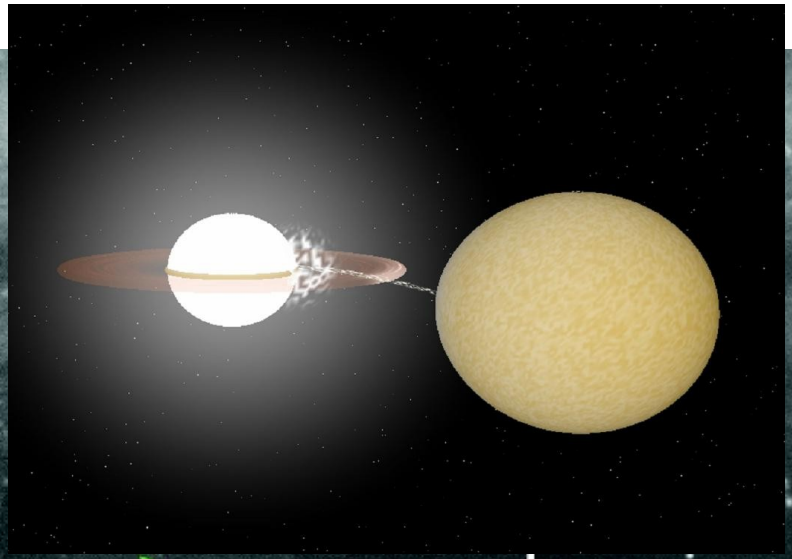
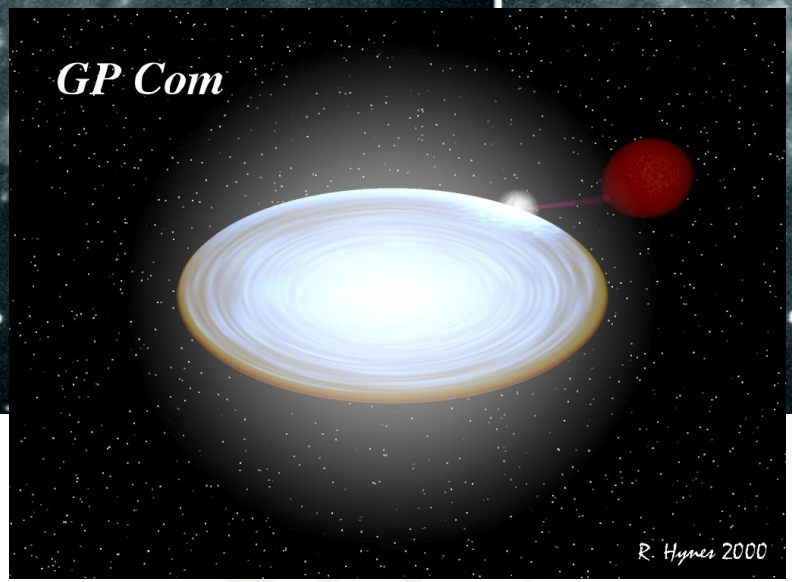
White dwarf binaries & pulsators in Transient Surveys

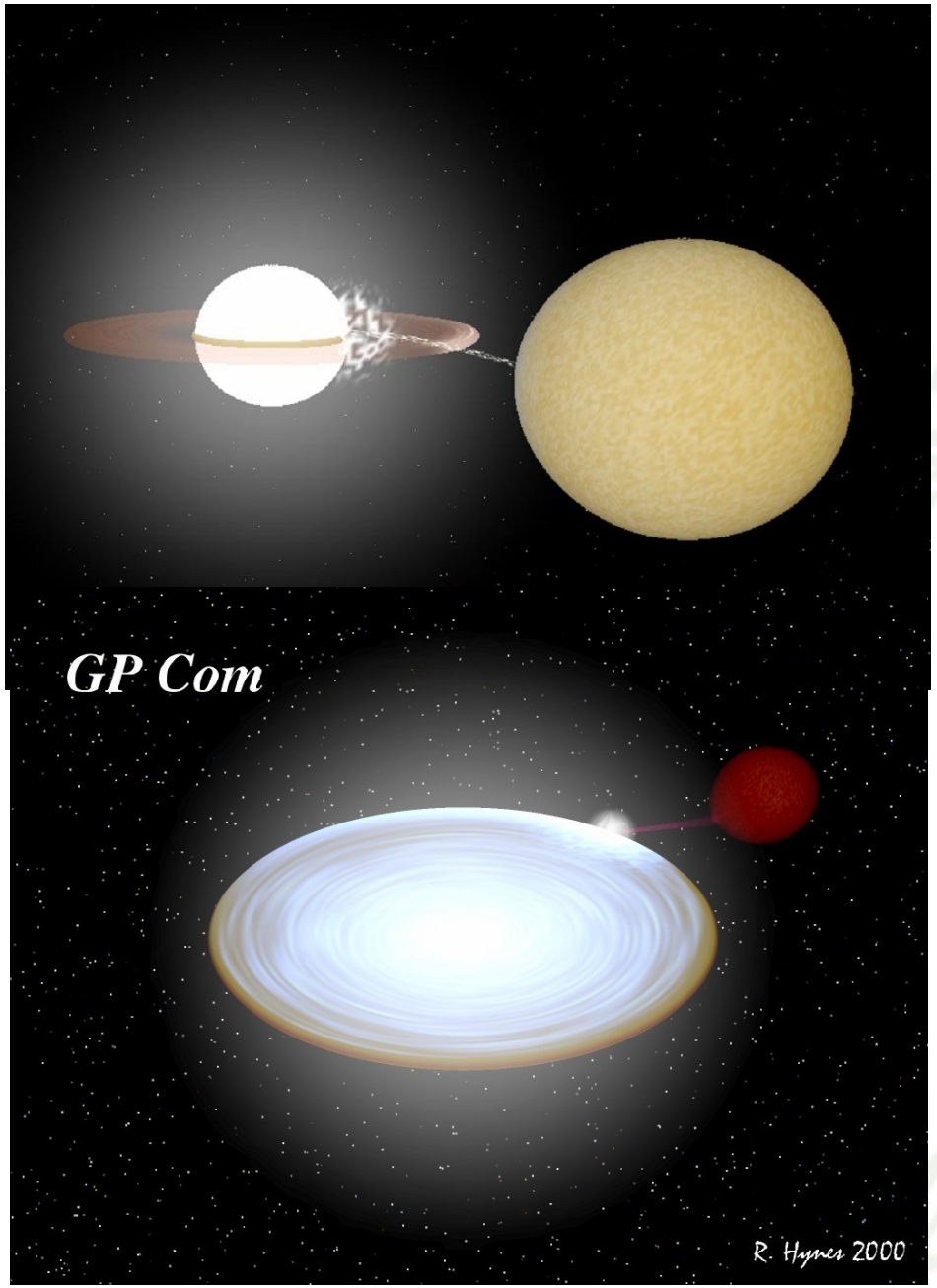




Paul Groot,
Radboud University Nijmegen
& Caltech

Collaboration:
Gijs Nelemans, Tom Marsh, Danny Steeghs, Patrick Woudt, Lev Yungelson,*Kars Verbeek*
Lars Bildsten, Tom Prince, Shri Kulkarni, *Gijs Roelofs, David Levitan, Thomas Kupfer*

