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INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

The accretion column of AE Aqr

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ACCRETION PROCESSES IN SYMBIOTIC STARS AND RELATED OBJECTS
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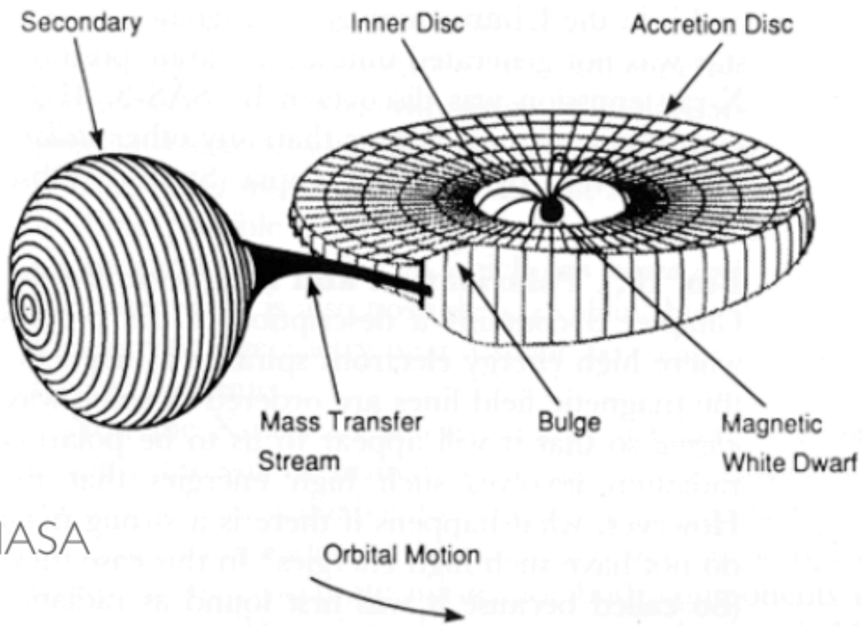
AE Aqr

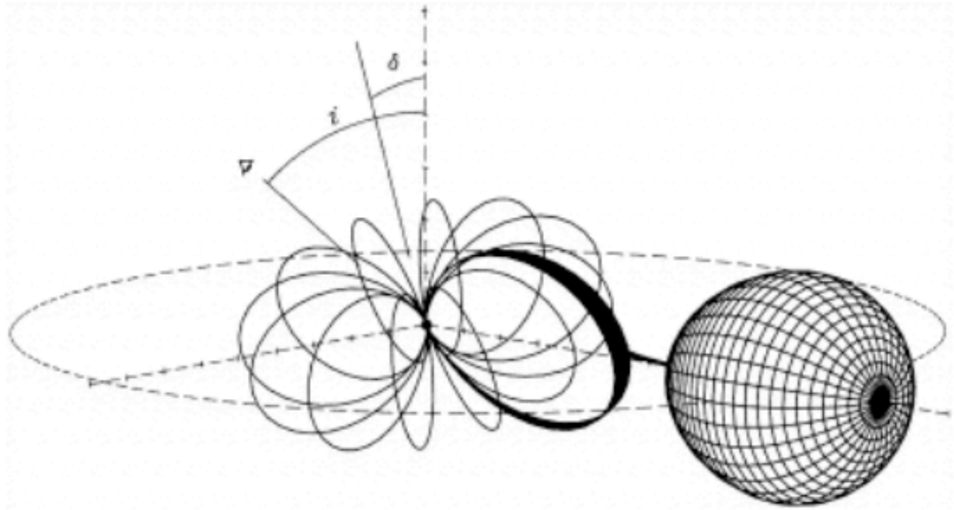
- AE Aqr is classified as a cataclysmic variable
  - ⇨ a system more compact than symbiotic binaries
    - ✓ orbital period = 9.88 h
    - ✓ a bit larger than the Sun...
  - ⇨ secondary
    - ✓ is a K4-5 V
    - ✓ loses mass from Roche Lobe overflow
  - ⇨ no disk detected
  - ⇨ magnetic white dwarf
    - ✓ so, a magnetic cataclysmic variable

Magnetic cataclysmic variables

- In magnetic CVs, the white-dwarf magnetic field prevents the formation of the accretion disk or truncates it internally



