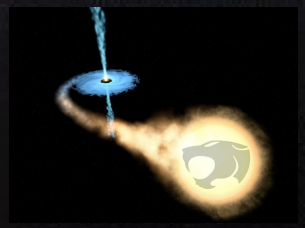

SALT Observations of Circinus X-1 and SXP1062

Matthew Schurch[1],
ThunderKAT Multi-wavelength team

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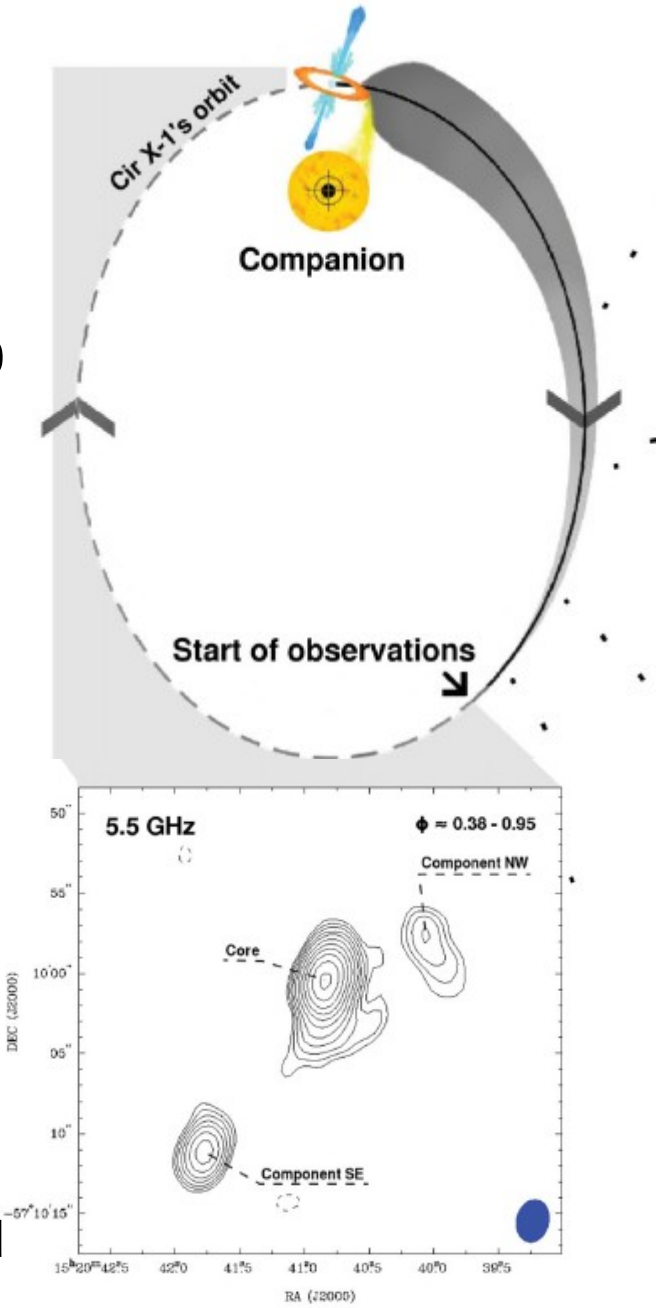
SALT Science Day
North West University – 11th November 2013

Brief History of Cir X-1

- An extremely peculiar X-ray binary.
- Rediscovery of bursting X-ray behaviour in May 2010 (Papitto et al. 2010) confirms Neutron star class binary.
- P_{orb}= MJD43076.27+16.57913n+0.0000421n^2 (HartRAO, George Nicolson). *e*=0.45 (Jonker et al. 2007).
- Highly reddened optical counterpart with magnitudes V=21.4 to K=11.0.
- Optical counterpart still unclassified possibly 3-5M_Θ subgiant or 10M_Θ supergiant (Jonker et al. 2007).
- Radio jet, inclination angle ~5^o (Fender and Hendry 2000)
- System is similar to BeXRBs, but with a lower B-field due to non detections of pulsations.

