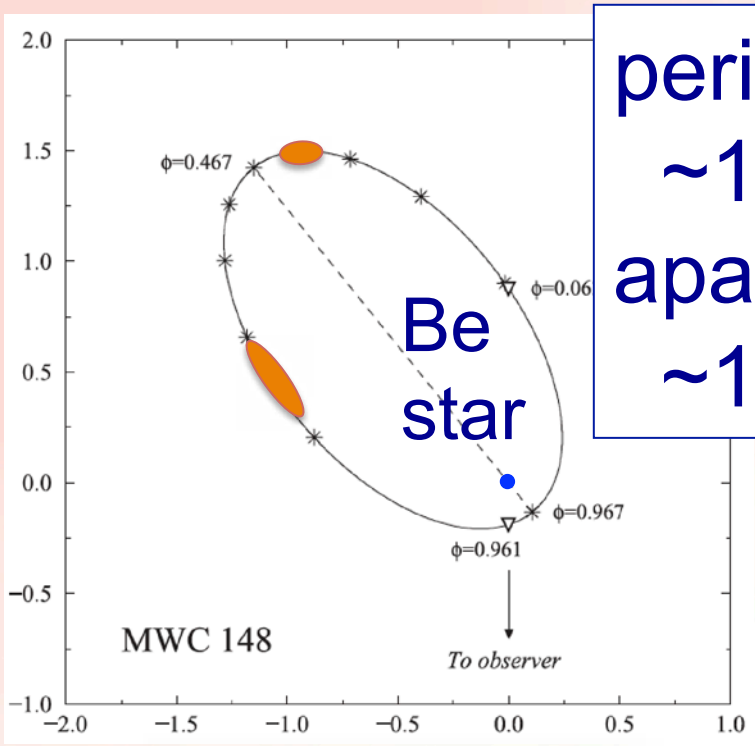




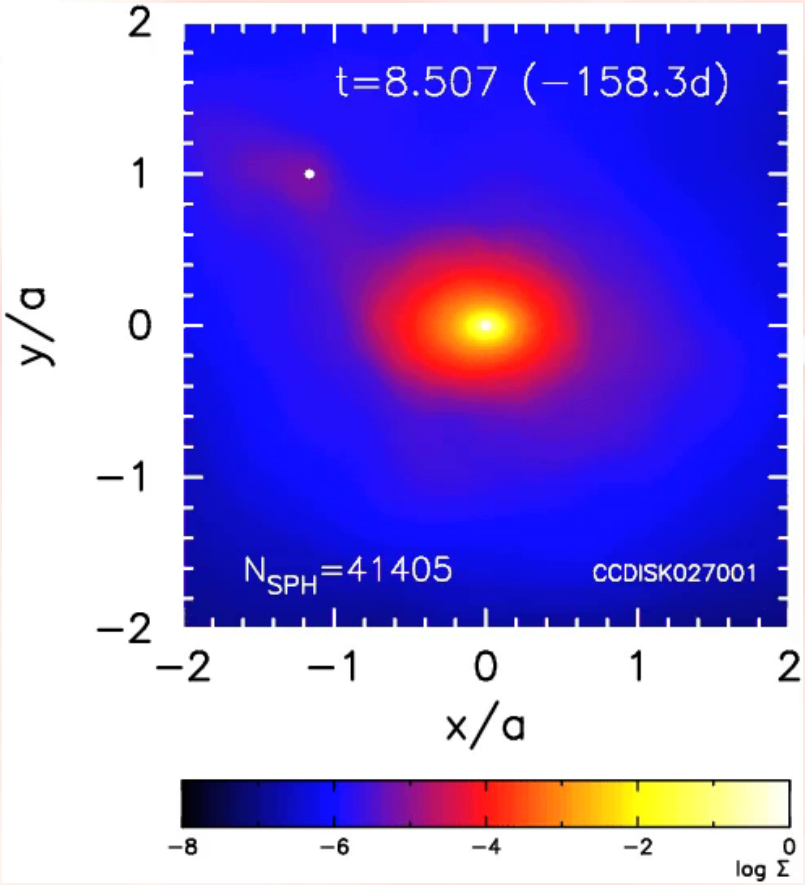
periastron
~10R*
apastron
~100R*

(VERITAS collaboration 2013)

(Casares+ 2012)

