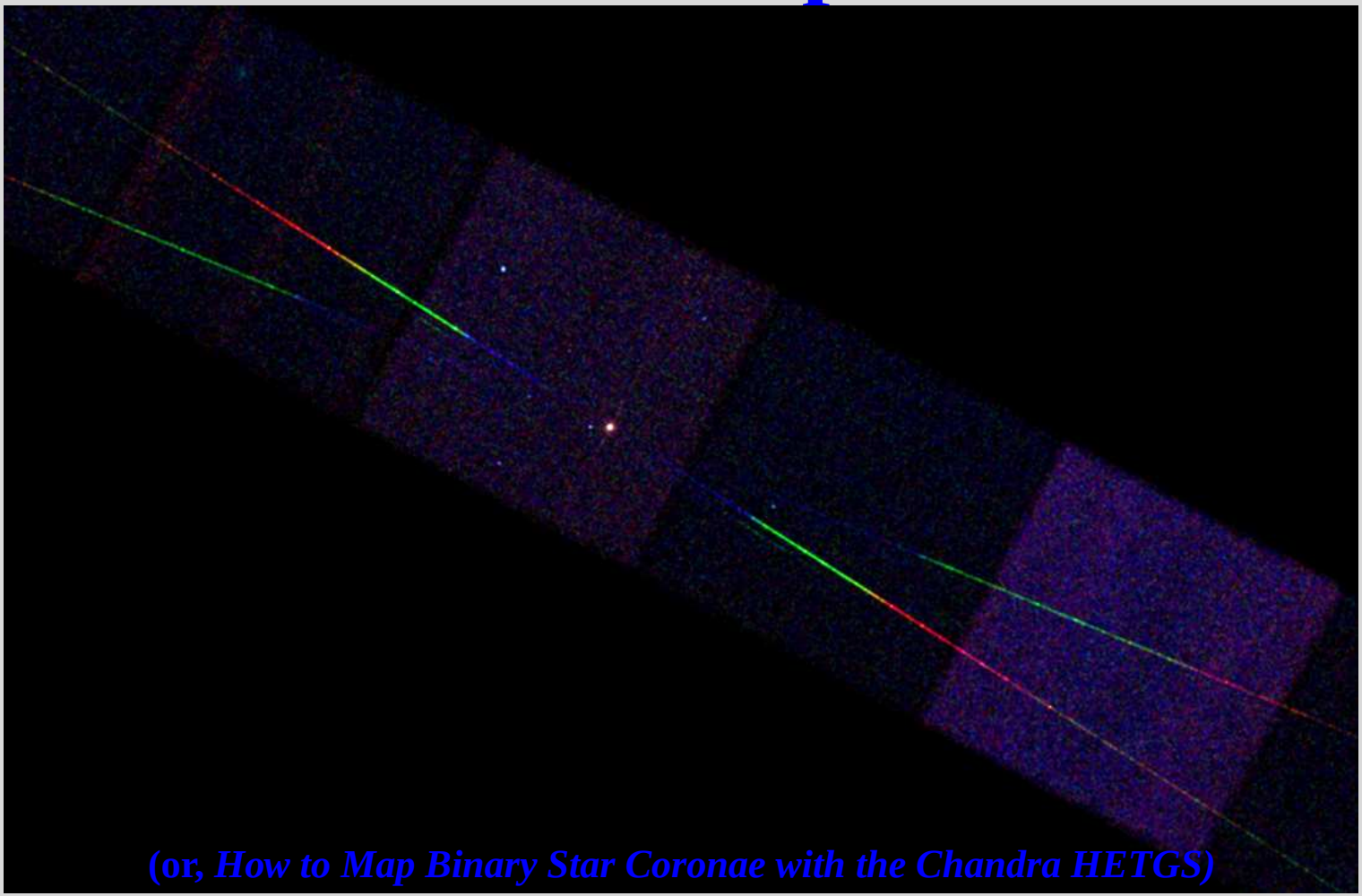
High Resolution Spectroscopy of the Super-saturated Contact Binary, VW Cep.