NASA

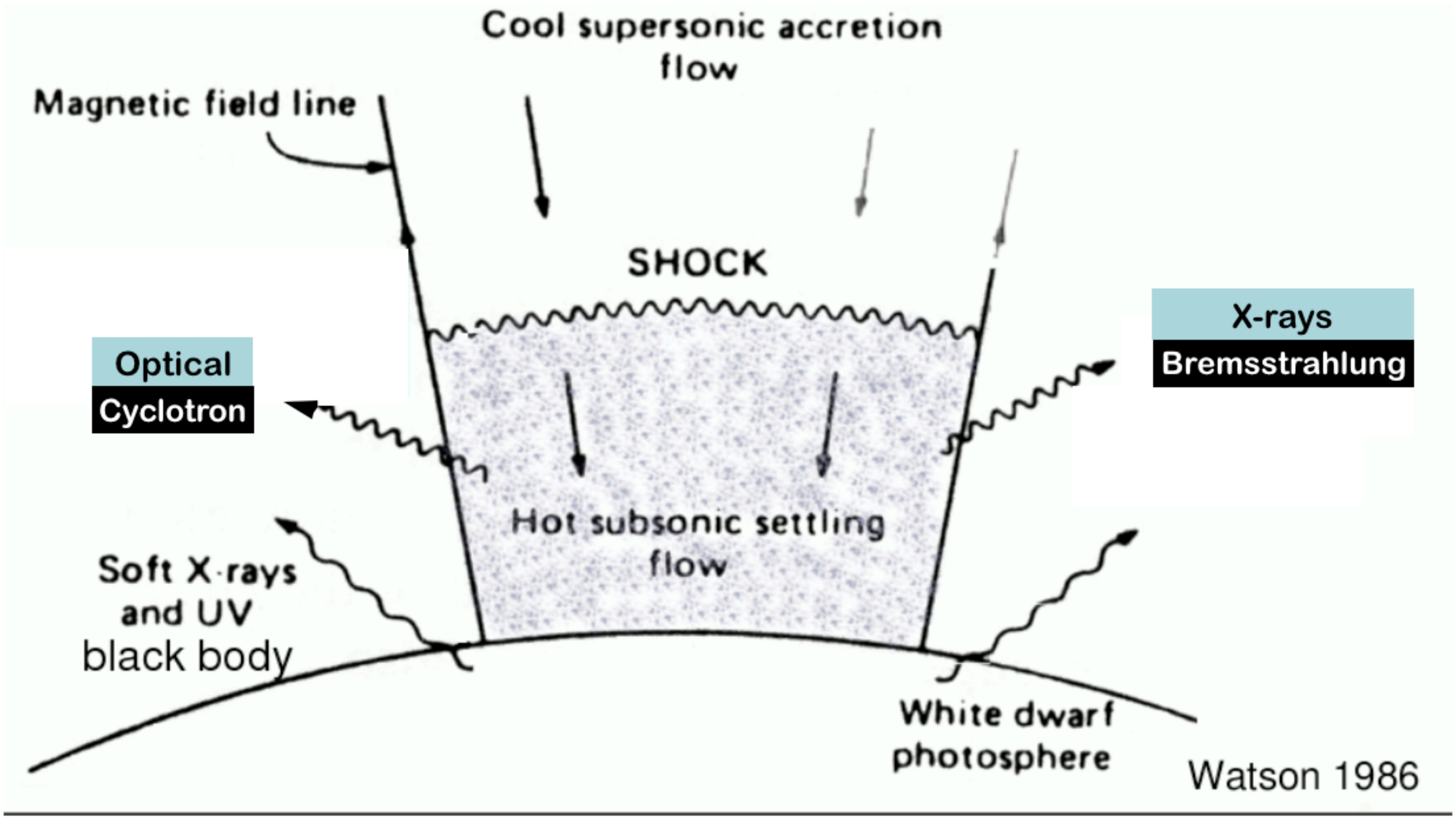


Schmidt+ 1999

DQ Her	AM Her
Intermediate polars	Polars
Asynchronous	Synchronous

Claudia V. Rodrigues

Post-shock region is very bright in MCVs!

