

# **SOURCES OF X-RAY POLARIZATION IN ACCRETING BINARY STARS**

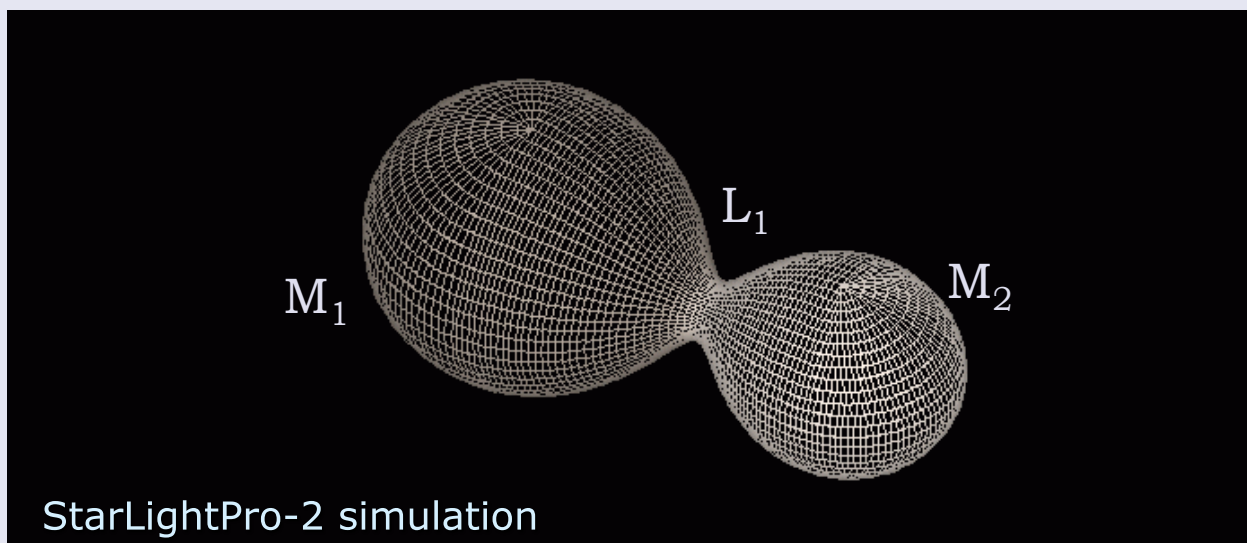
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- Objects
- Model of bursts and flare-ups
- Indications of active states by gas-dynamical and observational data
- X-ray emission
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- Future work



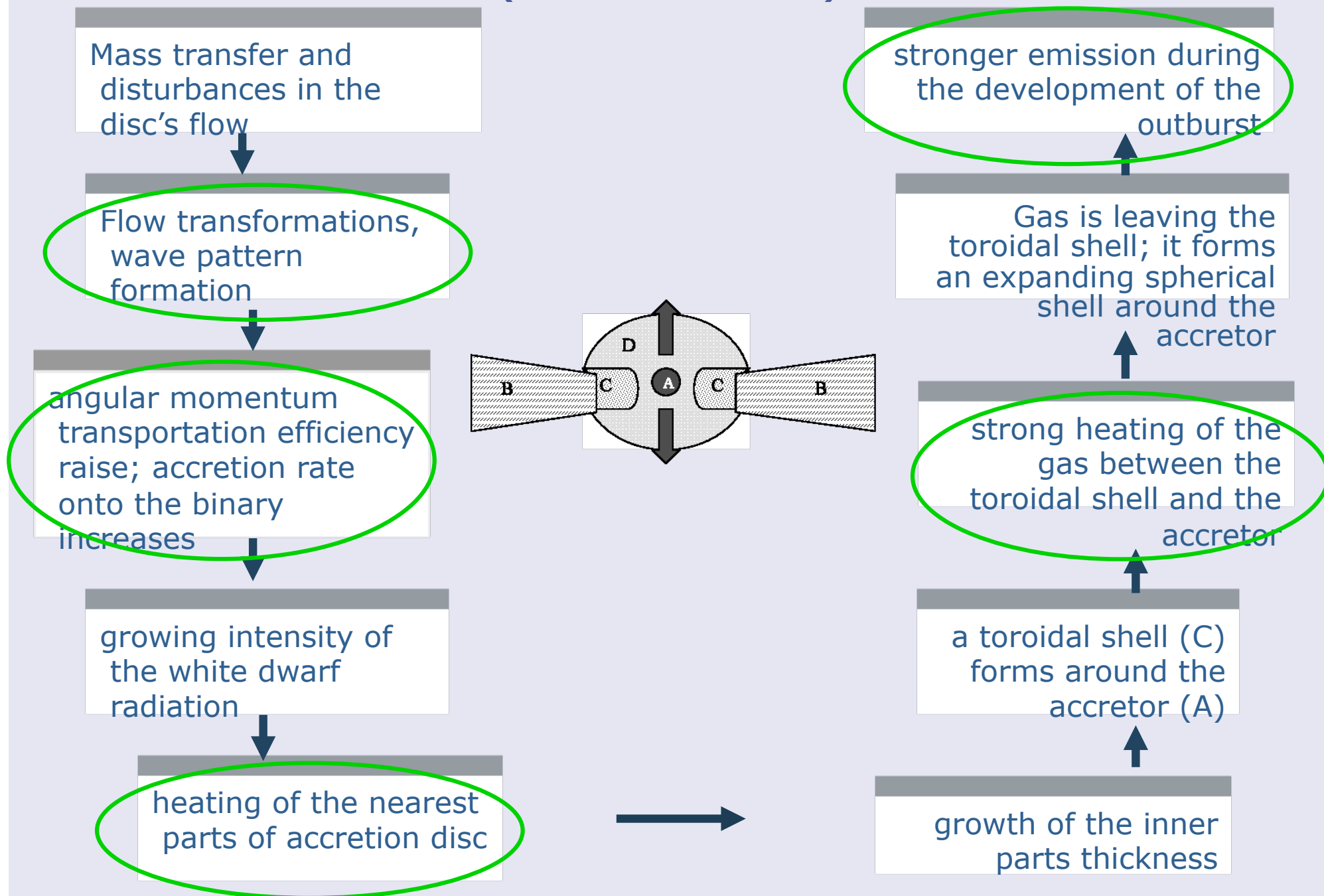
Accreting binaries:

