The ultimate Wide-Field TDA Survey:

DASCH

To explore the *~1wk - ~100y timescale*
and *extreme variability*
of stellar and non-stellar objects

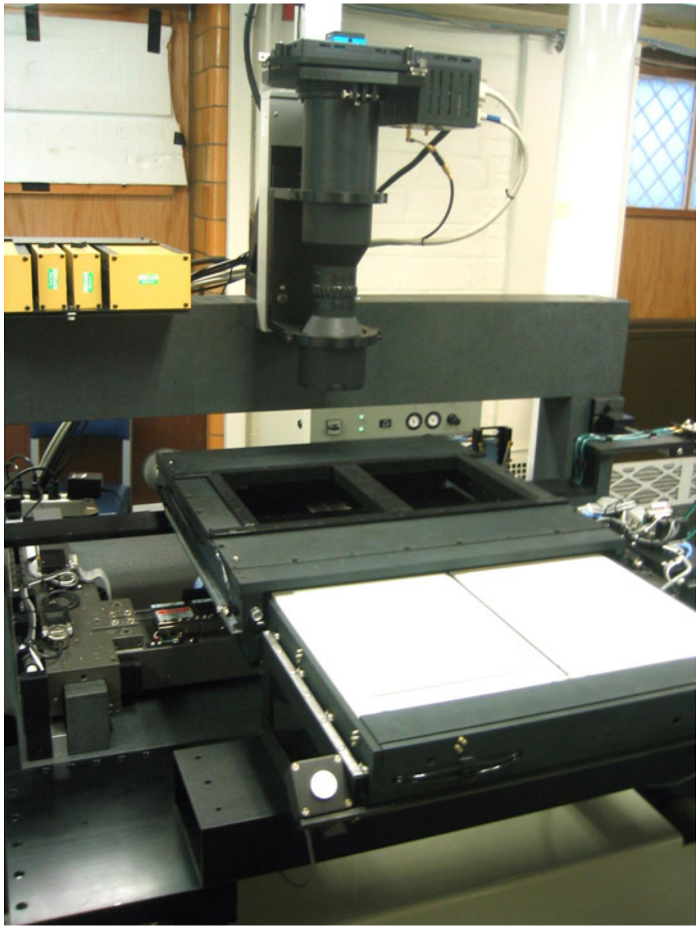
Josh Grindlay
(and Sumin Tang & DASCH Team)

Wide Field Surveys lunch, July 21, 2011

Overview of *DASCH*

(see DASCH website for full descriptions…)

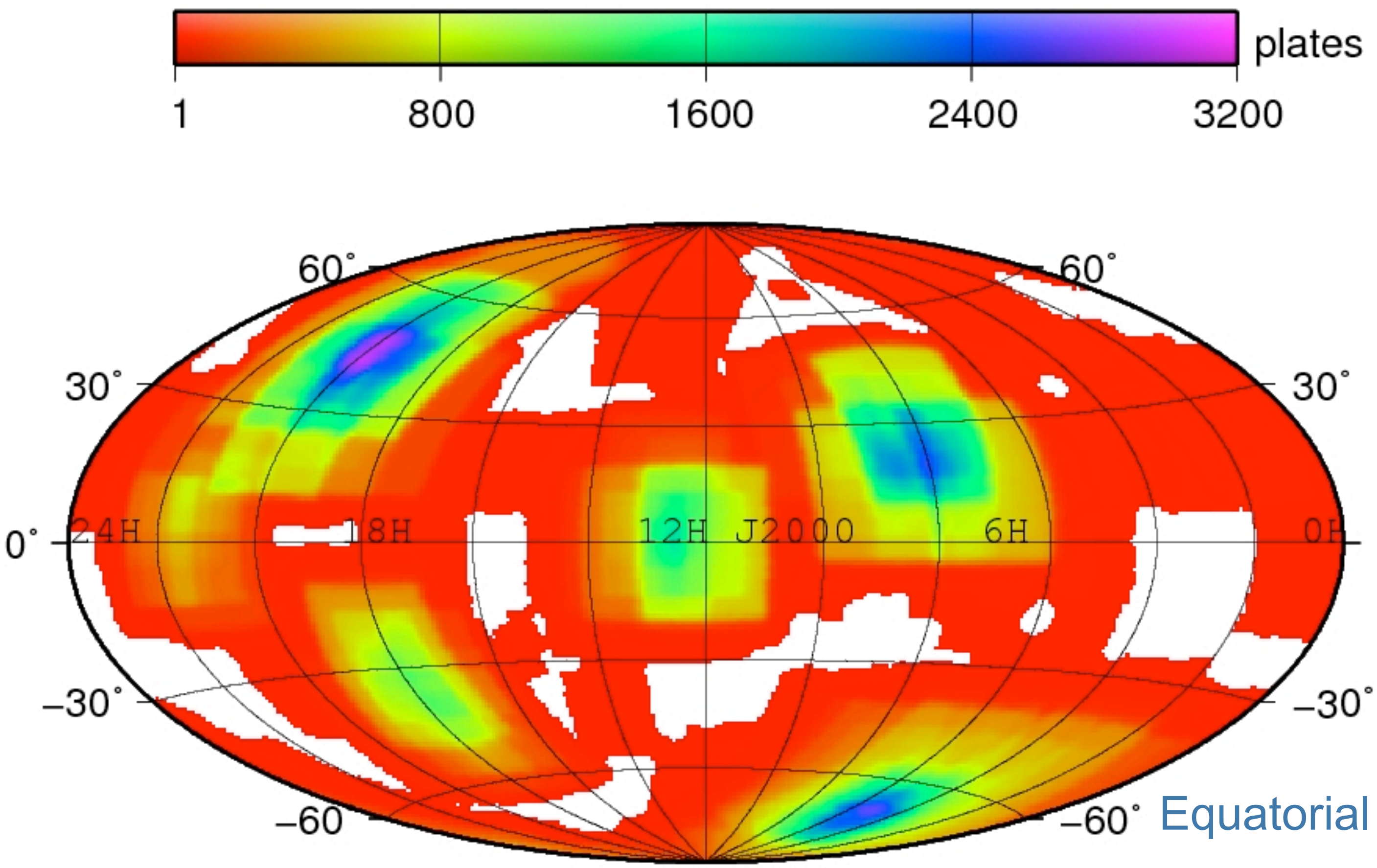
- **Goal:** scan the ~550,000 Harvard glass plates which image full sky 1880-1985 and open the ~10-100y TDA window
- **Scanner and software:** scan ~400 plates/day and derive photometric catalogs in overnight Odyssey processing
- **Status:** NSF (2 grants) and now a *Donor* enable start of production runs by Dec. 2011. Finish ~2014?



DASCH scanner: scans two standard 8 x 11 plates or one 14 x 17 plate into 10μm pixels in 95sec (Simcoe et al 2006)

DASCH has scanned ~15000 plates

(Now scanning LMC: ~5000 plates, including ~800 A-plates sensitive to B ~18-19)

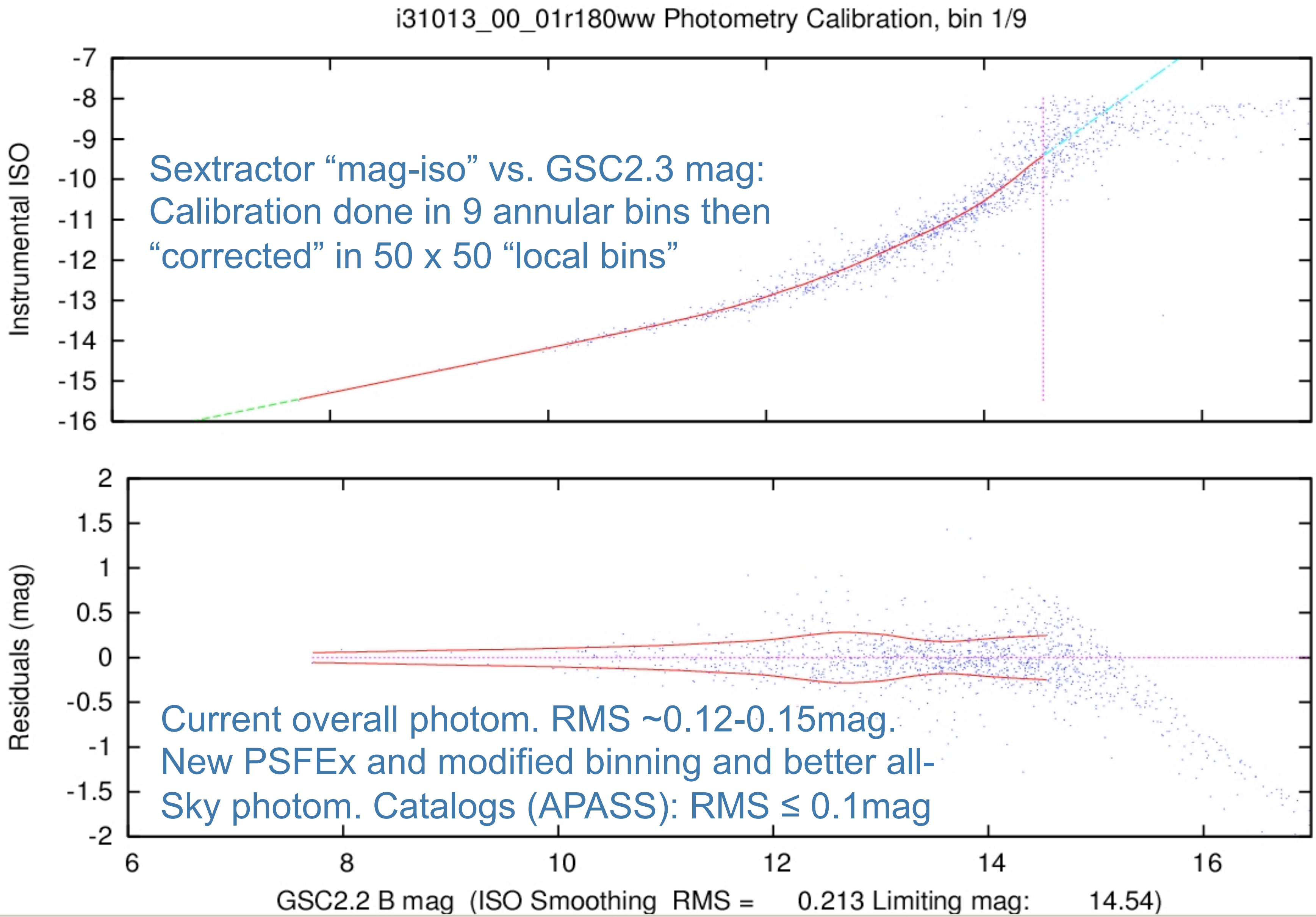


Equatorial coords

Brief summary of recent results

- Development and improvement of photometry pipeline and variable search algorithms
- Spectroscopic follow up of DASCH variables using FLWO 1.5m, MMT and Magellan telescopes
- Discovery of a new type of K giant long-term variables
- Discovery of “dust accretion” variable(s)
- Discovery of a new symbiotic nova (only 9 other known)
- Hundreds of other new variable candidates months -decades

