X-ray Binary Transients with SALT

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Outline: two interesting transients

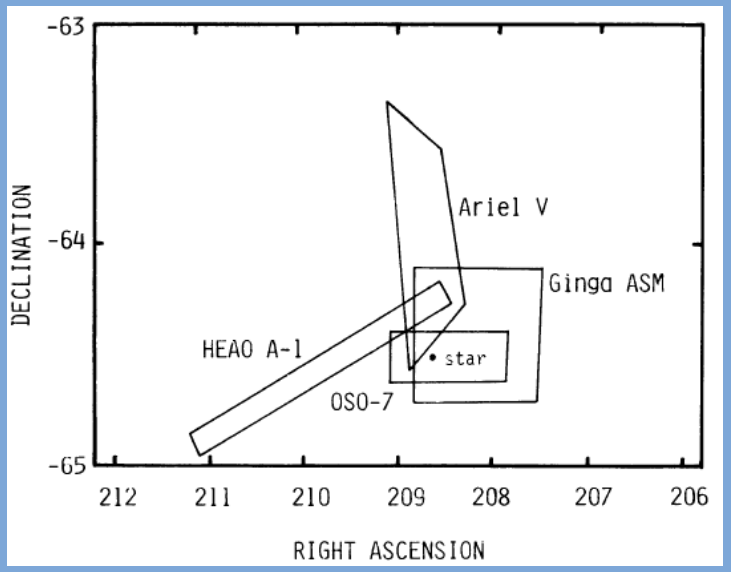
1) The first transient – Cen X-2/BW Cir?

   - a cautionary tale

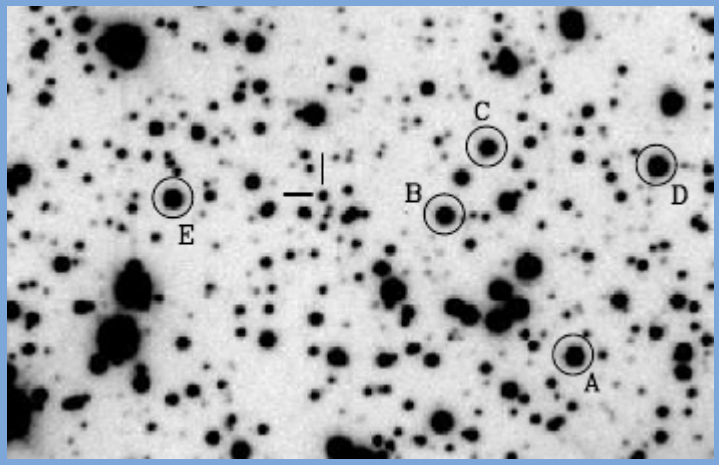
2) ASASSN-16oh:

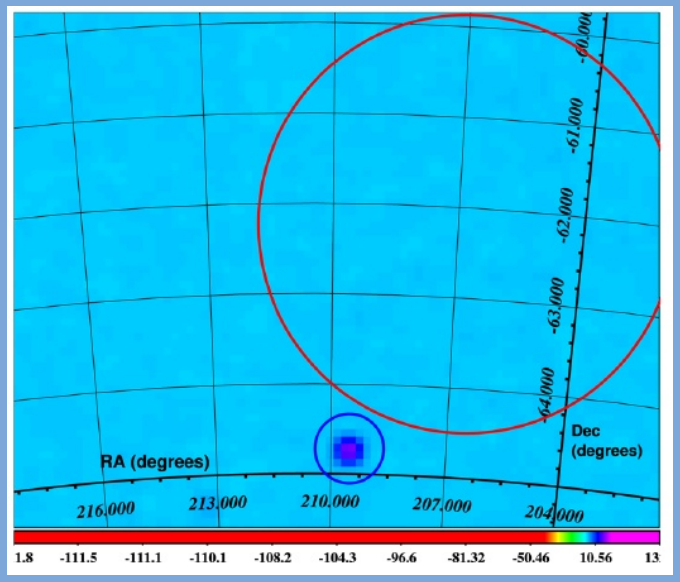
   - is it nuclear burning or accretion?

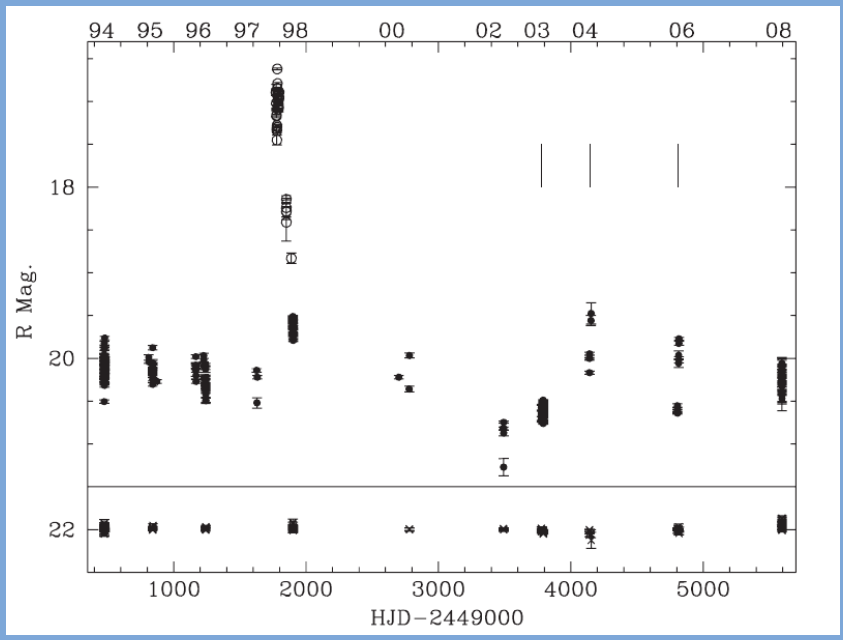
BW Cir (GS1354-64) [=Cen X-2?]



1987 outburst
→ optical ID of GS1354-64 with R~20.5 star
BW Cir



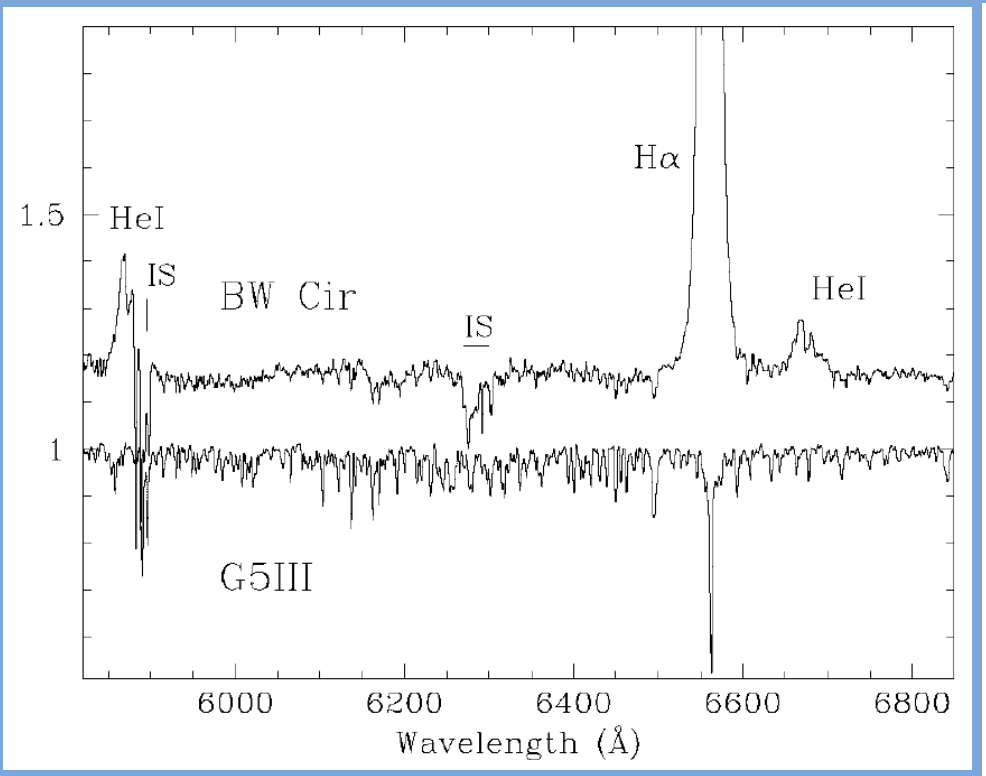


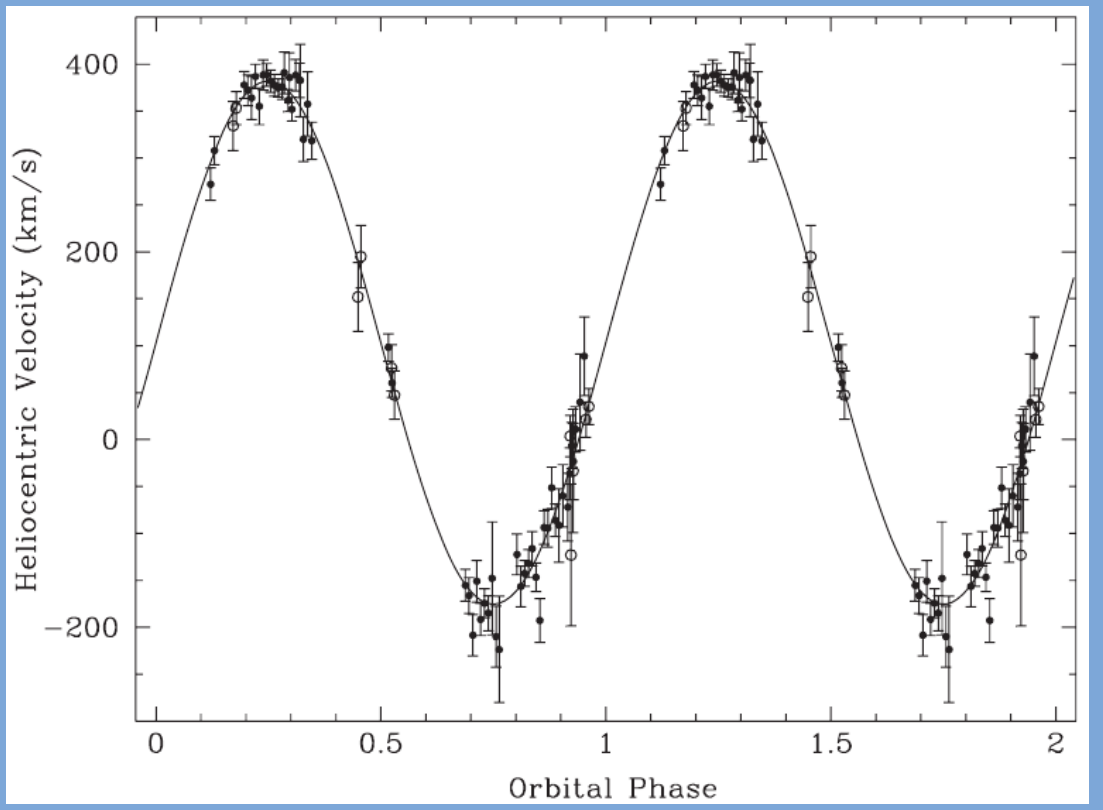


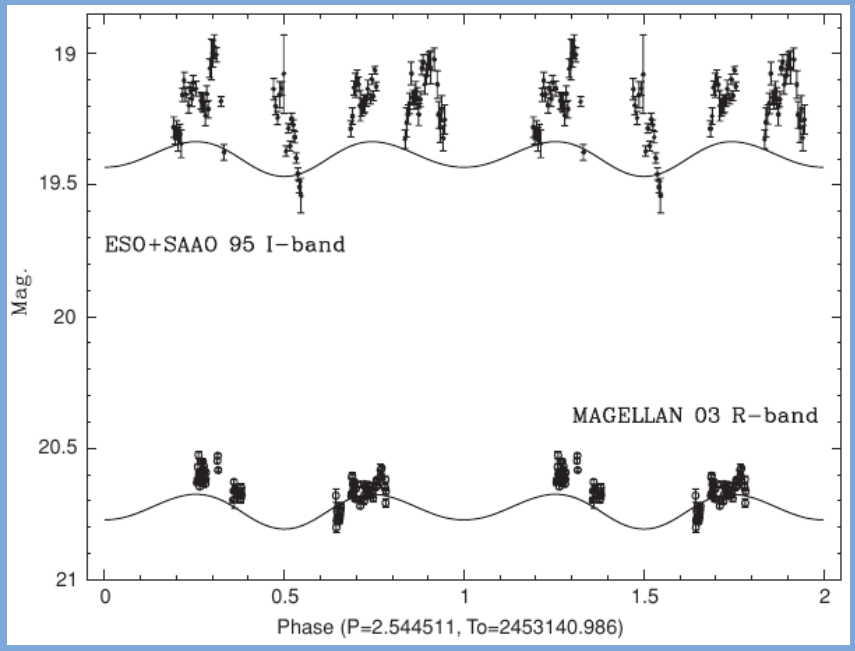
Could it be same as Cen X-2?
The First Transient found in 1967!

