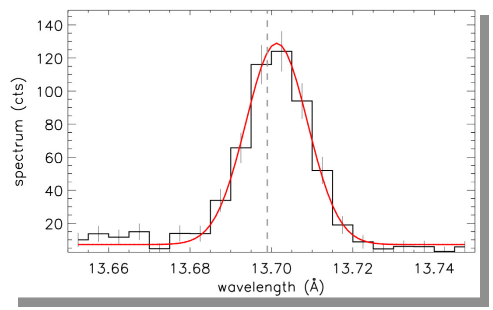
REDSHIFTED X-RAYS FROM THE MATERIAL ACCRETING ONTO TW HYA: EVIDENCE OF A LOW LATITUDE ACCRETION SPOT



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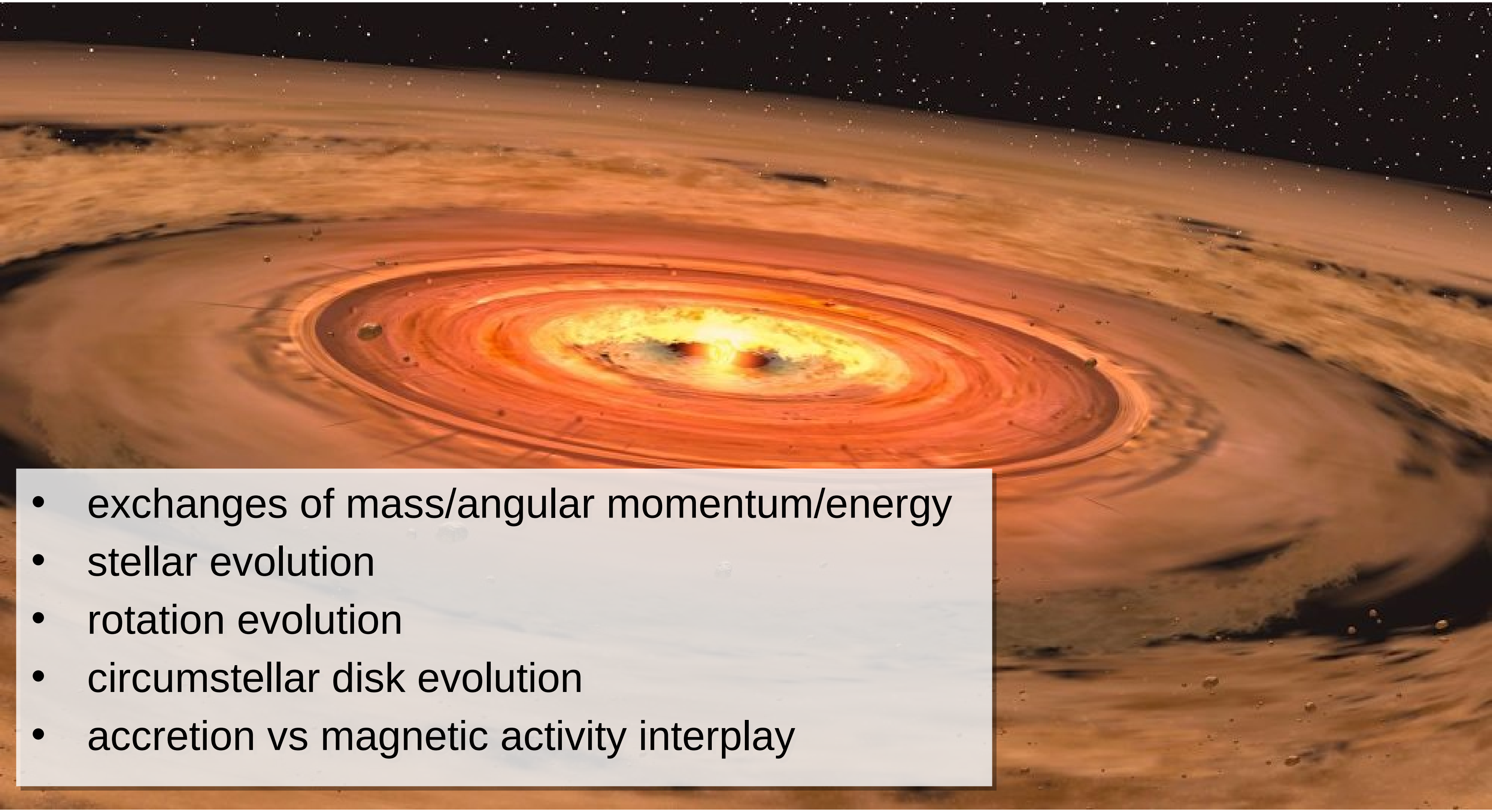
Accretion in Stellar Systems, Cambridge, MA, US, Aug 2018

ACCRETION IN YOUNG STARS



- exchanges of mass/angular momentum/energy
- stellar evolution
- rotation evolution
- circumstellar disk evolution
- accretion vs magnetic activity interplay

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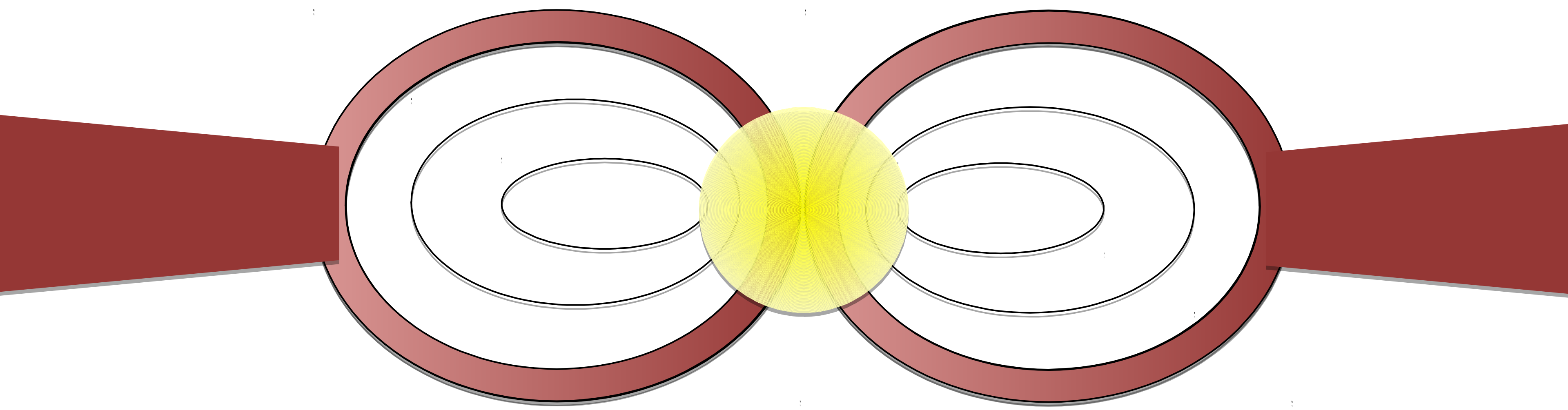
MAGNETOSPHERIC ACCRETION

- Rotational modulation hot spots and disk warps
- Spectral energy distribution inner disk disruption, hot spots
- Magnetic field measurements (1 kG) inner disk disruption
- Line profiles velocities of material at different temperature