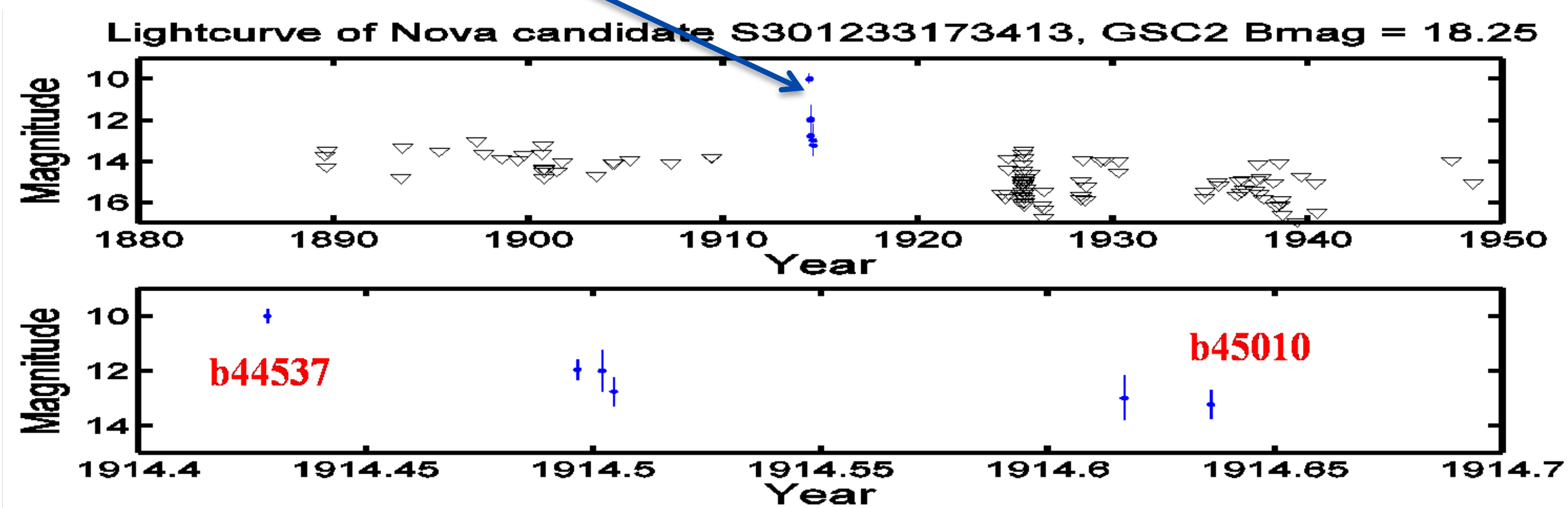
Photometry Calibration

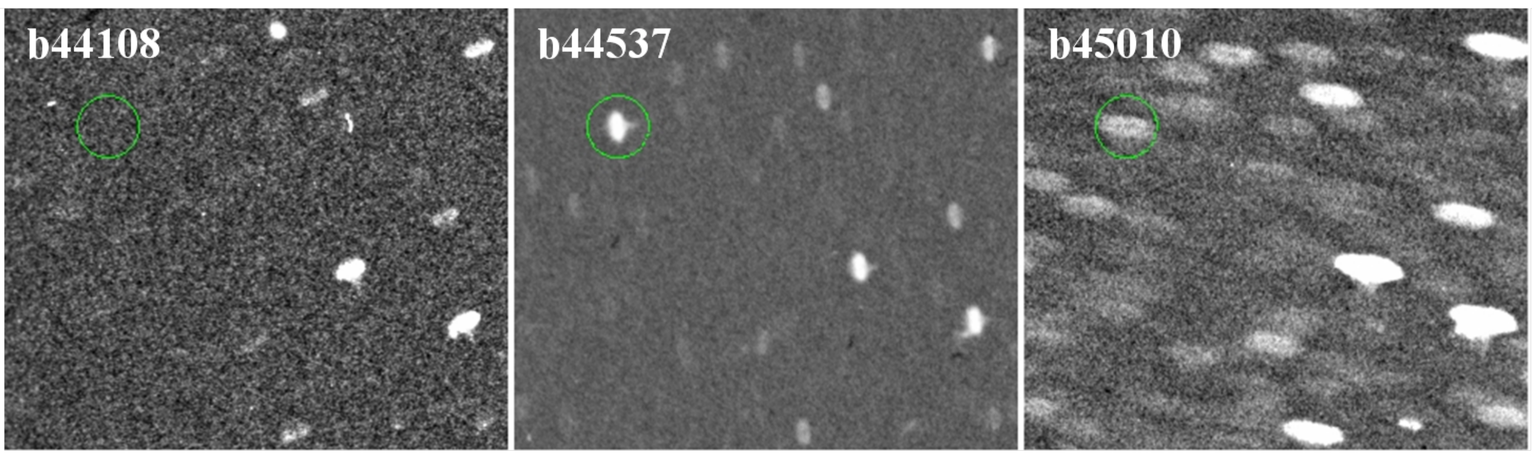


Discover a nova in Baade's window plates

(only preliminary analysis of limited scans…)

8-magnitude outburst in 1914 (brightened by a factor of 1600)





Before the burst | Early stage of the burst | Late stage of the burst

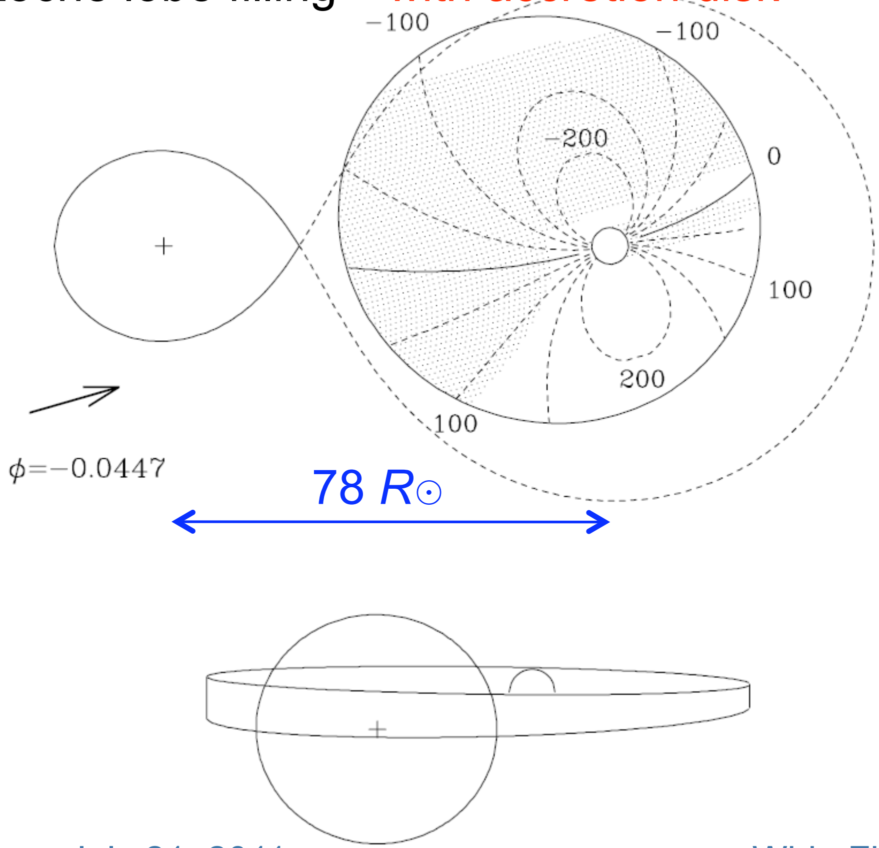
KU Cyg

Popper 1964, 1965; Olson 1988; Zola 1992; Olson et al. 1995; Smak & Plavec 1997

- Algol-type eclipsing binary
  3.85 $M_\odot$ F star + 0.48 $M_\odot$ K5III
- Large, thick and dusty accretion disk around the F star: ~10^{-8}-10^{-5} $M_\odot$
- Peak accretion rate: ~10^{-6} $M_\odot$/yr
- Accretion timescale: a few years
- P=38.439484 days, i=86-86.5 deg
- Extinction of the F star due to the disk: ~1.3 mag (*Smak & Plavec 1997*)