Further outbursts in 1997 and 2015

Casares+04, +09 with VLT → G5III donor in P=2.5d binary + f(M)=5.7M_O

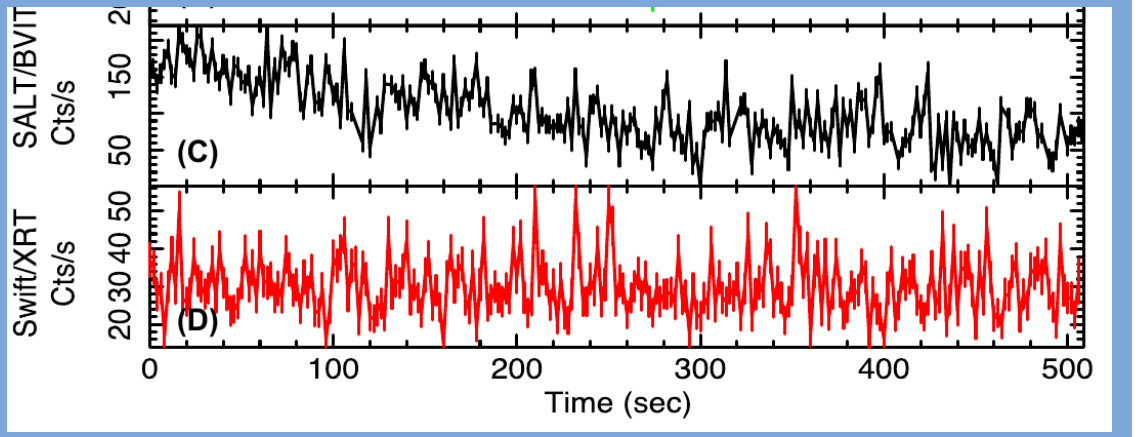




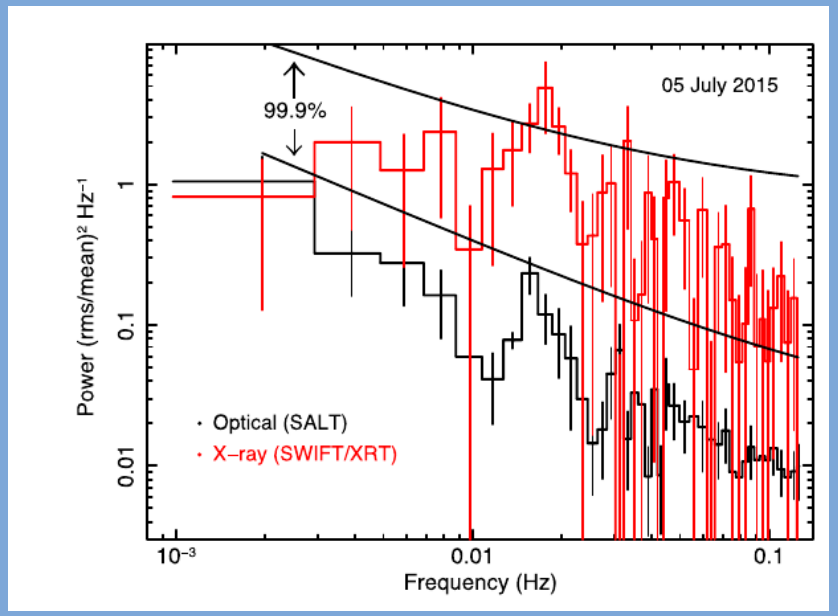


Quiesc variability → no ellipsoidal modulation
No X-ray eclipse → $i < 79^o$
G5III sp type + R~20.5 → d~15-25kpc
(not super-Edd in 1987)

Pahari+17: Simultaneous SALT/BVIT+Swift XRT in 2015 outburst



Evidence for ~18mHz (~50s) QPOs
→ typical of BH LMXBs



Rao+18 - astro/ph

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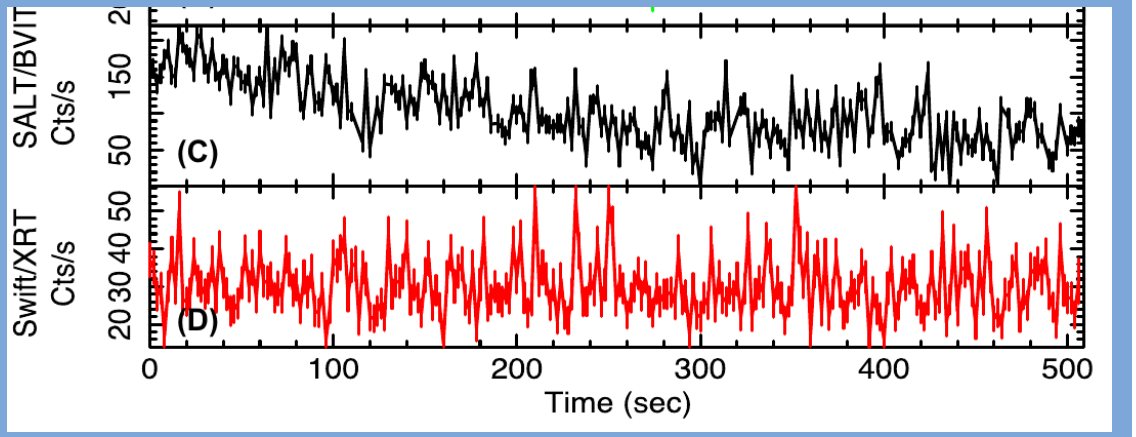

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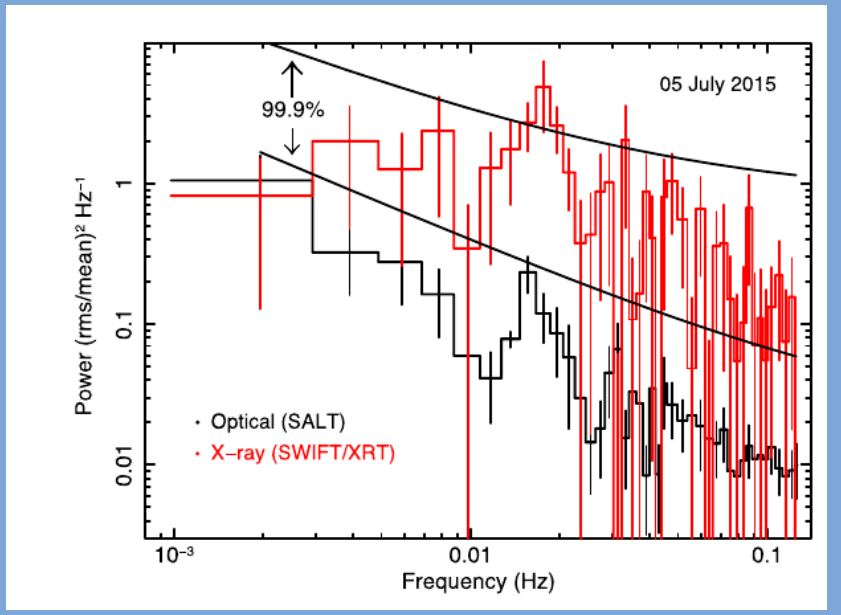
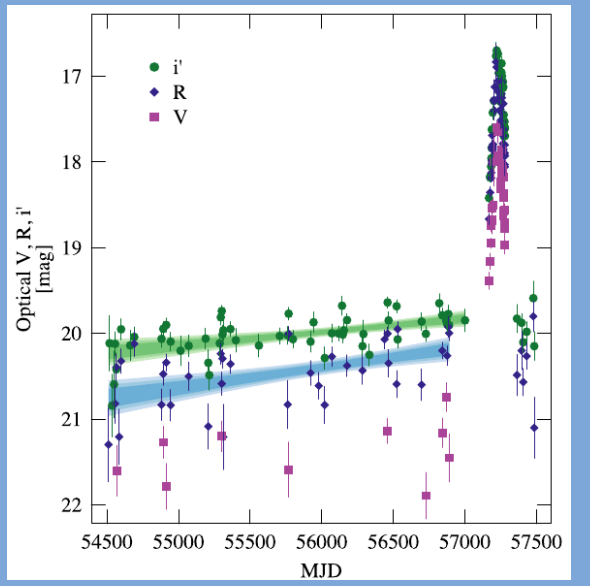
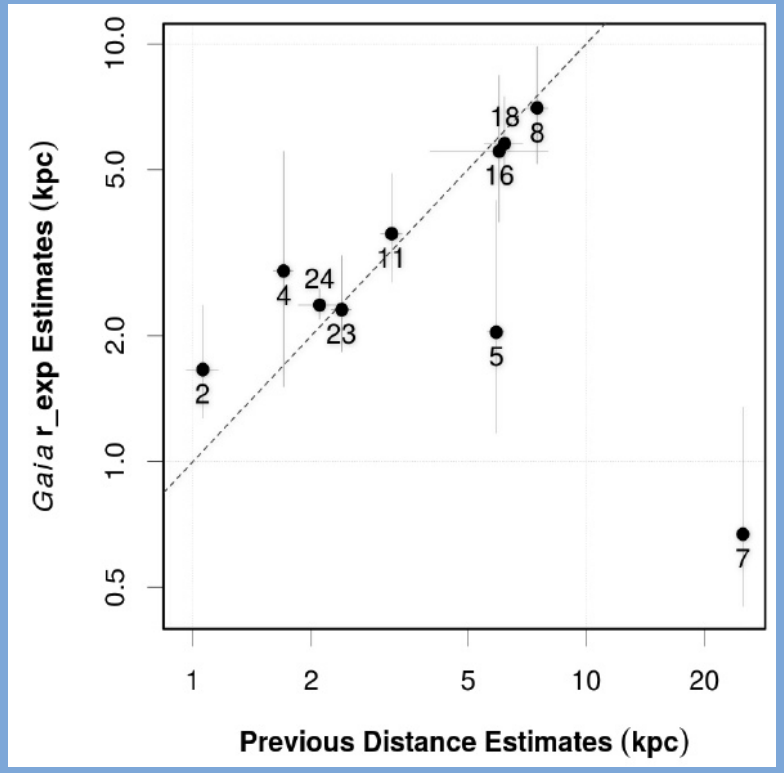


But BW Cir is in Gaia/DR2 → d=550+/-200pc!

→ can we believe Gaia?
N.B. R~20.5 except for 2015 outburst to R~17 (Koljonen+16)
→ must be cautious!

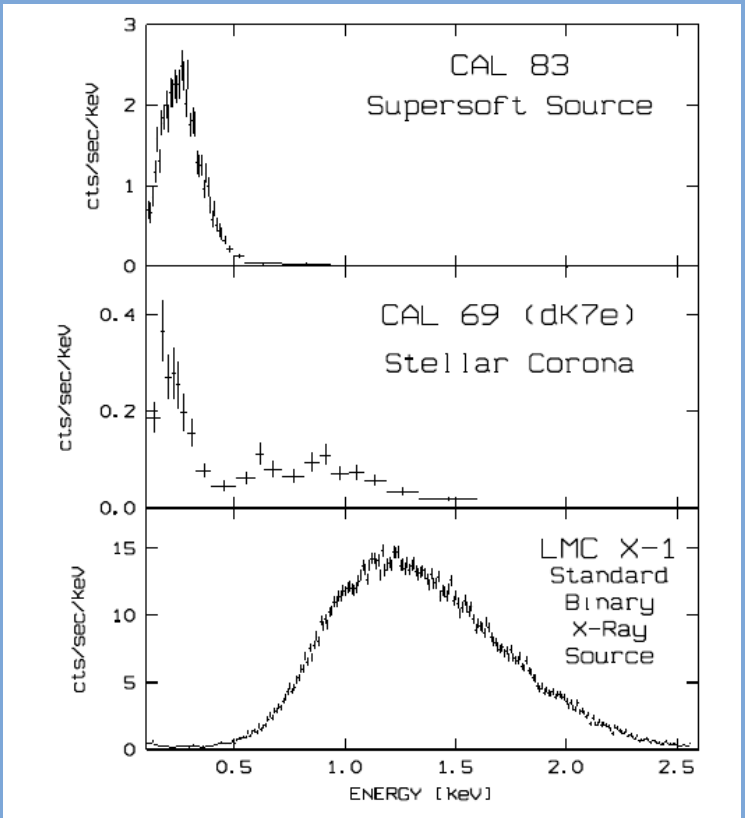




Rao+18 - astro/ph

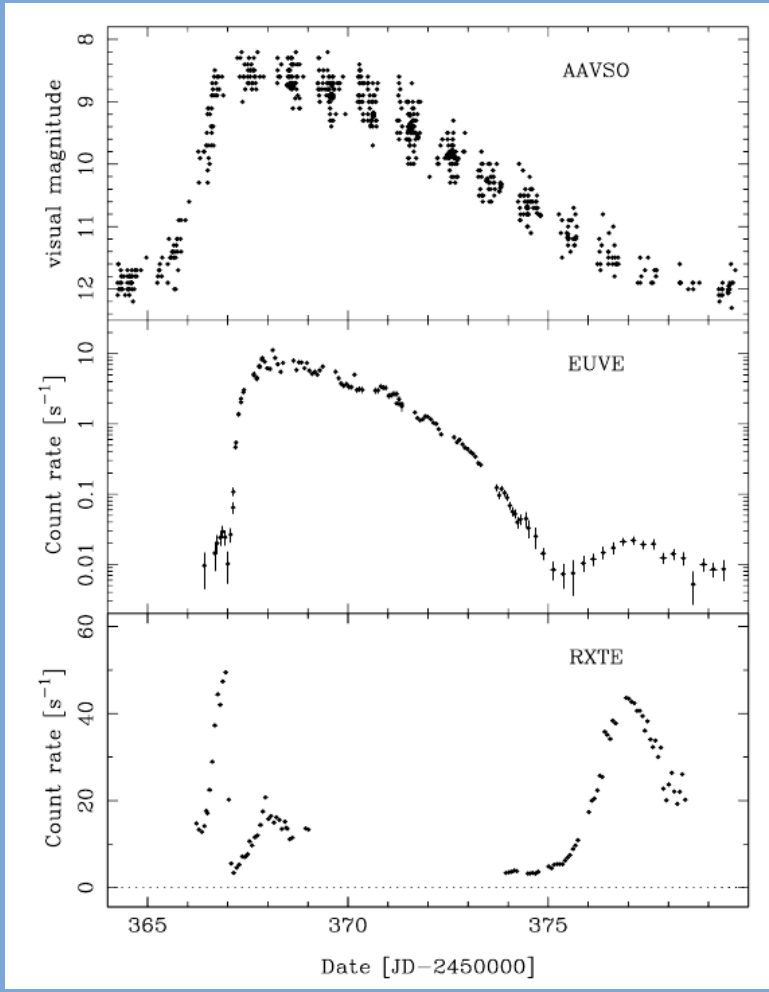
SSS key facts:

- $L_X \sim 10^{37} - 10^{38}$ erg s^{-1} (<0.5 keV)
- BB kT < 100 eV (T ~ 10^5 – 10^6K)
- e.g. prototypical sources CAL83, CAL87 in LMC
- Found there due to low N_X (galactic equivalents mostly obscured)



Kahabka & van den Heuvel 97

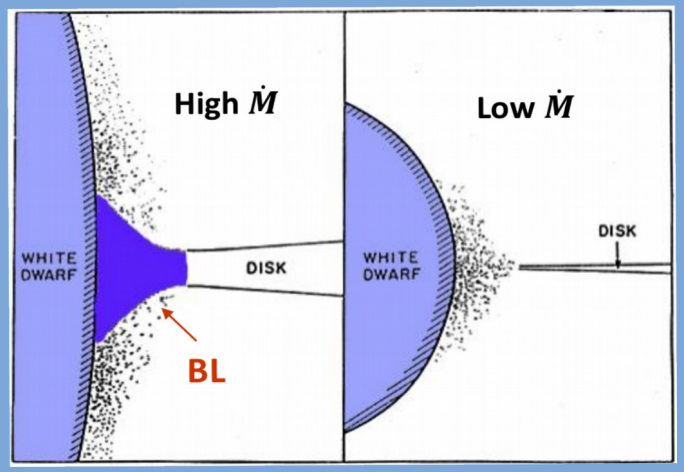
Accretion onto a WD e.g. SS Cyg DN outburst (Wheatley+03)



V

SX

HX



$$L_{\rm bb} \approx G M_{\rm wd} \dot{M} / 2 R_{\rm wd}$$

$$T = (L_{\rm bb} / 4\pi\sigma f R_{\rm wd}^2)^{1/4}$$

→ expected peak L_X (~10^{35} erg s^{-1}) for WD

Accreting White Dwarf Model (van den Heuvel et al 92)

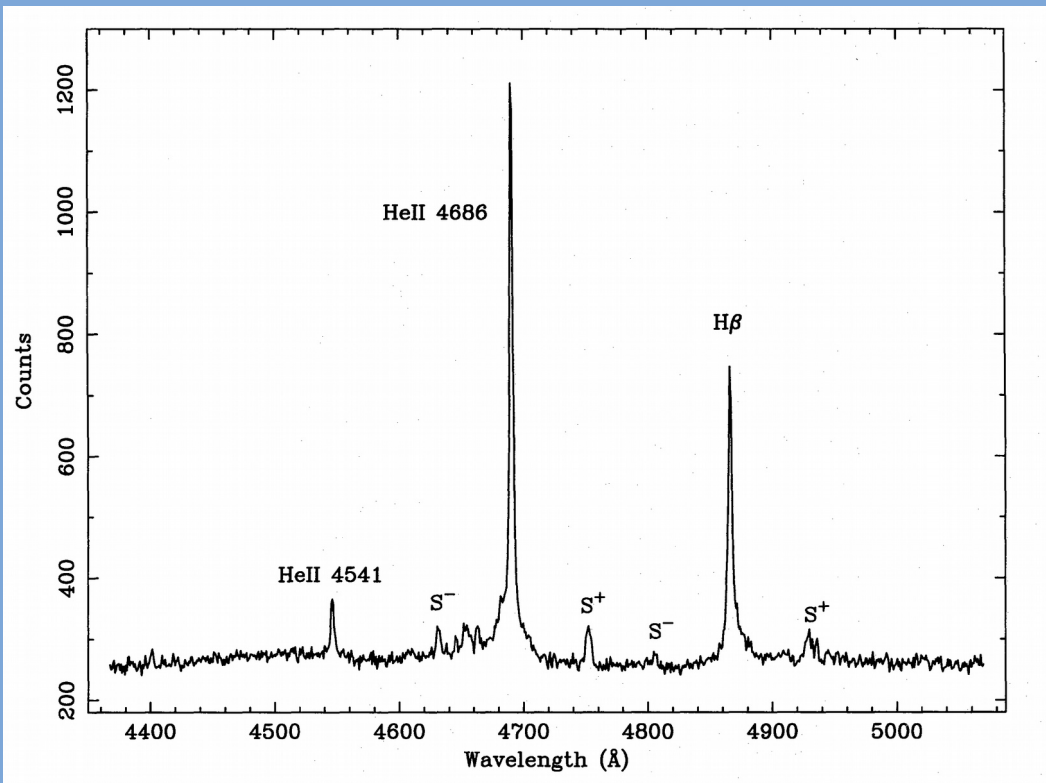
- **v high L_{bol} (sources in MCs)** + v low kT → (for BB) R ~ R_{WD}
  - WD compact object + sub-giant donor (i.e. ~ CV)
- for near L_{Edd} luminosities require steady nuclear burning at WD surface (exceeds L_{acc} by ~x10)
- requires v high accretion rate (~100 – 1000x higher than in CVs)
  - > 10^{-7} M_O yr^{-1}
- needs *q*~1 → thermally unstable mass transfer (→ short-lived phase)
- potentially important as massive WD / SN Ia progenitors

Southwell et al 96

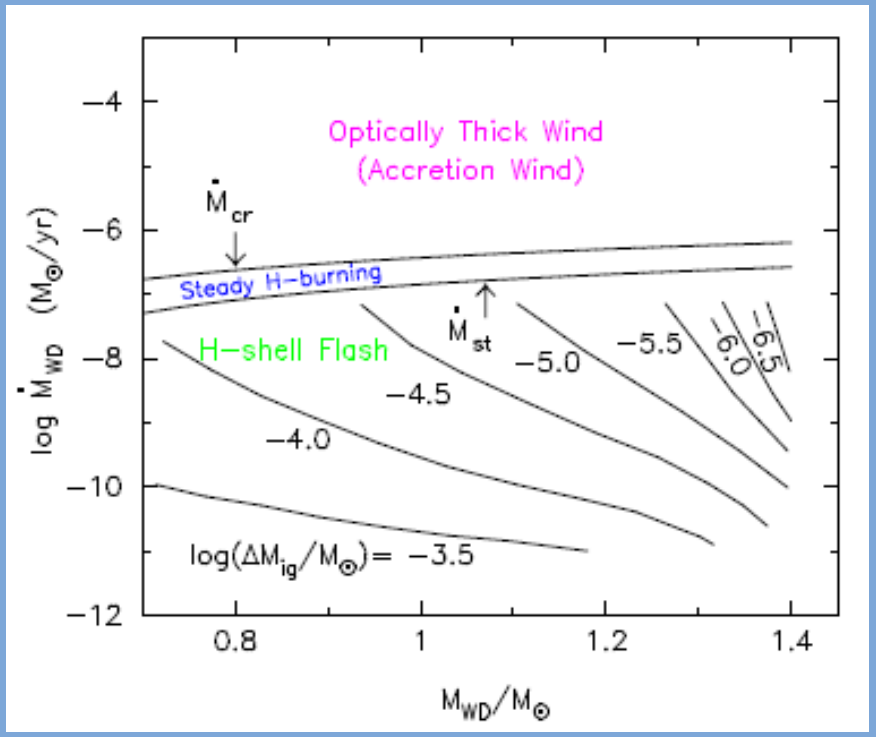
- need masses, but M_X ~ $1M_O$ (WD), M_2 slightly larger (→ faint wrt SSS)

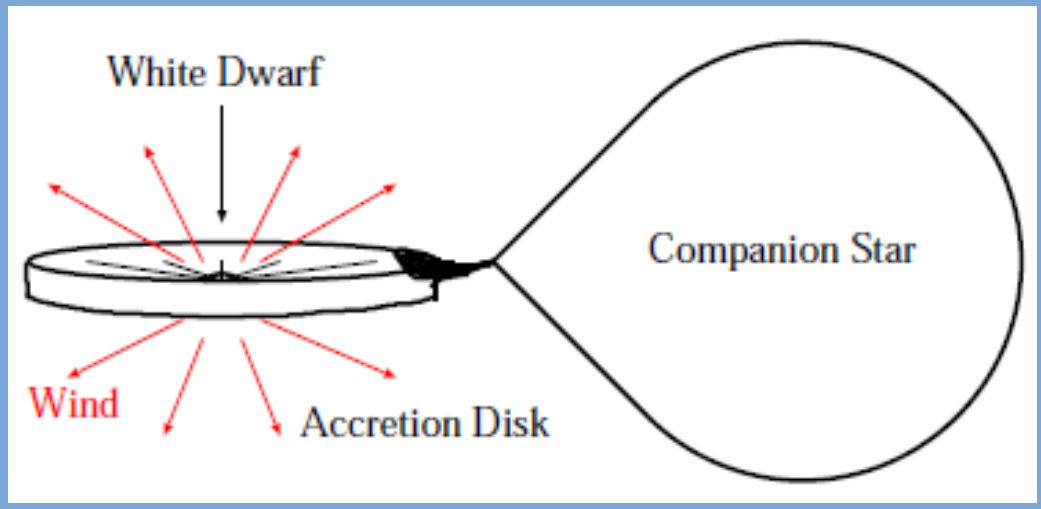
- circumstantial evidence:

  e.g. bipolar outflow (emission lines) from **RXJ0513.9-6951** → v_{esc} ~ WD

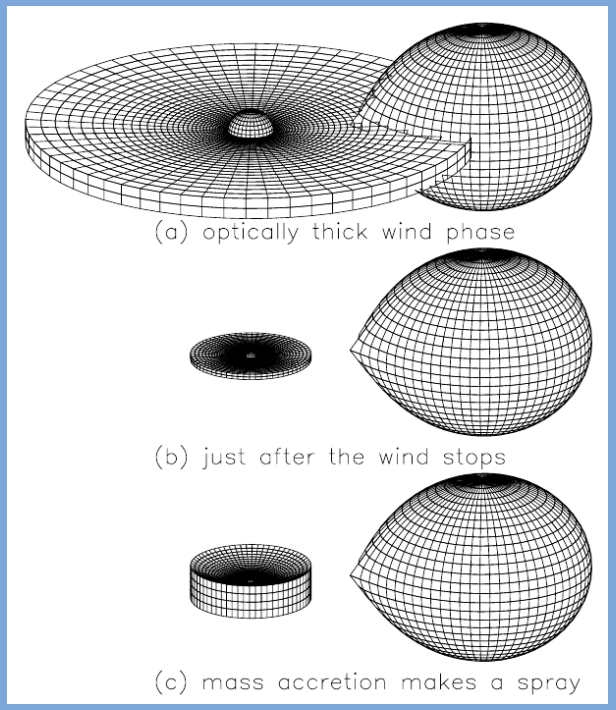


Hachisu, Kato, Wolf models →



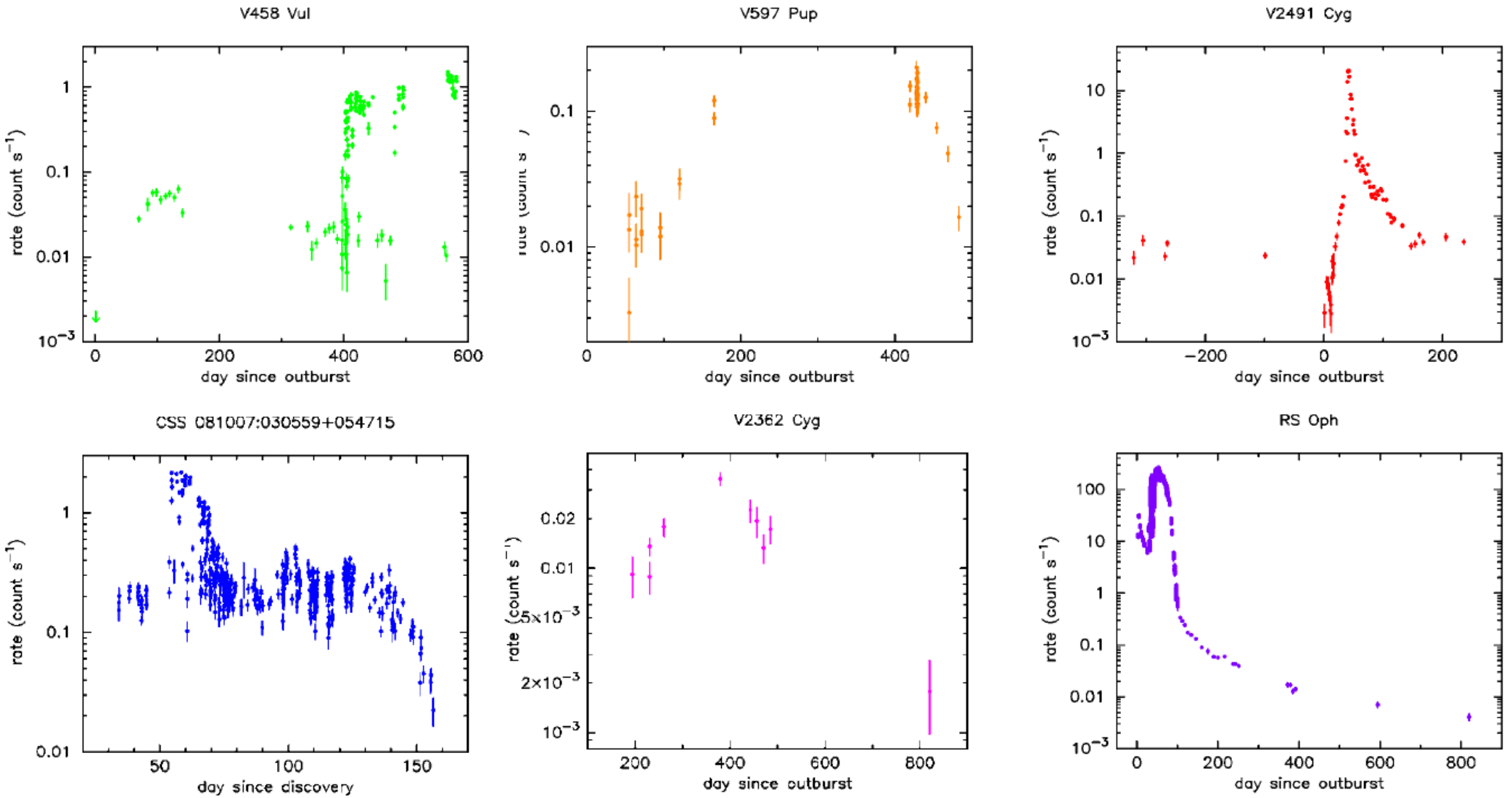


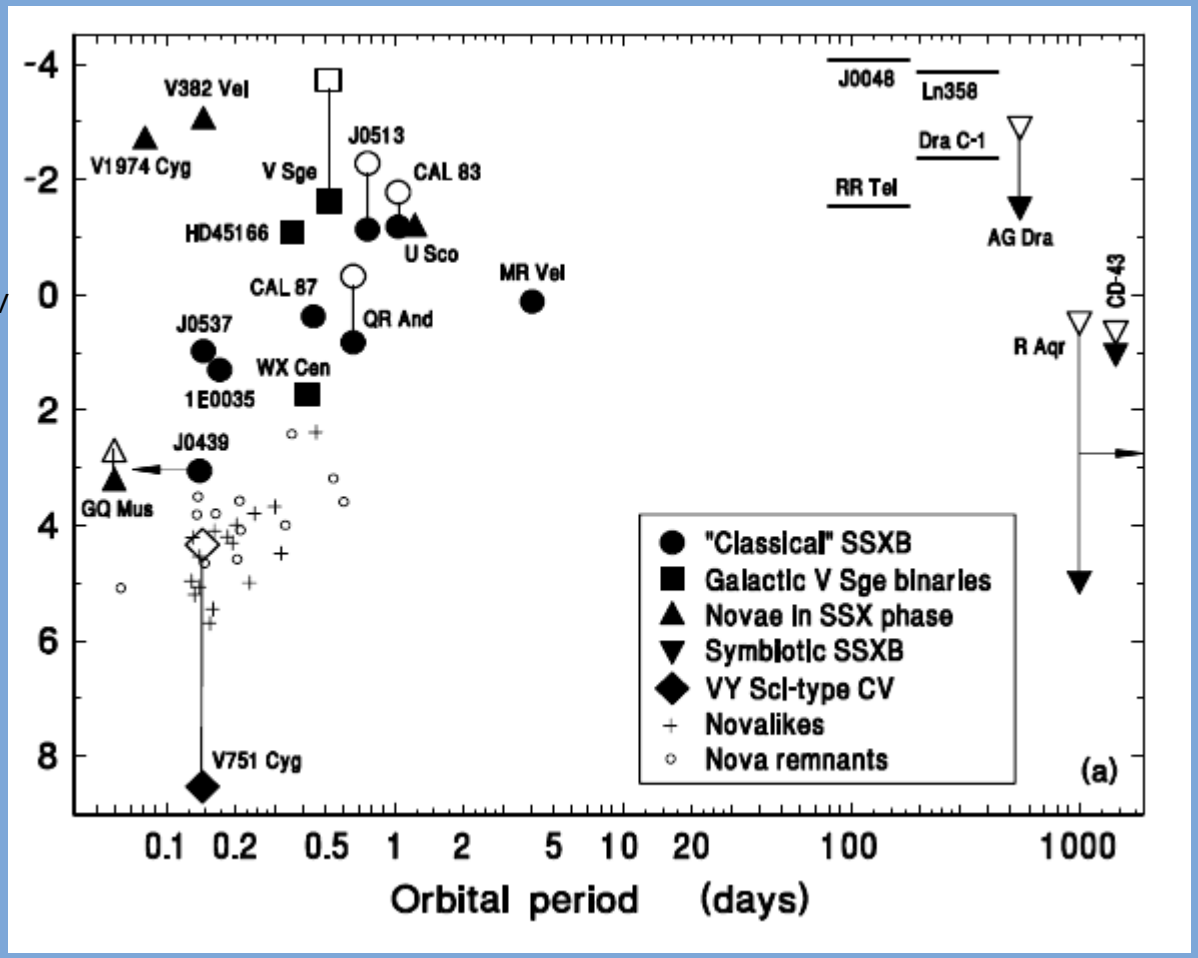
And in the v high mass transfer phase →
limit cycle behaviour (Hachisu & Kato 03)



SSS from Novae – classical and recurrent

Swift ideal for studying novae e.g. Osborne, Schwarz reviews:

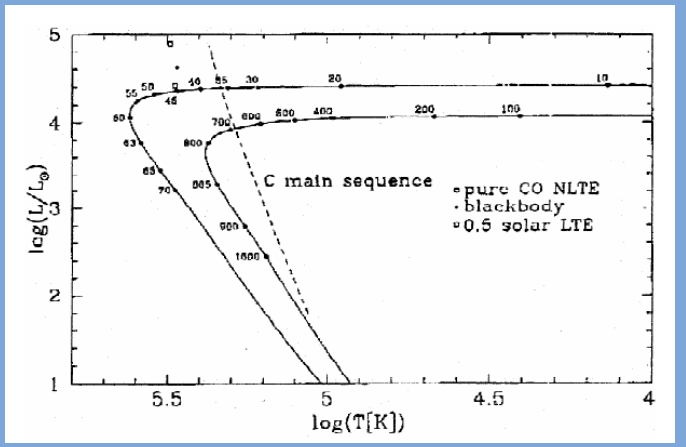




Simon03 – SSS properties cf galactic and symbiotics

N.B.
1) short P SSS cannot be *q*~1 systems → van Teeseling+99 → irradiated donor mass transfer, or (Orio) slow nova

2) RX J0439.8-6809 has high L_X, T=3x10^{5}K, V=21.6 and is *constant* → Gänsicke+00 → CO pre-WD on HB



→ **multiple routes to an SSS emission component**

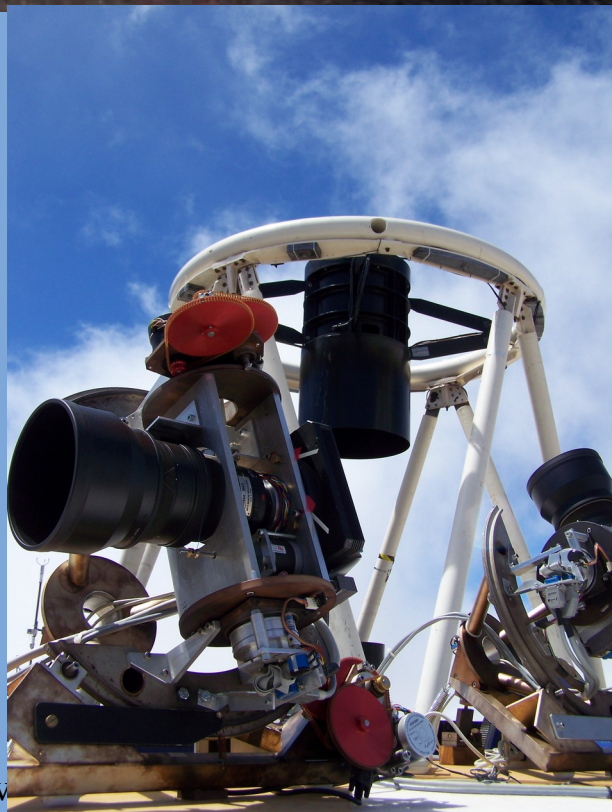
ASASSN 16oh

Observed with OGLE, SALT, Chandra, ASTROSAT - Maccarone+18

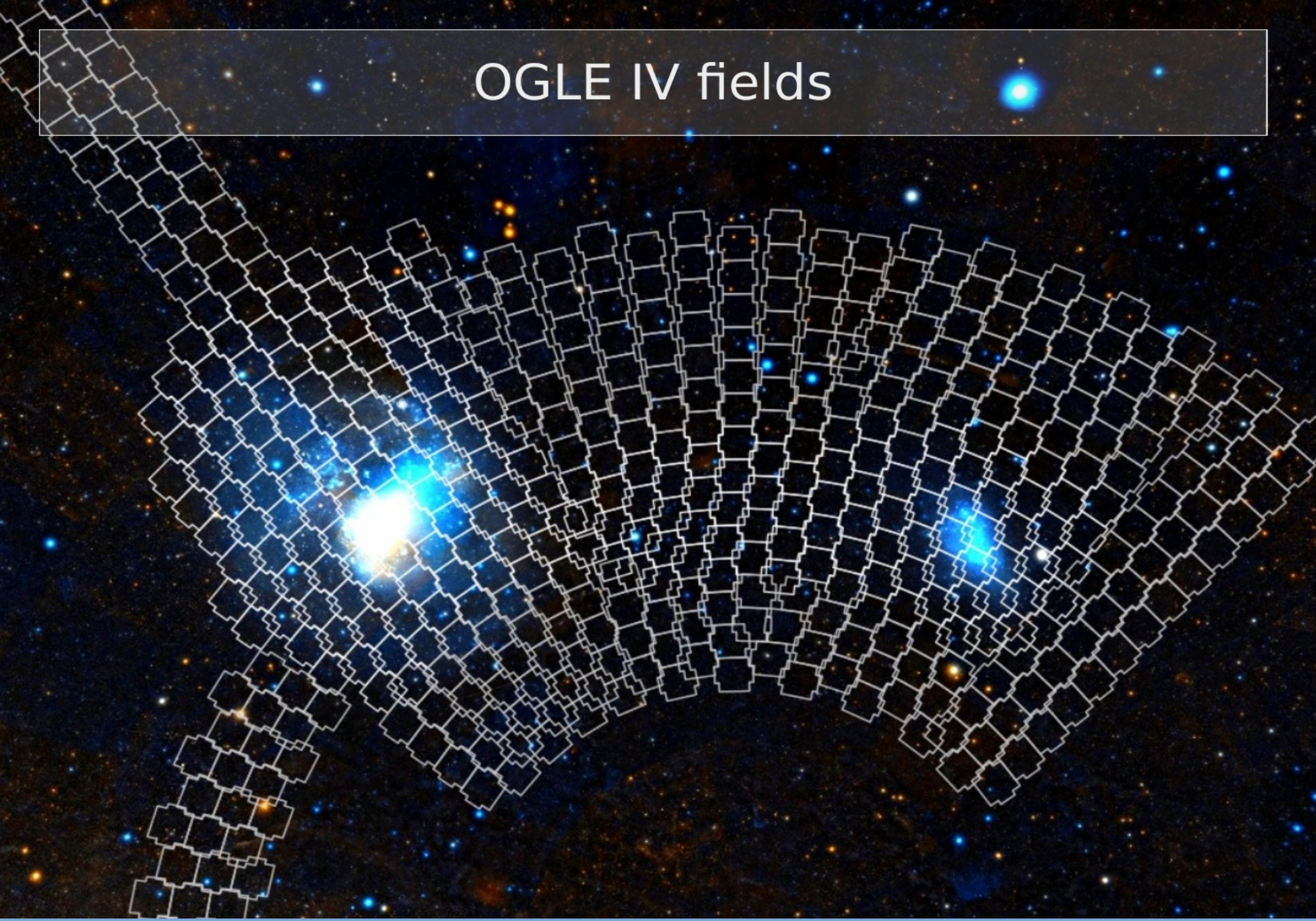
Haleakala, Maui LCO site:

CTIO, LCO site:

Each unit is an array of 4 telescopes (named *Brutus & Cassius*)