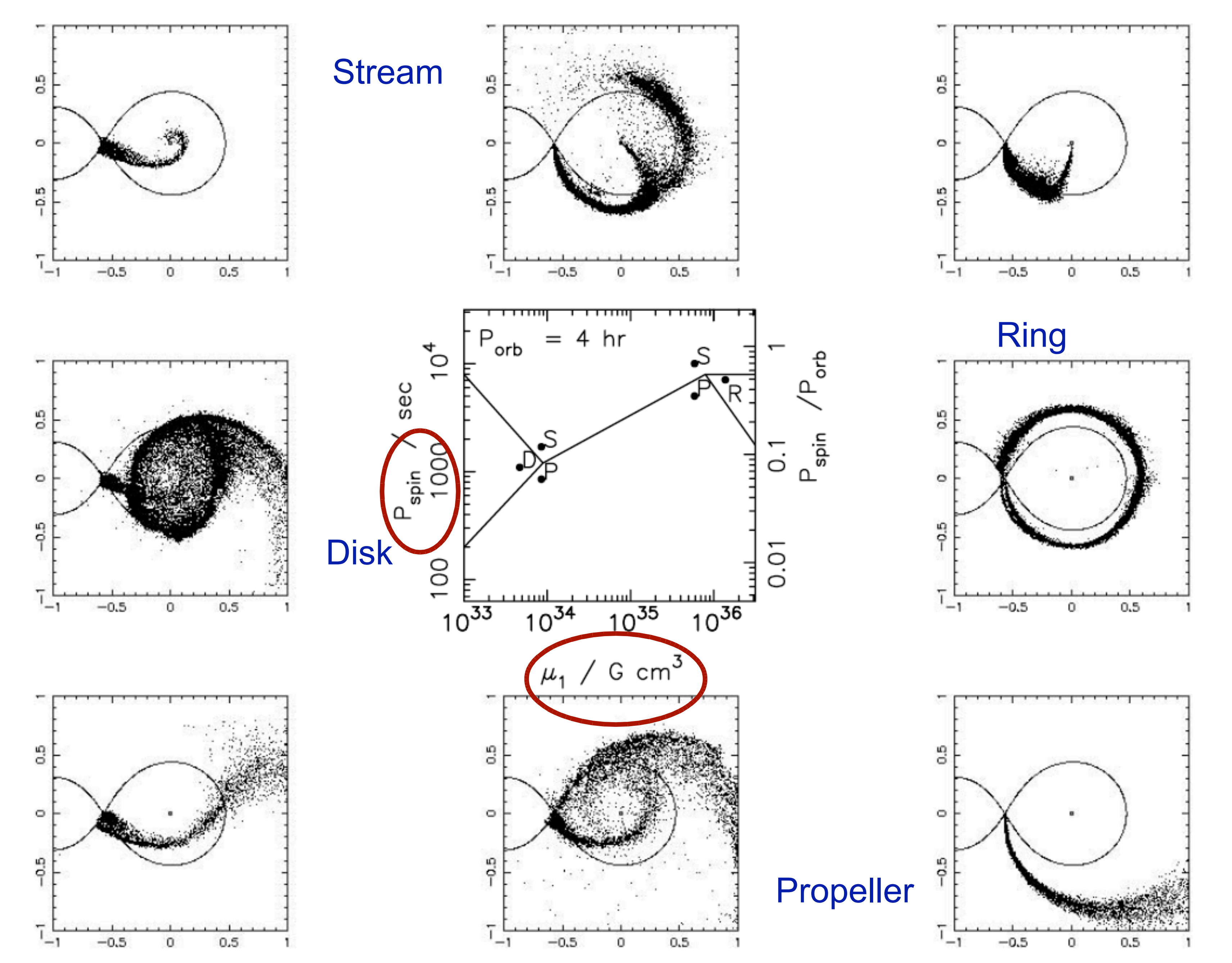


What makes AE Aqr different?

- its white dwarf rotates at the very fast rate of 33 s
  - ✓ flux modulated at this frequency from high-energies to optical wavelengths

- origin of the pulsed emission
  - ✓ propelled material?
  - ✓ accretion material?
  - ✓ location?
  - ✓ emission process? pulsar-like emission?

Could this fast rotation prevent the accretion on the white dwarf – propeller effect?


Stream
Disk
Ring
Propeller
P_{orb} = 4 hr
P_{spin} / sec
P_{spin} / P_{orb}
μ_1 / G cm^3
S
D
P
R

Norton+ 2008

What makes AE Aqr similar to bonafide CVs?

- No gamma-ray emission from MAGIC and Fermi (Aleksic+ 2014, Li+ 2016)
  - ✓ discarding propeller models similar to transitional pulsars
- Thermal soft and hard X-ray emission
  - ✓ for instance, Swift and NuSTAR data (Kitaguchi+ 2014)
- Optical and UV light curves (Eracleous+ 1994)
  - ✓ fitted by a polar cap model = hot spot on the white-dwarf

