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Multiwavelength Observations of AE Aqr

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C. W. Mauche (*LLNL*),

M. Abada-Simon (*Obs. de Paris*),

J.-F. Desmurs (*Obs. Astro. Nacional, Spain),*

M. J. Dulude (*SDSU/STScI*),

Z. Ioannou (*Univ. of Crete*),

J. D. Neill (*CalTech),*

A. Price (*AAVSO*),

N. Sidro (*Inst. for High Energy Phys., Barcelona*),

W. F. Welsh (*SDSU*), and members of the CBA and AAVSO

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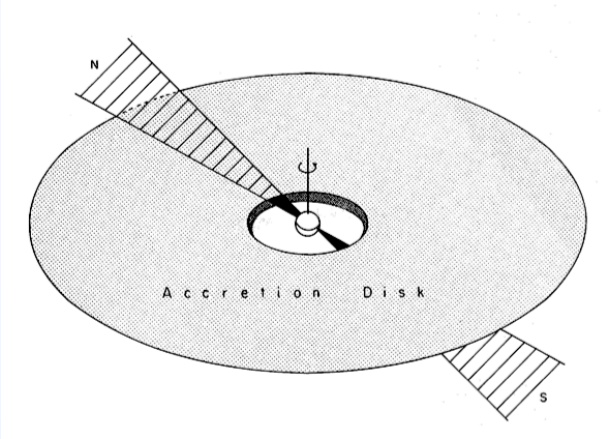
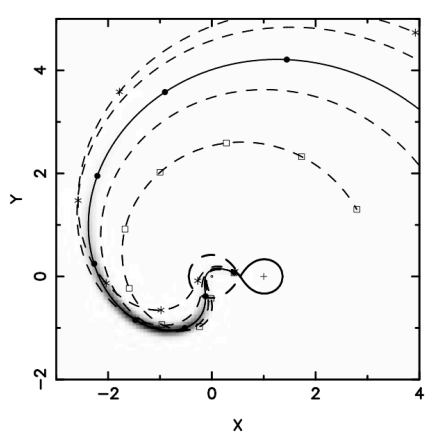
AE Aqr: many things to many people

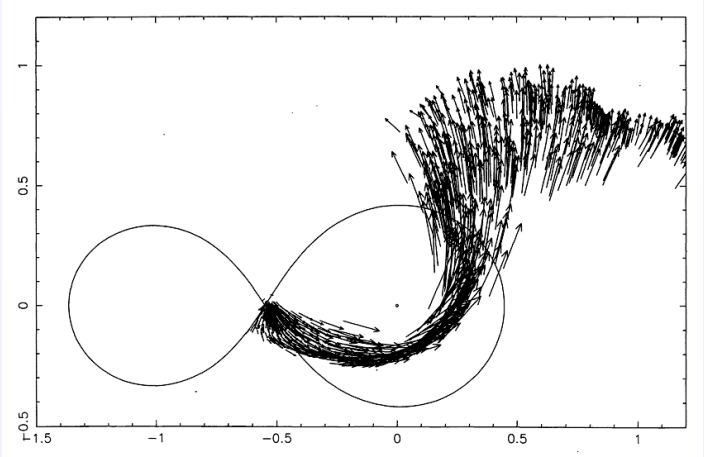
Patterson (1979): Oblique Rotator



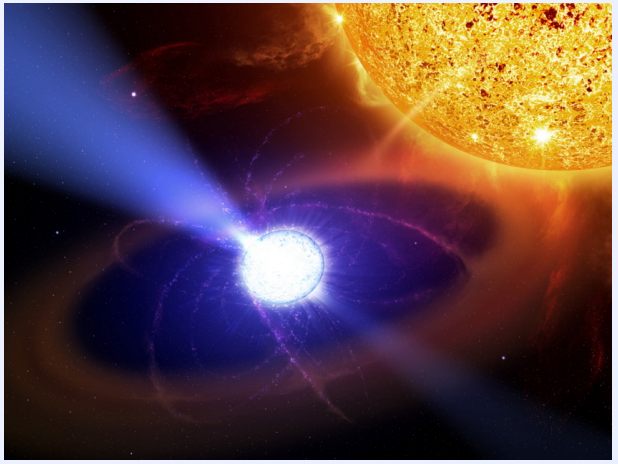
E&H (1996), WHG (1998): Magnetic propeller