ACCRETION-SHOCK REGION

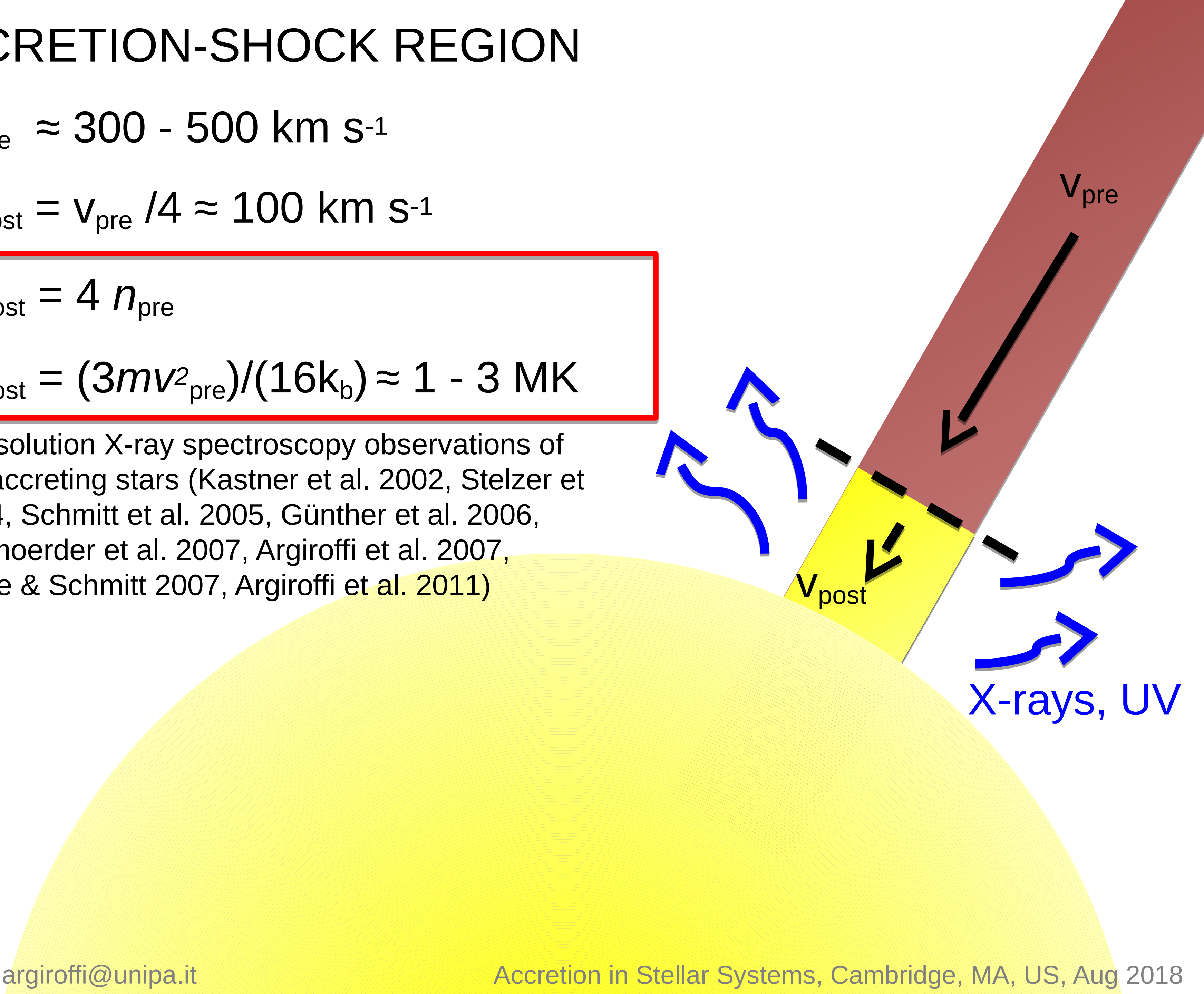
$v_{pre} \approx 300 - 500$ km s^{-1}

$v_{post} = v_{pre} / 4 \approx 100$ km s^{-1}

✔ $n_{post} = 4\, n_{pre}$

✔ $T_{post} = (3 m v^2_{pre})/(16 k_b) \approx 1 - 3$ MK

High resolution X-ray spectroscopy observations of young accreting stars (Kastner et al. 2002, Stelzer et al. 2004, Schmitt et al. 2005, Günther et al. 2006, Heunemoerder et al. 2007, Argiroffi et al. 2007, Robrade & Schmitt 2007, Argiroffi et al. 2011)



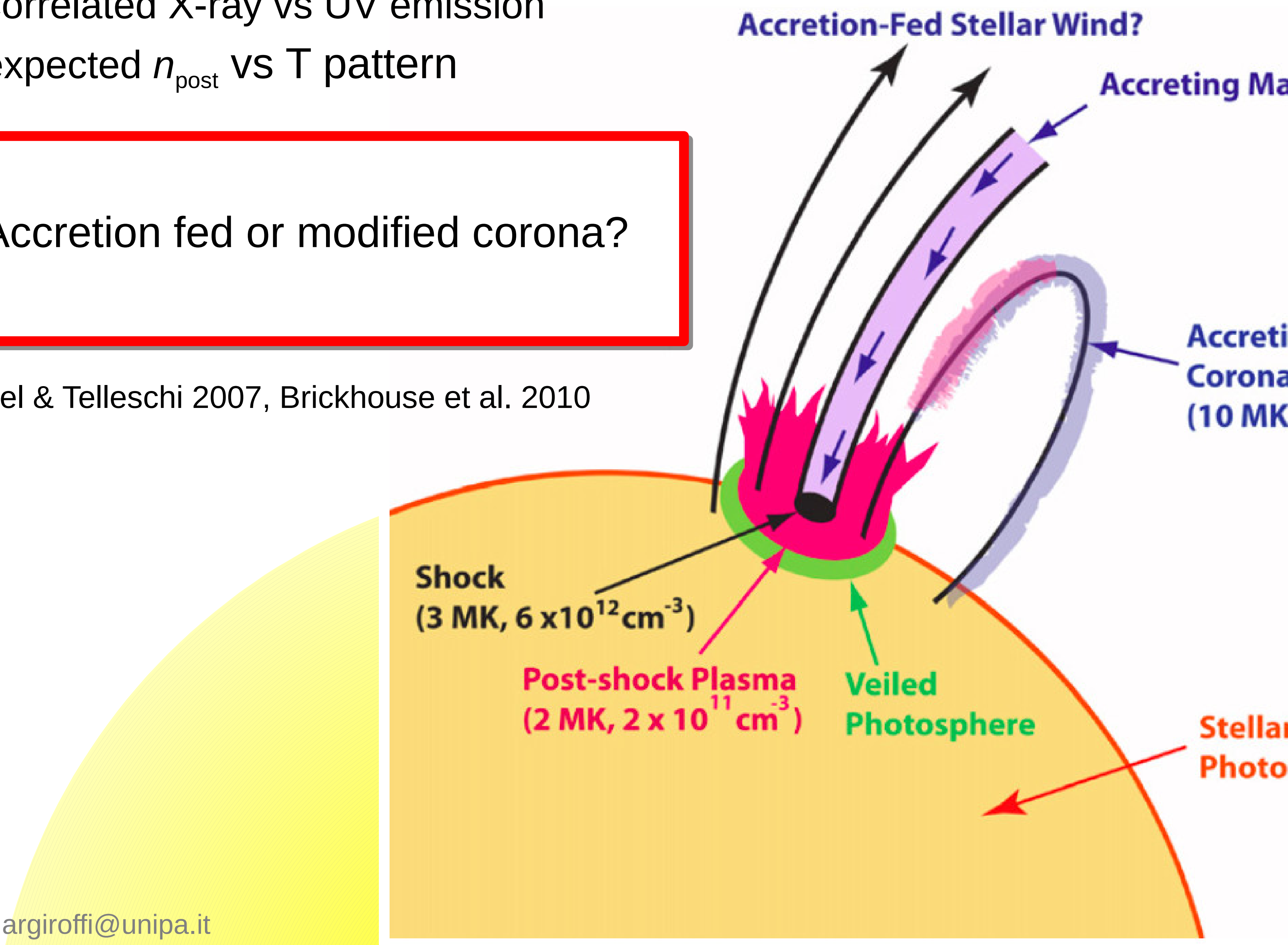
ACCRETION-SHOCK REGION

uncorrelated X-ray vs UV emission

unexpected n_{post} vs T pattern

Accretion fed or modified corona?

Güdel & Telleschi 2007, Brickhouse et al. 2010



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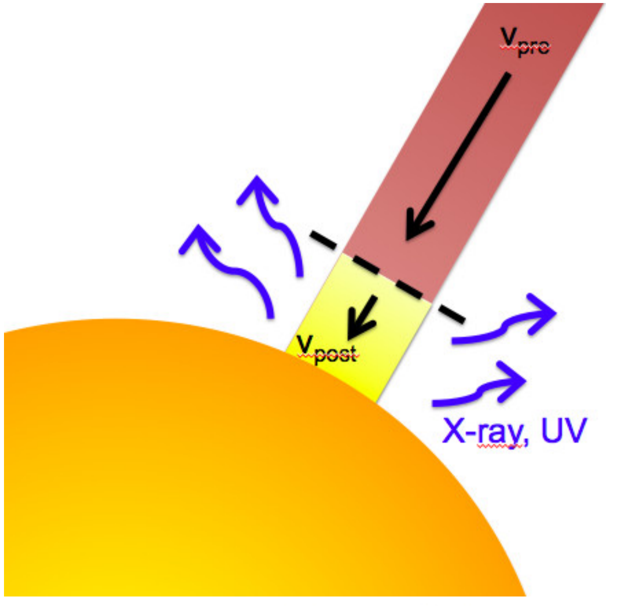
DOPPLER SHIFT TO CONSTRAIN PLASMA ORIGIN

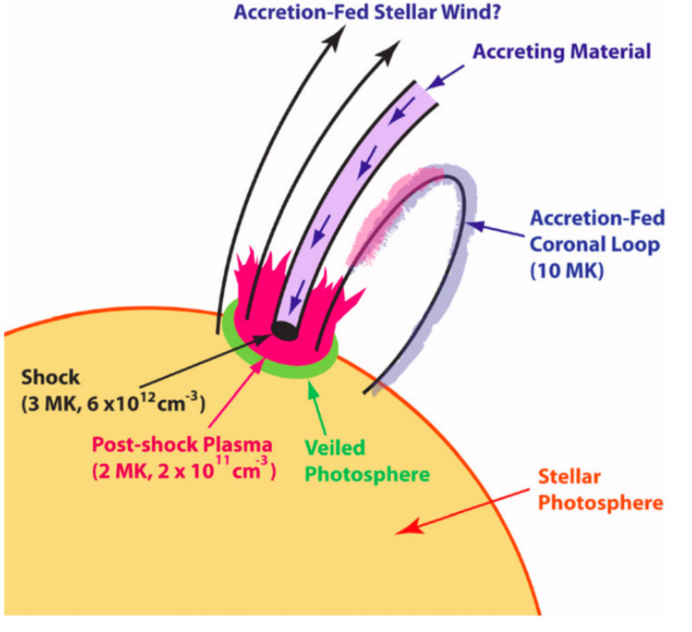
$v_{post} = v_{pre} / 4 \approx 100$ km/s