This (on going) work aims to…

- Verify if X-ray emission of AE Aqr can be explained by an accretion scenario

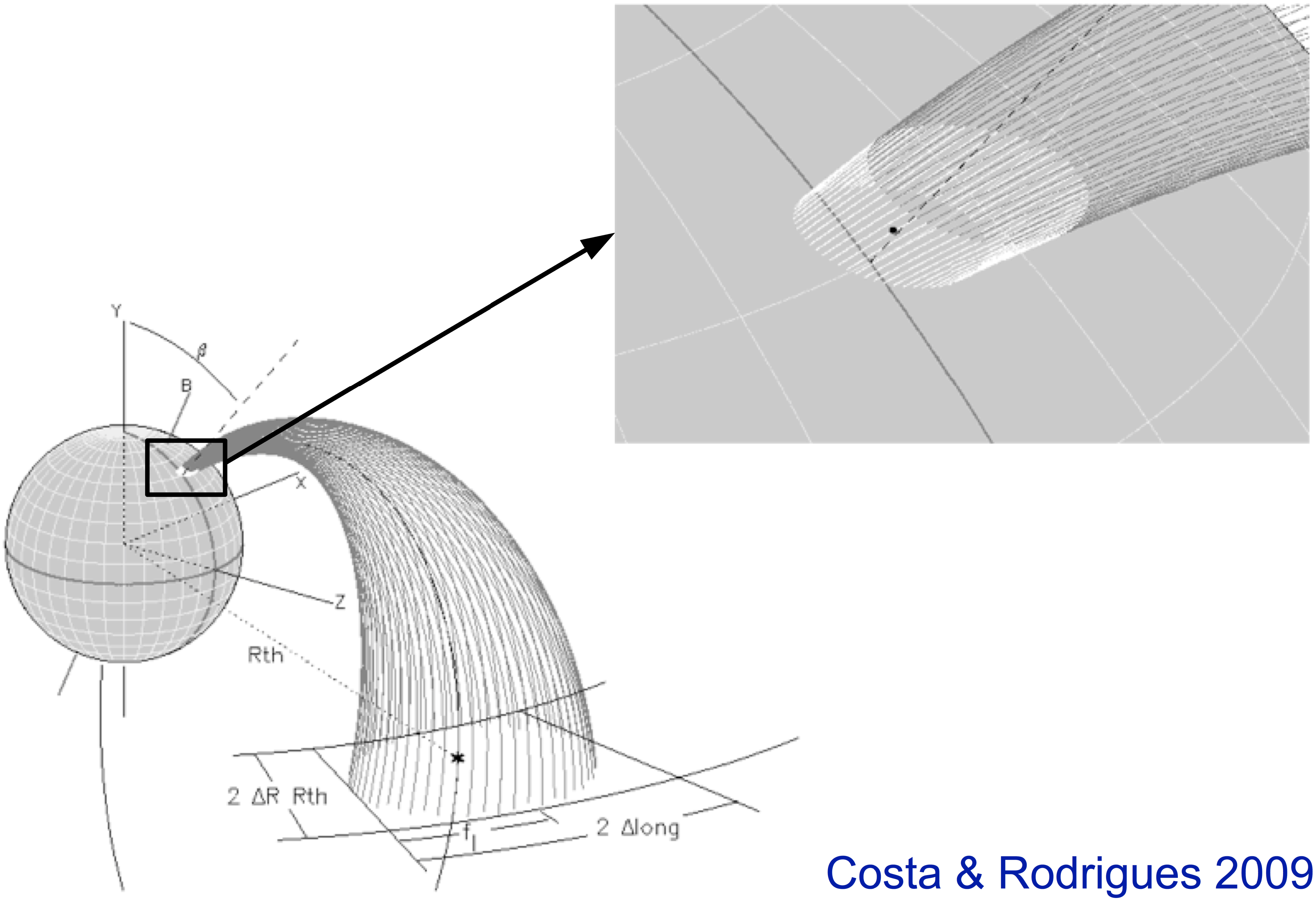
- Fitted data

  ⇨ NuSTAR and SWIFT spectrum and light curve of AE Aqr (Kitaguchi et al. 2014)

Cyclops
Cyclotron Emission of Polars

Cyclops code simulates the continuum emission from post-shock regions in magnetic cataclysmic variables

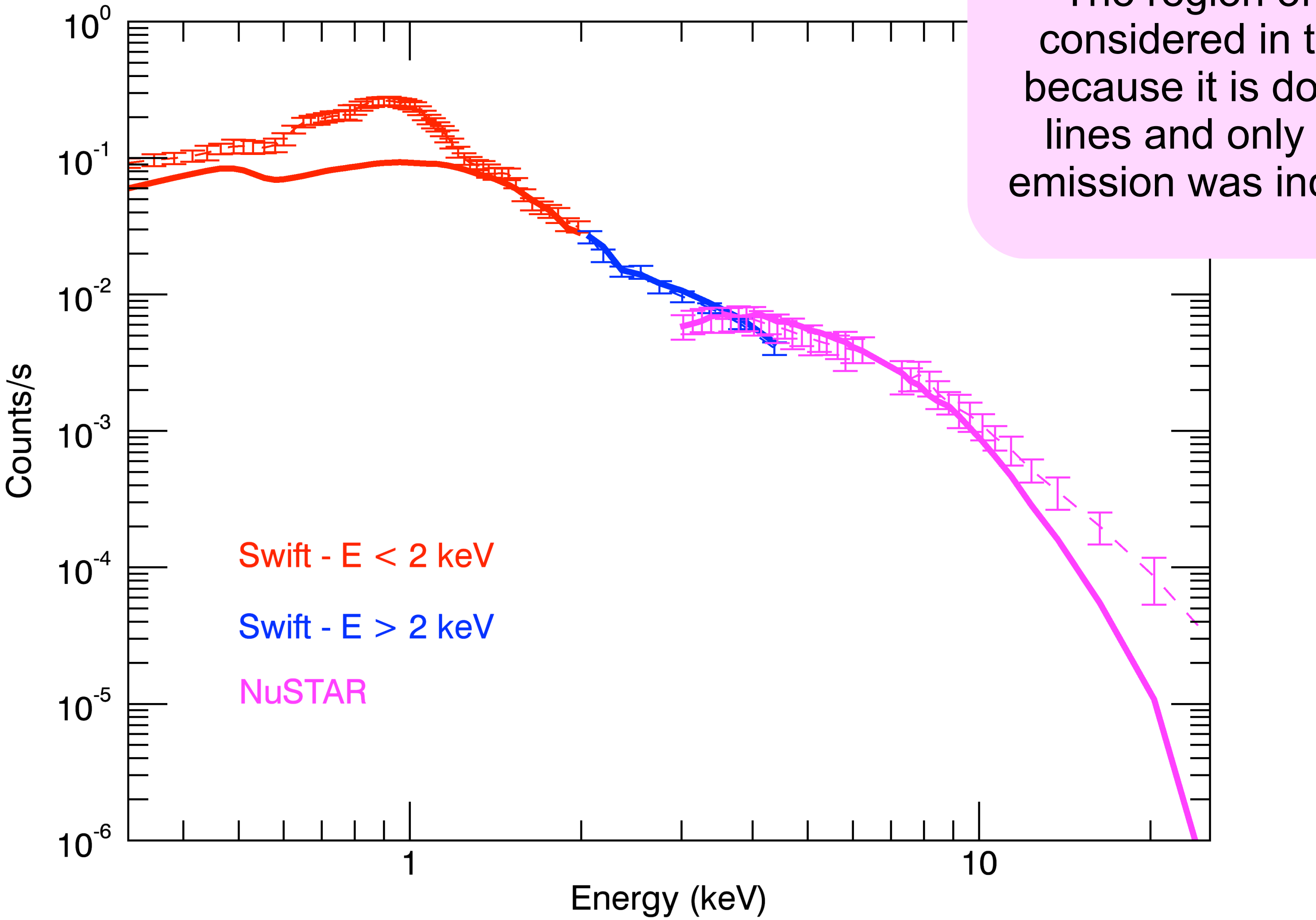
- 3D treatment
  - auto-eclipse
  - shock structure
- emission processes
  - cyclotron (optical)
  - bremsstrahlung (X rays)
- extinction processes
  - Thomson scattering internal to the binary (optical)
  - photo-absorption internal to the binary and interstellar (X-rays)
- routines to fit optical and X-ray data
  - high-energy instrumental files are considered in the procedure
- Costa & Rodrigues (2009); Silva+ (2013)



