Exploring Long-term Variability of Stars with DASCH

Sumin Tang

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David Sliski, Robert J. Simcoe and many volunteers

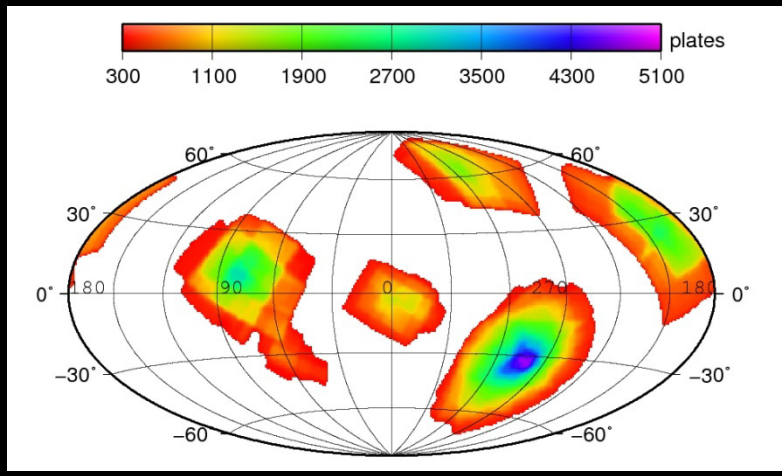
Wide-Field Survey Pizza Lunch, Tuesday, Jan 31, 2012

Introduction to DASCH

Digital Access to a Sky Century@Harvard

Digitize and Measure the Harvard Plates
to open the ~100yr TD Window

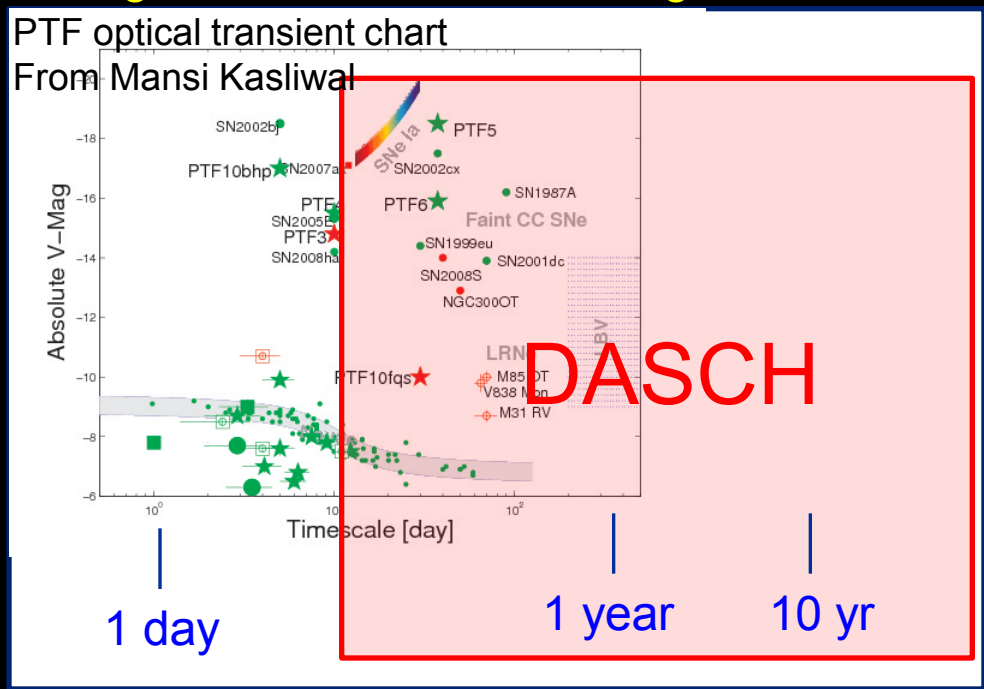
~19,600 plates scanned
1.7×10^9 magnitude measurements

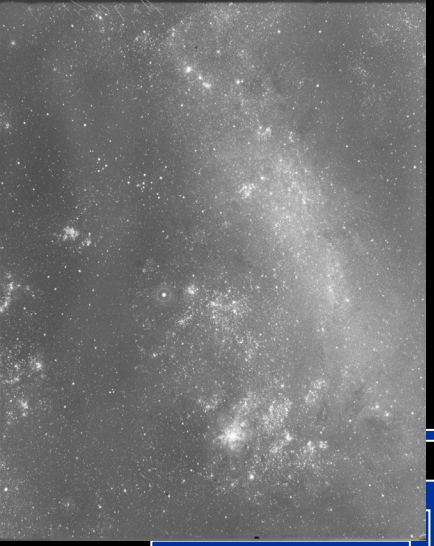


- ~500,000 photographic plates between 1880s-1980s covering the whole sky (*Grindlay et al. 2009*).
- ~500-1500 measurements for each object with B<15 (up to 18 mag in some regions)
- Study temporal variations of a wide variety of objects (stars to AGNs)
- Astrometry: 0.8-3 arcsec

  Photometry: 0.1-0.15 mag (*Laycock et al. 2010; Tang et al. in prep*).
- Start half/full production in 2012: ~400 per day. Finish ~2015?