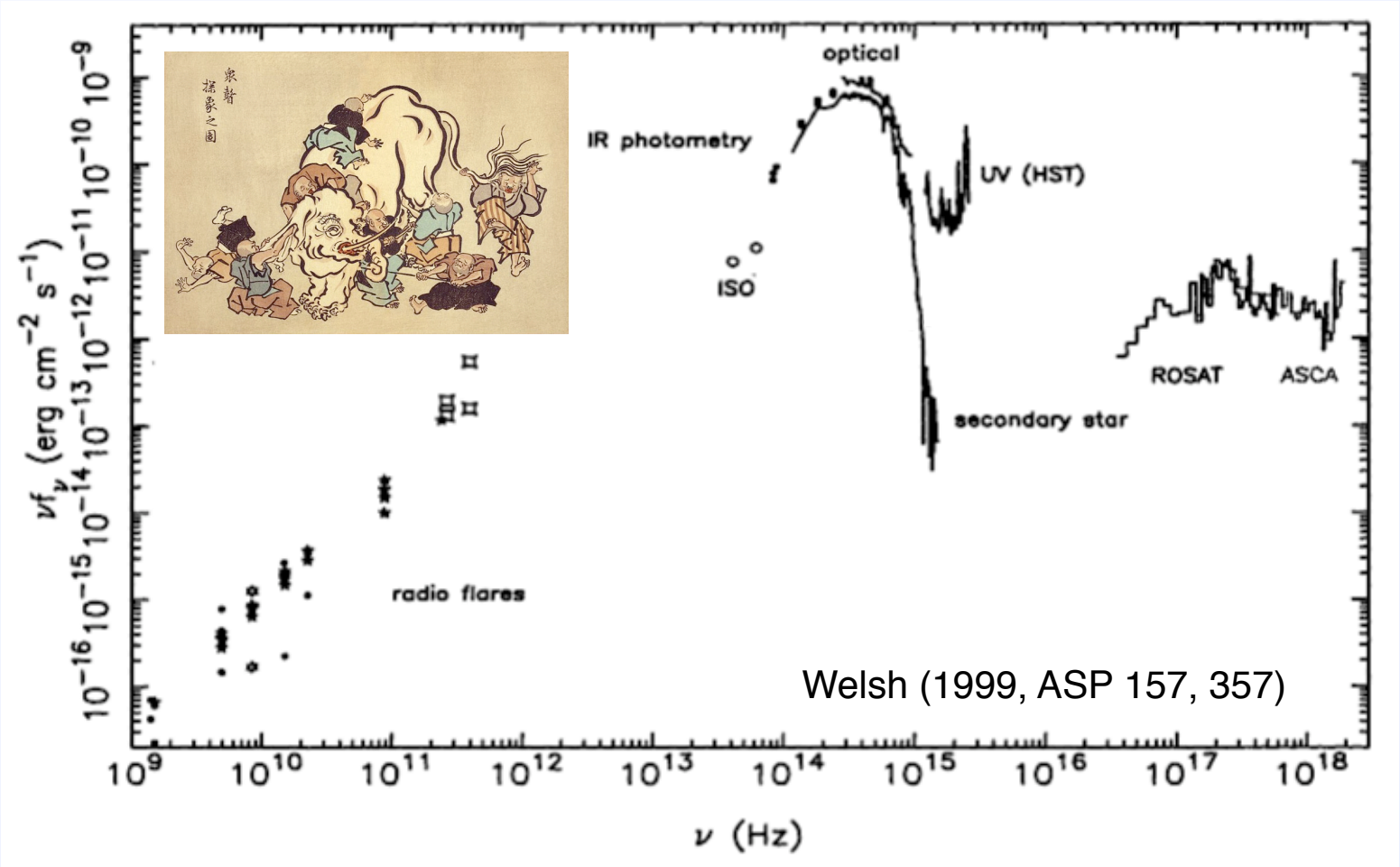
WKH (1997): Diamagnetic Blobs



Terada et al. (2008): Cosmic Ray Accelerator

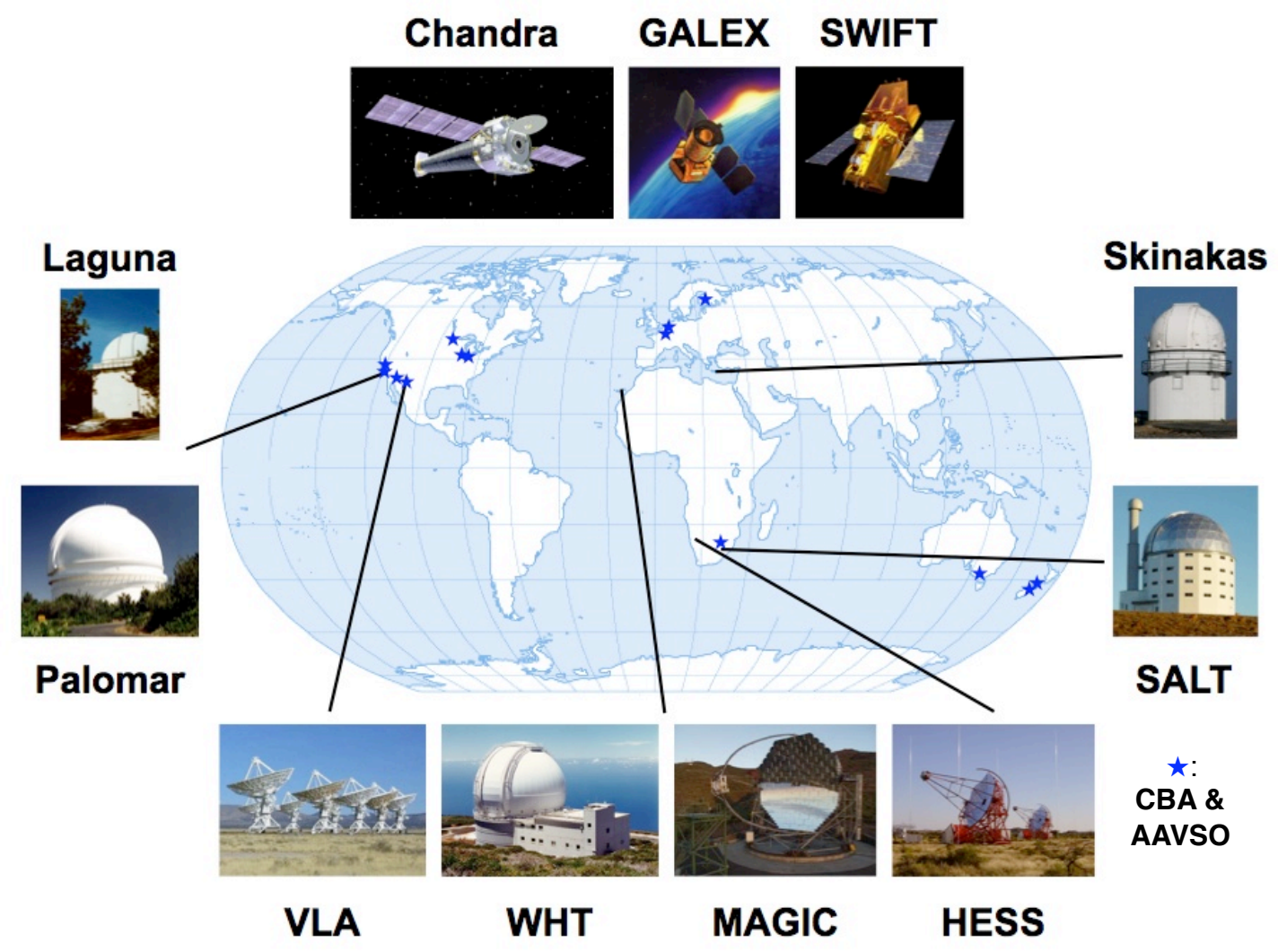


AE Aqr: the proverbial blind men and an elephant*

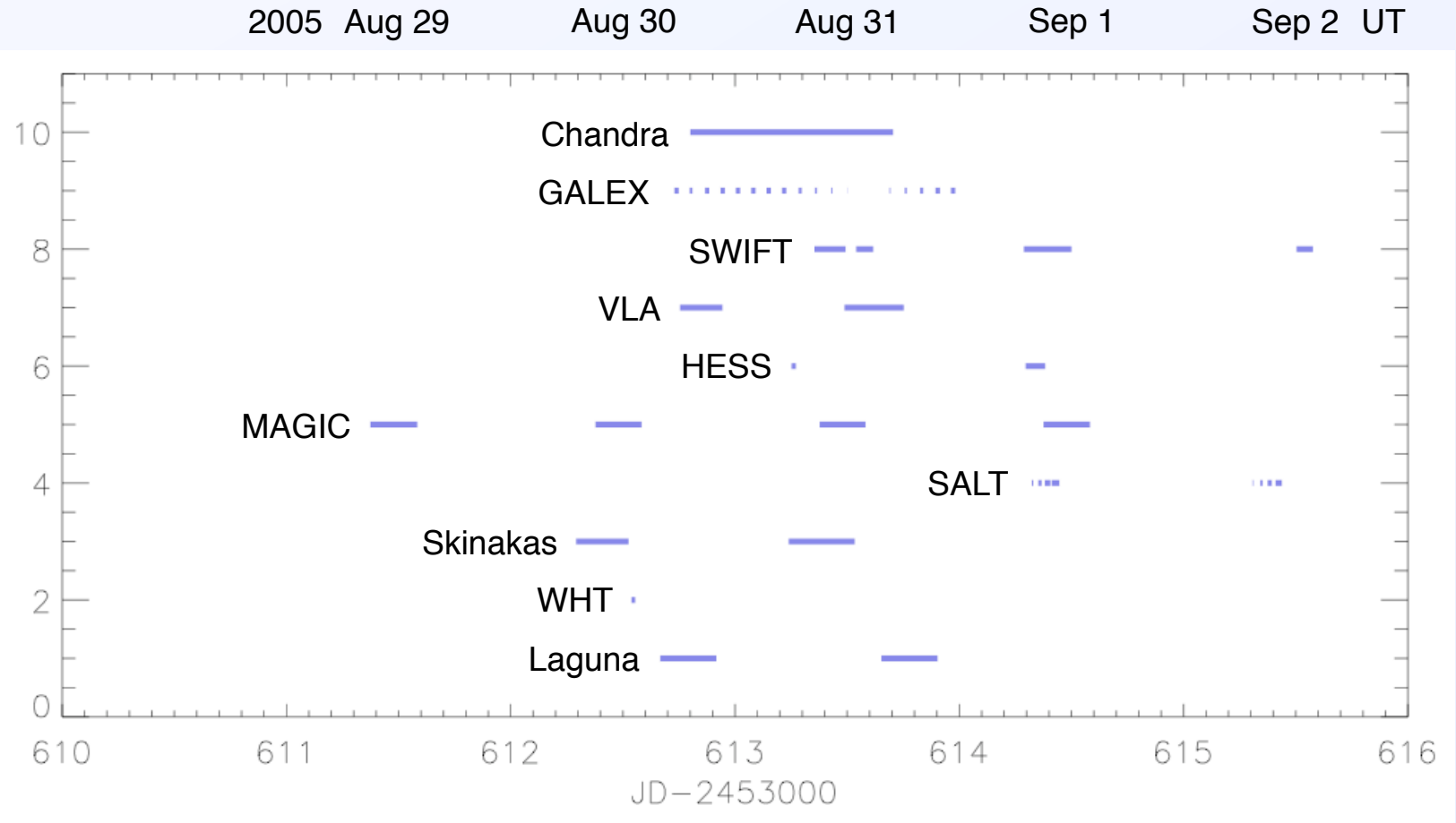