Tidal interaction sim w/o winds

Coplanar case

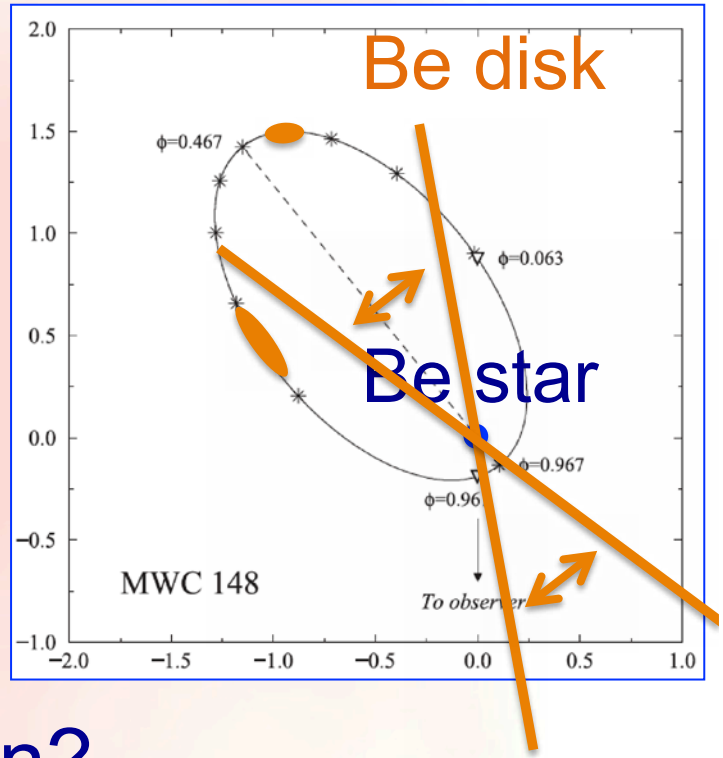


Disk can be big, because no tidal truncation works in this highly eccentric system

A flip-flopping pulsar? (1/2)

- From outburst phases,
  - accretion onto BH/NS
  - collision between pulsar wind (PW) and Be wind

  are unlikely to work.



PW interacting with misaligned Be disk?

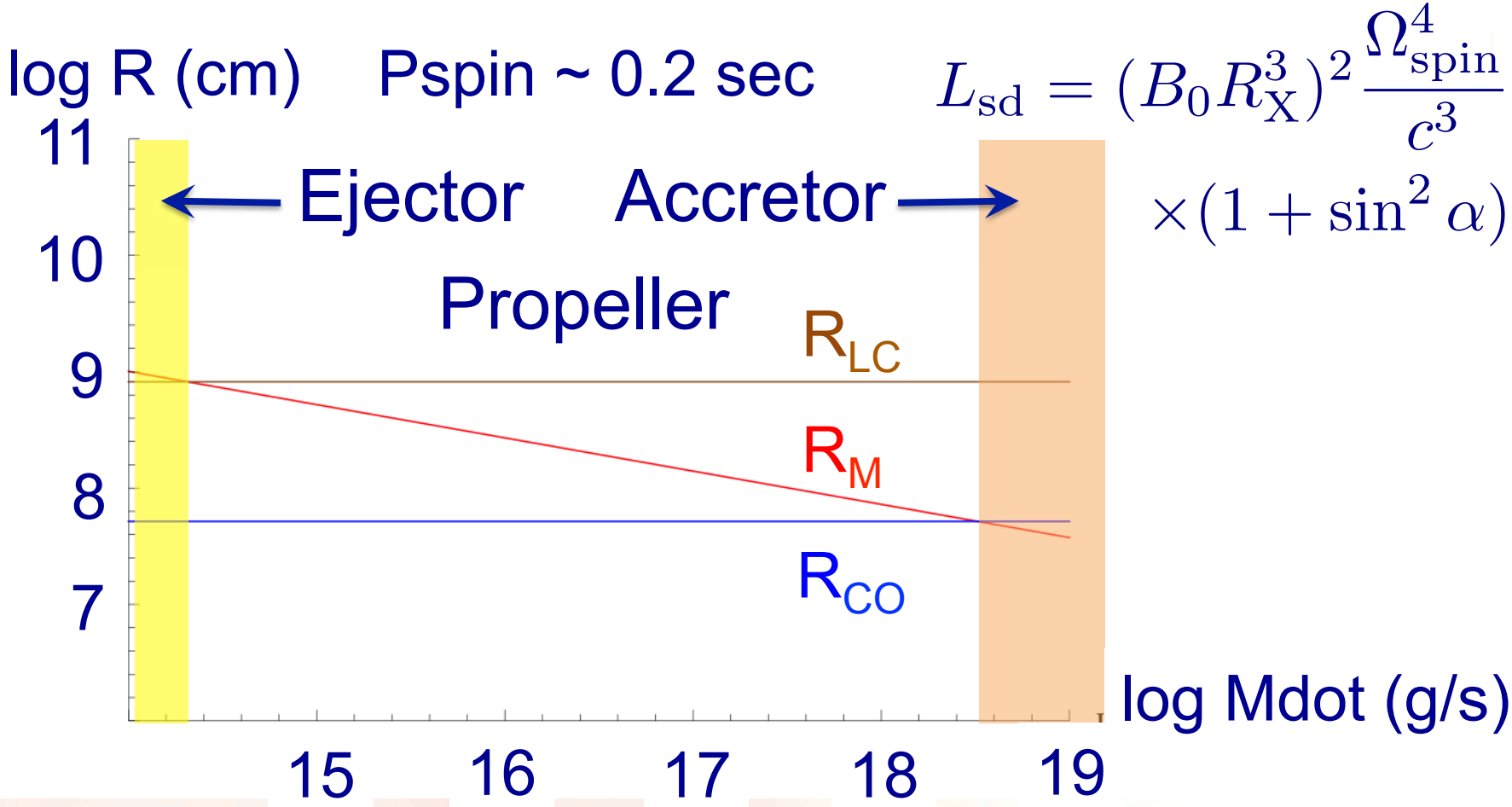
- Why quiescent at periastron?

PW quenched by accretion from disk?

