Accreting compact object binaries in transient surveys

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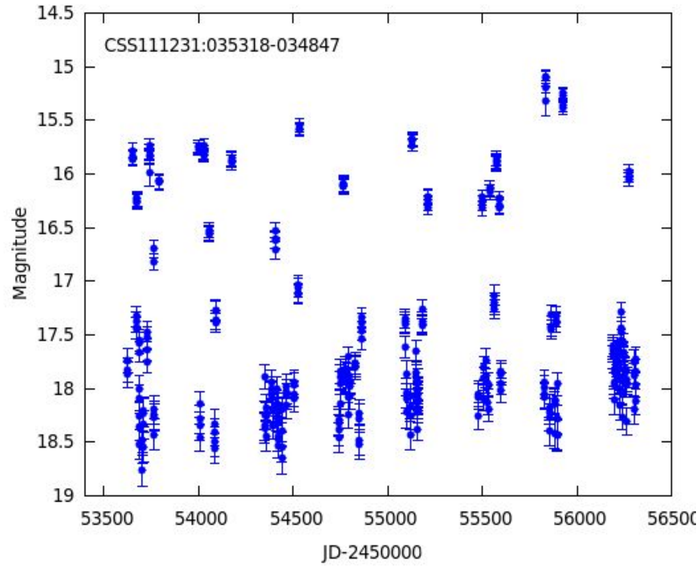
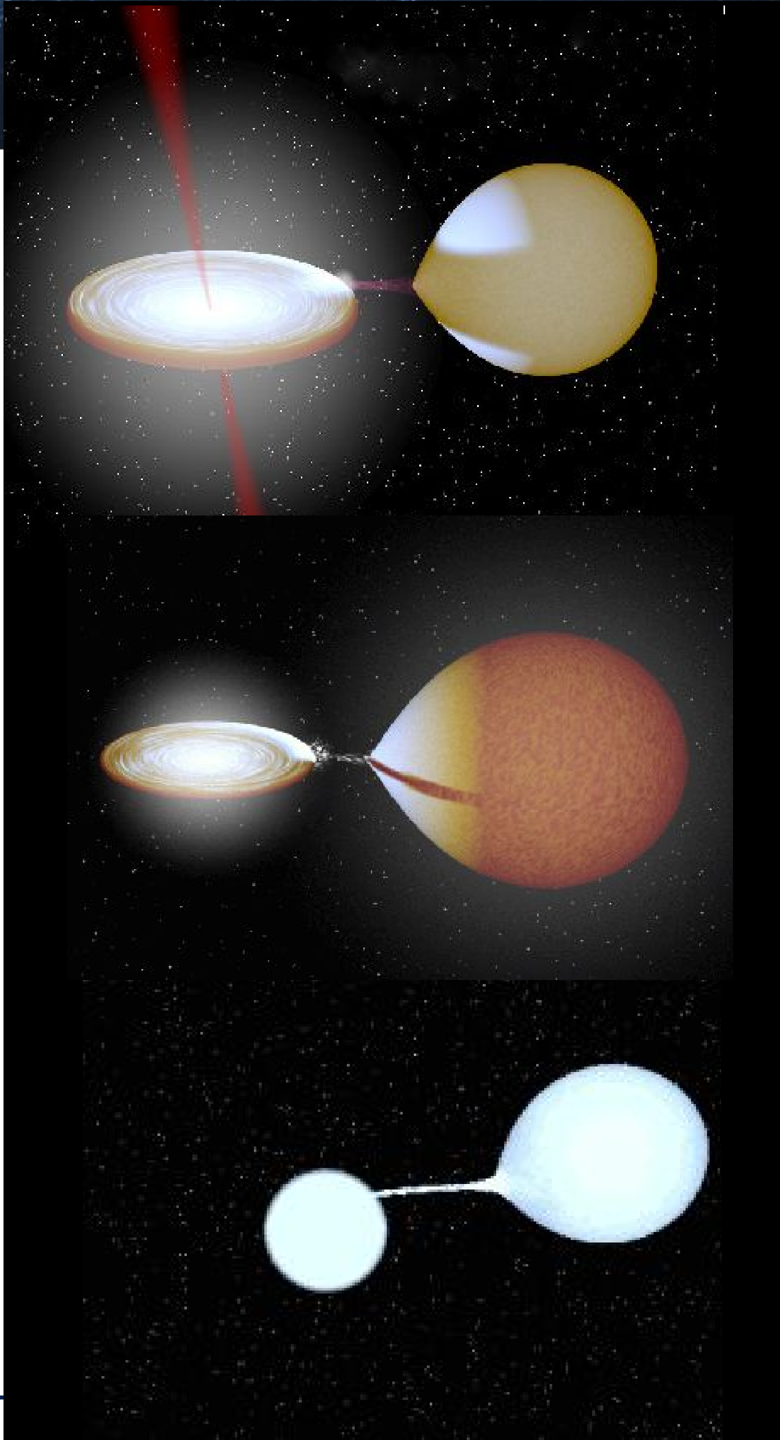
Accretion-driven transients

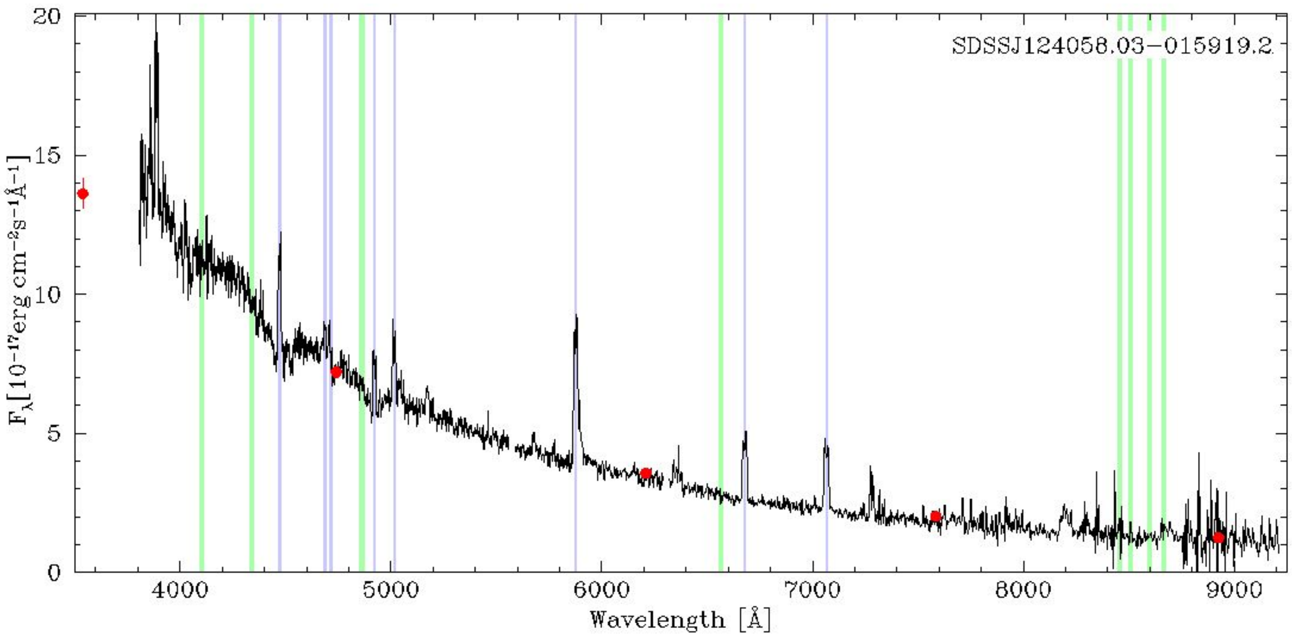
- Compact object (BH, NS, WD)
- Accreting from companion star
- Accretion disc
- Evolve by angular momentum loss -- same physics!