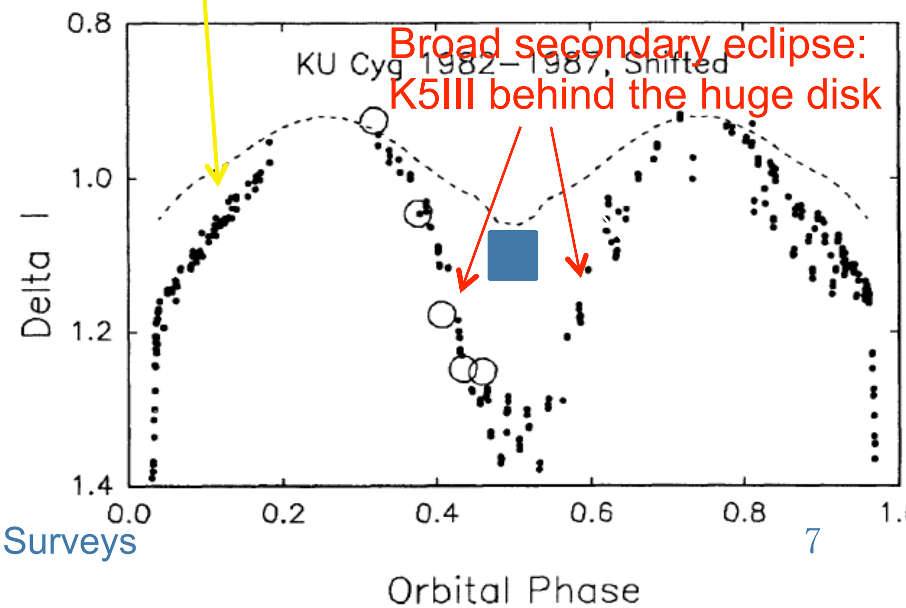
0.48 $M_\odot$ K5III
Roche lobe filling

3.85 $M_\odot$ F star
with accretion disk

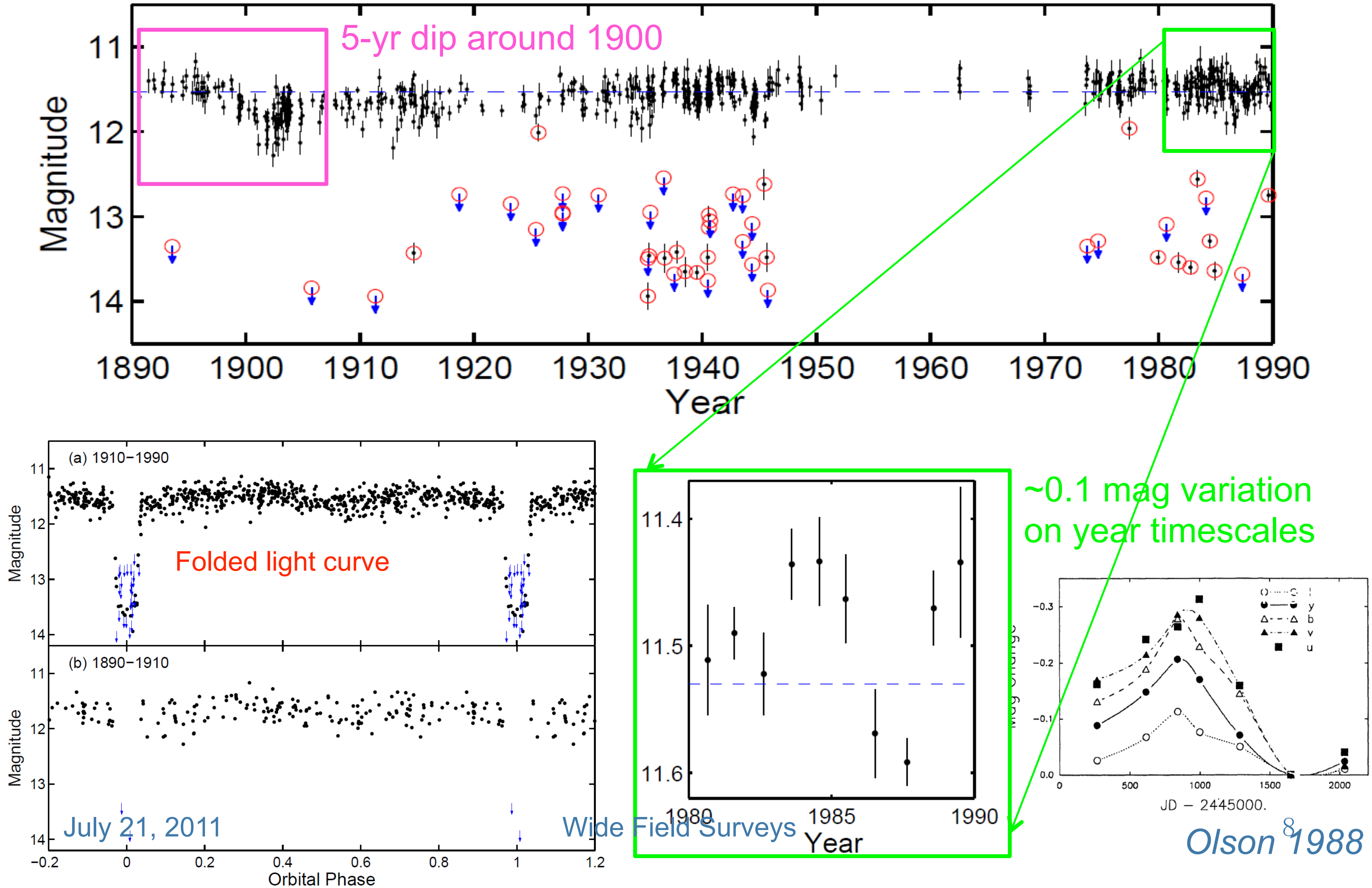


Smak & Plavec 1997

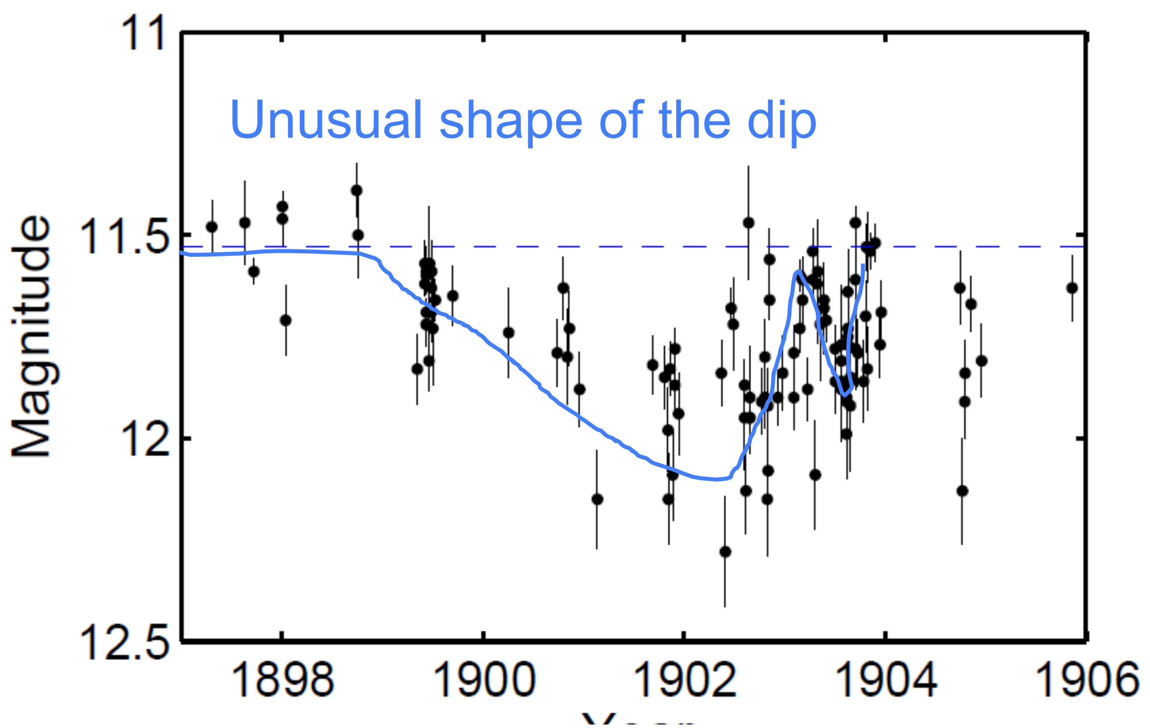
Broad wing in primary eclipse:
disk behind the K5III

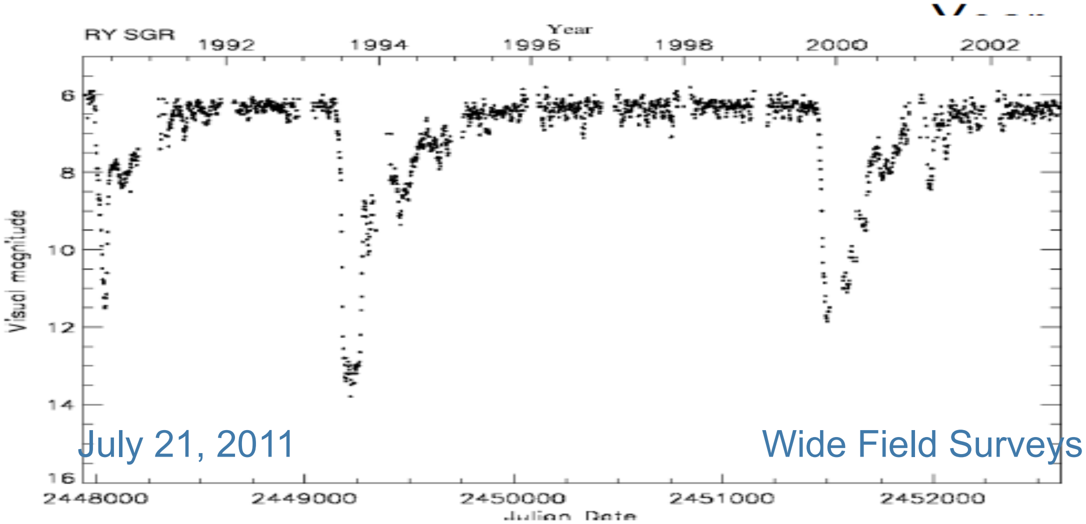


DASCH light curve of KU Cyg



Zoom in on the 5-yr dip around 1900





RY SGR:

faster fading, slower recovery b/c it usually takes shorter time to produce dust, and longer time for the dust to get dispersed

KU Cyg 5-yr dip model (Tang et al 2011, ApJ)

Increased disk extinction of the F star arising from increased m-dot and thus higher disk mass

Slow Fading:

- Increased disk mass => larger optical depth (dust extinction and neutral hydrogen scattering) => star looks fainter
- Timescale: a few years (accretion timescale)
- How much more mass do we need?