CVs stars (SS Cyg)

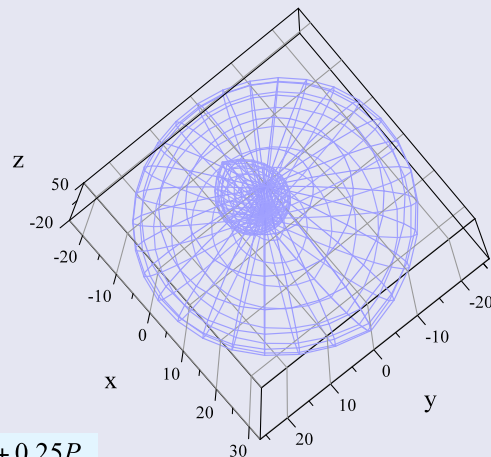
Be/X stars

Symbiotic binaries (RS Oph)

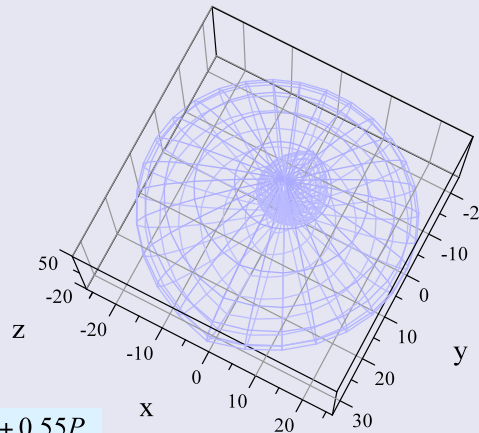
# Model of bursts and flare-ups activities (Boneva et al. 2009)



# Flow transformations, wave pattern formation. Gas-dynamical data



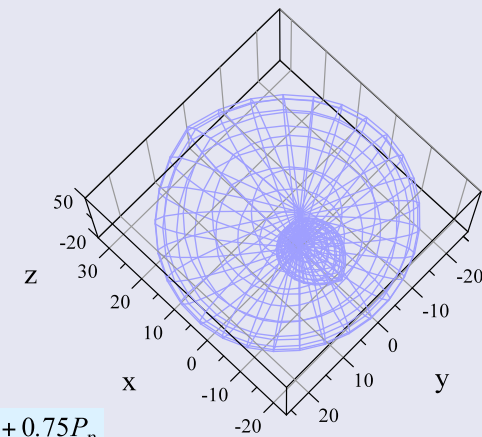
$\sim t_{m0} + 0.25P_p$



$\sim t_{m0} + 0.55P_p$

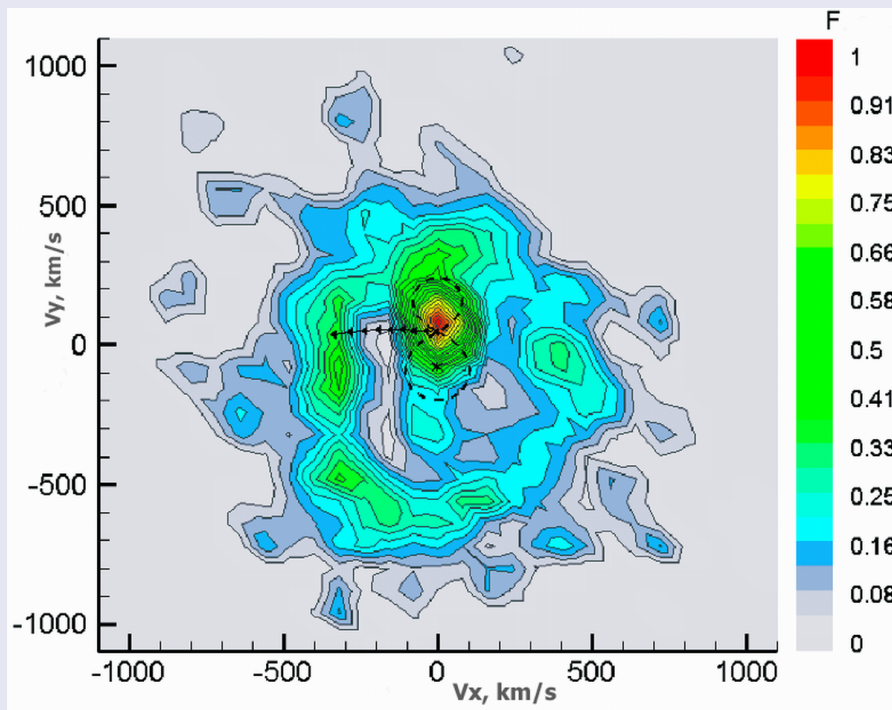
Thickened zone formation as a result of disturbances in the stability state, caused by mass transfer in a binary system.