Costa & Rodrigues 2009

Preliminary results

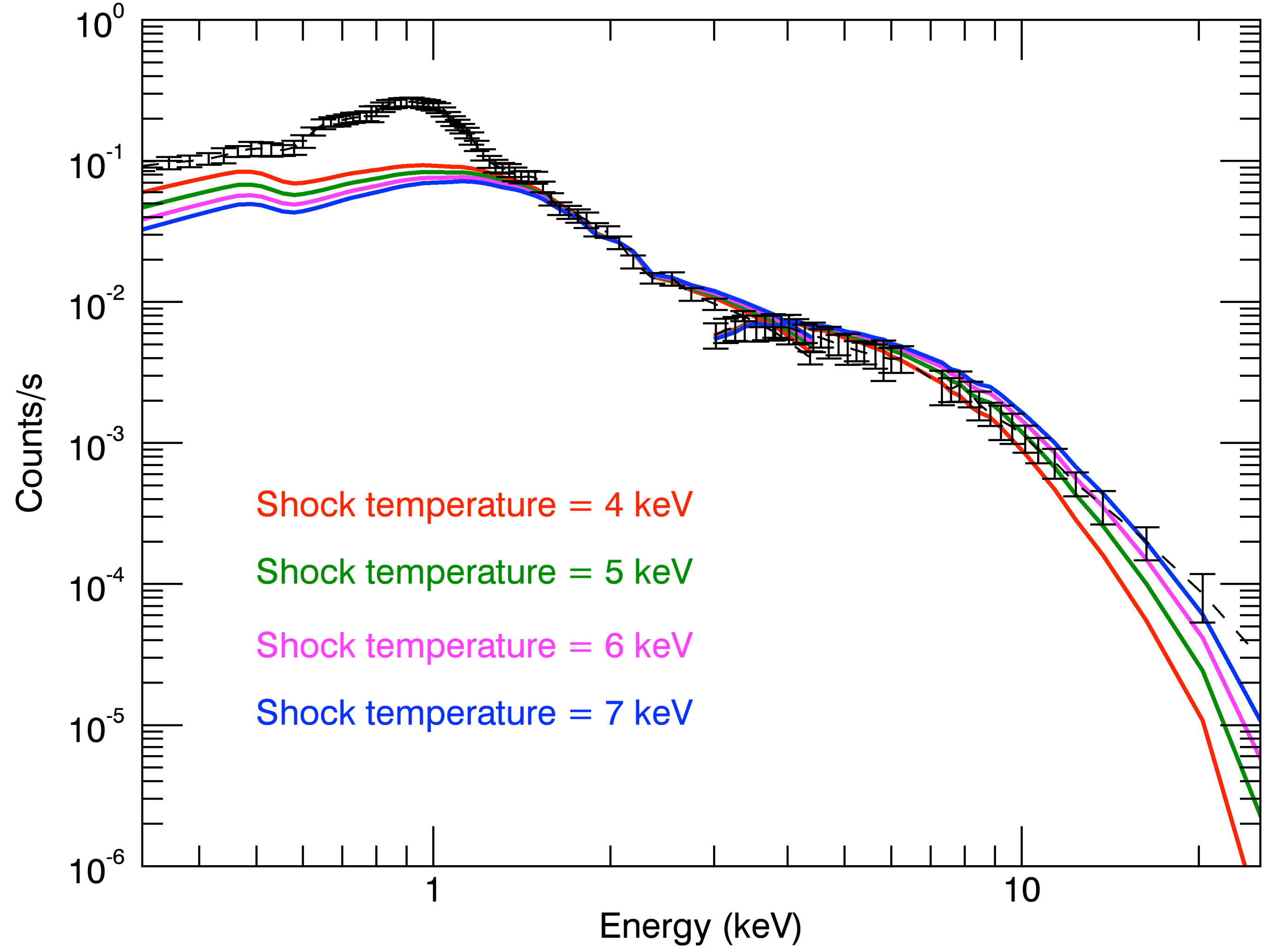
- We present a fit using a set of parameters for AE Aqr
  - ⇨ it should be considered as one possibility, since the domain of space parameters is huge and it was not completely explored yet
    - ✓ Cyclops has more than ten geometrical and physical parameters...
- The time-integrated spectrum of AE Aqr can be fit by many combinations of geometrical parameters, but it strongly constrains the temperature distribution.



The region of E < 2 keV was not considered in the fitting procedure, because it is dominated by emission lines and only free-free continuum emission was included in the models.