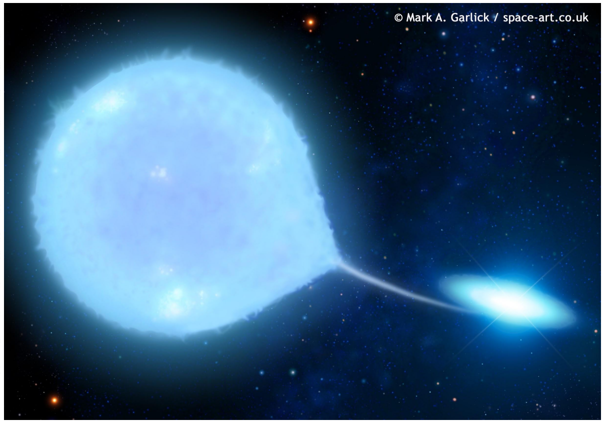




Characteristics of an AM CVn star

- Accreting white dwarfs
- Hydrogen-deficient
- Ultra-short periods: $\mathbf{P_{orb} = 5 - 65\ min}$



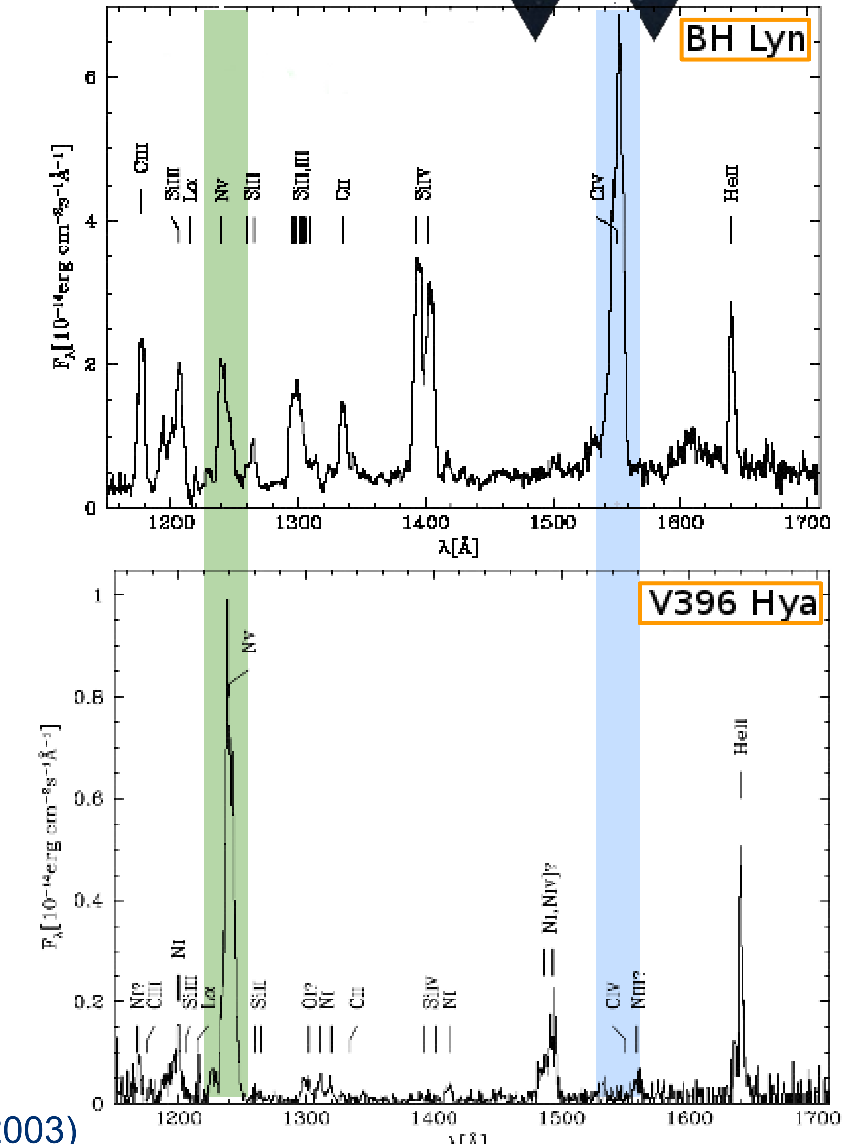


AM CVn donor stars

Period-density relation for Roche lobe-filling stars:

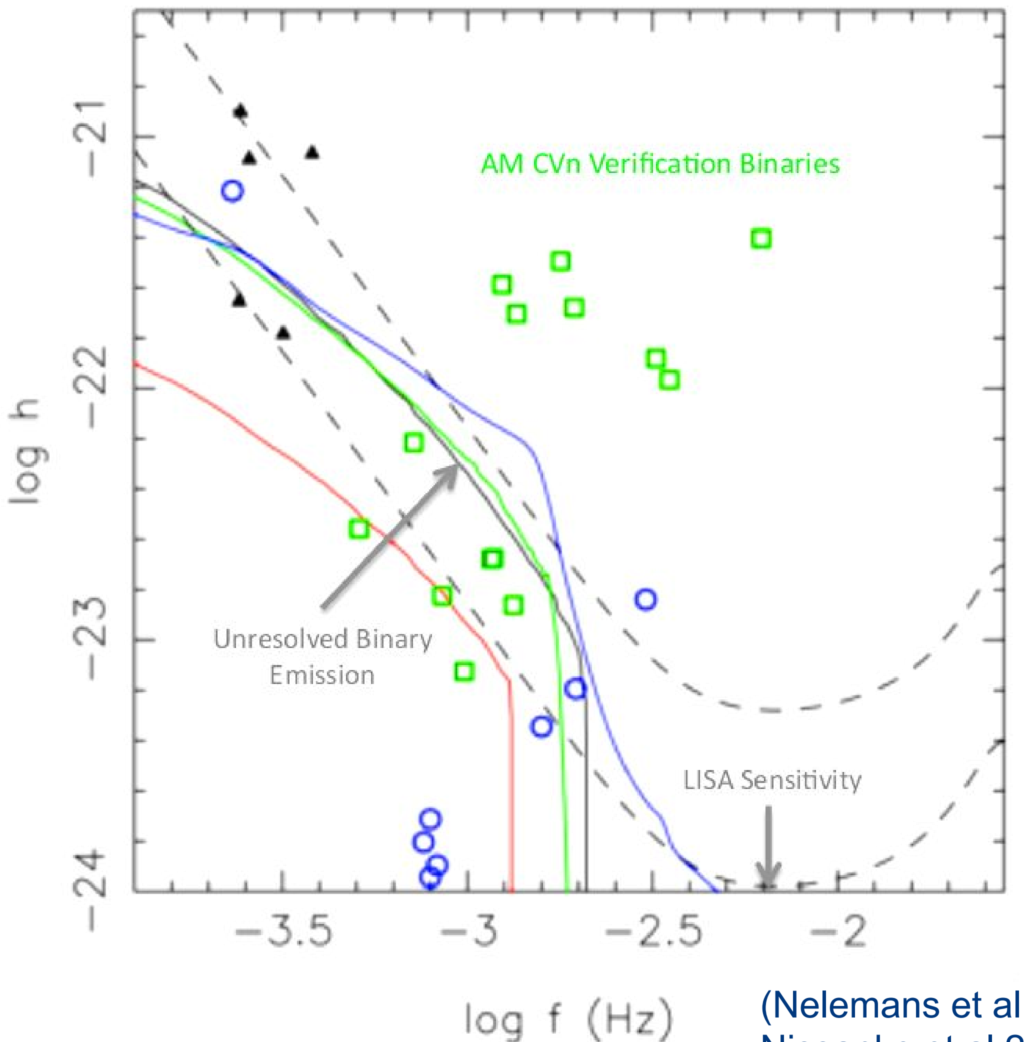
$$< \rho_2 > \simeq 107 \ P_{orb,h}^{-2} \ \mathrm{g\ cm}^3$$

