The Chandra Galactic Bulge Survey

Manuel Torres
(SRON/Nijmegen RU)

Peter Jonker[1,2], Rob Hynes[3], Chris Johnson[3], Tom Maccarone[4], Chris Britt[4], Gijs Nelemans[2], Serena Repetto[2], Tom Wevers[2], Danny Steeghs[5,6], Sandra Greiss[5], Jianfeng Wu[6], Craig Heinke[7],

[1] SRON, [2] Radboud Univ. Nijmegen, [3] Louisiana State University, [4] Texas Tech Univ.
[5] Univ. of Warwick, [6] Harvard-Smithsonian Center for Astrophysics, [7] Univ. of Alberta

The GBS goals are constraining:

- Black-hole formation and neutron star Equation of State.

  Finding (eclipsing) low-mass X-ray binaries in quiescence.

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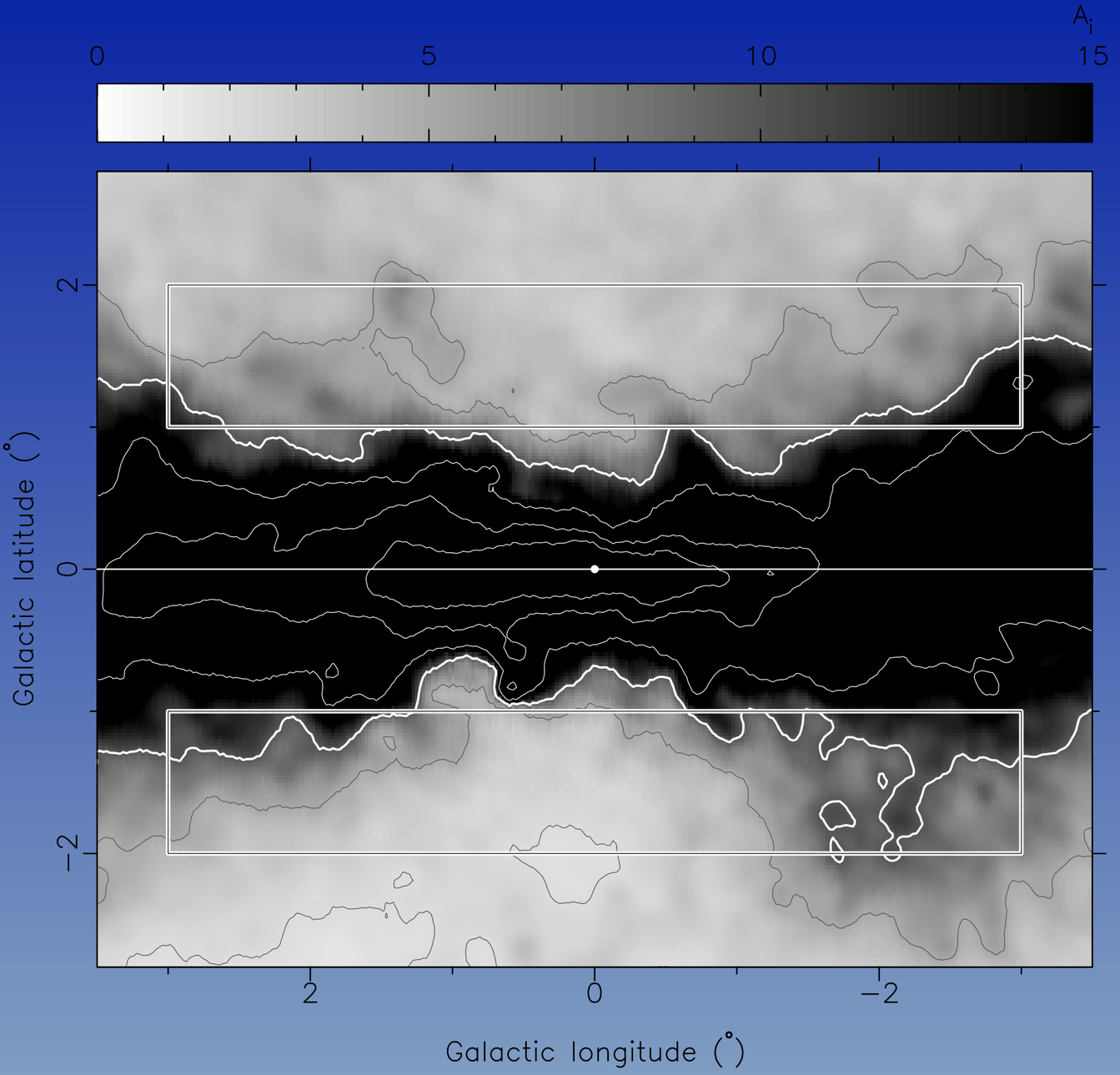
- Finding progenitors to SN Type Ia.

  Deriving the (magnetic) white dwarf mass distribution in CVs

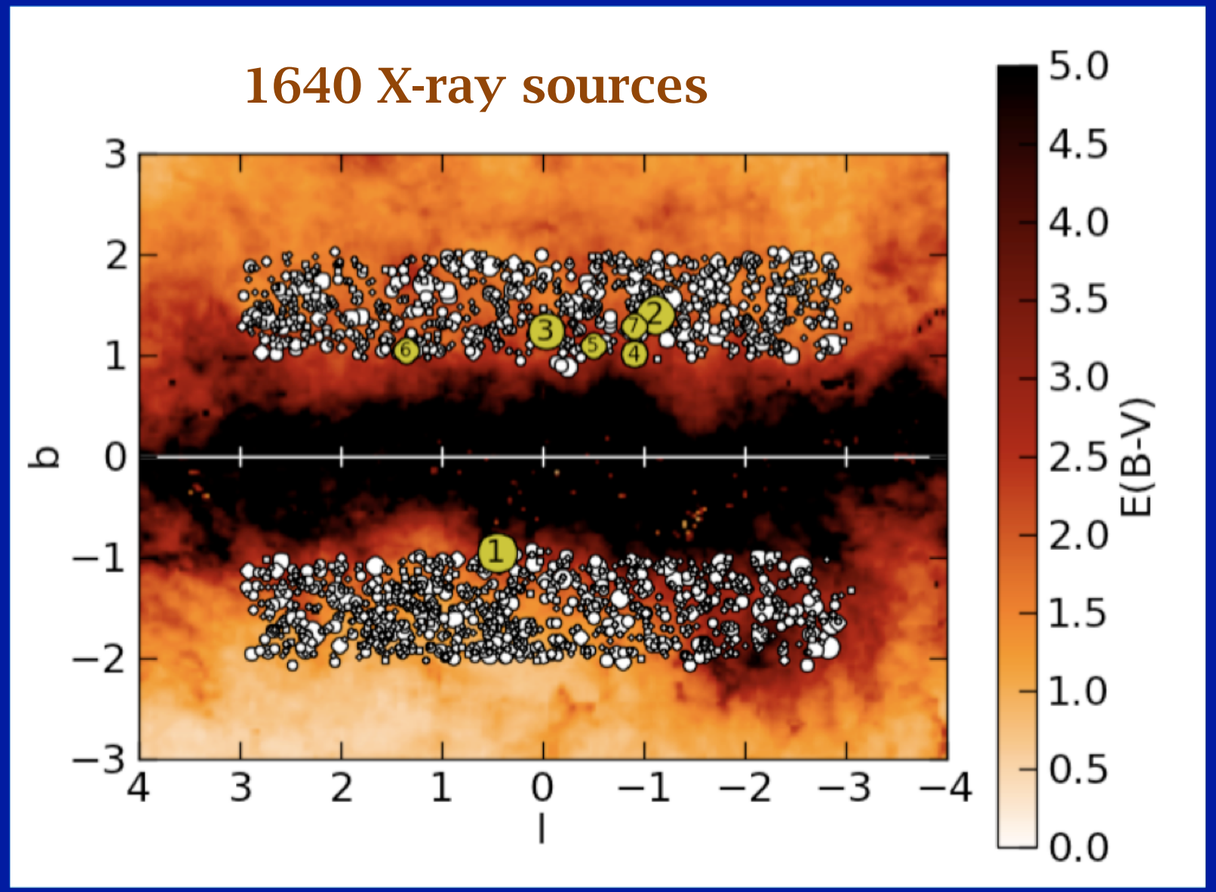
The GBS area:



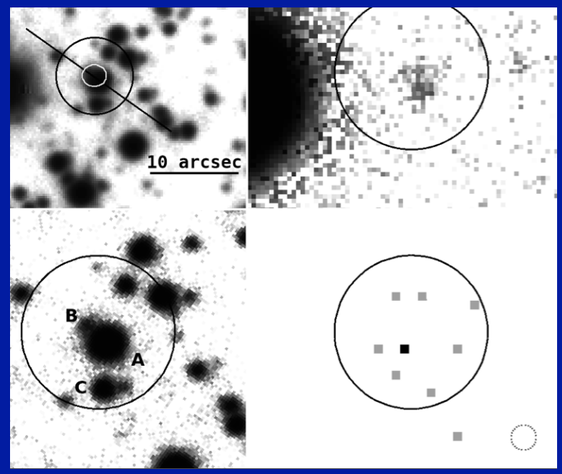
Extinction map i-band

A multi-wavelength project: X-ray survey.

- Sensitive to faint sources and excellent position accuracy.
- 260 observations. 2 ks each.

