Dwarf novae in globular clusters

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M. van den Berg (U. Utrecht, Netherlands)

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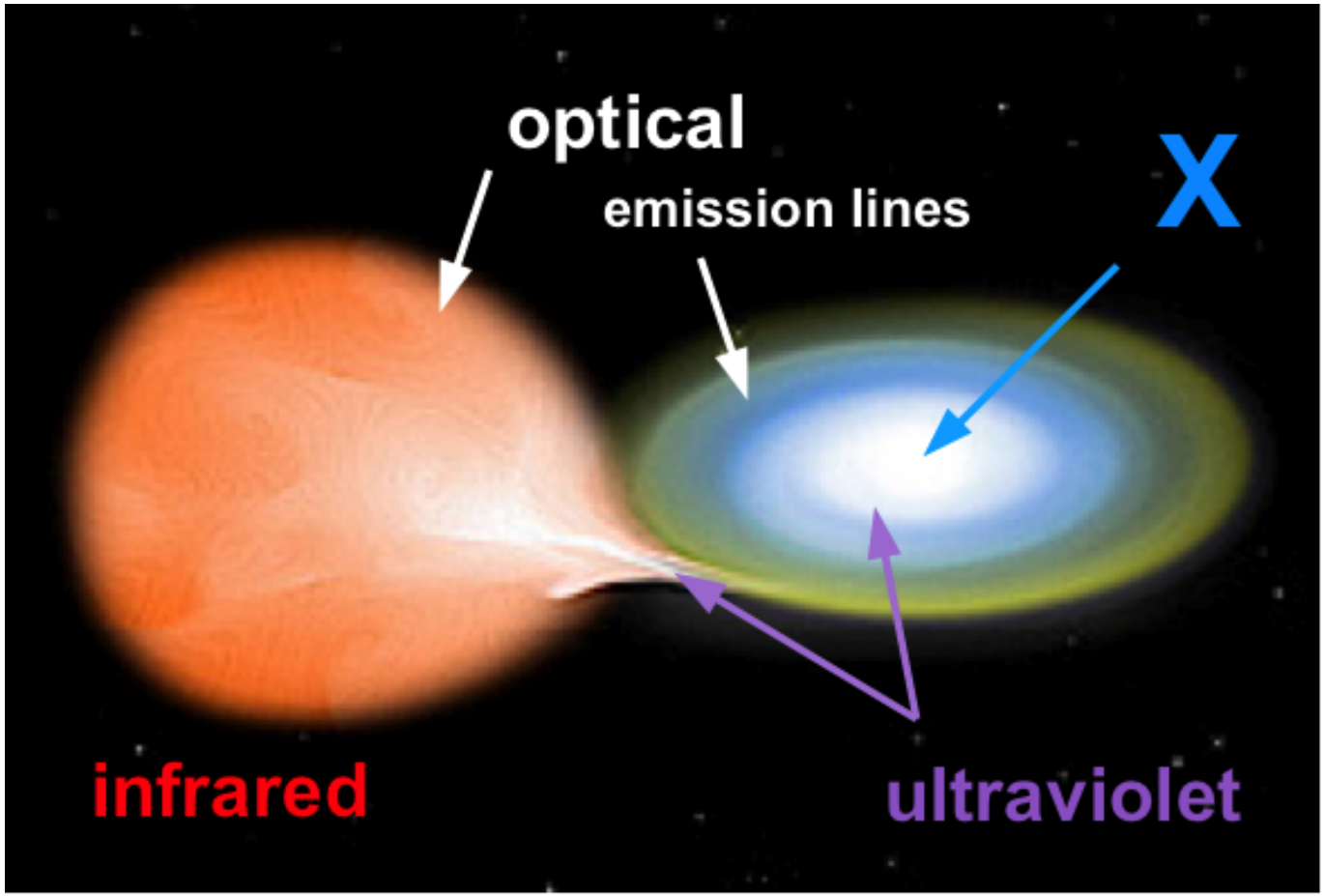
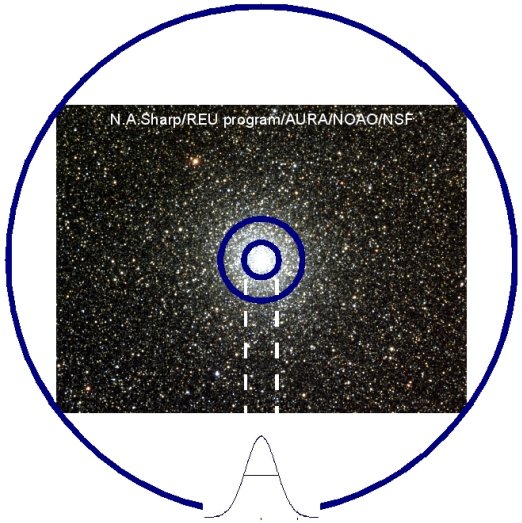
Outline

cataclysmic variable (CV) = white dwarf + late type companion star



- Disk instability => dwarf nova outbursts
- Magnetic field of the white dwarf => disk truncation or disruption
  -> Intermediate polars (IPs) and polars

Morphology and evolution of globular clusters



Definition

- 10^{5-6} stars
- Strongly bound by gravity
- Old ($> 10^{10}$ yr) -> Compact objects

Dynamical evolution

- Thermalization, mass segregation
- Core collapse $< 10^{10}$ yr

Other factors

- Million body problem + stellar evolution
  [Heggie et al. 2006; Fregeau et al. 2008]
- Intermediate mass black holes?
  [Maccarone & Servillat 2008] - M31-G1? - HLX-1?
- Close binaries!

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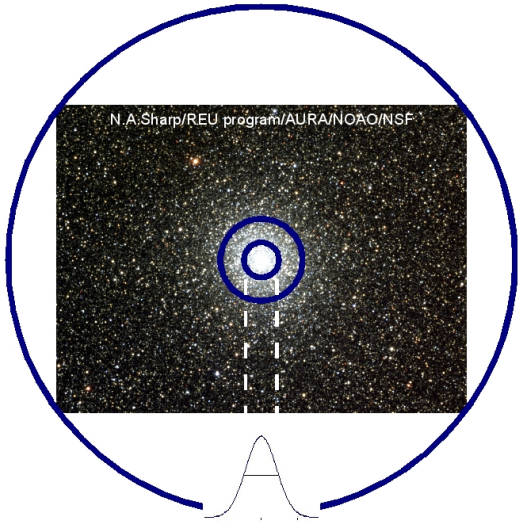

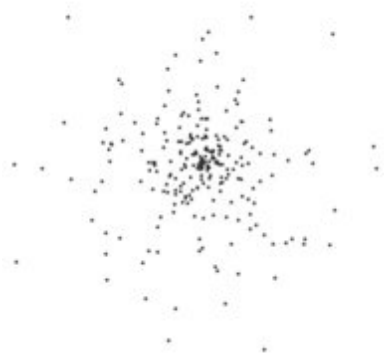

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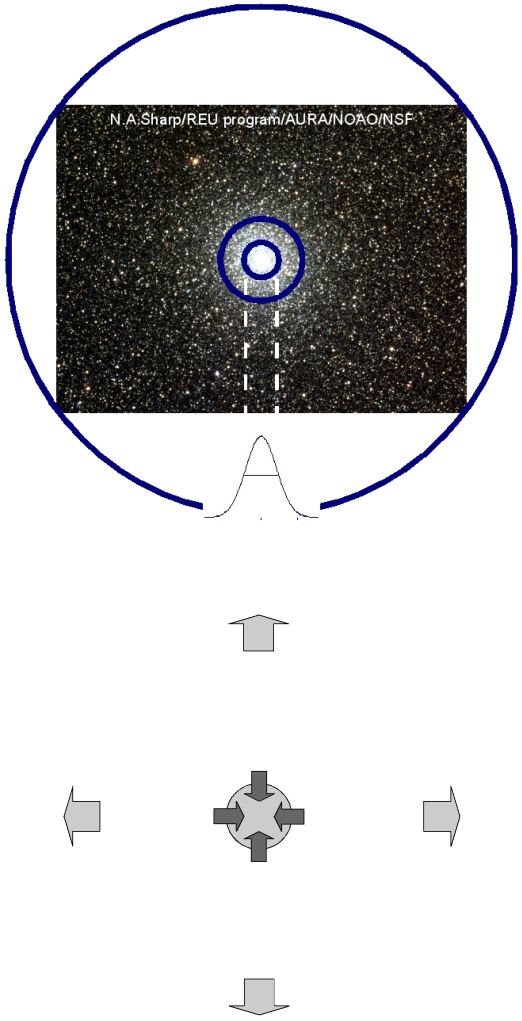