Two advantages of DASCH:
Long-term variables; Rare bright variables





DASCH Pipeline

Lightcurves

Variable Search

Plates

Clean

Scan

WCS solution

Flag blends, plate defects, pickering wedge, multiple exposures

Photometric calibration

Meta-Data

SKY2000 Tycho-2

Astrometry.net SCAMP

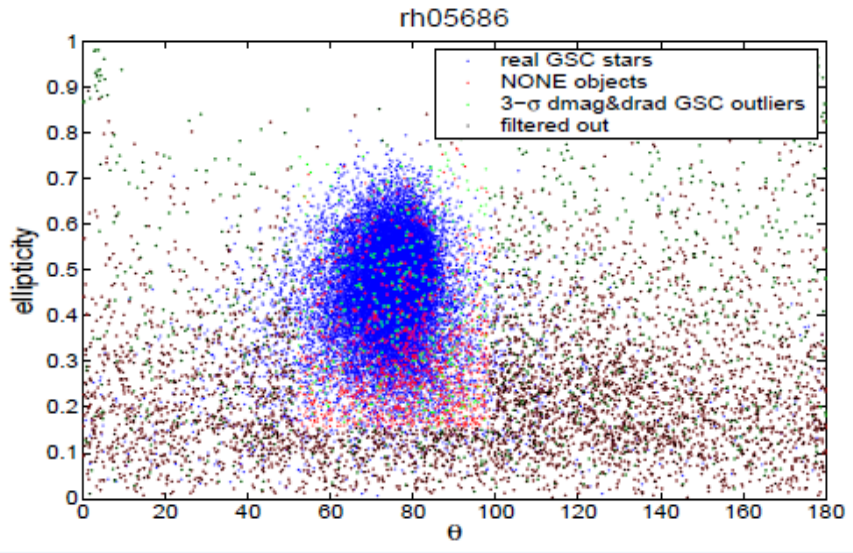
GSC2.3 KIC APASS

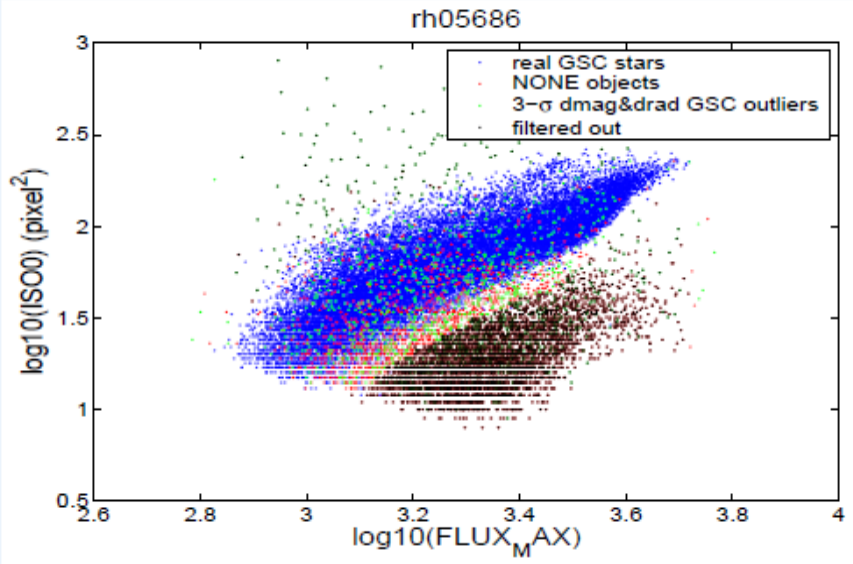
Logbooks

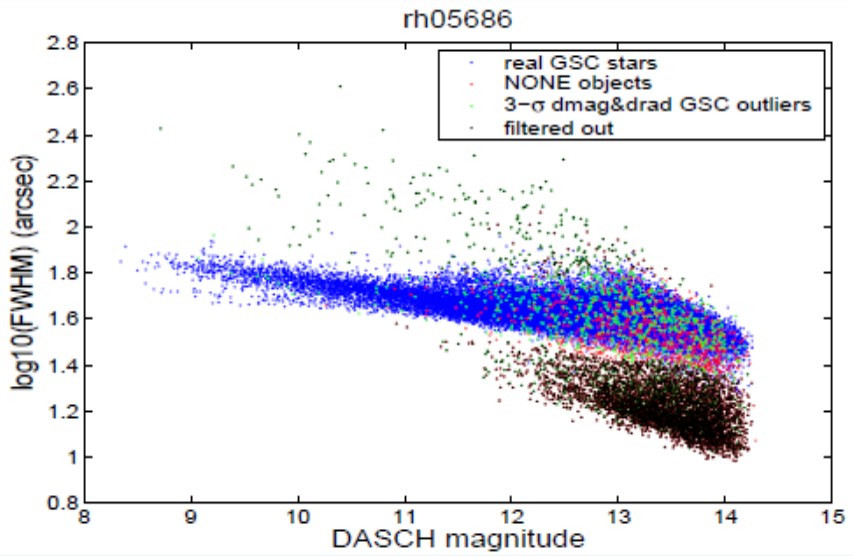
Lots of dubious signals: emulsion defects, dusts, inks, scratches…