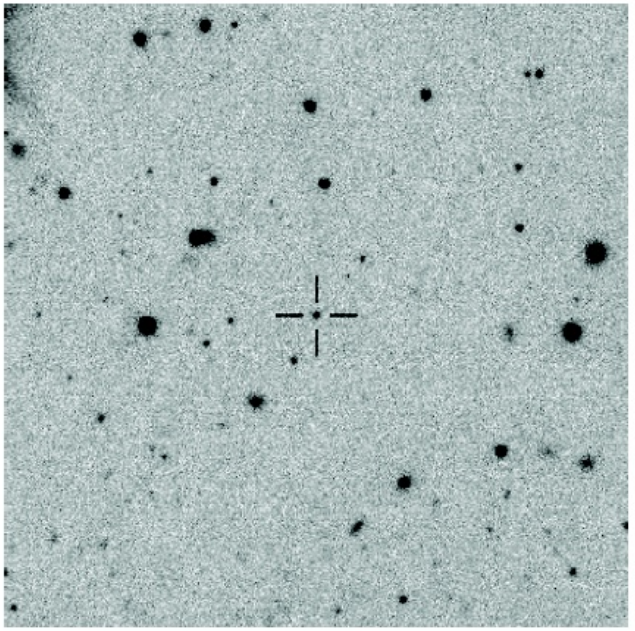
OGLE IV fields



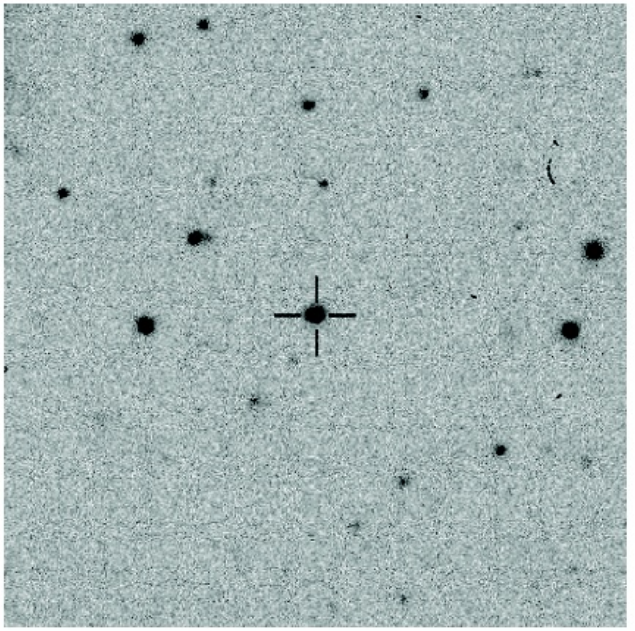
ASASSN 16oh

In SMC 15 Dec
(Jha+16, ATel 9859)

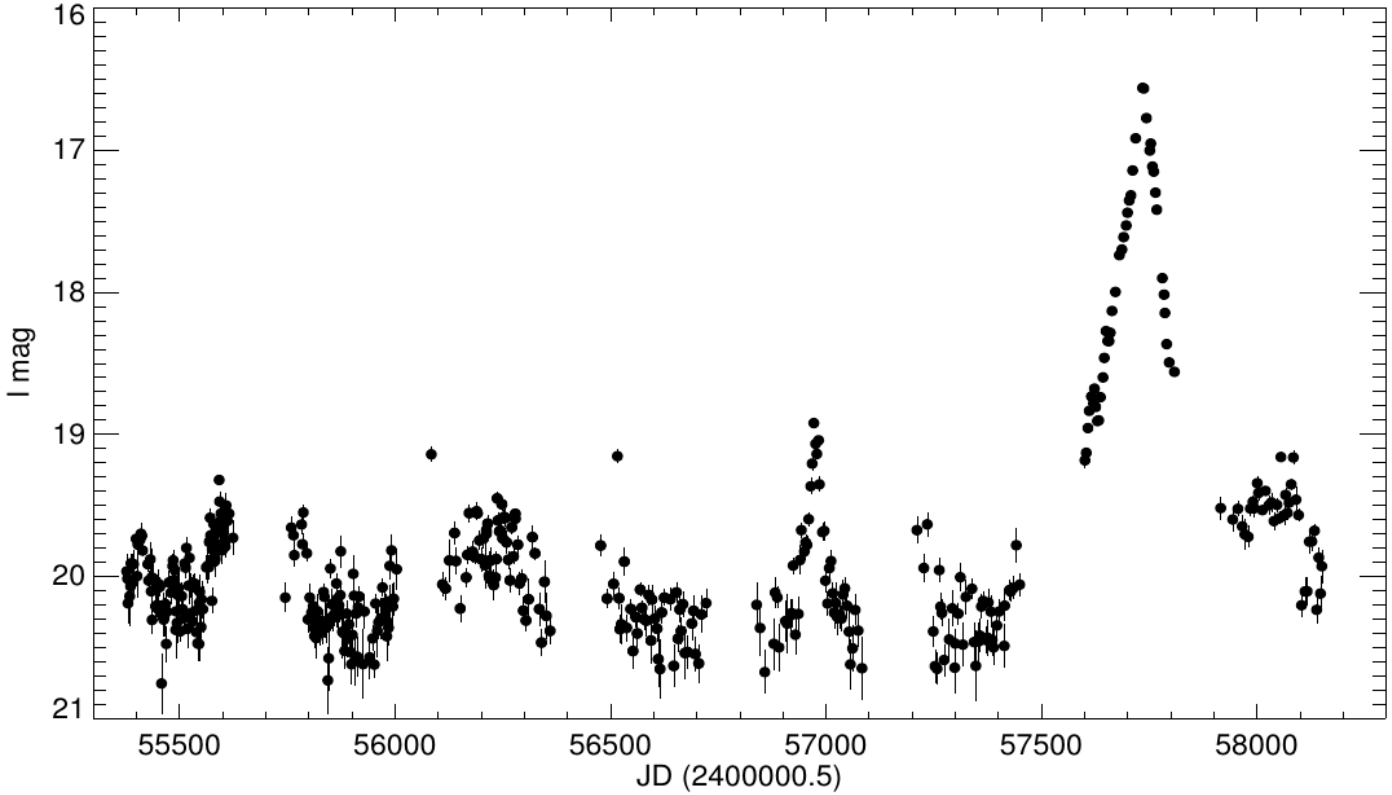
OGLE light curve
(Mroz+16, ATel 9867)



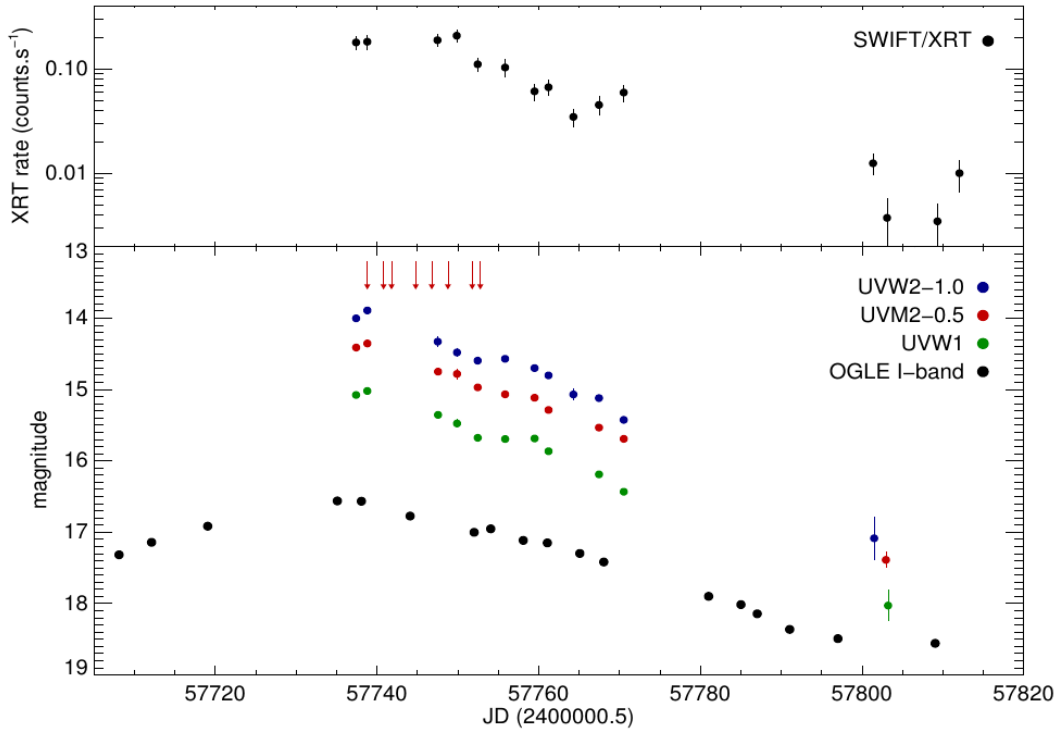
Reference image

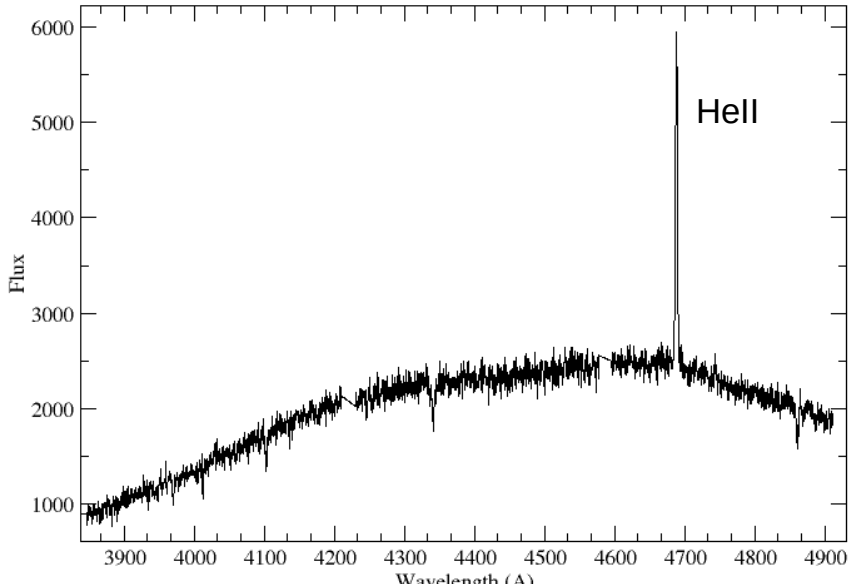


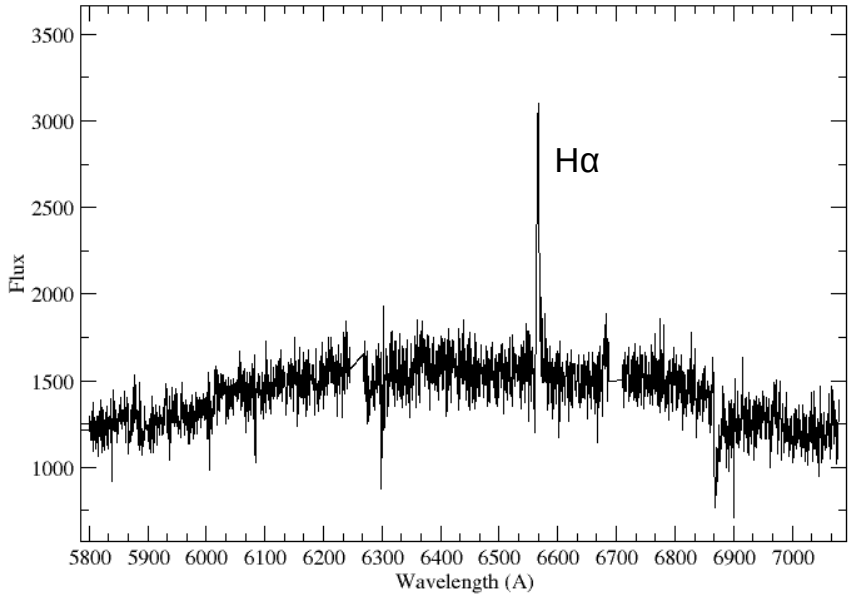
December 13, 2016



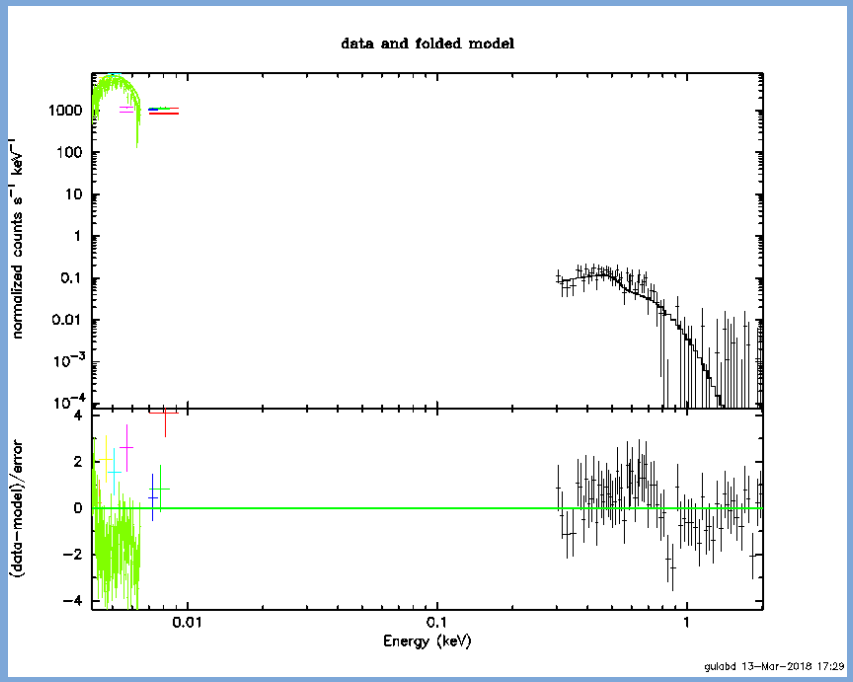
- Transient ToO invoked by DB
- SALT spectra over next 2 wks
- + Swift monitoring
  - → 10^{37} erg s^{-1} kT~80eV