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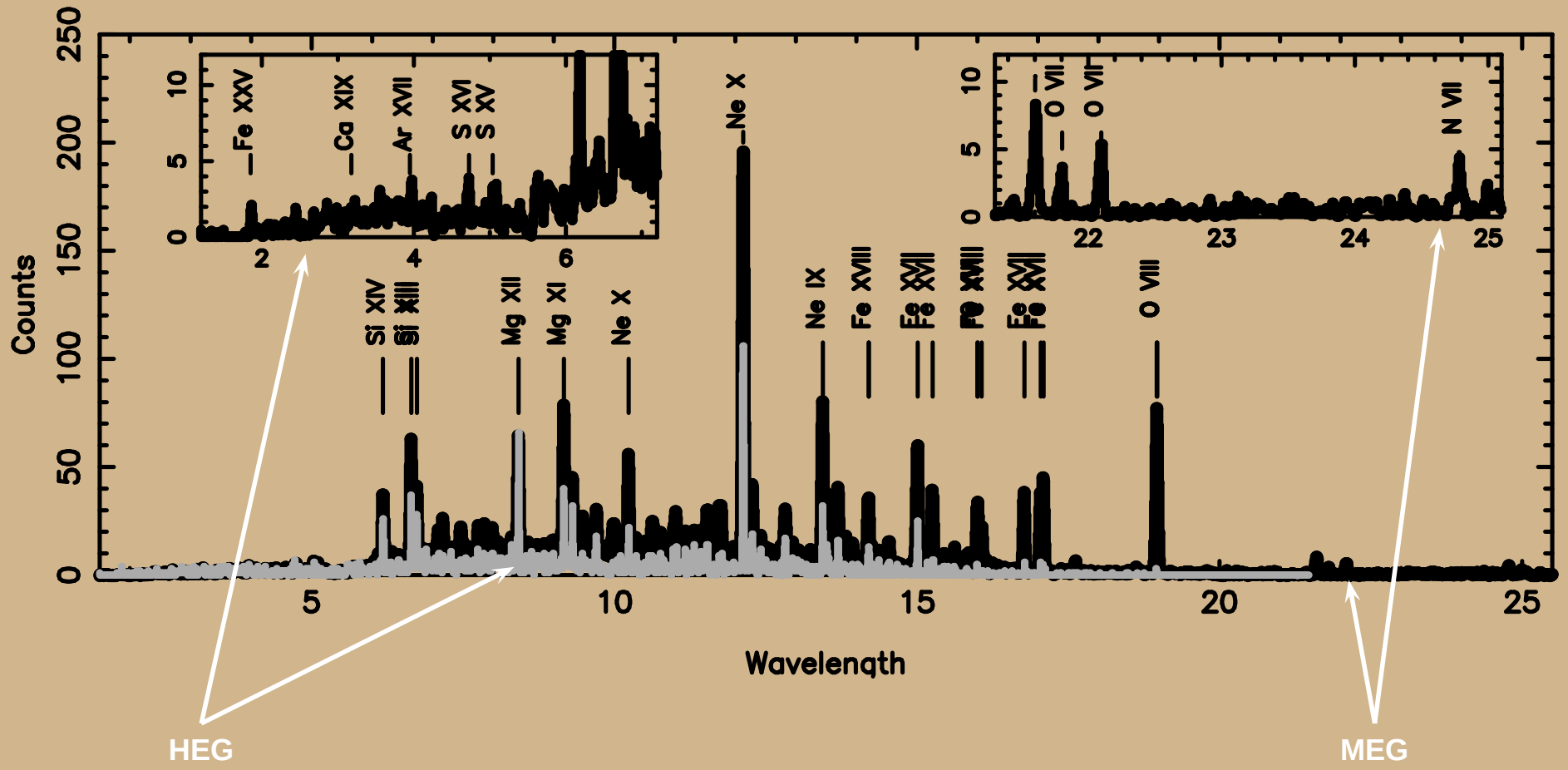
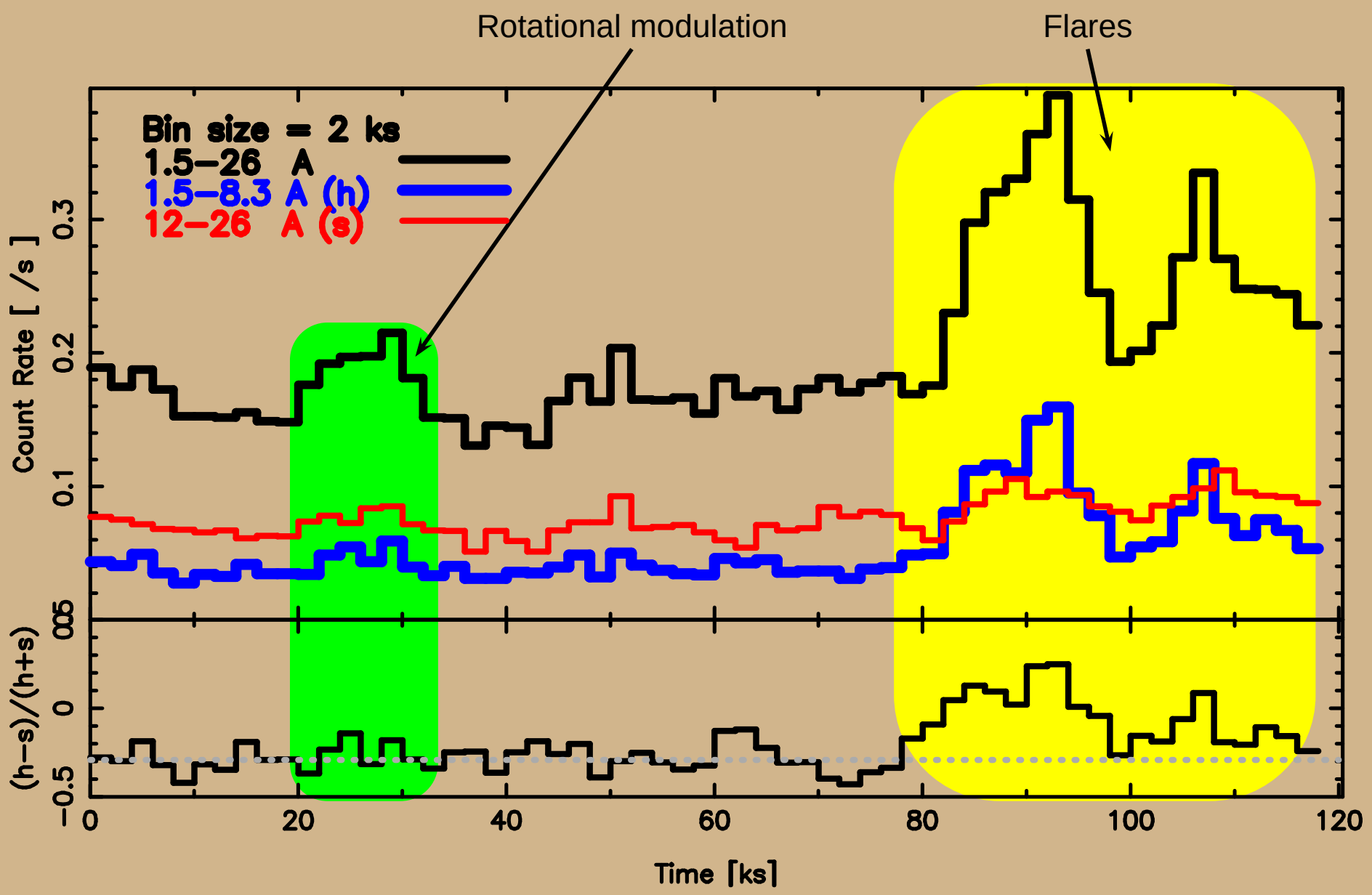
Abstract

Short-period binaries represent extreme cases in the generation of stellar coronae via a rotational dynamo. Such stars are important for probing the origin and nature of coronae in the regimes of rapid rotation and activity saturation. VW Cep ($P = 0.28$ d, 24 ks) is relatively bright, partially eclipsing, and very active object. Light curves made from Chandra HETGS data show flaring and rotational modulation, but no obvious eclipses. Velocity modulation of emission lines indicates that the larger, more massive component dominates the X-ray emission. The emission measure is highly structured, having three peaks. Helium-like triplet lines give electron densities of about 3×10^{10} to $3 \times 10^{11} \mathrm{cm}^{-3}$. The modulation, emission measure, and densities together suggest that the emitting structures are compact.

VW Cep Spectrum (120ks)



VW Cep X-ray Light Curve



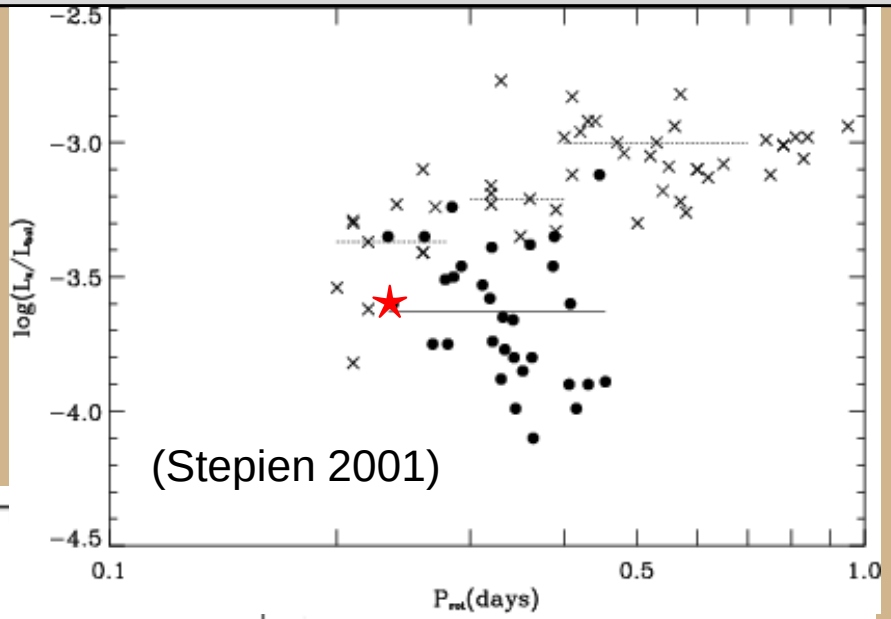
Period vs. Activity vs. (Super)Saturation