Detectable with Chandra/HETGS



X-ray redshift

Confirmation of the post-shock origin of the high-density cool plasma



no X-ray redshift

High-density cool plasma is also located in modified coronal structures

TW HYA: THE NEAREST YOUNG ACCRETING STAR

TW Hya:

d ≈ 59.5 pc

age ≈ 8 Myr

$M \approx 0.8\ M_{\odot}$

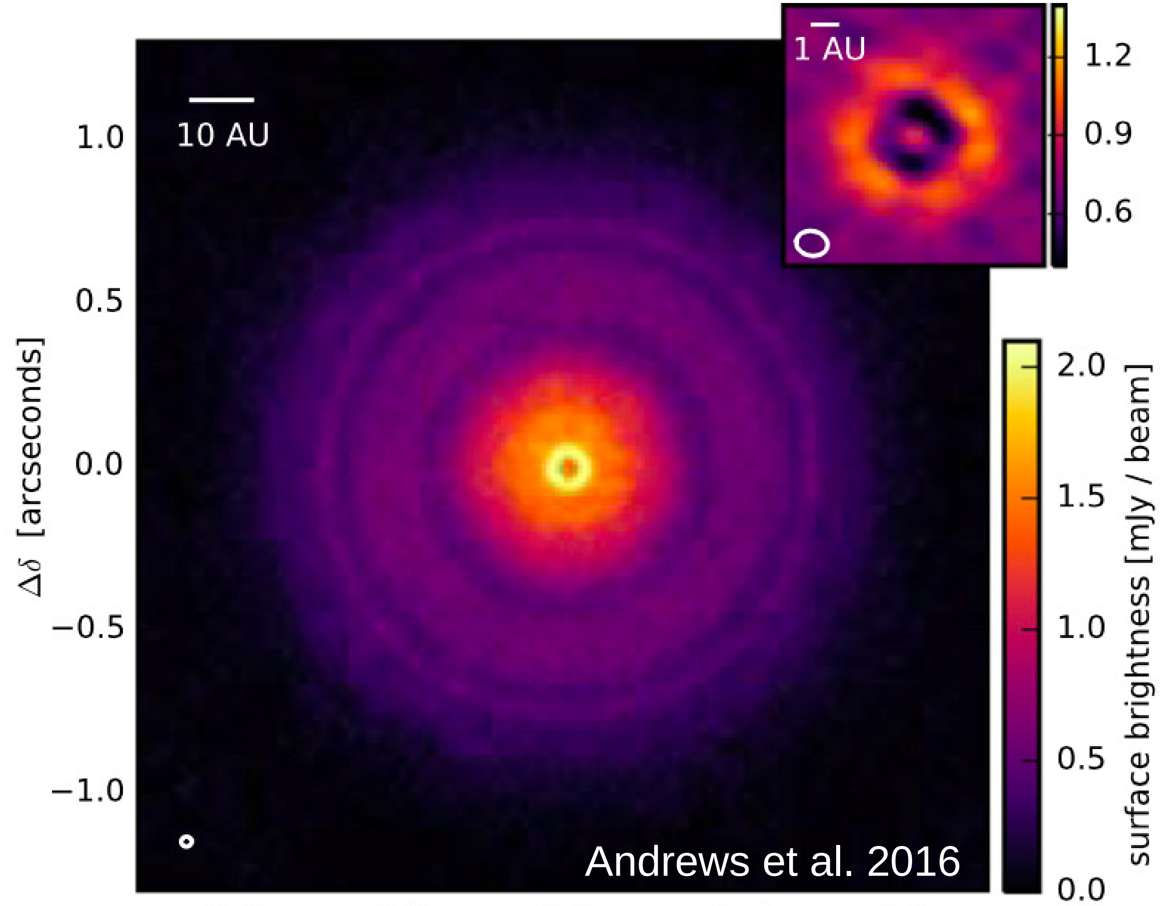
$R \approx 1.1\ R_{\odot}$

$dM/dt \approx 10^{-9}\ M_{\odot}\ yr^{-1}$

$P_{rot} \approx$?