(e.g., Torres+ 2012, Papitto+ 2012 for LS I +61 303)

A flip-flopping pulsar? (2/2)

L_{sd} = 10^{35} erg/s, B_0=10^{12} G vs. ADAF



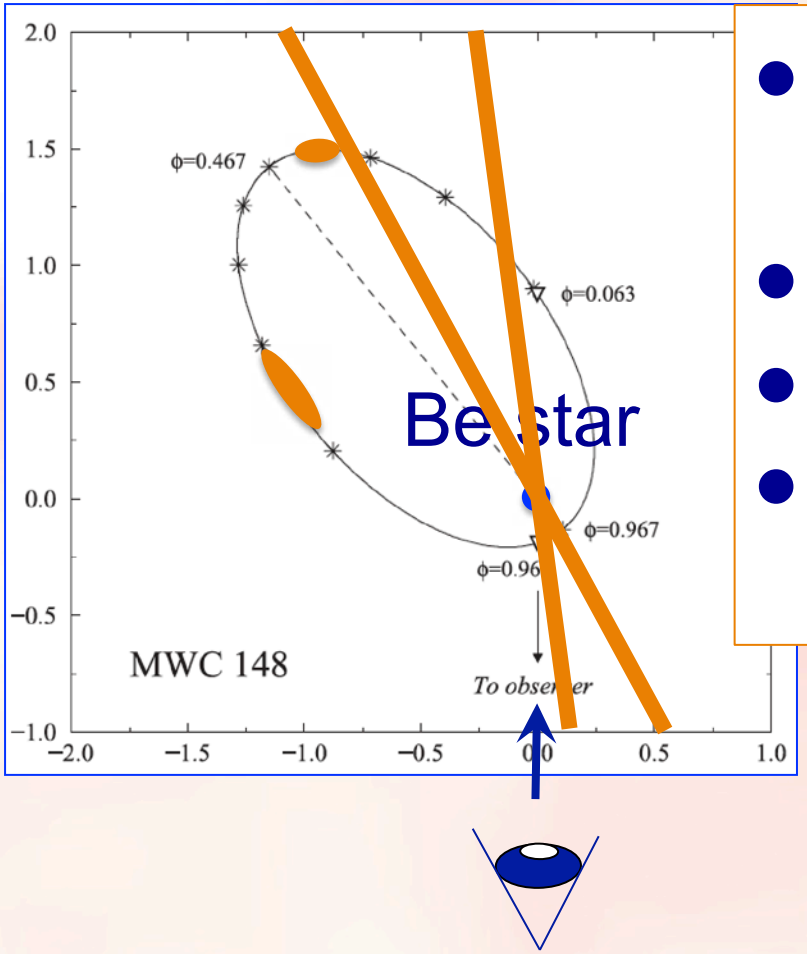
Numerical setup (1/2)

- 3D non-relativistic SPH
- Stellar wind: 1,000 km/s spherical wind
- Pulsar wind: emulated by a 10^4 km/s wind with the same momentum flux
- Spin down luminosity = 10^{35} erg/s
- Optically-thin radiative cooling

- In flip-flopping pulsar wind sims:
  PW on if $P_g + P_{ram}$ (accreting gas) < P_{ram} (PW)
  PW off for t_{acc} after the last accretion event

Numerical setup (2/2)

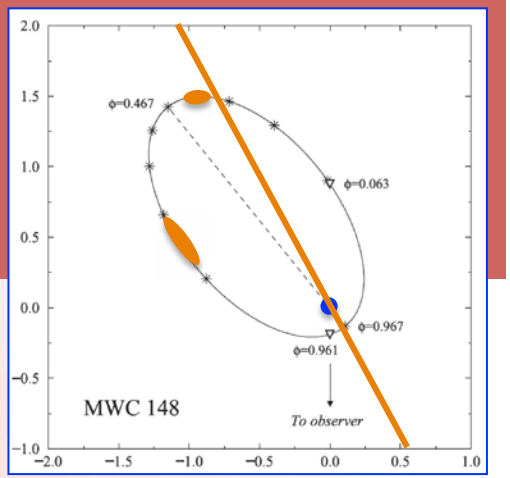
Misaligned Be disk



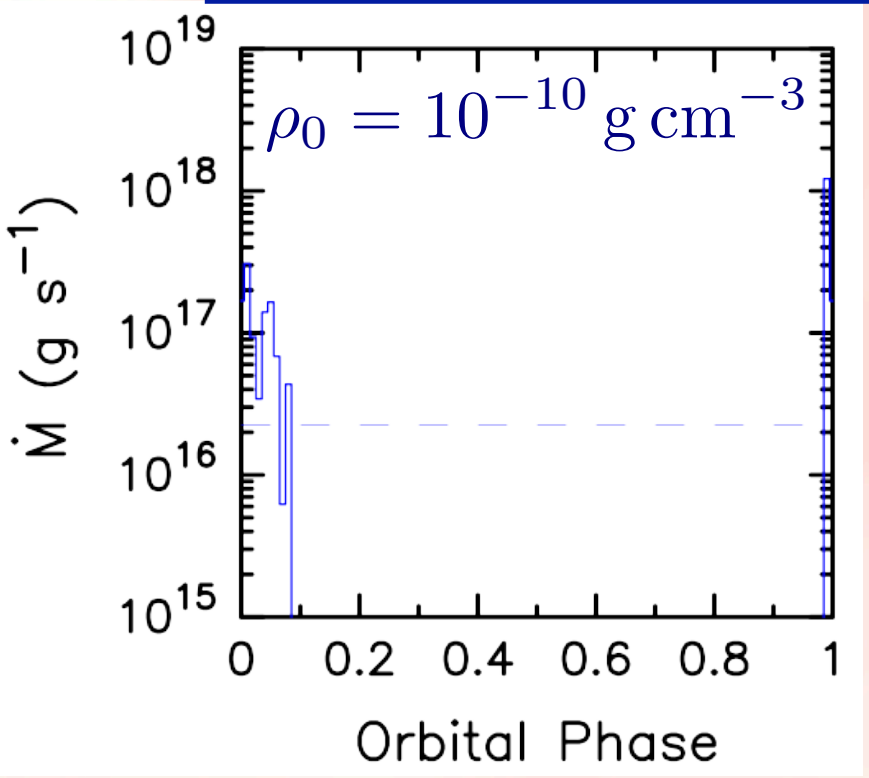
- Base density = 10^{-9} or 10^{-10} g/cm^3
- Initial outer radius = 3*a*
- Tilt angle=30 degrees
- Azimuth of tilt: 60 or 80 degrees