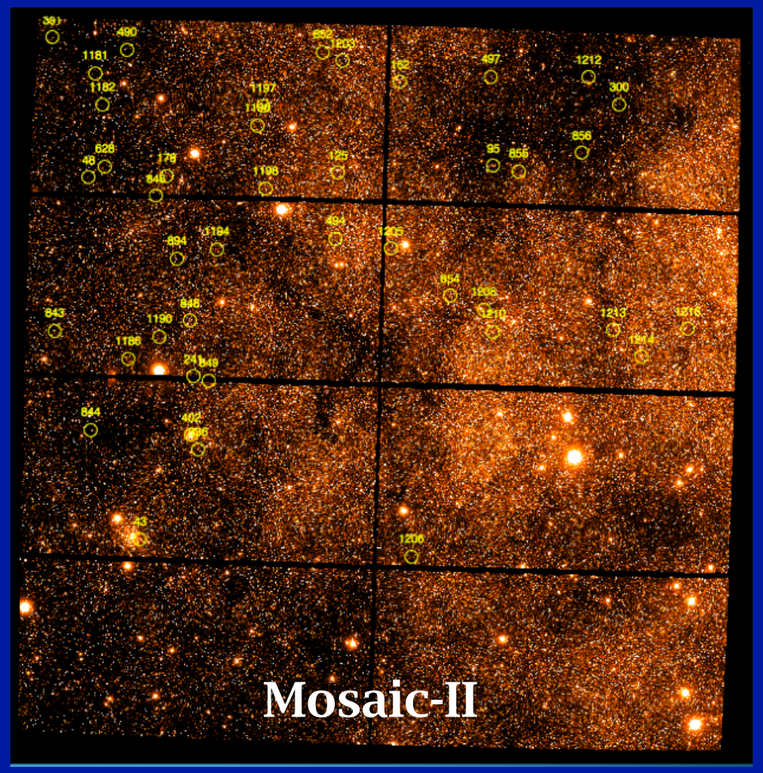


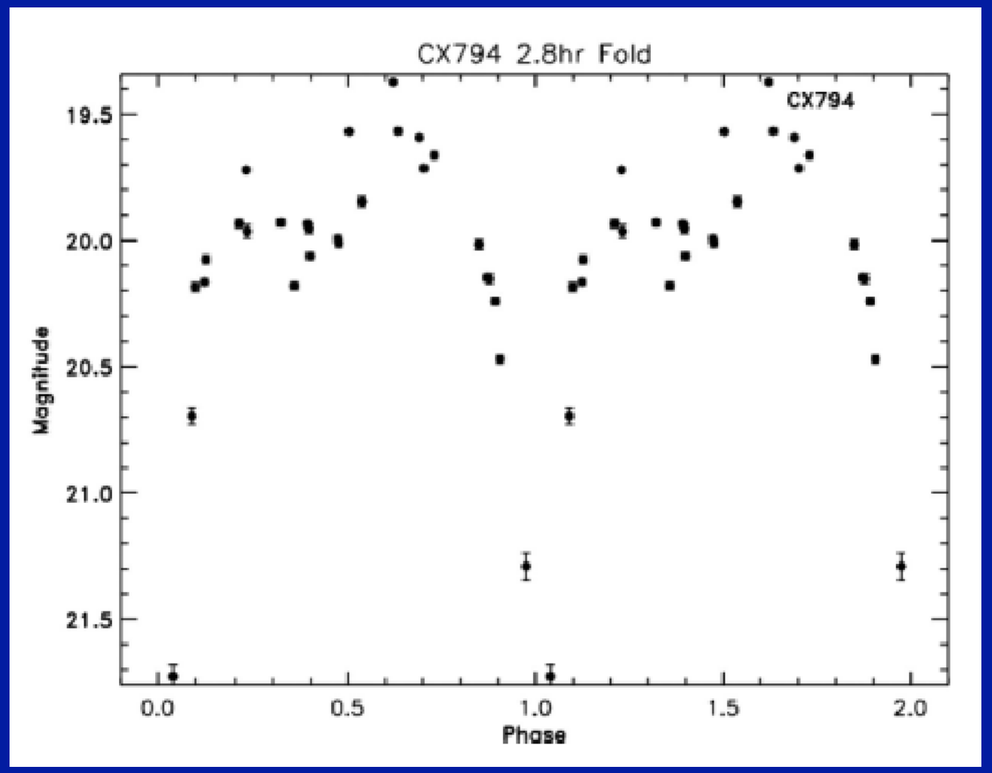
The majority of sources are 3 count detections.



A multi-wavelength project: optical survey.

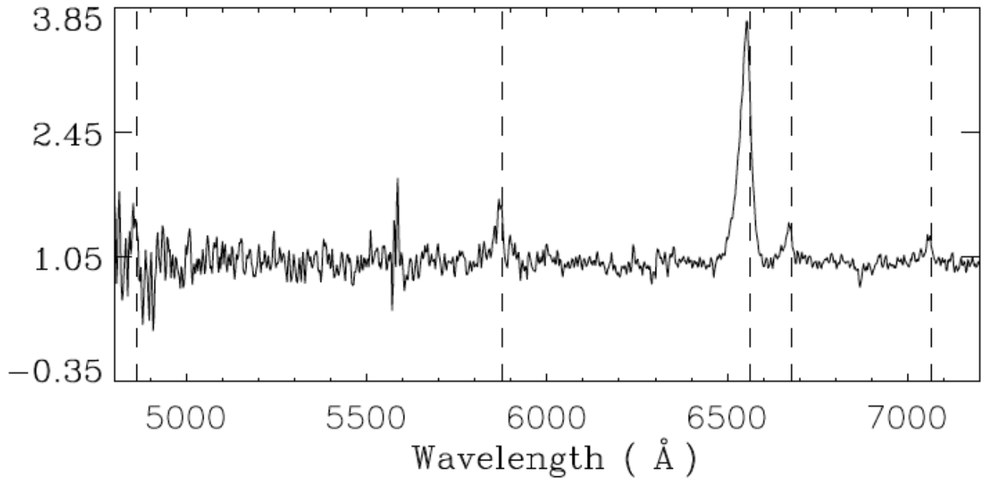
- r',i'< 23 and H_α imaging with Mosaic-II.
- Mosaic-II and DECam time-resolved photometry.

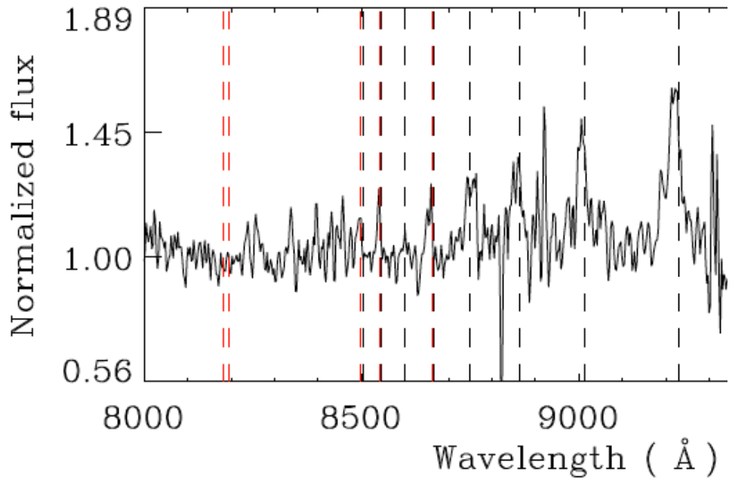


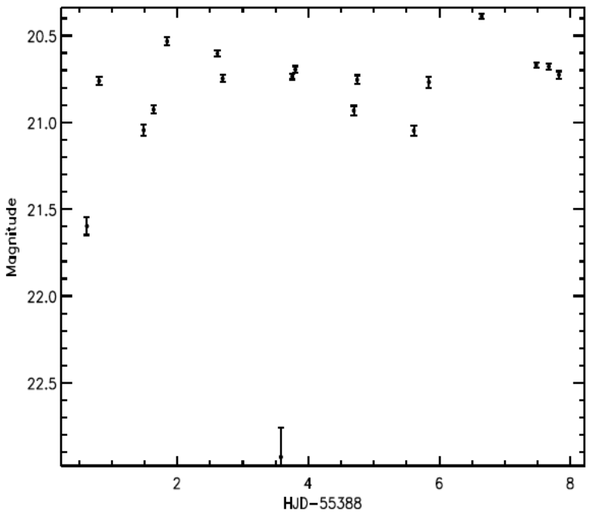


A multi-wavelength project: optical survey.

- r',i'< 23 and H_α imaging with Mosaic-II.
- Mosaic-II and DECam time-resolved photometry.
- Spectroscopy with VIMOS (VLT), EFOSC2 (NTT), GMOS (Gemini).







First Results

X-RAY SURVEY

1.- The Galactic Bulge Survey: Outline and X-ray Observations (Jonker et al. 2011)
2.- The Galactic Bulge Survey: Completion of the X-Ray Survey Observations (Jonker et al. 2014)

SHALLOW PUBLIC SURVEYS

3.- Identification of Galactic Bulge Survey X-Ray Sources with Tycho-2 Stars (Hynes et al. 2012)
4.- Radio sources in the Chandra Galactic Bulge Survey (Maccarone et al. 2012)

NEAR-INFRARED SURVEY

5.- Near-infrared counterparts to the Galactic Bulge Survey X-ray source population (Greiss et al. 2014)

OPTICAL (VARIABILITY) SURVEY

6.- Variability of Optical Counterparts in the Chandra Galactic Bulge Survey (Britt et al. 2014)

OPTICAL (SPECTROSCOPY) SURVEY

7.- Identification of 23 accreting binaries in the Galactic Bulge Survey (Torres et al. 2014)
8.- Identification of Five Interacting Binaries in the Galactic Bulge Survey (Britt et al. 2013)
9 Gemini Spectroscopy of Galactic Bulge Sources: A Population of Hidden Accreting Binaries Revealed? Wu et al. submitted.

INDIVIDUAL SOURCES

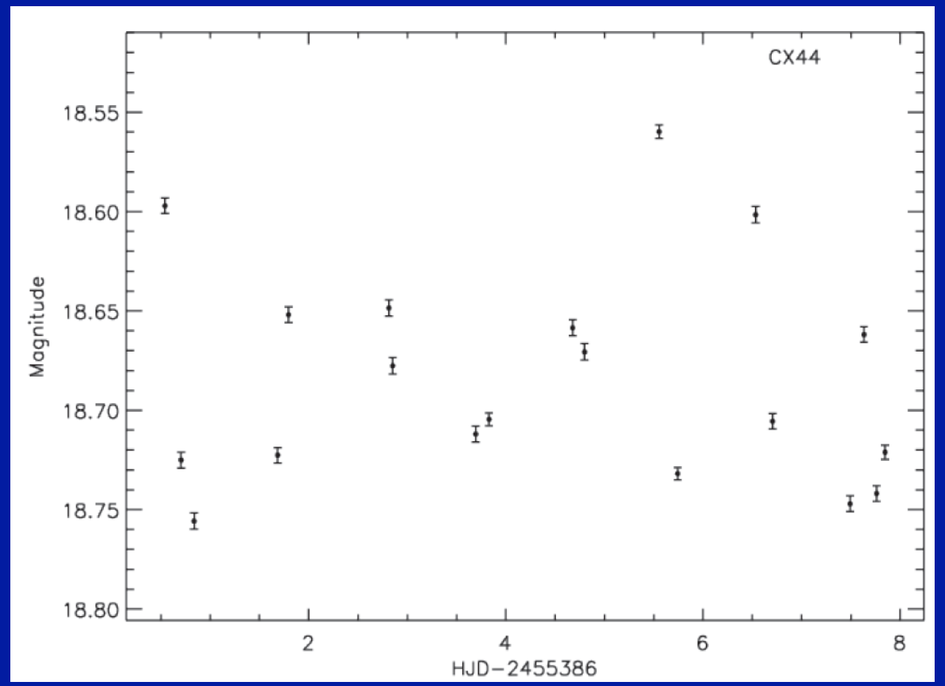
10.- HD 314884: a slowly pulsating B star in a close binary (Johnson et al. 2014)
11.- CXOGBS J174444.7-260330: a new long orbital period cataclysmic variable in a low state (Ratti et al. 2013)
12.- CXOGBS J173620.2-293338: A Candidate Symbiotic X-Ray Binary Associated with a Bulge Carbon Star (Hynes et al. 2014)