AM CVn stars

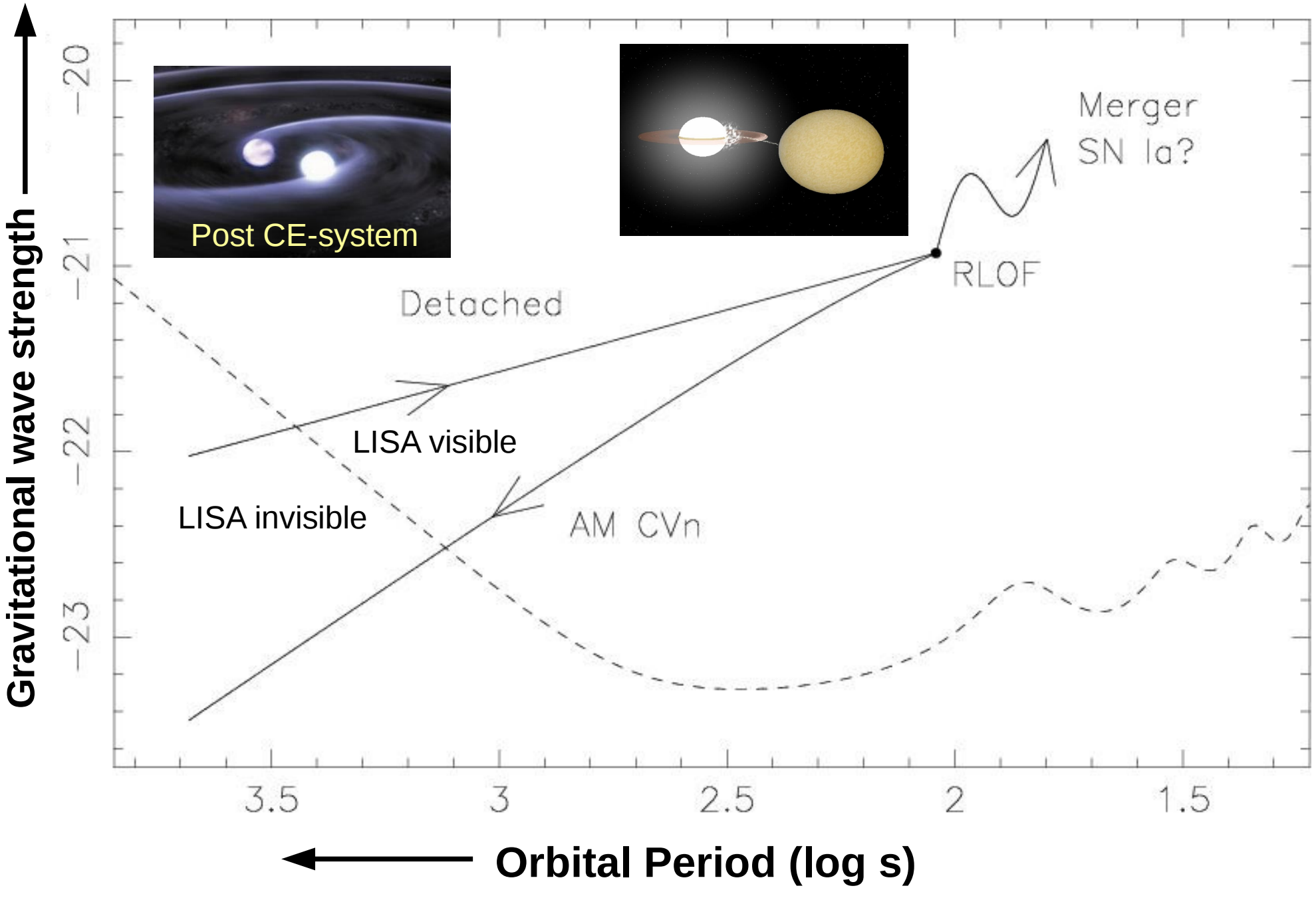


- Interacting binary white dwarfs
- Completely hydrogen deficient
- Orbital periods: 11-65 minutes
- Only 31 systems known
- Only known LISA sources
- Ultimate survivors:
  2 x CE phase + Direct impact phase
- Evolution fully (?) set by GWR losses

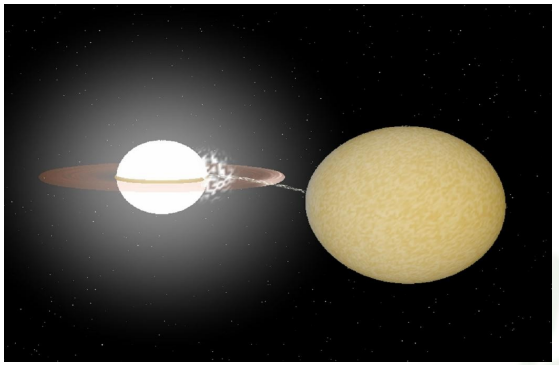
$$\frac{\dot{J}}{J} = -\frac{32}{5}\frac{G^3}{c^5}\frac{M_1 M_2 (M_1 + M_2)}{a^4}$$

$$\frac{\dot{M}_2}{M_2} = \frac{\dot{J}}{J}\frac{2}{\zeta_2 + 5/3 - 2q},$$

Gravitational wave evolution



Triple point outcomes: Branching ratios?

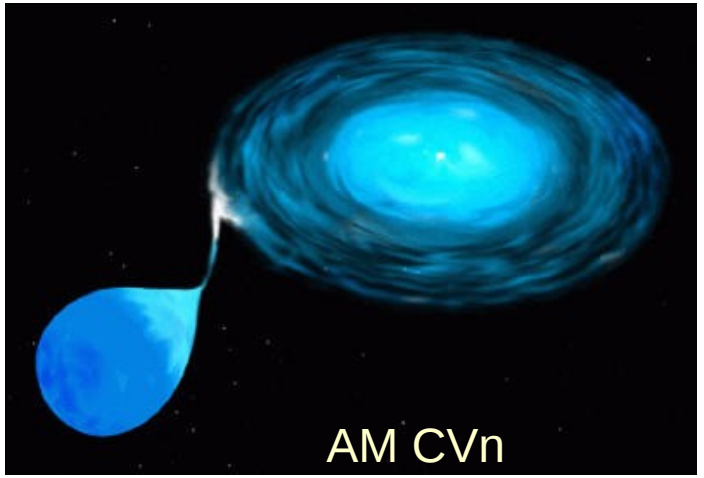


Stable

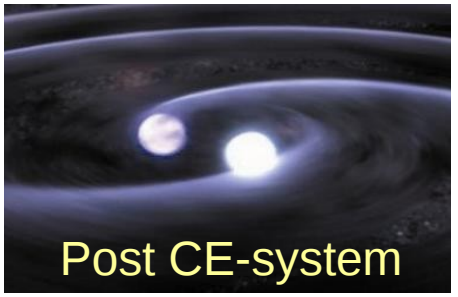
Unstable
$M_{tot} < M_{ch}$

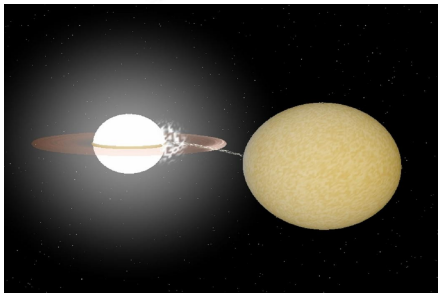
?

Unstable
$M_{tot} > M_{ch}$



Gravitational wave evolution





Merger
SN Ia?

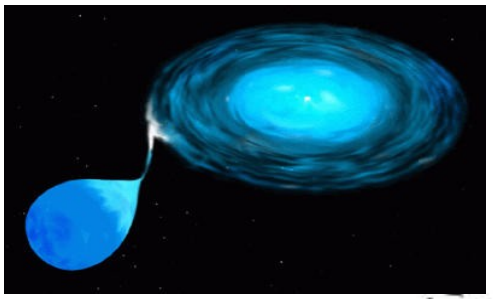
RLOF

Detached

LISA visible

LISA invisible

AM CVn



Gravitational wave strength

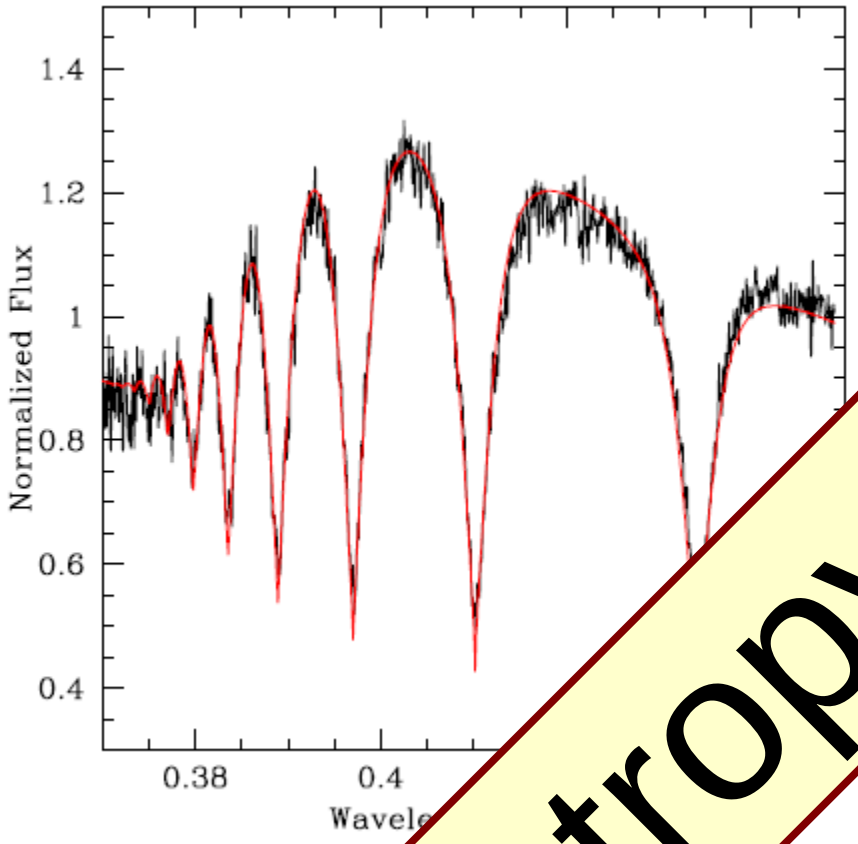
−20
−21
−22
−23

3.5
3
2.5
2
1.5

Orbital Period (log s)