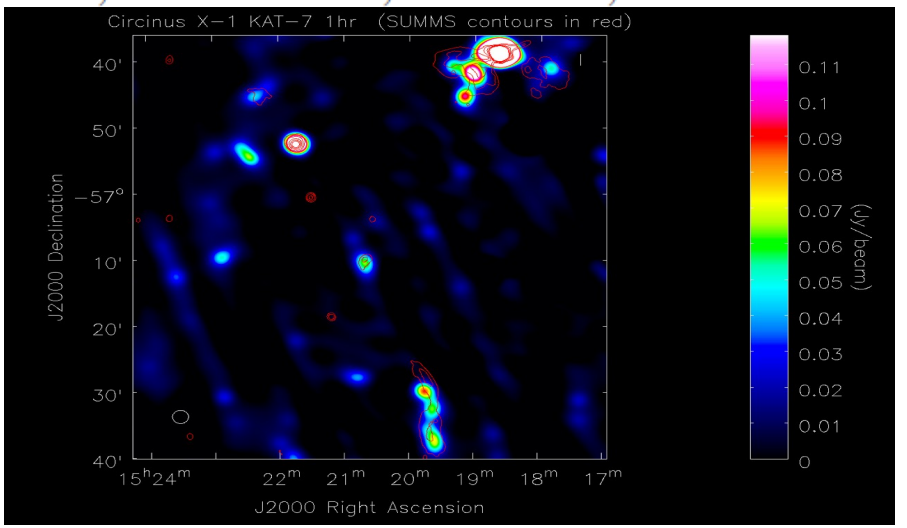


Calvelo et al. 2012

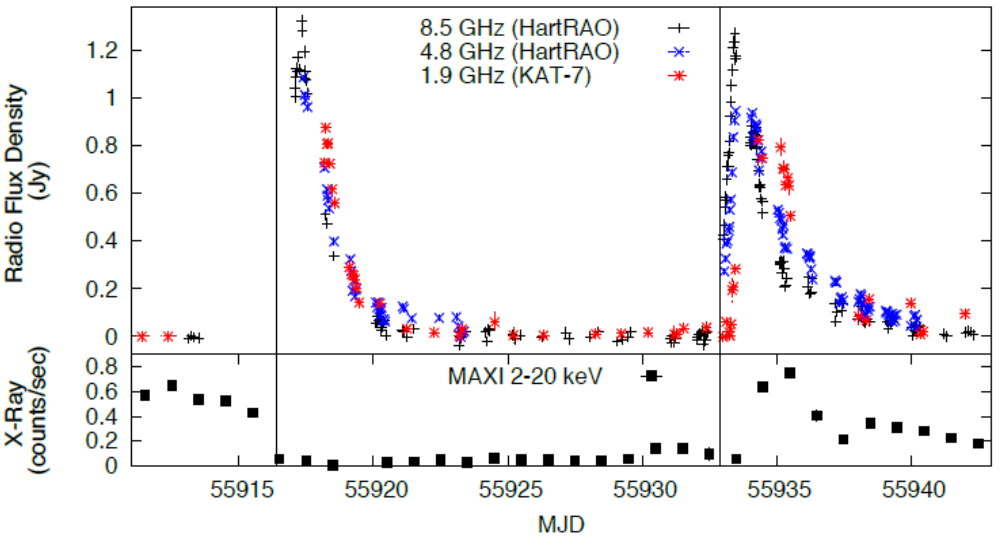
MNRAS 433, 1951–1957 (2013)
Advance Access publication 2013 June 13
doi:10.1093/mnras/stt860

A return to strong radio flaring by Circinus X-1 observed with the Karoo Array Telescope test array KAT-7

R. P. Armstrong,[1,2]★ R. P. Fender,[2,3] G. D. Nicolson,[4] S. Ratcliffe,[1] M. Linares,[5] J. Horrell,[1] L. Richter,[1] M. P. E. Schurch,[2] M. Coriat,[2,3] P. Woudt,[2] J. Jonas,[1,6] R. Booth[1,6] and B. Fanaroff[1]

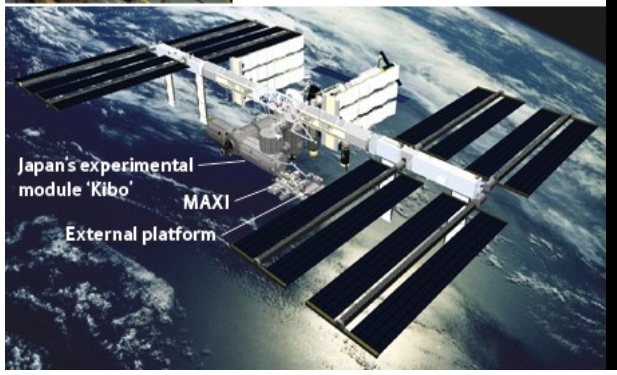


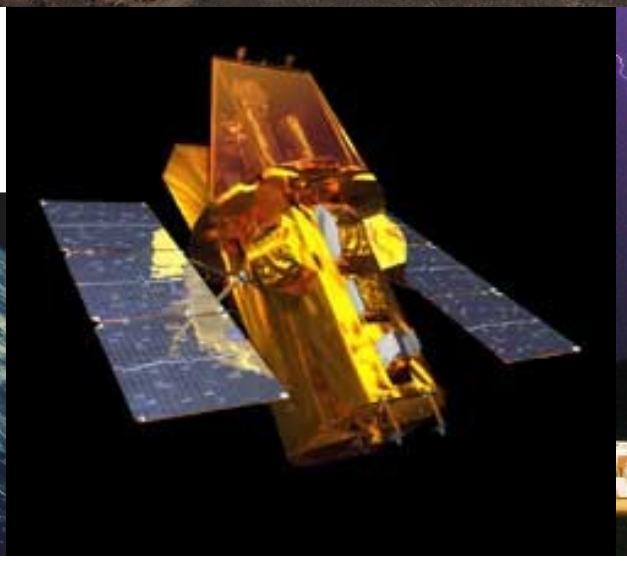
- Clear spectral evolution from +2.0 to -0.5.
- Typical of synchrotron-flaring sources (van der Laan, 1966).
- Outbursts peaks later and less energetically at given frequency.
- X-ray – Radio relationship is complex.
  - Linked to variations in accretion rate?
  - Or precession of disk/jet?