  ~ less than double the original disk mass is enough. Given the 1.3 mag extinction in V (0.7 mag blocking + 0.6 mag absorption by disk atmosphere) by the disk in normal state (*Smack & Plavec 1997*)

Fast brightening and fluctuations:

- Dust evaporates when moves closer to the F star -> brightening
- Some evaporated dust is transported outwards, cools down to condensate (~1500 K), more extinction -> fading
- Energy release on the BL when accreted on the F star -> brightening

Or higher dust to gas ratio?

- Dust ejection from the K5III star in KU Cyg? Similar to dips discovered from K giants probably due to dust ejection (*Tang et al. 2010*)

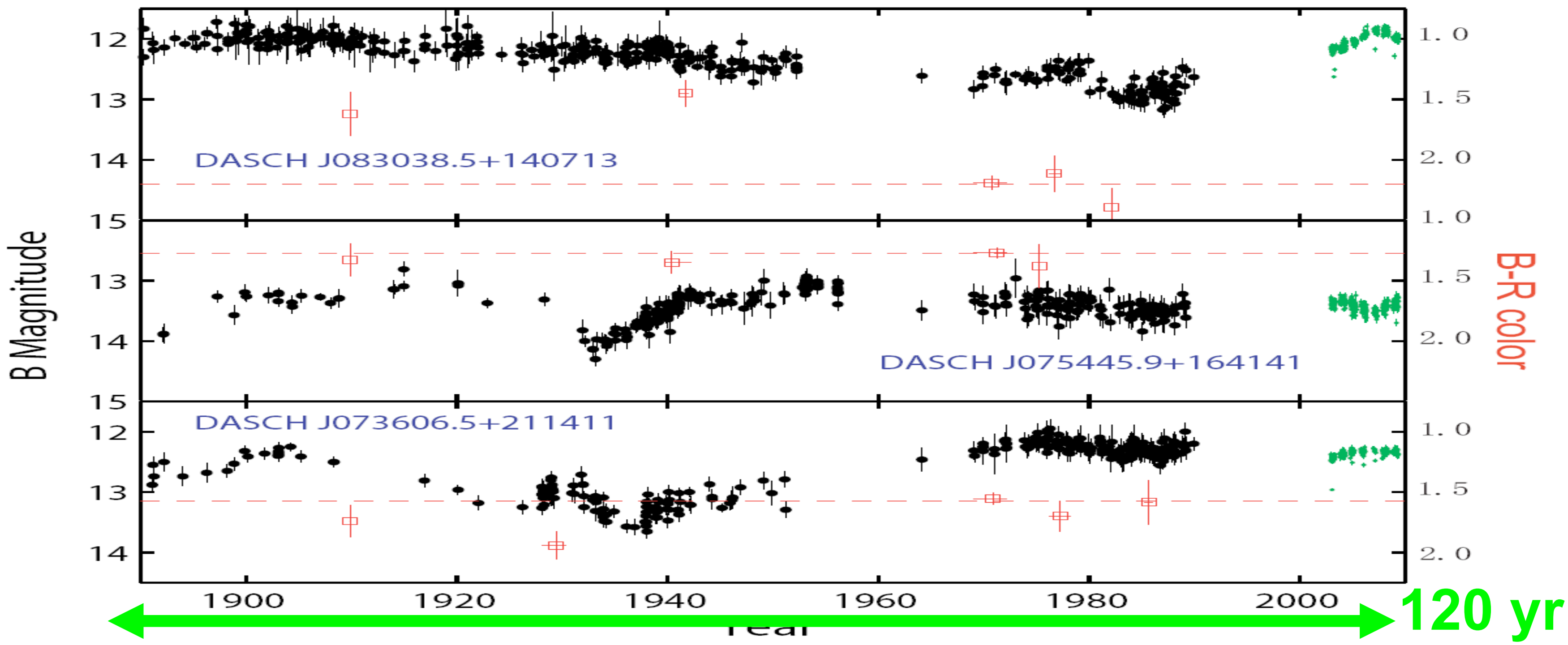
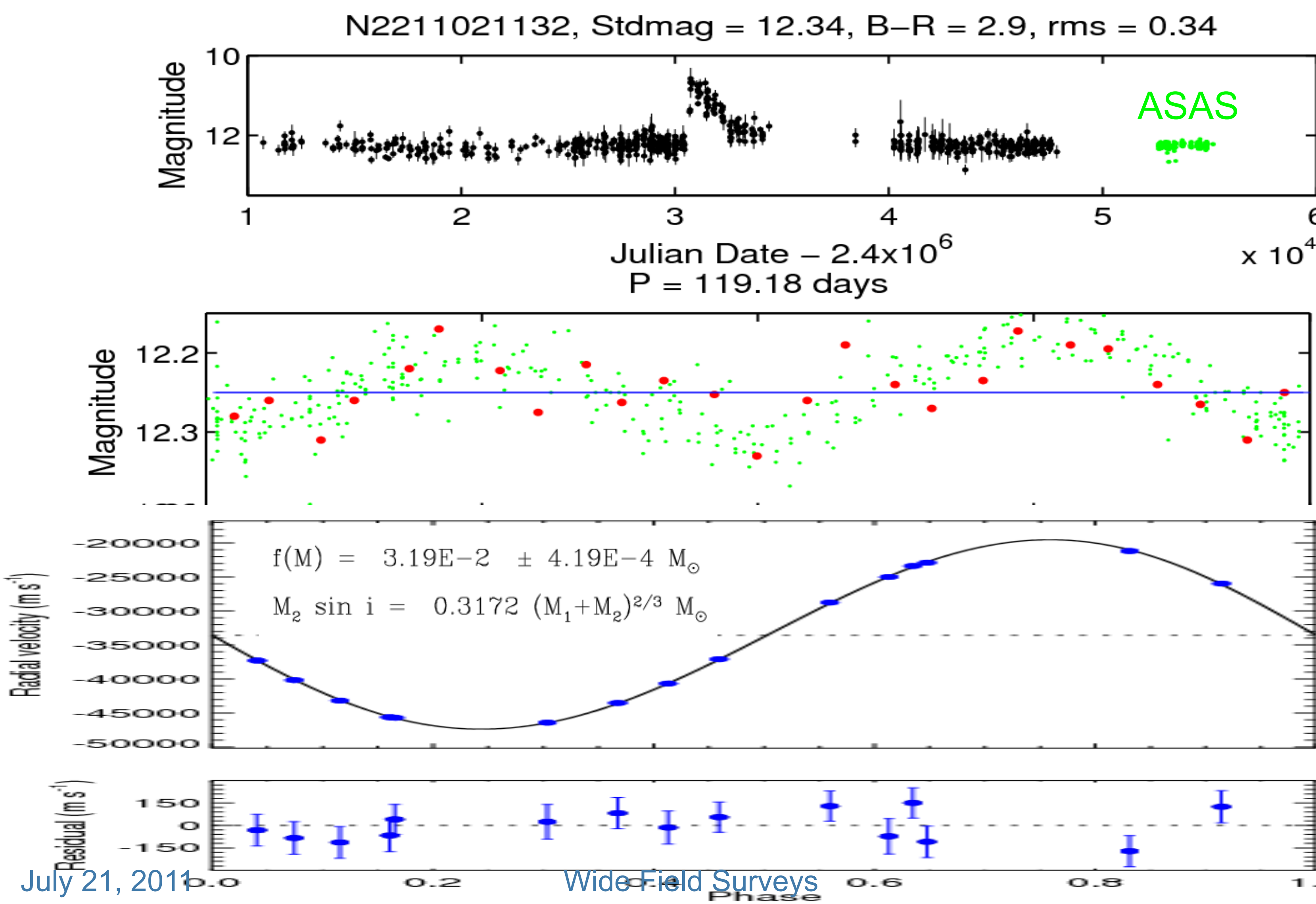


FIG. 1.— Lightcurves and color evolution of 3 unusual long-term variables which were found in DASCH scans near M44. Black dots with errorbars are the lightcurves from DASCH, small green dots are the lightcurves from ASAS. Since ASAS data are in V band, while DASCH magnitudes are blue, we added 1.16 mag to the ASAS V magnitudes in the plots which is the mean B-V value for K2III stars (Cox 2000). Red open squares are the B-R color derived from plates with y-axis labeled in the right, and red dashed lines mark the weighted mean B-R color values from 1970s to 1980s.

- vs. *rapid rise* in KU Cyg: dust moves in through the disk and is evaporated as it approaches the hot star

An interesting variable with10yr flare: a M1III + WD(?) symbiotic nova?