Consecutive phases of rotation in three stop-steps of one rotational period  $P_p$

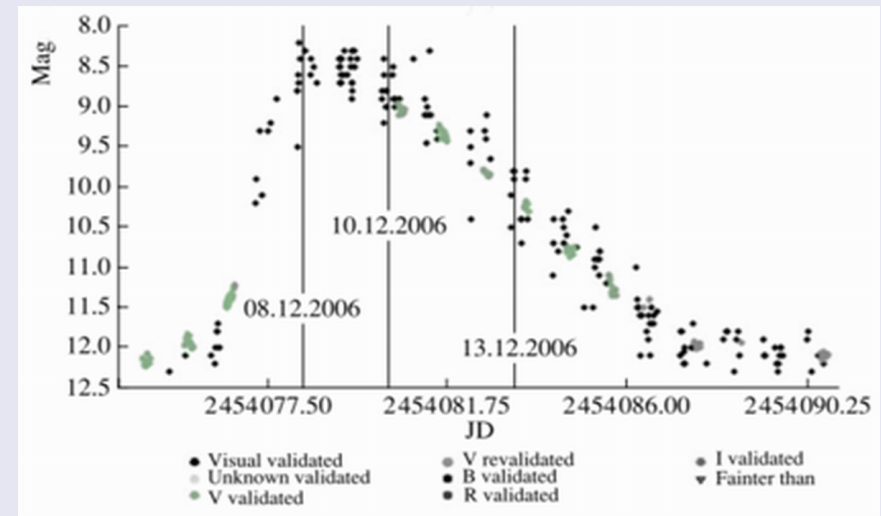


$\sim t_{m0} + 0.75P_p$

## Flow transformations, wave pattern formation. Development of the outburst. Gas-dynamical and observational data

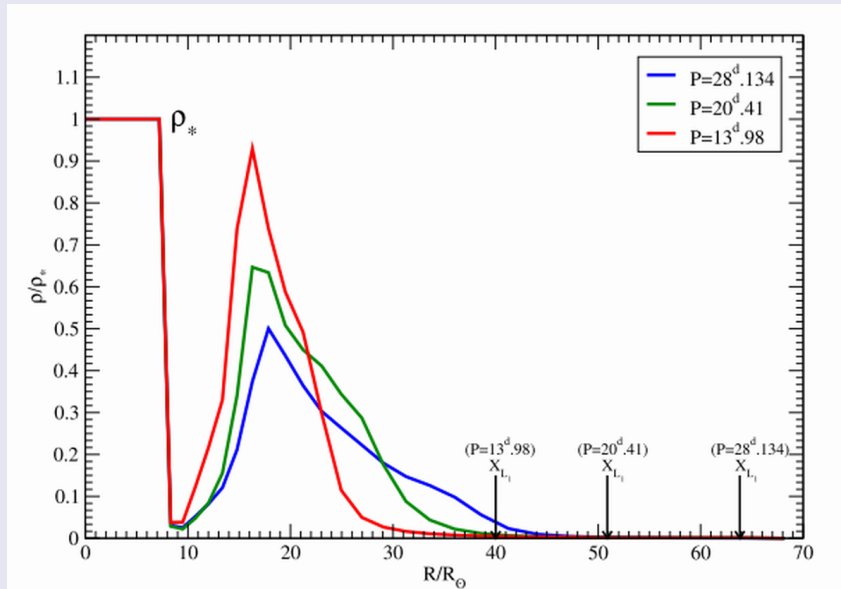


H $\gamma$  Doppler tomograms for SS  
Cyg in its active state from  
spectral observations of this star  
(Boneva et al. 2009).



Light curves of SS Cyg  
based on AAVSO light curve  
data generator. The vertical  
lines indicate the dates of  
our observing nights.

## Flow transformations, wave pattern formation. Gas-dynamical and observational data



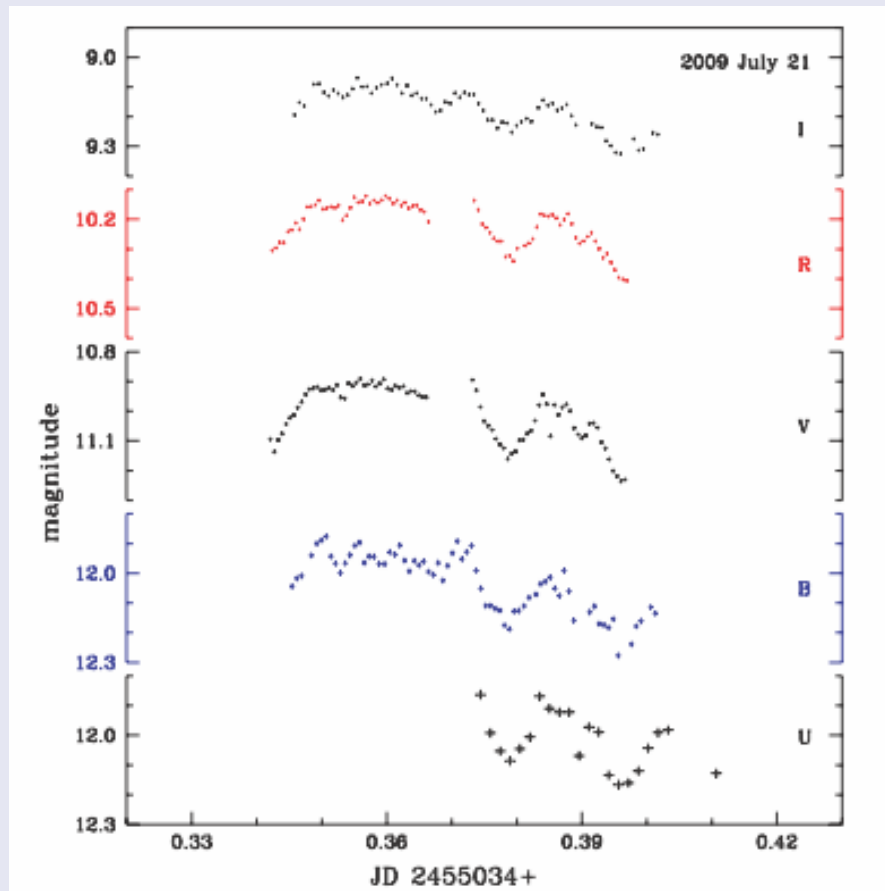
*Be/X star's parameters:*

$$L_x \sim 10^{34} \div 10^{39} \text{ erg/s}$$

$$\dot{M} \sim 1.39 \times 10^{-20} L_x \text{ (g/sec)}$$

Density distribution of Be/X stars for three runs with different orbital periods. The density is normalized to the surface density of B-star.  
(Kaygorodov, Bisikalo, Kononov, Boneva, 2013)

## Flow transformations, wave pattern formation. Development of the outburst. Observational data



(Zamanov et al. 2010; Boneva et al. 2013)

UBVRI light curve: observations of the National Astronomical Observatory (NAO) Rozhen, Bulgaria.