B ~ 1-3 kG

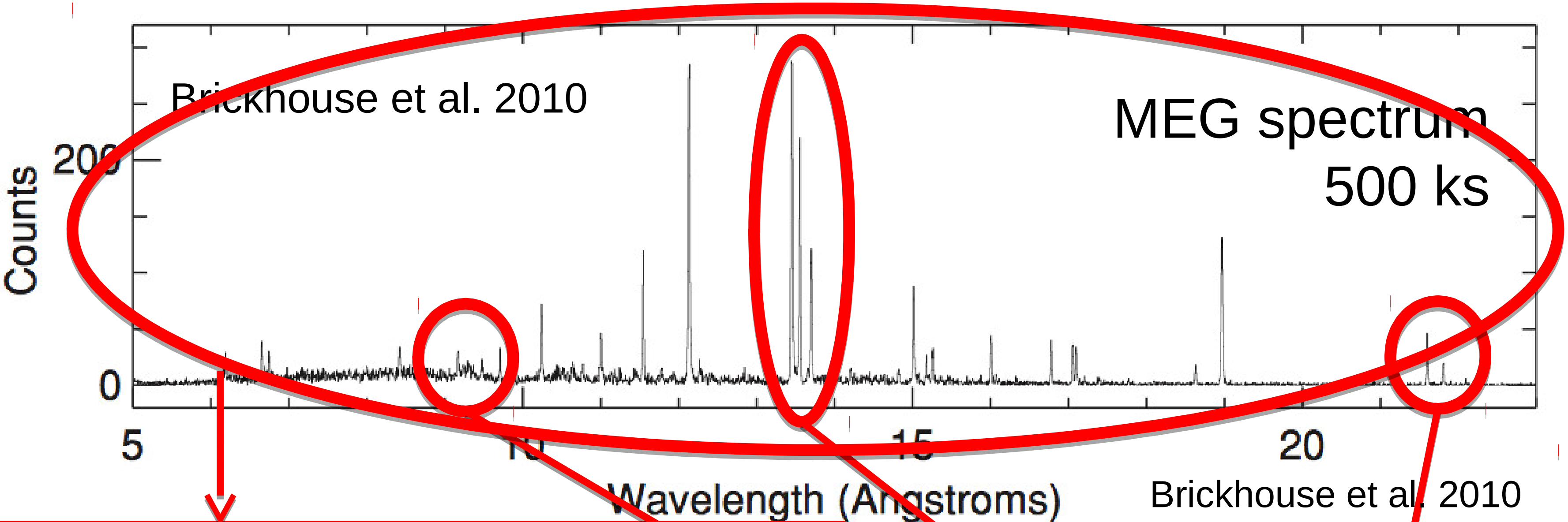
i ≈ 7°



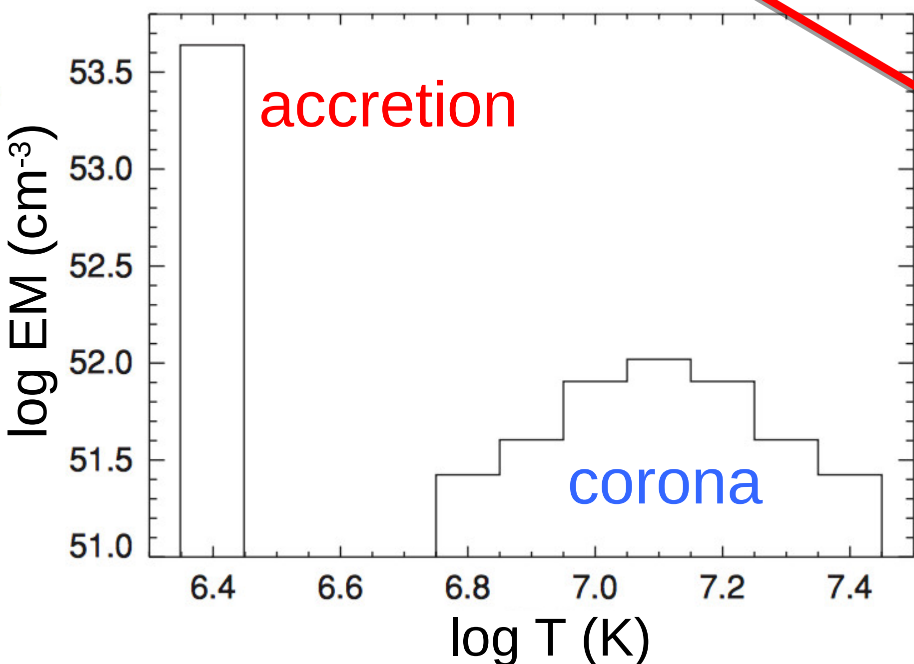
- No rotational modulation

- Chandra/HETGS LP of 500 ks

500 ks CHANDRA/HETG OBS OF TW HYA



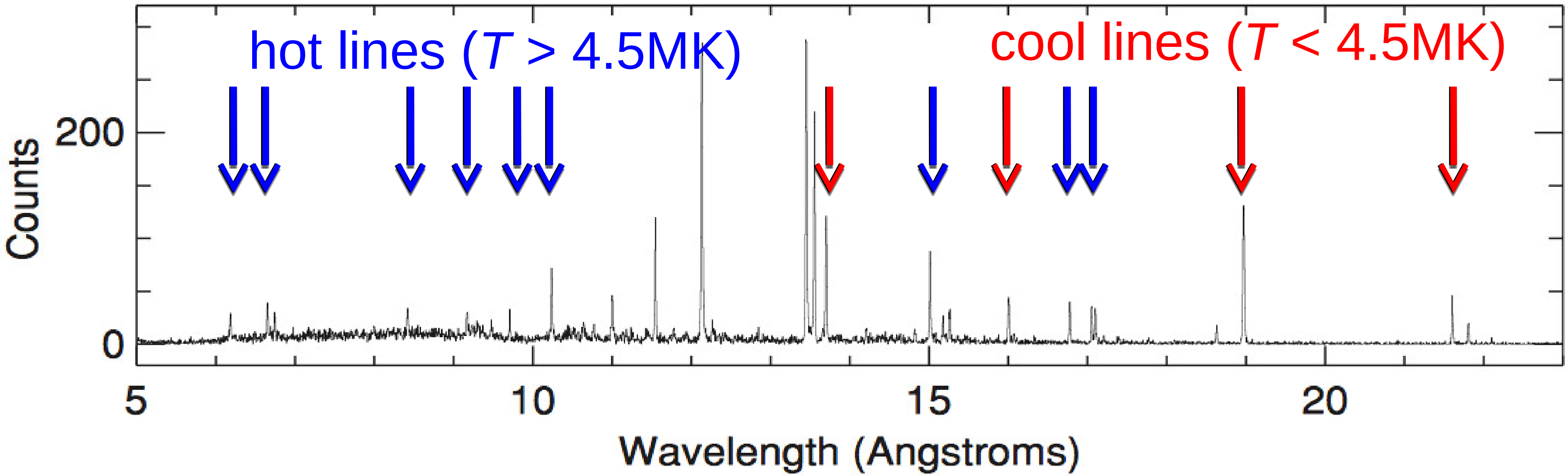
Brickhouse et al. 2010



$n_e \sim 10^{12}\ \mathrm{cm}^{-3}$

$T \approx 3$ MK

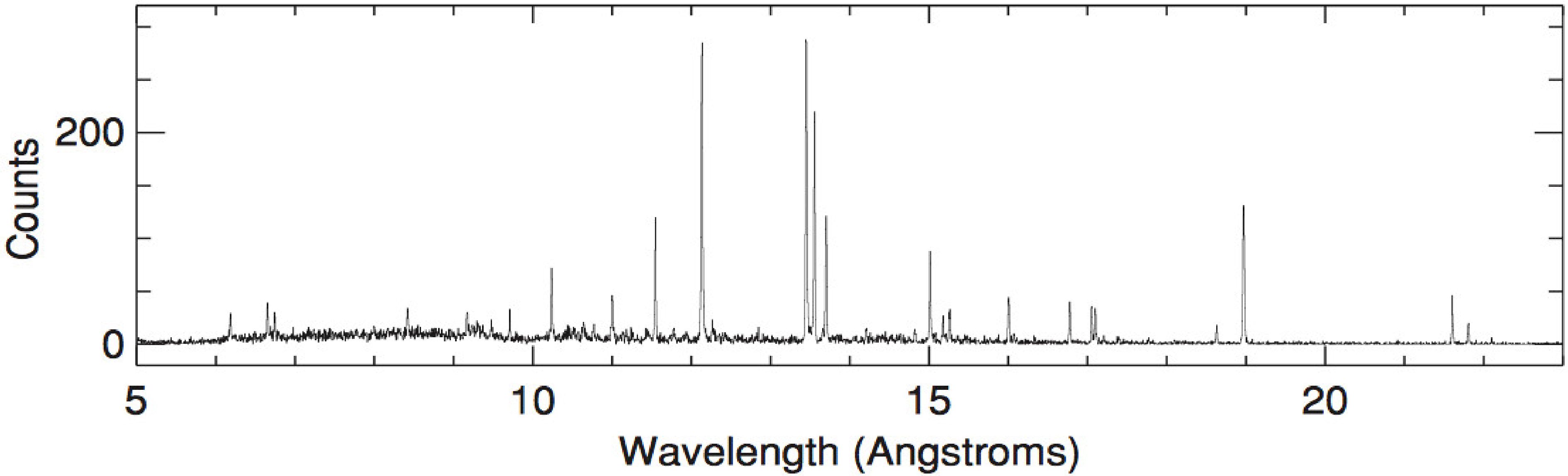
X-RAY DOPPLER SHIFT MEASURE: METHOD 1



Method 1: individual line position

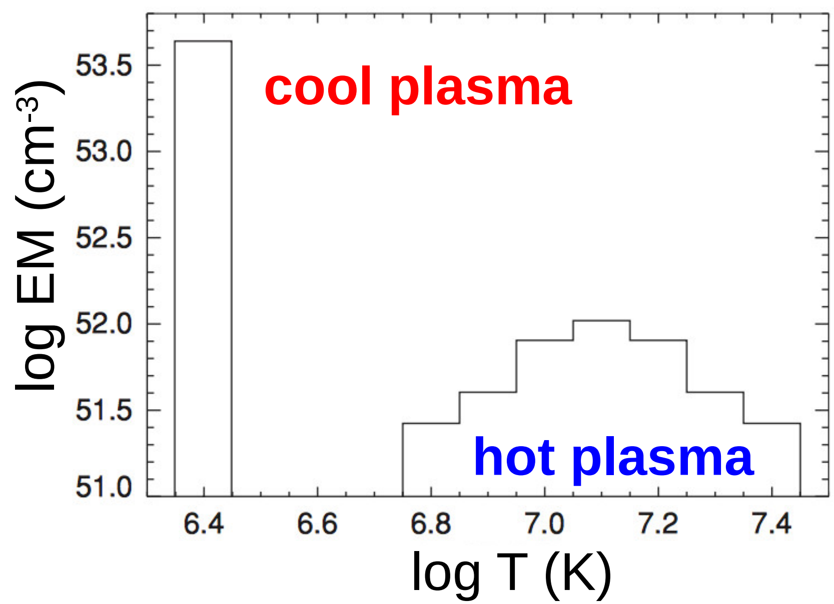
- isolated lines
- **hot** and **cool** line subsets
- measure the shift of each line
- v_{cool} and v_{hot} as weighted average from cool and hot line subsets

X-RAY DOPPLER SHIFT MEASURE: METHOD 2

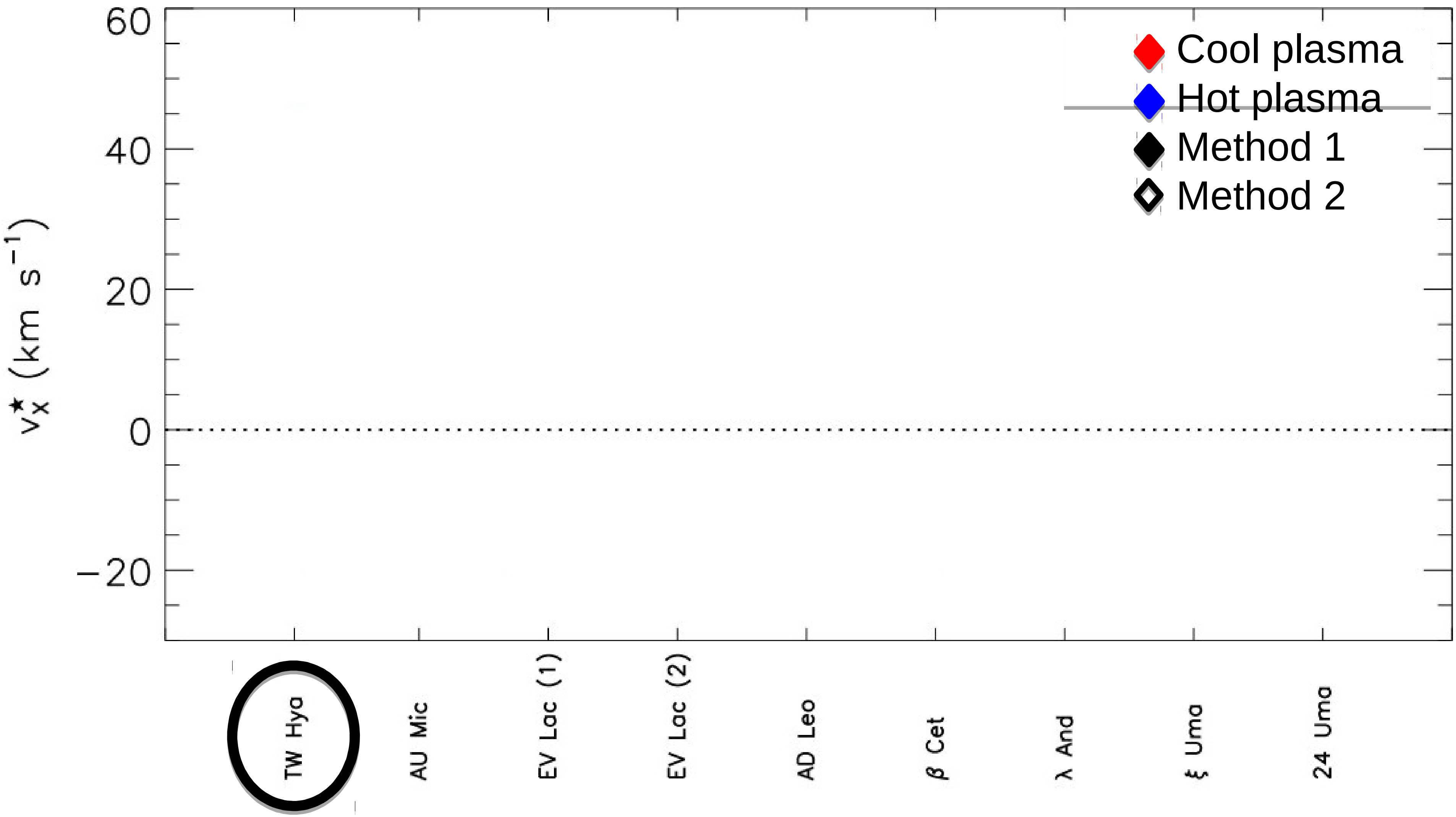


Method 2: spectral fitting

- cool and hot plasma components
- two different velocities
- fit the whole spectrum