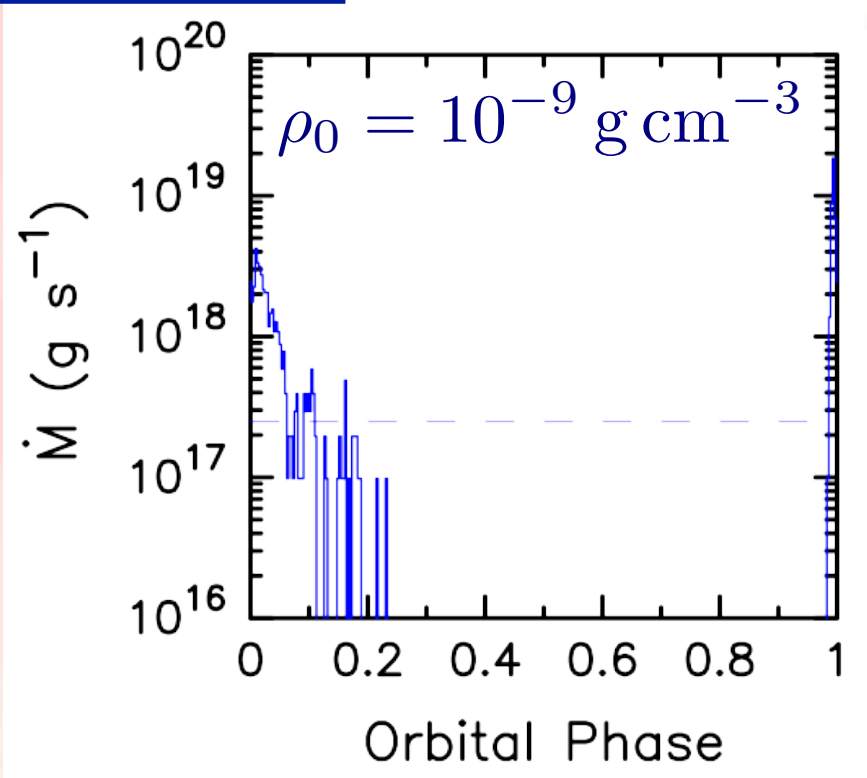
Accretion rates in ejector sims

$$\beta = 30^\circ,\ \gamma = 80^\circ$$

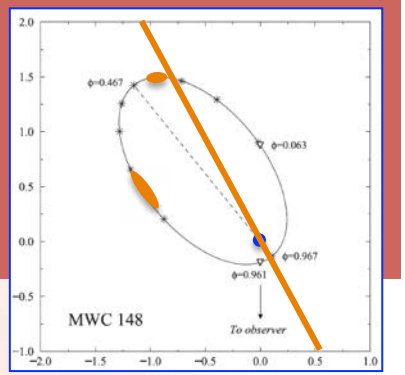


Pulsar seems to become a propeller at periasron



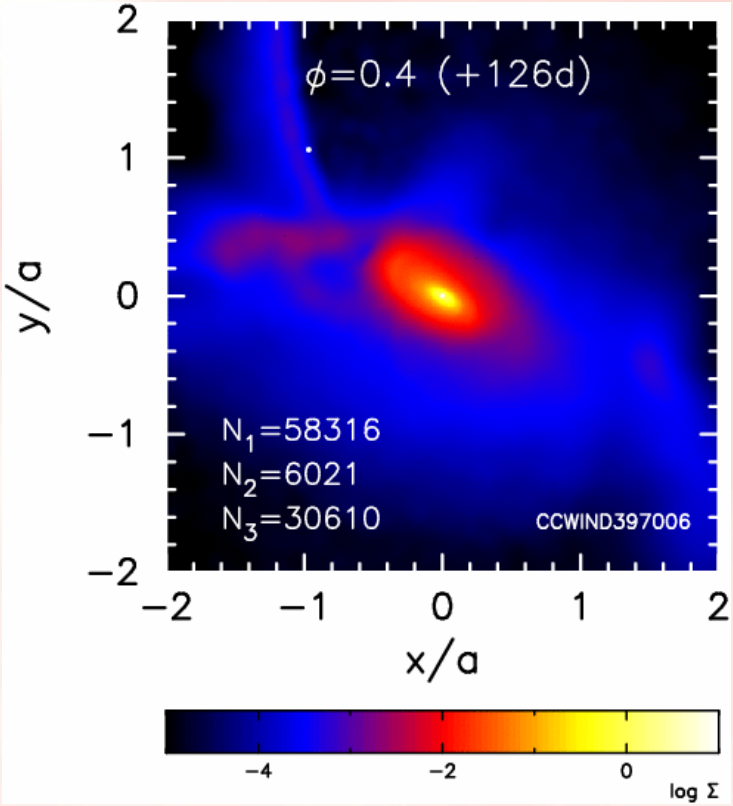


Snapshots at phase 0.4 in ejector sims with $\beta = 30^\circ, \gamma = 80^\circ$