Flickering activity of the symbiotic recurrent nova RS Oph.

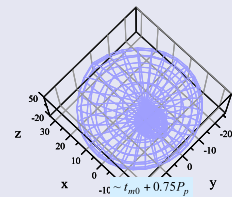
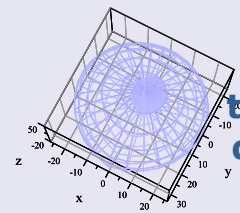
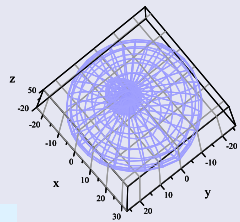
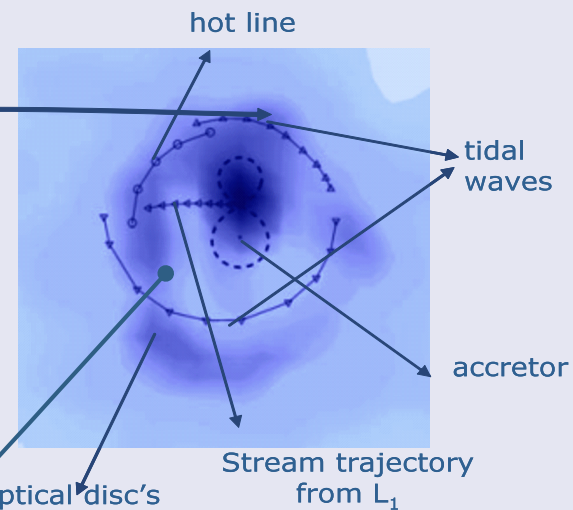
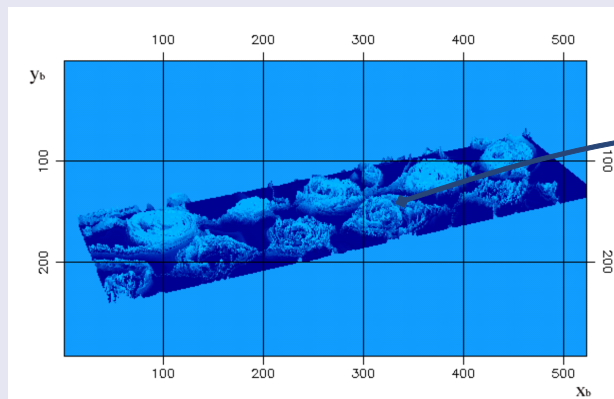
Temperature and luminosity of the flickering source –  $T \approx 9500 \pm 500$  K and  $L \approx 50 - 150 L_{\odot}$ .

Most possible source of soft X-rays – accretion boundary layer.



Aim: to measure the degree of X-ray polarization during the active flare-up states

- relation between structure transformation during the flare-ups, flare-ups (bursts) and X-ray polarization



**Vortical-like wave patterns may propagate throughout the disc, along the outer sides.**

**The flow structure during the outburst. A result from the Doppler tomogram with superposed flow elements inferred from the numerical simulations.**

# A Schematic view of the polarization modeling: bursts to polarization

Algorithm of the processes

Bursts; Flare-ups

dramatic flux and polarization variations in the optical, near-infrared and X-Ray bands

Variations in the flow density level

the polarization degree increasing significantly

Stages of calculation

Flare-ups

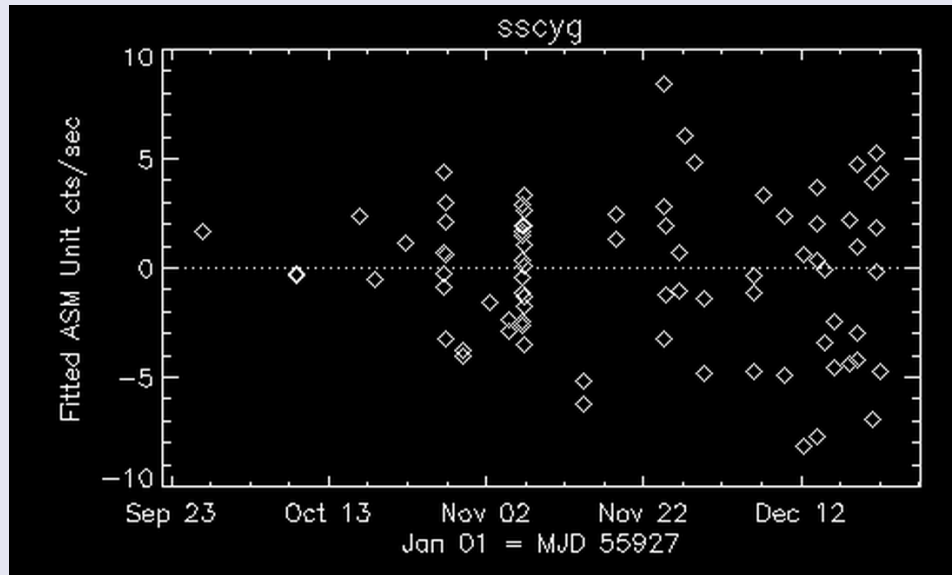
Measurement of the stronger emission intensity