http://www.sron.nl/~peterj/gbs/

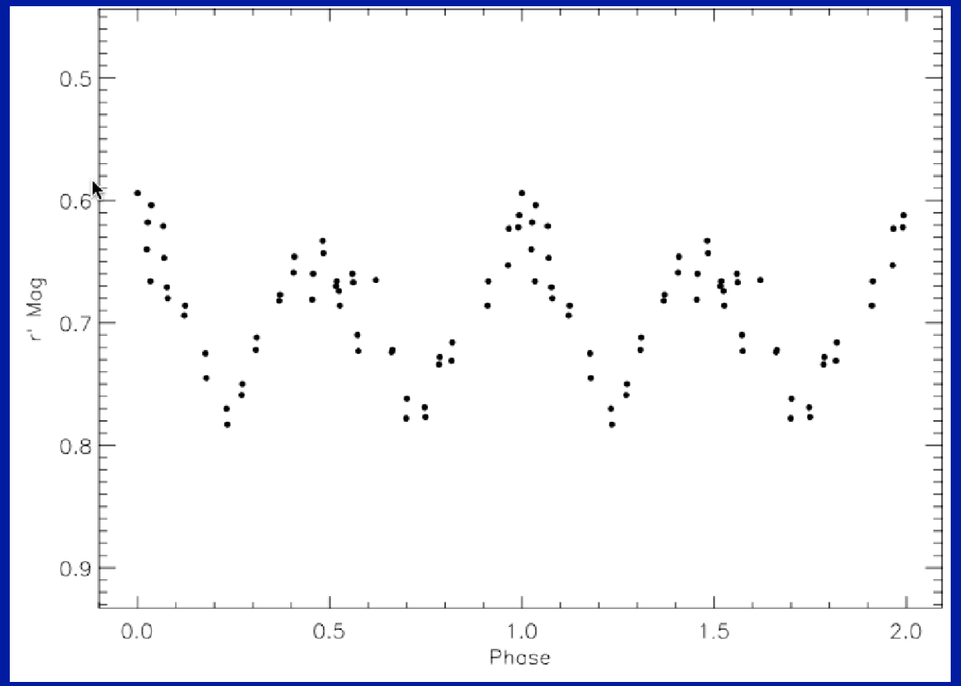
INDIVIDUAL OBJECTS

CX44 (=AX J1755.7-2818): quiescente LMXB or CV

Photometric long-term variability and $L_x = 1e^{32}$ erg/s

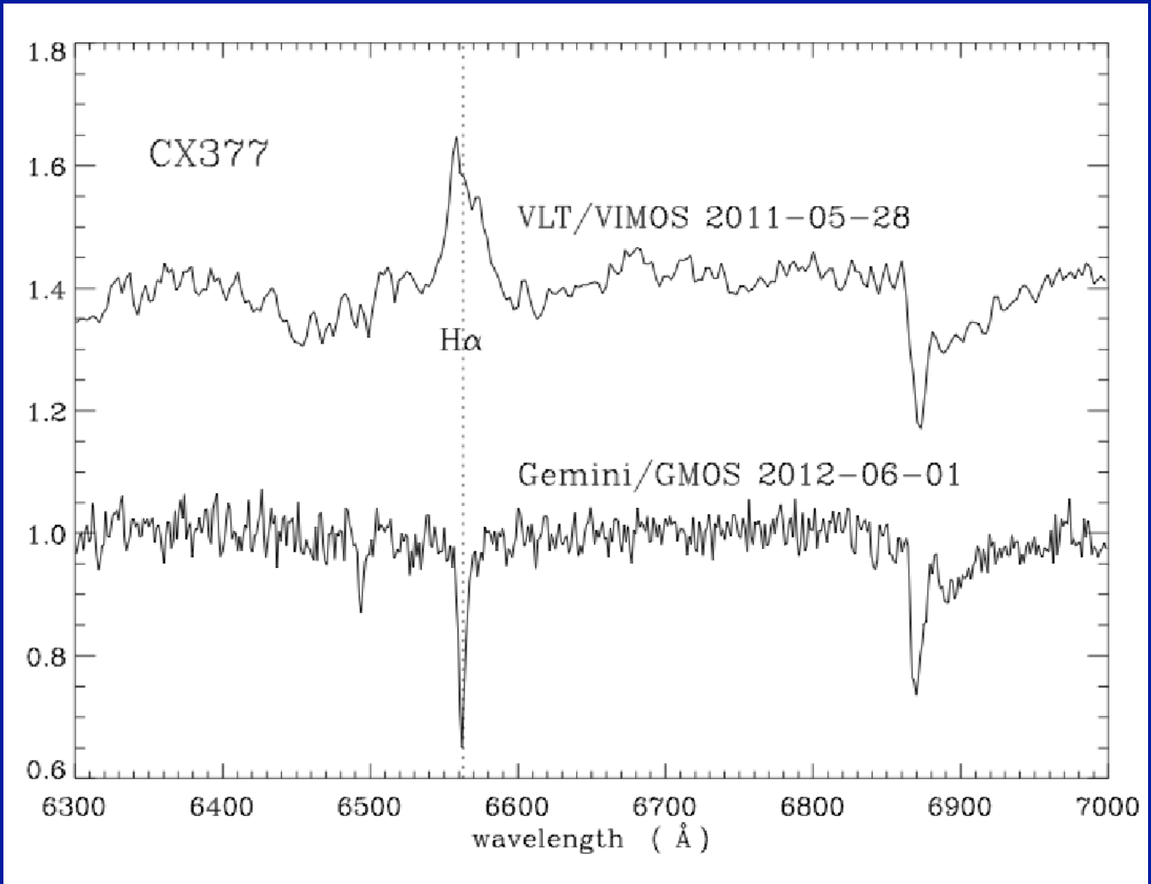


Mosaic-II shows flickering



DECam shows modulation

CX377: a likely quiescent LMXB



Hα: FWHM = 1200 km/s

Hα long-term variability.

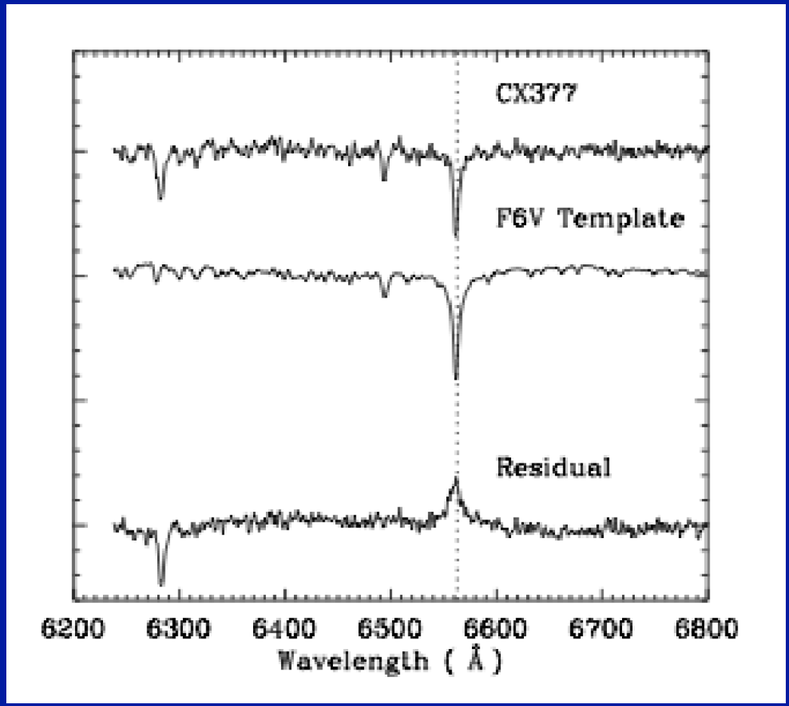
F-type companion.

High extinction (distant)

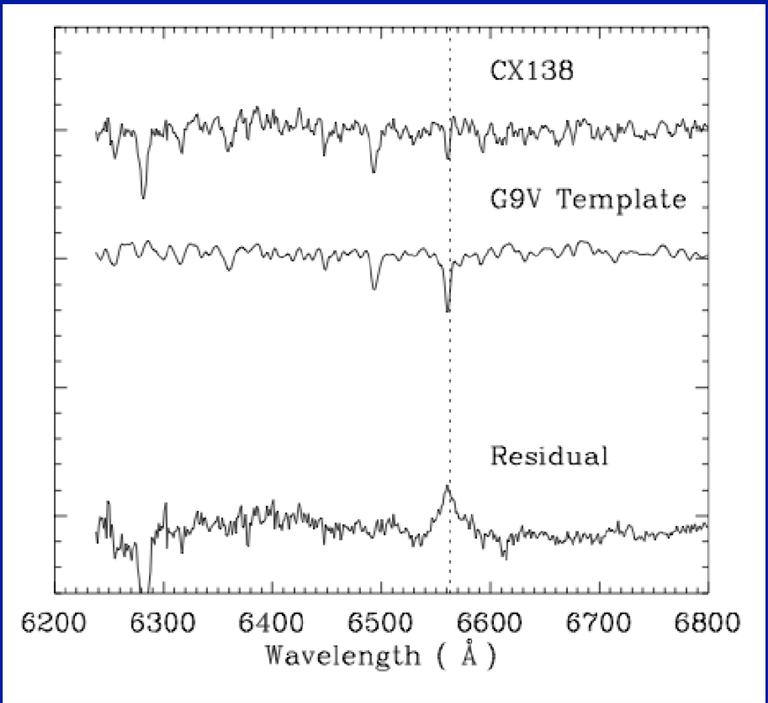
$L_x = 8e^{32}$ erg/s

Unveilig accreting binaries (Wu et al. 2014)

Optimal subtraction of spectral template to objects that do not show Hα in emission.