X-RAY PLASMA MOTIONS IN TW HYA



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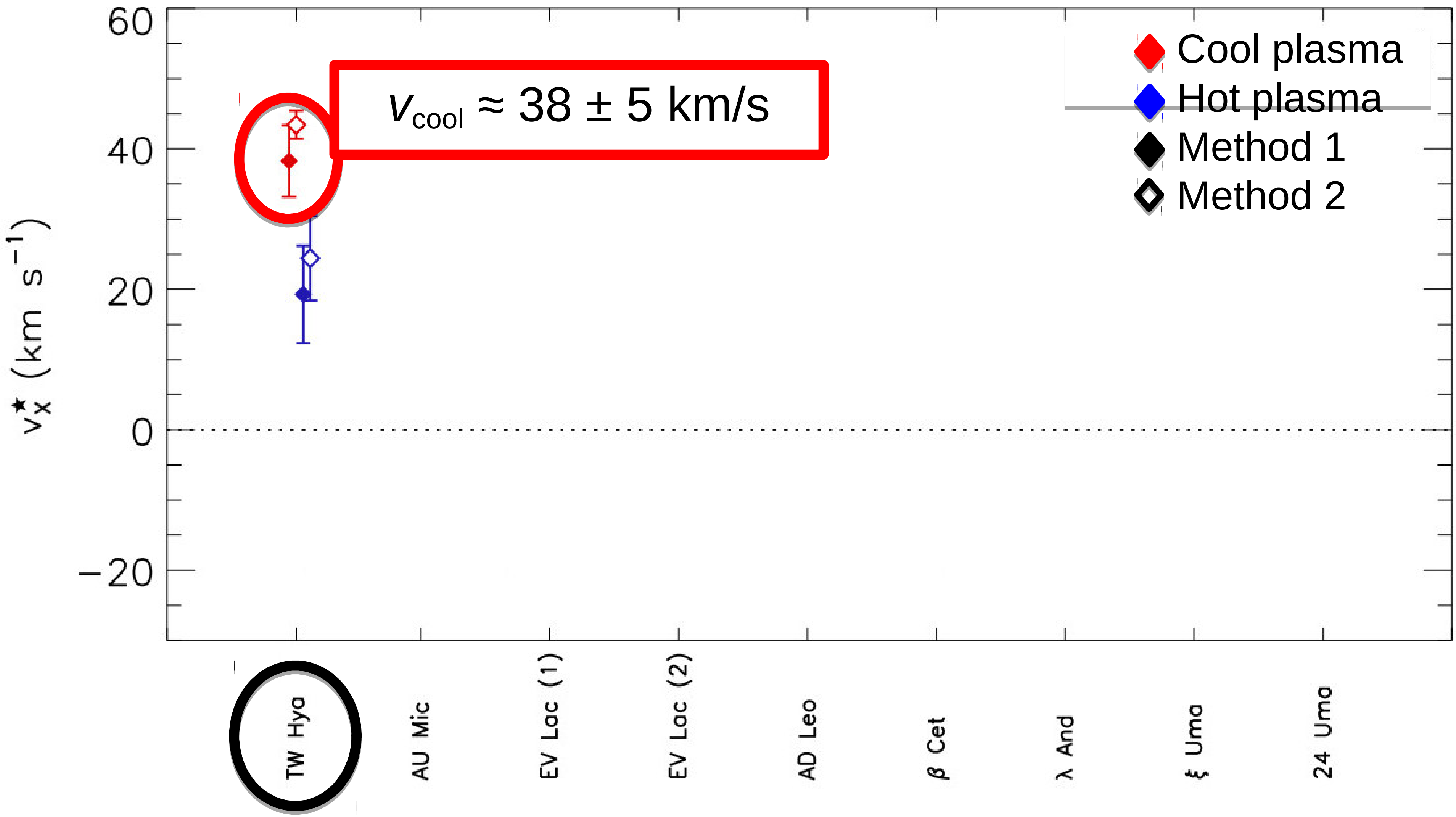

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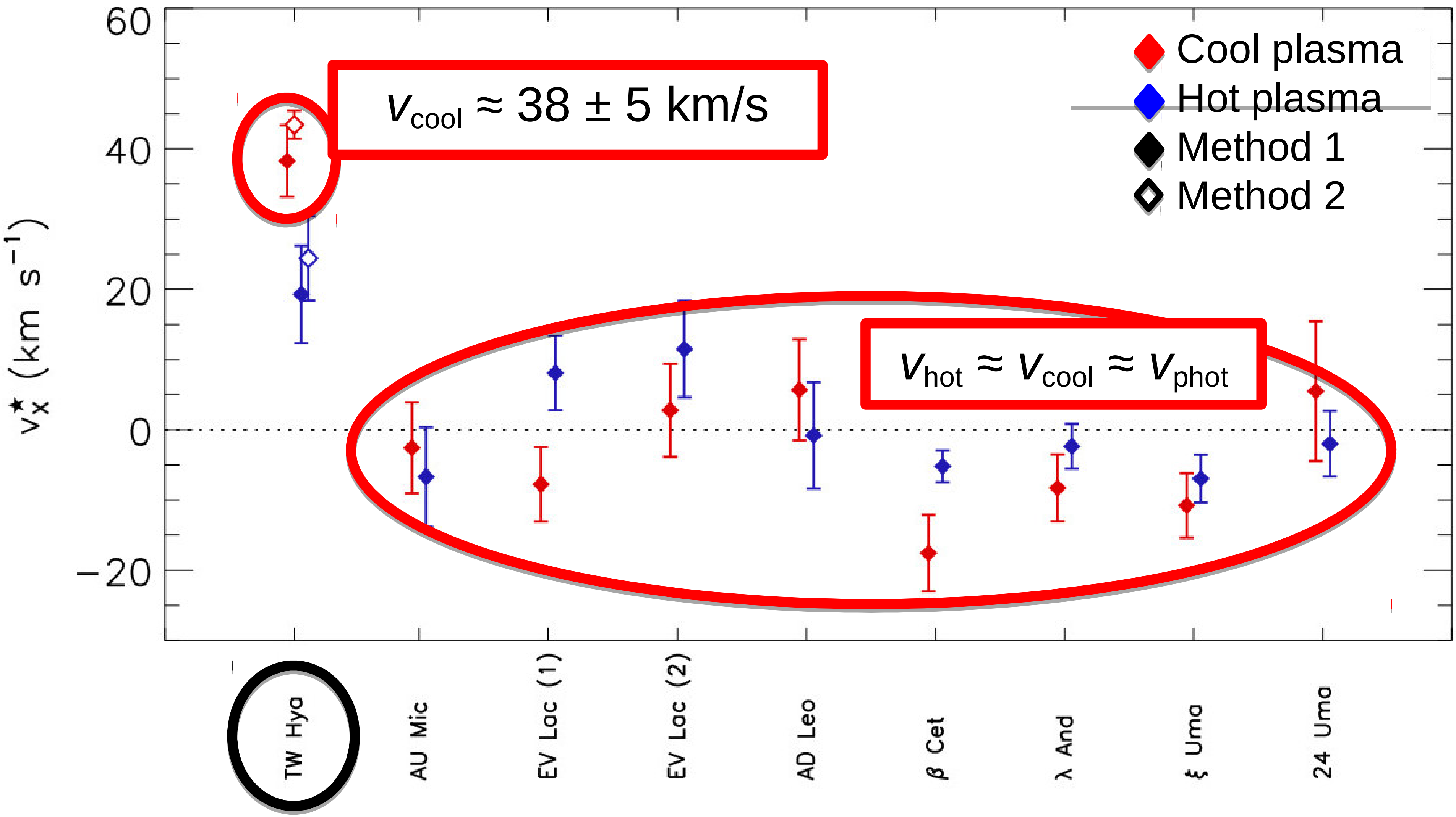
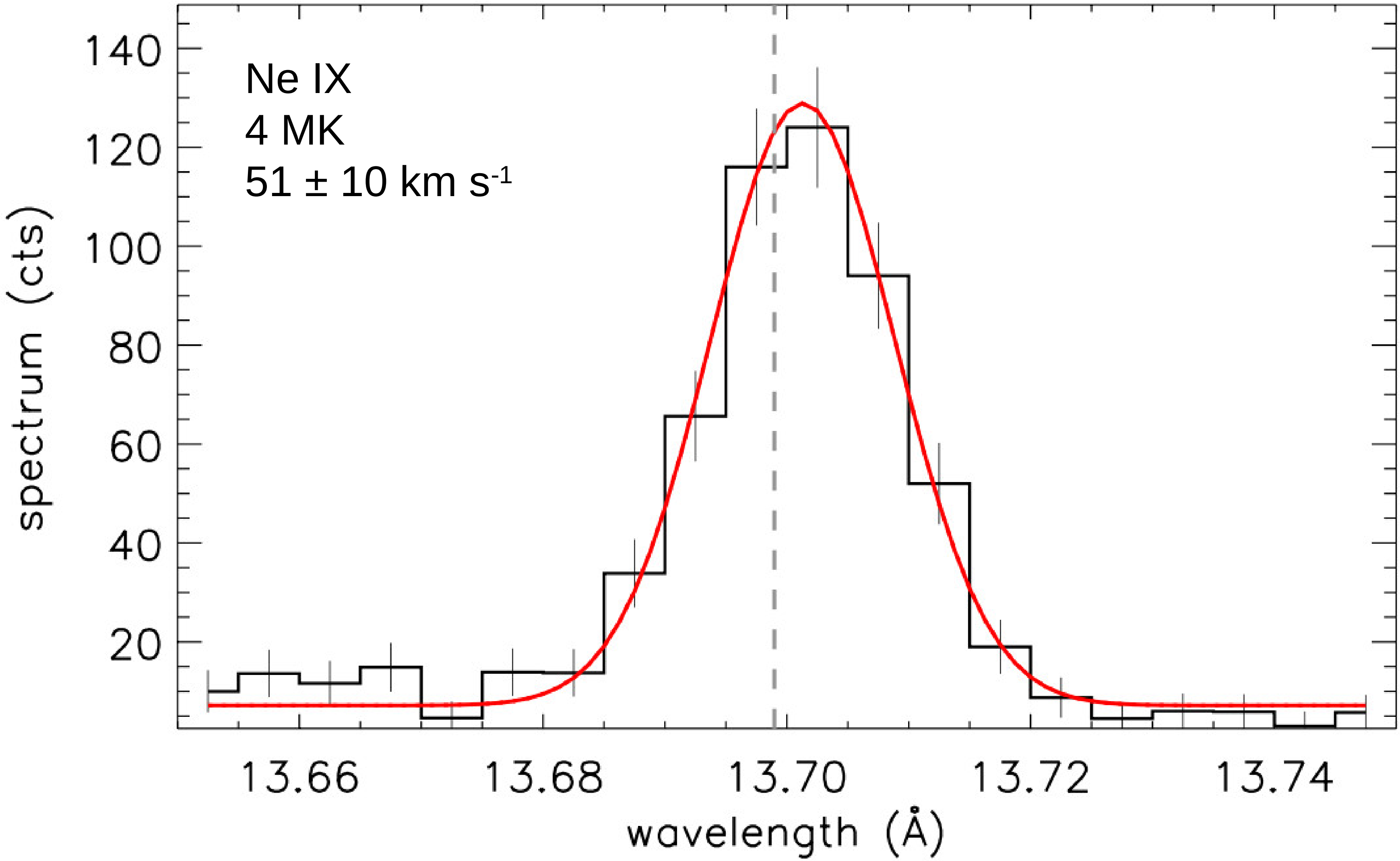