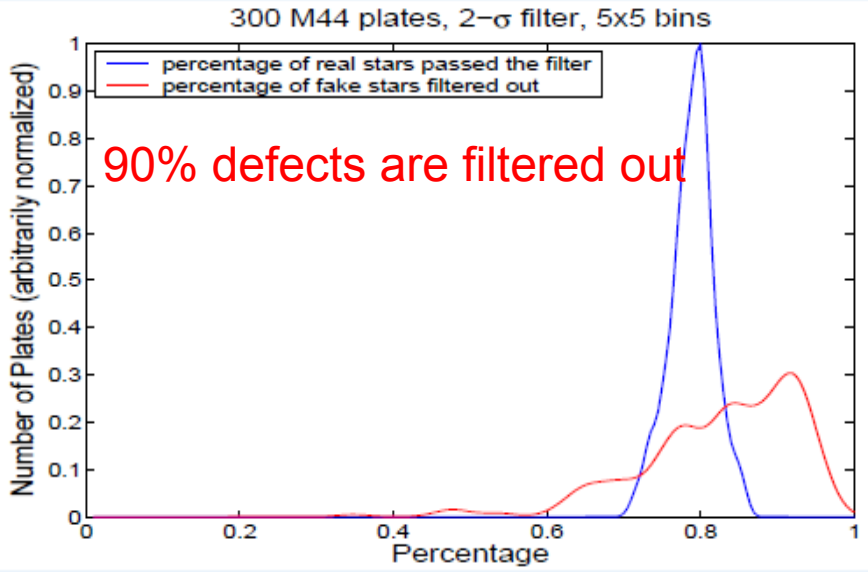
Step 1. Filter out emulsion defects, dusts, inks, scratches, etc.

Tang et al. in prep.









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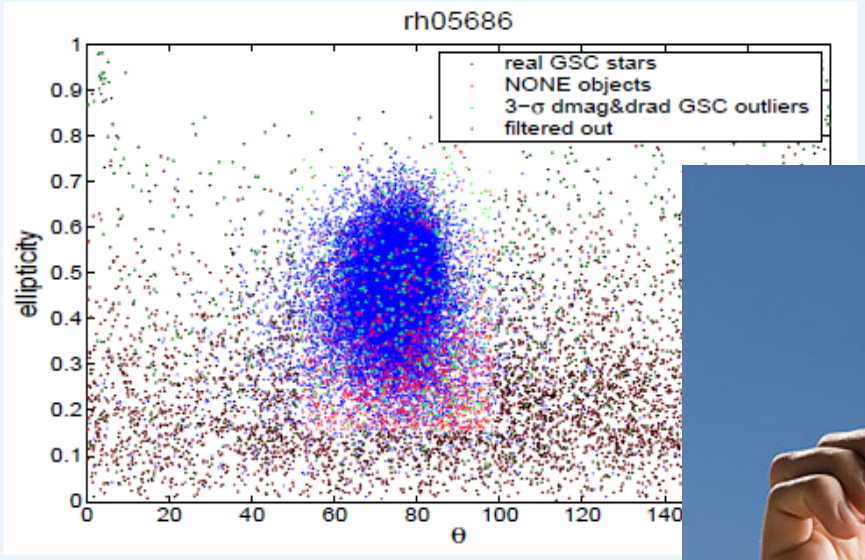
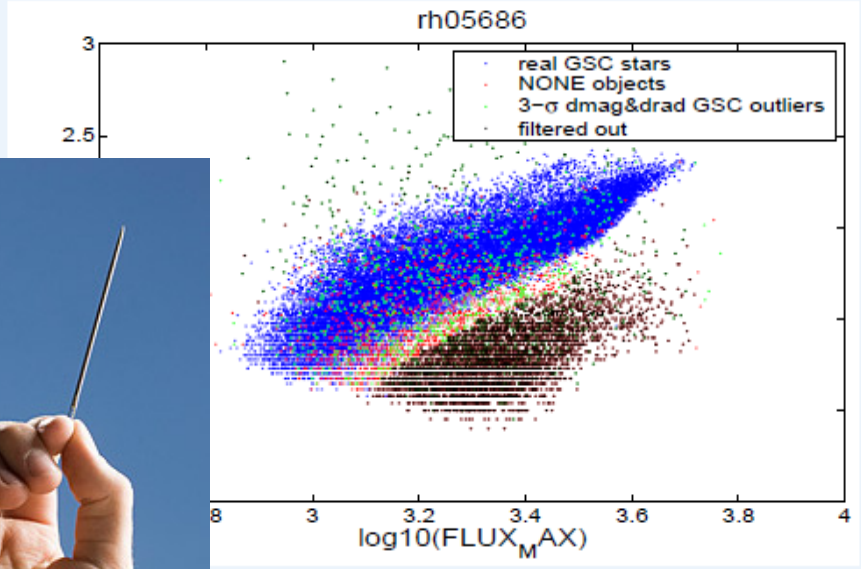
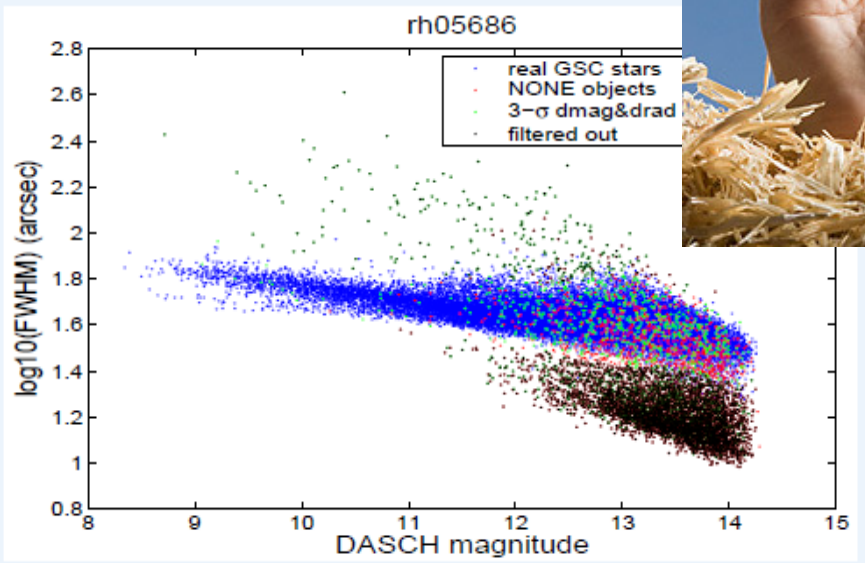
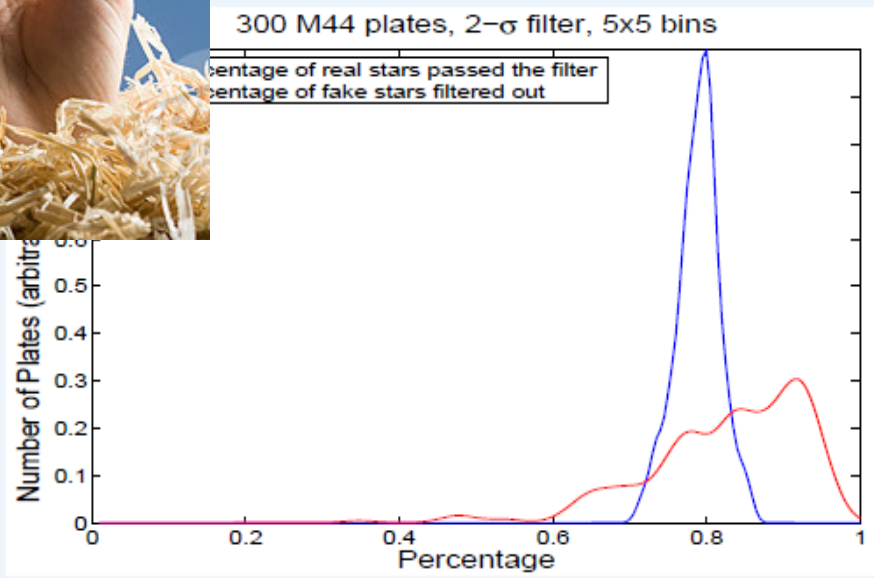
Tang et al. in prep.