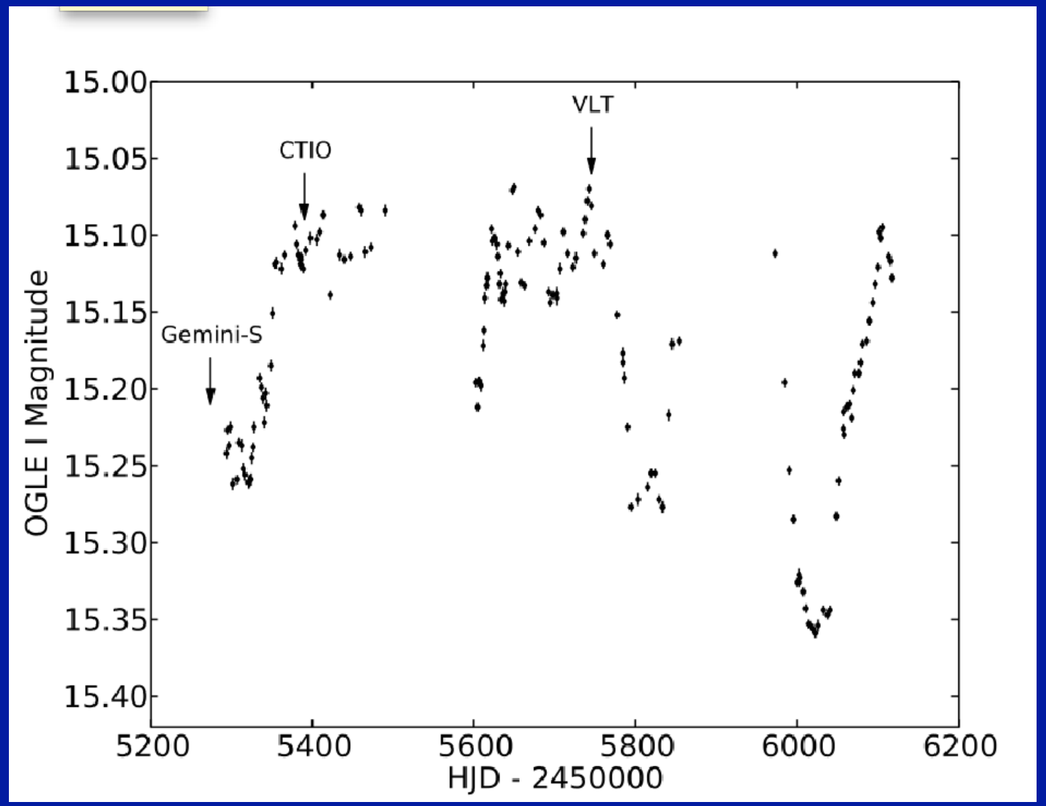


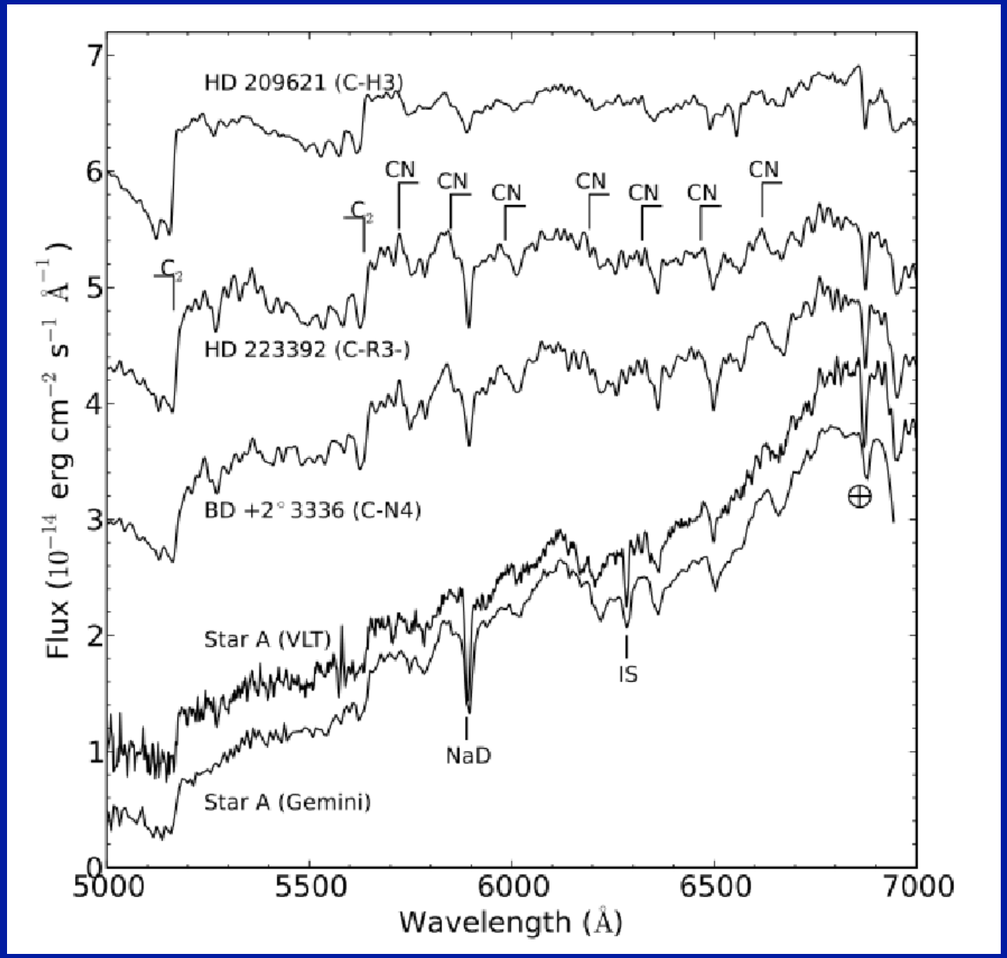
Hα: FWHM = 660 km/s



Hα: FWHM = 1350 km/s

CX332: a candidate symbiotic X-ray binary



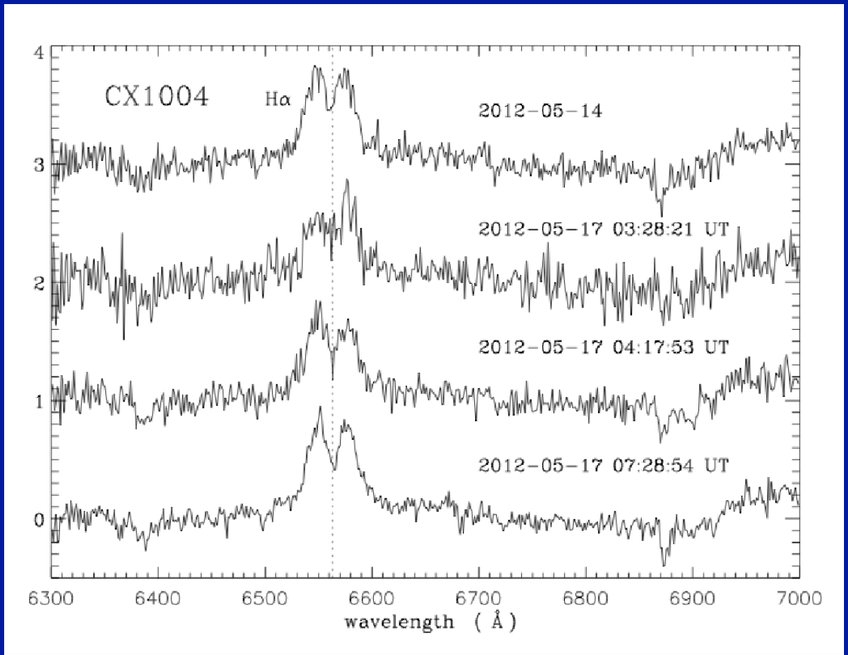


At Bulge distance: $L_X = 2e^{32}$ erg/s.

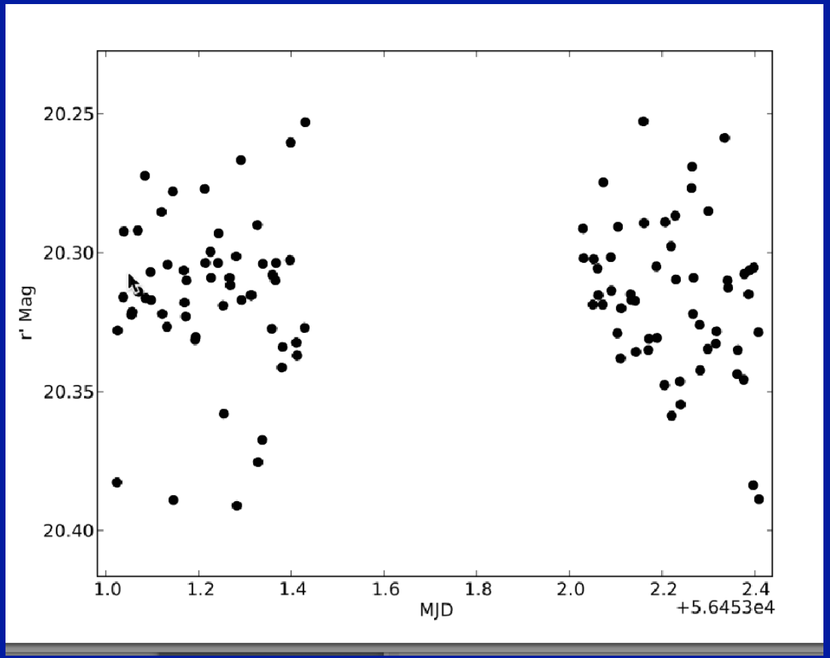
CX1004: a quiescent black hole LMXB?

Hα profile consistent with a BH LMXB or eclipsing CV.

M-type companion. Low extinction (nearby). $L_X = 2e^{30}$ erg/s



Hα: FWHM = 2100 km/s
Δv=1170 km/s.



DECam shows
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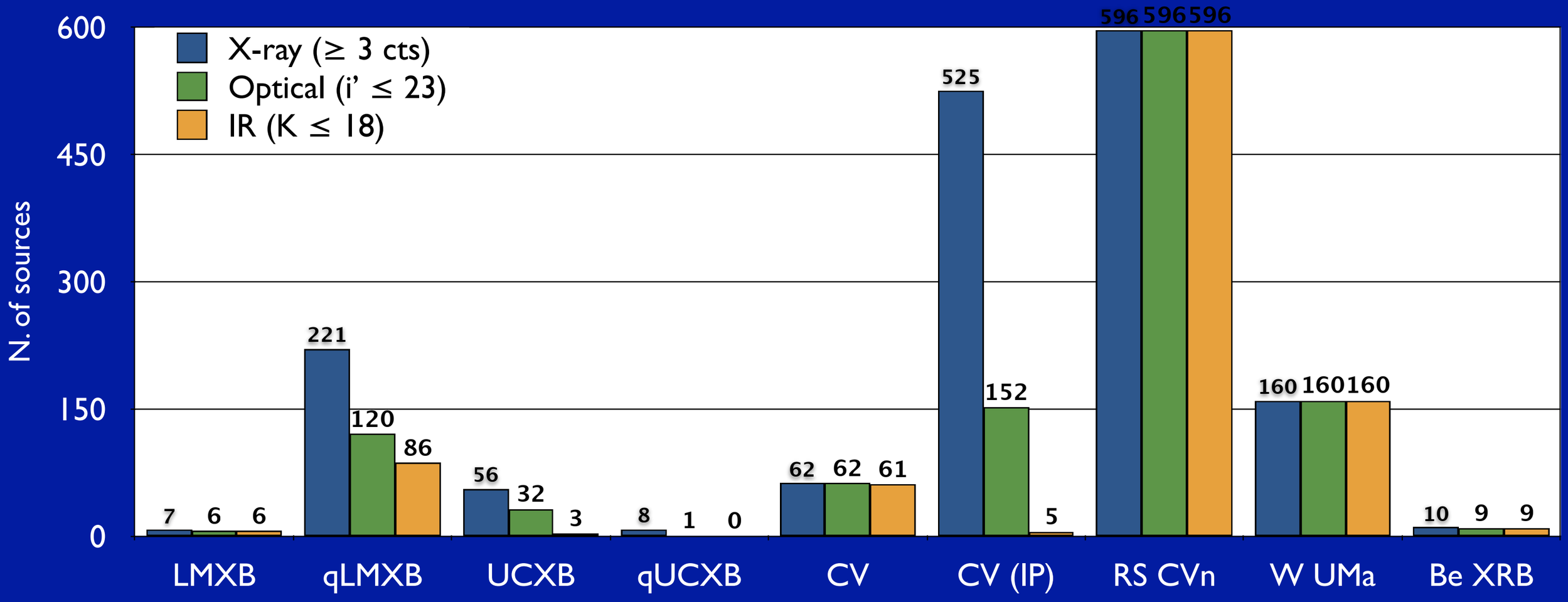
The GBS Predictions