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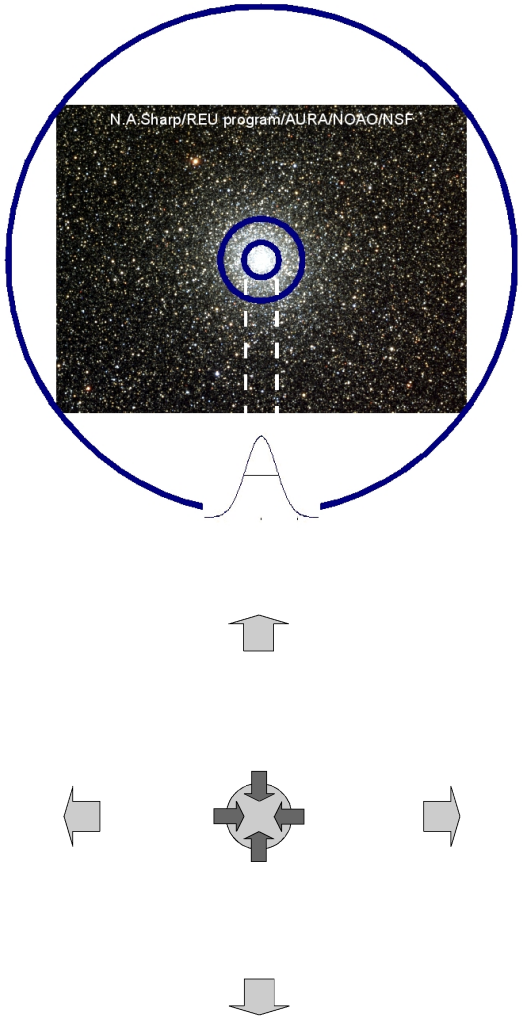

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Close binaries as a central source of energy

Where are the binaries?

- Crowding issues in the optical...
- An excess of X-ray sources [Clark 1975]
- Correlation with encounter rate
  - [Pooley et al. 2003, 2006]
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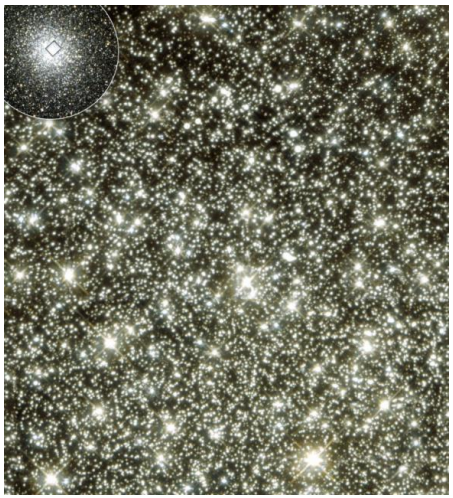
- Are CVs intrinsically different in GCs?



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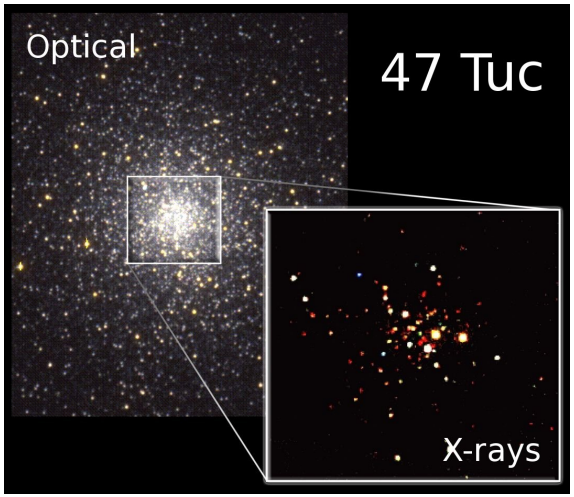

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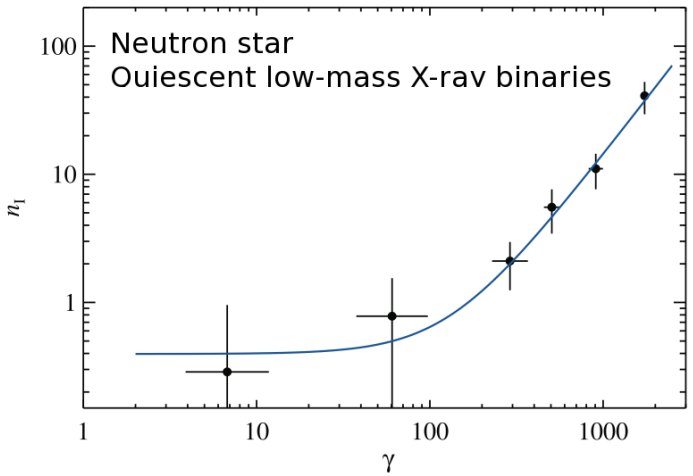

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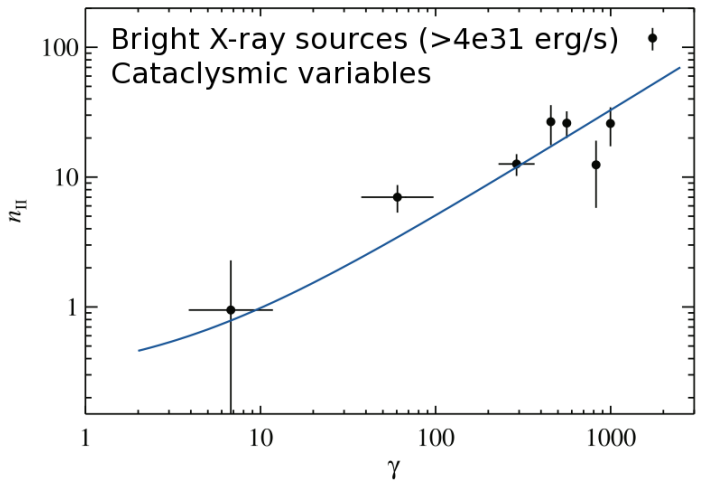

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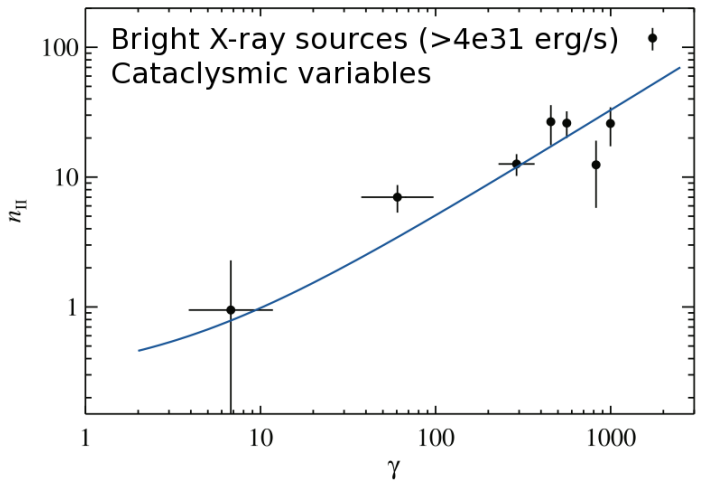

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14 dwarf novae in 157 Galactic globular clusters

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M15-CV1(A)
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NGC6397-CV2
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M22-CV2
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M13-CV1

[Servillat et al. 2011]
ApJ, 733, 106

- First detection in 1941 on plates
- M5-V101 confirmed with spectrum, P=5.8 h
- All have X-ray counterparts $>10^{31}$ erg s^{-1}
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- 47 Tuc with *Hubble* [Shara et al. 1996]
- CASE (16 GCs) [Pietrukowicz et al. 2008]

Possible explanation

- Excess of intermediate polars?
- More massive white dwarfs?