VW Cep: W UMa Type (contact) binary

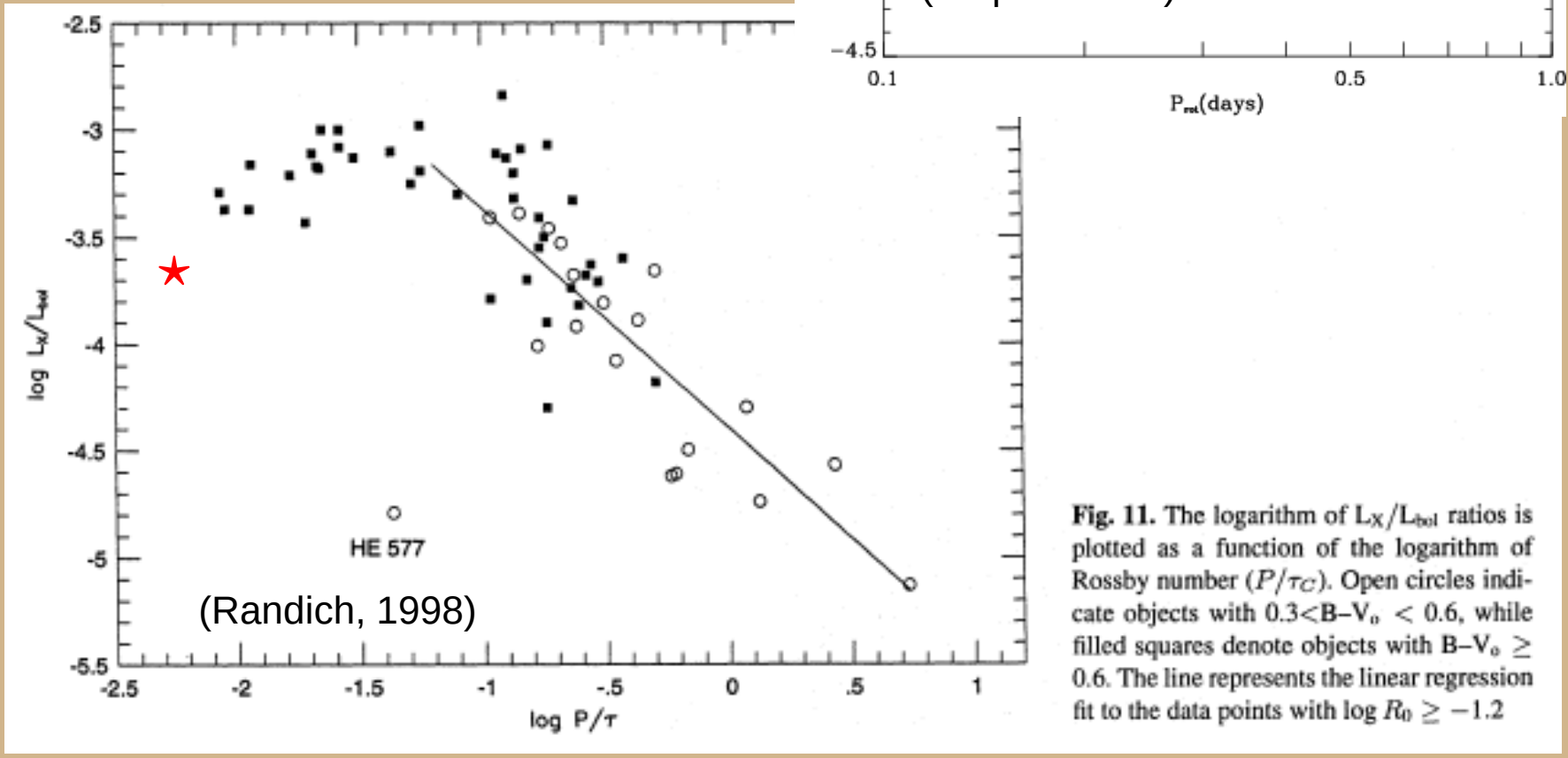
Period: 0.278 days (6.67 hr)

Mass Ratio: 0.39 (0.457 / 1.157)

Spectral Types: K0 V, G5 V



(Stepien 2001)

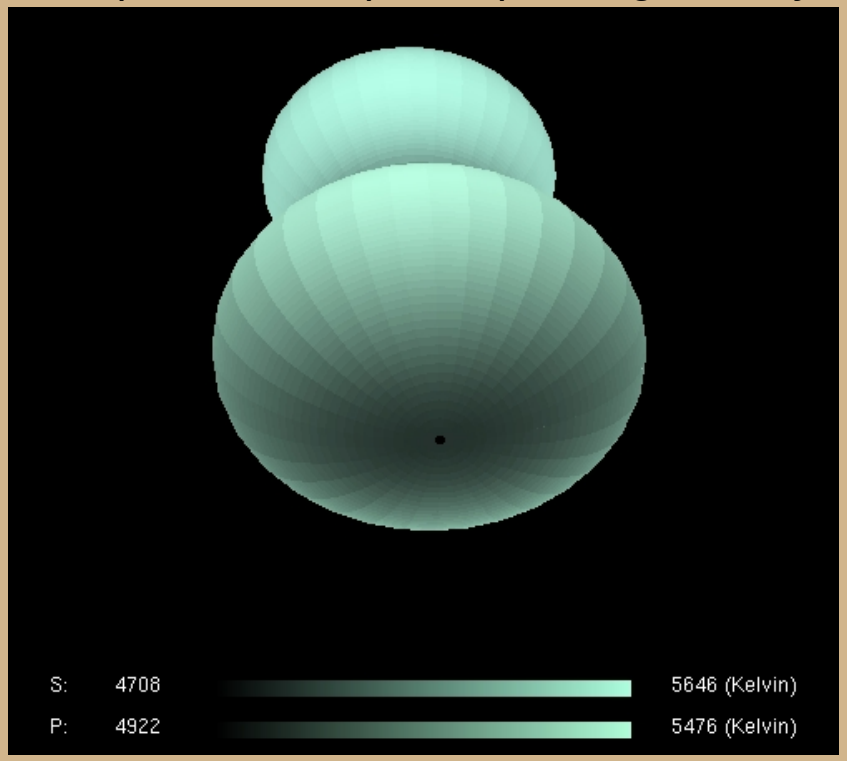


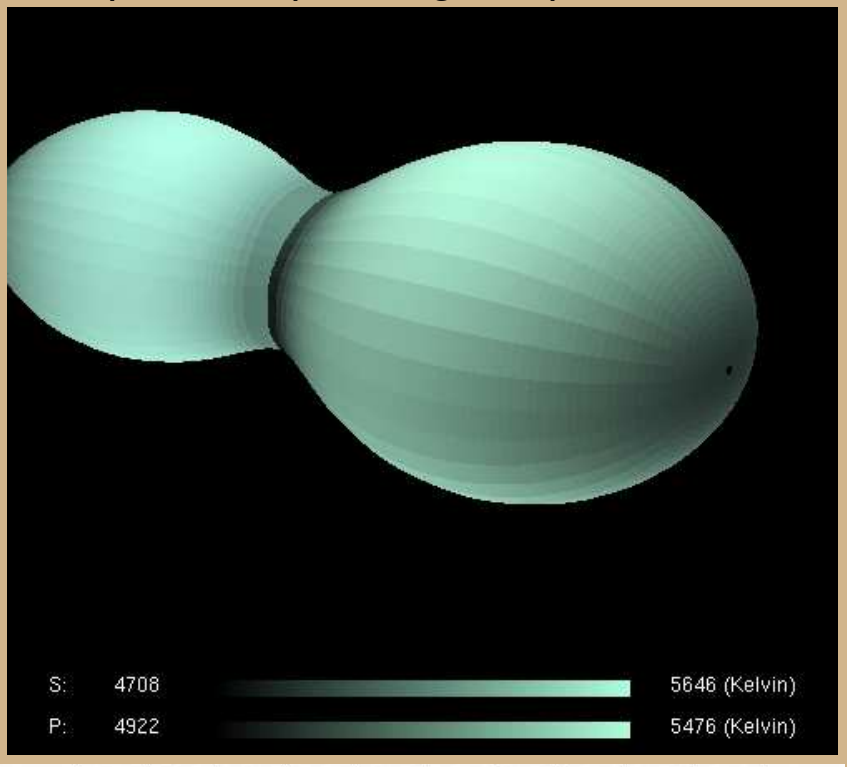
(Randich, 1998)

Fig. 11. The logarithm of L_X/L_{bol} ratios is plotted as a function of the logarithm of Rossby number (P/τ_C). Open circles indicate objects with $0.3<B-V_o<0.6$, while filled squares denote objects with $B-V_o \geq 0.6$. The line represents the linear regression fit to the data points with $\log R_0 \geq -1.2$