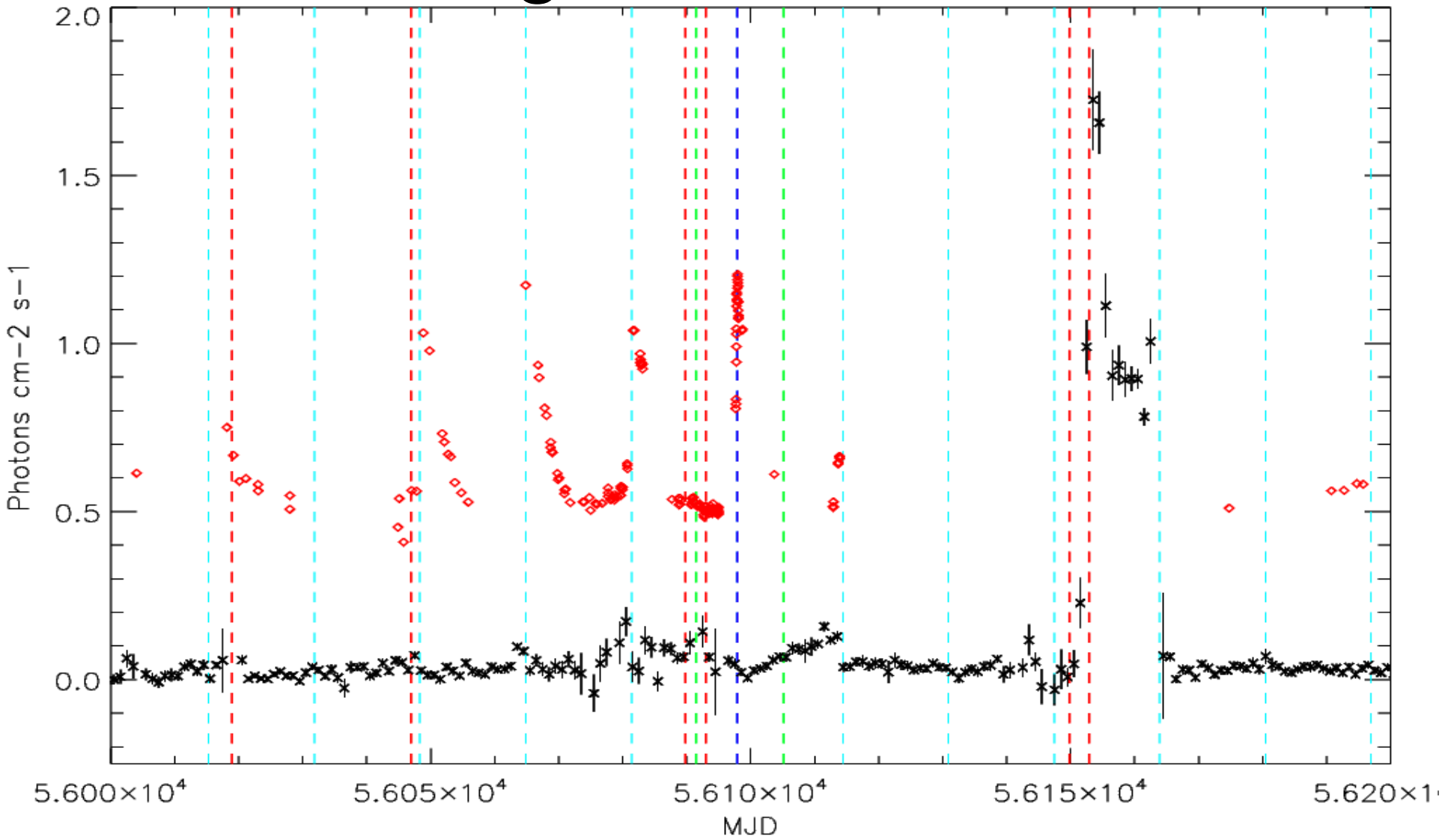
The Big Campaign

11th – 26th June 2012





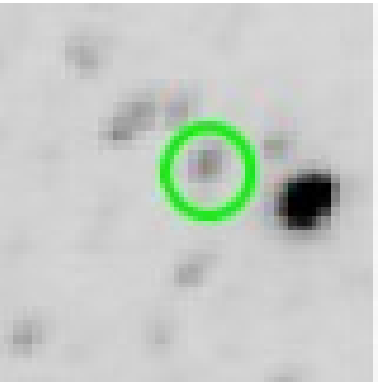
Light Curves



SALT Log 2012-06-19 - “Photometric dark night with seeing varying from excellent to mediocre. Lots of science done”