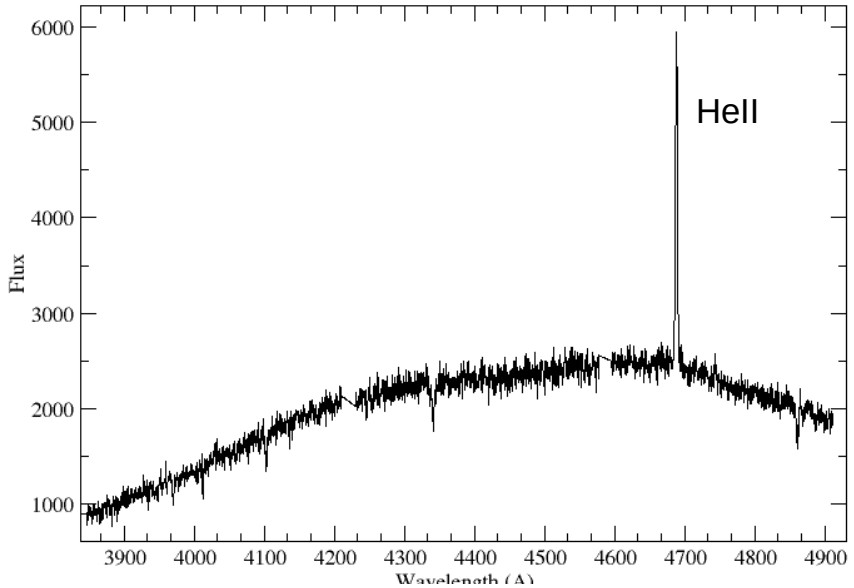


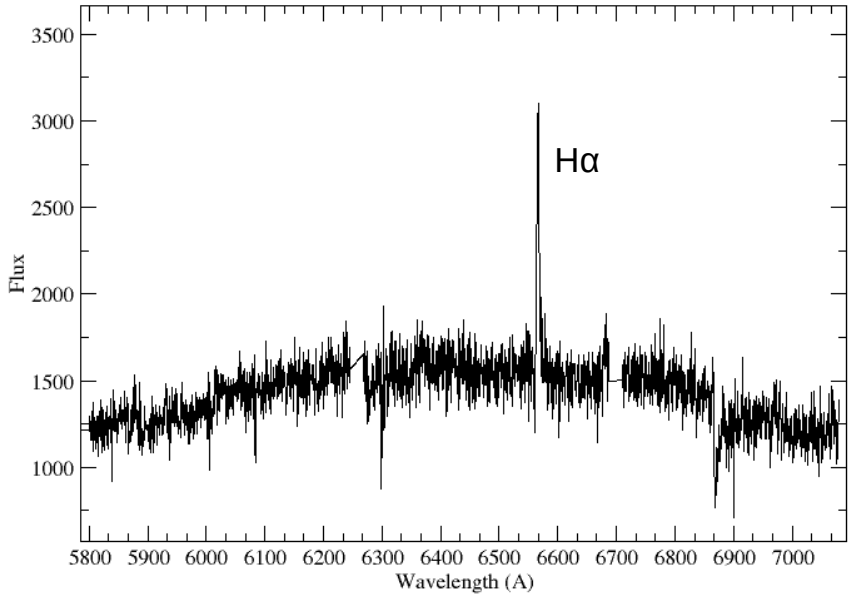




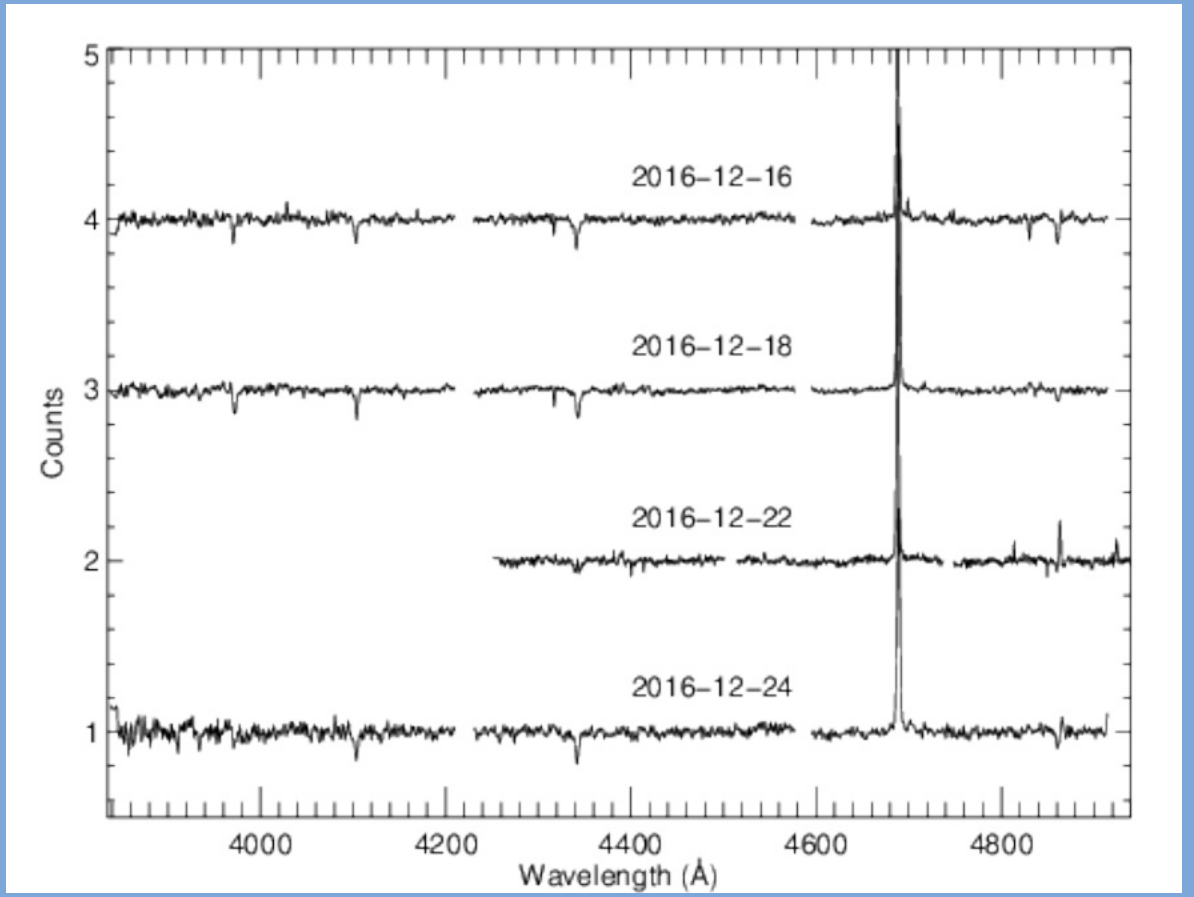
- Transient ToO invoked by DB
- SALT spectra over next 2 wks
- + Swift monitoring
  - → 10^{37} erg s^{-1} kT~80eV
- + ASTROSAT
  - BB kT~80eV + cooler disc component (preliminary, awaiting FUV spec)



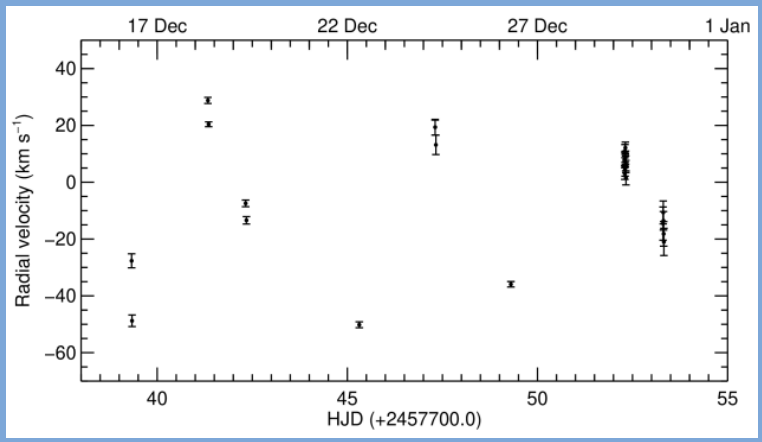




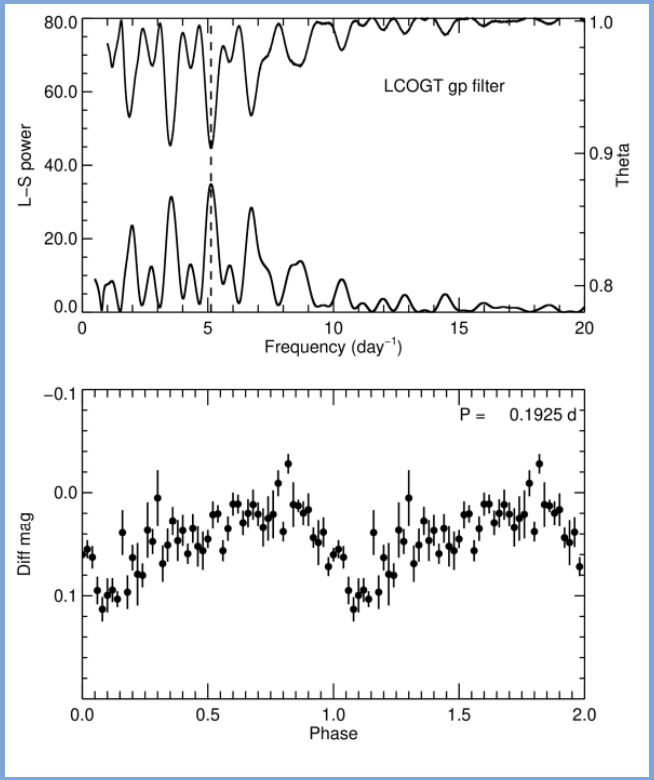
25 SALT spectra during 16oh outburst



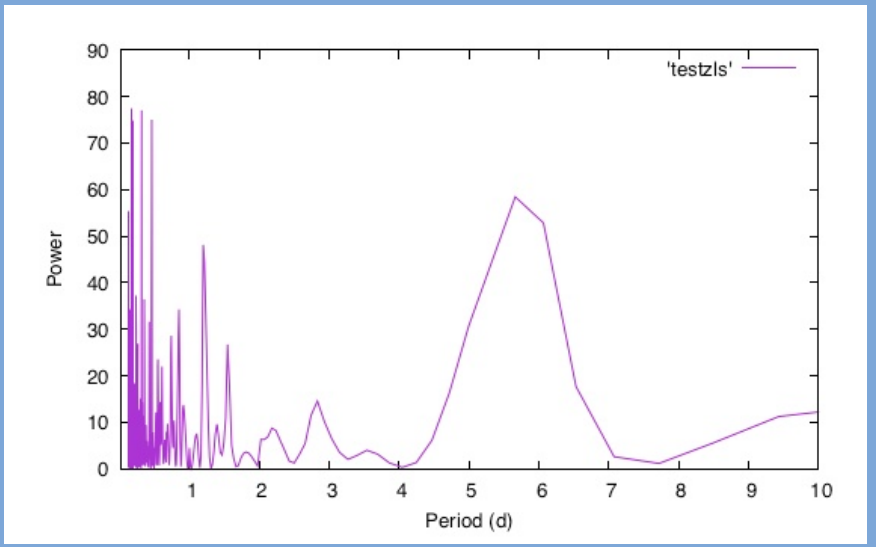
- SALT HeII velocities do change over ~100km/s range
- No periodicity in quiescent OGLE data
- LCOGT monitoring to search for shorter periods



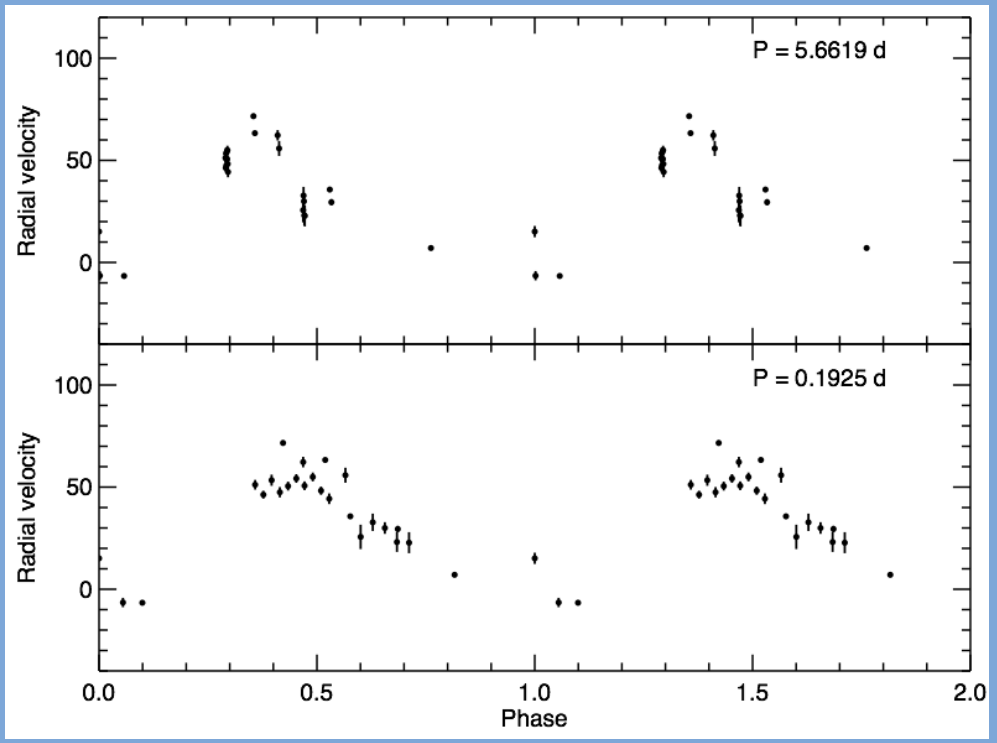
LCOGT photometry:



Radial velocities power spectrum:



- Periodogram of photometry and RVs → P = 4.6hr or 5.6d
- Phase sampling is poor for both → cannot distinguish
- N.B. low amplitude → low inclination

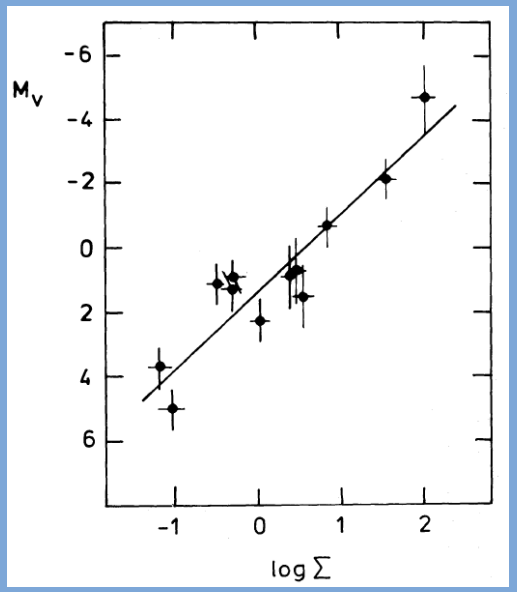


Which period is correct?

van Paradijs & McClintock 94:
LMXB M_V from

$$L_V \propto L_X^{1/2} R$$

Assuming X-ray irradiated disc of outer radius *R* and donor fills RL → L_V α $L_X^{1/2}$ $P^{2/3}$



$$\Sigma = (L_X/L_{Edd})^{1/2} (P/\ 1\mathrm{hr})^{2/3}$$

van Paradijs & McClintock 94:
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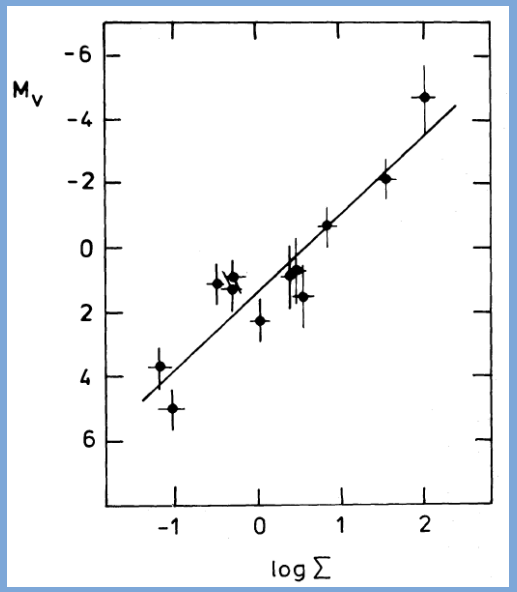

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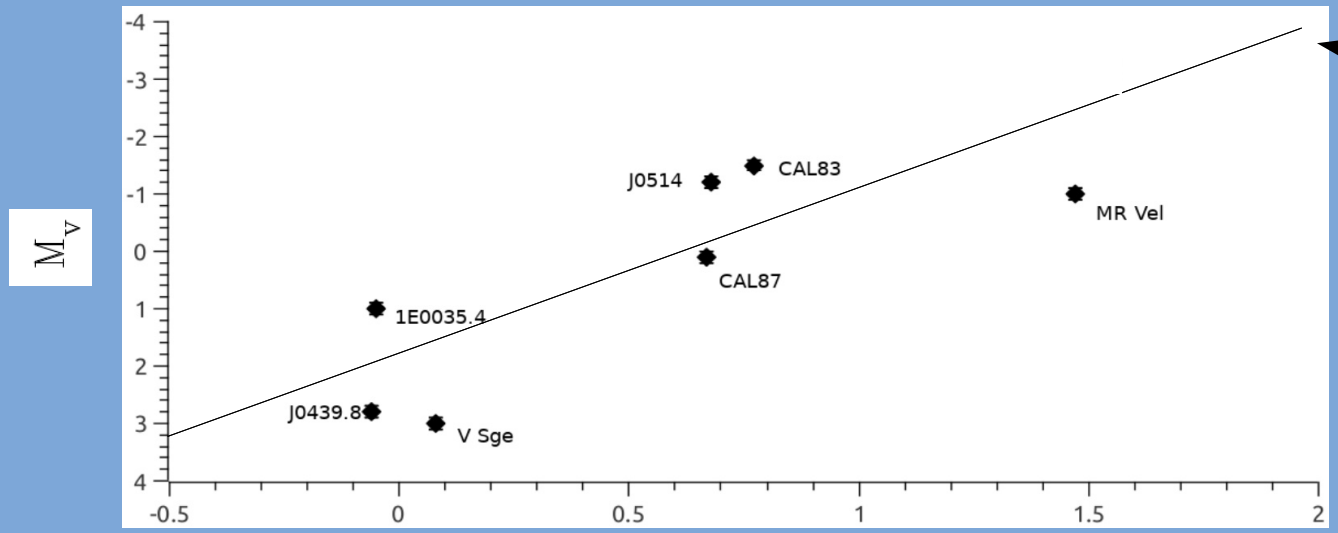
van Teeseling+97 applied same relation to SSS:



LMXB relation

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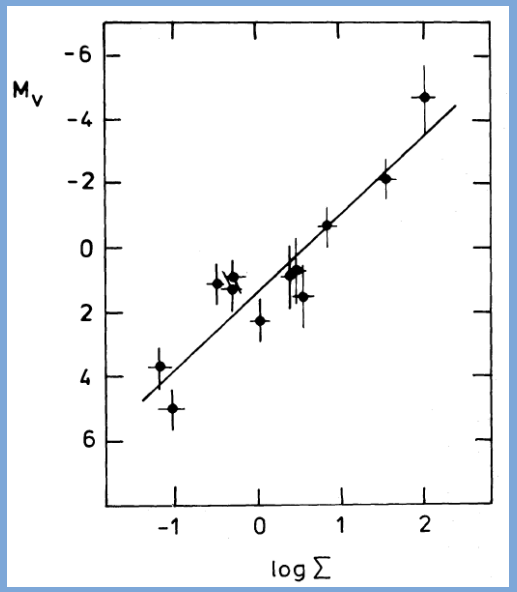

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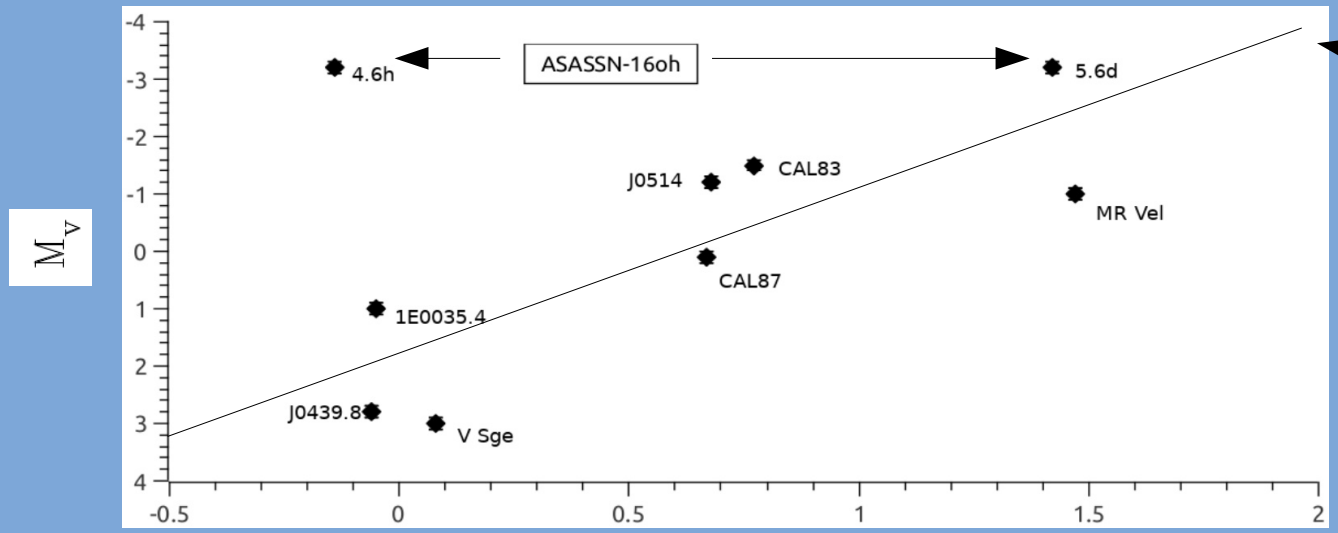
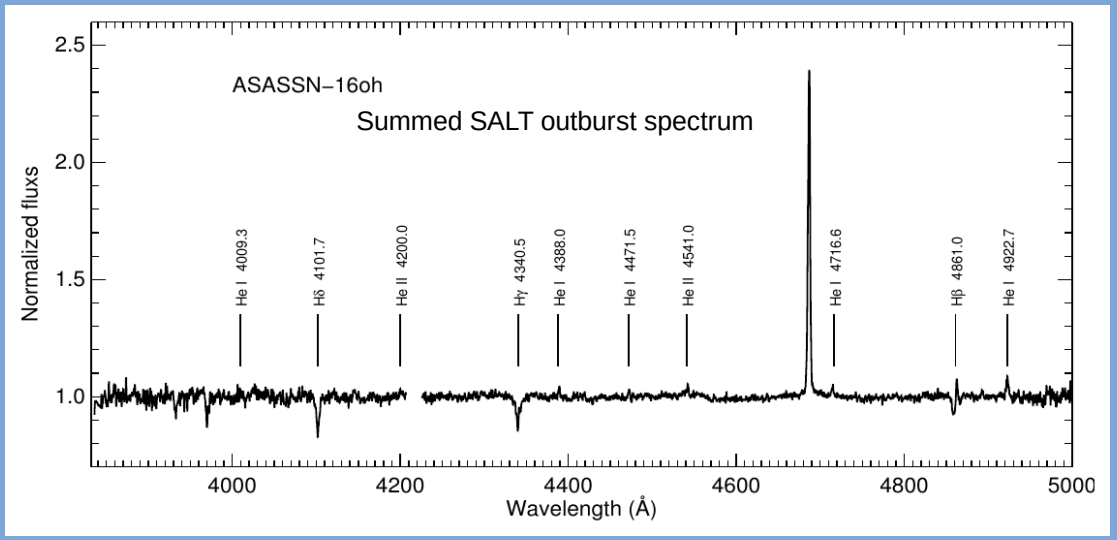
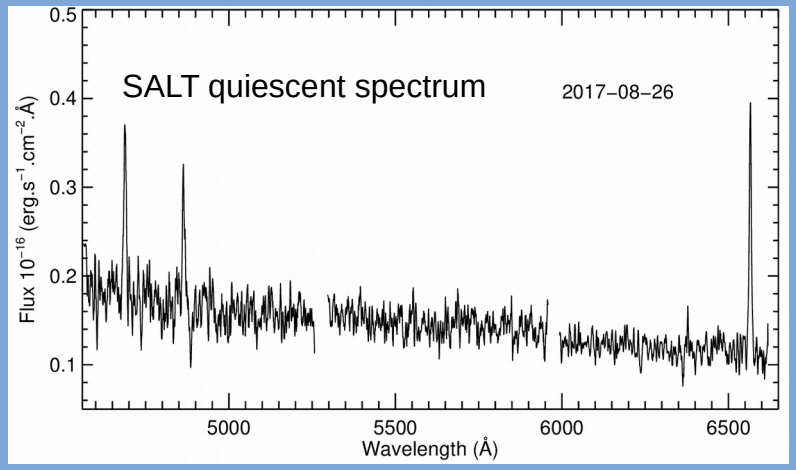
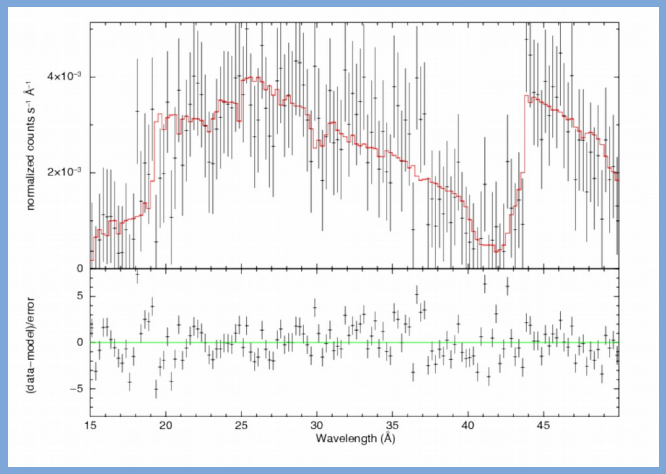