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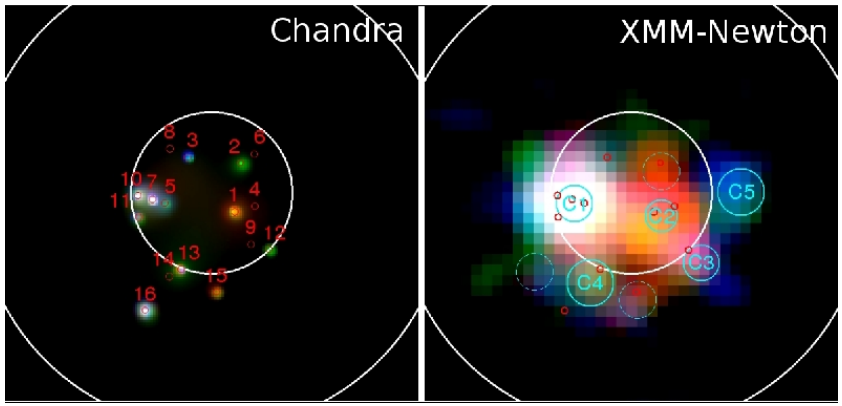

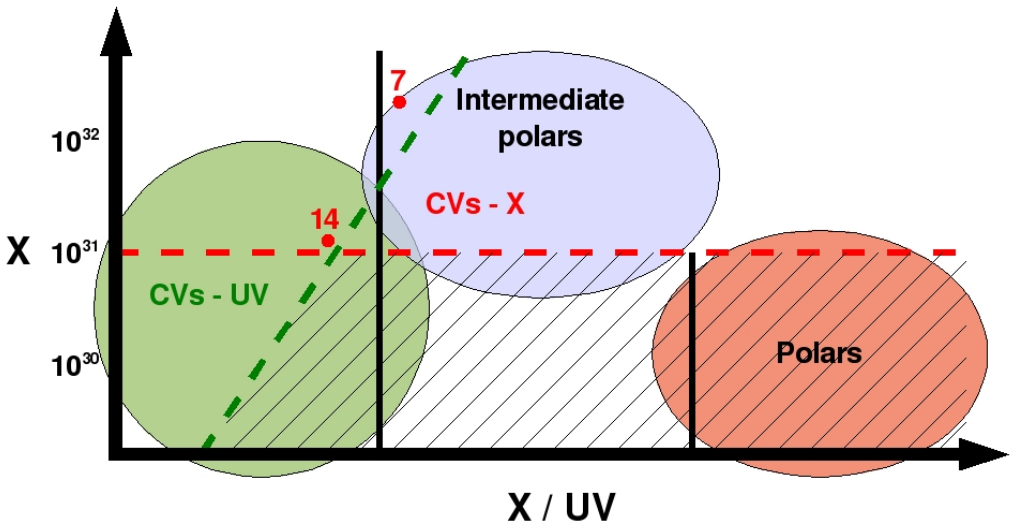

NGC 2808: Identifications of CVs

- $\sim$ 15 in X-rays
- $\sim$ 30 in UV
- Distinct populations

Intermediate polars?

- In NGC 2808:
  - 30% of observed
  - $\sim$ 7% total
- In the Galaxy: 5-10%

- Large uncertainties

Servillat et al. 2008a,b

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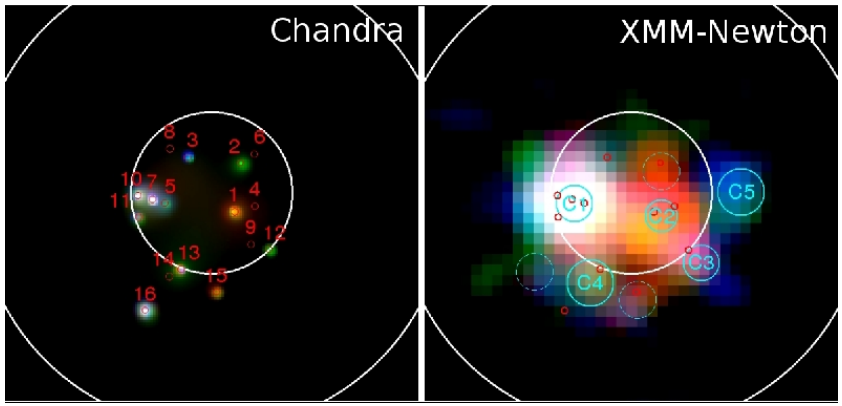

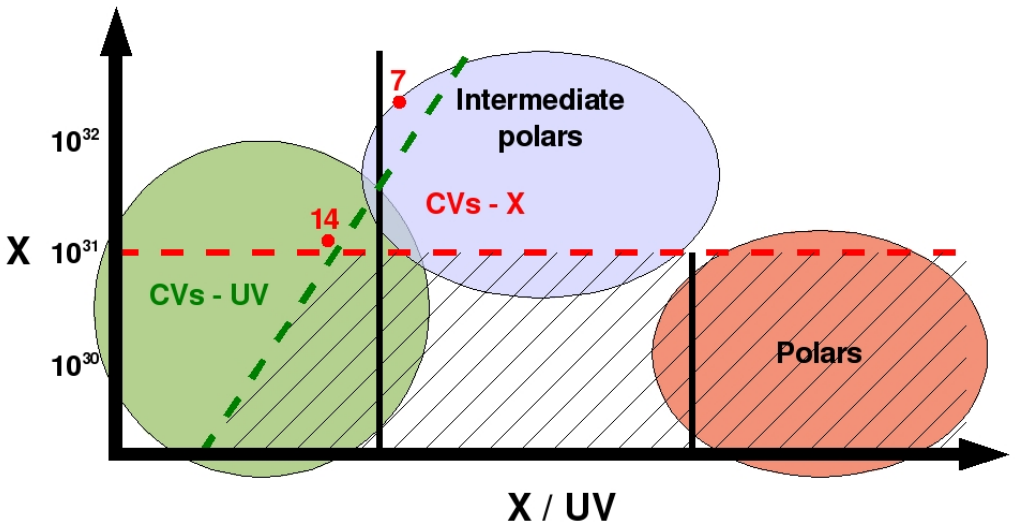

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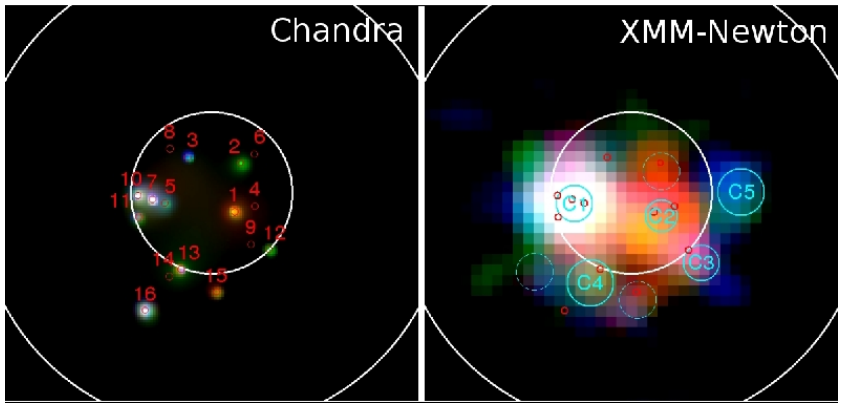

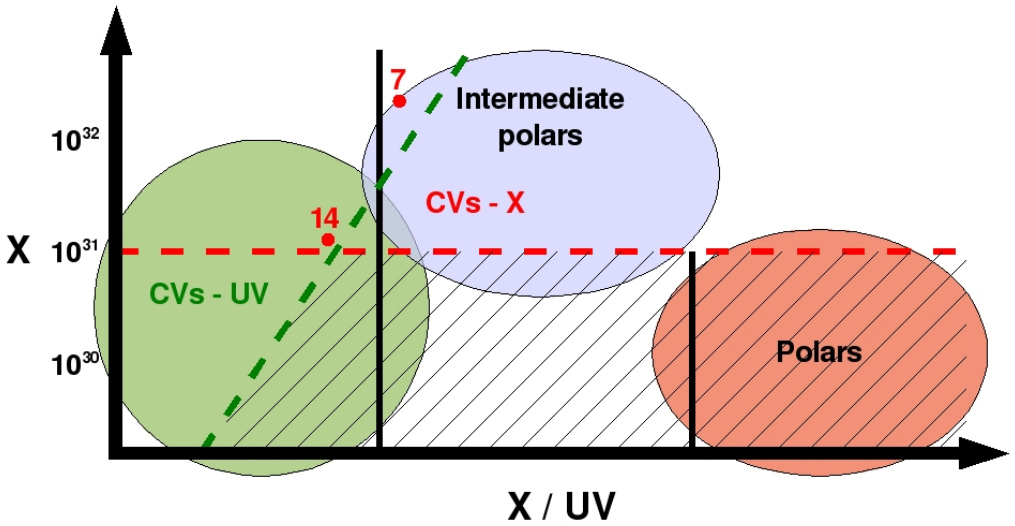

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How to detect a dwarf nova?