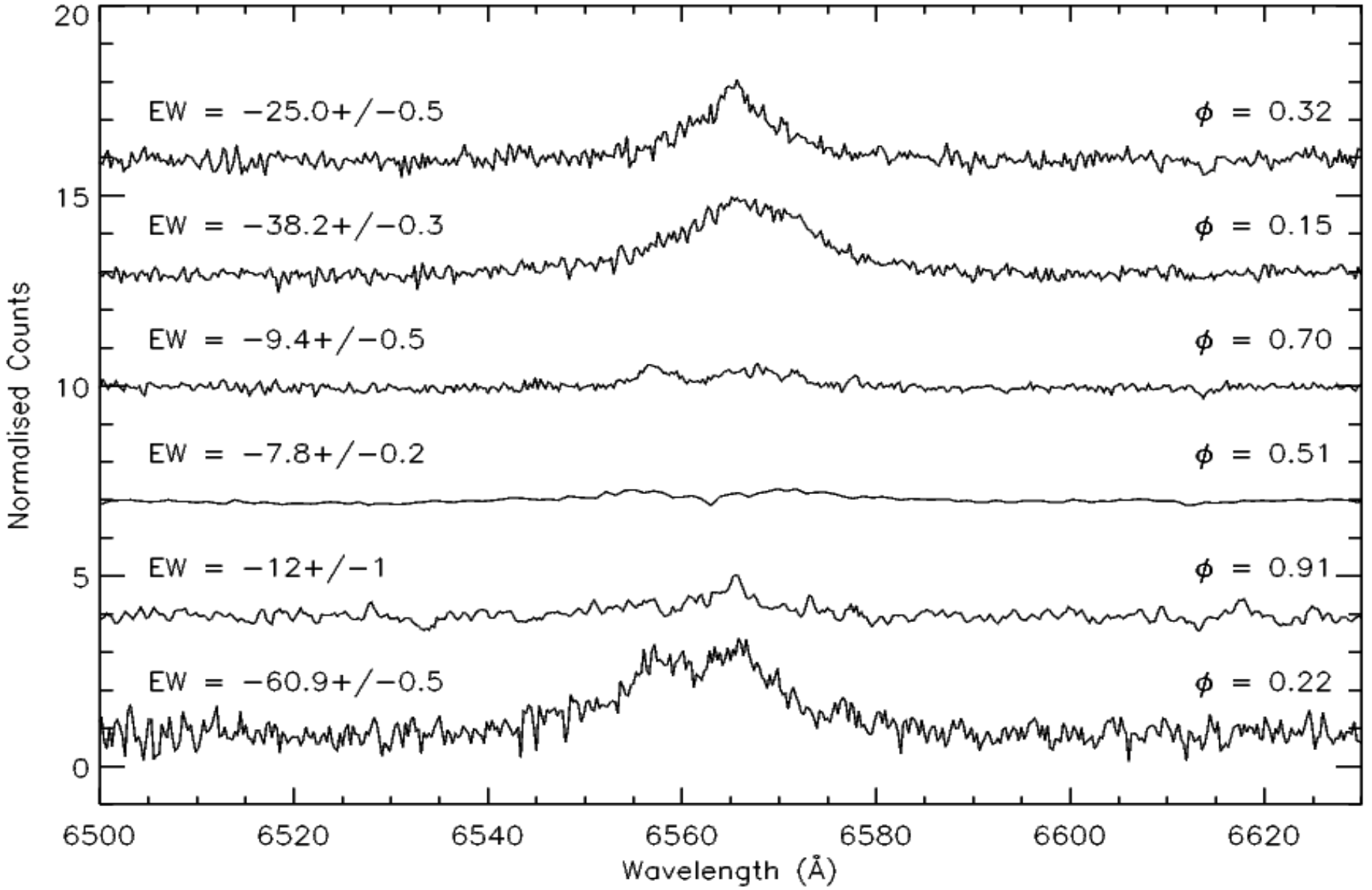
http://maxi.riken.jp/top/

SALT Observations

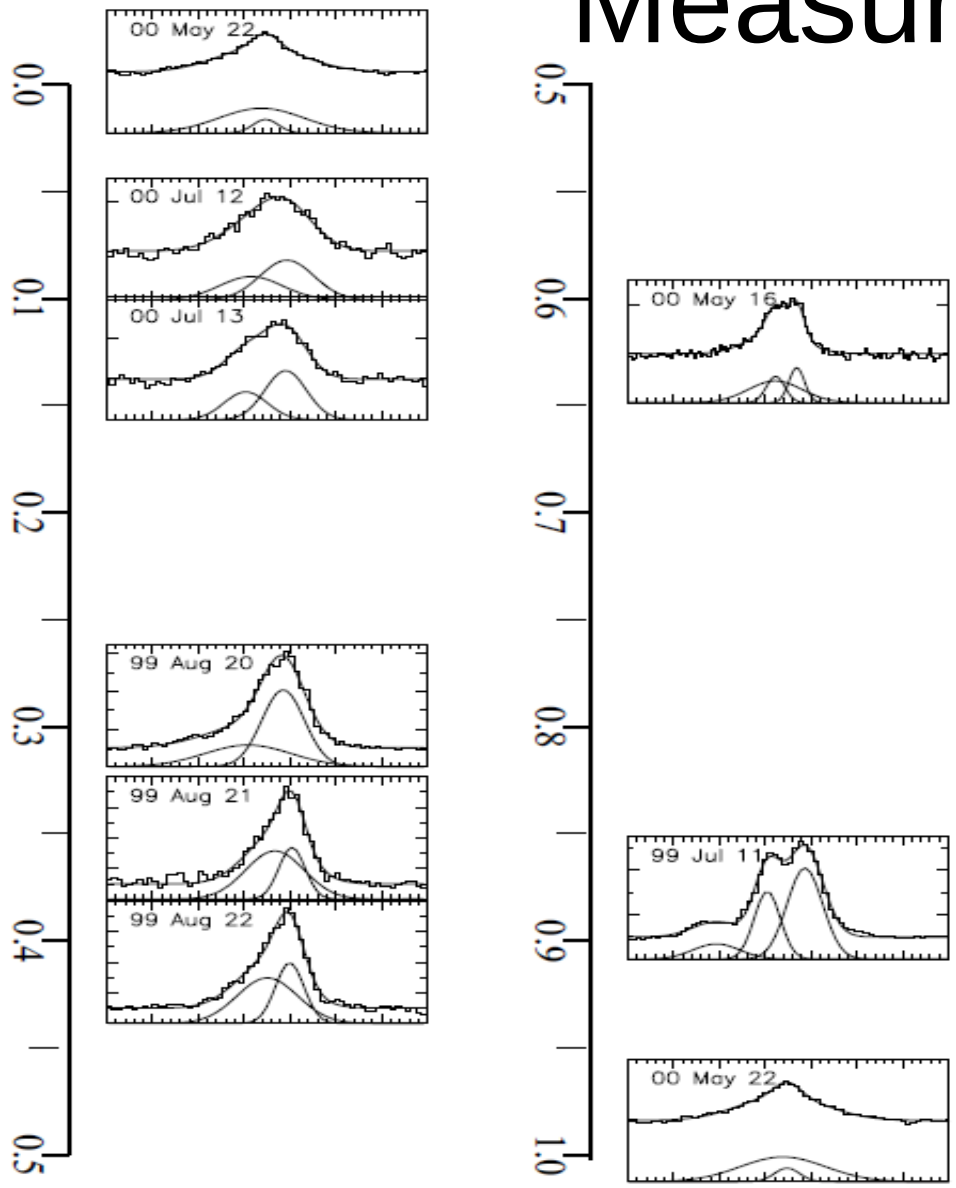


- ToO time assigned to program 2011-3-RSA_UKSA-001 was used to observe Cir X-1.
  - This program was set up to perform high resolution red spectroscopy of X-ray binaries throughout outbursts.
  - 2 epochs during April 2012
- 2012-3-RSA_UKSA-003 Cir X-1 specific proposal.
  - 4 epochs; 2 in June and 2 in August 2012.
- 3x1200s Hα (6160-7000Å) and 1x688s Paschen lines (7925-8980Å). Totalling 46.5ks.
- Grating PG2300 with a slit width of 1.5” producing medium resolution, R=4400 and 5400 spectra.
- Dispersion of 0.13 and 0.16Å per pixel