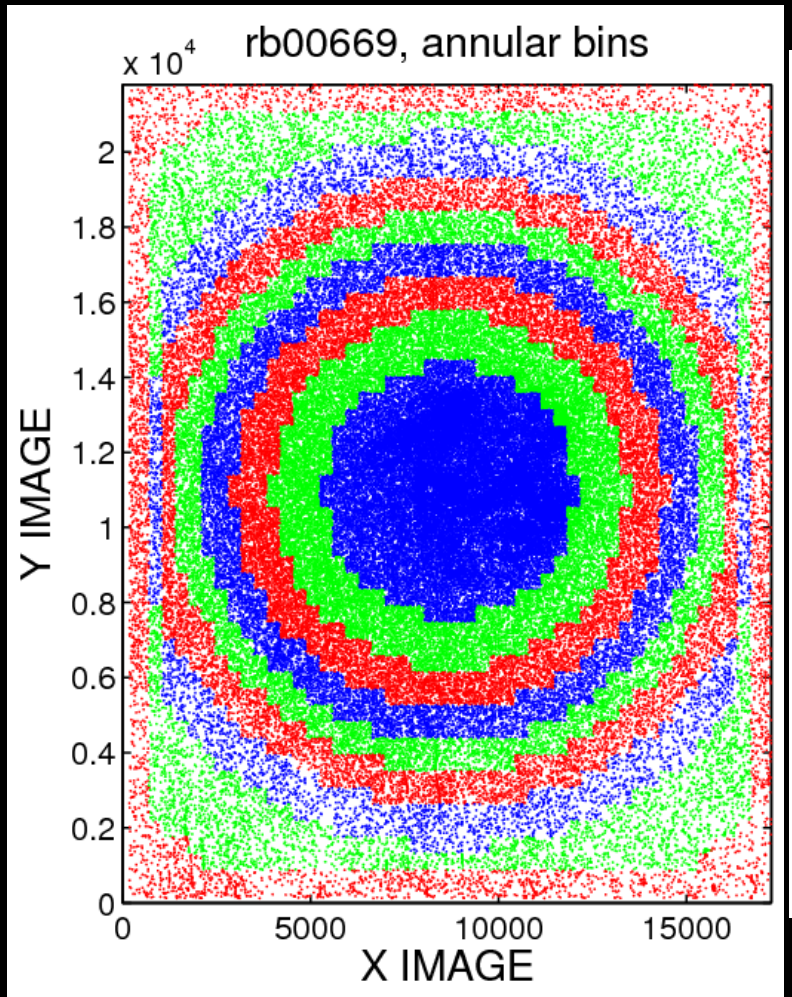


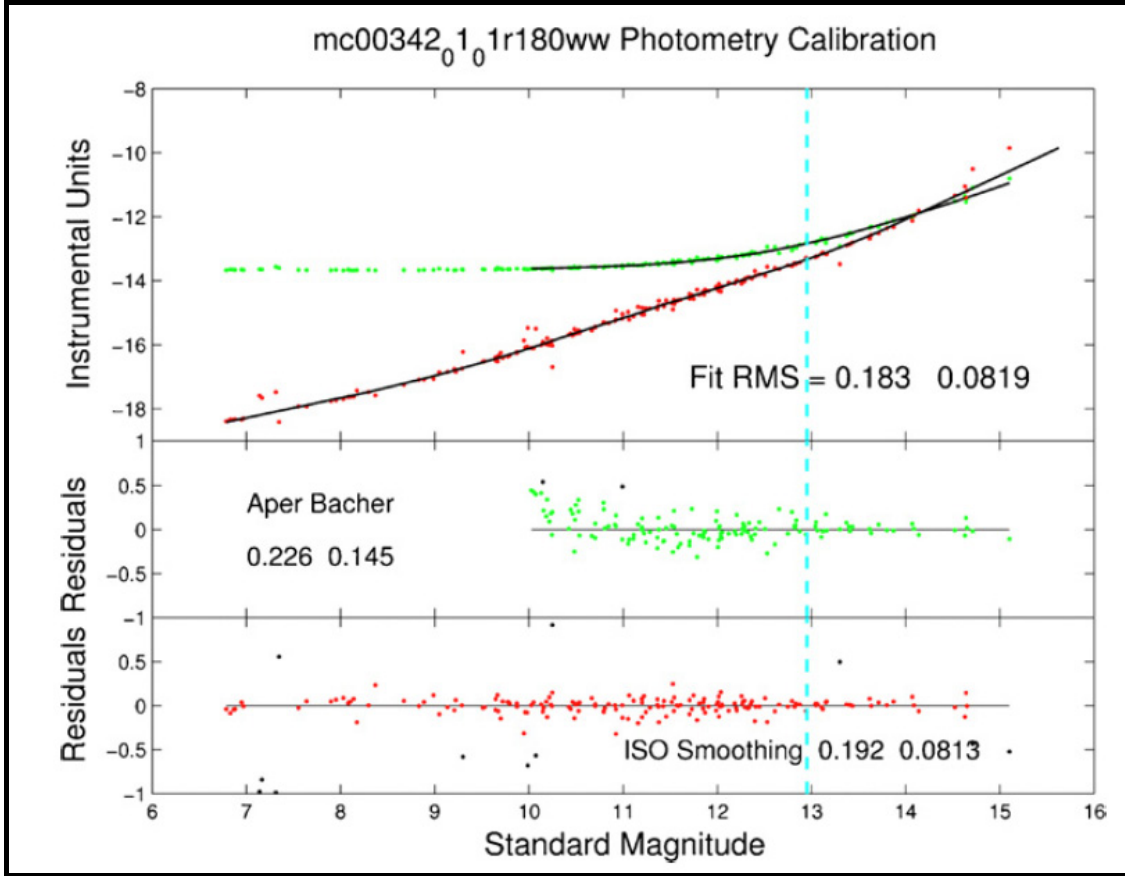


Step 2. Photometric calibrations:

annular bins & local calibrations to correct the inhomogeneity of the plates