Stokes parameters measurement

Degree of polarization

Type of polarization

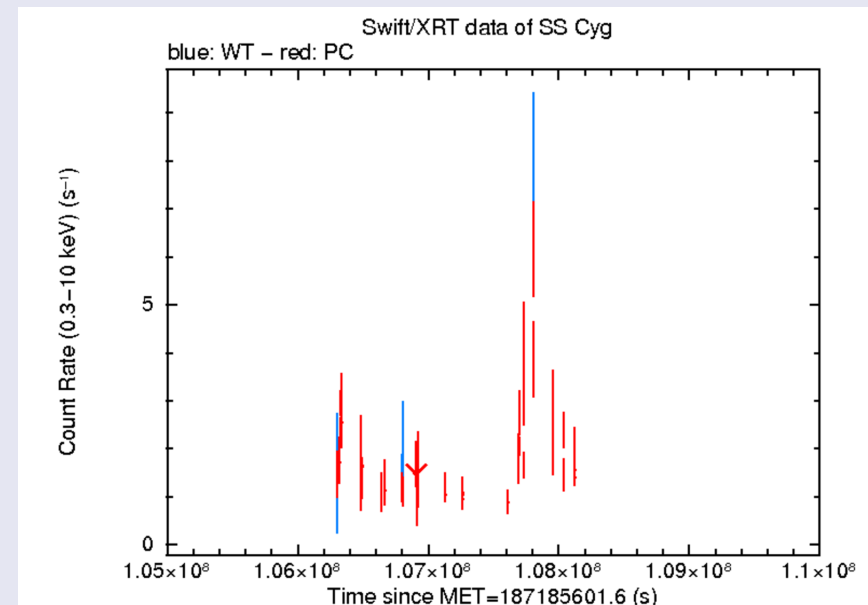
# X-ray emission → degree of polarization



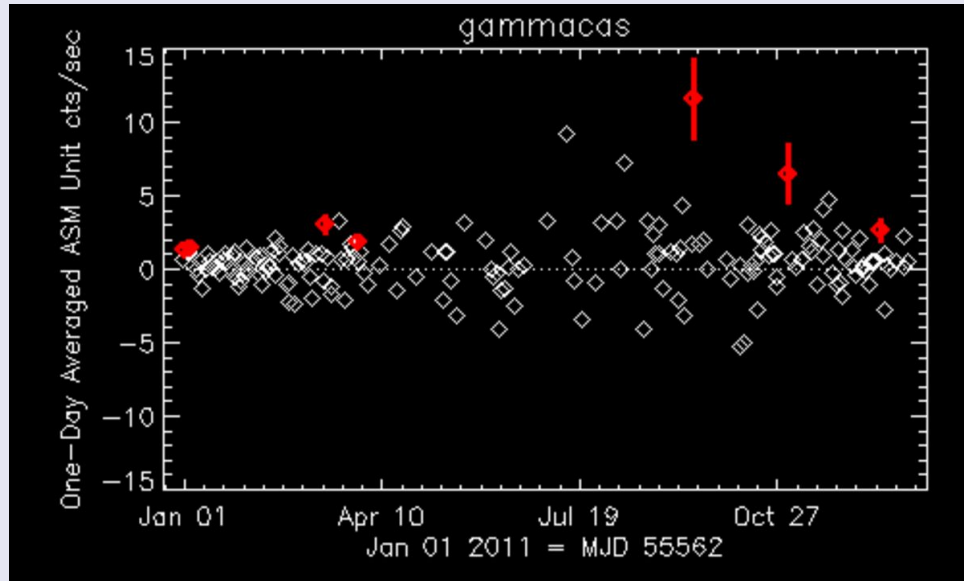
MIT X-ray timing explorer data of SS Cyg

Swift-XRT light curve of SS Cyg (Swift-XRT generator)

- Sources of X-ray polarization:
- Bursts
  - Hot parts of the disc



## X-ray emission → degree of polarization

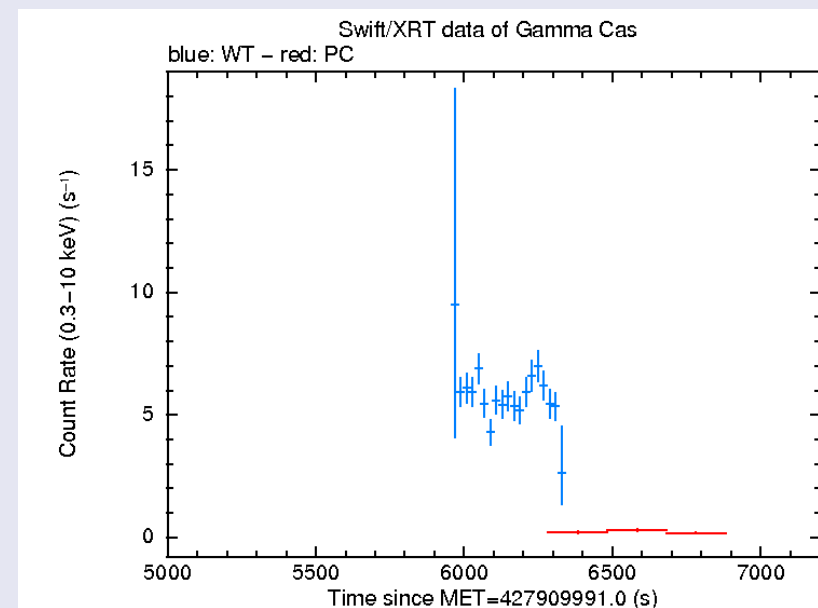



- X-ray emission of  $\gamma$ Cas (Be/X star)

Source of X-ray emission:

- high level of mass accretion rate

Swift-XRT light curve of  $\gamma$  Cas (Swift-XRT generator)