Only 9 other Symbiotic Novae known

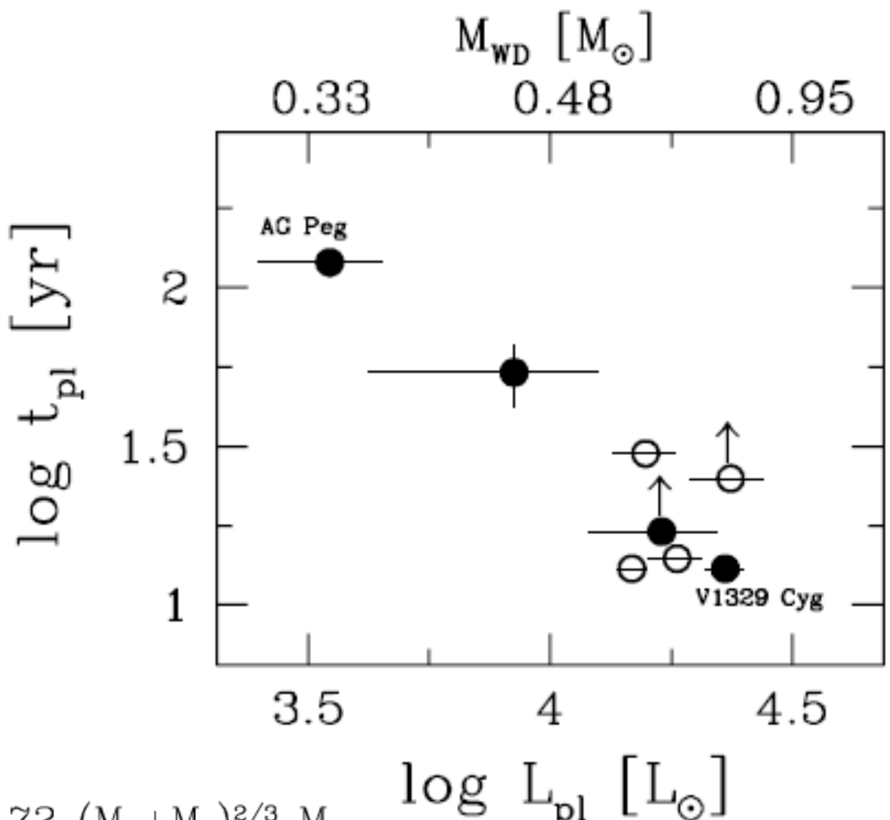
Kenyon 1986; Iben 2003; Mikolajewska 2010

- *Thermonuclear novae* in symbiotic systems: an evolved red giant + a hot companion star (mostly WD) accreting from the giant
- *Orbital period >2 yr*, slow & quiet *wind-accreting*; **strong emission lines.** Mostly discovered in outburst and thus pre-outburst observations not available.
- Our star: period 119 days, NO emission lines – no strong wind: Roche lobe filling?

Table 1. Observed properties of symbiotic novae

Star	Distance [kpc]	Period [yr]	$\dot{M}_{gw}$ (-7)	L_{pl} [$L_\odot$]	R_{max} [$R_\odot$]	τ_{obs}^{red} [yr]	τ_{obs}^{blue} [yr]
AG Peg	0.7	2.26	1.6	4000	18	60	50
V1329 Cyg	3.7	2.60	8	18 000	26	15	20
RT Ser	9.4	12.0	25	28 000	100	25	40
PU Vul	3.2	13.4	2.5	25 000	50	10	–
V1016 Cyg	3.9	> 15	130	36 000	6	0	> 40
HM Sge	2.9	> 15	100	28 000	20	4	> 20
RR Tel	2.6	> 15	50	17 500	110	7	> 30
RX Pup	1.8	200?	40	16 000	60	4	9

Symbiotics WD mass ~1/Period: is this P ~1/3y symbiotic a massive WD and thus SNIa progenitor?

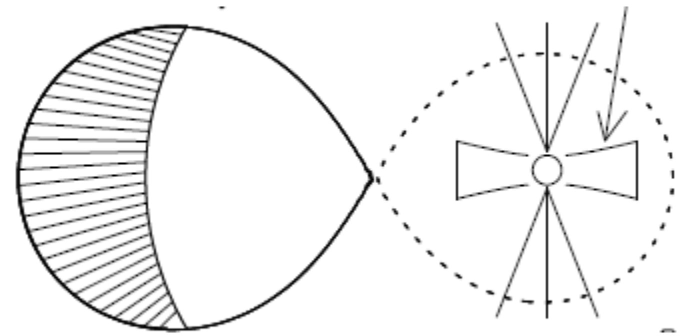


Mikolajewska 2010

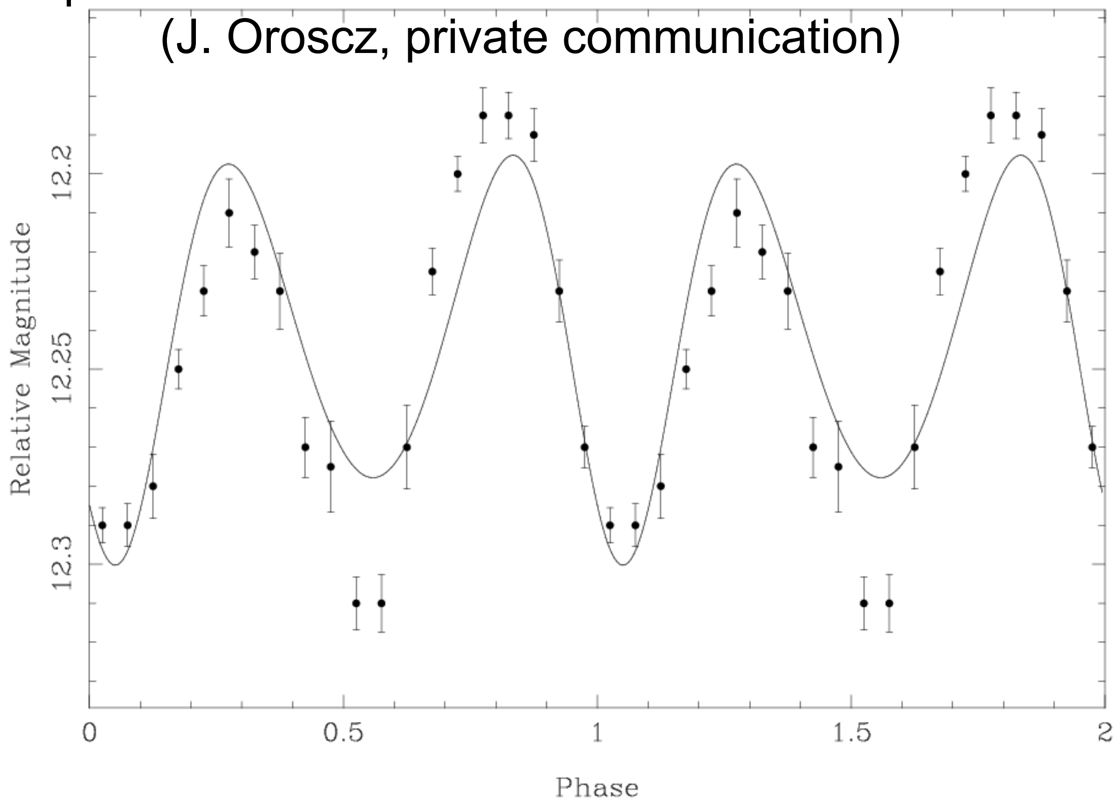
$$M_2 \sin i = 0.3172\ (M_1+M_2)^{2/3}\ M_\odot$$

If i=46.2 deg & M_giant=2.24 M_solar, M_WD=0.98 $M_\odot$
If i=48.9 deg & M_giant=1.92 M_solar, M_WD=0.84 $M_\odot$

Question: HOW to power the outburst (no wind) and is the M giant Roche lobe filling?



Ellipsoidal Variation? No reasonable solution
(J. Oroscz, private communication)



If the M giant rotates synchronous to the orbital period, then R~24 $R_{\odot}$, far from filling its Roche lobe (~60-70 $R_{\odot}$)

Not Roche lobe filling?

How to power the outburst in 1940s?
There is no strong wind:
no emission line,
very symmetric absorption lines

Atmosphere fitting of M stars are extremely hard due to the molecular bands (TiO). Bob Kurucz is trying, but not sure whether he could help constrain the size of the star.

This DASCH variable is an *unusual symbiotic nova*

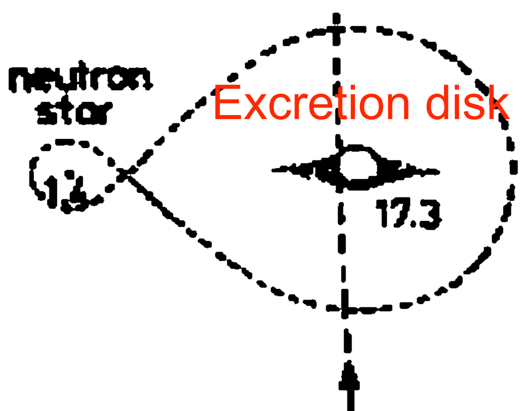
Iben 2003; Townsley et al. 2005

Symbiotic Nova	Classic Nova
Outburst amplitude: 1-3 mag	8-10 mag
Wind accreting	Roche lobe filling
Accretion rate ~10^{-8} solar mass/yr	10^{-9} – 10^{-11} in quiescence
Slow and quiet burning, without massive optically thick wind, the white dwarf can retain most of the accreted mass	Higher burning rate. Matter expands far and lost soon after the eruption
Outburst timescale: years to decades	weeks
Orbital period: a few years	A few hours

A missing part of symbiotic family: Its current photometric and spectroscopic profile is not different from a normal red giant binary**. It would not be picked out without the capture of its long outburst in 1940s. Must be more (YES….!)**

A new way of hunting for Be X-ray High Mass X-ray binaries? (Be + NS)