Recipe

- Long coverage (years)
- Dense coverage (days/weeks)
- Angular resolution?
- Image subtraction

Faulkes Telescope North

- 2m Telescope
- Education and outreach
- Science products

Faulkes Telescope North, Maui, USA

Roberts et al. 2008; Lewis & Roche 2009; Las Cumbres Observatory Global Telescope Network

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M13: Variability search

- 78 images over 1 year
- 5 epochs
- Image subtraction
- 16 variables, most are BL Her, RR Lyr

Star 4: a new variable

- Long term variability
- In outburst:
  - $U = 17.3 \pm 0.3$
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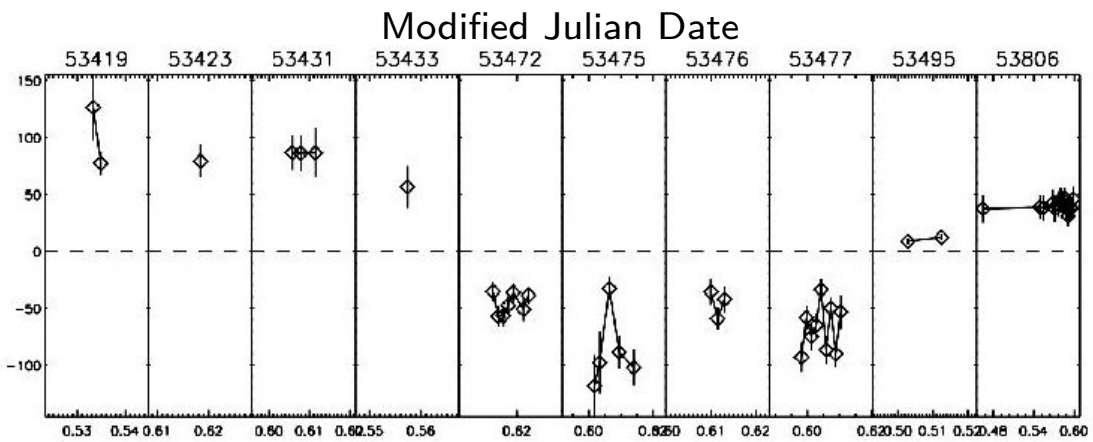

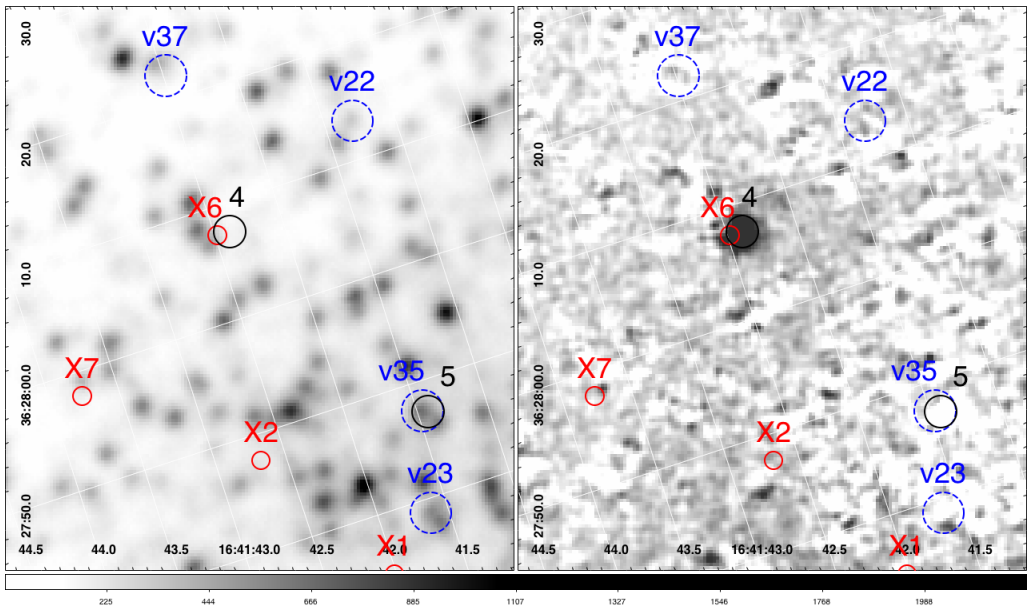

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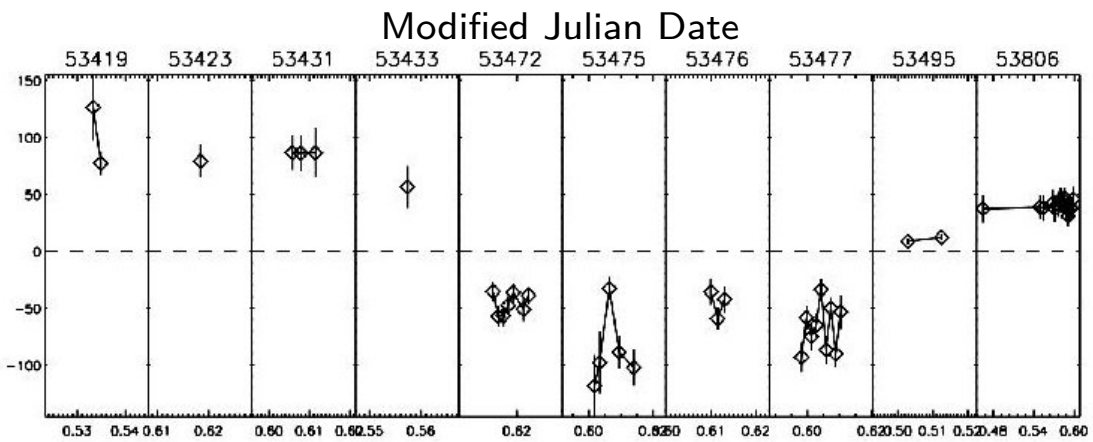