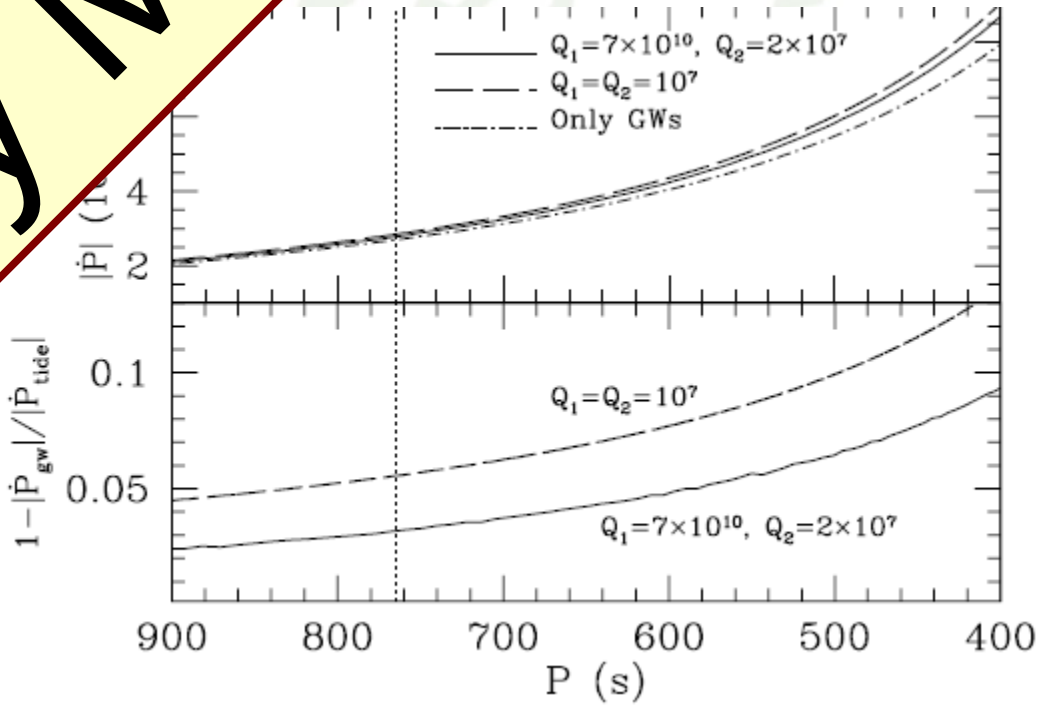
Hot secondary in 12 min DD

$M_1 = 0.55\ M_{sun}$, $M_2 = 0.25\ M_{sun}$, ***T_2 = 17000 K***



- Remnant h… …nvelope (~20min)
- Late… …*y 1 flash* *(see Sterl & Jing)*

…*orques* *(Fuller et al., 2011; Piro 2011; Benacquista 2011)*



Shift in …pse over 1 ye… …nds!

Entropy Matters!

New leads : Short period detached binaries

Within one year:

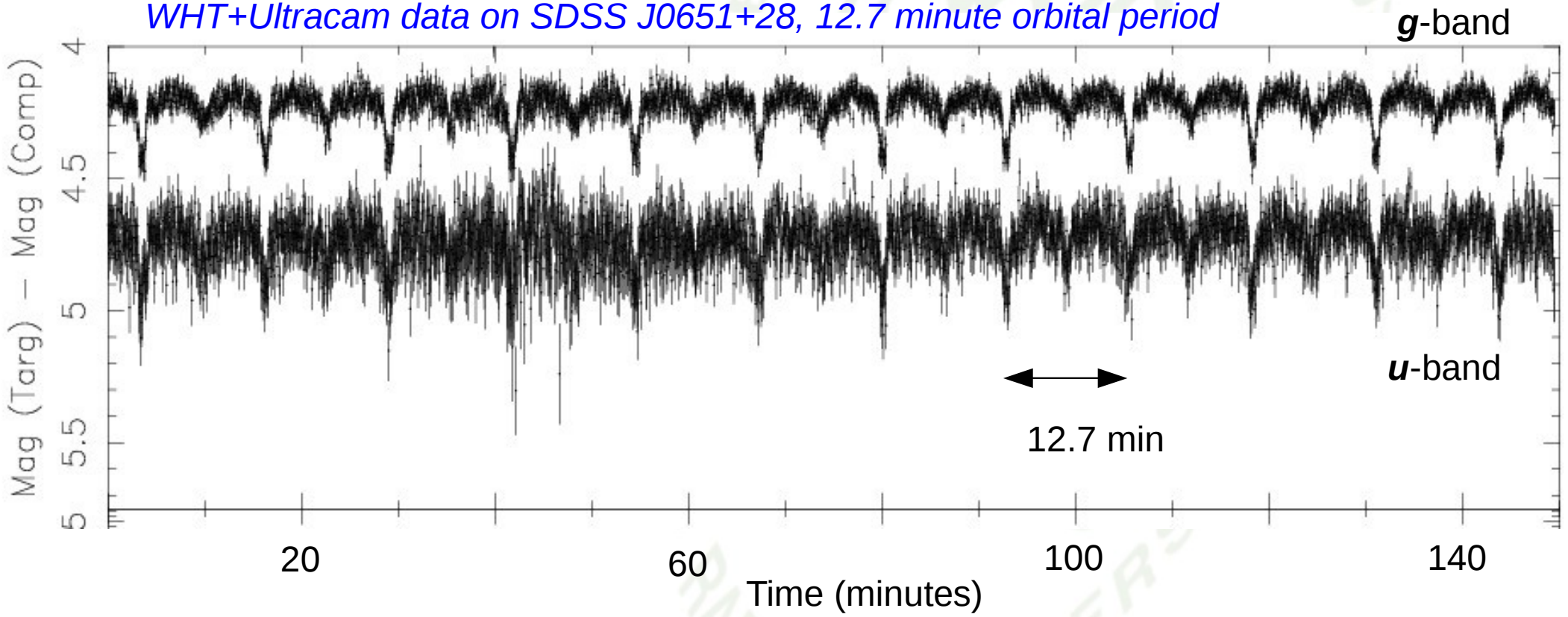
- 3 detached white dwarf – white dwarf binaries with *P*<1 hour

(ELM survey; Kilic, Brown et al. 2011)