~100 systems known so far, all from X-ray detections



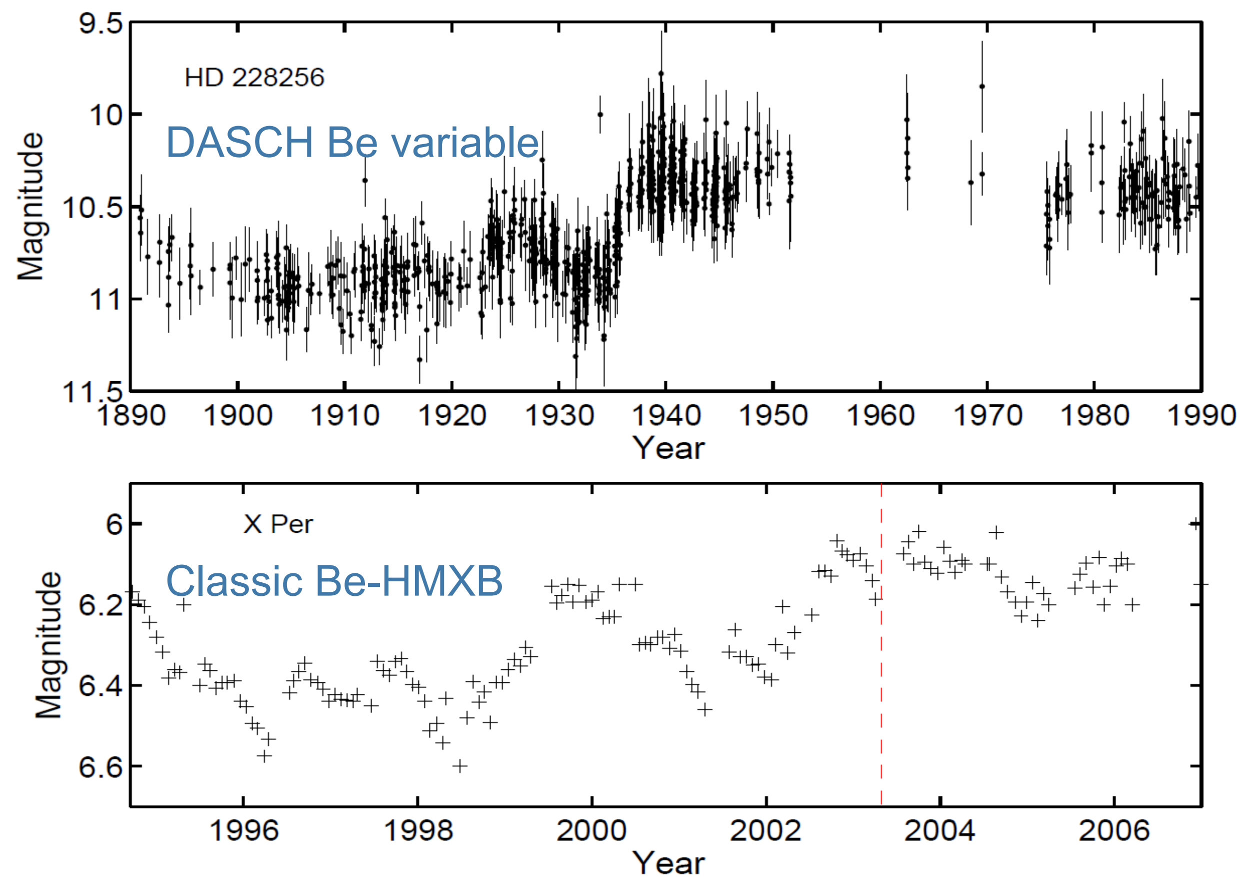


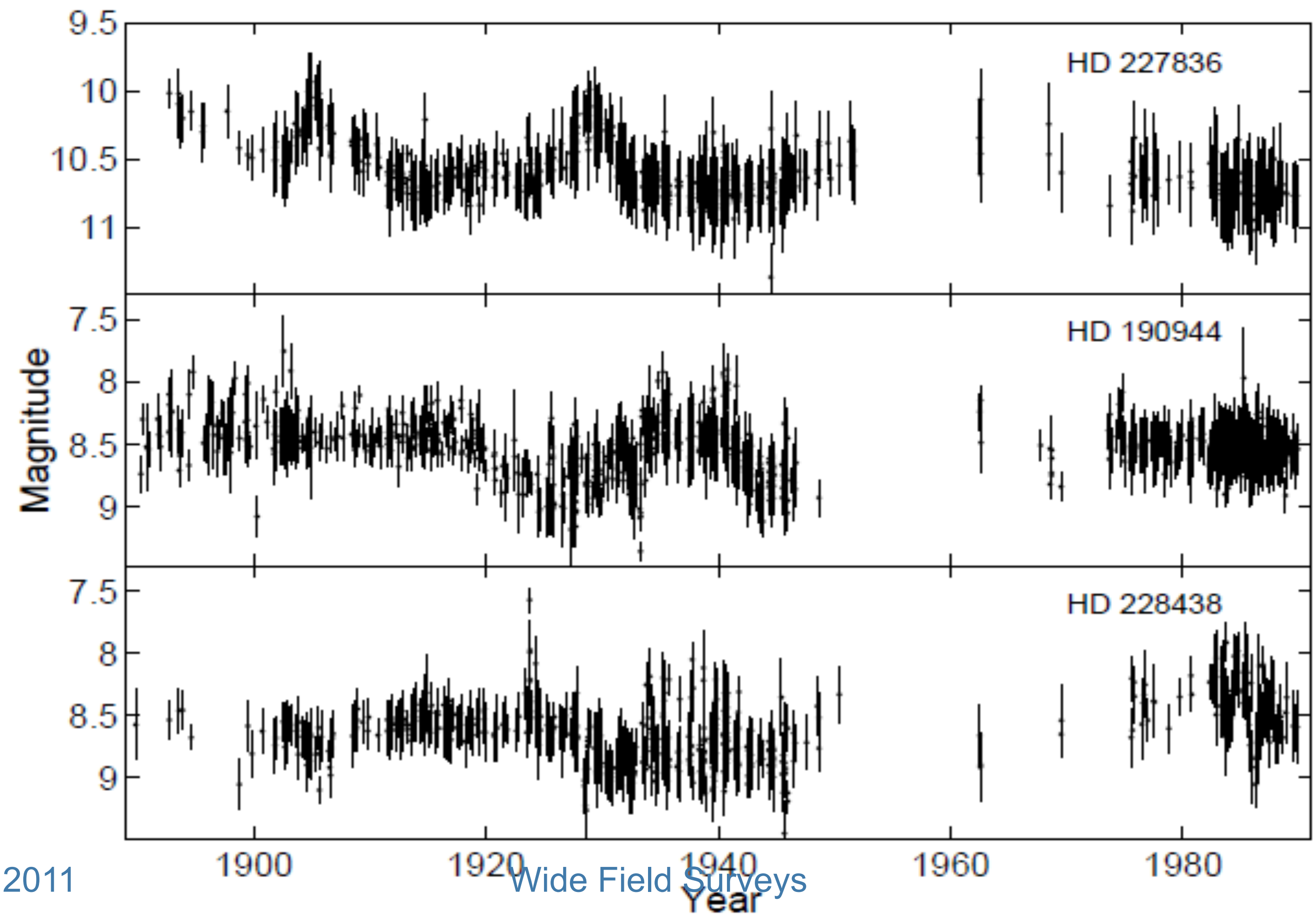
Figure 1: **Upper panel:** DASCH light curve of B1e star HD 228256. **Lower panel:** AAVSO V band light curve of Be X-ray binary X Per binned in 25 day increments, with time of its X-ray burst in 2003 marked by red dashed line (Grundstrom et al. 2007).

More on Be X-ray binaries

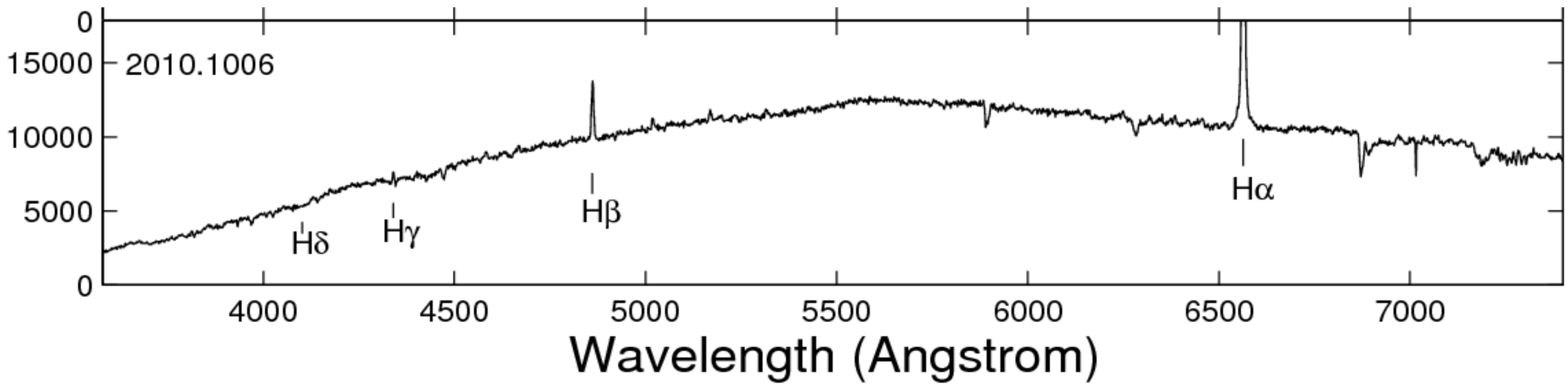
- In 42 out of 64 known BeHMXBs within the Milky Way, the compact object emitted X-ray pulsations confirming its identity as a neutron star; the remaining 22 unknown.
- No Be+black hole binaries yet identified and only one system, gamma Cas, is a possible Be+WD system, despite predictions from population synthesis models that 70% of BeXRBs should harbor a WD companion (Raguzova 2001).
- Most Be X-ray binaries were first discovered with X-ray telescopes during outbursts, increasing the susceptibility of the known sample to undetected selection effects.