Laycock, Tang et al. 2010
Tang et al. in prep.



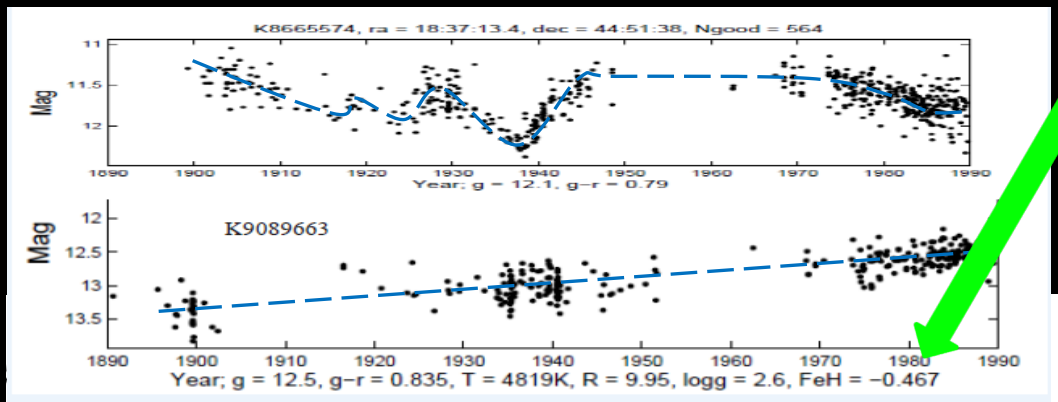


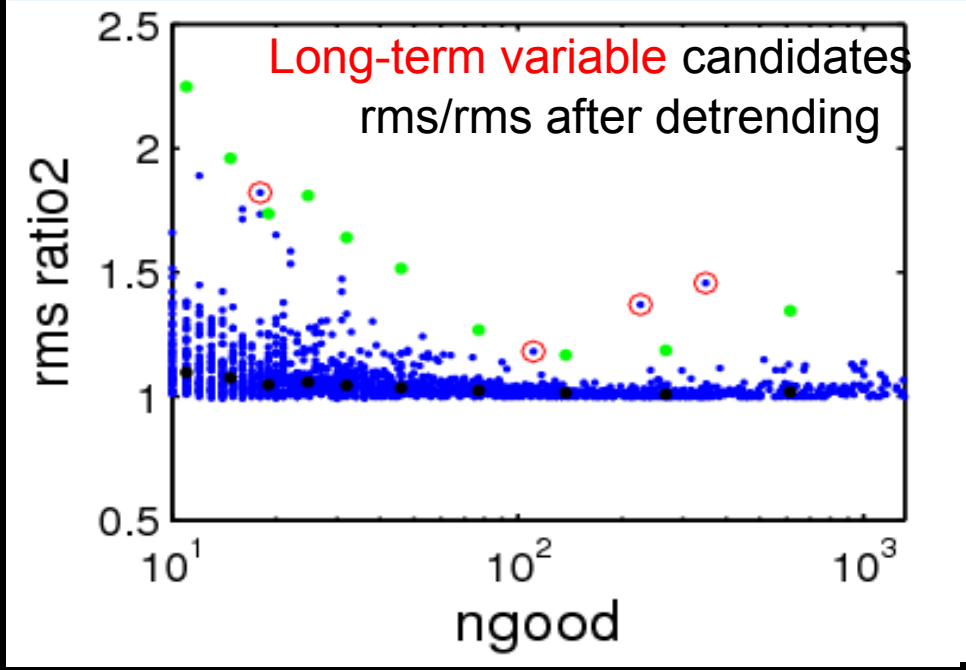
Variable Search:

1. divided into local 2ºx2º bins
2. calculate light curve statistics for each star
3. pick up outliers (variable candidates)

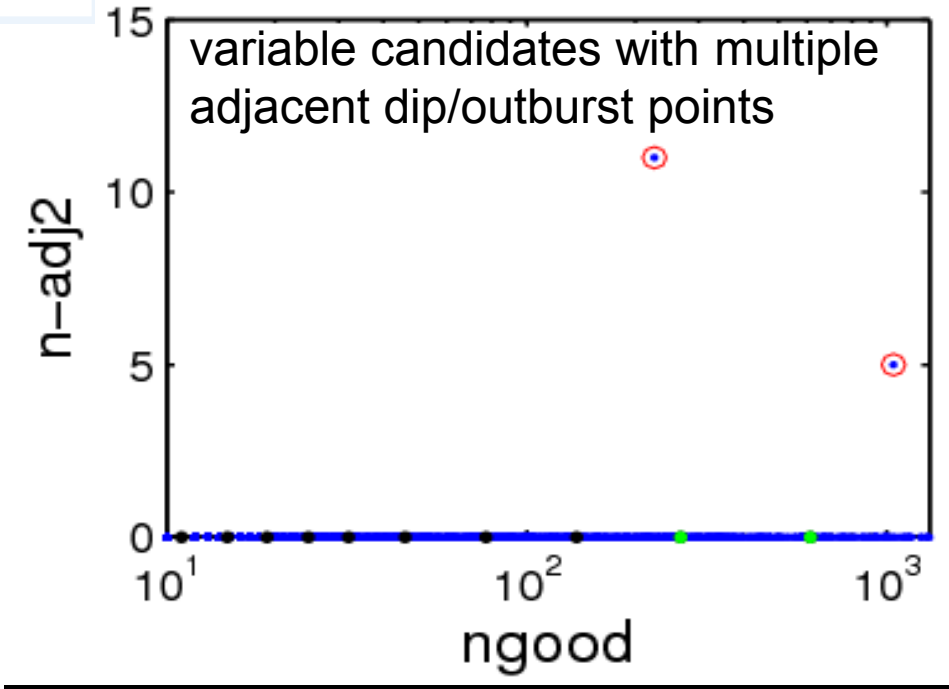
Tang et al. 2012d

- Light curve RMS/clipped RMS
- Amplitude/clipped amplitude
- RMS ratio before and after detrending
- Number of outburst points
- Number of dip points
- Number of adjacent outburst/dip points