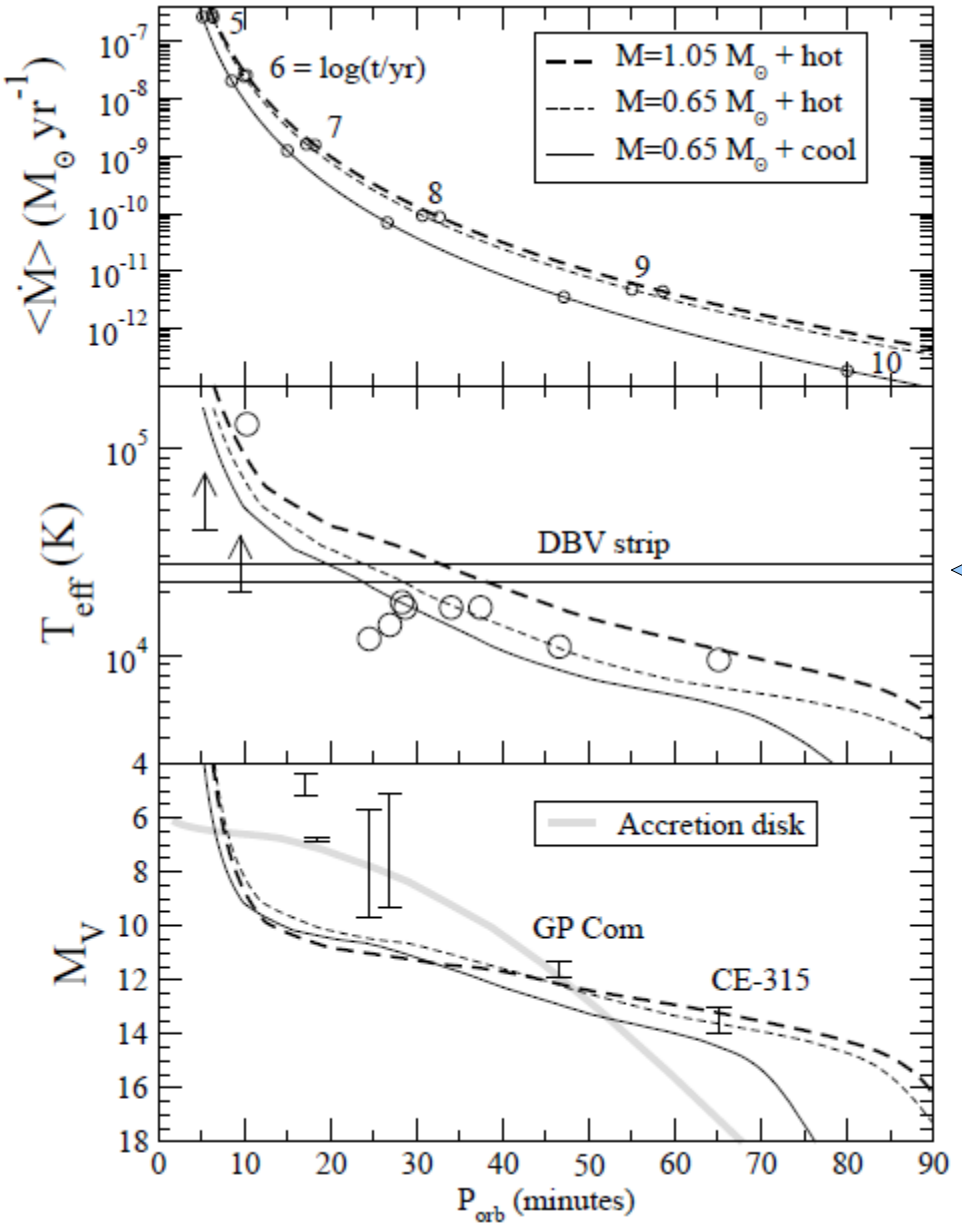
- 6 new semi-detached systems from PTF

But....

WHT+Ultracam data on SDSS J0651+28, 12.7 minute orbital period



Pulsating white dwarfs in AM CVn stars?



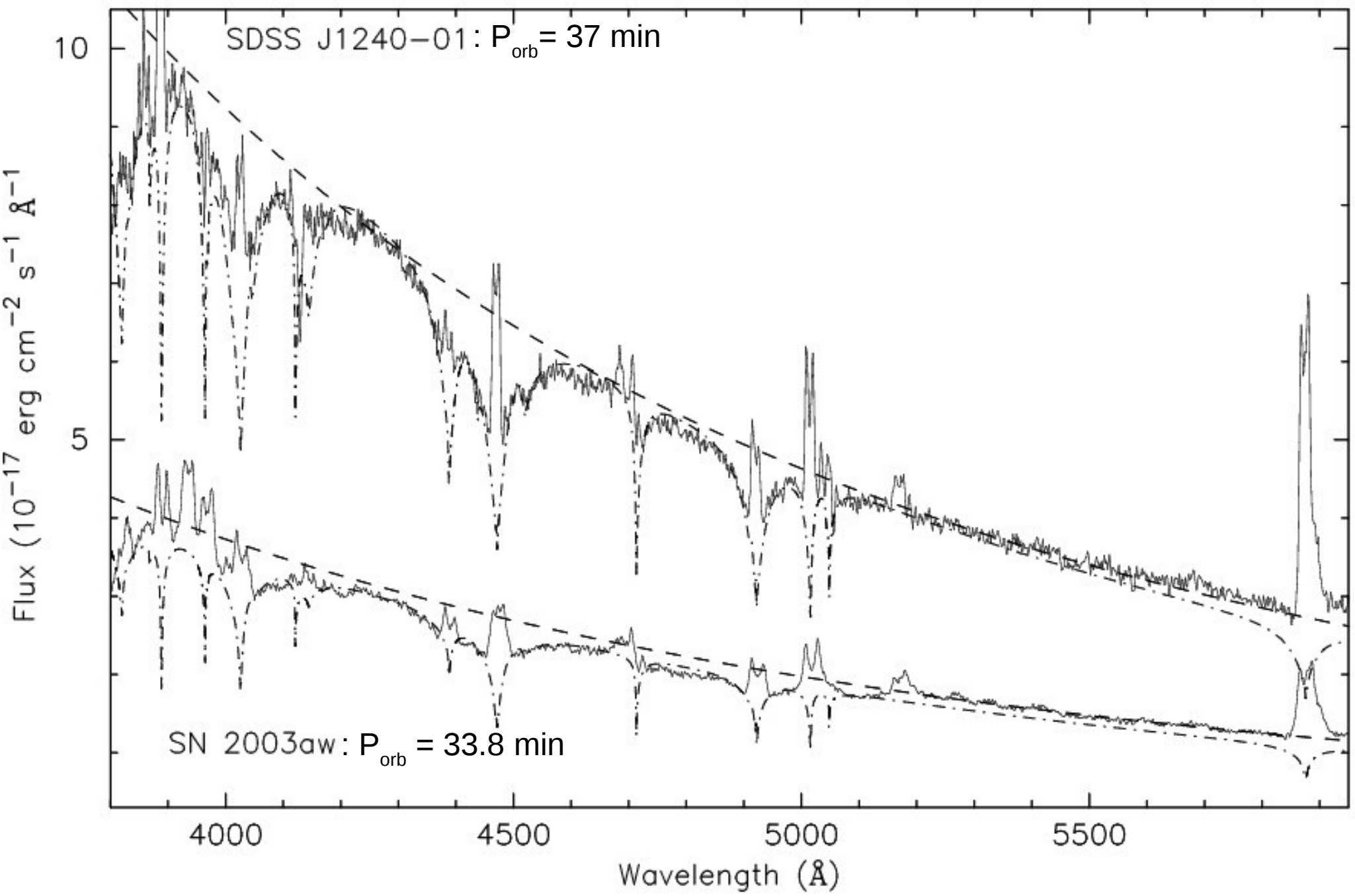
When primary white dwarf cools, it passes through instability strip.