⇒ Donors stars of AM CVn binaries are *evolved* (another WD, or a partially degenerate star)



(Gaensicke et al 2003)

Gravitational wave sources



Evolution driven by gravitational wave radiation (Paczynski 1967)

Strongest known low-frequency GW sources (verification sources for eLISA)

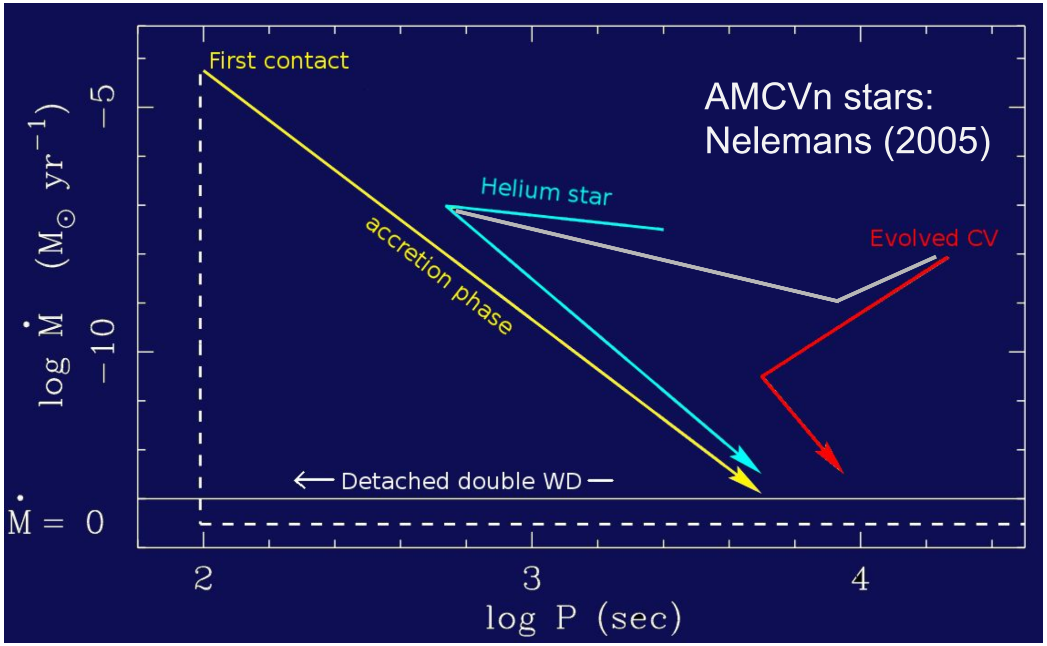
(Nelemans et al 2004, 2005, 2011; Nissanke et al 2012)

Formation channels / evolution

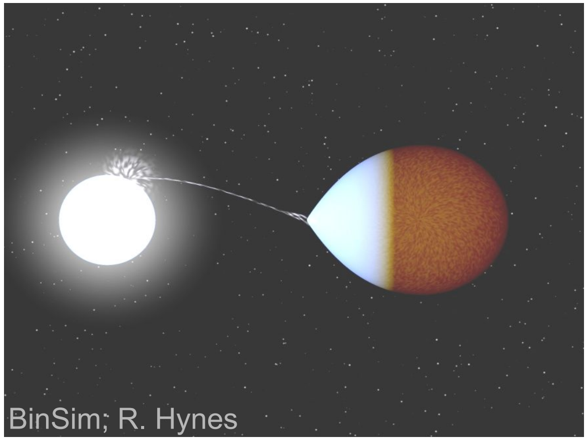
- Double WD binaries
  (Paczynski 1967;
  Nelemans et al 2001)

- WD + He-star
  (Iben & Tutukov 1991;
  Yungelsson 2008)

- Evolved CV
  (Sienkiewicz 1984;
  Podsiadlowski et al 2003)



$\dot{m}$ stable?
(Marsh et al 2004)



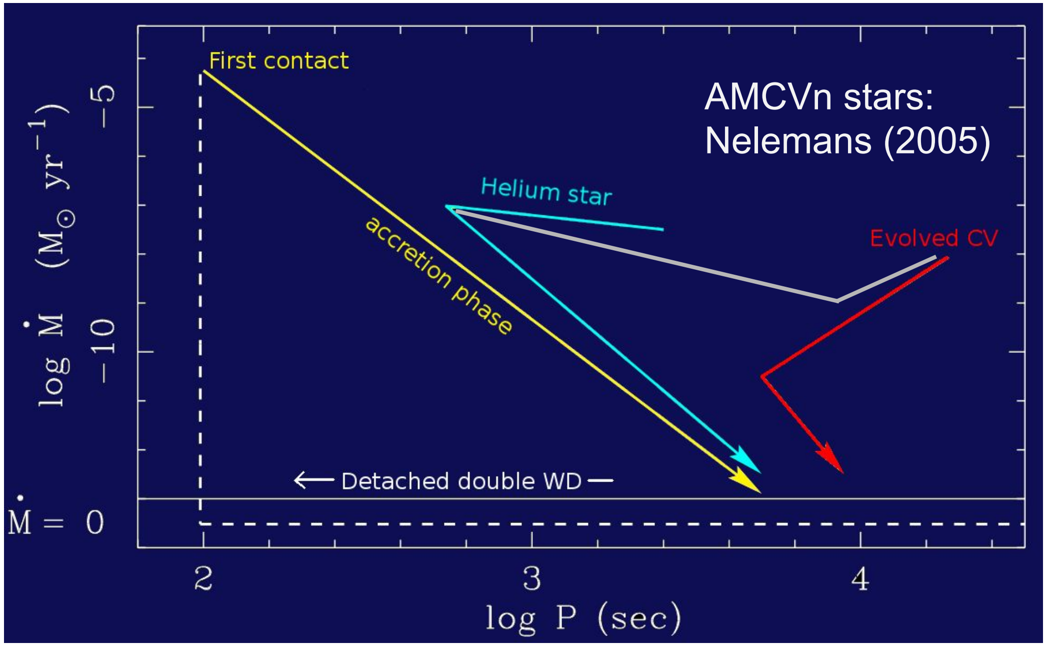
Formation channels / evolution

First contact at short P_{orb}
-- evolve to long periods

Roche lobe + GWR + degenerate star + Kepler III

$$\Rightarrow \quad \dot{m} \propto P^{-14/3}$$

(e.g. Warner 1995;
Cannizzo & Nelemans 2015)