X-RAY PLASMA MOTIONS IN TW HYA



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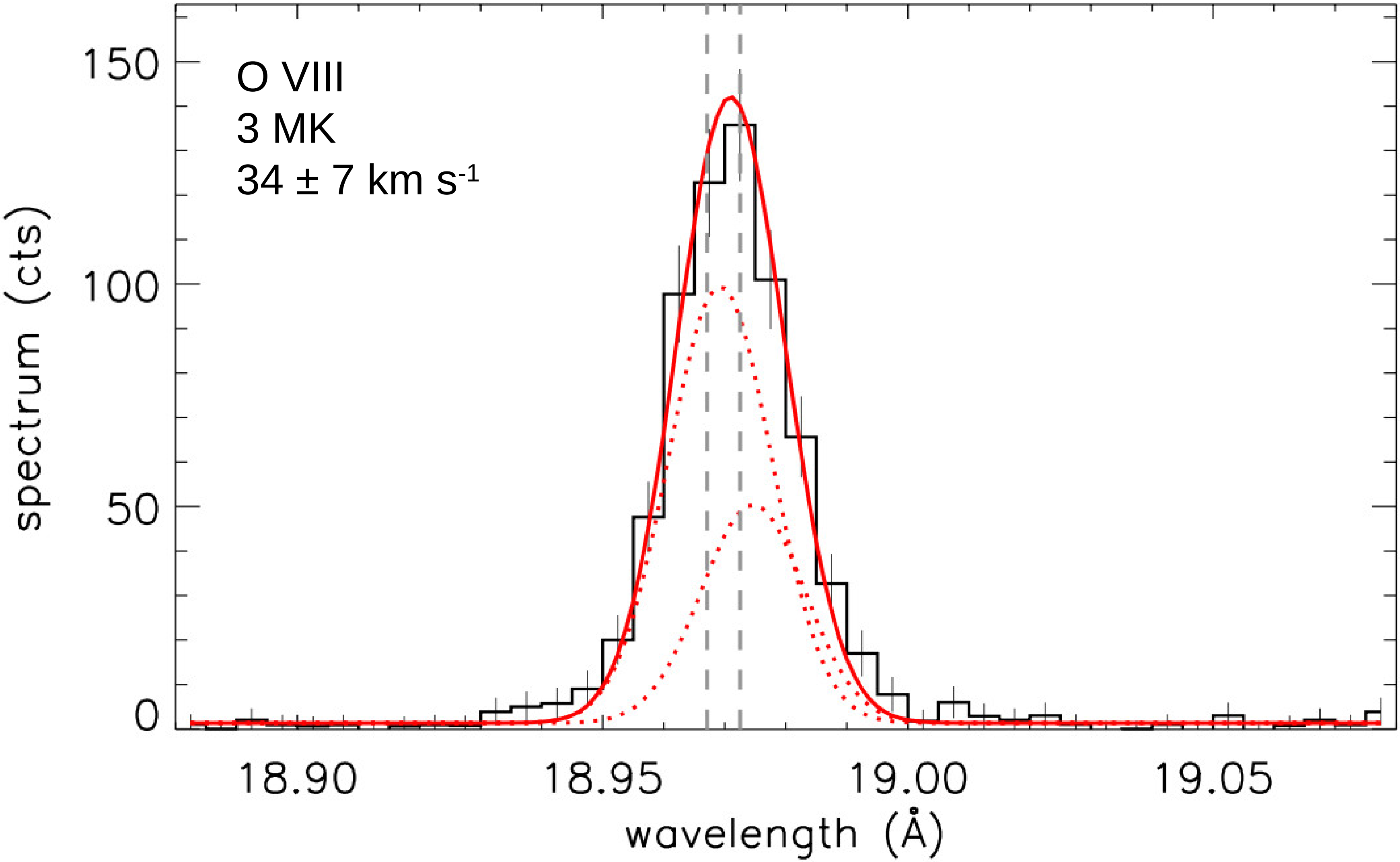
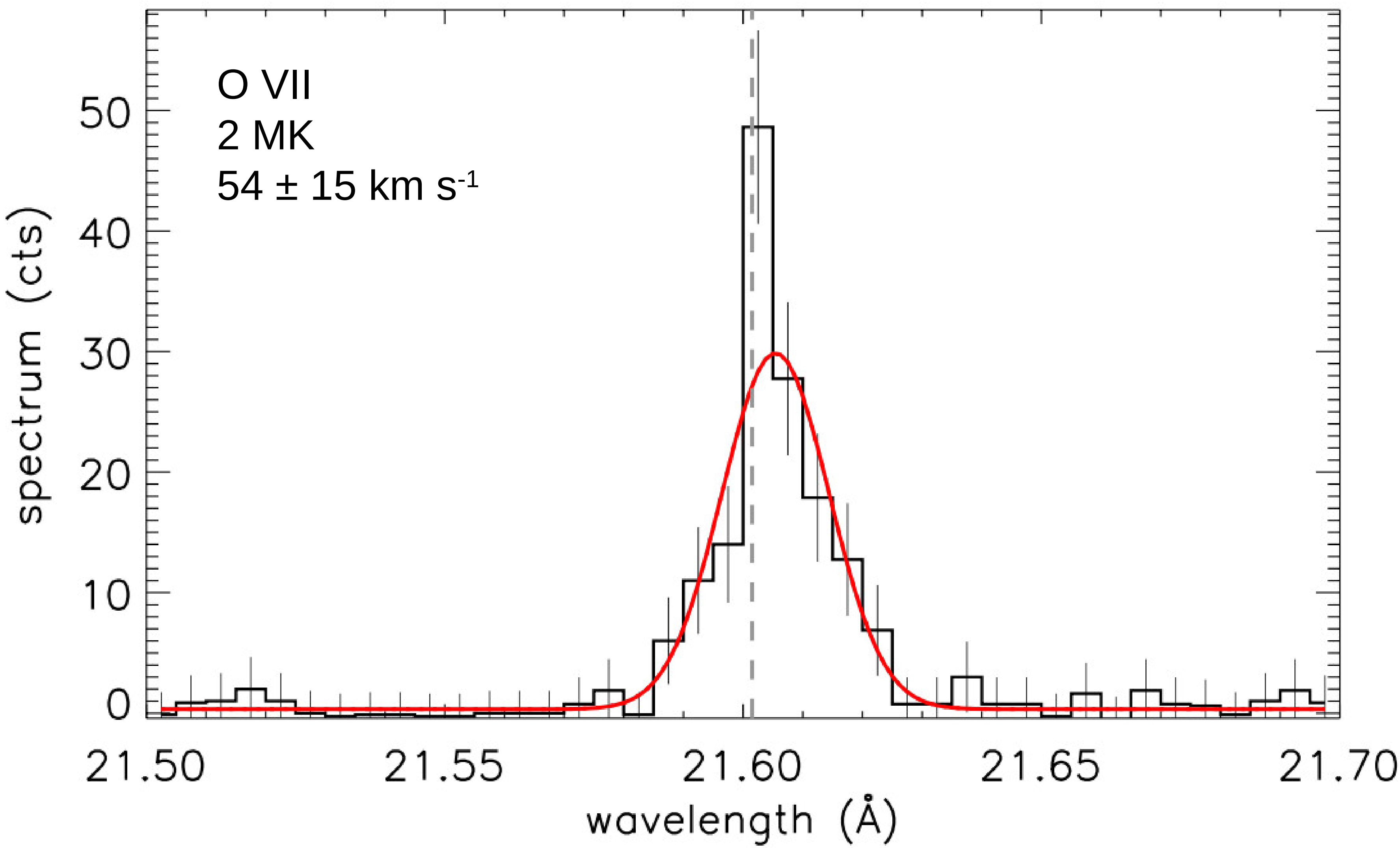