Unique moment to probe structure of the accretor

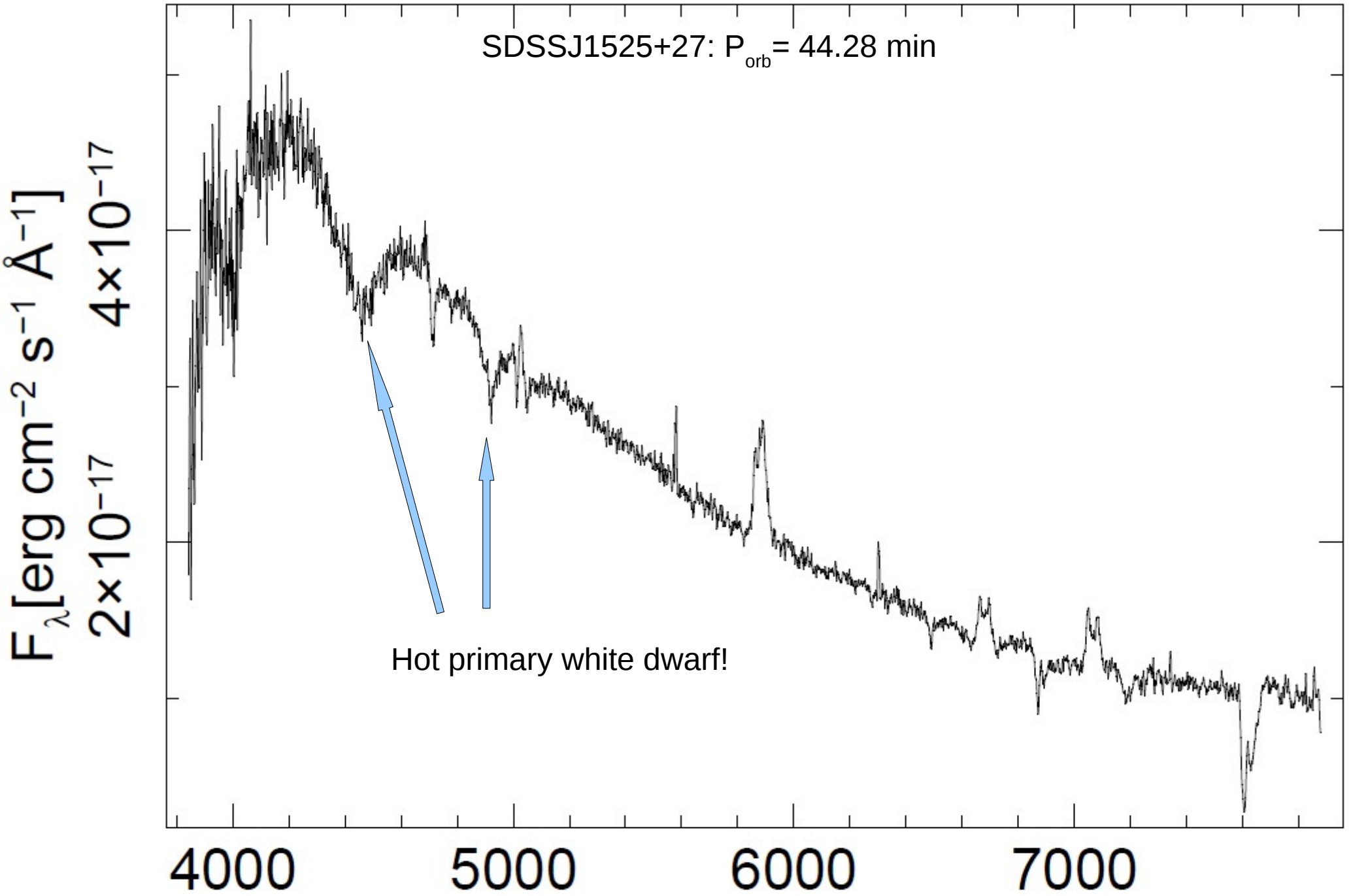
?

Bildsten et al., 2006

Seeing the primary in binaries:



Seeing the primary in binaries:



Ultracompact Binaries

Stellar binaries with degenerate primary and secondary star

White dwarf

+ WD

10

- Detached
  Double degenerates
- Semi-detached:
  AM CVn stars

33

Neutron Star

+ WD

- Detached WD+NS systems:
  WD+pulsar

1

- Semi-detached:
  Ultracompact X-ray binary

9

+NS

- NS+NS system: **double pulsars**

3

Black Hole

+ WD ?

0

+ NS ?

0

+ BH ?

0

Short period systems: $P_{orbital}$ < few hrs
Intrinsically *rare!* Observationally rare!

Increasing the numbers: Surveys

- Palomar Transient Survey (PTF)
- European Galactic Plane Surveys (IPHAS/UVEX/VPHAS+)

Major Optical Synoptic Surveys

Name	Start	Hemis	A (m^2)	Ω (sq.degr.)	$A^2\Omega$	Limit Mag.	Cadence	Filters
CRTS	2007	N&S	1.0	3x8	24	19-22	1d-1m?	clear
PTF - I	2009	N	1.2	7.9	11.4	21	1h-5d	*r*,g,Hα
PS - I	2009	N	1.8	3.0	9.7	24	Var	*g*,r,i,z
SkyMapper	2011	S	1.3	5.7	6.9	22	N=6	u,v_s,*g*,*r*,i,z, Hα
PTF - II	2014	N	1.2	40.0	57.6	21	<3d	r,*g*,Hα
Gaia	2013	N&S	1.0	0.25	0.25	20	N=100	SpecPhom
PS - 4	2014+	N	4 x 1.8	4 x 3.0	38.8	24	Var.	*g*,*r*,i,z
LSST	2018+	S	8.4	9.6	405.6	24.5	N=1000	u,g,r,i,z,y

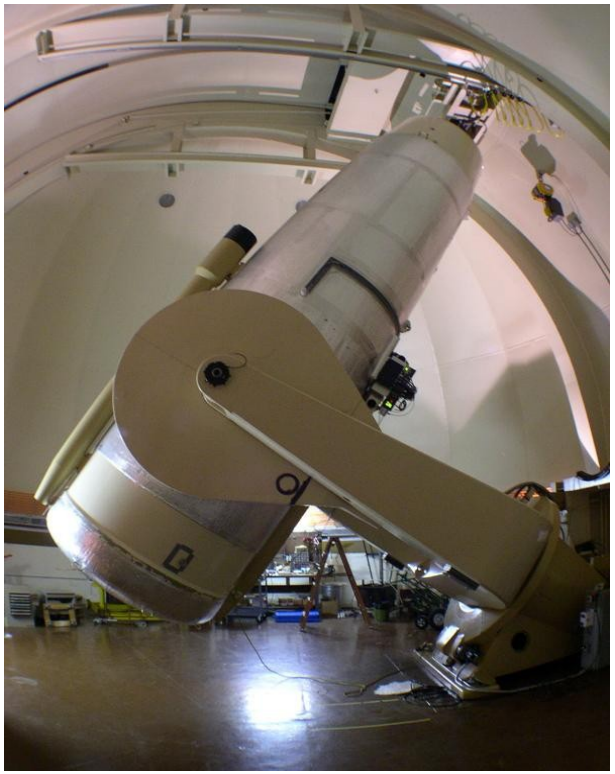
Note 1: All but LSST on 'mediocre' sites (seeing >1")
Note 2: Gaia is space mission.

Palomar Transient Factory - I

Unique dual telescope approach:

- 48” Oschin Schmidt Telescope for transient ***discovery***
- 60” Palomar Telescope slaved for photometric transient ***follow-up***

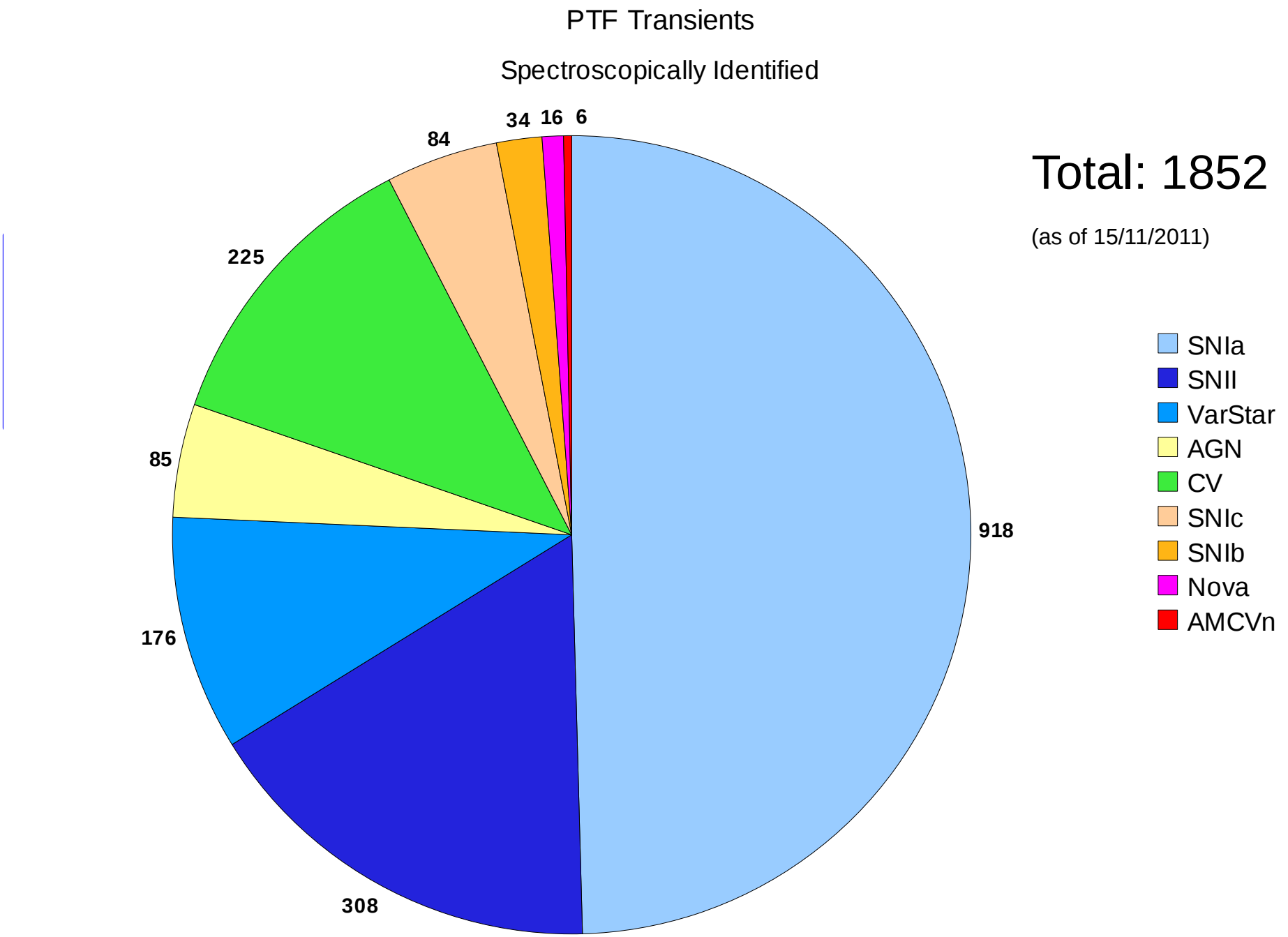
- Spectroscopic follow-up with slew of telescopes:
  Hale, Keck, WHT, NOT, KPNO