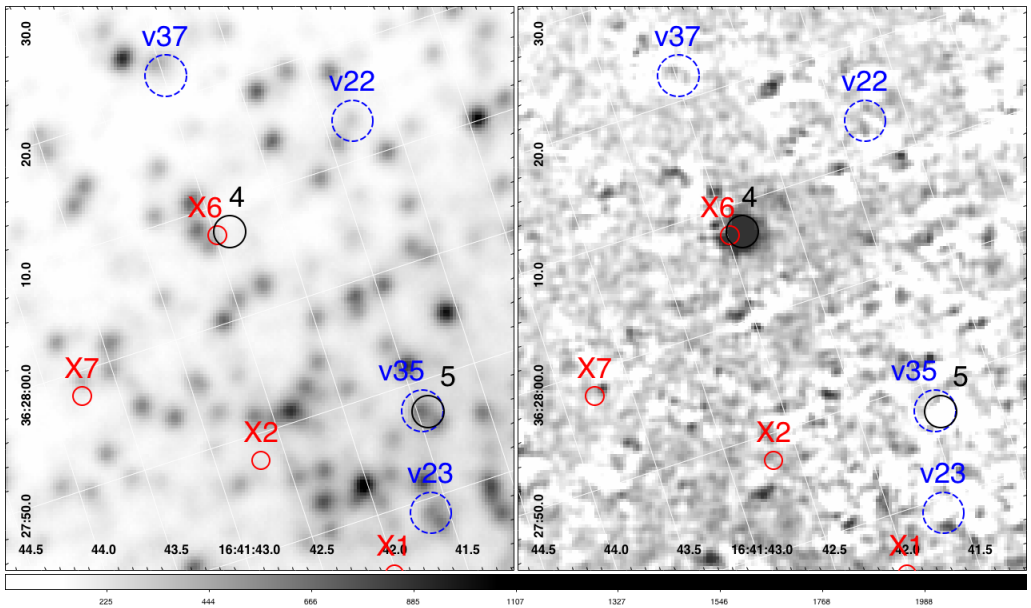

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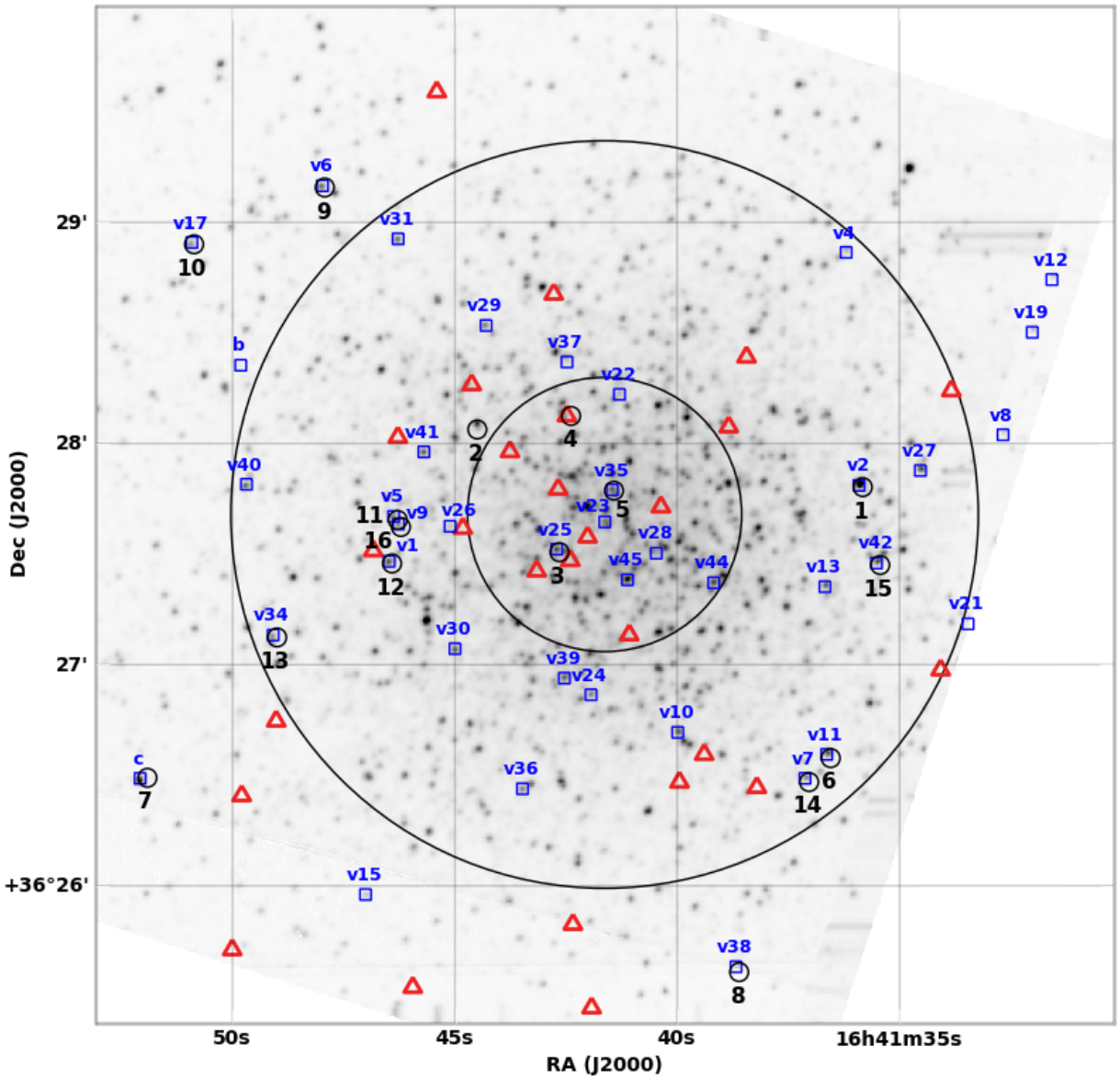

△ = *Chandra* sources
○ = detected variables
□ = known variables

X-ray source X6

- Aligned with star 4
- $L_X = 1.8 \cdot 10^{32}$ erg s^{-1}
- $\Gamma = 1.4 \pm 0.2$
- $N_{\rm H} = 1.1 \cdot 10^{20}$ cm^2
- Flare

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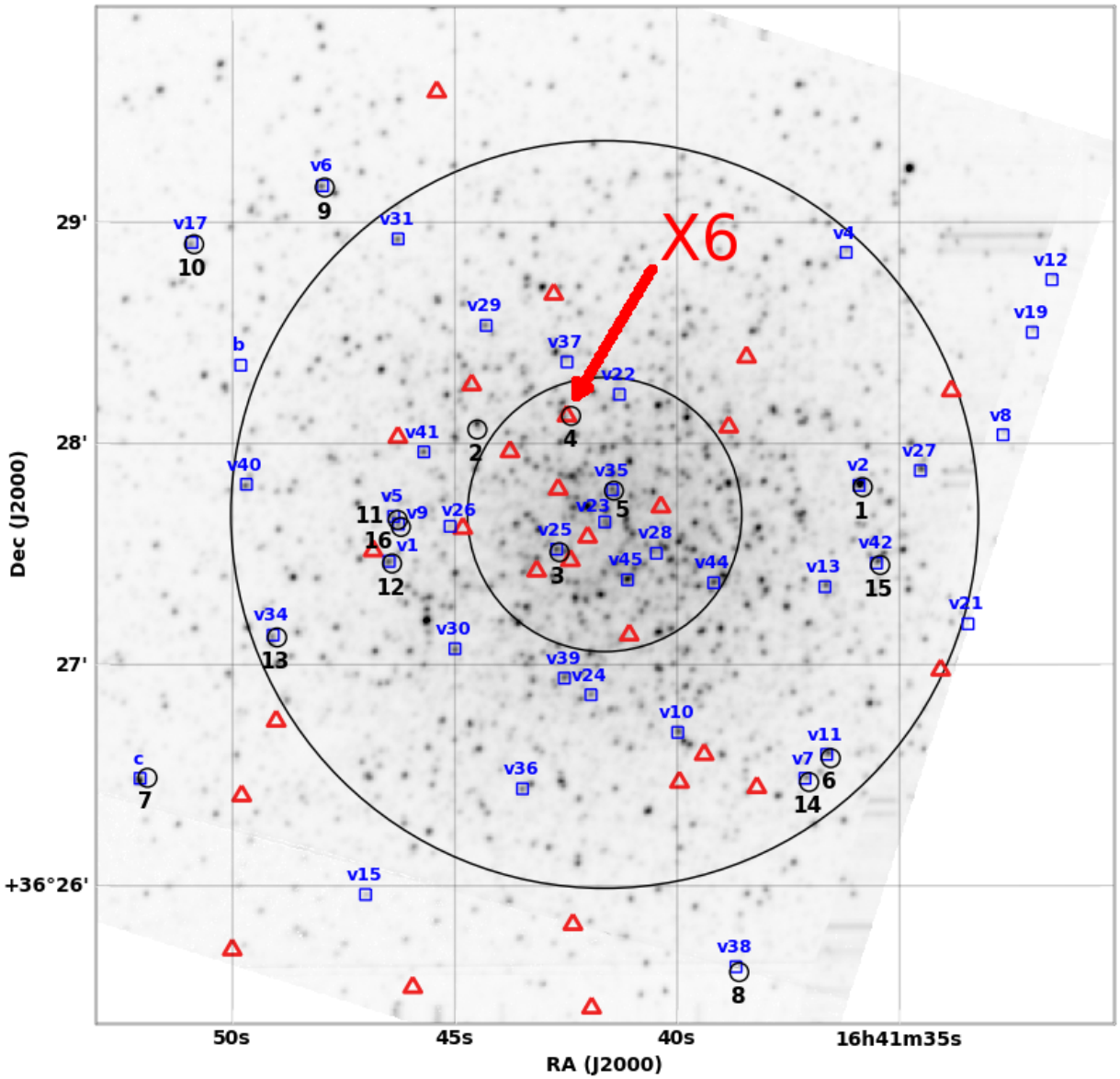

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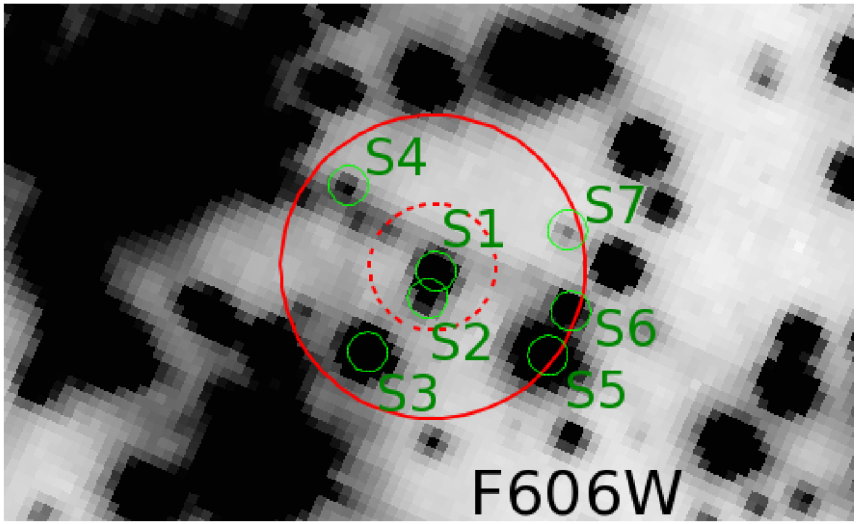