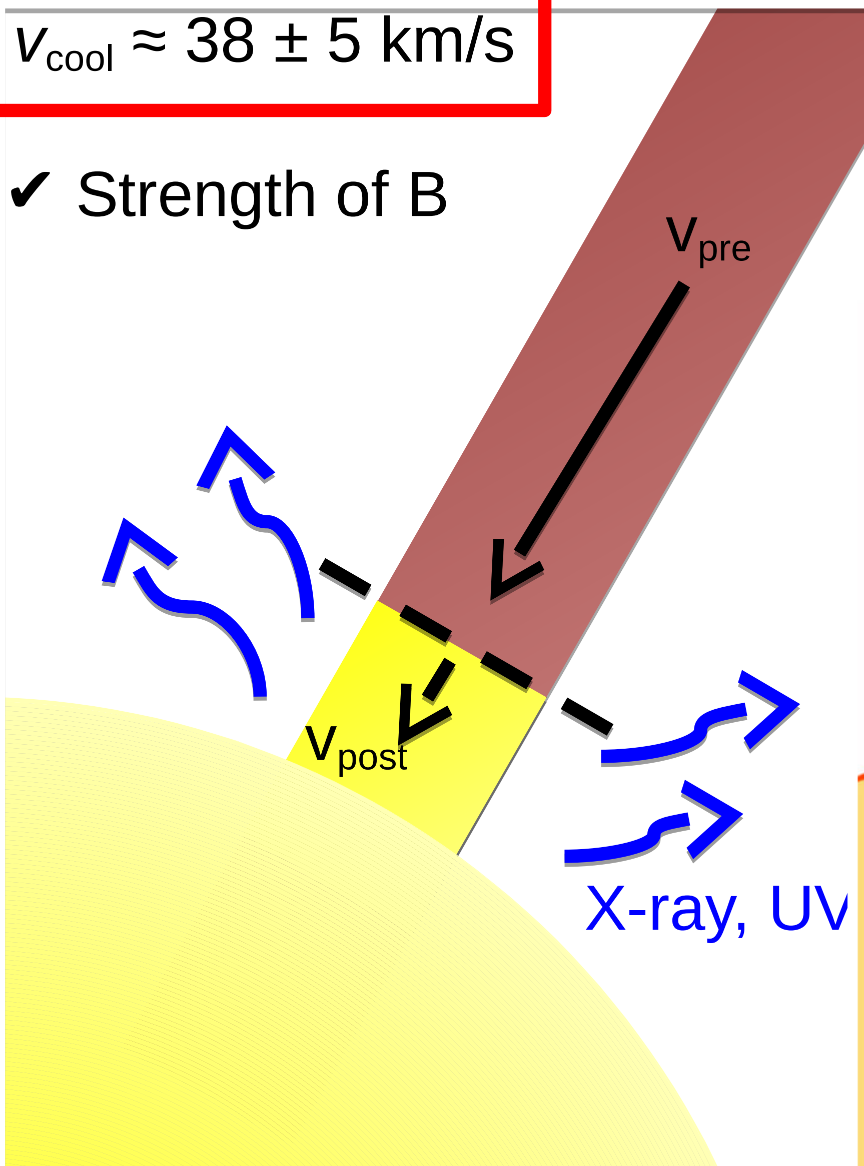
X-RAY PLASMA MOTIONS IN TW HYA

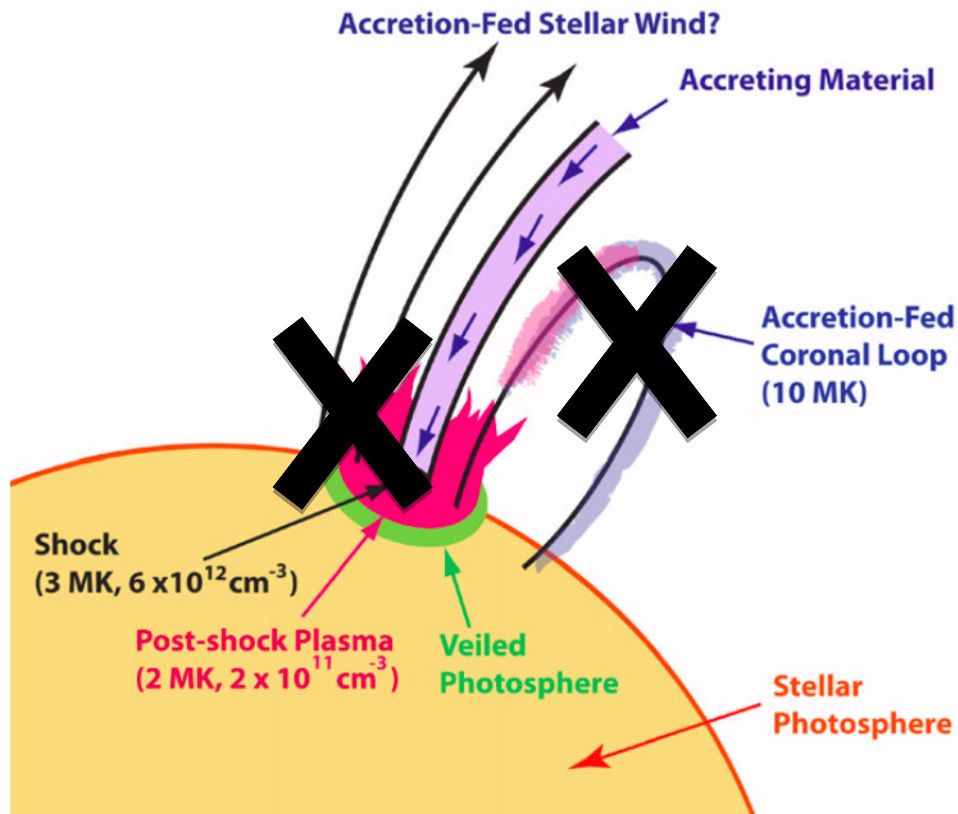


1. SOFT X-RAYS ORIGINATE IN THE POST SHOCK

$v_{cool} \approx 38 \pm 5$ km/s

✔ Strength of B





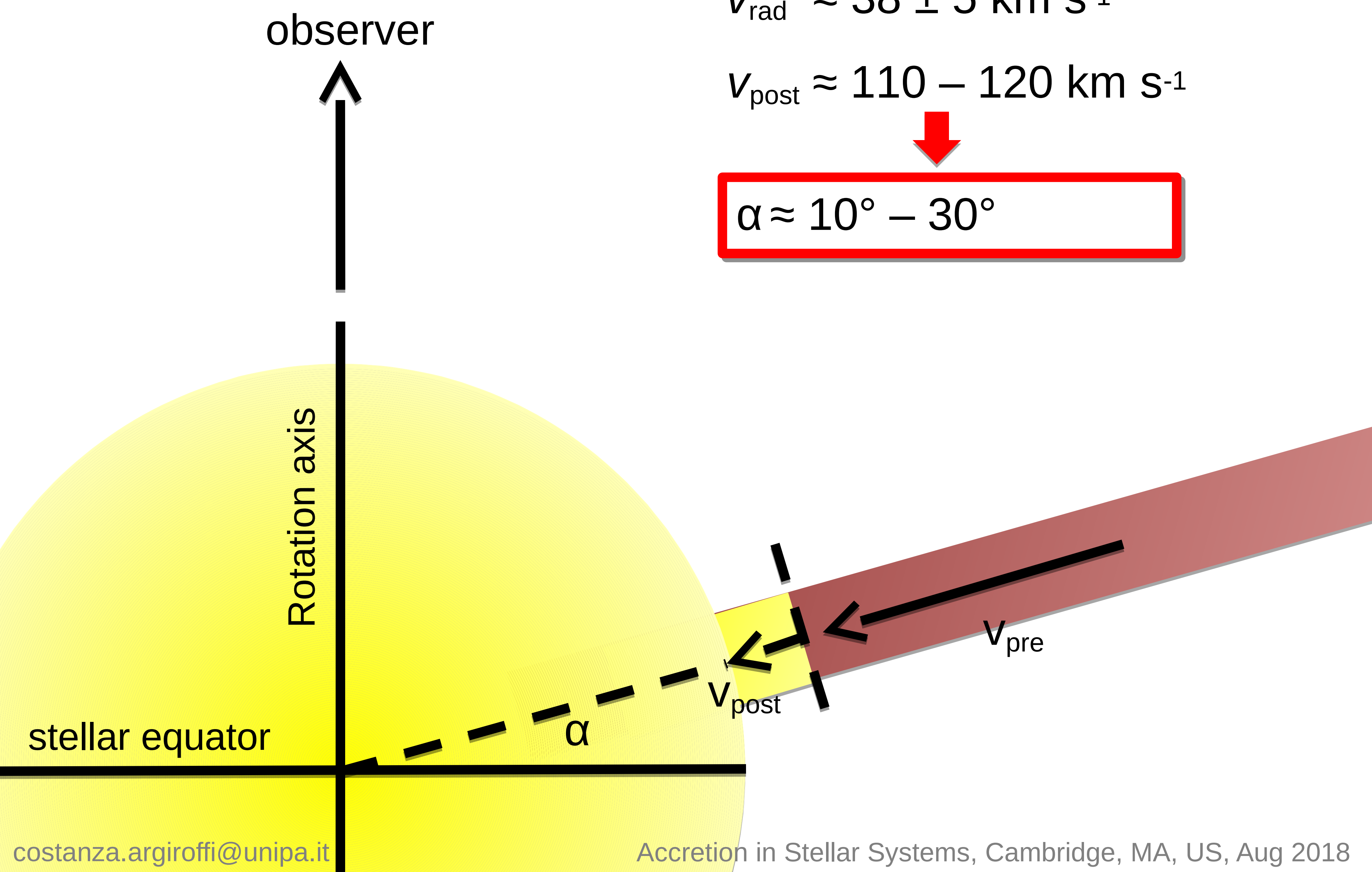
Brickhouse et al. 2010

2. THE STREAM TERMINATES AT LOW LATITUDE

$v_{rad} \approx 38 \pm 5$ km s^{-1}

$v_{post} \approx 110 - 120$ km s^{-1}

$\alpha \approx 10° - 30°$



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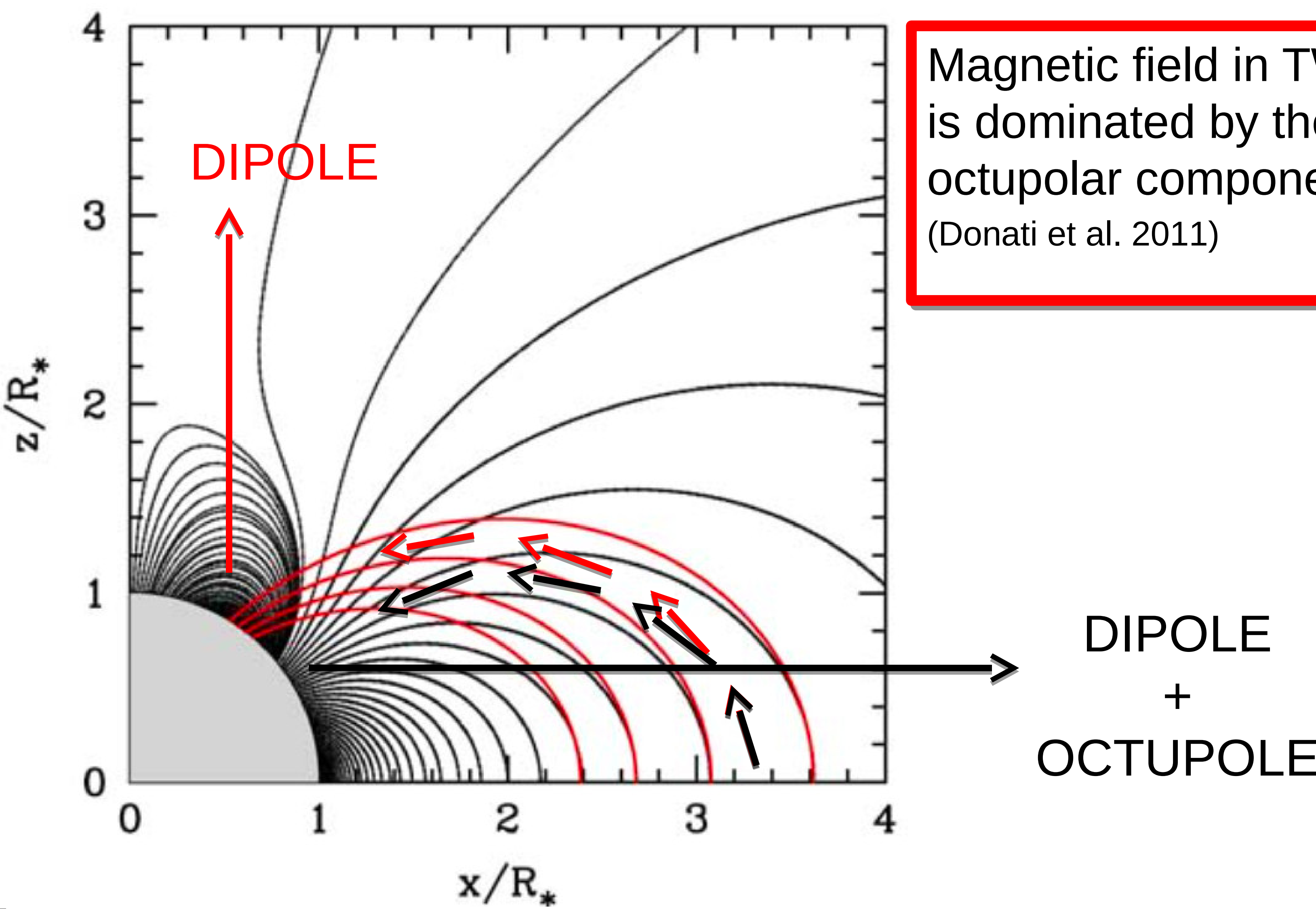
DOPPLER SHIFT TO CONSTRAIN ACCRETION GEOMETRY



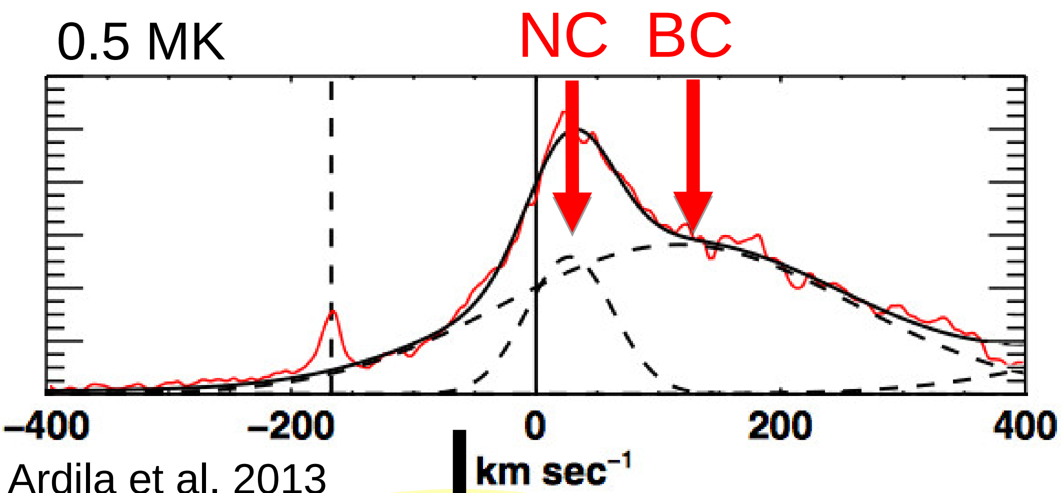
Magnetic field in TW Hya is dominated by the octupolar component
(Donati et al. 2011)