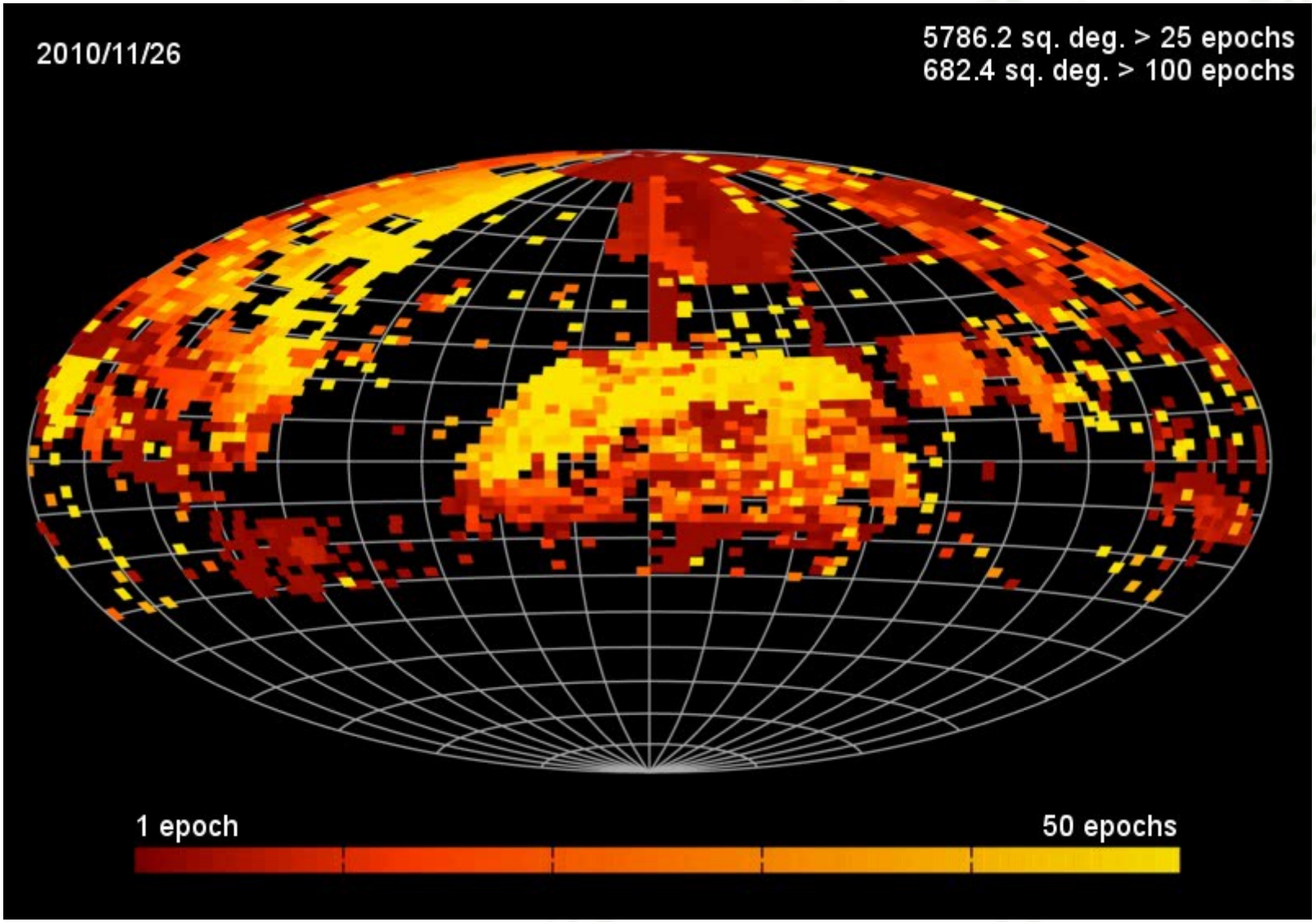
48”

60”

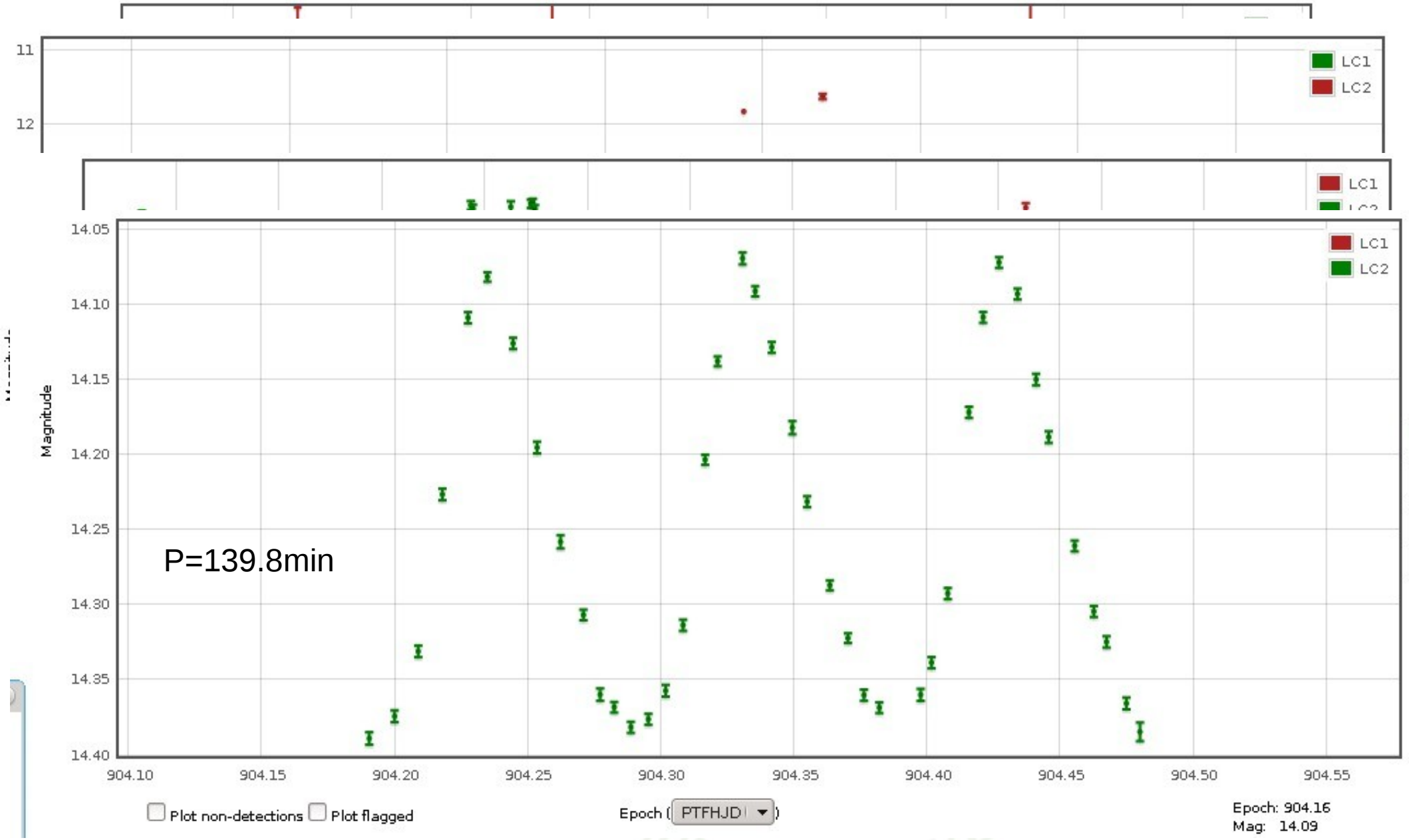
Harvest after 2.5 years of operation:



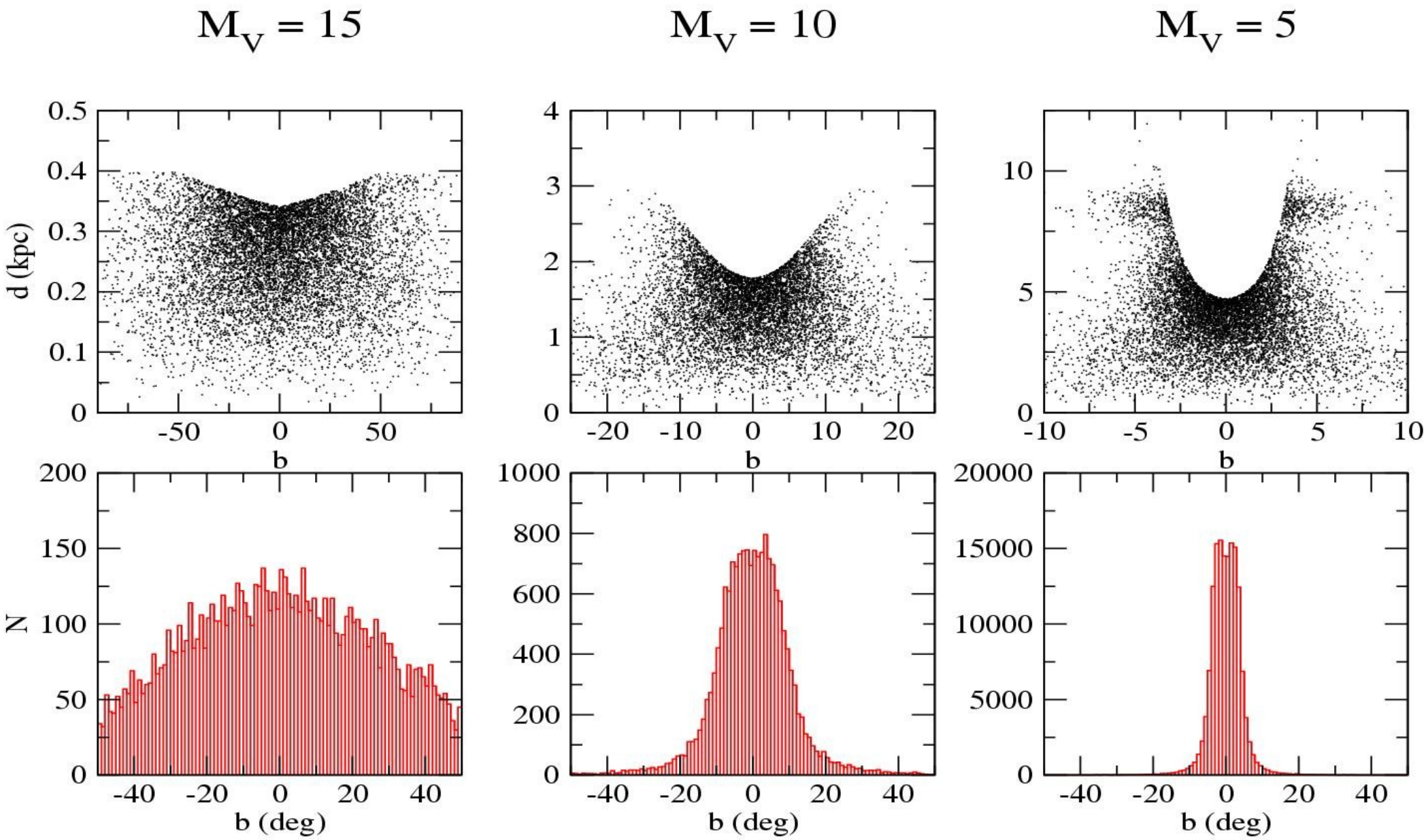
Sky Coverage



Example pulsators

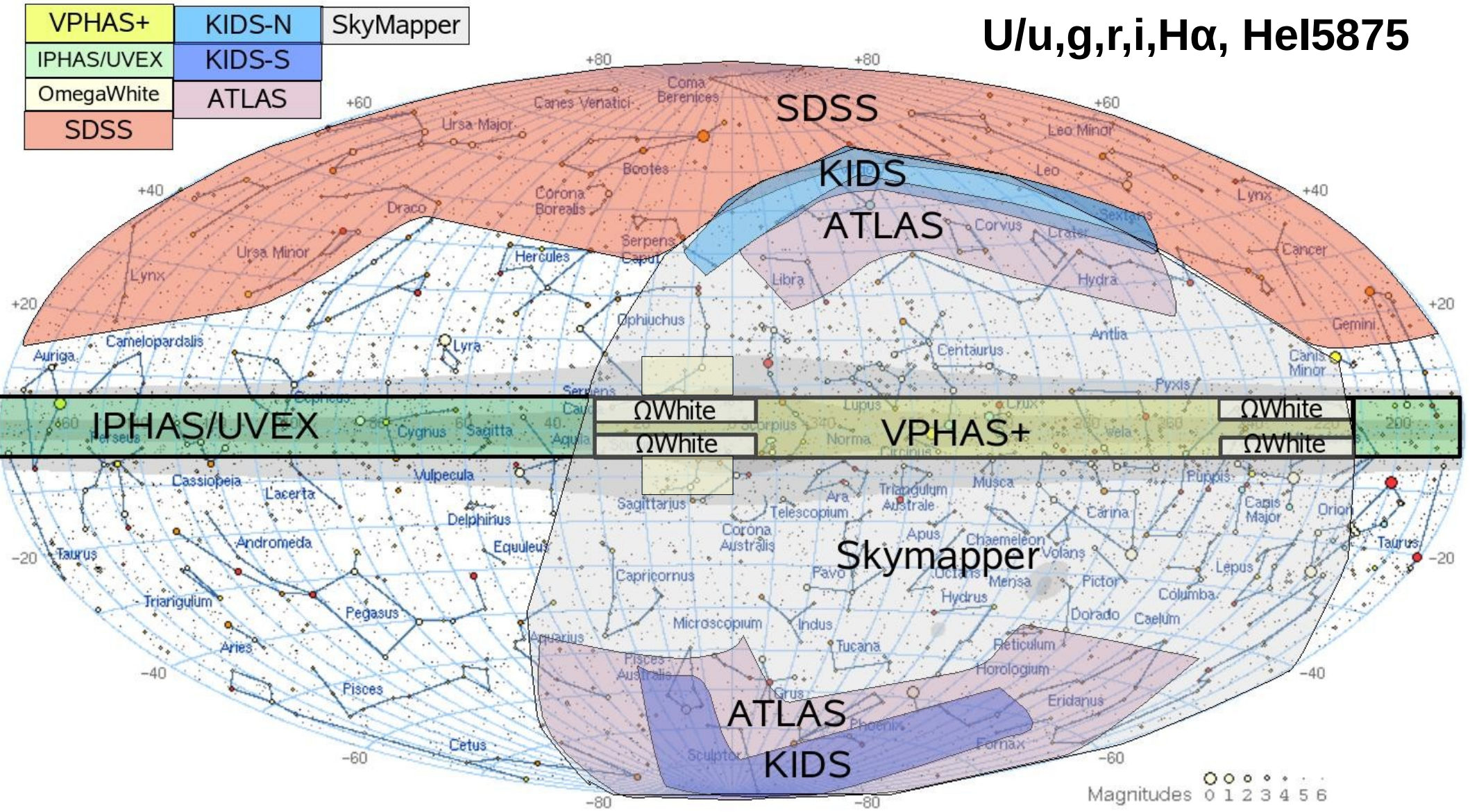


But Sloan is limited: high latitude



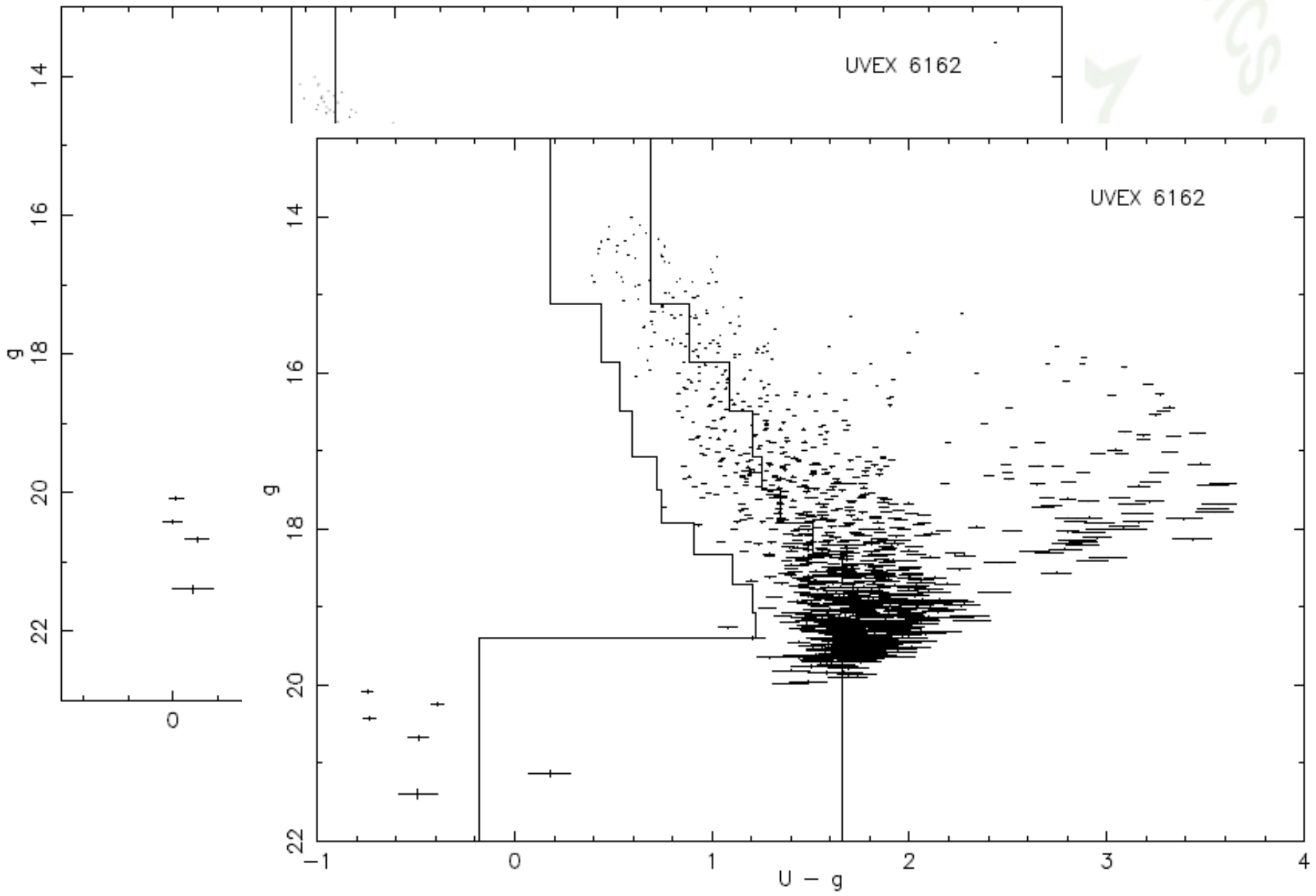
Groot et al., 2009

European Galactic Plane Surveys (EGAPS)



IPHAS: *Drew et al., 2005*; UVEX: *Groot et al, 2009*, VPHAS+: ESO Public Survey on VST