Hα Emission Line



Historical Hα Emission Measurements

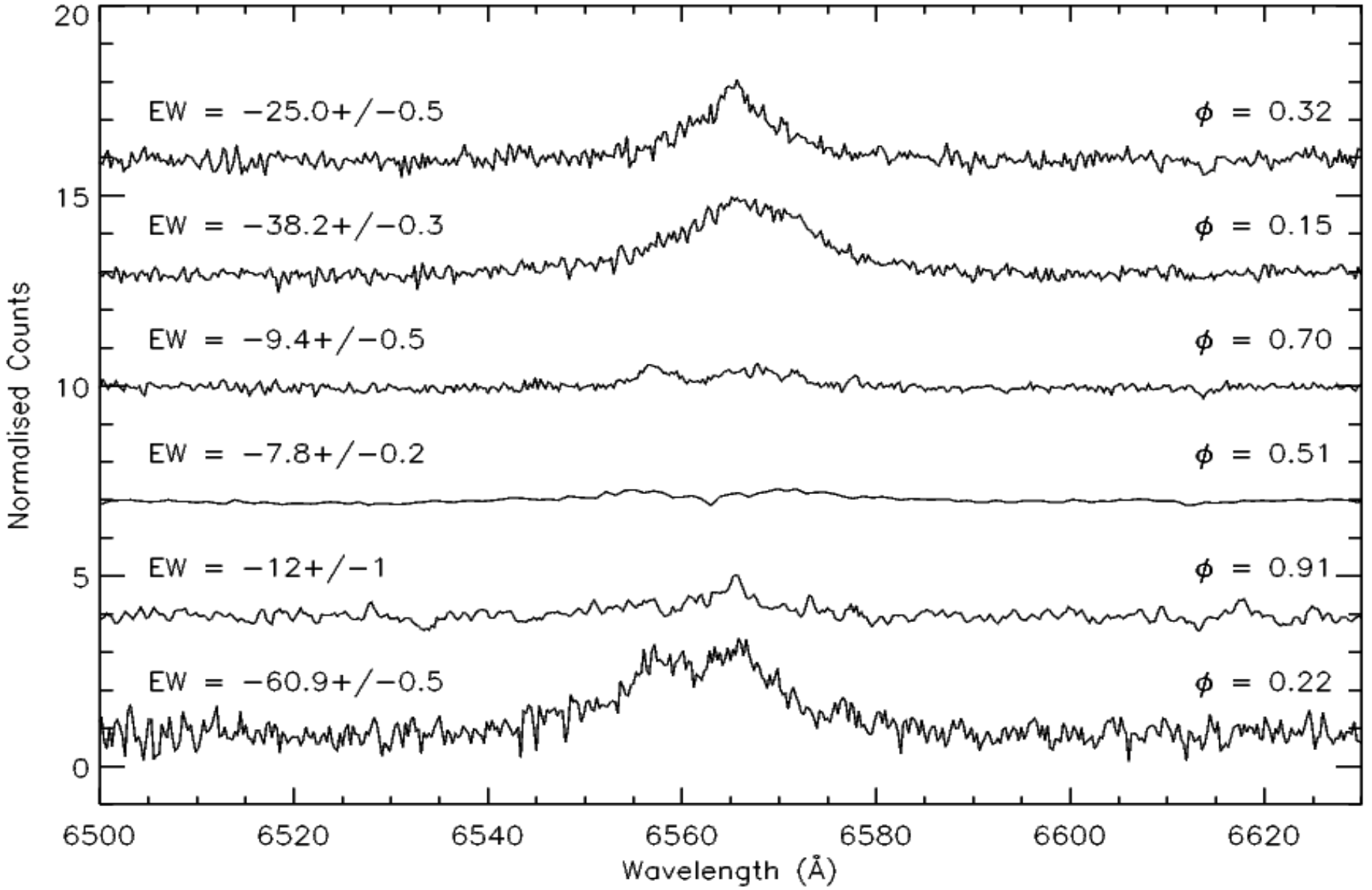


UT Date	Phase	$W_{\lambda t}$ Hα (Å)
1999 Jul 11	0.880	81
1999 Aug 20	0.292	80
1999 Aug 21	0.350	79
1999 Aug 22	0.411	83
2000 May 16	0.622	12.2
2000 May 22	0.985	10.1
2000 Jul 12	0.073	25.0
2000 Jul 13	0.129	26.3

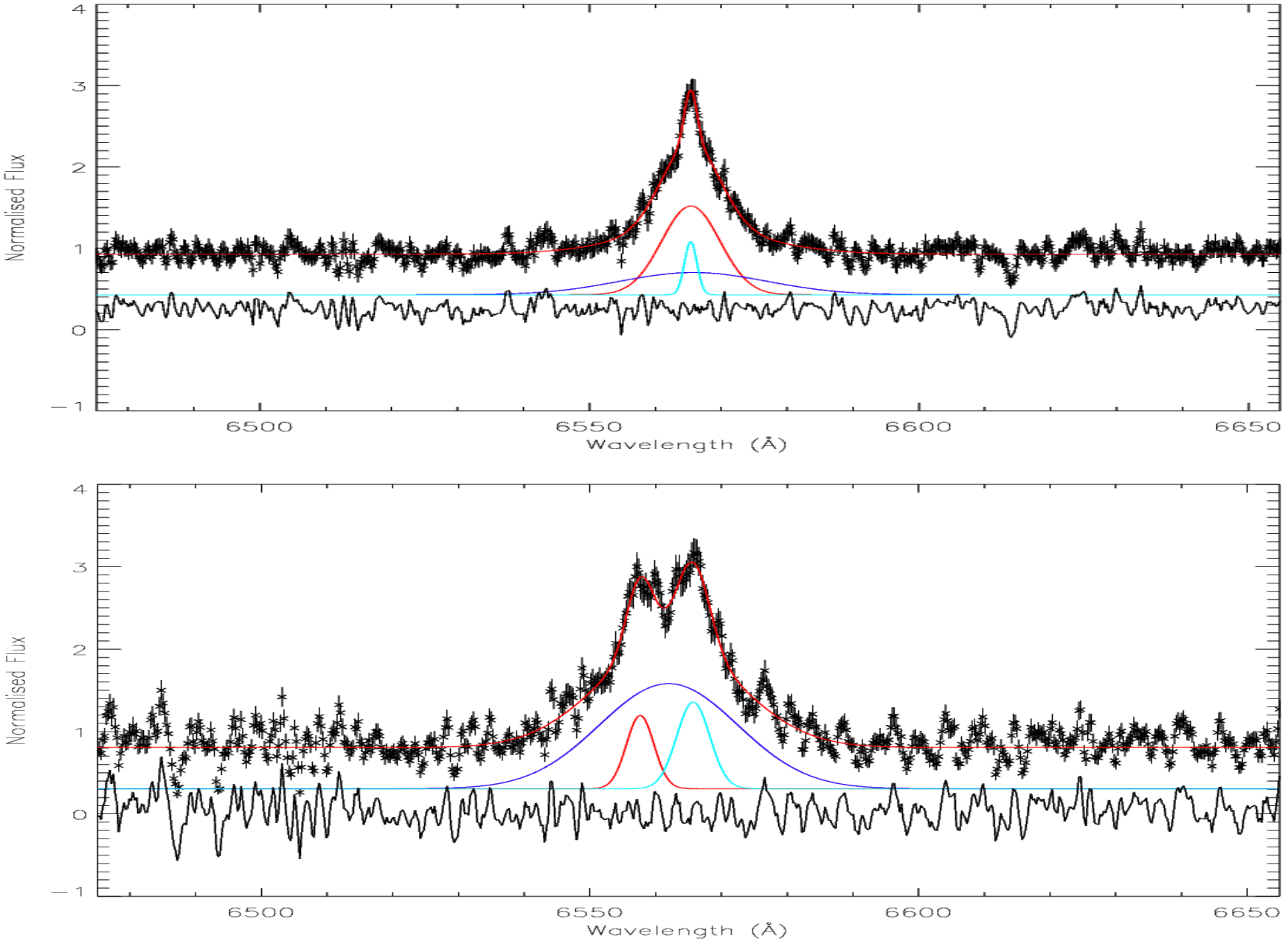
Figure 1. Line profiles of Hα, showing the Gaussian fits to the lines and their sum. The spectra have been normalized by a polynomial fit to the continuum. The spectra are shown in order of phase, with the spectrum taken at phase 0 (1999 May 22) repeated at phase 1 for clarity. The spectrum at phase 0 is symmetric, with a broad component on the blue wing appearing at phases 0.1–0.5. At phase 0.6 the line appears to be double-peaked (or flat-topped?), while clear double peaks are seen at phase 0.9.