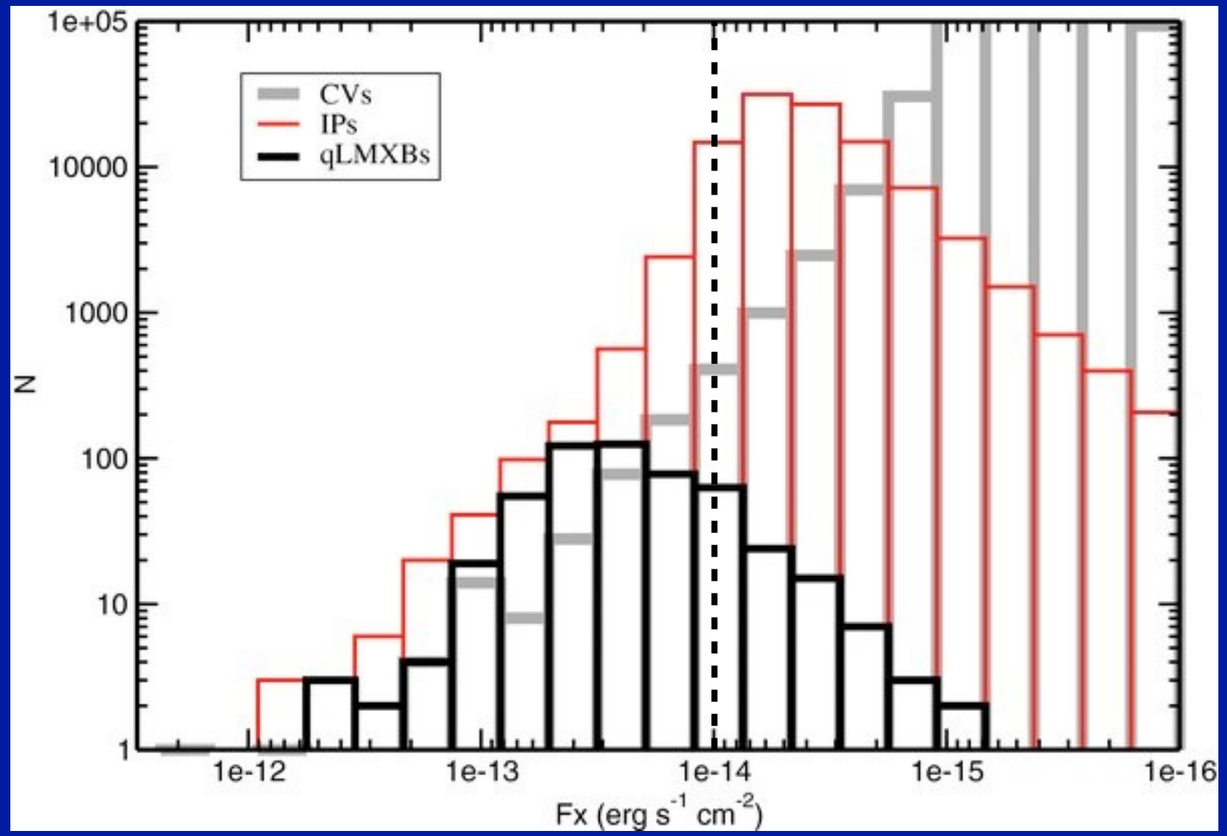


The GBS predictions and strategy:

Survey upper limit:

$F_X = (1\text{-}3)e^{-14}$ erg/s/cm^2

($L_X = (1\text{-}3)e^{31}$ (d/1 kpc)^2 erg/s)



Number of non-magnetic CVs, intermediate polars and quiescent LMXBs

Hα long-term variability:

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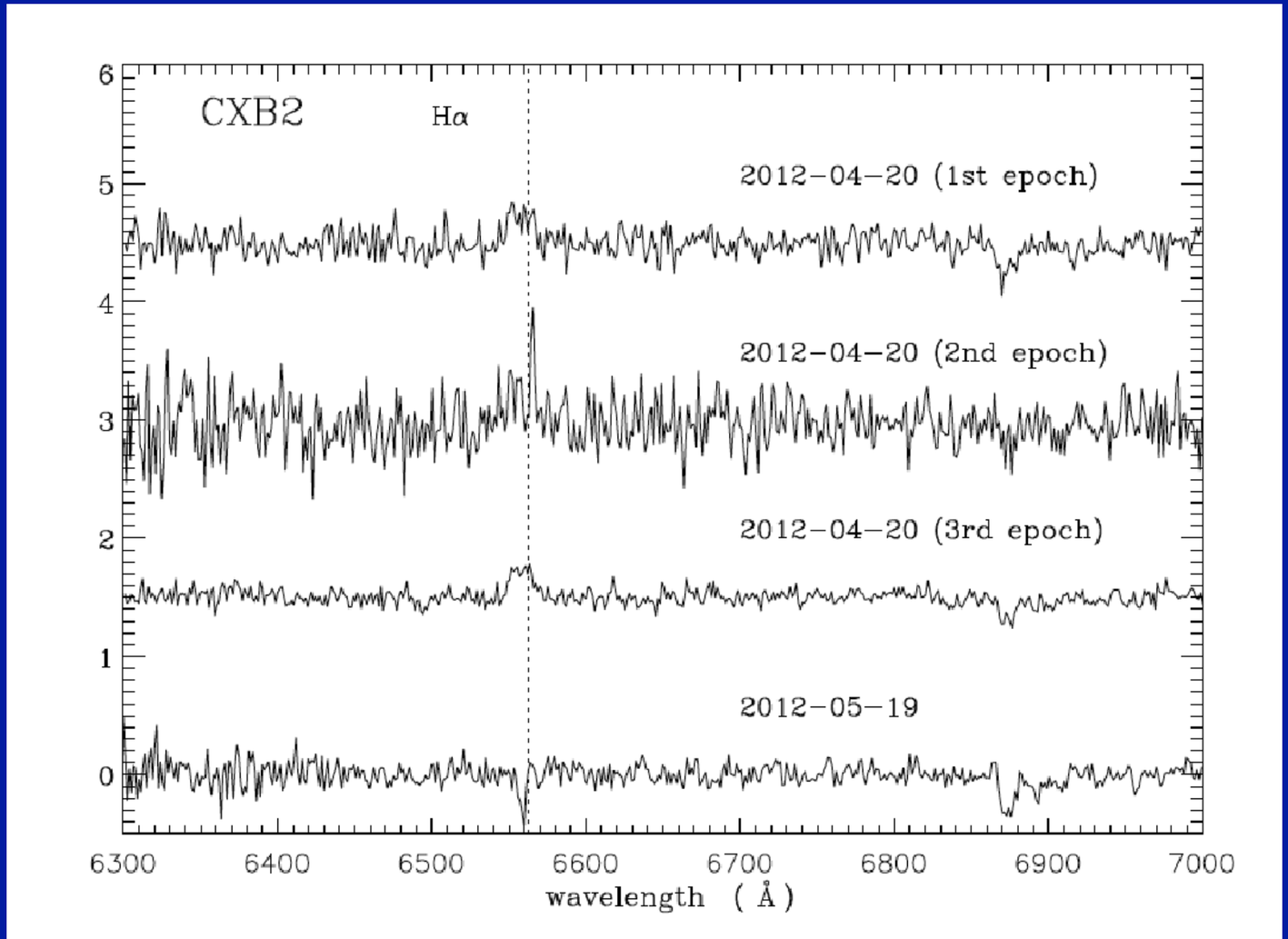
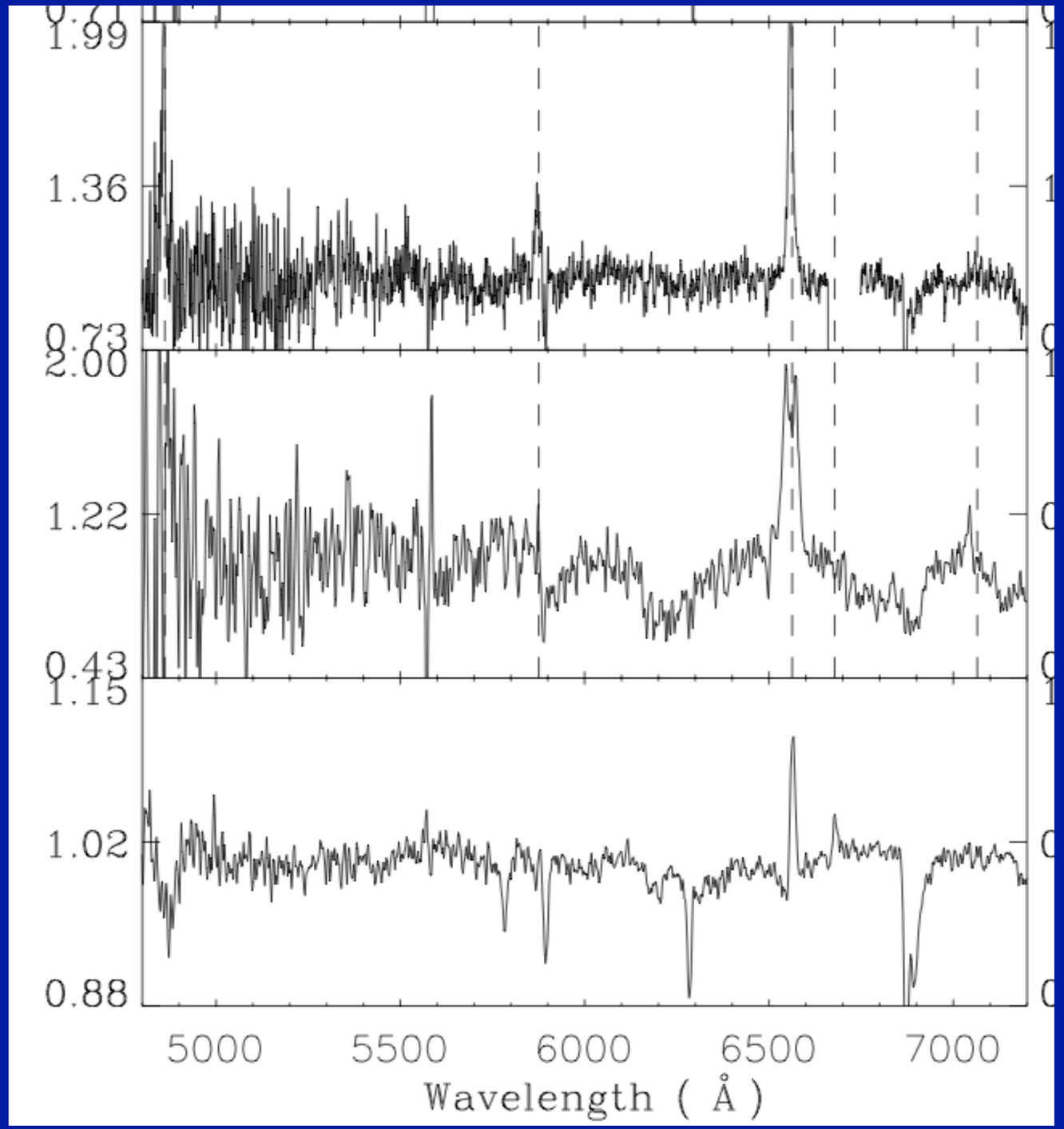
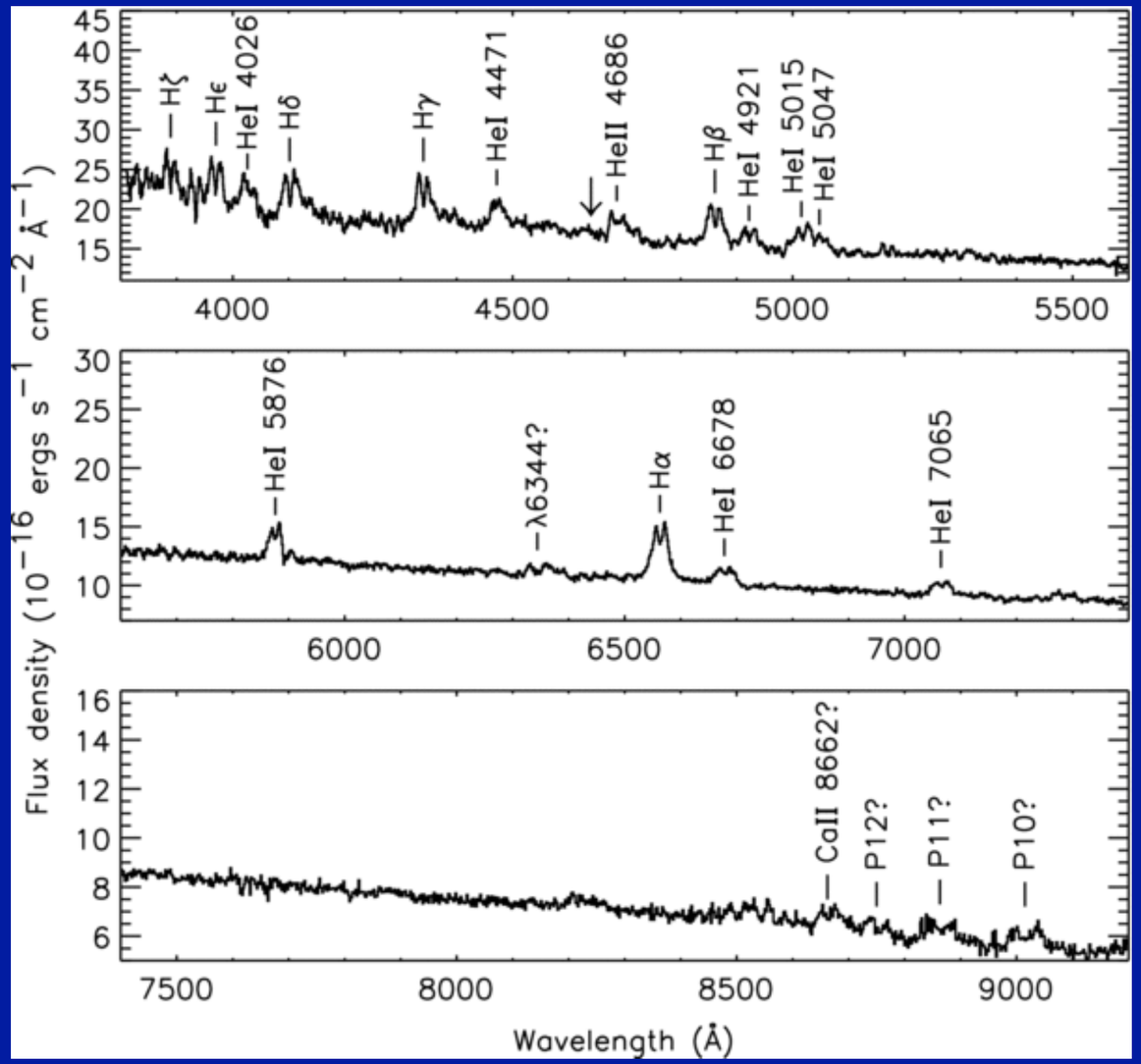