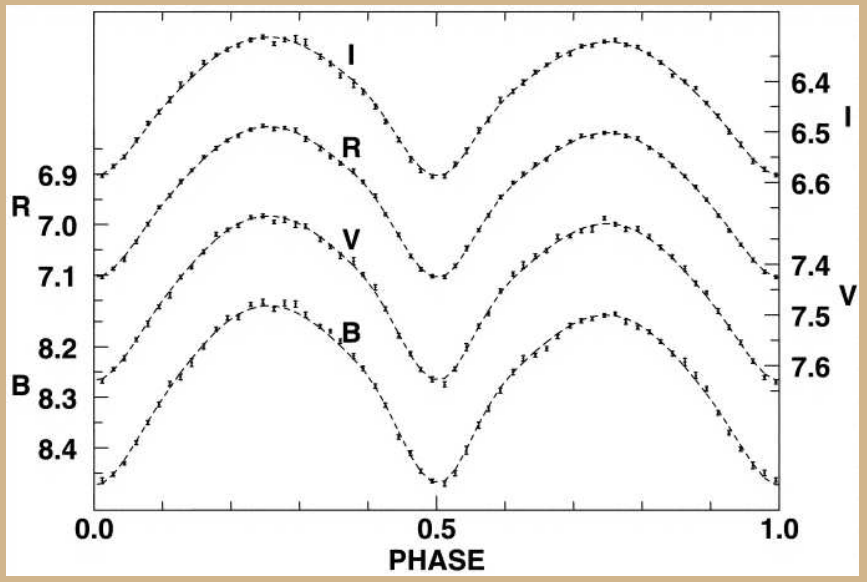
Contact Binaries

VW Cep schematic photospheric geometry and temperature (from *nightfall*).

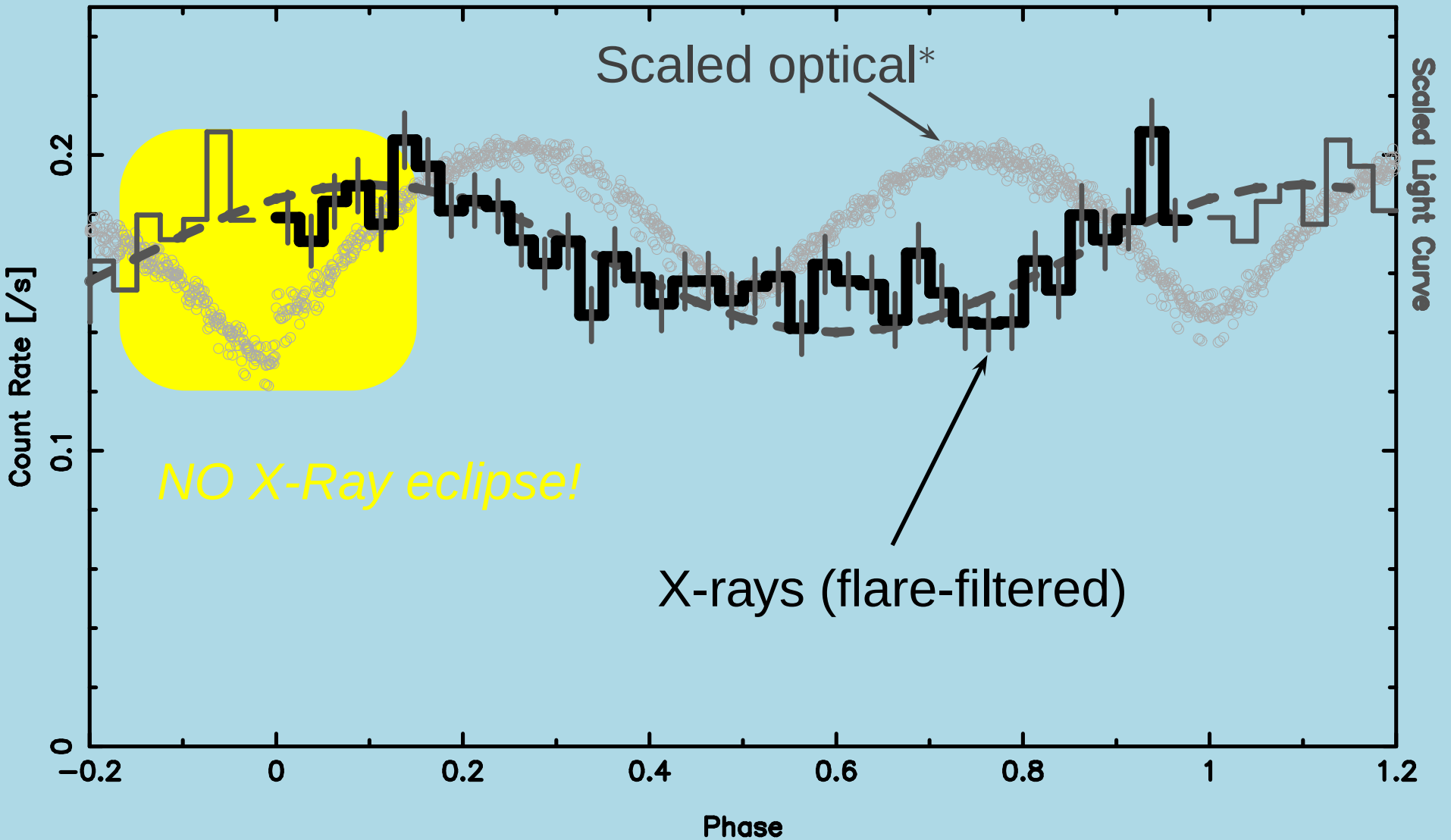




Typical W-type W UMa optical light curves.
(Hendry & Mochnacki 2000 ApJ 531, 467)

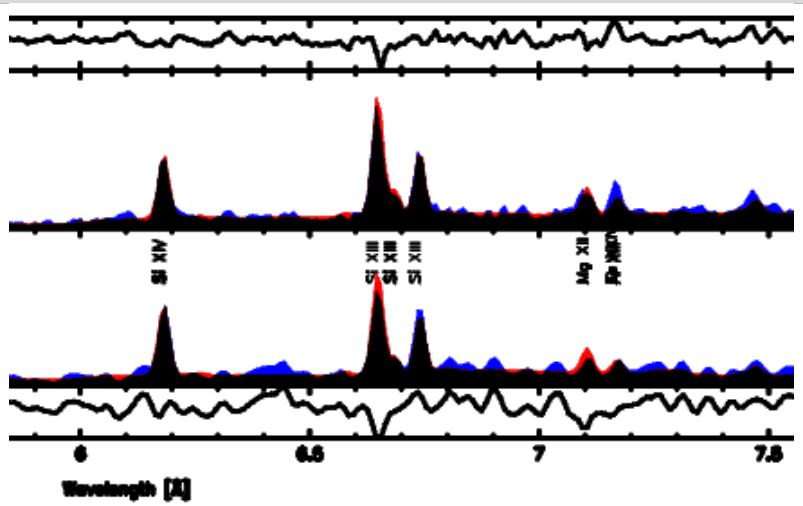


VW Cep Phased X-ray Light Curve



*Pribulla; http://www.astro.sk/∼pribulla/lc.html

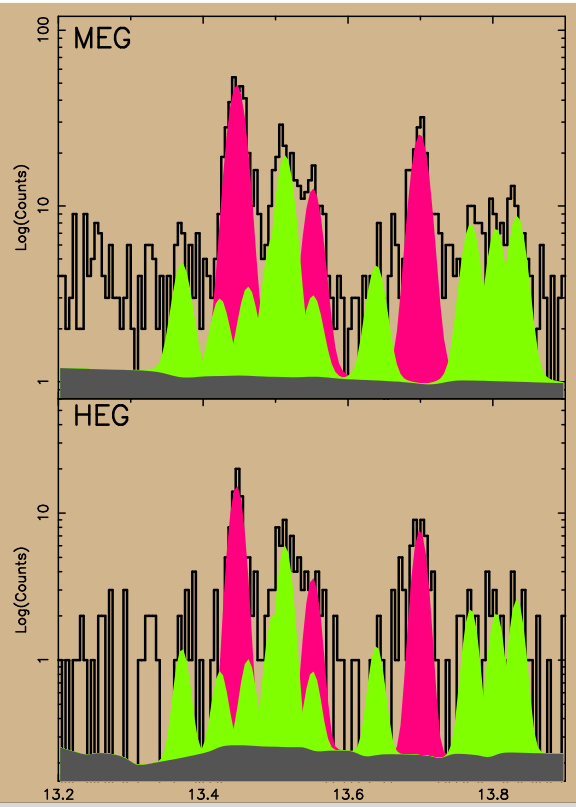
Plasma Volume, Density, & Geometry



Ne IX

Fe XIX-XX

Continuum



Fit Line Fluxes: $\rightarrow$

Emission measure

$N_e^2 \times Volume$

$(\sim 5 \times 10^{52} \mathrm{cm}^{-3})$

Fit Line Ratios:

Helium-like lines

(O VII, Ne IX, Mg XI)

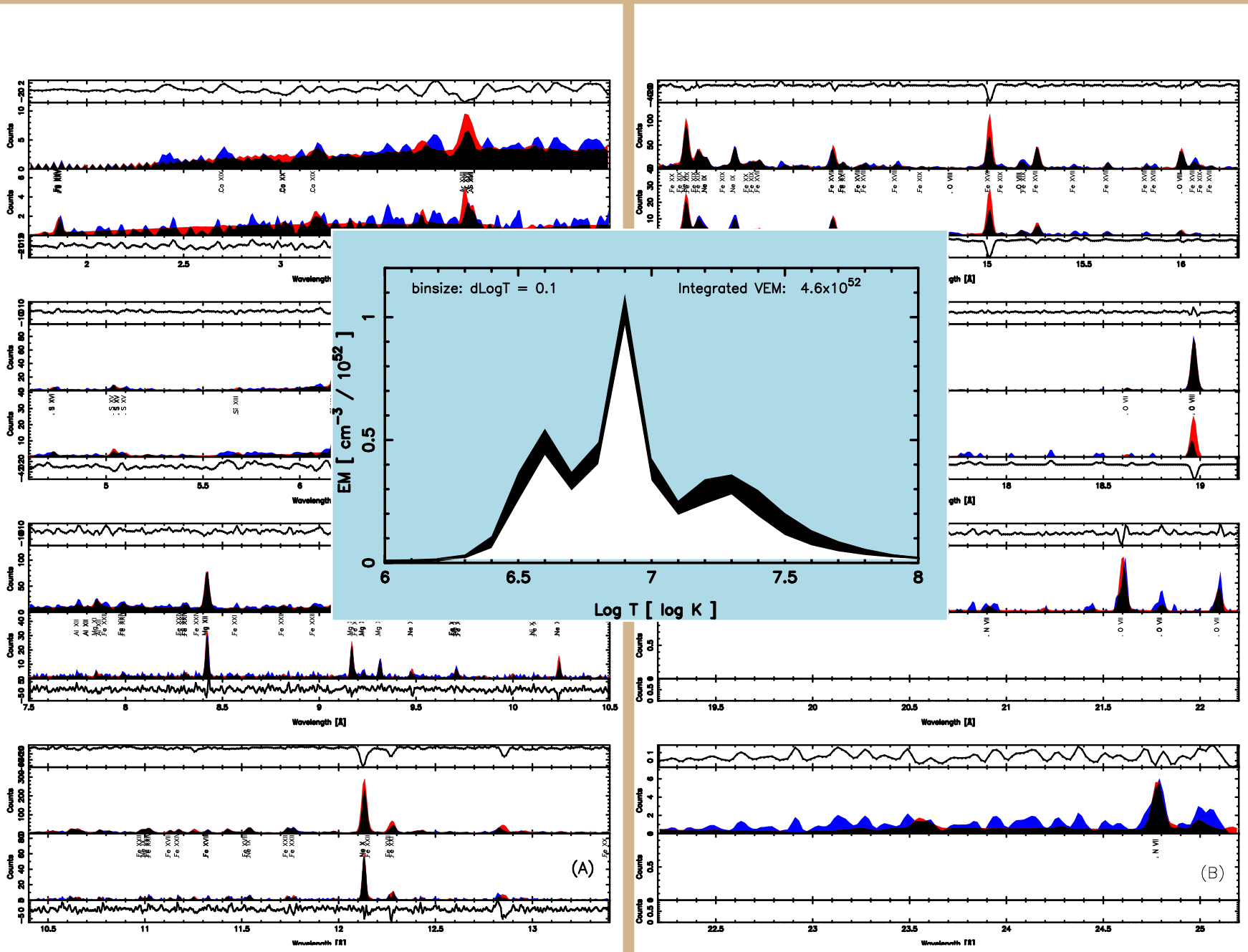
$\rightarrow N_e$

$(\sim 3 - 18 \times 10^{10}\,\mathrm{cm}^{-3})$

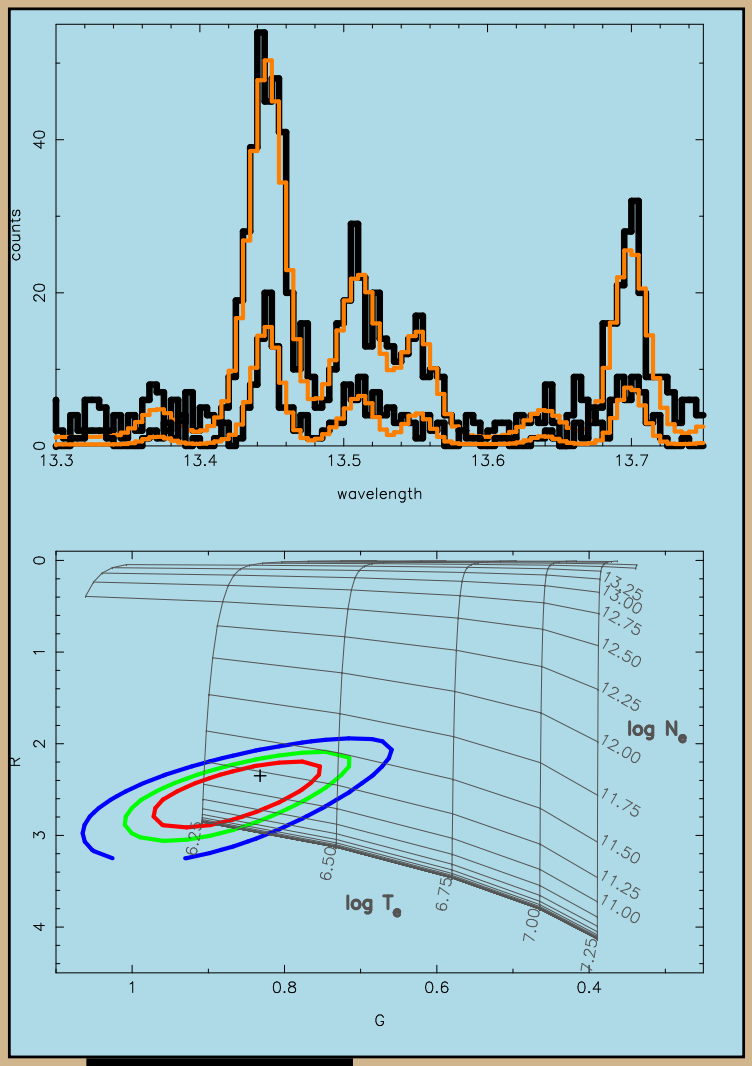
Geometry: $(N_e, V) \rightarrow$

$R(corona)/R_\star < 0.2$

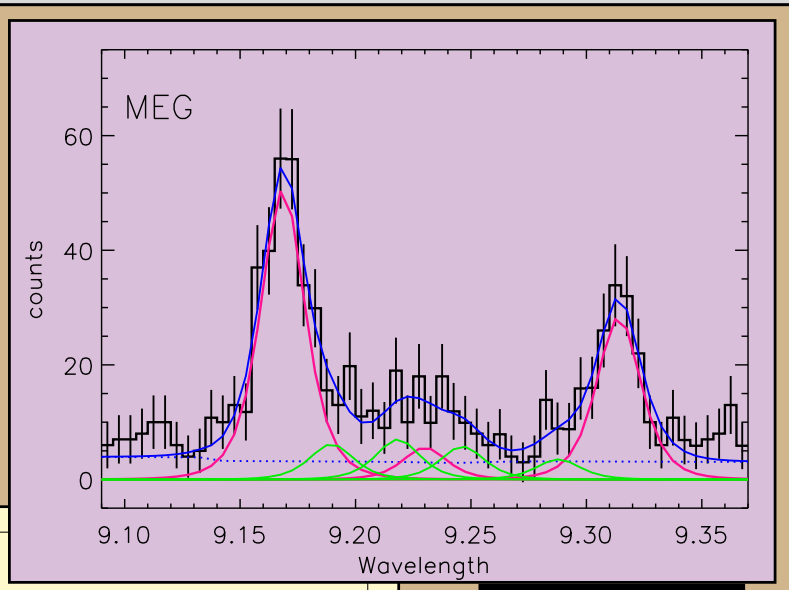