Johnston et al. 2001

Hα Emission Line



Hα Emission Line Fits



SXP1062

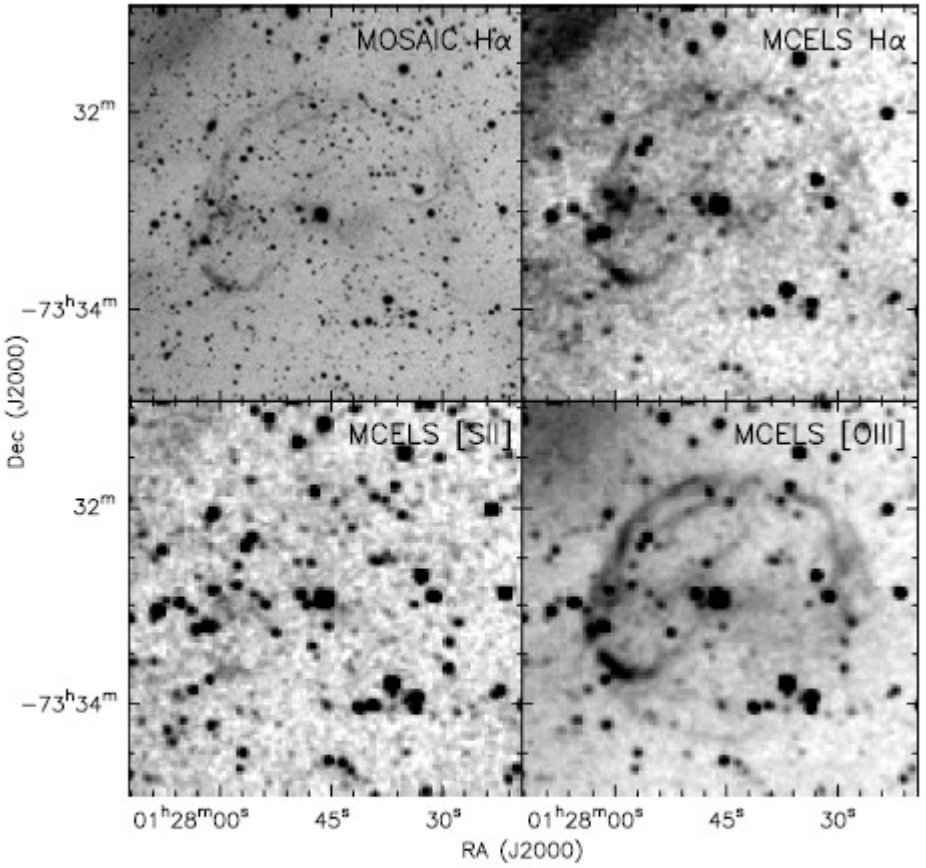


Figure 5. MOSAIC Hα image and MCELS Hα, [S II] and [O III] images of a region centred on the position of 2dFS 3831 = SXP 1062 and showing the shell nebula detected around the target.

H'enault-Brunet et al. 2012

Chandra detection near NGC602

2dFS 3831
RA = 01:27:46
Dec = −73:32:56
P_s = 1062s
$Pdot_s$ = 94.9 syr^{-1}

H'enault-Brunet et al. 2012,
Haberl et al. 2012,
Fu et al. 2012,
Popov and Turolla 2012,
Ikhsanov 2012.