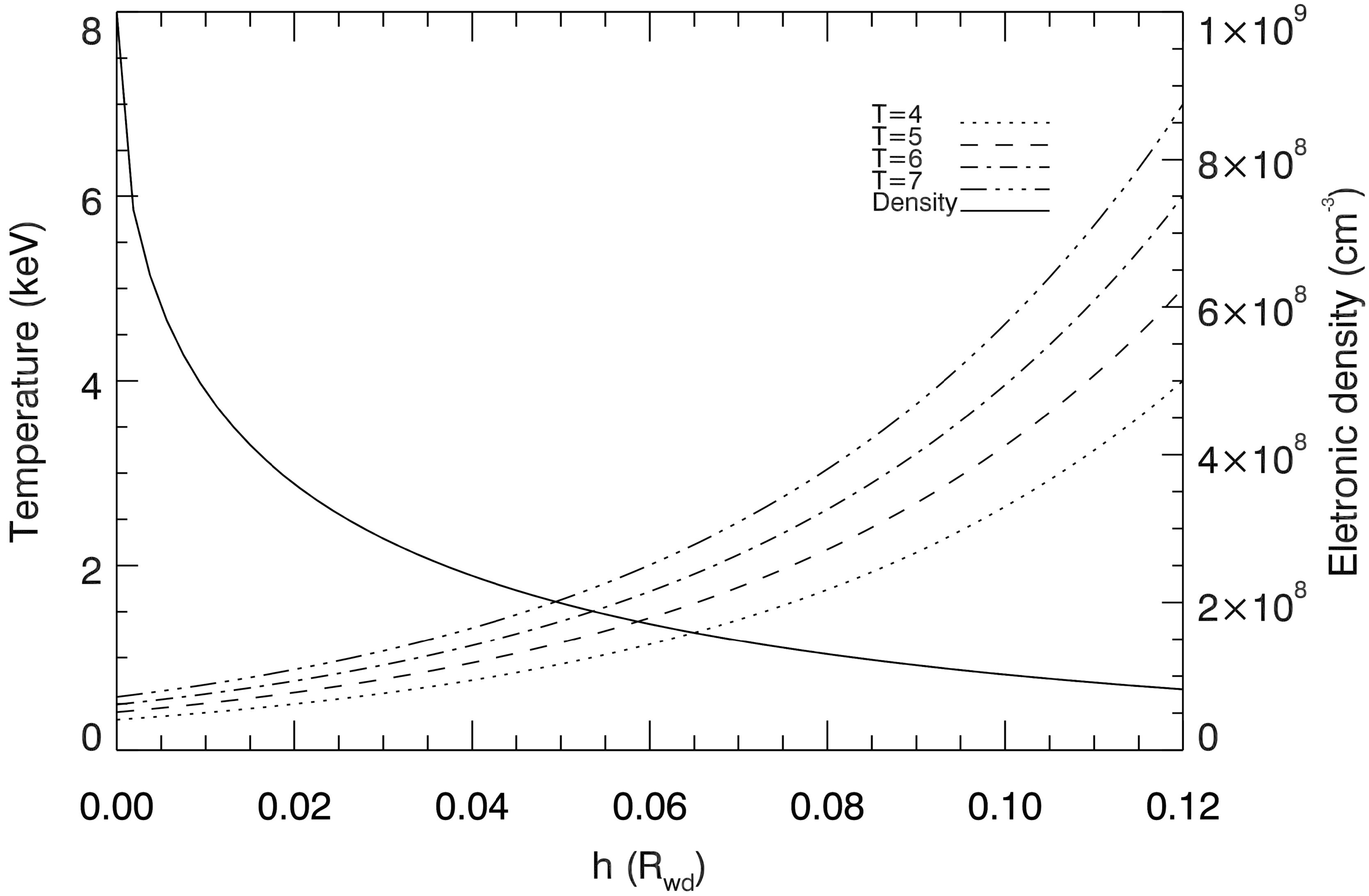
Swift and NuSTAR spectra (error bars) and the Cyclops spectrum for a shock structure with Tmax = 4 keV (solid line).