Sharp drop in $\dot{m}$ as the system evolves to longer periods

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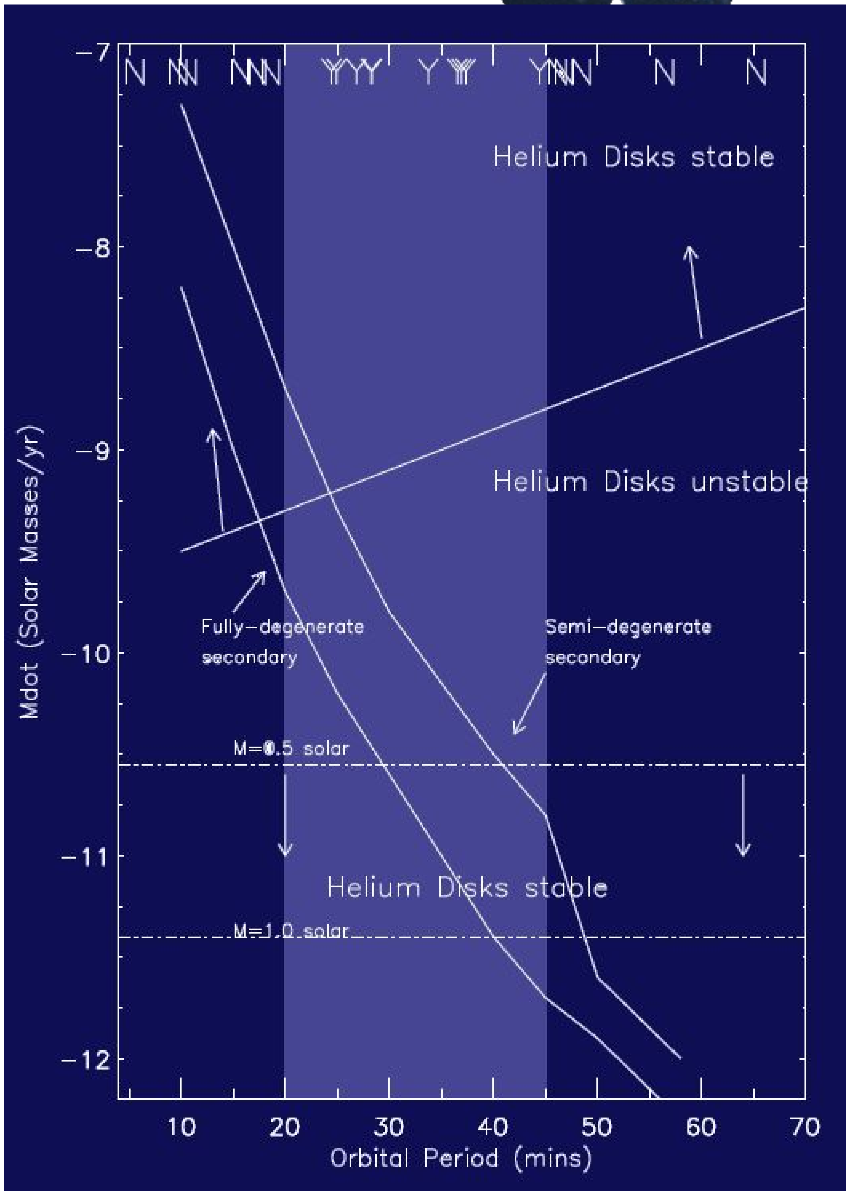
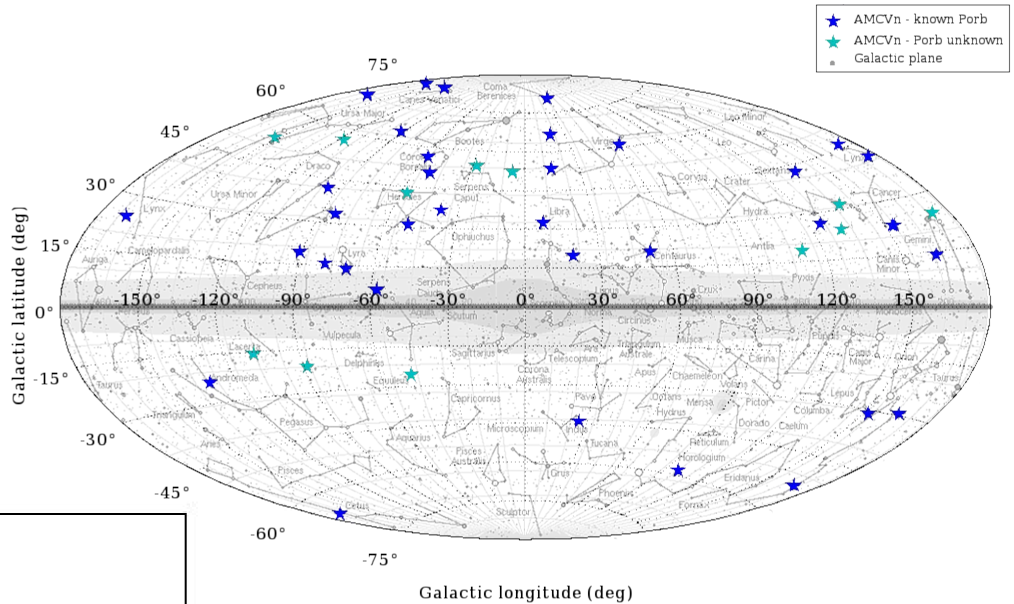
(Ramsay et al 2012)

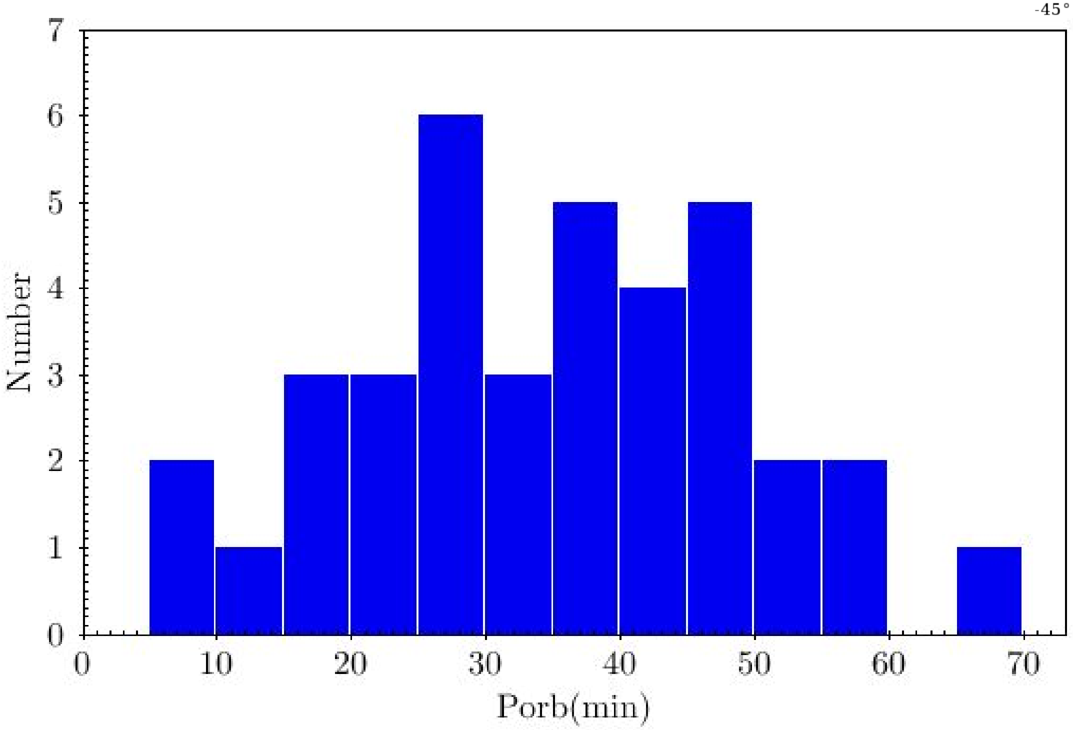


The AM CVn population in numbers

50 known systems

38 with known P_{orb}





g mag = 13.5 − 24

Observed space density

5×10^{-7} pc^{-3}

(Carter et al 2013)