Four Stokes parameters and Poincare vector of polarization - characterize the intensity and polarization of X-ray emission:

$$P = \text{sqrt}(S_1^2 + S_2^2 + S_3^2) / S_0$$

P – degree of polarization

$$S_0 \geq \text{sqrt}(S_1^2 + S_2^2 + S_3^2)$$

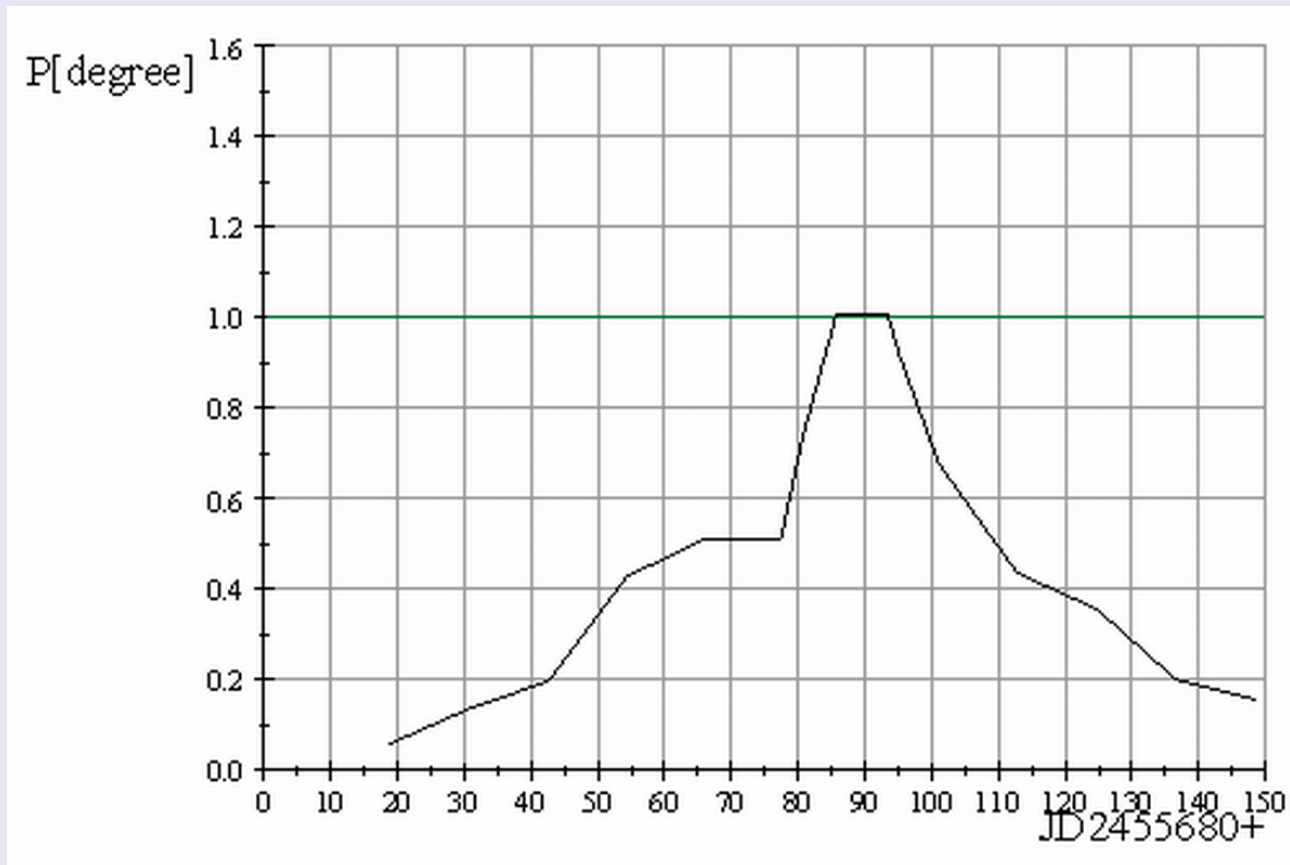
For general X-ray plane

If  $P_i = S_i / S_0$  ( $i = 1, 2, 3$ ) is the Poincare vector of polarization