LMXB relation



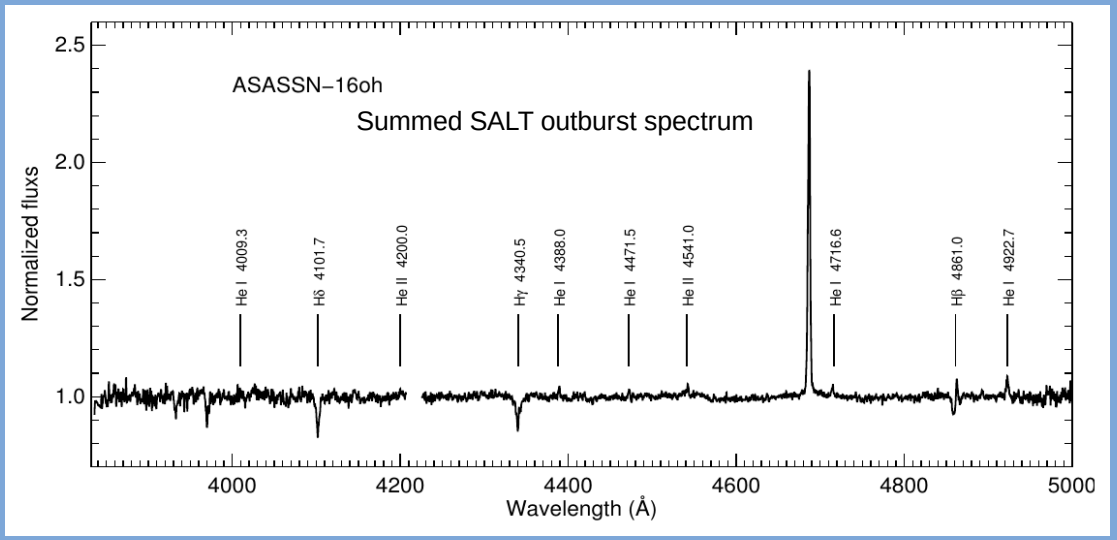
Mean FWHM ~ 160 km s^{-1}



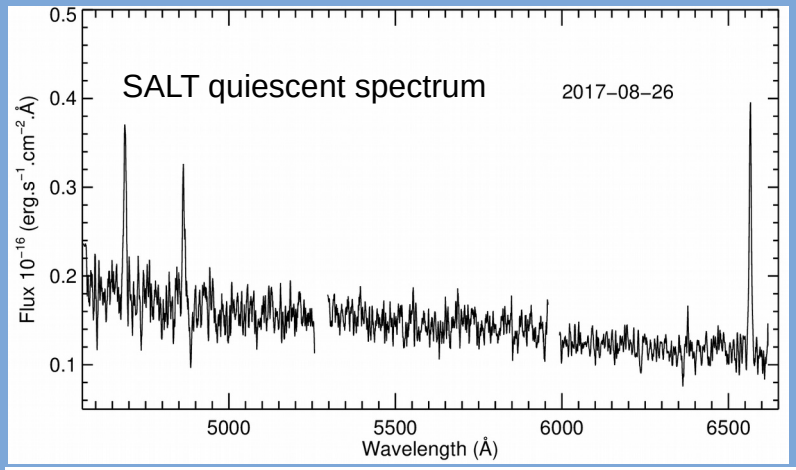


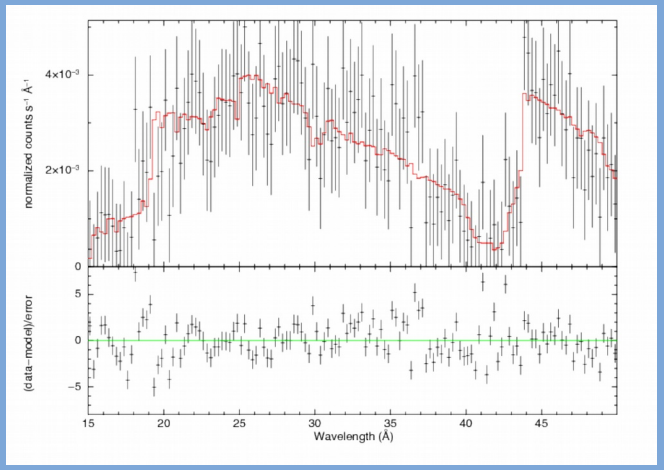
Chandra LETG
T_{BB}= 9x10^5K

→ no nova features!



Mean FWHM ~ 160 km s^{-1}



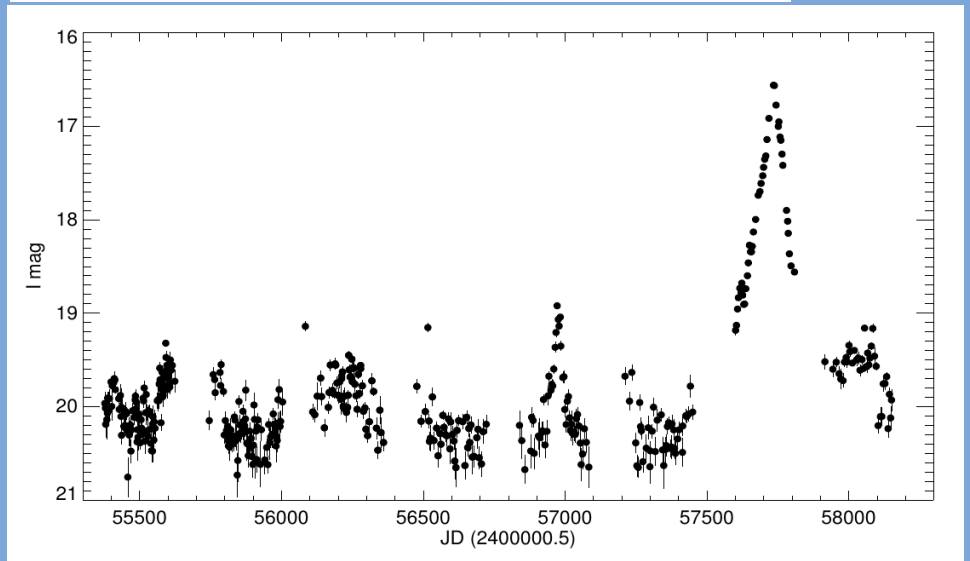


Maccarone+18

Chandra LETG

T_{BB}= 9x10^5K

→ no nova features!



Complete OGLE light curve → I_{quies} ~20.5

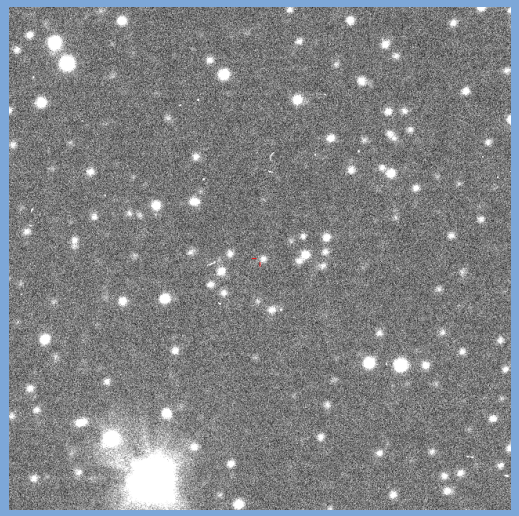
→ M_V ~ +1.5

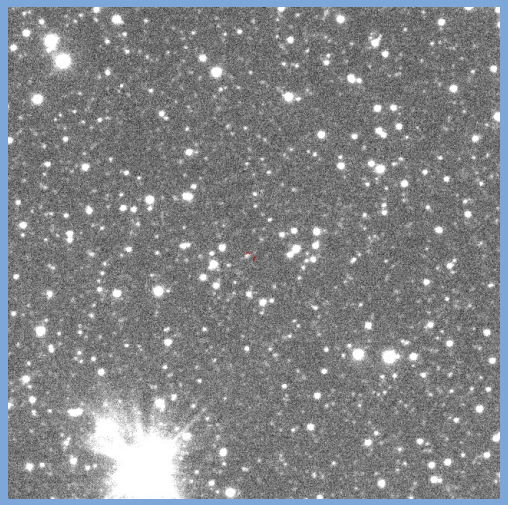
N.B. variability ~ 1 mag in quiesc

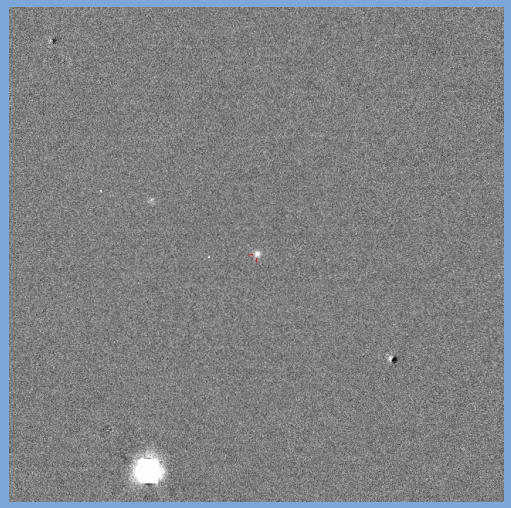
→ consistent with NL-system in SMC

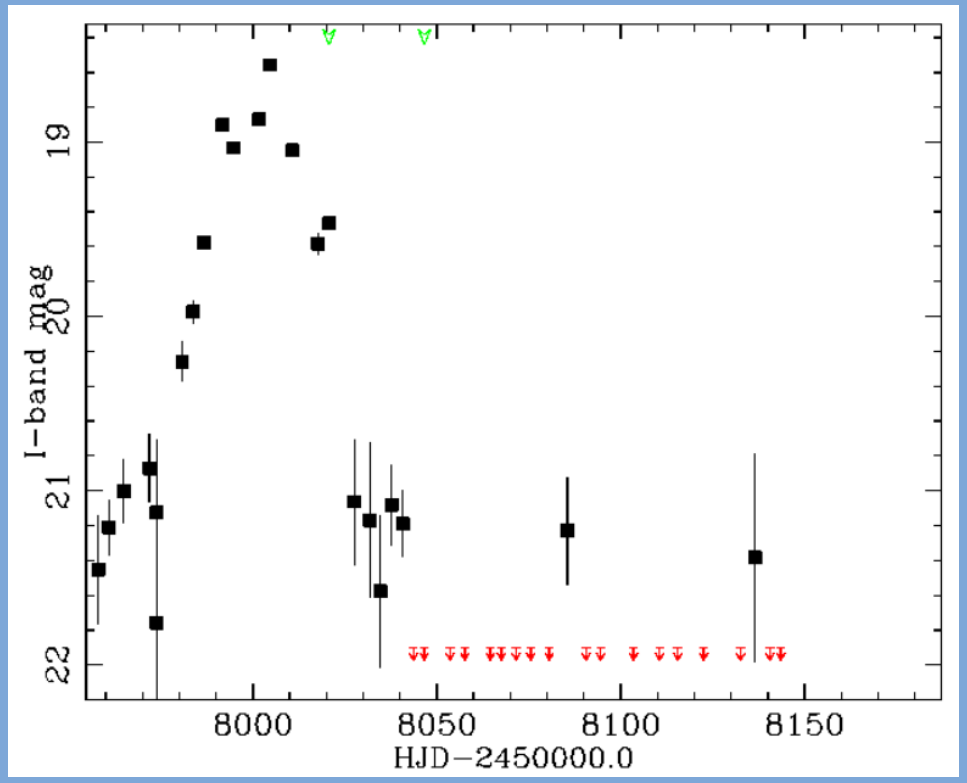
→ even late G sub-giant not visible

OGLE 17nif light curve

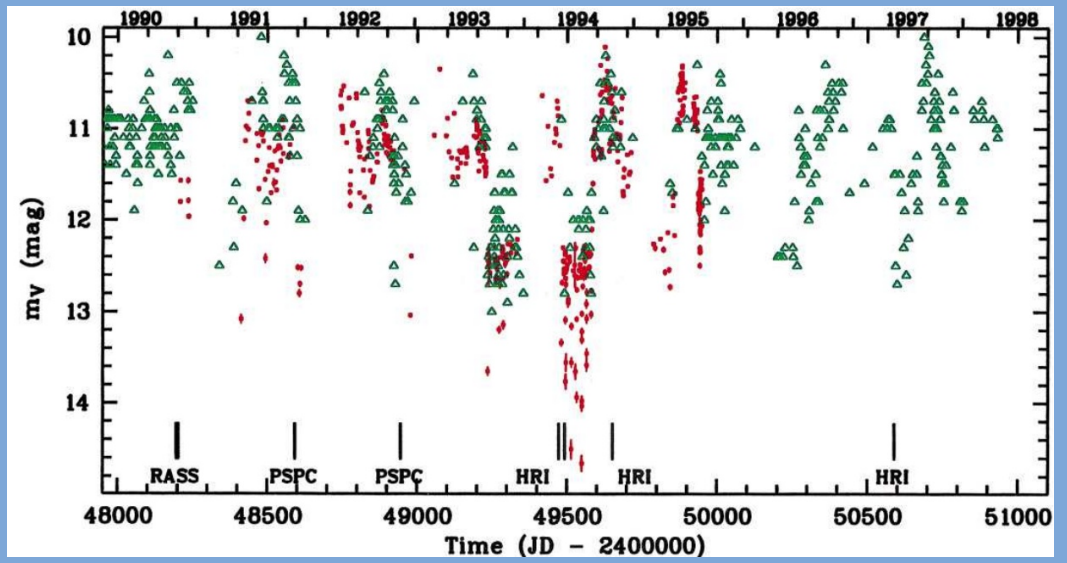








N.B. OGLE 17nif also in SMC
- quiescent level = ASASSN 16oh
  = NL brightness in SMC
+ galactic system V Sge



Strange behaviour of ASASSN 16oh:

- Light-curve unlike other classical SSS, but note OGLE 17nif → link to NLs
- Substantial variability in pre-outburst interval (including mini-outburst)
  - dominant component is *not* donor
- Very long, slow climb to outburst, and no (apparent) nova outburst!
- N.B. at optical peak, Swift → SSS already on (not seen in novae)
- In SMC → ~0.1 Eddington
- Likely long P of 5.6d → evolved donor
- Maccarone+18 → is SSS due to accretion ("spreading layer") or nuclear burning?
  - If latter, how turn-on without nova event?
  - M_V-Σ relation → address similar question with other SSS?
- Potentially very important system for understanding classical SSS properties