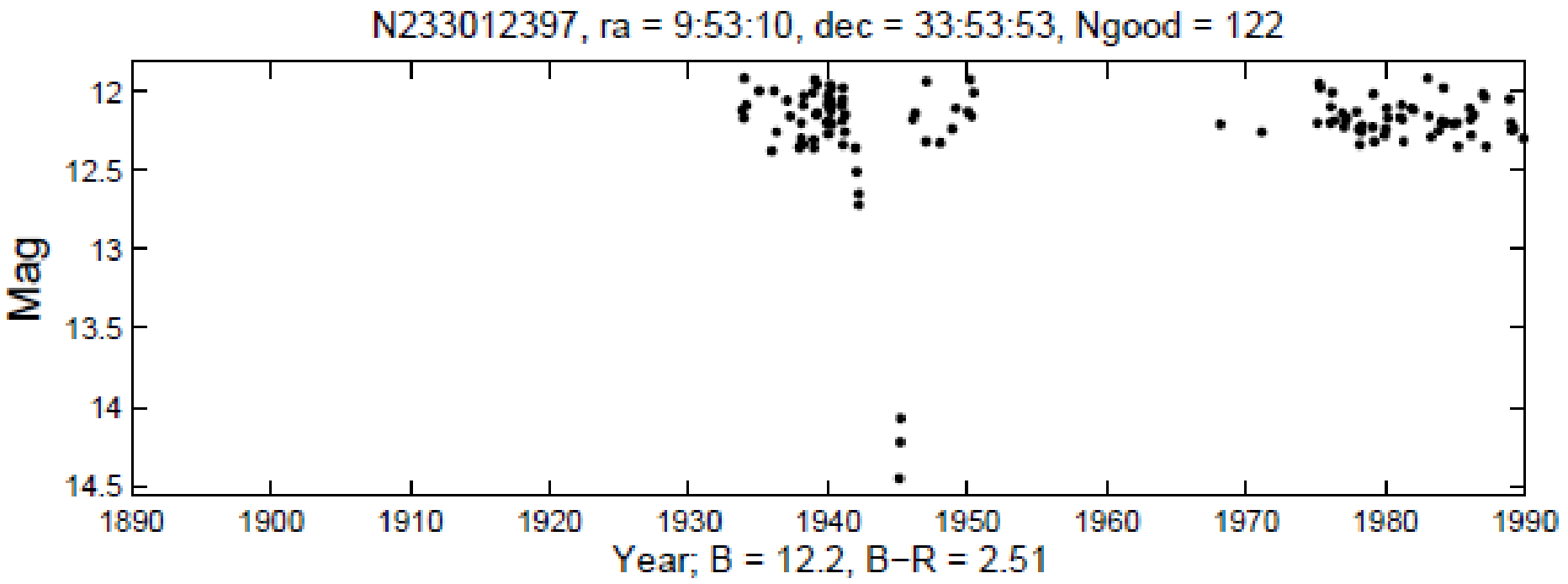




2 10σ outliers



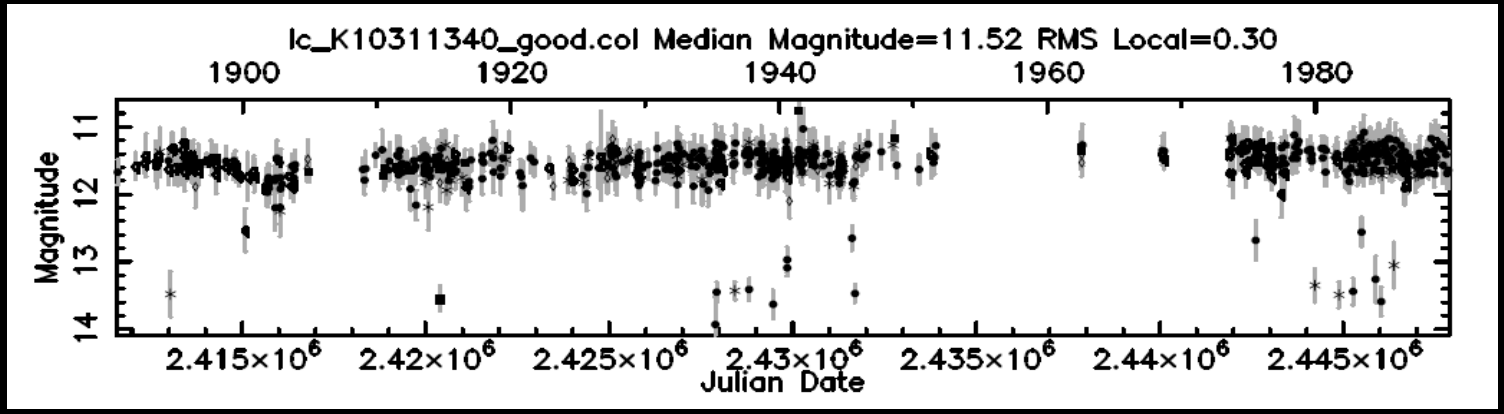
Example of a variable with adjacent dip points… more on it later



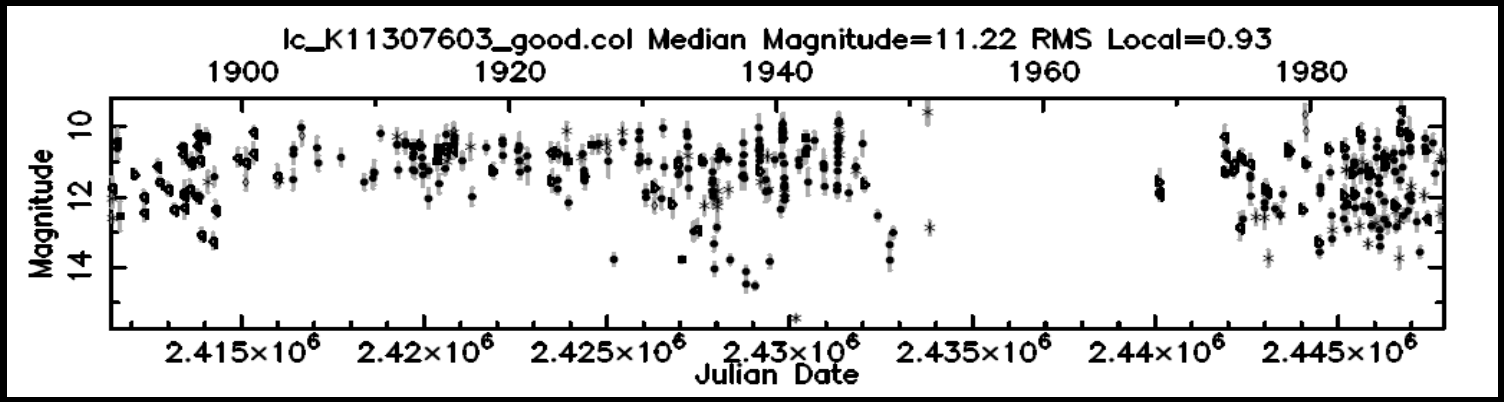
Further Analysis and Classification of Variables