*Wikipedia: “The story is used to indicate that reality may be viewed differently depending upon one's perspective, suggesting that what seems an absolute truth may be relative due to the deceptive nature of half-truths.” [Insert: Hanabusa Itchō. ~1700]

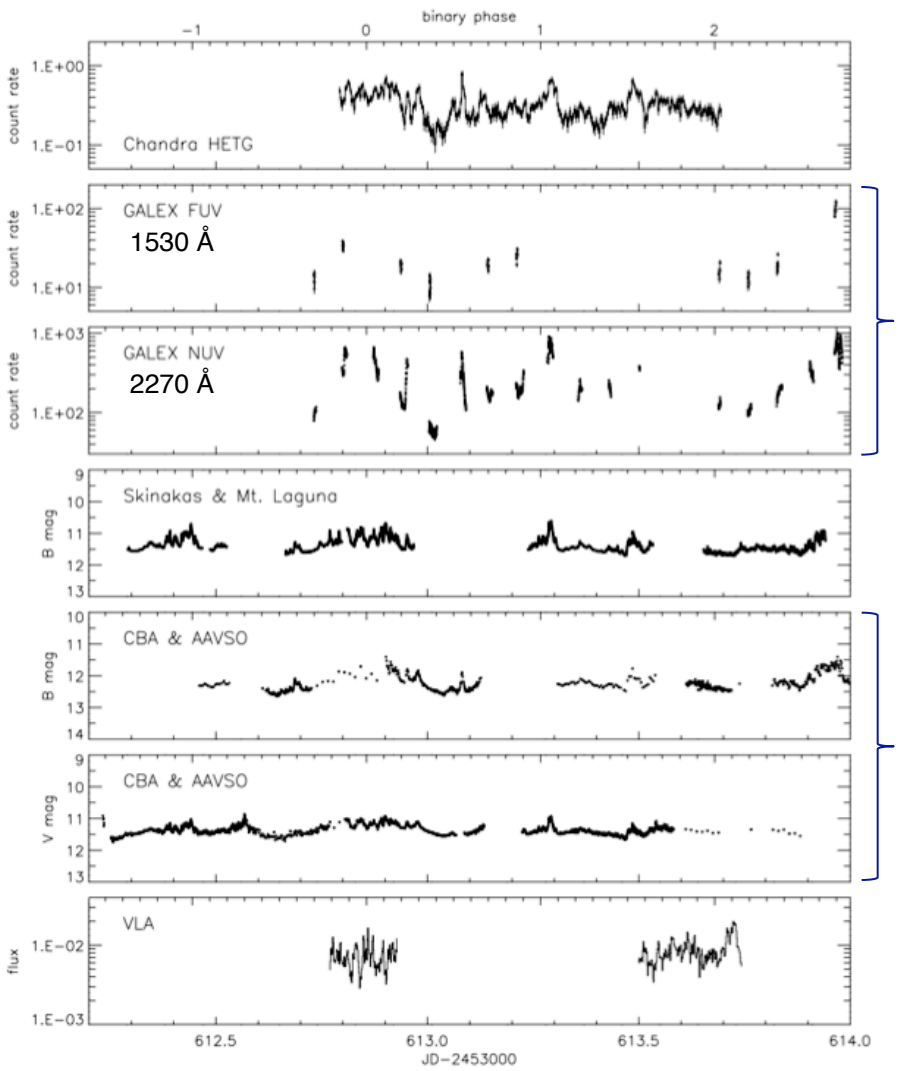
2005 multiwavelength campaign: observatories