A&A 556, A139 (2013)
DOI: 10.1051/0004-6361/201321755

Astronomy & Astrophysics

Long-term evolution of the neutron-star spin period of SXP 1062⋆,⋆⋆

R. Sturm[1], F. Haberl[1], L. M. Oskinova[2], M. P. E. Schurch[3], V. Hénault-Brunet[4], J. S. Gallagher III[5], and A. Udalski[6]

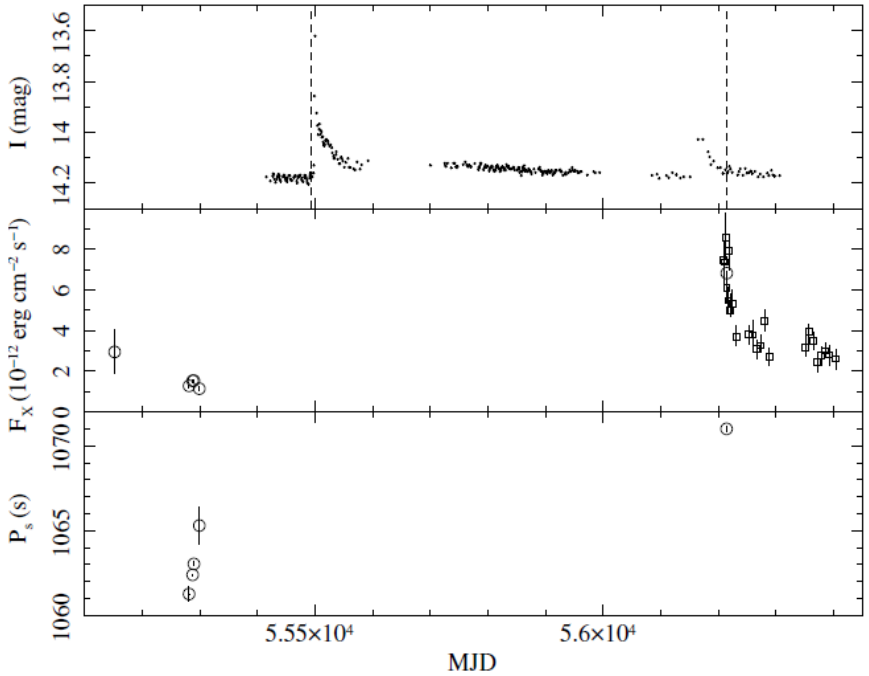


Fig. 1. *Upper panel*: OGLE-IV *I*-band light curve. Dashed lines indicate the time of optical spectroscopy observations. *Middle panel*: X-ray fluxes in the (0.2–10.0) keV band from *Swift* (open squares) and *XMM-Newton* (open circles) including the 2009 slew-survey data and the 2010 measurements. *Lower panel*: NS spin period as measured with *XMM-Newton*.

XMM-Newton

- 1071.01s period
- Pdot = 2.27 syr^{-1}. Implies an initial magnetic field ~10^{14} G
  - Γ~0.774+/-0.009

SALT Program:
2012-1-RSA_UKSC-003
- PI: Schurch.

13th/14th October 2012.
2x400s in blue
180s in red.

Observing conditions: 3”

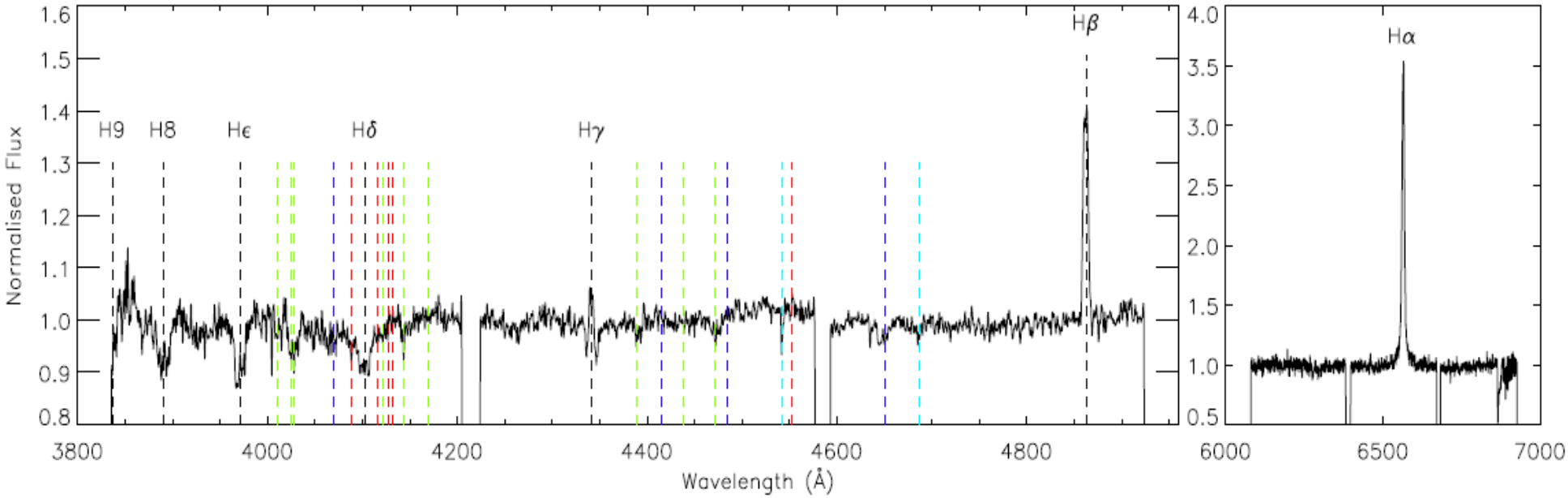


Fig. 5. SALT blue and red (*left* and *right* respectively) smoothed spectra of SXP 1062. Clearly visible are the chip gaps between the three CCDs. Dotted lines indicate: Balmer lines (black), He I (green), He II (light blue), Silicon (red) and other metal lines (dark blue).