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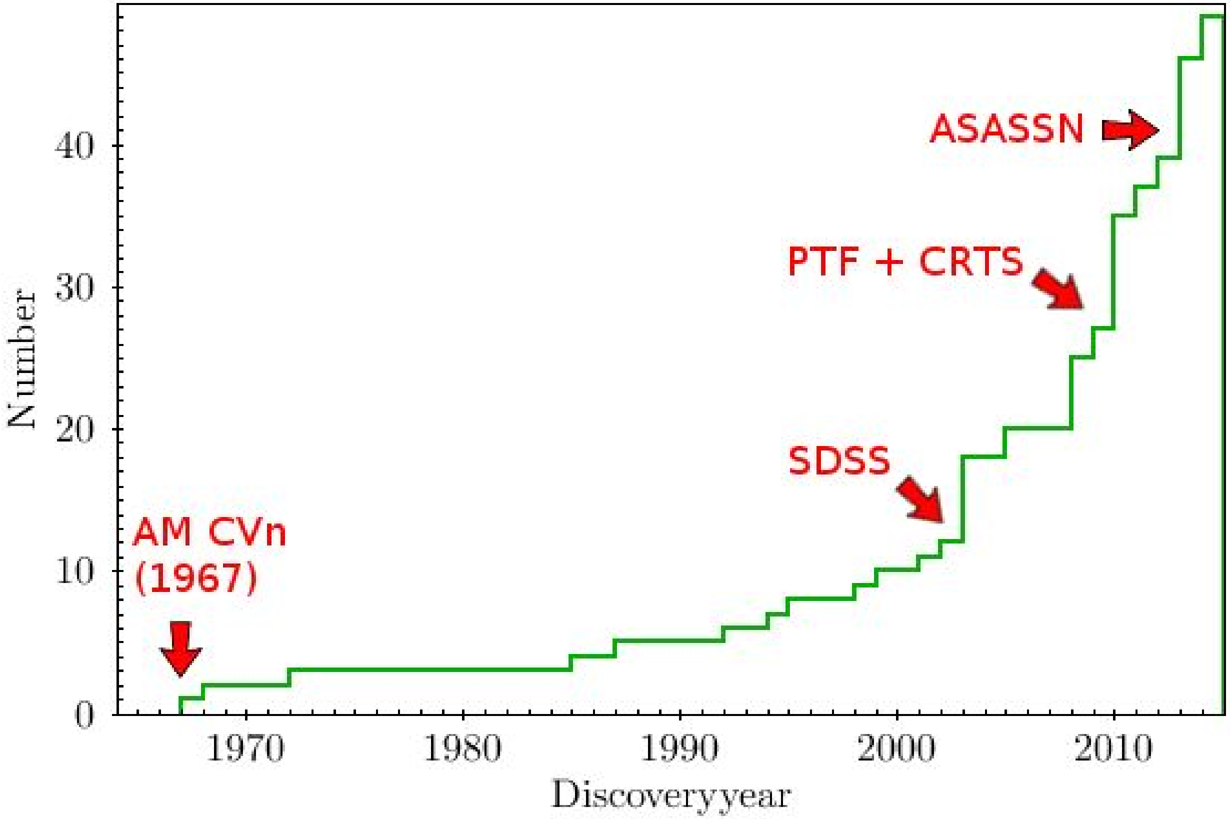


Transient surveys

Pros:

- ★ Much deeper than possible with spectroscopy
- ★ Wide sky coverage
- ★ No colour pre-selection
- ★ High event rates, so it also finds the rare objects

Cons:

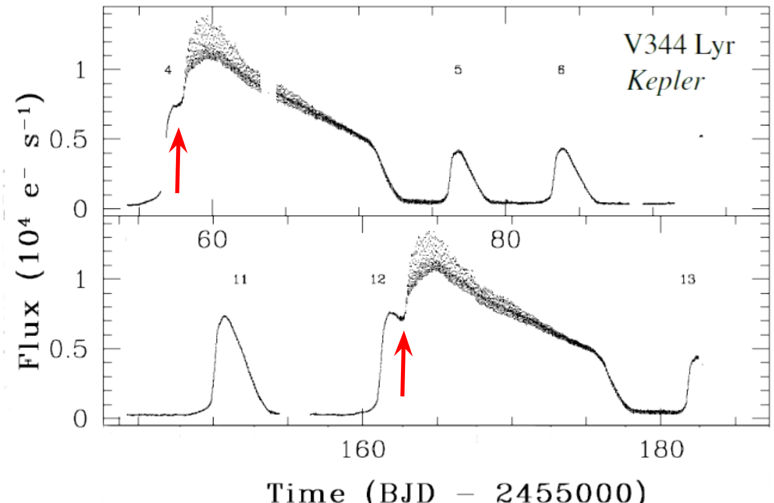
- ❖ Selects AM CVns from only a specific period range
- ❖ Statistics are harder
- ❖ Many too faint for spectroscopic follow-up

Recent advances as a result of follow-up of transient events

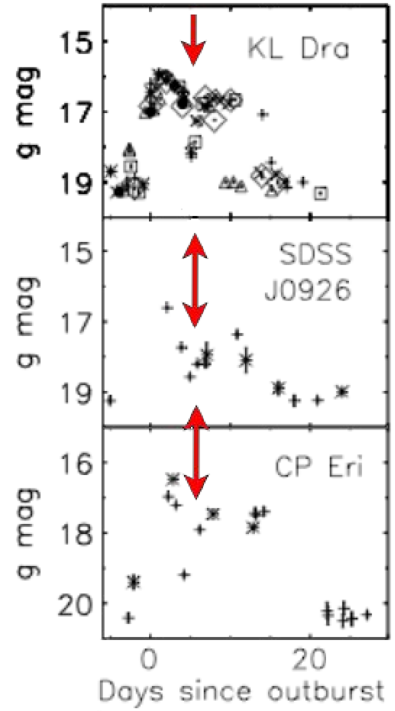
- ➢ Helium disc instability - link to CV DNe
- ➢ Long term photometric variability - low $\dot{m}$ AM CVn
- ➢ First deeply eclipsing AM CVn

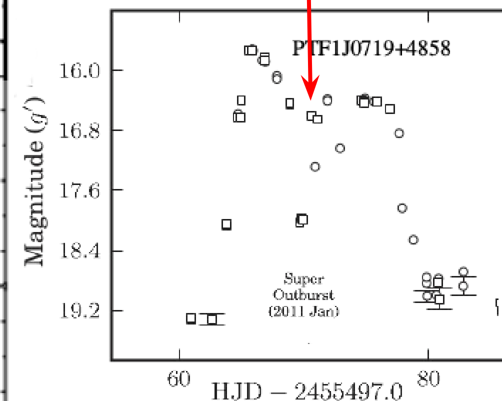
i) Disc phenomena

- **Superoutburst "dips"**



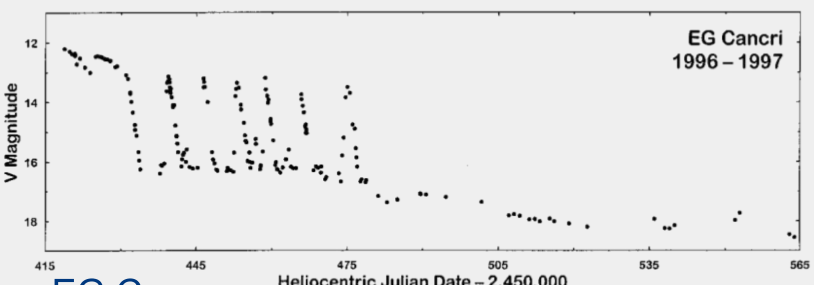
(Wood et al 2011; Cannizzo et al 2012
Osaki & Kato 2013)