2005 multiwavelength campaign: timeline



2005 multiwavelength campaign: light curves



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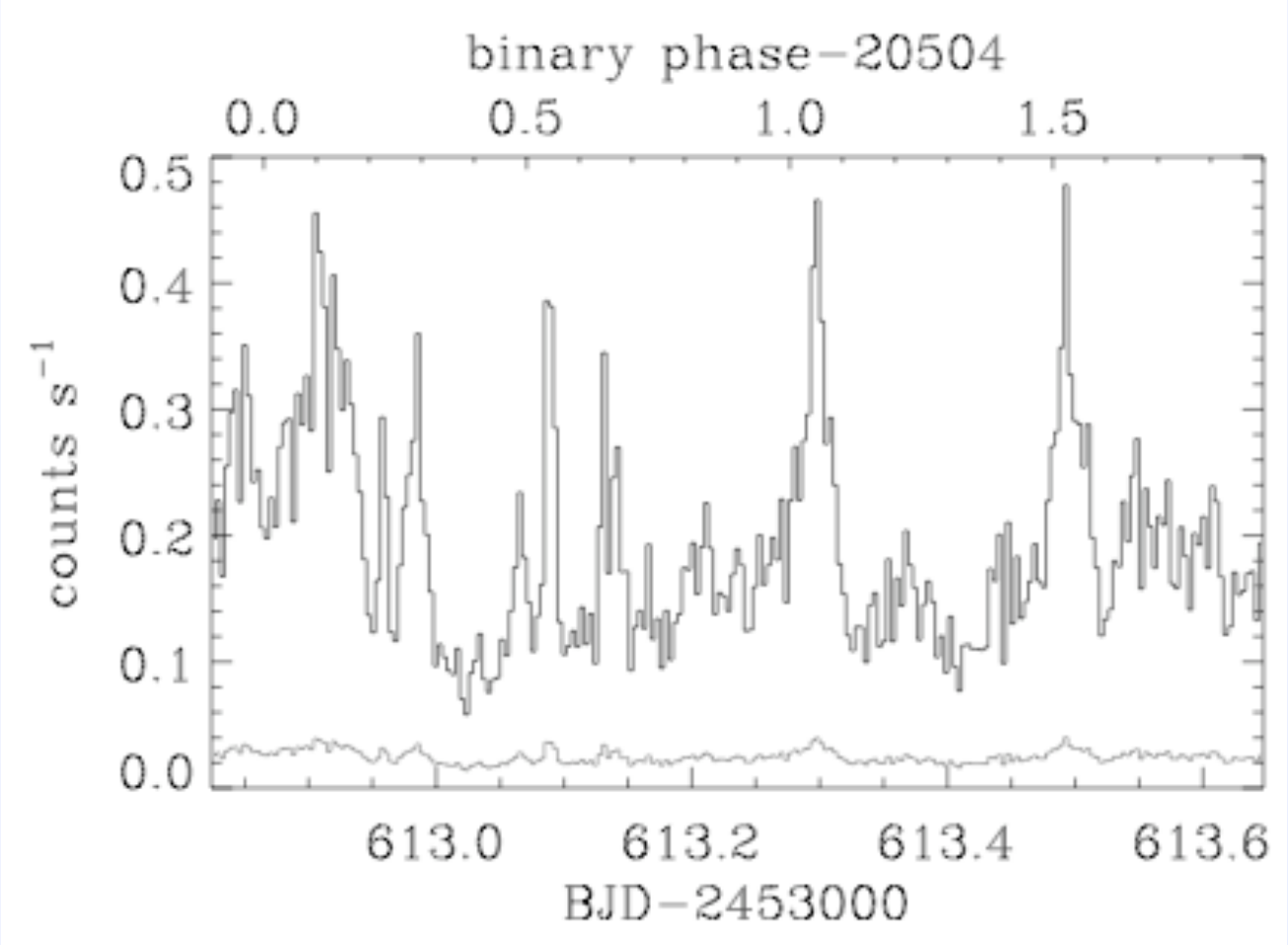
Correlated flares and the 33 s white dwarf spin pulse are observed in the optical through X-ray wavebands

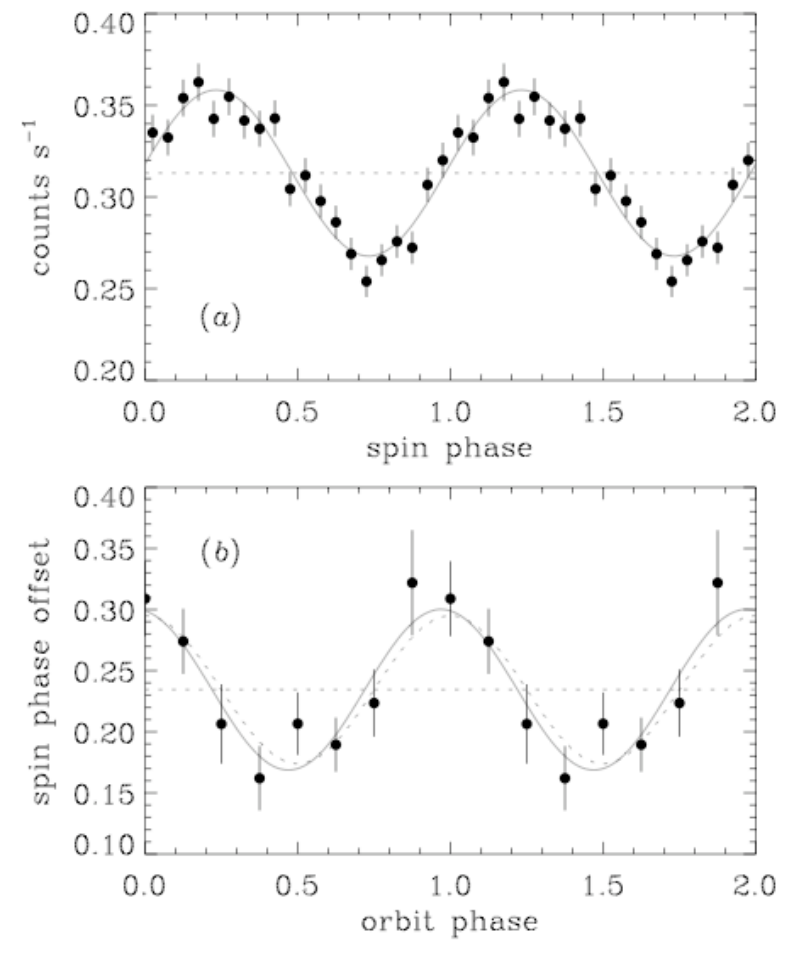
The radio light curve is uncorrelated with the other wavebands, implying that the radio flux is due to independent processes

Chandra HETG observation: light curve



Chandra HETG observation: spin pulse

Mauche (2006, MNRAS, 369, 1983)



Phase offset relative to the de Jager et al. spin ephemeris of 0.232 ± 0.011 cycles

➔ **White dwarf is spinning down at a rate that is slightly less than that predicted by the de Jager et al. (1994) quadratic ephemeris**