Gregory et al. 2006, Gregory et al. 2011

3. SOFT X-RAYS AND UV ORIGINATE IN THE SAME LOW-LATITUDE ACCRETION SHOCK

C IV @ 1550 Å

0.5 MK

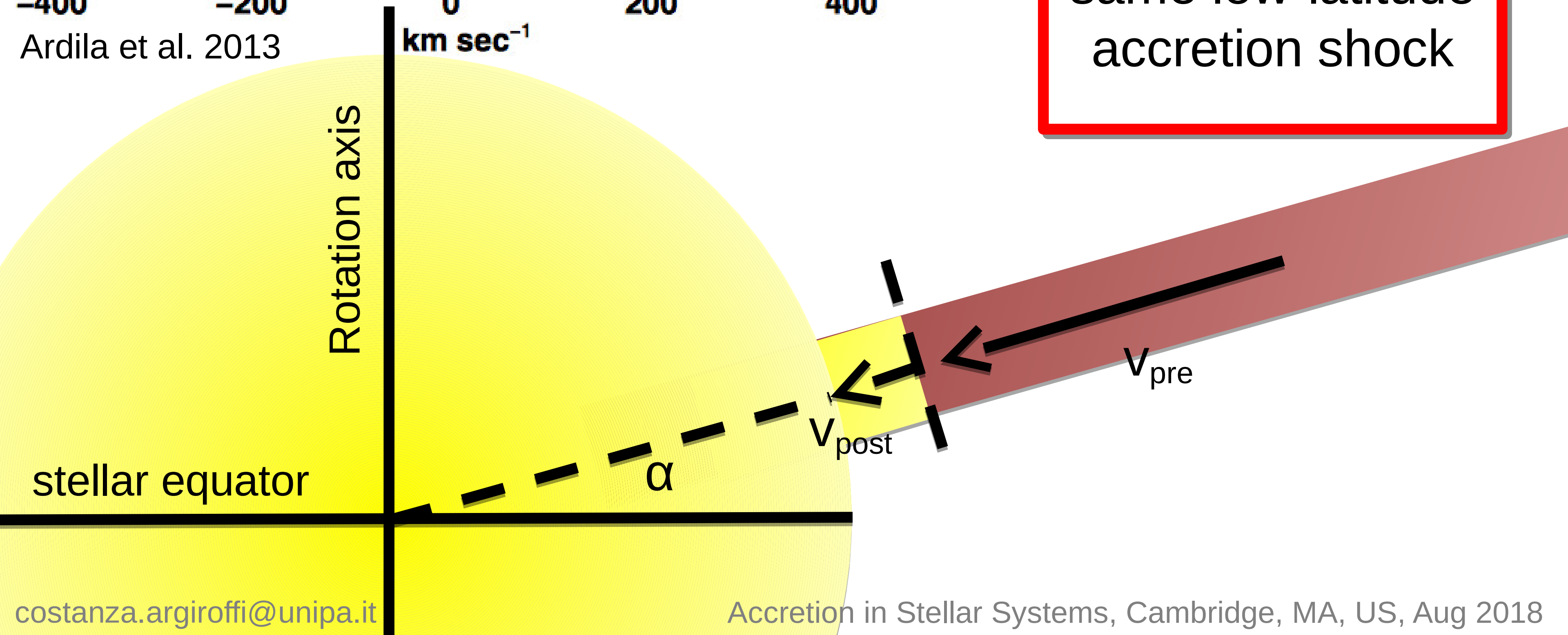


Ardila et al. 2013

$v_{NC\text{-}UV} \approx 30$ km s^{-1}

$v_X \approx 40$ km s^{-1}

same low-latitude accretion shock



CONCLUSIONS

The detected redshifted X-rays indicate that:

- soft X-rays entirely come from the post-shock region, as predicted by MHD simulations,
- the observed accretion shock is located at low latitude,
- soft X-rays and NC of UV lines likely originate in the same post-shock region,
- Chandra/HETGS absolute wavelength calibration allows velocity measurements down to ≈ 10-20 km s^{-1}.

Argiroffi et al. 2017, A&A, 607, 14A