Tores et al. (2014)

SDSS J102347.6+003841



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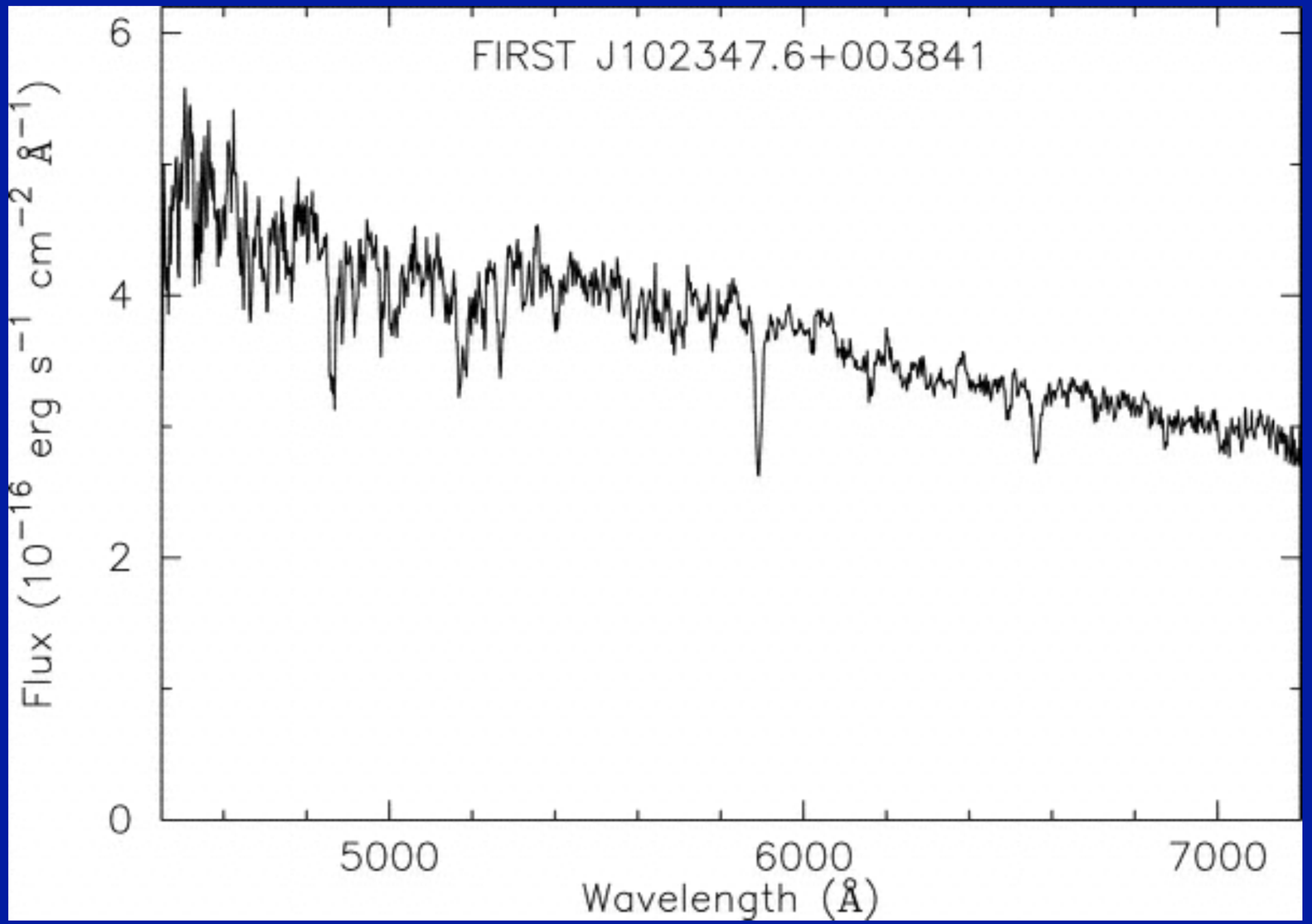
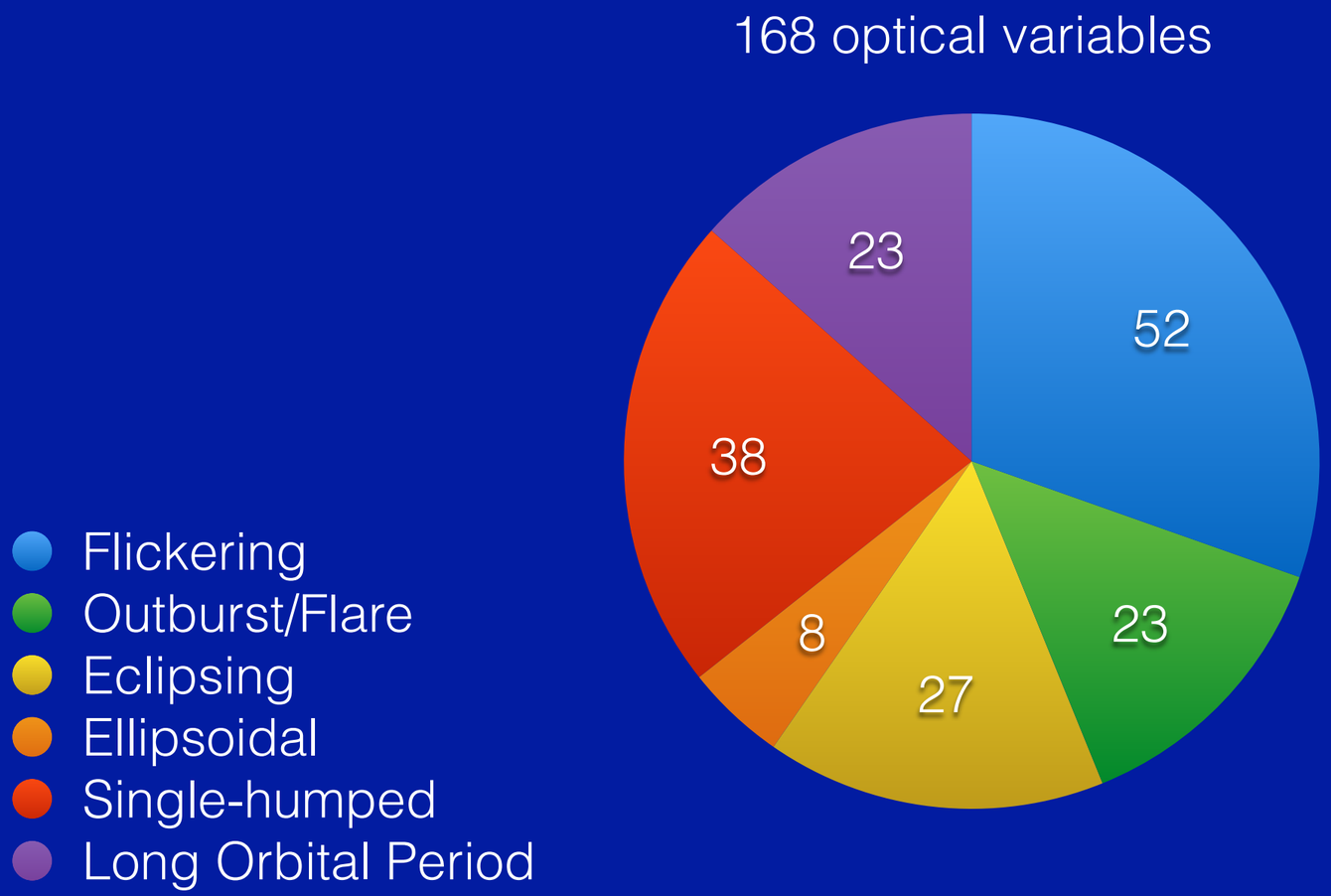