Variation of the models as a function of Tmax

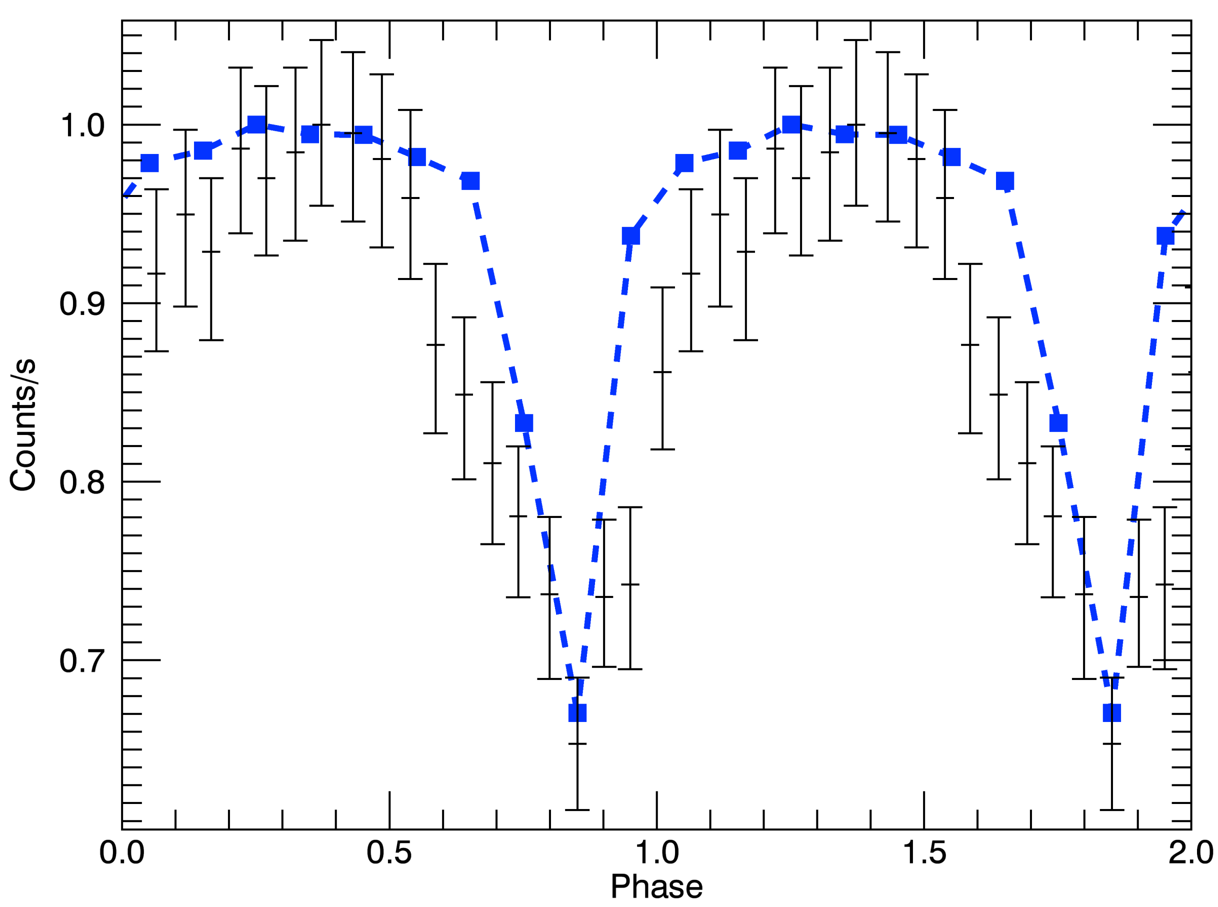


Tmax = 7 keV produces a visually better model, but chi-square is larger...

Temperature and density distributions for the models in previous figures

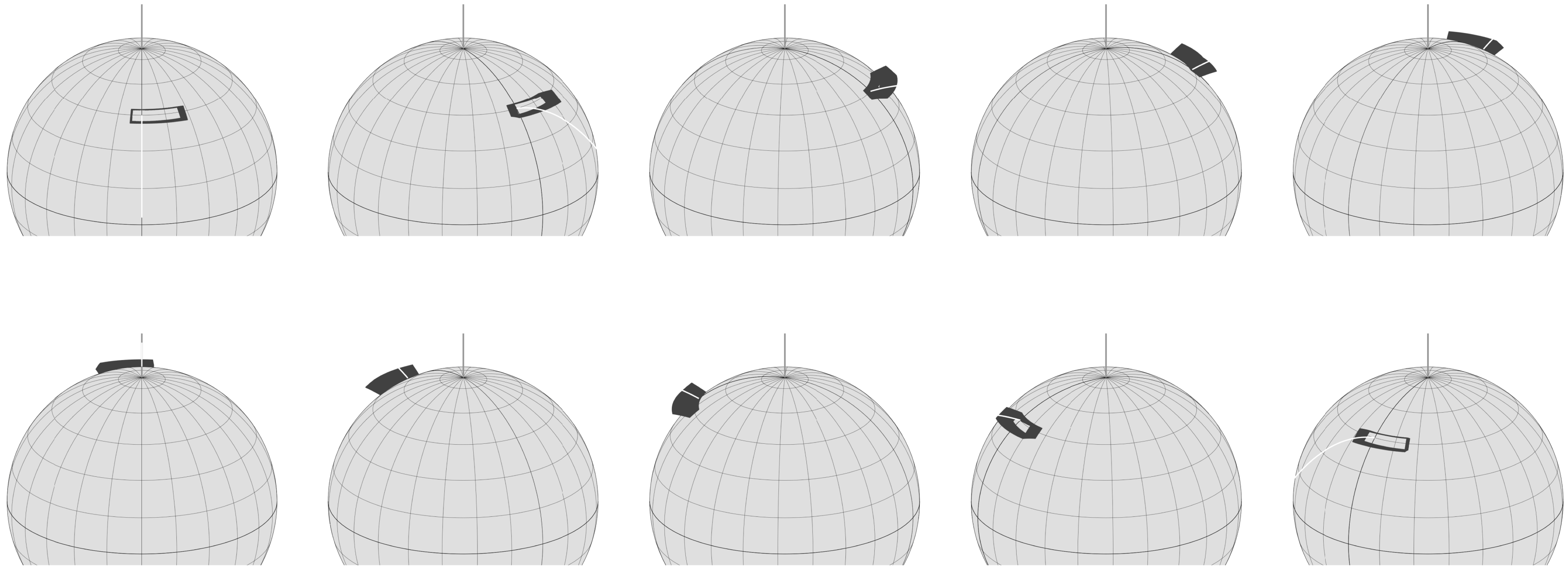


- We are able to reproduce quite well the light curve of AE Aqr from 3 to 20 keV.
  - ⇨ The modulation is caused by partial auto-eclipse of the accretion column by the white dwarf.