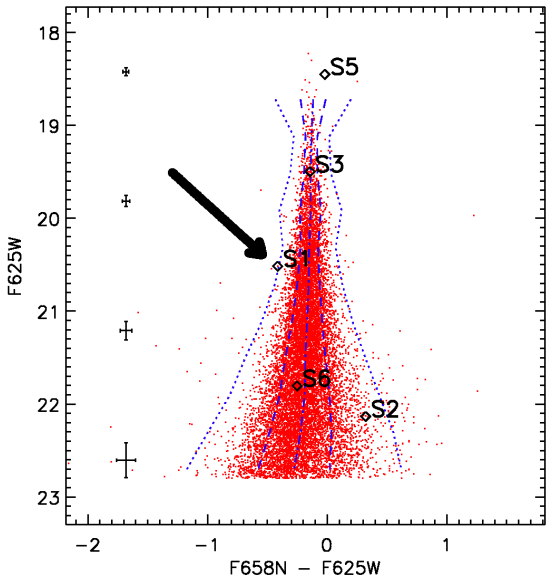

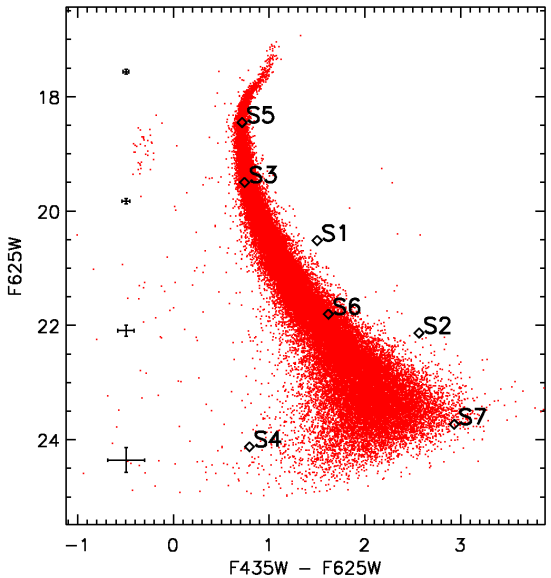

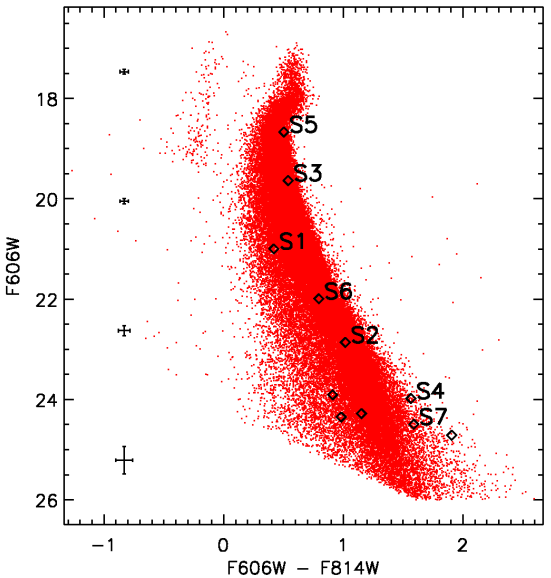

M13: Comparison with estimates

Estimate		Shara et al. 96	"unbiased"
Initial number of CVs	[Ivanova et al. 2006]	150	150
Fraction of dwarf novae	[Downes et al. 2006]	50% 75	50% 75
Duty cycle	[Szkody & Mattei 1984]	15%	1%
5 epochs = 5 chances	$(1 - \text{duty cycle})^5 =>$	54% 42	5% 3
Completeness correction		66% 28	66% 2

Can we really claim a lack?

- Initial estimate uncertain, but low impact
- Proportion of dwarf novae likely biased
- Duty cycle extremely biased
  - Evidence for faint CVs with long duty cycle [Gansicke 2009]
  - Should dominate the population (70%) [Kolb 1993]

Servillat et al. 2011, ApJ, 733, 106

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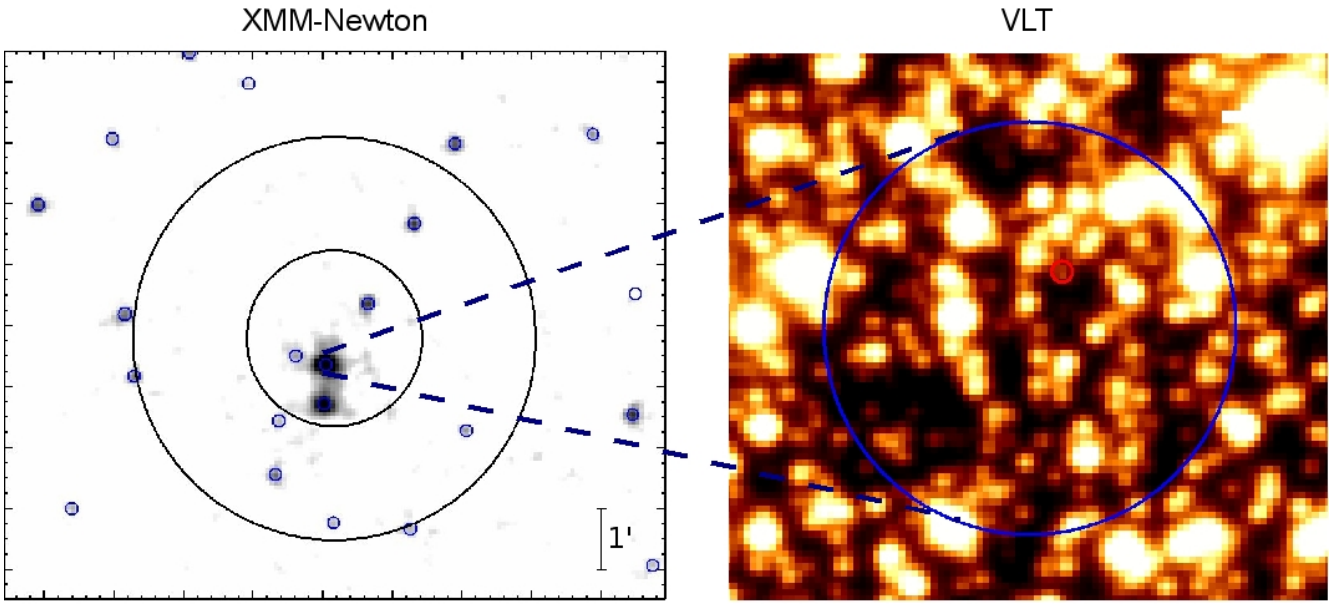
Servillat et al. 2011, ApJ, 733, 106