Column density along l.o.s. (i=45 deg)

$\rho_0 = 10^{-10}\,\mathrm{g\,cm^{-3}}$



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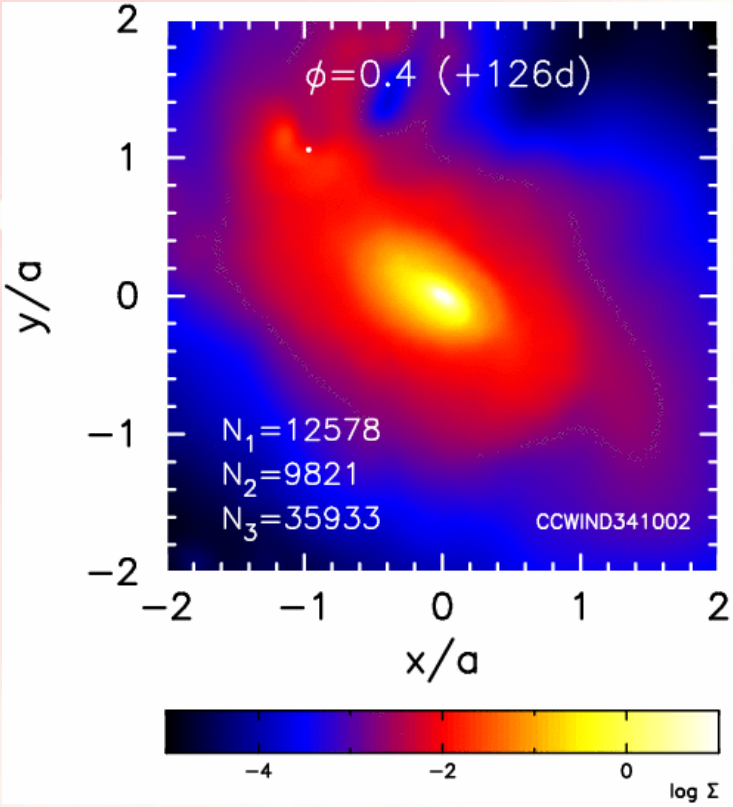
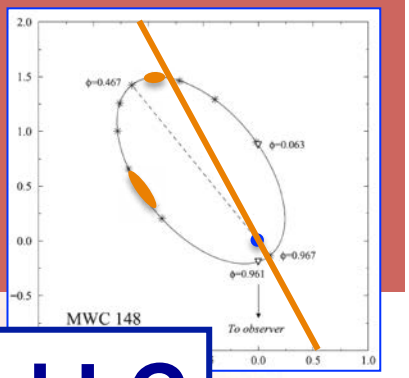
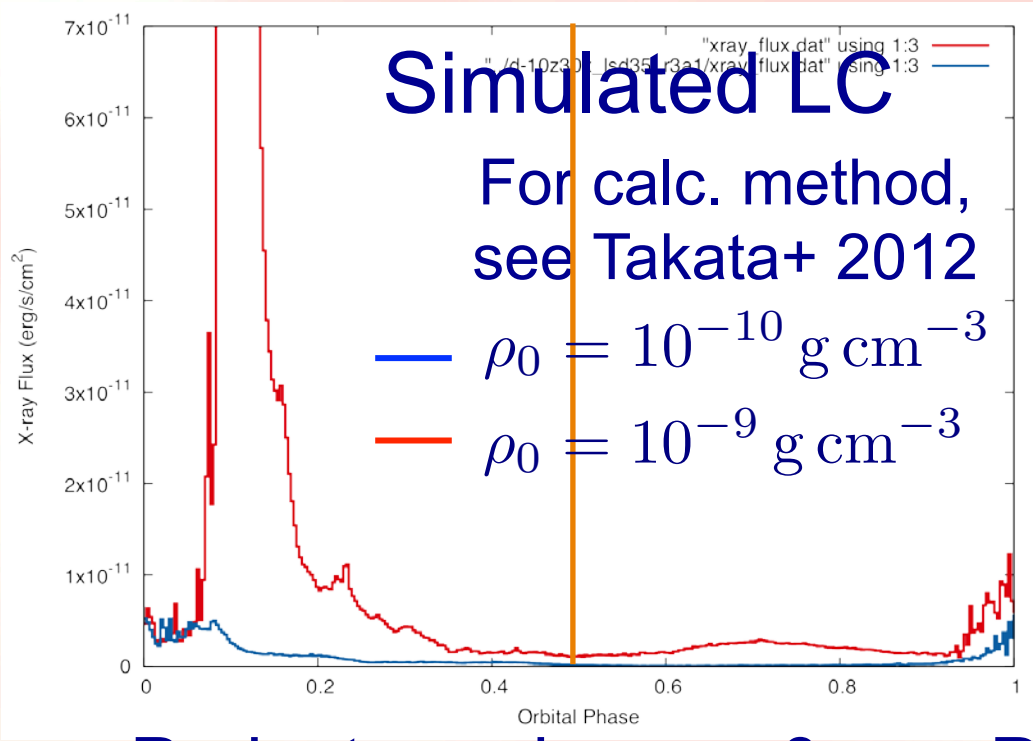
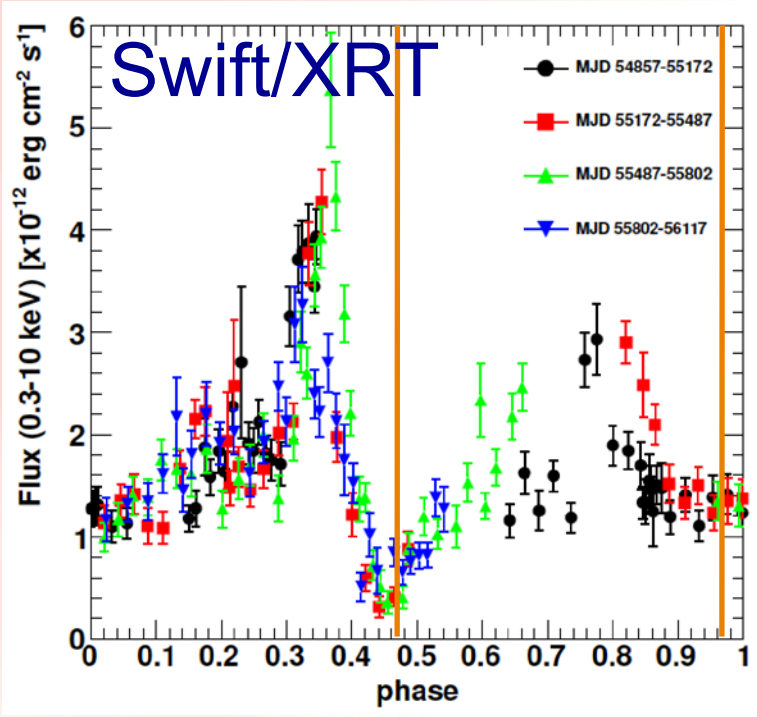