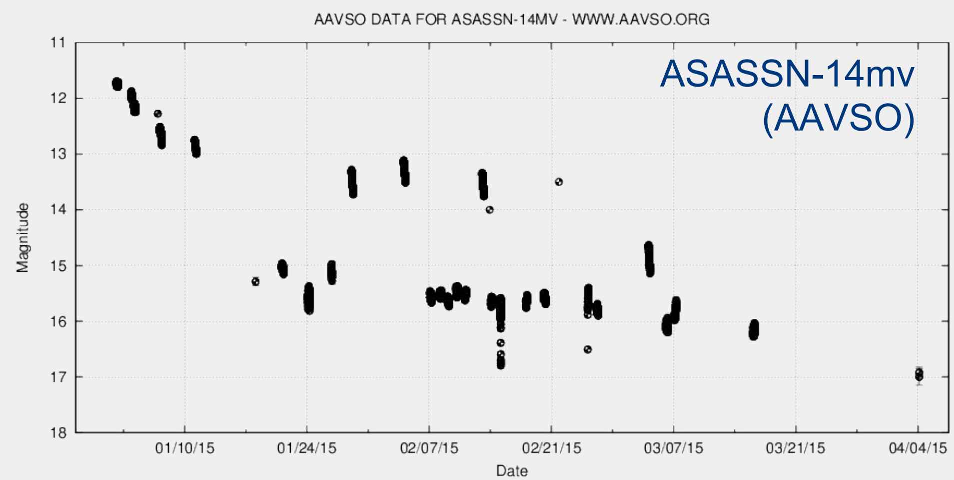


(Levitan et al 2011;
Ramsay et al 2012)

- **Echo outbursts**



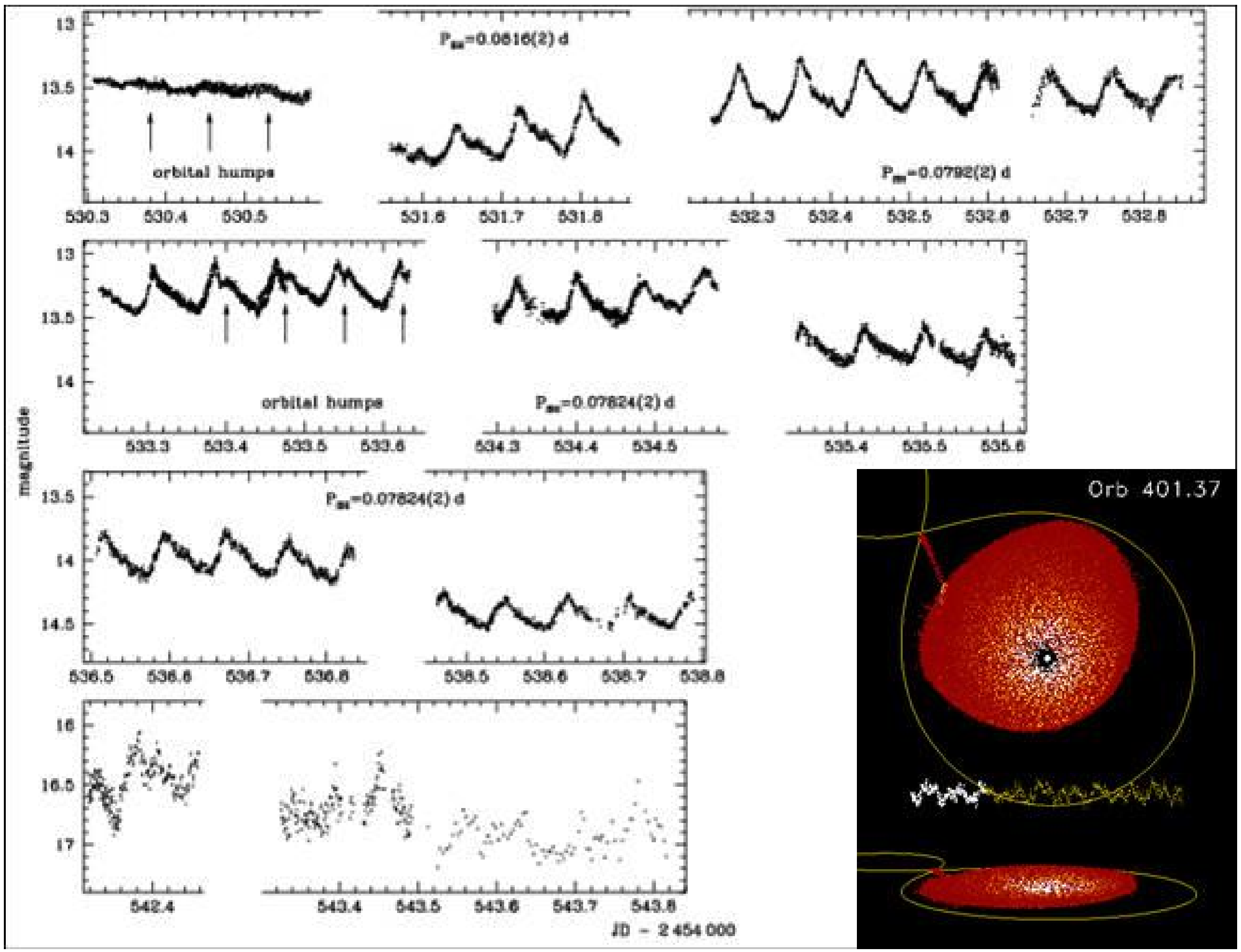
EG Cnc
(Patterson et al 1998)



ASASSN-14mv
(AAVSO)

i) Disc phenomena

- **Superhumps**



Only observed during superoutburst

Efficient way of measuring the orbital period

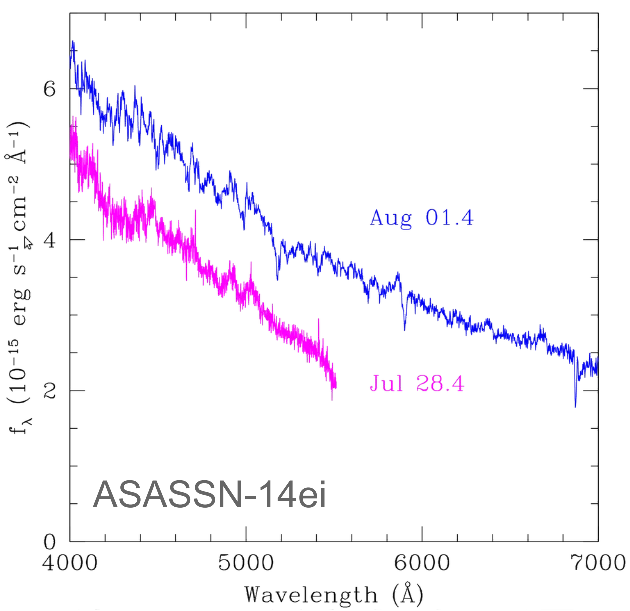
Requires rapid follow-up → **Gaia alerts**!