3 more Be X-ray binary candidates

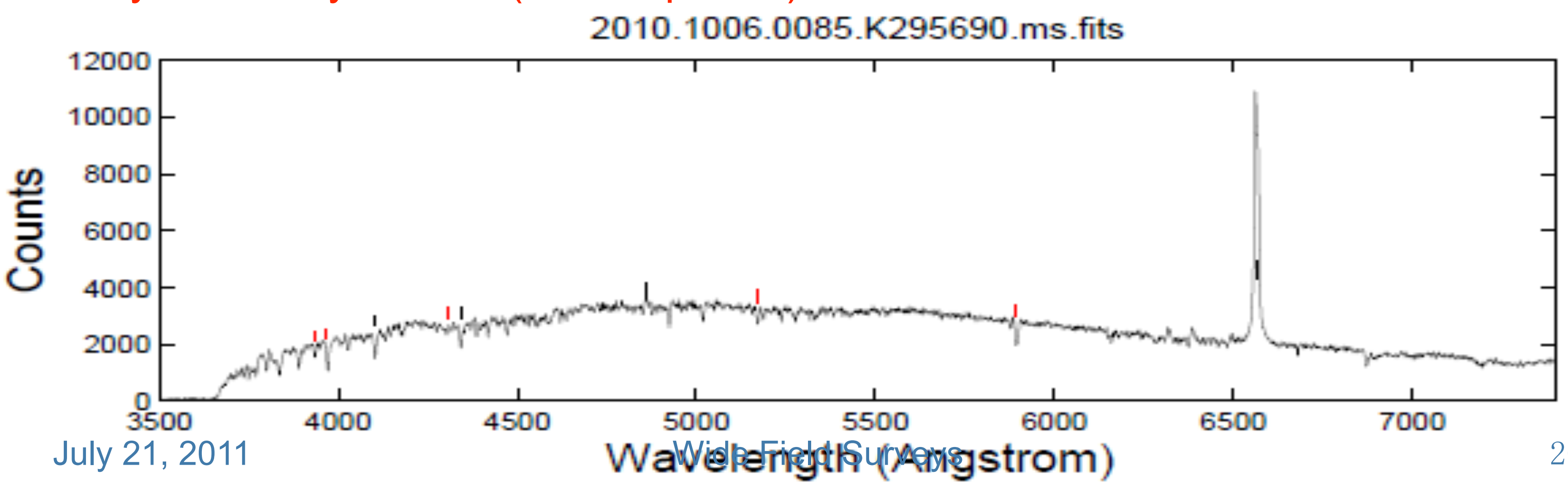
Further observation needed: X-ray (Swift/XRT), pending; binary orbit (TRES): ongoing



Name	Type	B	B-V	E(B-V)	E(J-K)	A(V)	nH(21)	D [kpc]
HD 228256	B1pe	10.4	0.38	0.62	0.46	1.922	3.4	1.4
HD 227836	B2npe	10.67	0.07	0.29	0.83	0.899	1.6	2.6
HD 190944	B1.5Vne	8.54	0.18	0.41	0.40	1.271	2.3	0.8
HD 228438	B0.5III	8.699	0.33	0.611	0.26	1.8941	3.4	1.6



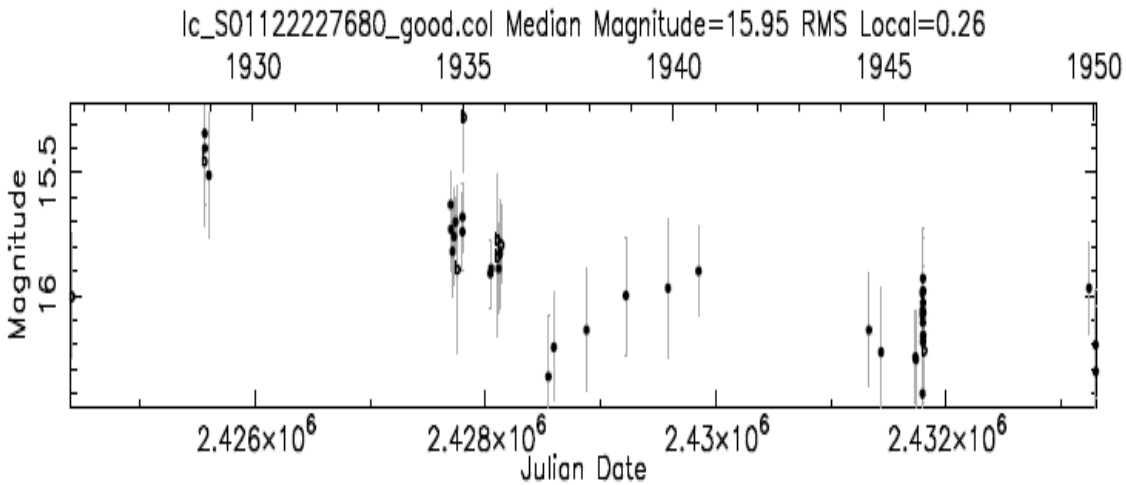
They **are** Be systems…(FAST spectra)

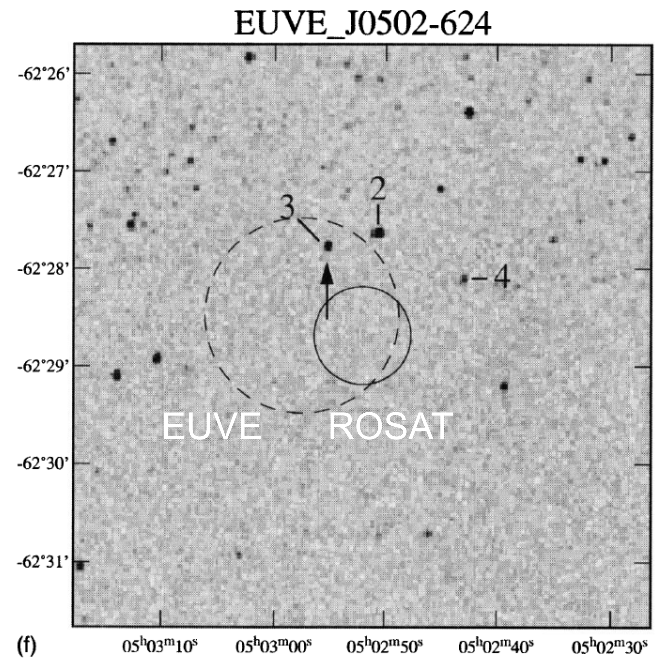


Why are DASCH Be variables interesting?

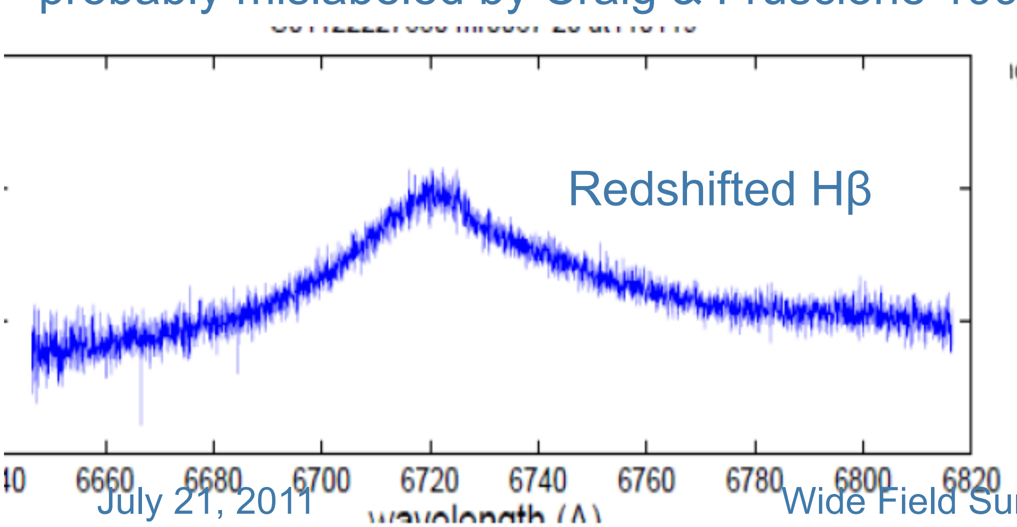
- The luminosity of a typical Be star is subject to variability as a result of mass ejection on a scale < 0.3 mag (Percy et al. 1988; Hubert et al. 2000). Larger variations (~1 mag) seen from transient accretion onto a NS binary companion
- BeHMXBs might be discovered by optical lightcurves, and may reveal long-dormant BeHMXBs
- If confirmed (orbital velocity + X-ray), DASCH lightcurves would constrain the galactic BeHMXB population
- May help uncover Be+BH systems, which must be present but not yet discovered

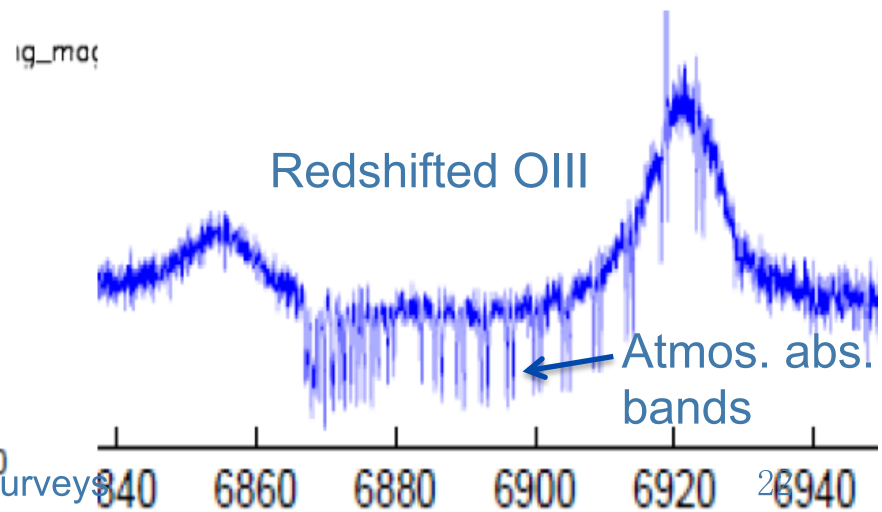
DASCH variability “re-discovery” of an AGN