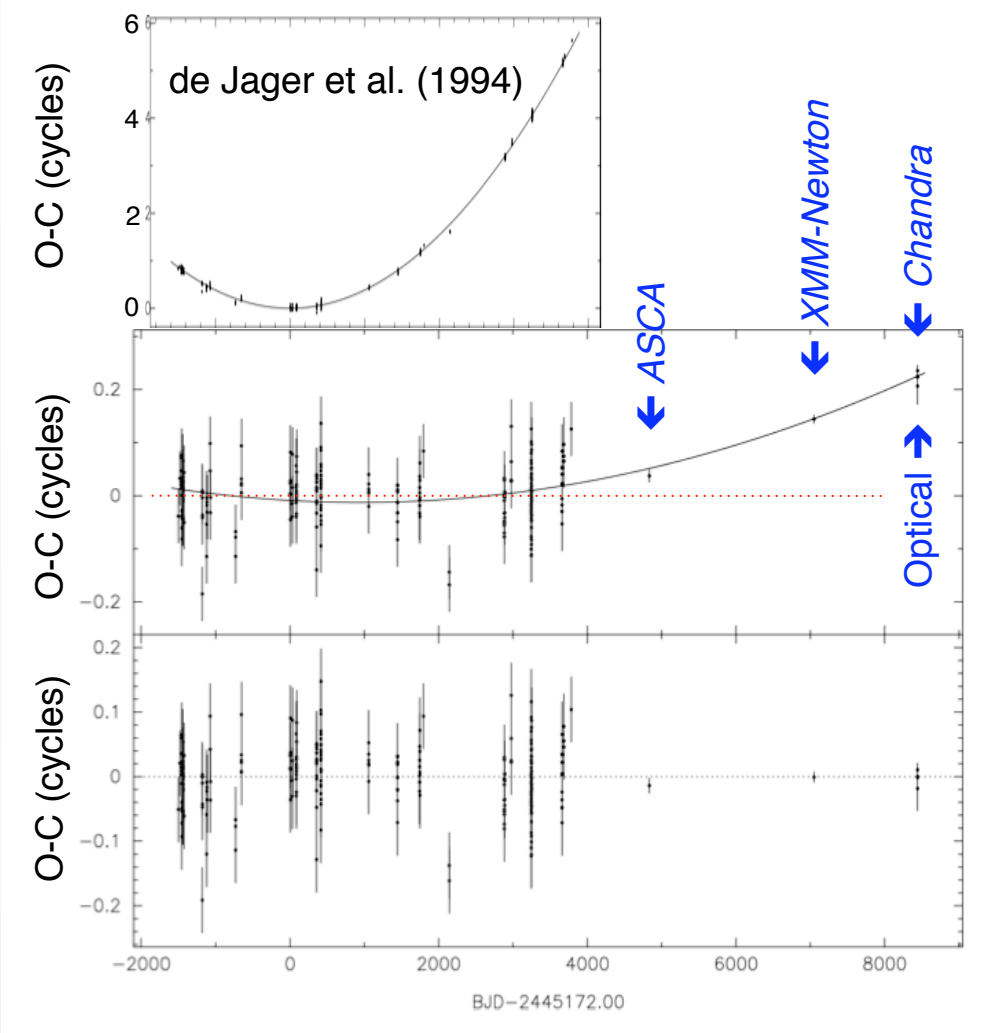
Spin phase offset variations correspond to a pulse time delay of $a \sin i = 2.17 \pm 0.48$ s*

➔ **X-ray source follows the motion of the white dwarf around the binary center of mass**

*A similar result was derived by de Jager (1995)

Spin evolution

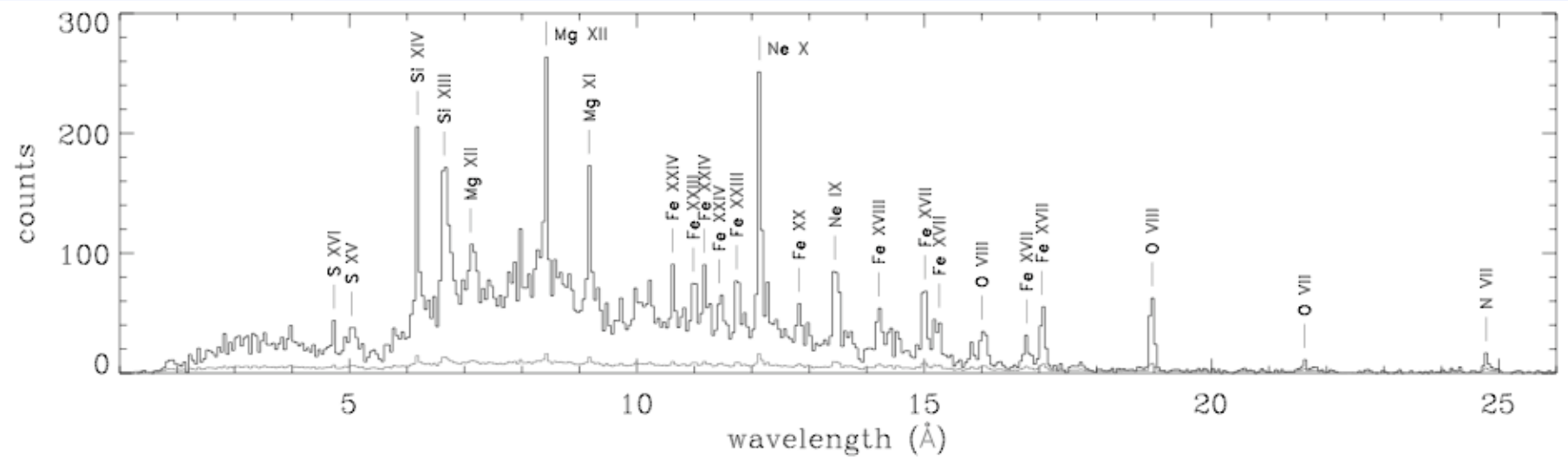
Mauche (2006, MNRAS, 369, 1983); Dulude (2009, SDSU Masters thesis)



Optical photometry acquired during the campaign confirm the trend away from the de Jager et al. (1994) quadratic spin ephemeris

Chandra HETG observation: spectrum

Mauche (2009, ApJ, submitted)