A variability project: optical



Britt, Hynes et al. (2014)

Mass compact object:

$$M_1 = \frac{P_{\rm orb}}{2\pi G}\left(\frac{1+q}{q}\right)^2 \frac{K_2^3}{\sin^3 i},$$

K_2,P

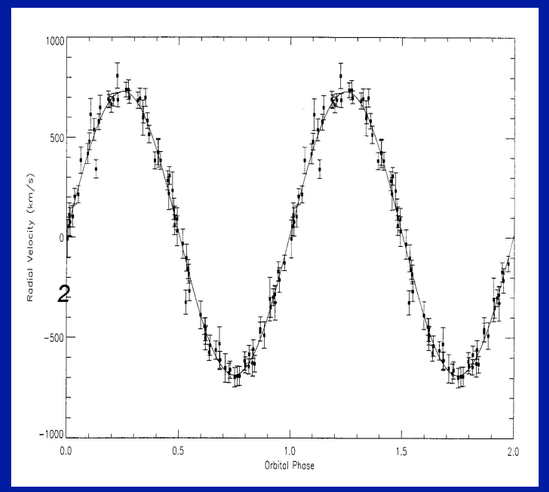
$q=M_2/M_1$

inclination, i

$$V_R = \gamma + K_2\left[\sin\frac{2\pi}{P}(t-T_0)\right],$$

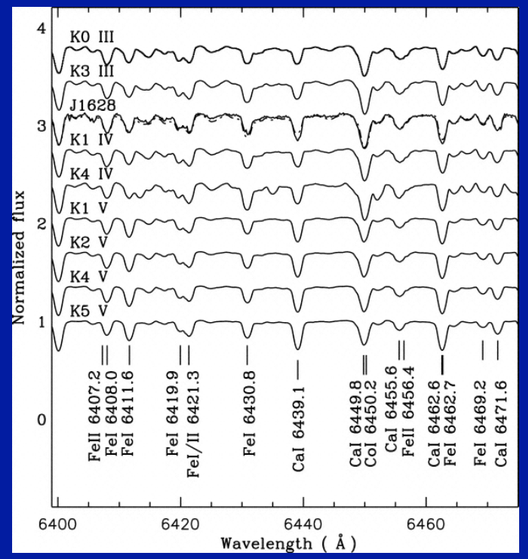
K_2

$$\frac{v\sin i}{K_2} = 0.462[(1+q)^2 q]^{1/3}.$$



Radial velocity curve (*Vr*)

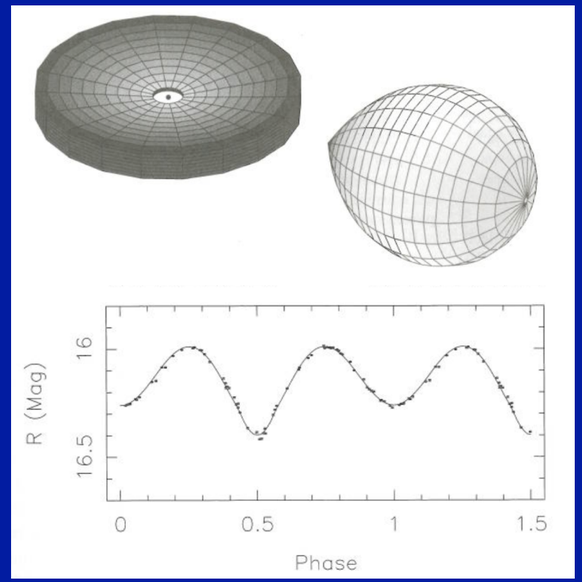
K_2, P, T_0



Optimal subtraction (*vsini, sp. type, f*)

f

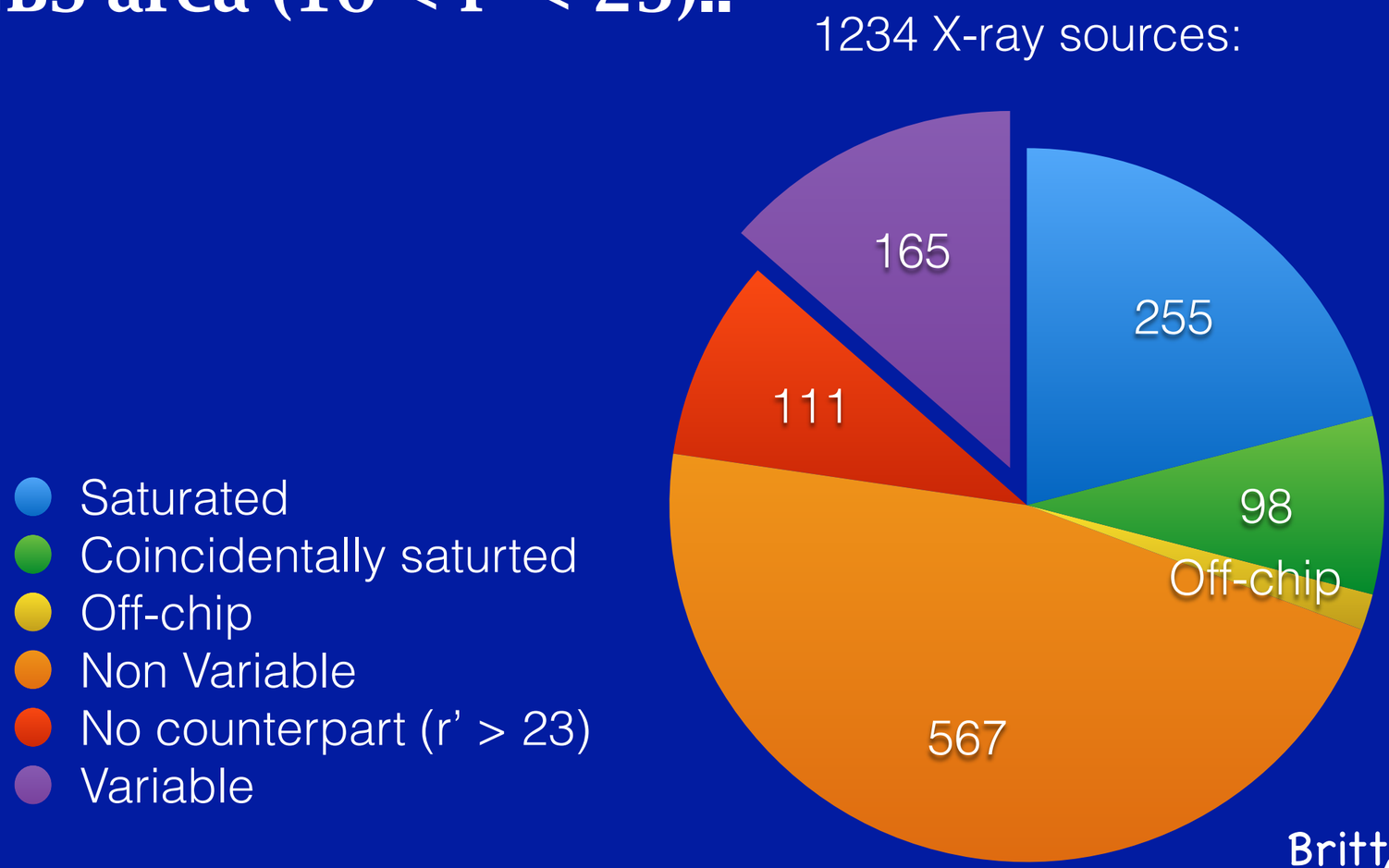
sp. type



Light Curve modelling (*i*)

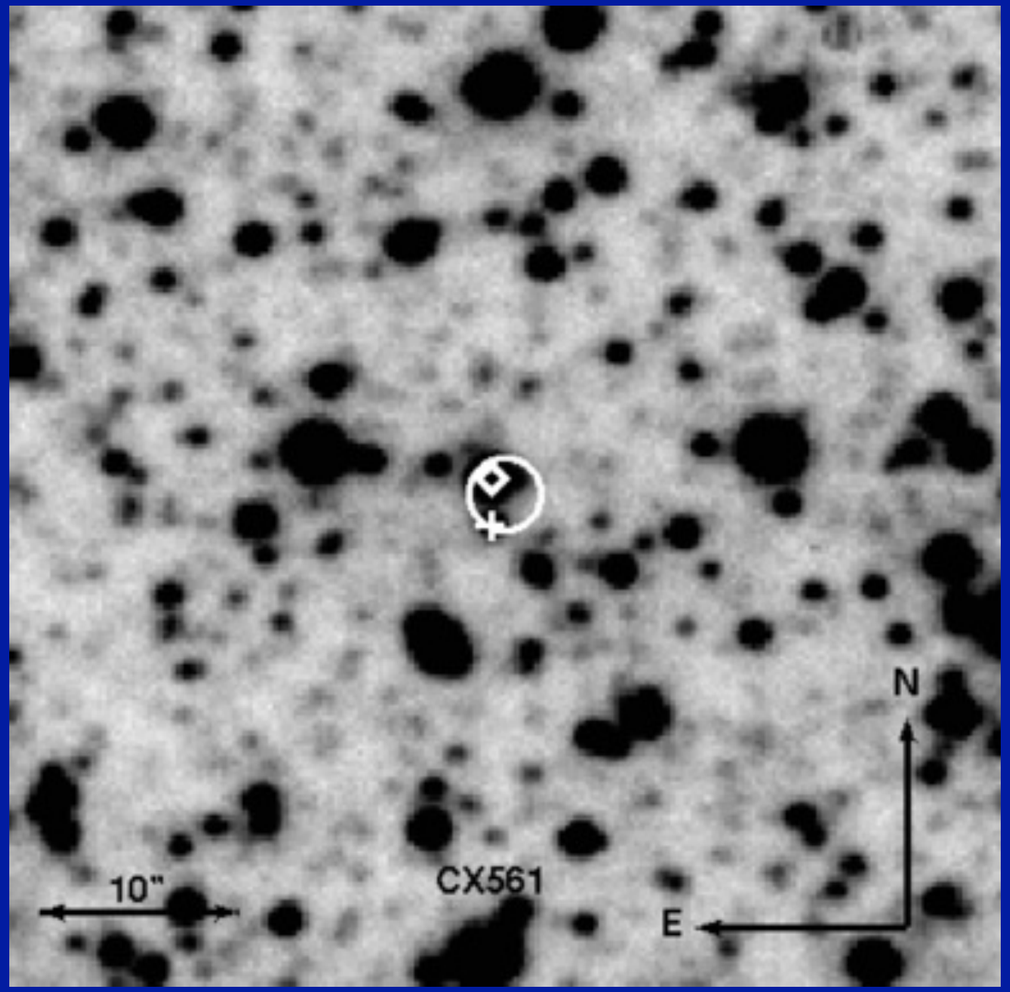
A variability project: optical

- **Blanco 4m/Mosaic-II. r'-band only. 12-18 July 2010. Covering 3/4 of the GBS area (16 < r' < 23)..**