- Main geometrical parameters used in the fitting:
  - ⇨ inclination: 67°;
  - ⇨ emission region located 42° from the pole, extended by 30° in longitude, and having 0.12 white-dwarf radius in height;
  - ⇨ magnetic field axis parallel to the rotation axis.

The top left figure represents the phase of maximum counts/s.



Only walls are shows, but region is filled with eletrons!

Conclusions and perspectives

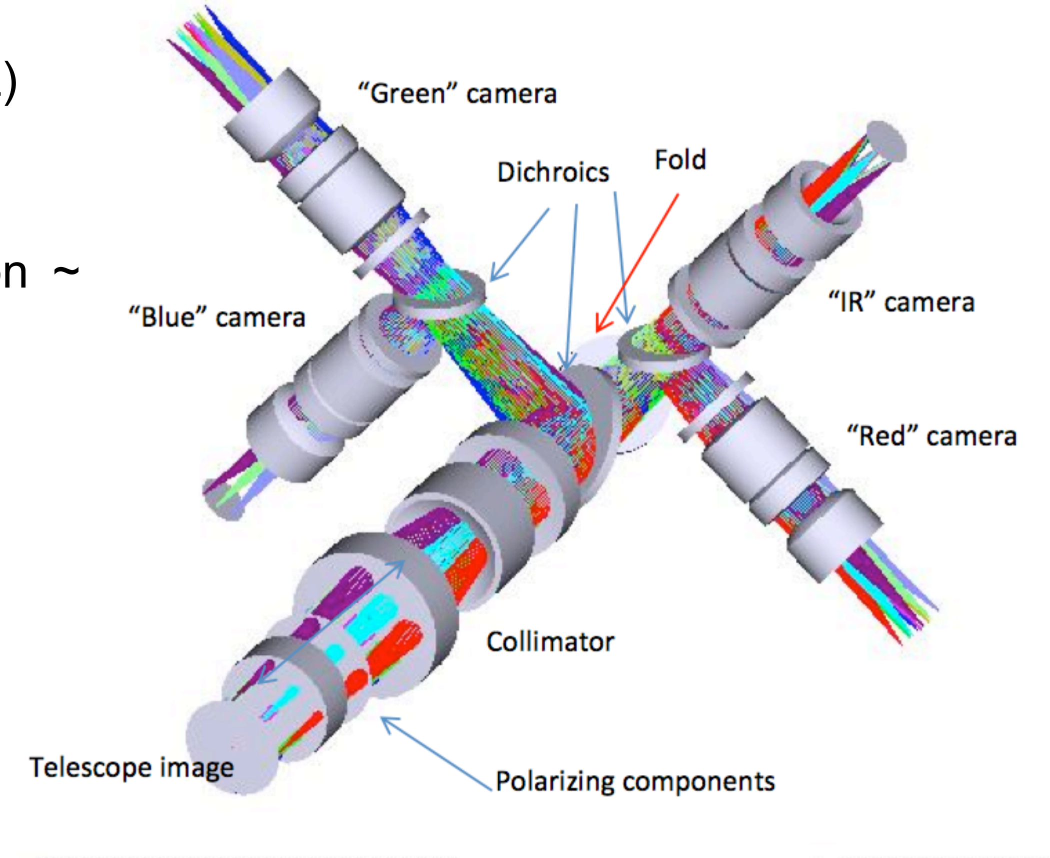
- We present a preliminary physical and geometrical scenario for AE Aqr high-energy emission.
  - ⇨ It is based on a post-shock region near the white-dwarf surface created by magnetic accretion.
  - ⇨ It explains AE Aqr spectrum and rotational flux variation.
  - ⇨ As far as we know, this is the first model to the X-ray light curve of AE Aqr.

- We intend to improve this study by:
  - ⇨ fitting time resolved X-ray spectra;
  - ⇨ using of different shock structures, including other cooling process. This may provide temperature distributions that can improve the spectrum fitting;
  - ⇨ a better exploration of the parameter space (understand degeneracy of parameters);
  - ⇨ checking consistency of the luminosity produced the model;
  - ⇨ extending the model to other wavelengths.

SPARC4

Simultaneous Polarimeter and Rapid Camera in Four Colors

- Simultaneous imager in 4 bands SDSS (griz)
- Polarimetry and photometry
- EMCCDs: Andor Ixon USB (time resolution ~ 1s)
- Field of view: 5.6 arcmin x 5.6 arcmin
- Telescope: 1.6-m - OPD/Brazil
- In construction
- Detectors and optics acquired
- Funding: INPE, LNA, Fapesp, INCT-A
  - FINEP (approved, not yet avaliable)



Thank you!!

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  - ⇨ Fapesp: 2015/24393-7 (I.J.L./C.V.R.); 2013/26258-4 (C.V.R.,J.G.C., I.S.L.); 2013/15088-0 (J.G.C.).
  - ⇨ FONCyT/PICT: 2014/0478 (G.J.M.L.).
  - ⇨ The organizing commitee of this meeting!

- References

  - ⇨ Aleksic et al., 2014, A&A, 568,109
  - ⇨ Costa & Rodrigues, 2009, MNRAS, 398, 240
  - ⇨ Eracleous et al. 1994, Apj, 433,313
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  - ⇨ Patterson et al, 1980, ApJ, 240, 133
  - ⇨ Norton et al. 2008, ApJ, 672, 524
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