SALT (Oct 2012) EW_{Ha} = -26.65+/-0.09 Å

2df (Sept 1999) EW_{Ha} = -22.02+/-0.05 Å

SALT (Oct 2012) EW_{Hb} = -2.40+/-0.29 Å

2df (Sept 1998) EW_{Hb} = -1.58+/-0.10 Å

A&A 556, A139 (2013)

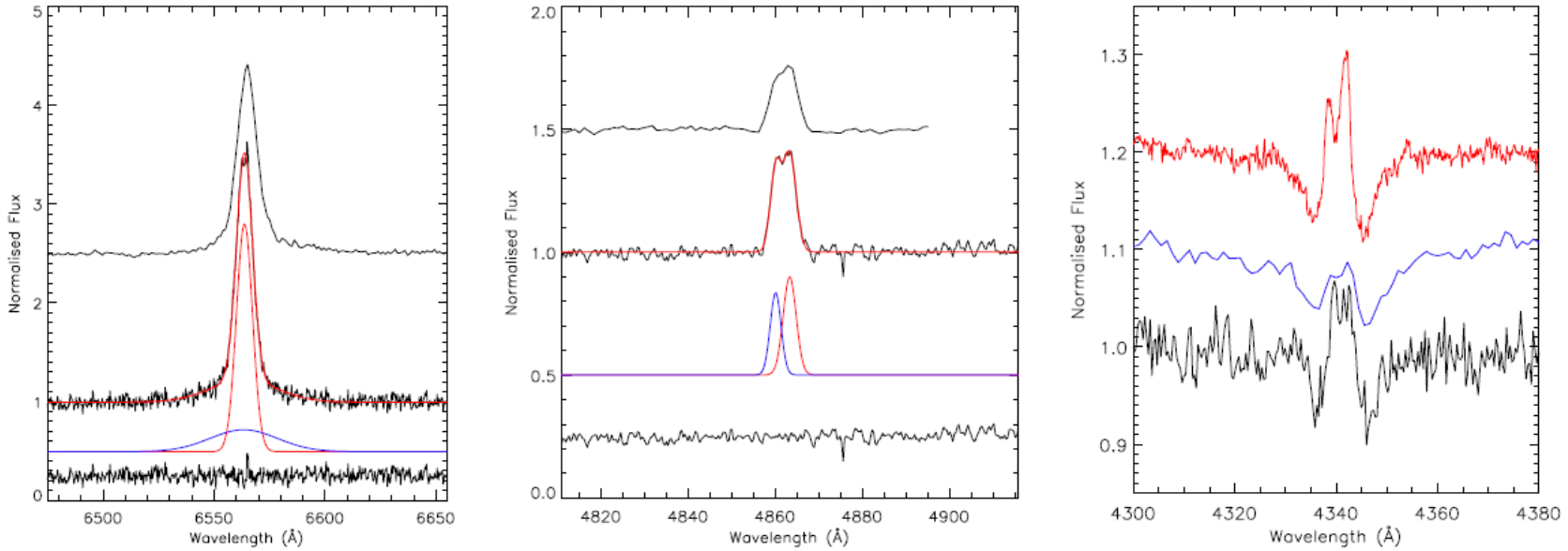


Fig. 6. *Left*: Hα as seen with SALT (normalised) and according modelling with two Gaussians and continuum. The lowest line gives the residuals. The 2dF spectrum is shown on the top for comparison. *Middle*: same as before, but for Hβ. *Right*: Hγ as seen with VLT FLAMES (top), 2dF (middle) and SALT (bottom).

SALT (Oct 2012) EW_{Ha} = -26.65+/-0.09 Å

2df (Sept 1999) EW_{Ha} = -22.02+/-0.05 Å

SALT (Oct 2012) EW_{Hb} = -2.40+/-0.29 Å

2df (Sept 1998) EW_{Hb} = -1.58+/-0.10 Å

SXP1062 Periodic Outburst?

- Outburst in July 2014?
- Accepted joint Chandra and Swift proposal
  - Swift monitoring will trigger Chandra.
  - 24 x 2ks observations.
  - 120ks Chandra time (4 observations)
- Propose for simultaneous KAT-7 and SALT observations.

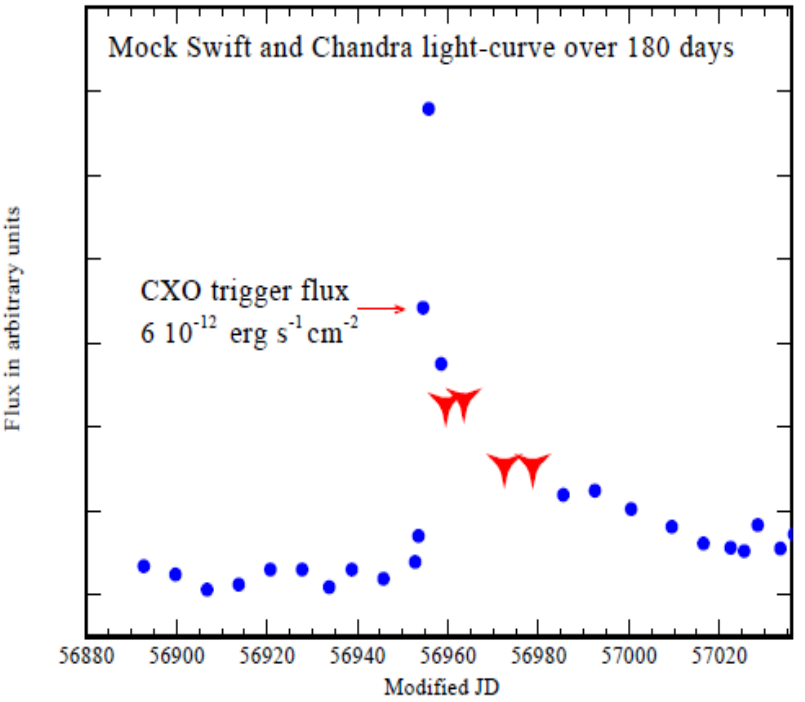


Figure 3: Mock X-ray light-curve to illustrate our observing strategy. *Swift* monitoring is over 24 weeks (2 ks). At flux level 6×10^{-12} *Chandra* observations are triggered with medium response time (red diamonds). The 120 ks *Chandra* observing time can be split on exposures of any duration. *Swift* observations resume afterwords.

Summary

- Circinus X-1
  - Large variation in Hα emission line between outburst cycles, but small variation within a single orbit.
  - Consistent with previous observations (Johnston et al., 2001).
  - Full comparison of data with KAT-7 and HartRAO monitoring is still to be done. Should be published early 2014.
- SXP1062
  - Confirmation of spectral type.
  - Basic modelling of circumstellar disk emission lines.
  - 2014 observations planned.

SALT Science Day - 11th November 2013