For  $|P| = 1$  X-ray wave is totally polarized

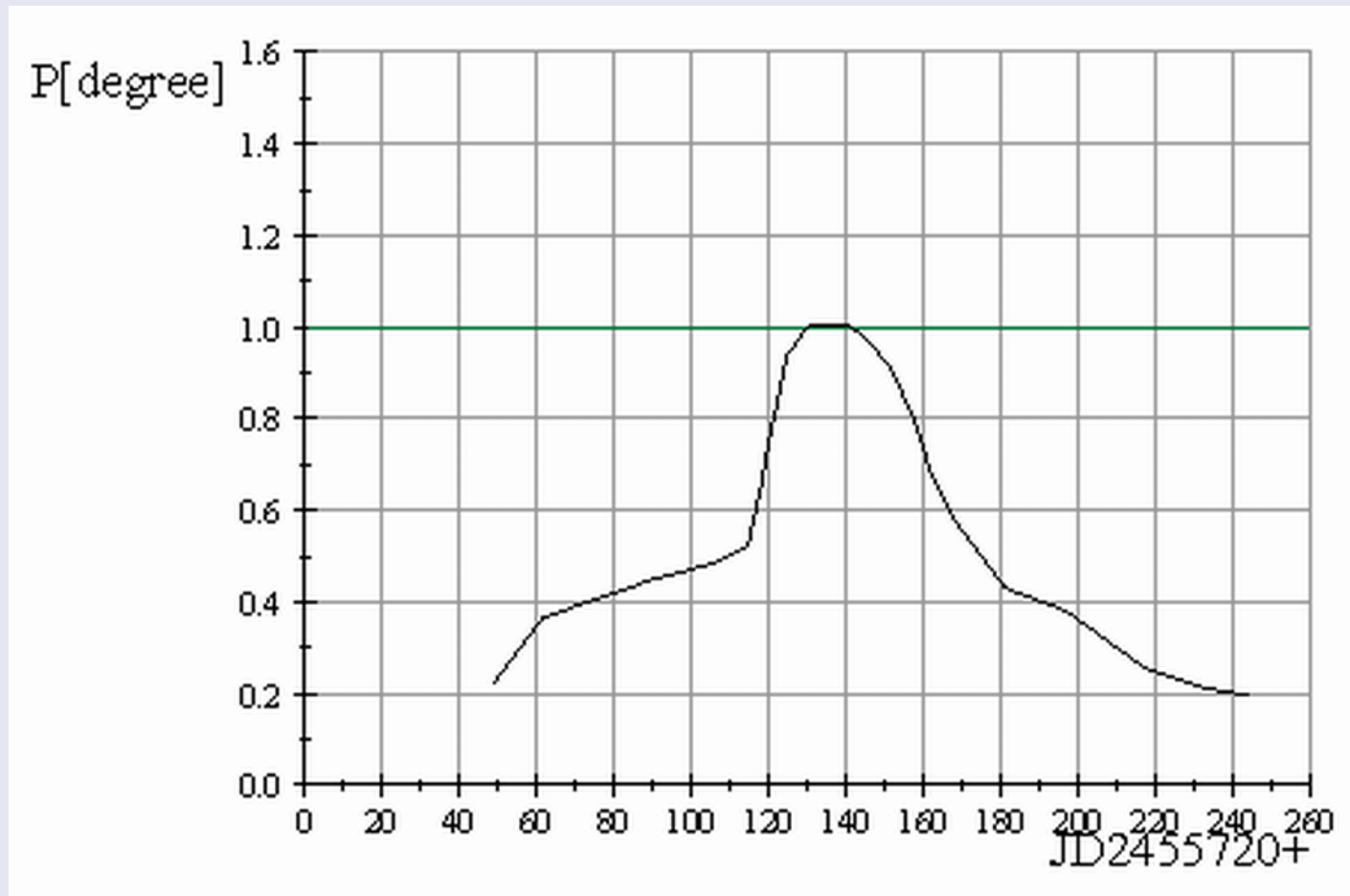
On the base of models: (Churazov et al. 2002), (Marin et al. 2014) and (Molinary et al. 2011) ....

Polarization Degree (P).  $P=1$  – fully polarized



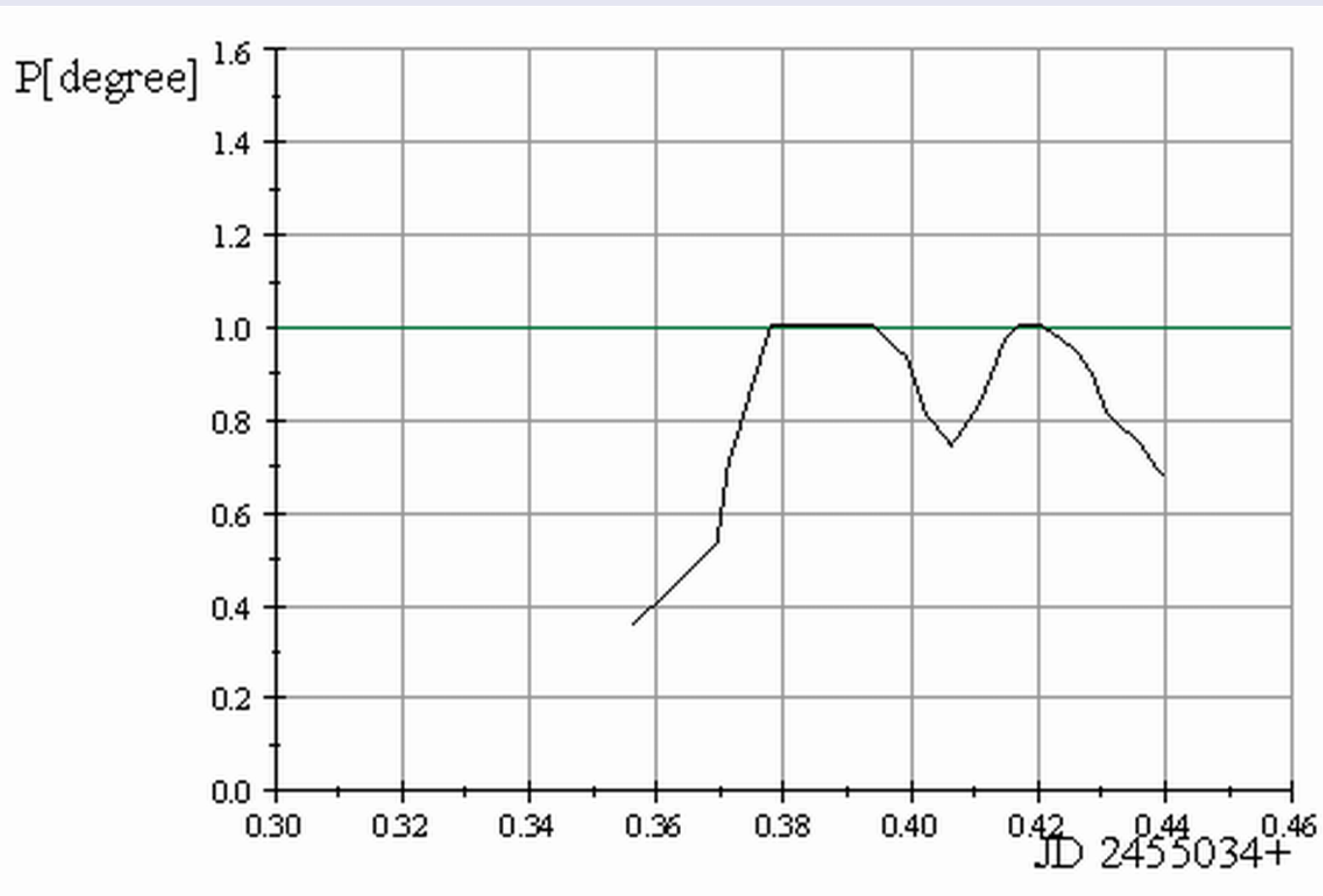
Polarization degree (P) during the bursts activity of SS Cyg