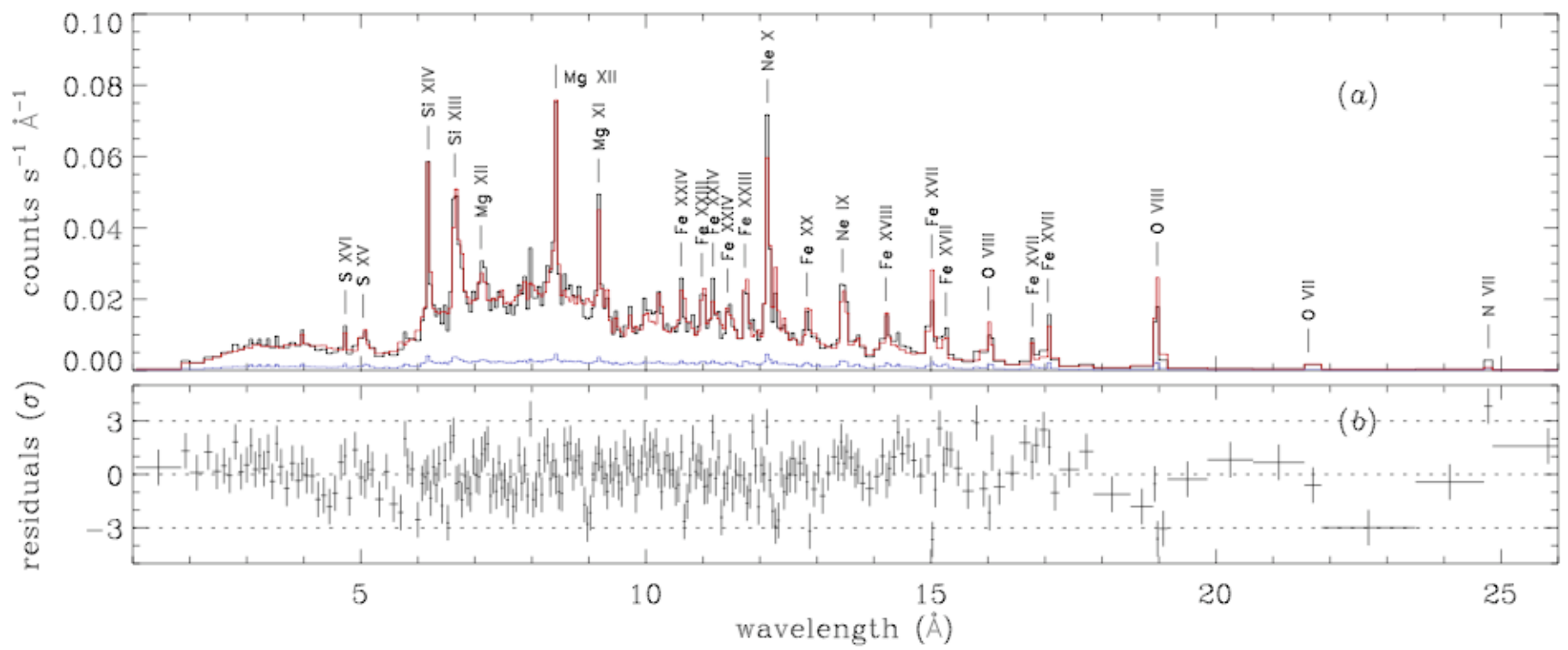


Lines from H- and He-like O, Ne, Mg, Si, and S plus Fe L-shell ions: multi-temperature thermal plasma

Lines are broad: widths increase with line energy from 510 km s^{-1} for O VIII to 820 km s^{-1} for Si XIV

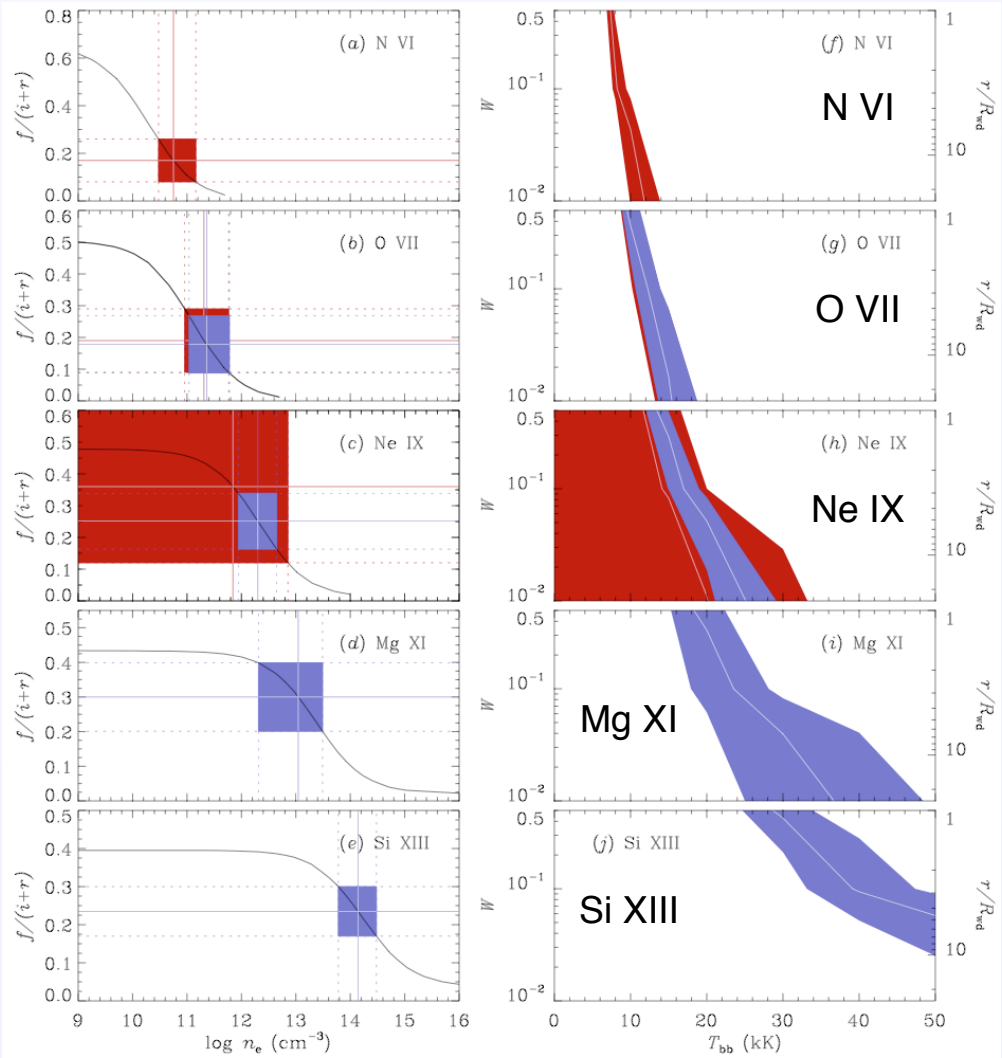
Chandra HETG observation: spectrum

Mauche (2009, ApJ, submitted)