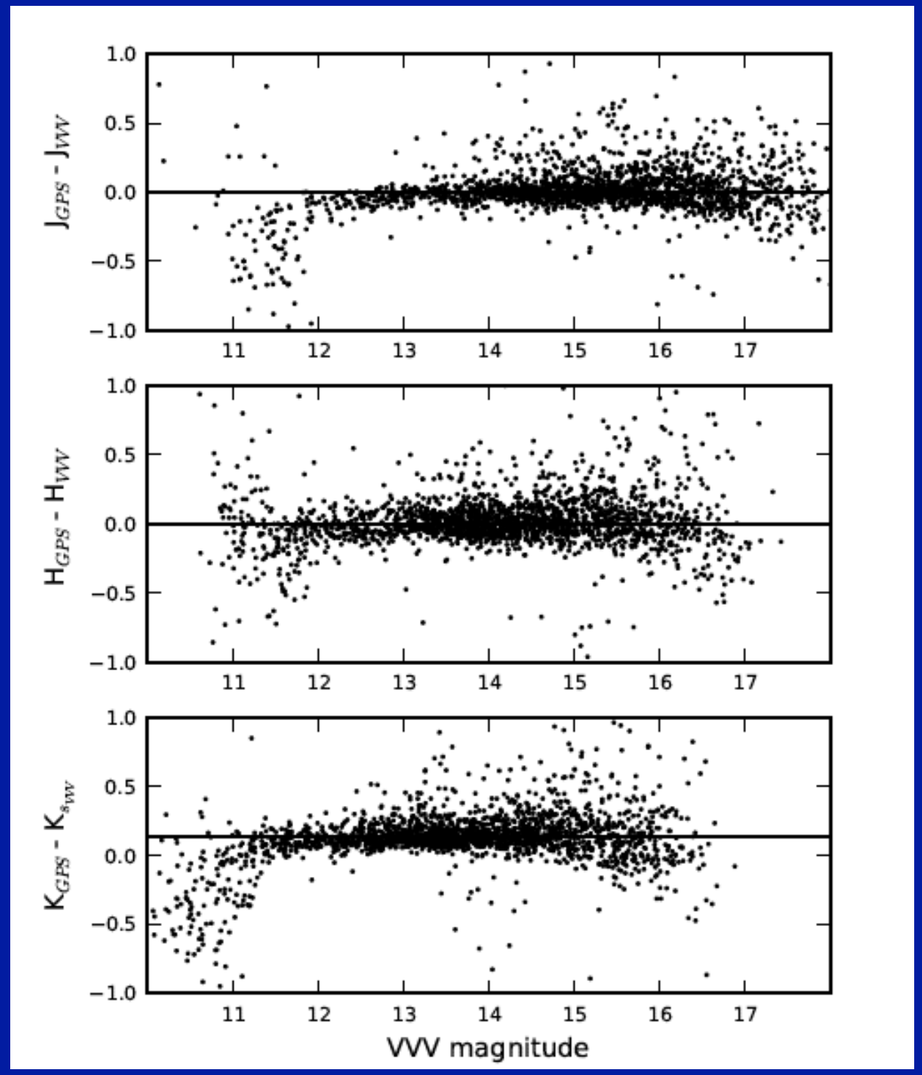
Britt, Hynes et al. (2014)

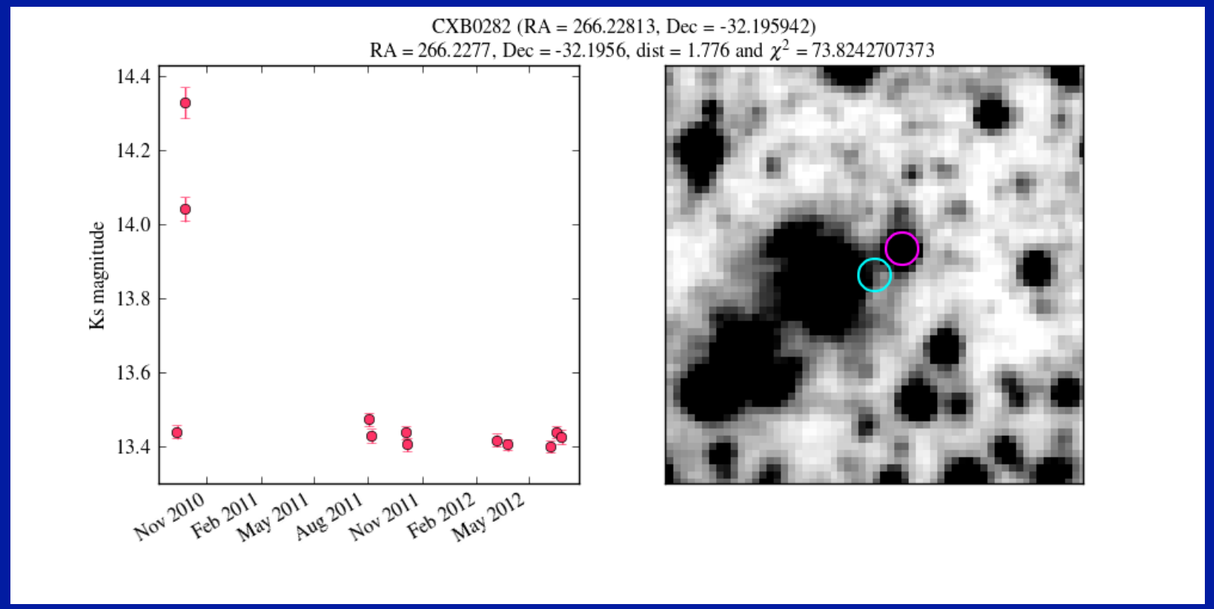
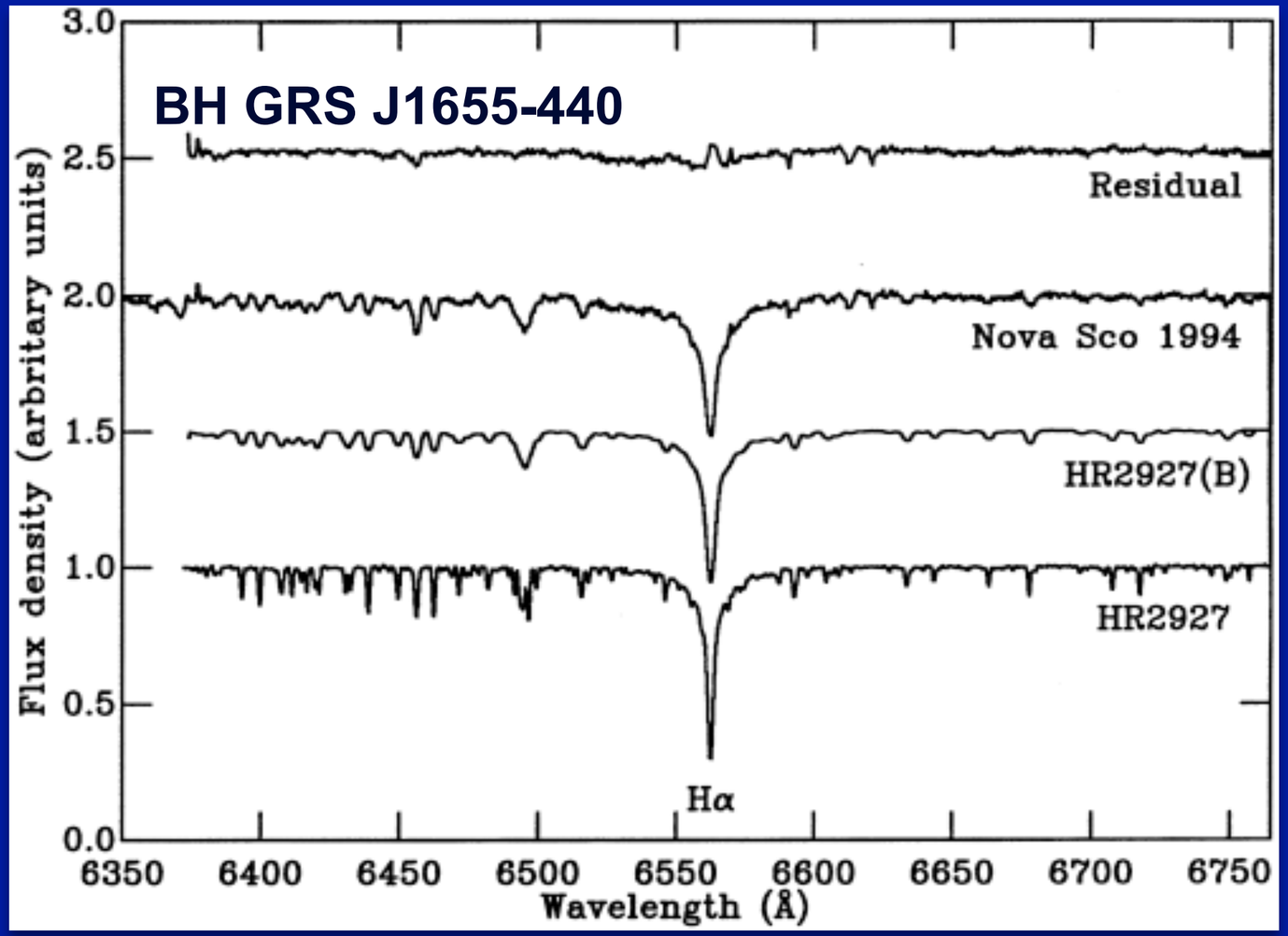
Variability not enough to confirm counterparts.



A variability project: infrared

- VVV/UKIDSS GPS/2MASS comparison. Greis, Steeghs et al. (2013).





donor star dominated light curves