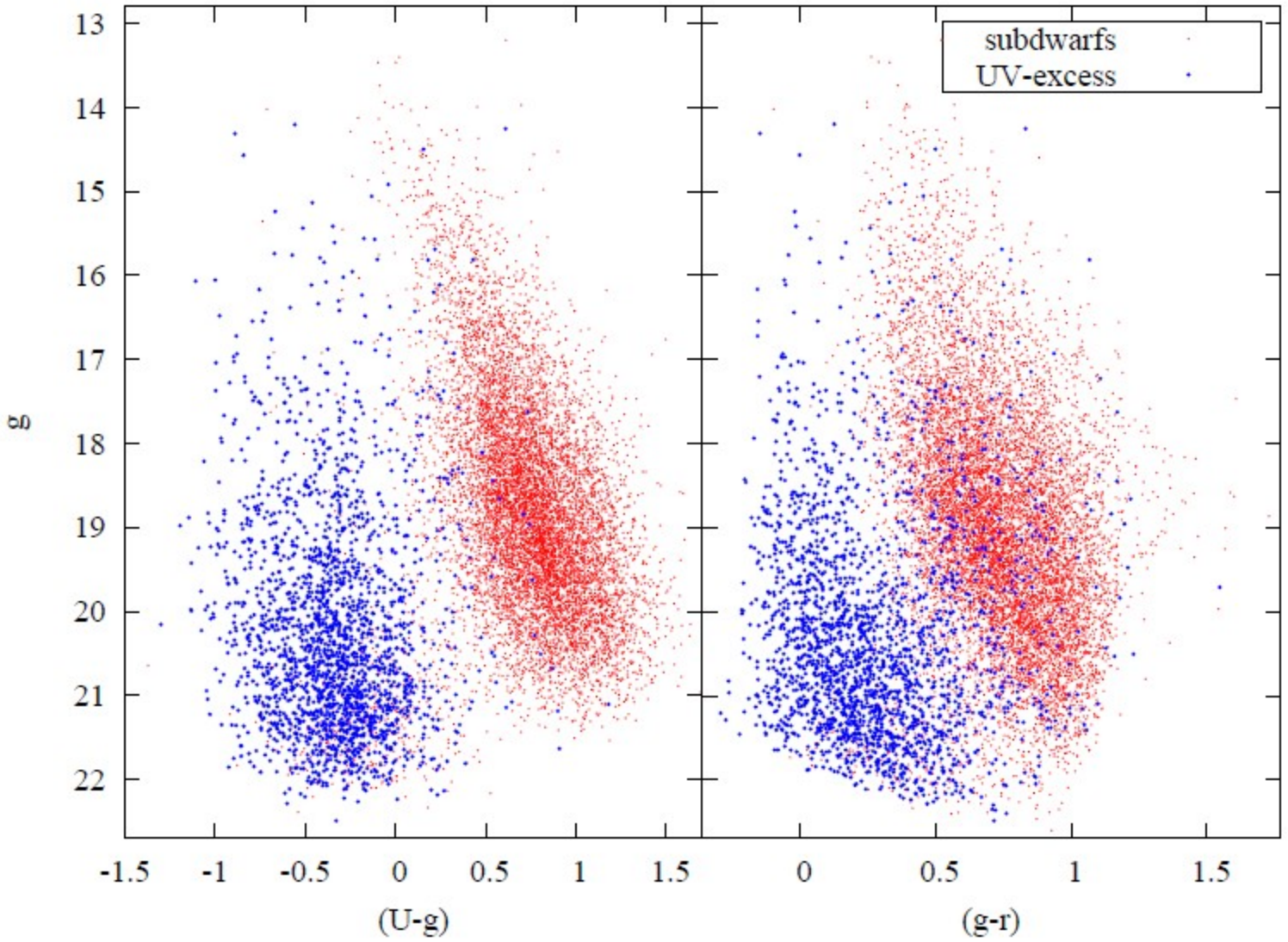
UV excess source selection



10 UV-excess sources per square degree.

Groot et al., 2009, Verbeek et al., 2011

UV excess source selection



10 UV-excess sources per square degree: 2100 stellar remnants in first 211 sq.degr.
Verbeek et al., 2011