Spectrum is reasonably well fit by a Gaussian emission measure distribution with a peak at log T(K) = 7.16, a width σ = 0.48, Fe/Fe$_\odot$ = 0.44, other metals $Z/Z_\odot$ = 0.76, EM = 8x10^{53} cm^{-3}, and L_x = 1x10^{31} (d/100 pc)^2 erg s^{-1}

Chandra HETG observation: He-like triplet *f*/(*i*+*r*) line ratios



Red: *XMM-Newton* RGS*
Blue: *Chandra* HETG

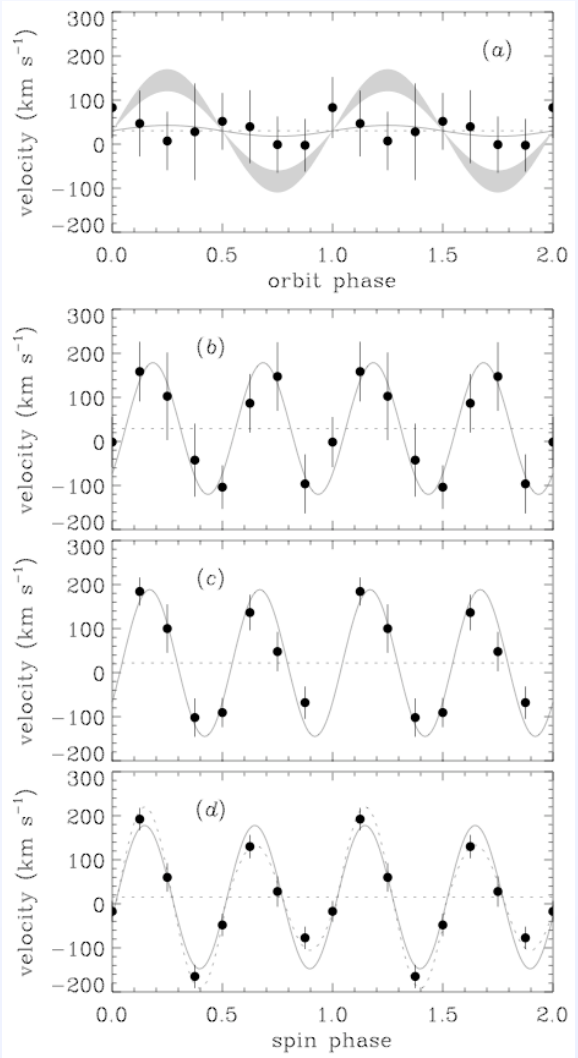
Left: Density increases with temperature from $n_e \sim 6 \times 10^{10}$ cm^{-3} for N VI to $n_e \sim 1 \times 10^{14}$ cm^{-3} for Si XIII

Right: Photoexcitation can mimic high densities, but (at least for the high Z elements) high T_{bb} and/or large dilution factors are required to explain the observed ratios

➔X-ray plasma is of high density and/or in close proximity to the white dwarf

*Itoh et al. (2006, ApJ, 639, 397)

Chandra HETG observation: emission line radial velocities



Radial velocities don't appear to vary on the white dwarf orbit phase!

(a) composite line profile technique

➔ **This is an unexpected result, but differs from the predicted radial velocity of the white dwarf (gray shading) by only 2.3σ**

Radial velocities vary on the white dwarf 33 s spin phase, with two oscillations per cycle

(b) composite line profile technique
(c) cross-correlation technique
(d) boot-strapped cross-correlation technique

➔ **X-ray plasma is trapped on, and rotates with, the white dwarf's dipolar magnetic field**

Chandra HETG observation: summary

Mauche (2009, ApJ, submitted)

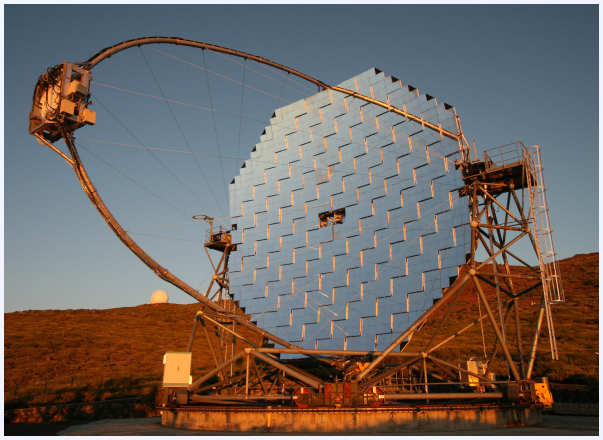
- The (pulsating component of the) source of X-rays in AE Aqr follows the motion of the white dwarf around the binary center of mass.
- Contrary to the conclusions of Itoh et al. (2006), the majority of the plasma in AE Aqr has a density $n_e > 10^{11}$ cm^{-3}, hence its spatial extent is orders of magnitude less than their estimate of 5×10^{10} cm.
- The radial velocity of the X-ray emission lines varies on the white dwarf 33 s spin phase, with two oscillations cycle and an amplitude $K \approx 160$ km s^{-1}, broadly consistent with plasma tapped, and rotating with, the white dwarf's dipolar magnetic field.
- These results are inconsistent with recent models* of an extended, low-density source of X-rays in AE Aqr, but instead support earlier models in which the dominant source of X-rays is of high density and/or in close proximity to the white dwarf.
- To paraphrase Bill Clinton, "*It's accretion, stupid.*"

*Itoh et al. (2006); Ikshanov (2006); Venter & Meintjes (2007)

MAGIC (TeV gamma-ray) observations

Sidro et al. (2008, 30*th* ICRC, **2**, 715)

- AE Aqr was observed with the 17 m MAGIC telescope on 4 consecutive nights, 2005 August 29−September 1, at zenith angles of 30^0−50^0, for a total of 15.5 hr.