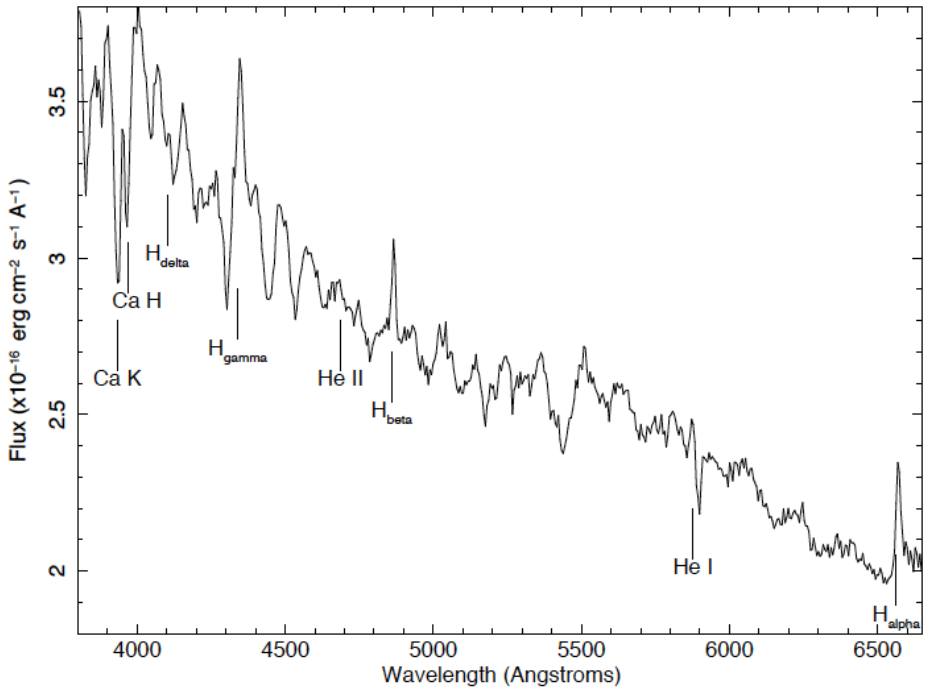
M22: The cataclysmic variable CV1

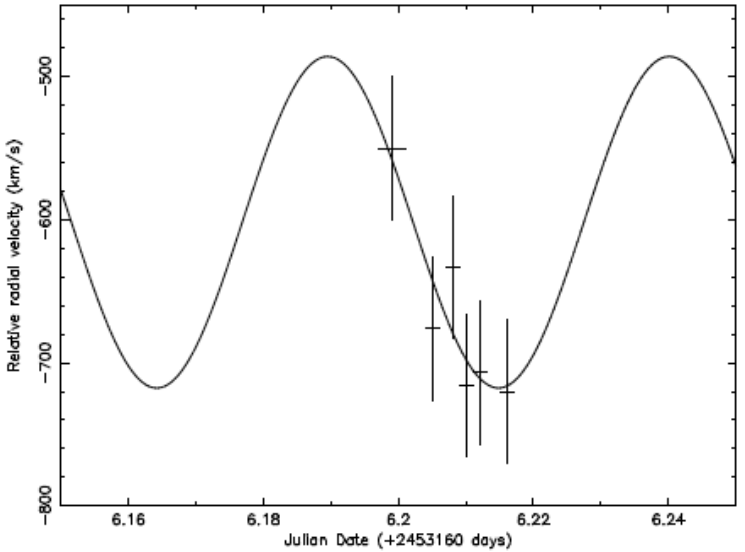


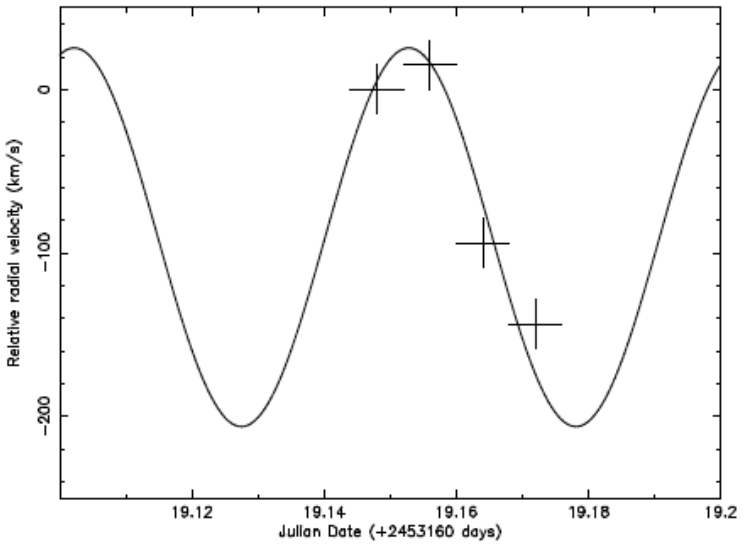
- $L_X = 1.2 \pm 0.2 \cdot 10^{32}$ erg s^{-1}
- Bremsstrahlung $kT = 10 \pm 3$ keV
- Outbursts (1999, 2000, 2001, 2002, 2003, 2004)
- Red: larger star than main sequence?
- M_{606}=2.6 => $P \sim 12$ h

Webb et al. 2004; Anderson et al. 2003; Bond et al. 2005

M22 CV1: Period from VLT/VIMOS



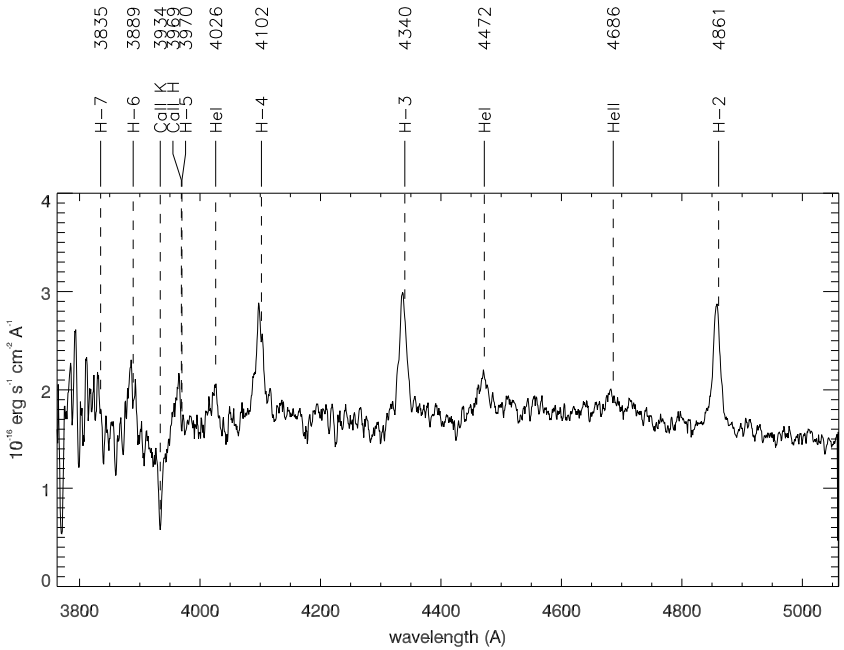


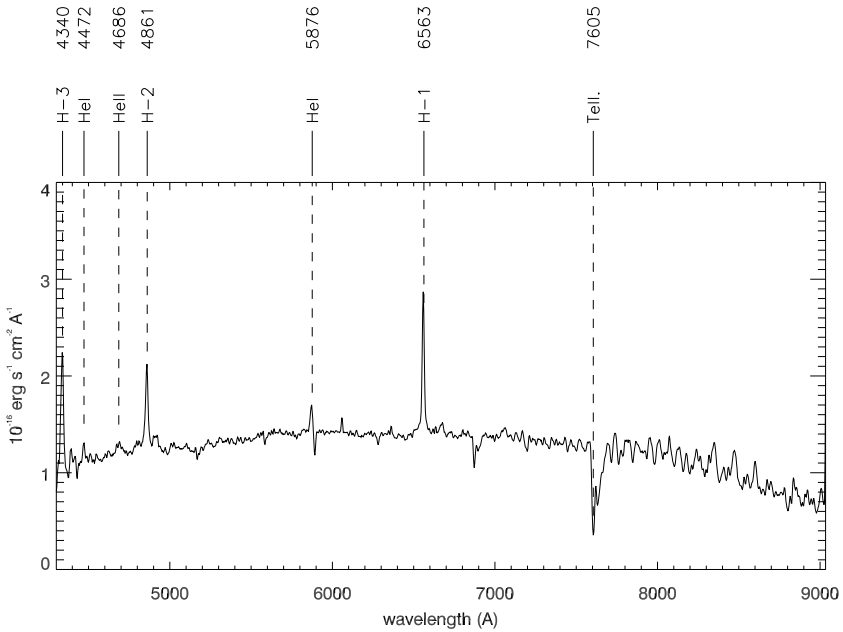


- Optical spectrum of a core CV
- Possible short period ∼1.2 h
- Not consistent with standard evolution
- Result of a recent collision?