Emission Measure



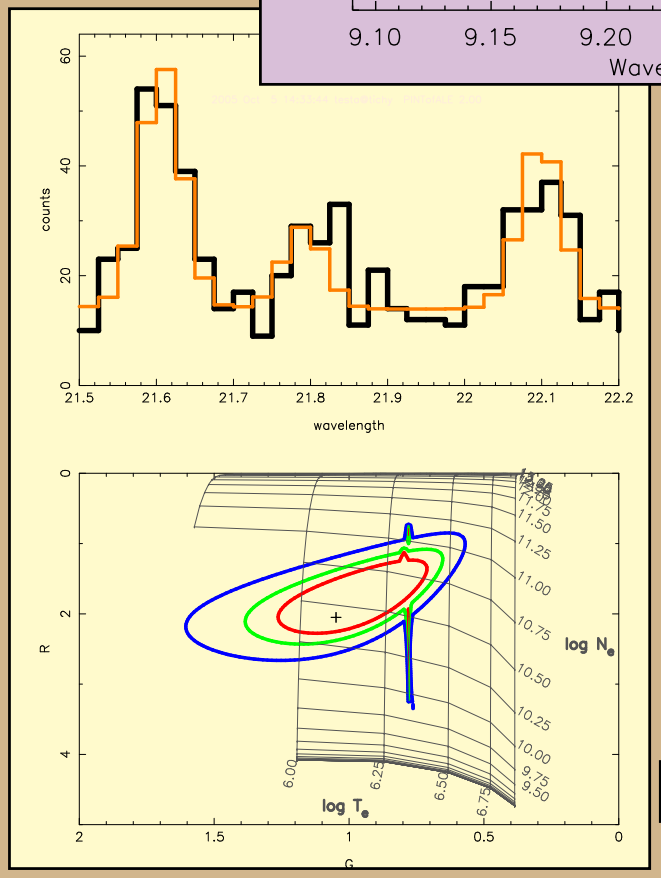
He-like Line Ratio Fits



HEG Ne IX

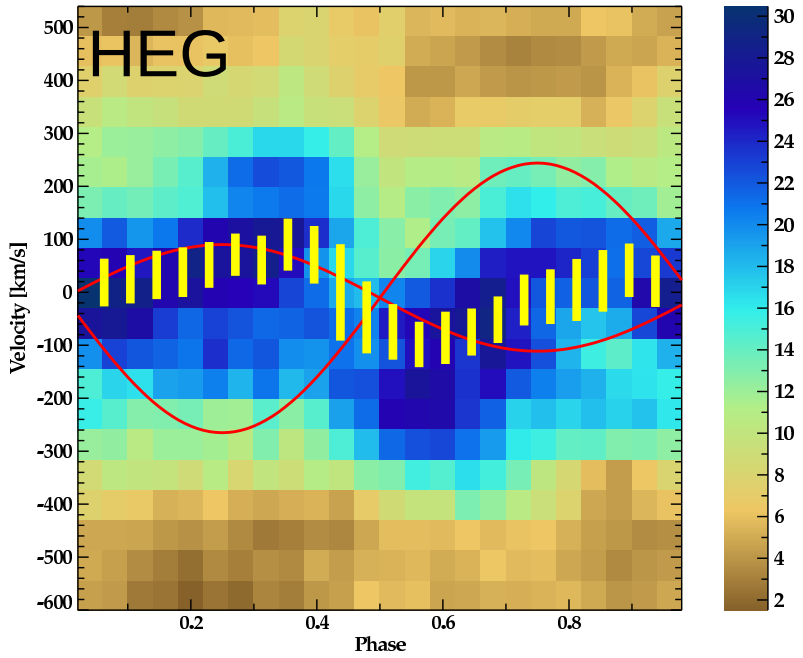


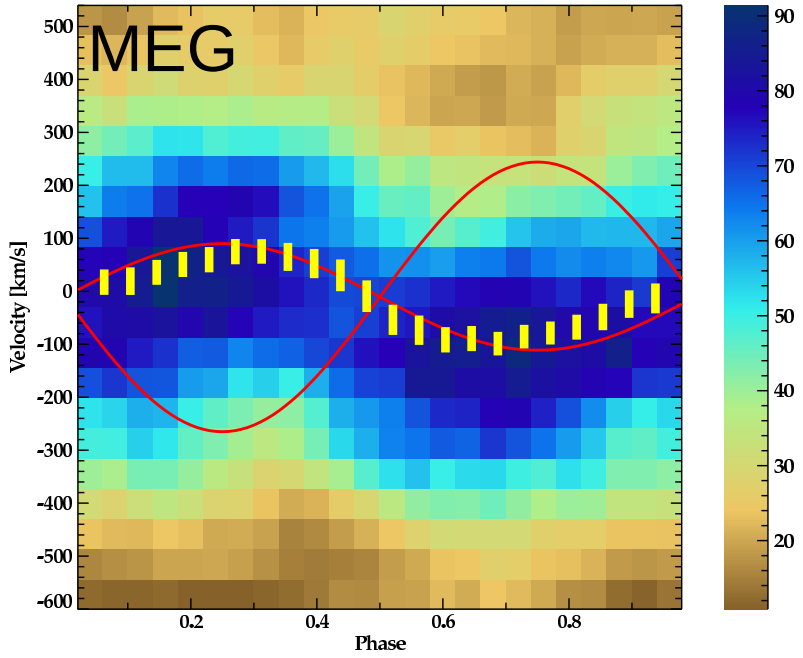
MEG Mg XI



LETGS O VIII

Velocity Modulation

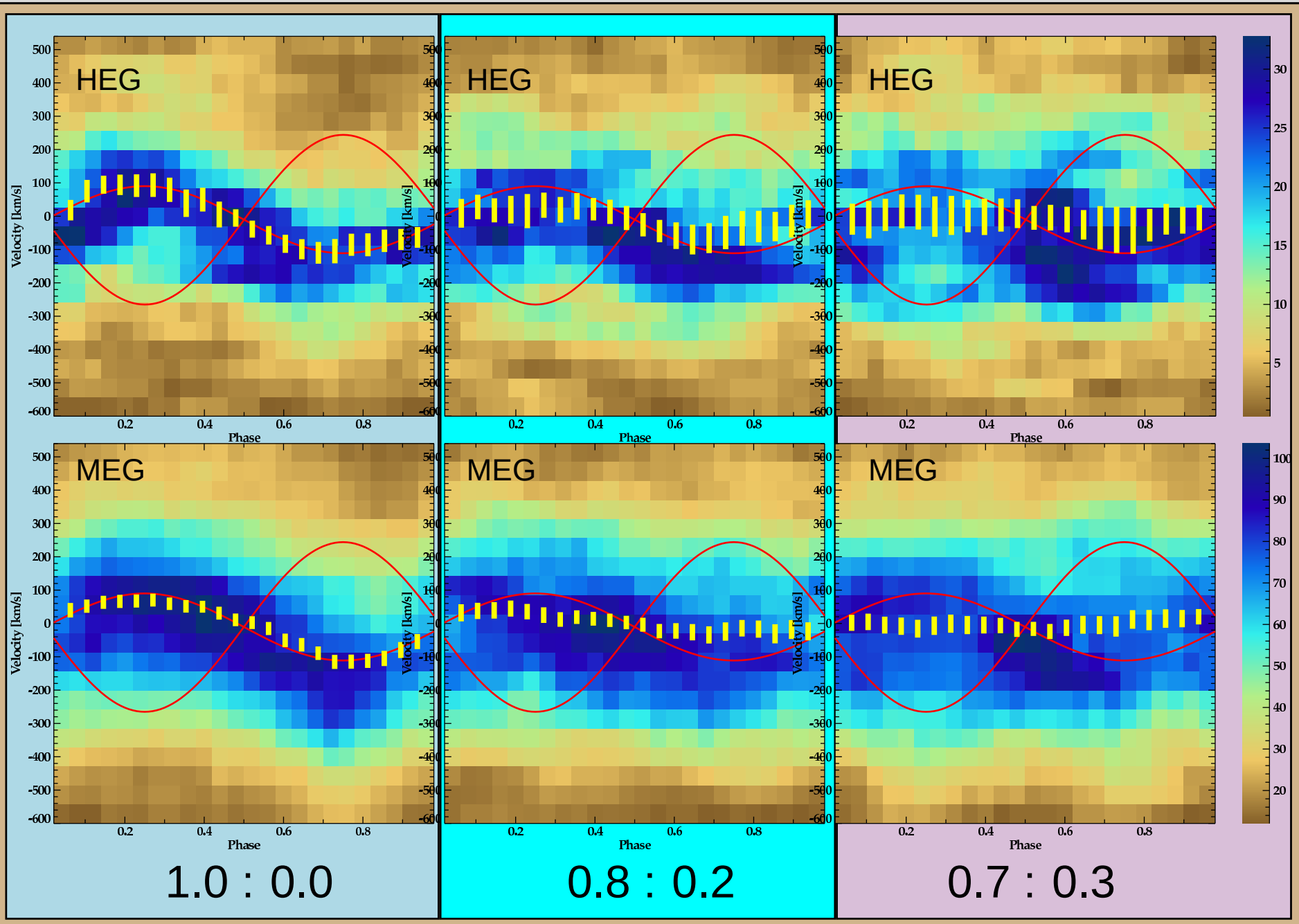