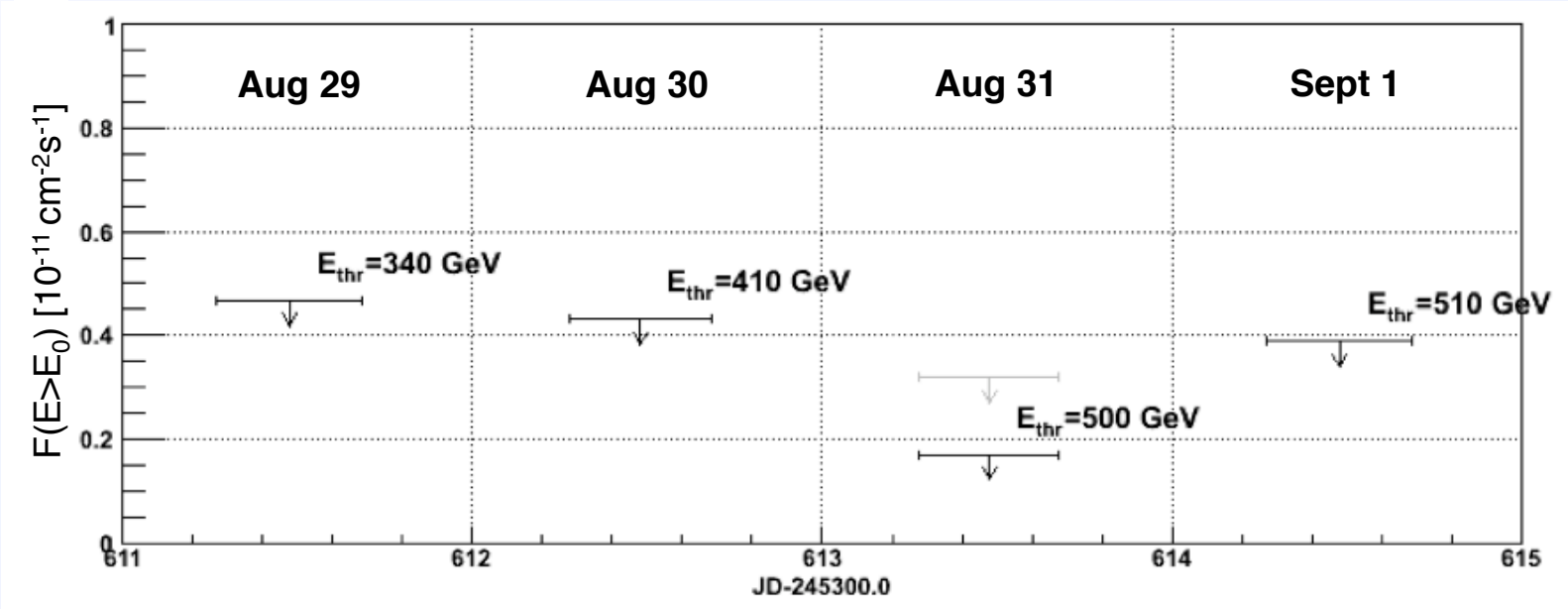


- Analysis of *each* of the 4 nights: **no steady excess emission.**
- Analysis of the *sum* of the 4 nights: **no steady excess emission.**
- Periodic analysis of each night, using (*a*) the Rayleigh test on frequencies around the pulse frequency ν_0 and $2\nu_0$ and (*b*) phase-folding on frequencies near ν_0 and $2\nu_0$: **no excess emission.**

MAGIC (TeV gamma-ray) observations

Sidro et al. (2008, 30*th* ICRC, **2**, 715)

No detections on *any* of the 4 nights:

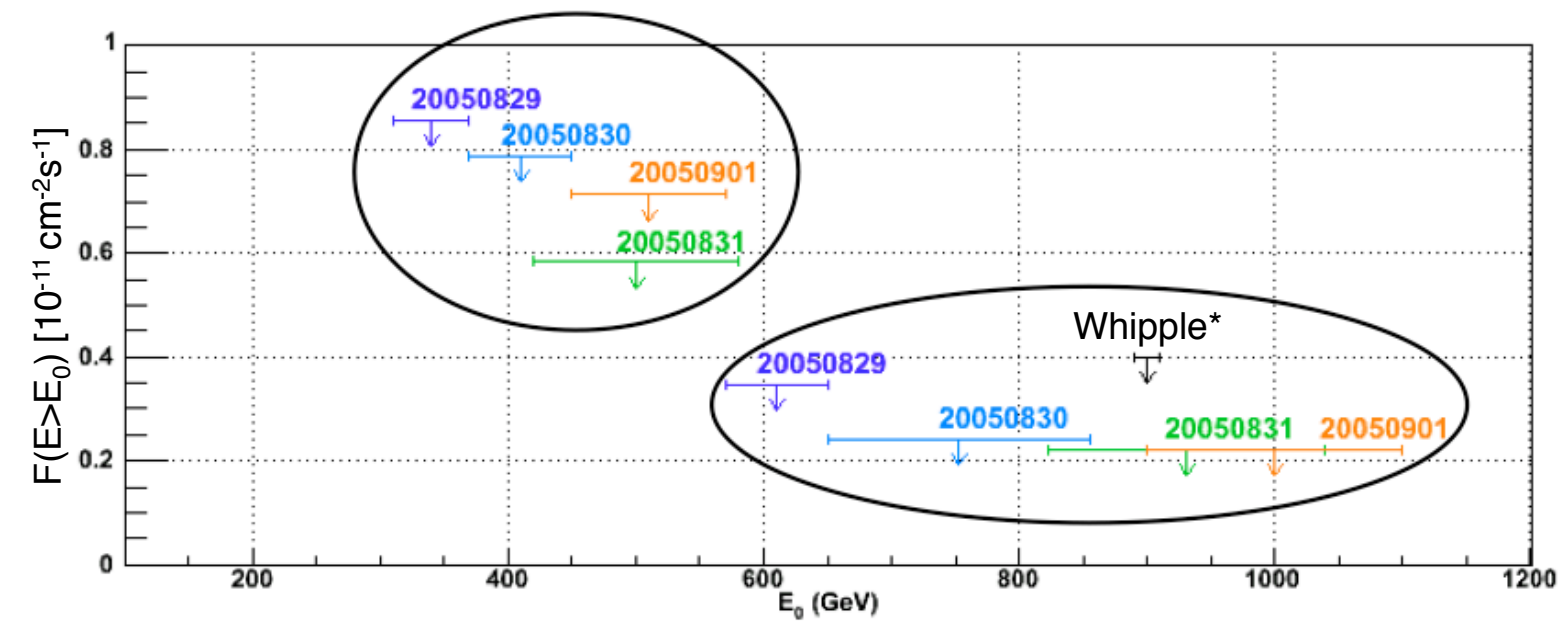


Upper limit of 4×10^{-12} photons cm^{-2} s^{-1} = 6.3×10^{-12} erg cm^{-2} s^{-1} or 8×10^{30} (d/100 pc)^2 erg s^{-1}, comparable to the 0.5–10 keV X-ray luminosity

MAGIC (TeV gamma-ray) observations

Sidro et al. (2008, 30*th* ICRC, **2**, 715)

No detections on the *sum* of the 4 nights:



I'd like to suggest the possibility that, contrary to previous claims and common belief, **AE Aqr is not a TeV gamma-ray source**

*Lang et al. (1998, Astroparticle Physics, 9, #3, 203)

Acknowledgements

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