Webb & Servillat, submitted

M22 CV1: VLT/FORS1 optical spectroscopy

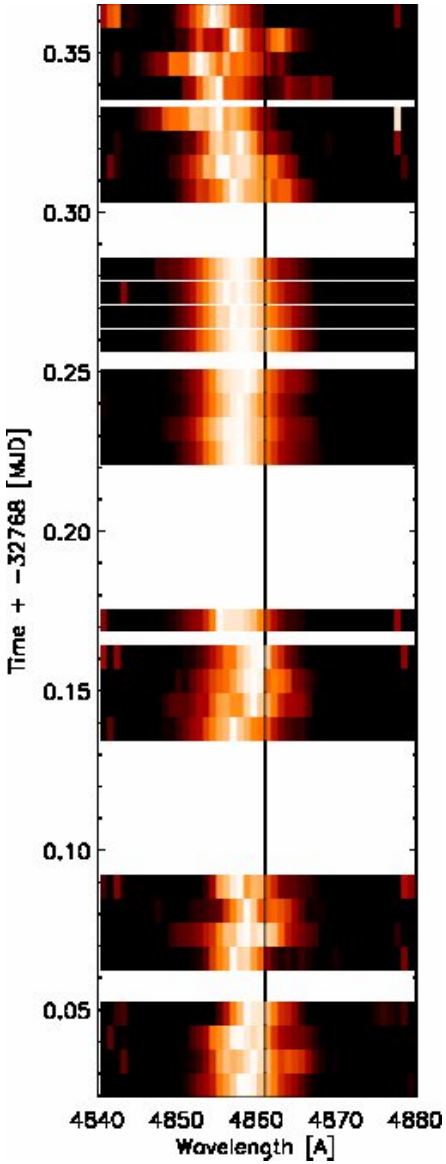


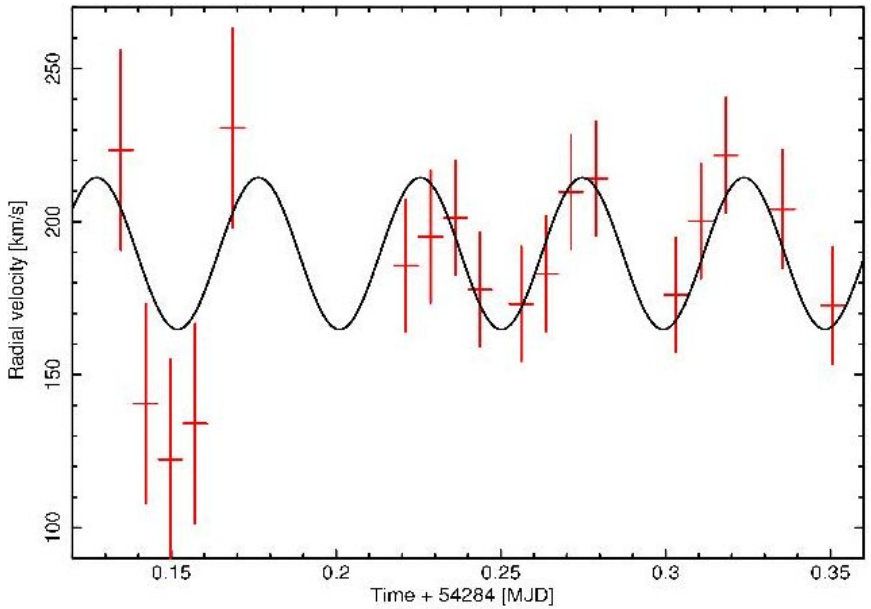


- Emission lines: accretion disk
- HeI and HeII lines : high temperature, magnetic nature?

Servillat & Webb, in prep. (preliminary)

M22 CV1: Radial velocity curve





Preliminary results

- Short period: 1.12 to 1.25 h
- Consistent with VIMOS period
- Very low amplitude...

- Detection of dwarf novae in globular clusters are suspiciously rare
- Previous authors reported a possible lack of outbursts
- An excess of intermediate polars could explain such a lack

Population study in NGC 2808

- No clear excess of intermediate polars
- Weak constraints due to low number of sources

A dwarf nova in M13

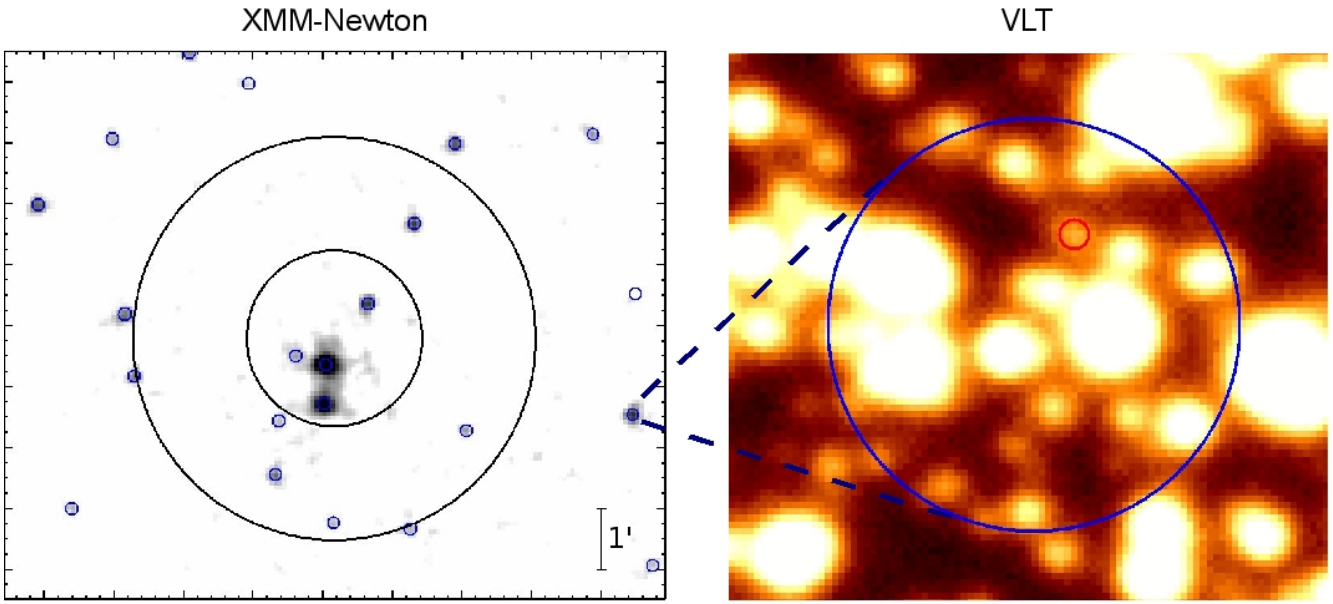
- Detection of an outburst consistent with a dwarf nova (optical, X-ray)
- This single detection does not imply a dearth of outbursts in GCs
- Indicates strong biases in our reference population

Spectra of dwarf novae in M22

- First radial velocity measurements of a GC core dwarf nova
- Possible short period of CV1, inconsistent with its brightness

- To be tested: peculiar CVs in GCs <=> dynamical influence

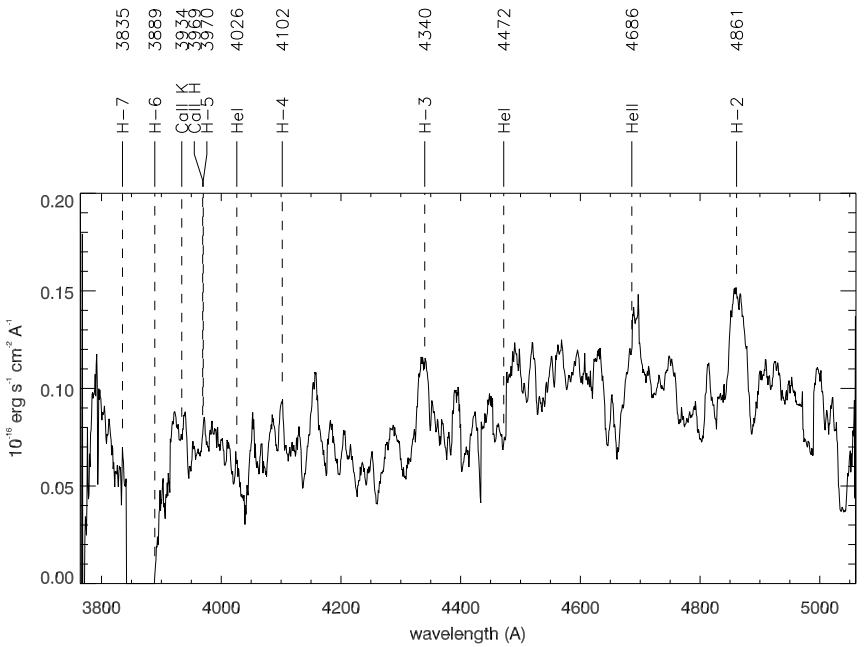
M22: The cataclysmic variable CV2

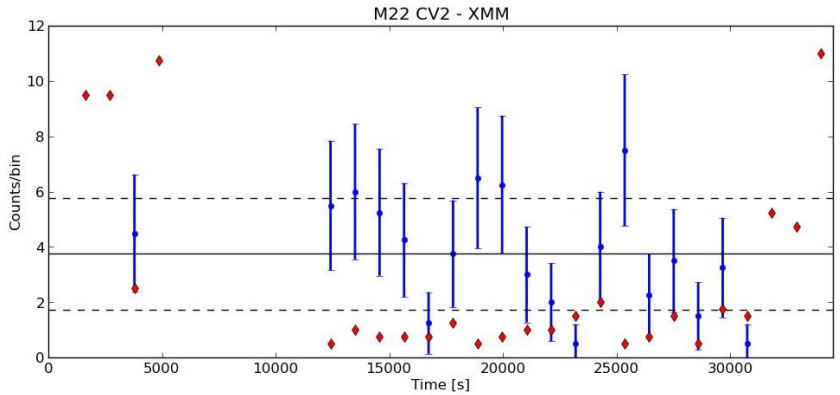


- $L_X = 4.6 \pm 0.8 \cdot 10^{31}$ erg s^{-1}
- Bremsstrahlung $kT > 10$ keV
- Outburst in the optical (2000)
- $P = 2.039 \pm 0.003$ h

Webb et al. 2004; Pietrukowicz et al. 2005

M22 CV2: FORS1 and *XMM-Newton*





- H, HeI and HeII emission lines
- HeII/Hβ : intermediate polar
  [Silbert 1986]
- XMM: 2h eclipses?
- Magellan 6.5m recent observations