(HS0417+7445 - J. Shears, B.T. Gänsicke et al. 2011, New Astronomy, 16, 5)

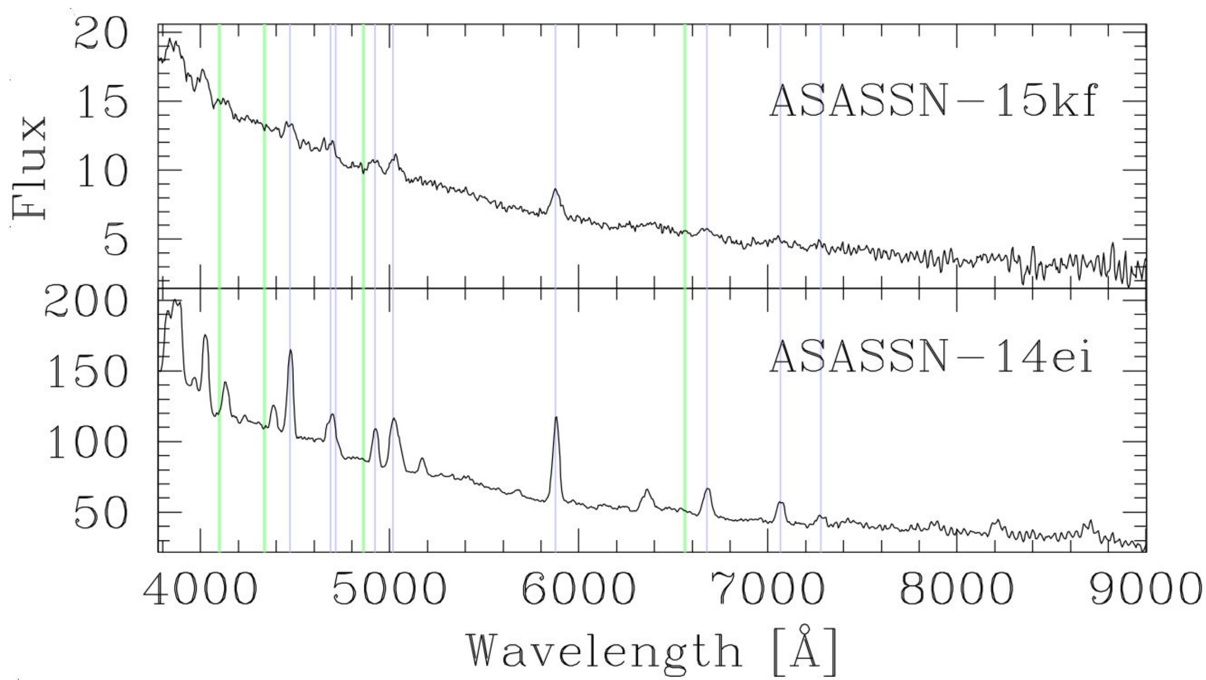
i) Disc phenomena

Recent discoveries:

- ASASSN-14mv P_{sh} = 40.52 min q = 0.08 (vsnet-alert 18230)
- ASASSN-14ei P_{sh} = 42.89 min 14 rebrightenings!
- ASASSN-14fv P_{sh} = ? (Wagner et al 2014 ATEL#6669)
- ASASSN-15kf P_{sh} = 27.68 min (vsnet-alert 18669)
- ASASSN-14cc P_{sh} = 22.46 min Very freq outbursts (Kato et al 2015)



(Prieto et al 2014 ATEL#6475)



(Carter, Breedt et al, in prep)

ii) Long term photometric behaviour

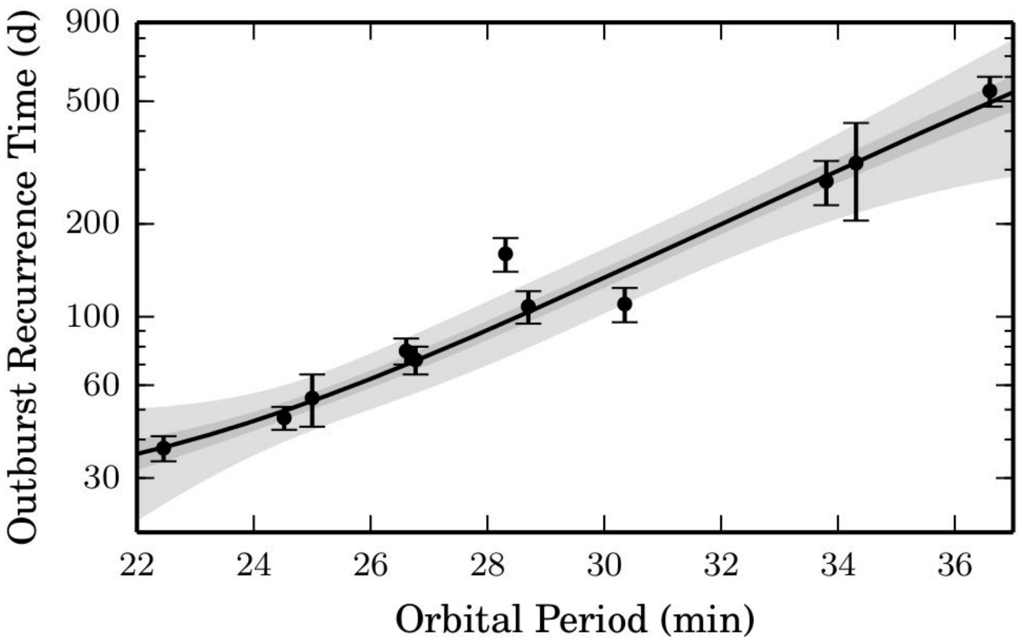
Modified DIM: unstable disc for $20 \lesssim P_{orb} \lesssim 40$ min
(Tsugawa&Osaki 1997; Kotko et al 2012)

Levitan et al (2014): long term light curves

$T_{rec} \propto \dot{m}^{-1} \propto P_{orb}^{7.35}$

Cannizzo & Nelemans (2015):

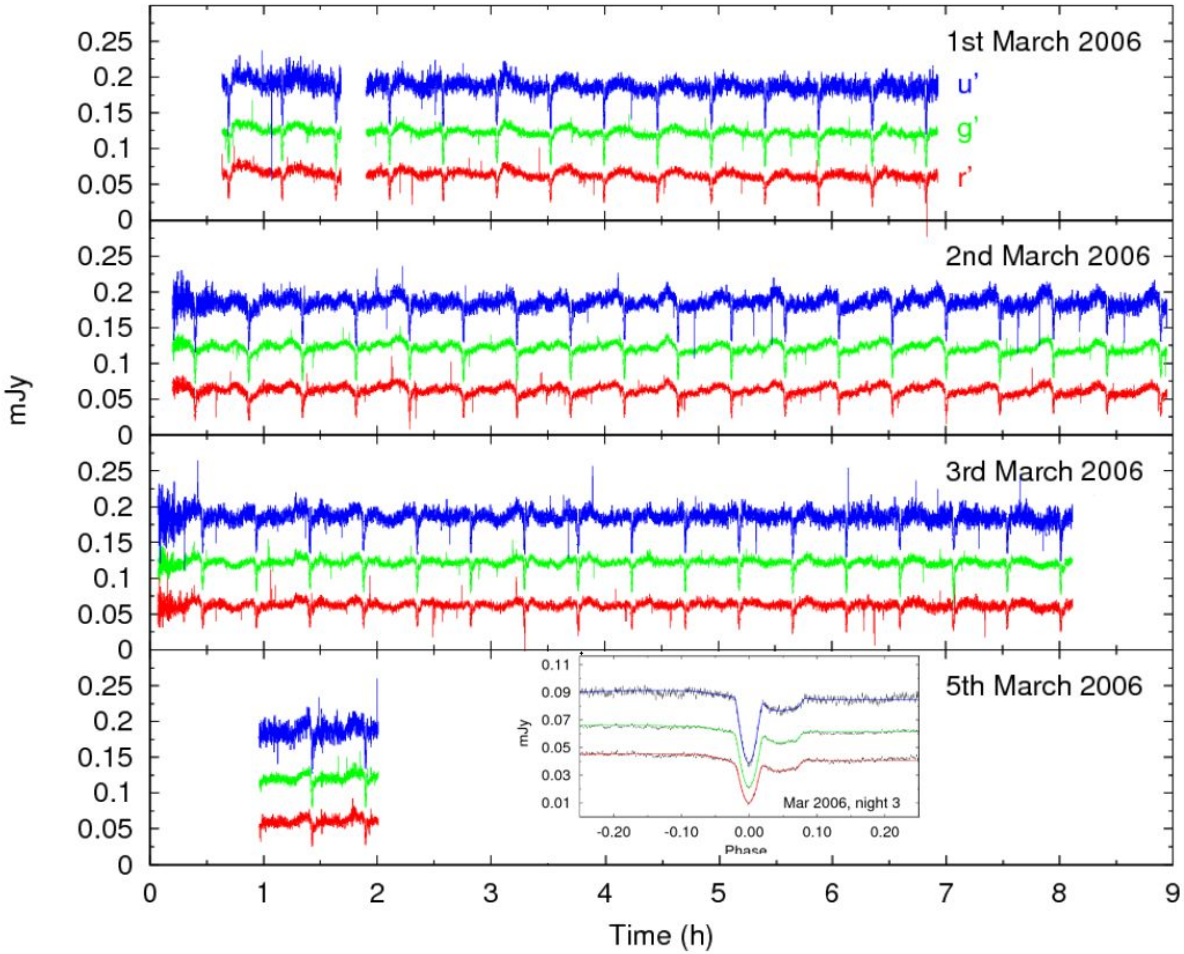
- systems with higher primary masses have a steeper $\dot{m}$ - P_{orb} relation
- Parameter studies are still important!