Simulated vs. observed X-ray lightcurves ($\beta = 30°, \gamma = 80°$)



Sim LCs don't agree with observed LC



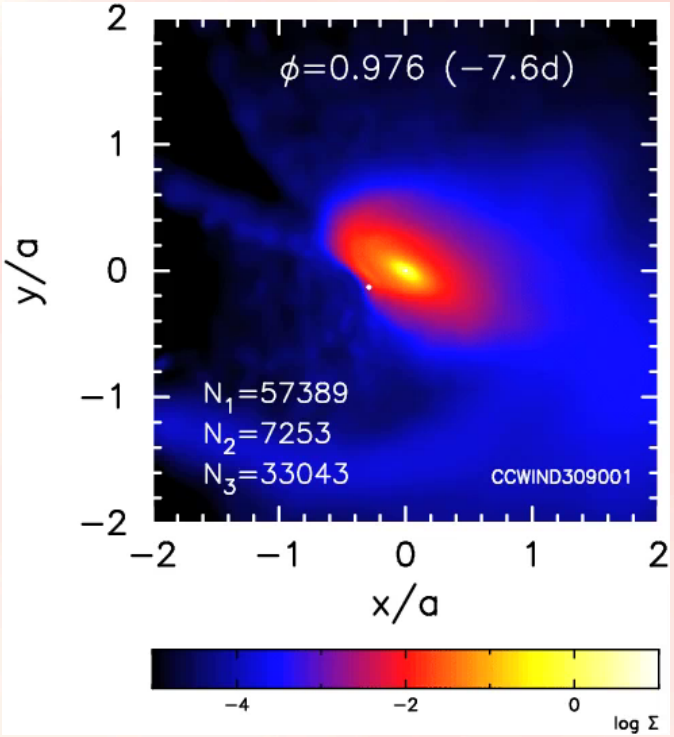


Periastron phase = 0 Periastron phase = 0.967

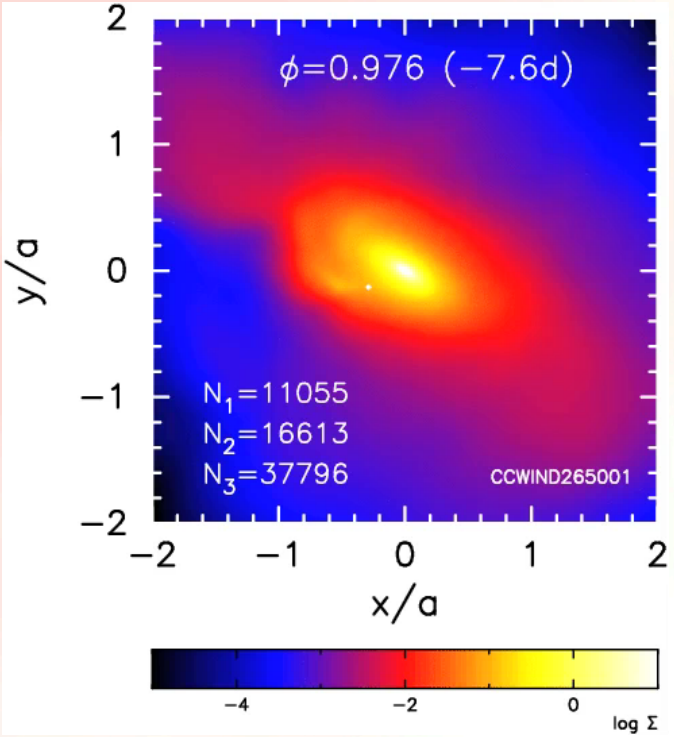
Hydrodynamic interaction in flip-flopping pulsar sims ($\beta = 30°, \gamma = 80°$)

Column density along l.o.s. (i=45 deg)

$\rho_0 = 10^{-10}\,\mathrm{g\,cm^{-3}}$

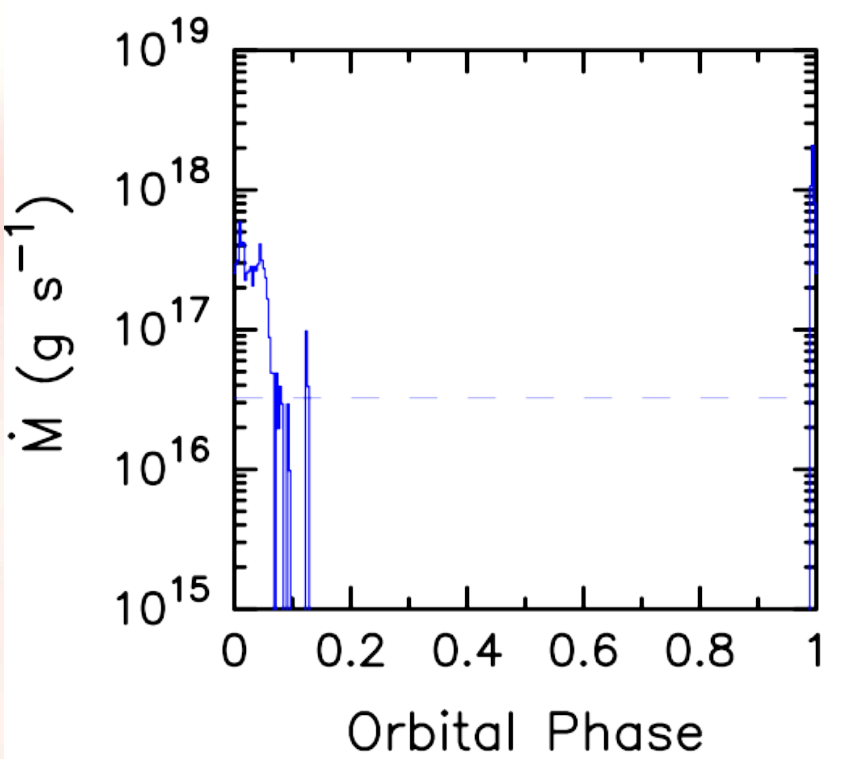


$\rho_0 = 10^{-9}\,\mathrm{g\,cm^{-3}}$



Accretion rates in flip-flopping pulsar sims $(\beta = 30^\circ, \gamma = 80^\circ)$