Polarization Degree (P).  $P=1$  – fully polarized



Polarization degree (P) during the bursts activity of  $\gamma$ Cas (Be/X)

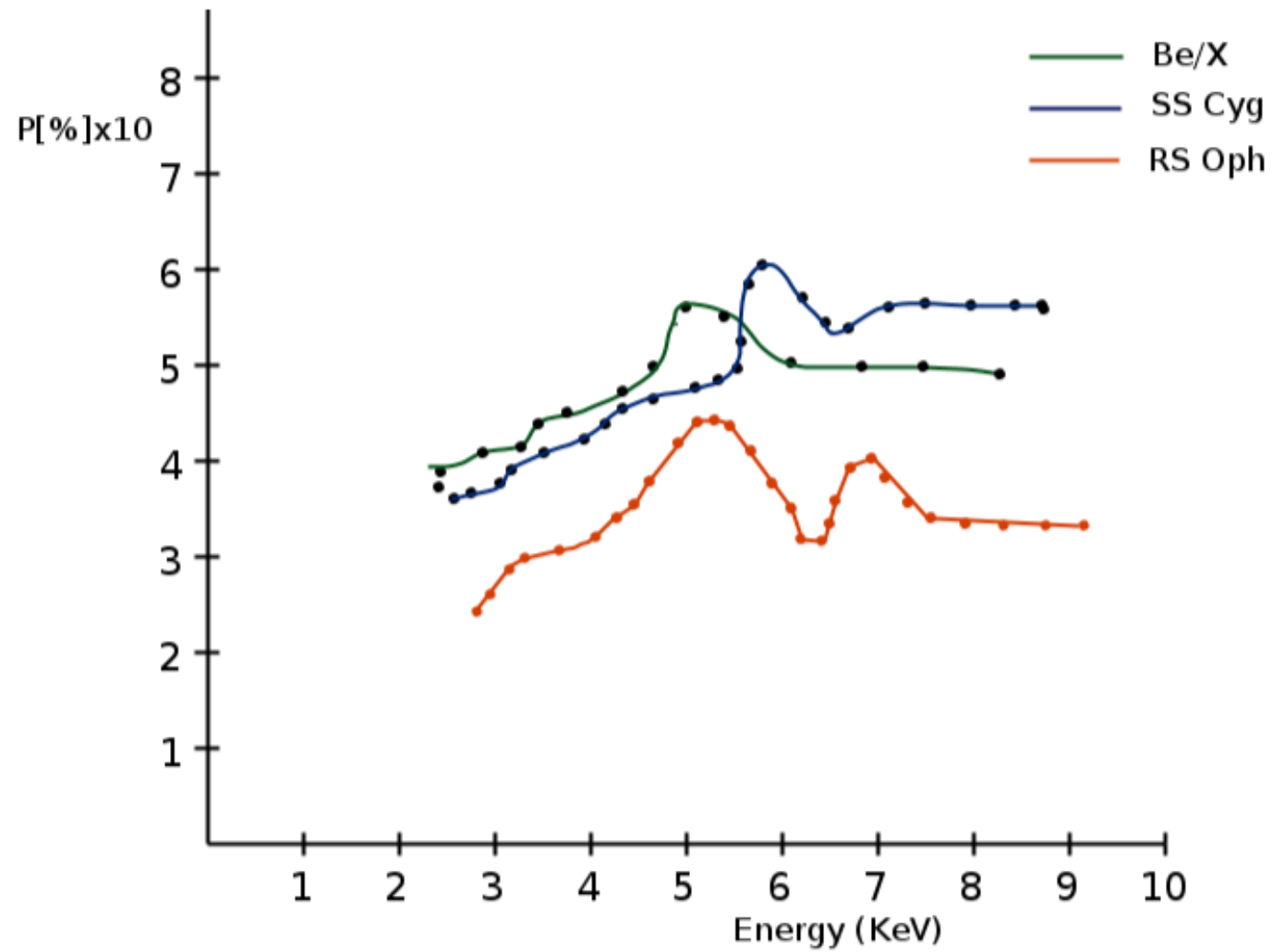
Polarization Degree (P).  $P=1$  – fully polarized



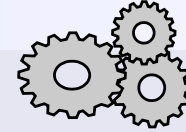
Polarization degree (P) during the bursts activity of RS Oph



## Polarization Degree (P)

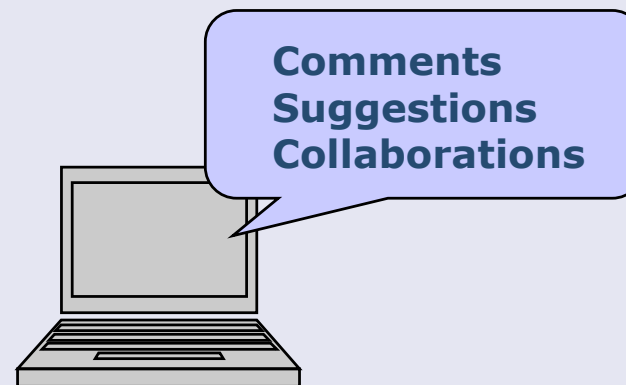


...to be continued



Future work:

- To develop and improve the model
- Is it possible to detect the mechanisms that could trigger bursts by the methods of polarimetry?





**THANK YOU!** 😊

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- ***THIS WORK MADE USE OF DATA SUPPLIED BY THE UK SWIFT SCIENCE DATA CENTRE AT THE UNIVERSITY OF LEICESTER.***
- ***QUICK-LOOK RESULTS PROVIDED BY THE ASM/RXTE TEAM OF MIT X-RAY TIMING EXPLORER***