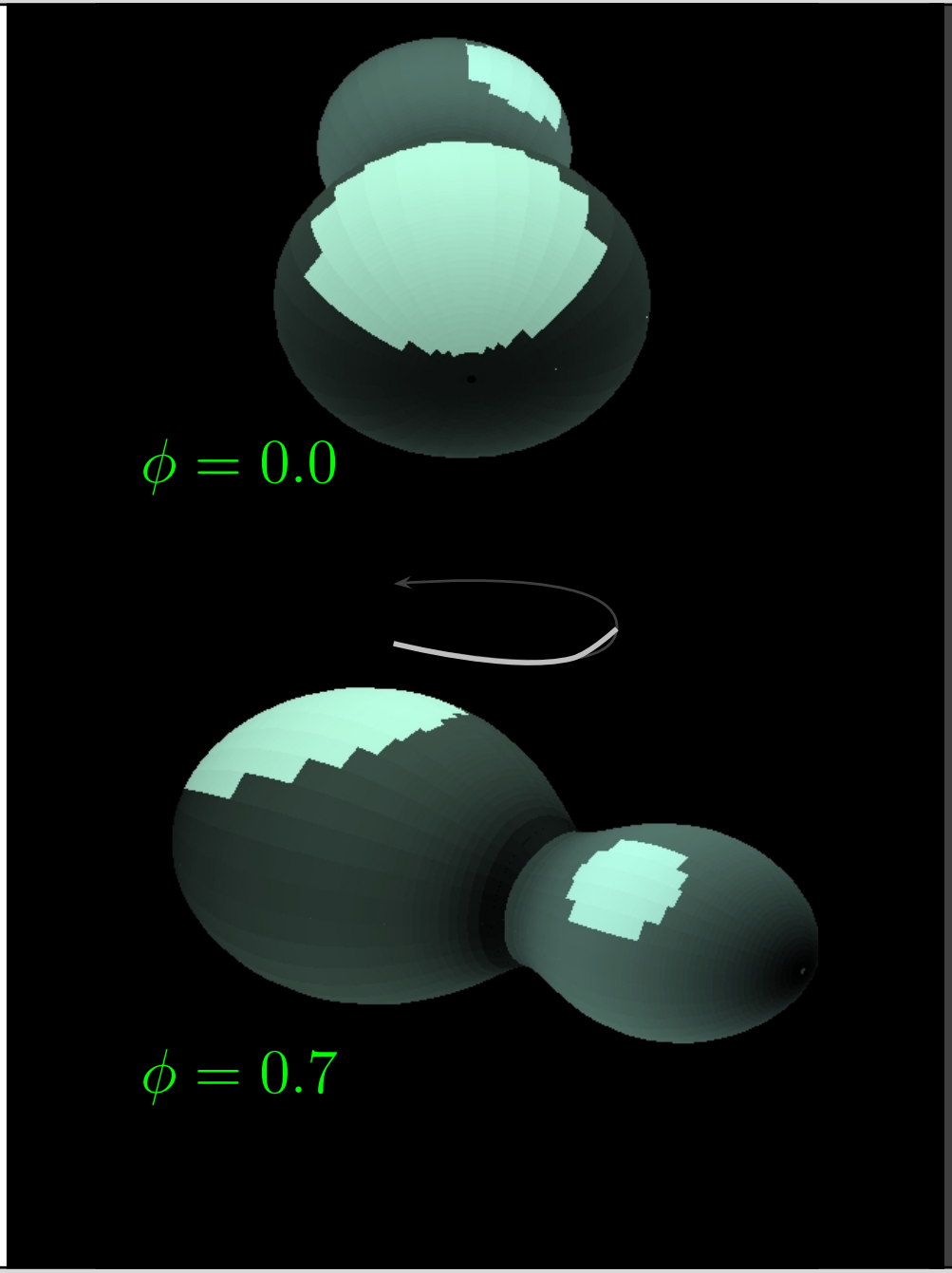
Composite Line Profile: In each phase bin, transform several lines to velocity scale and sum. Measure centroid of core.

The Primary Dominates; Simulations imply $\leq 20\%$ of the flux from the secondary at some phases (0.7–0.9).