$\rho_0 = 10^{-10}$ g/cm^3



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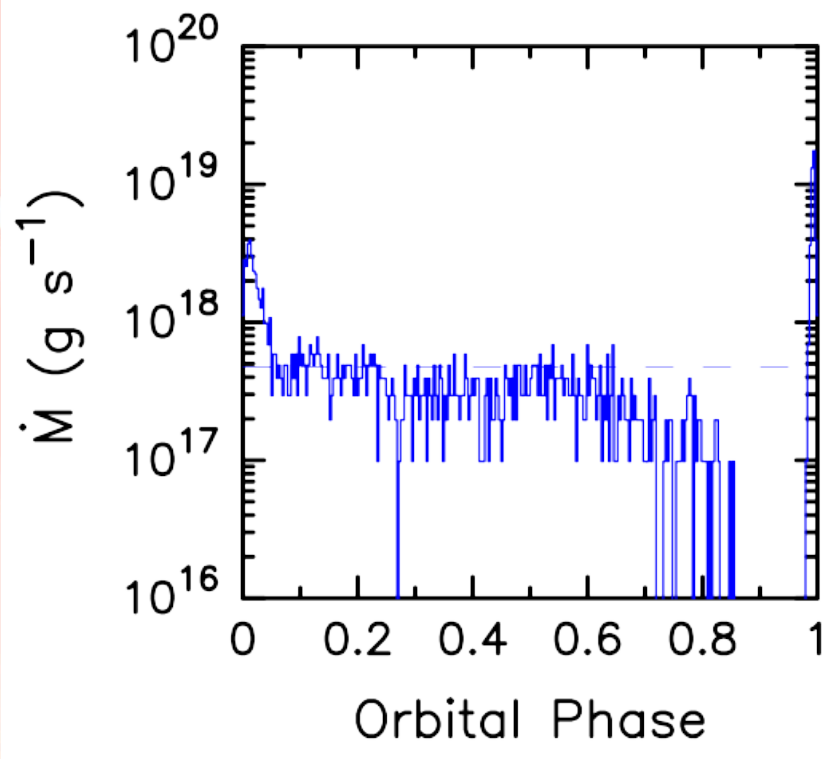
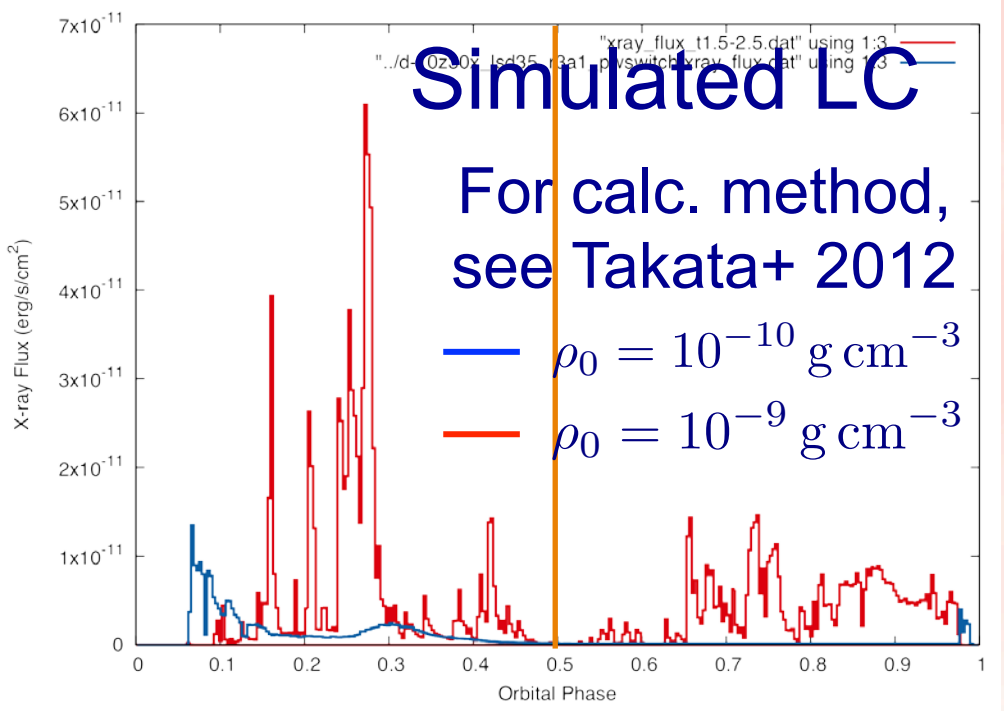
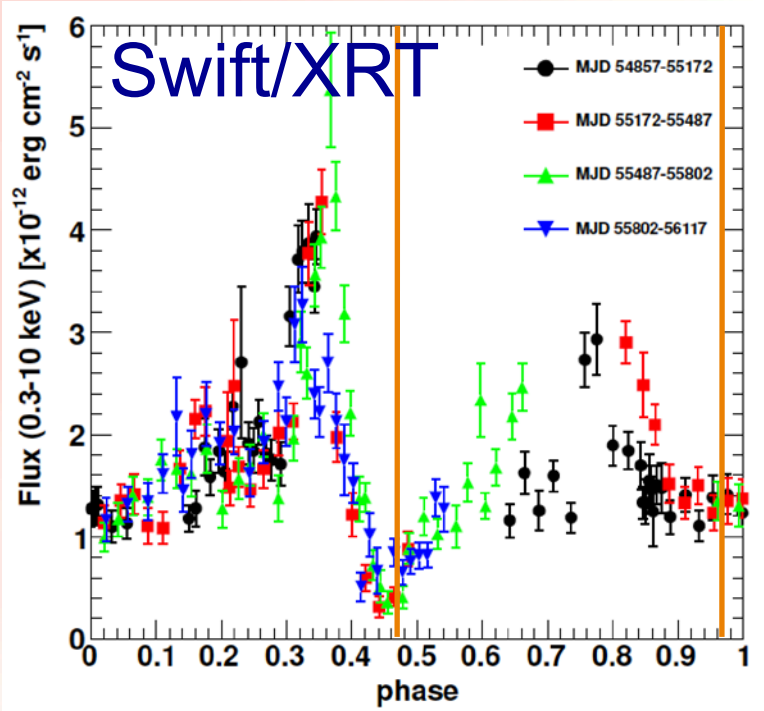


Simulated vs. observed X-ray lightcurves
$(\beta = 30^\circ, \gamma = 80^\circ)$

Dense-disk sim LC, which rapidly fluctuates, looks similar to observed LC





Periastron phase = 0

Periastron phase = 0.967

Concluding remarks

- 3D sims of gamma-ray binary HESS J0632+057, where quenching of PW by accretion is taken into account, provides a non-thermal X-ray light curve similar to the observed one, if the disk is misaligned and the line of nodes is roughly along the semi-major axis. The disk density should be high, but the exact value depends on L_{sd}.
- The origin of X-rays in the periastron, which is significantly higher than in the dip at apastron, remains to be clarified.