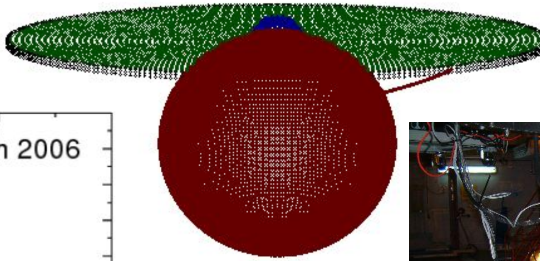


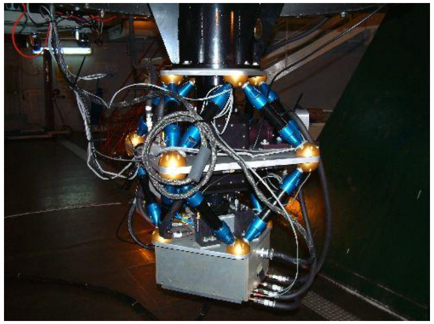
iii) Eclipsing systems

SDSSJ0926+3624

The first-ever eclipsing AM CVn







WHT+ ULTRACAM

$P_{orb} = 28.3$ min

$q = 0.043$

$i = 82.5$

$T_{WD} = 17000$ K

$M_1 = 0.82\, M$

$M_2 = 0.035\, M$

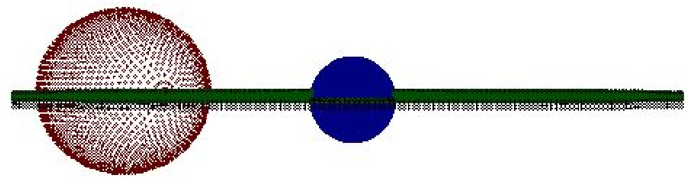
iii) Eclipsing systems

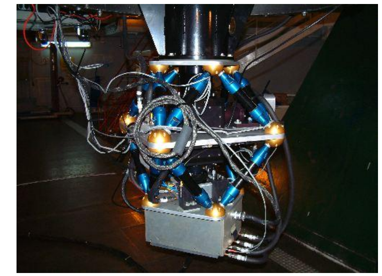
ASASSN-14cn / Gaia14aae

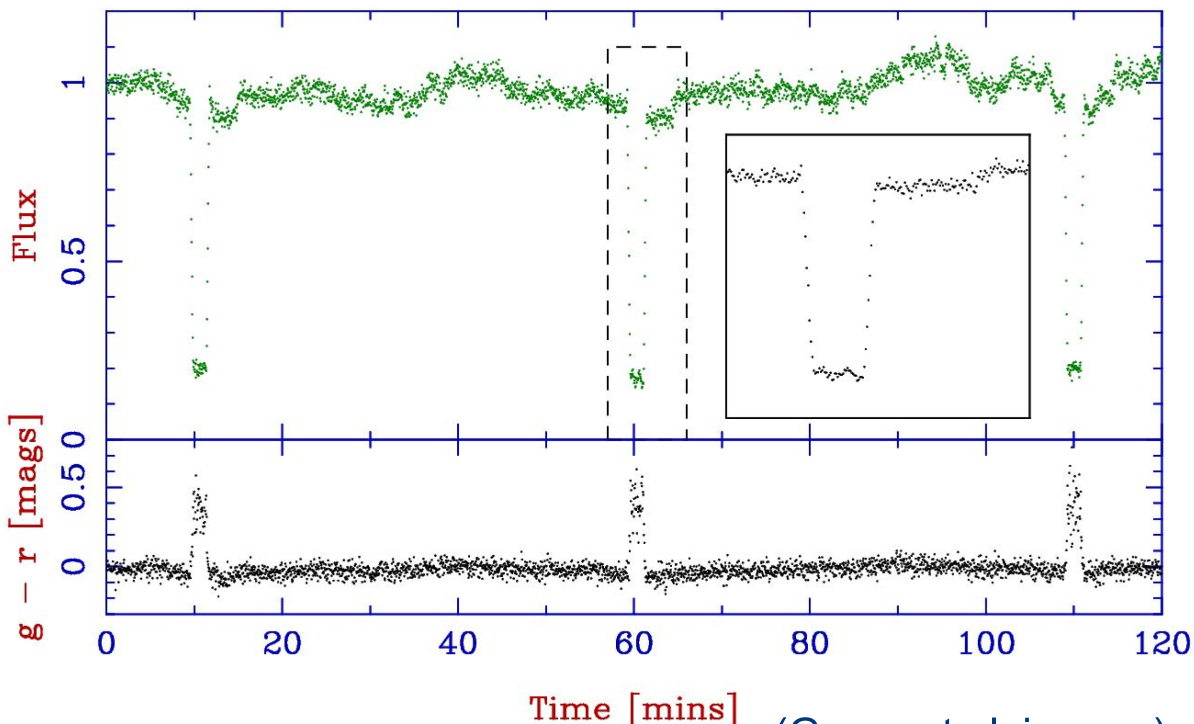
First AM CVn in which the WD is fully eclipsed
- ideal for parameter studies

$$P_{orb} = 49.71 \text{ min}$$
$$T_{WD} = 12900 \text{ K}$$
$$a = 0.41\ R_\odot$$
$$q = 0.019$$
$$M_1 \simeq 0.79\ M_\odot$$
$$M_2 \simeq 0.015\ M_\odot$$
$$= 15.7\ M_J$$

(Campbell et al 2015)







(Green et al, in prep)

Longest P_{orb} with outbursts

Final thoughts

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- **18** new AM CVns from **variability surveys**; several surveys to come: **Gaia**, PanSTARRS, LSST - but follow-up observations are essential.
- Huge interest and involvement from **citizen scientists** (aka amateur astronomers)
- **Gaia14aae**: extremely valuable discovery, both for the eclipse and for helium disc instability models. Thank you for all your observations!
- Future observations: phase resolved spectroscopy; could we detect the **donor star** directly?
- Future work with Gaia: **space density** of AM CVn stars