Composite Profile Simulations



A Consistent View



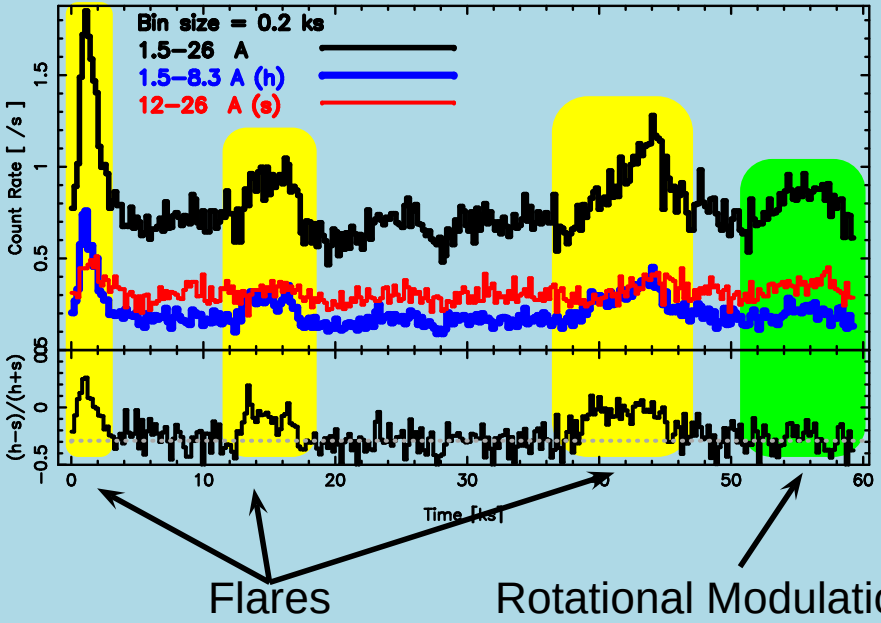
Polar/asymmetric corona: no eclipses;

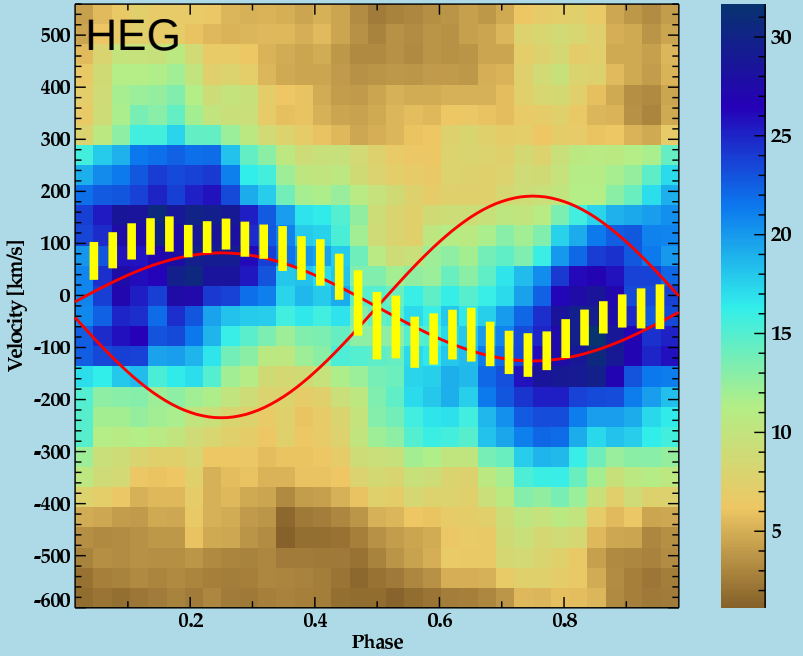
Compact corona: some modulation; density & volume arguments;

Primary Star Dominates: velocity+ light curves

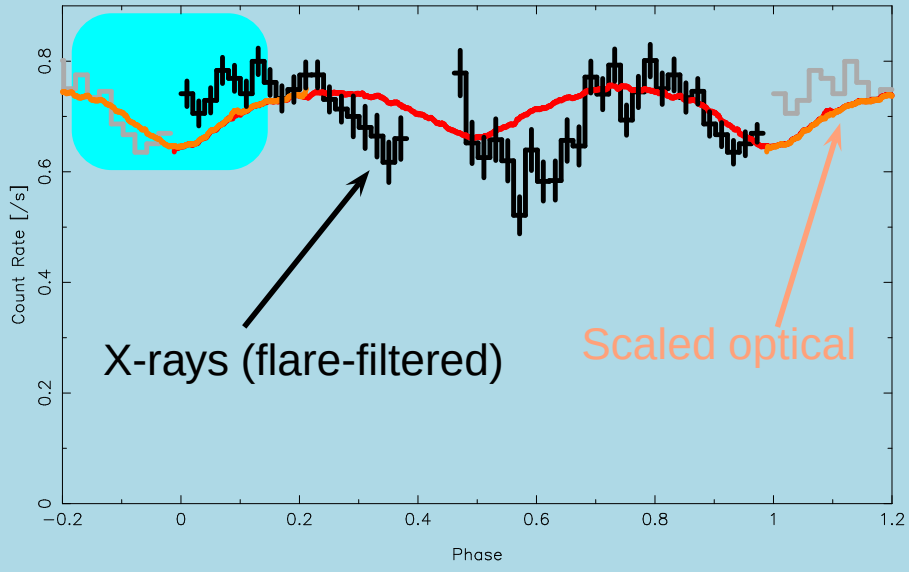
Supersaturation is manifested in compact, near polar, and few coronal emitting regions (*why* is still TBD).

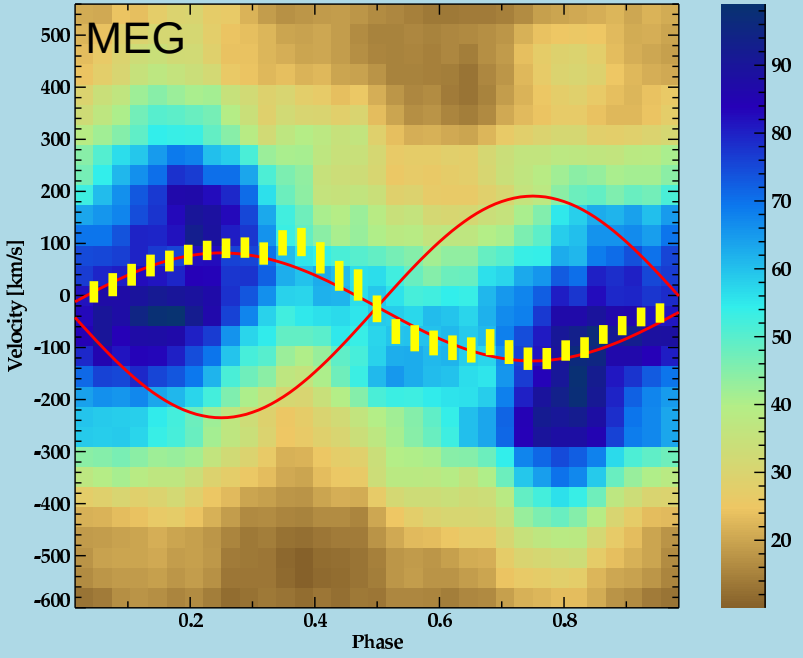
Another W UMa Case: 44 Boo





X-Ray eclipse!





Acknowledgements

- Standard data products and responses were made with CIAO software, version 3.2 (`http://cxc.harvard.edu/ciao/`). Analysis and custom programming was done with ISIS (`http://space.mit.edu/cxc/isis`).
- Contact binary geometry images were made with the program `nightfall` (Rainer Wichmann et al., `http://www.lsw.uni-heidelberg.de/~rwichman/Nightfall.html`).
- Photometric data for VW Cep are from T. Pribulla et al (2000 IBVS 4847, 2002 IBVS 5341) and on the web from the same epoch as the X-ray data. (`http://www.astro.sk/~pribulla/lc.html`).
- The idea for forming Composite Line Profiles from X-ray spectra came from Hoogerwerf et al 2004, ApJ 610, 411, as applied to EX Hya.
- Thanks to John Houck for ISIS support and help.
- Thanks to John Davis for use of his S-Lang `xfig` module, with which the line-profile images were made.
- Thanks to Nancy Brickhouse (CfA) for tables of theoretical He-like line ratios.
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