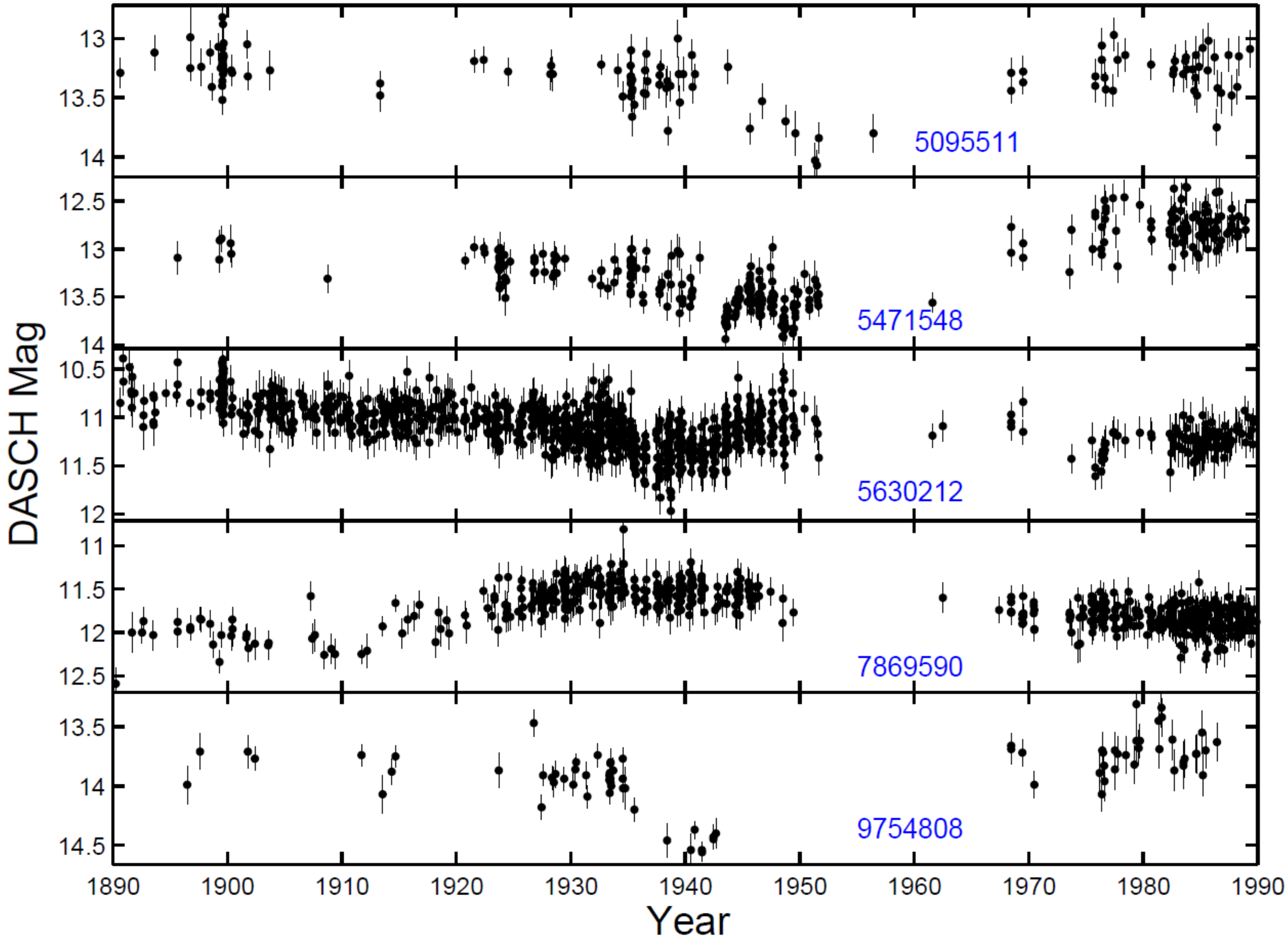


Turned out to be a z=0.382 AGN;
probably mislabeled by Craig & Fruscione 1997

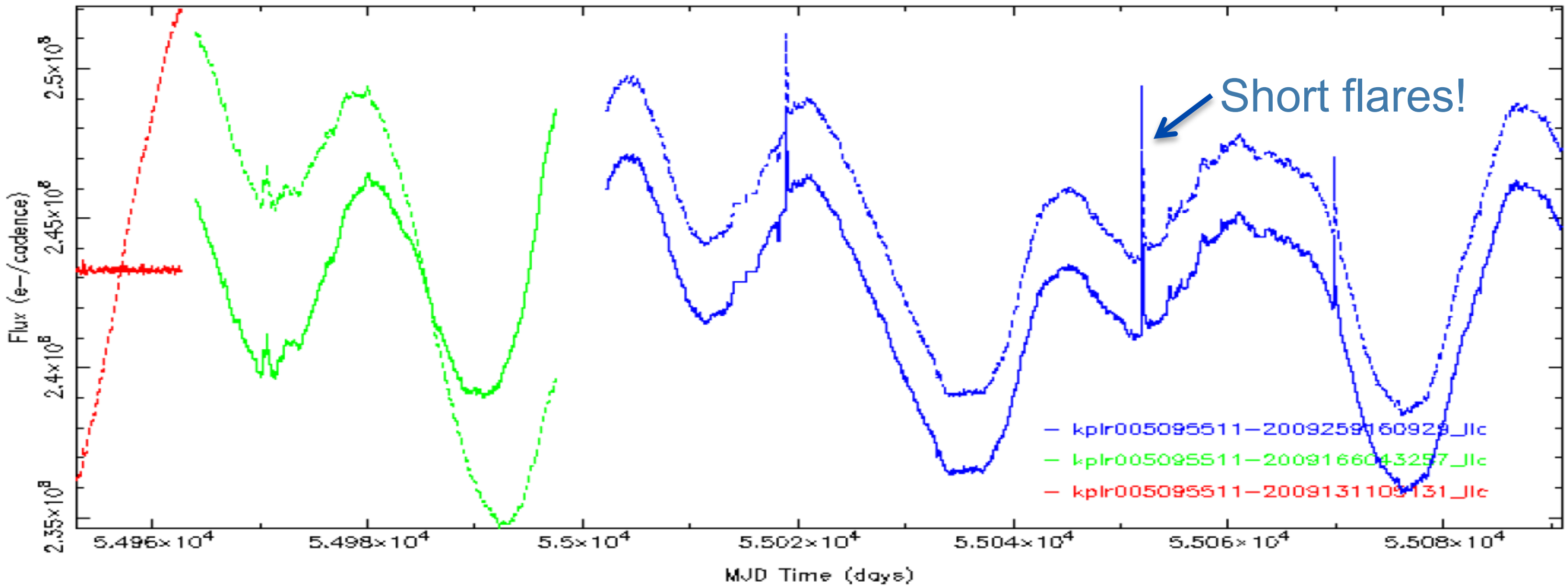


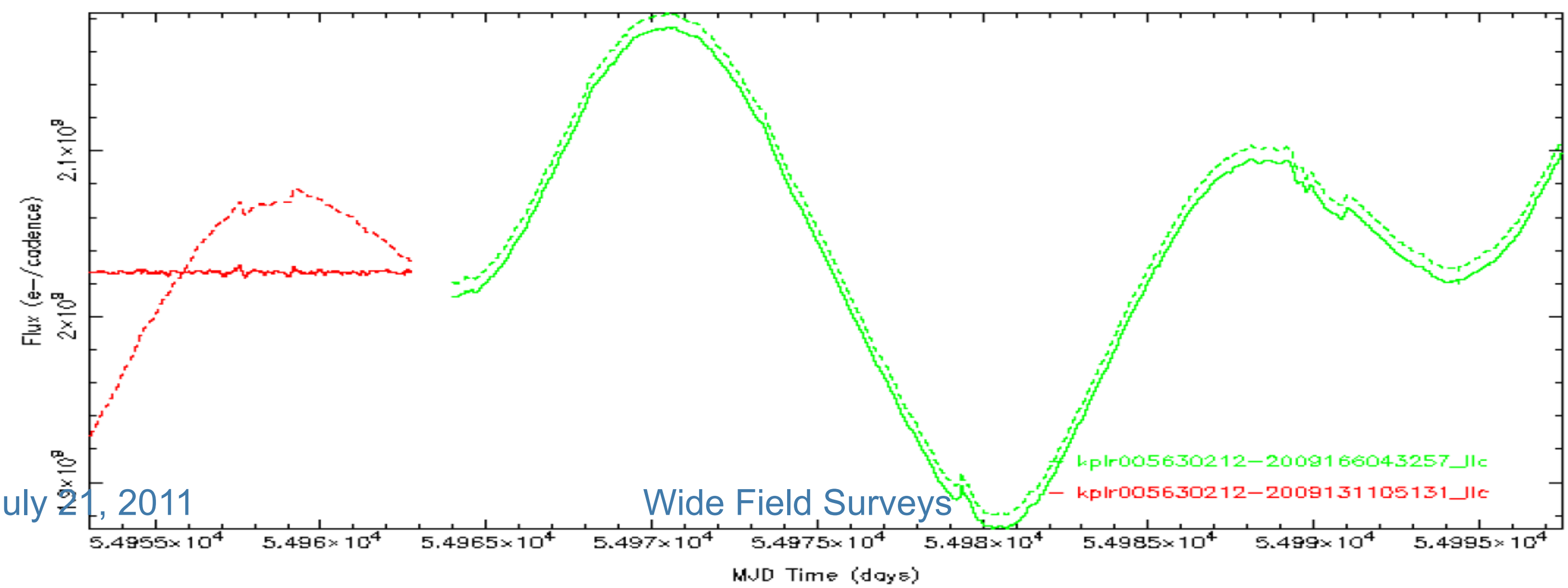


New Long-term K giant variables in the Kepler field: Now studying with Kepler GO data… (RSCVn's ?)



Example Kepler light curves





Summary

- *DASCH* is churning forward. Enormous potential for discovery and opening the ~100y TDA window
- *New* graduate student being sought to succeed Sumin Tang who finishes in May 2012!
- *Volunteers* are key part of DASCH (scanning ~400 plates today for first time!); more are needed