Example variables in the Kepler field

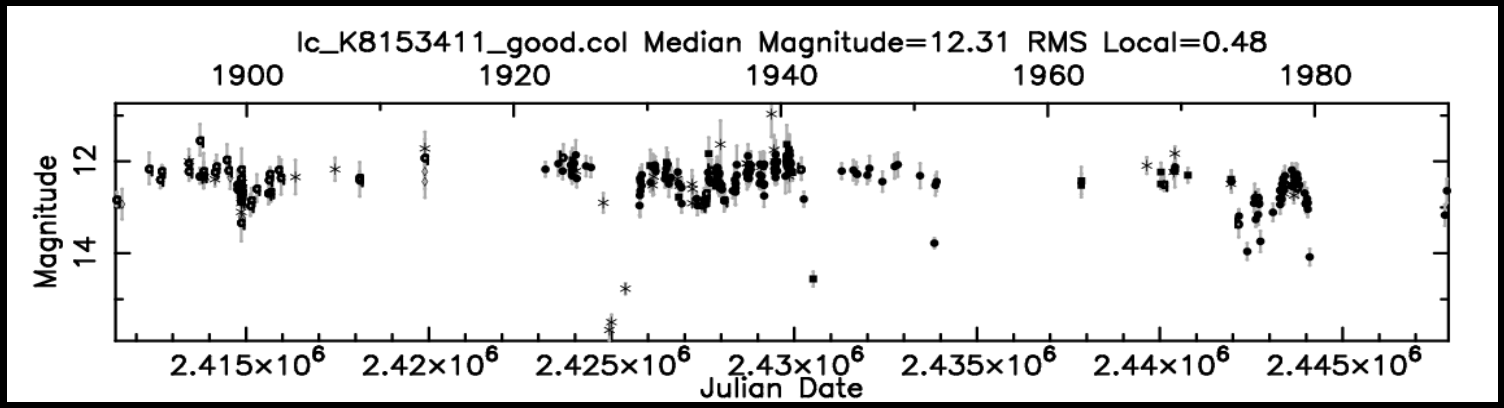
Eclipsing Binary
(Algol system)
Objects with dips, normal clipped rms



Pulsating Star
(Mira, TU Cyg)
Large clipped rms



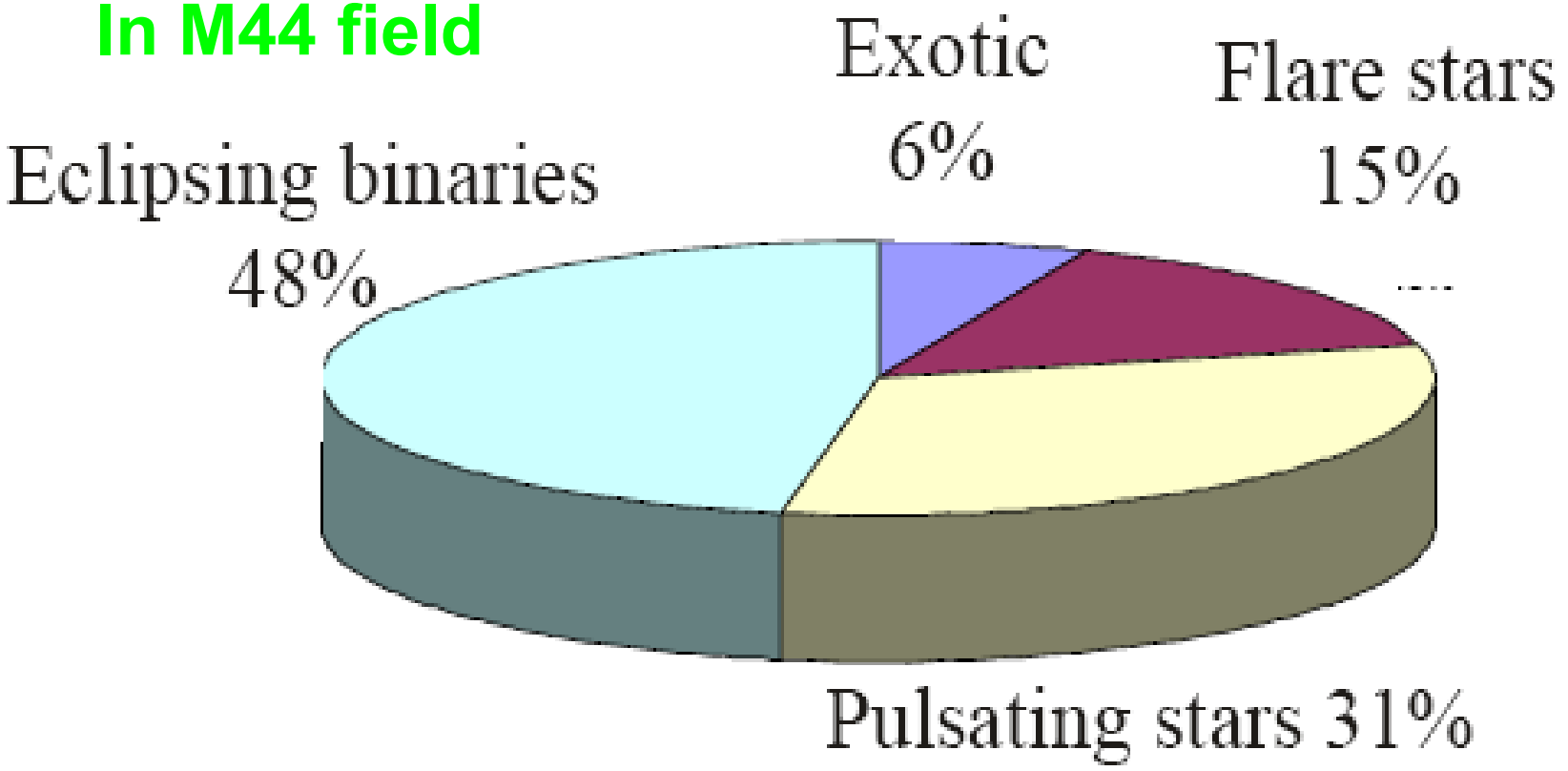
Exotic
(CV, MV Lyr)



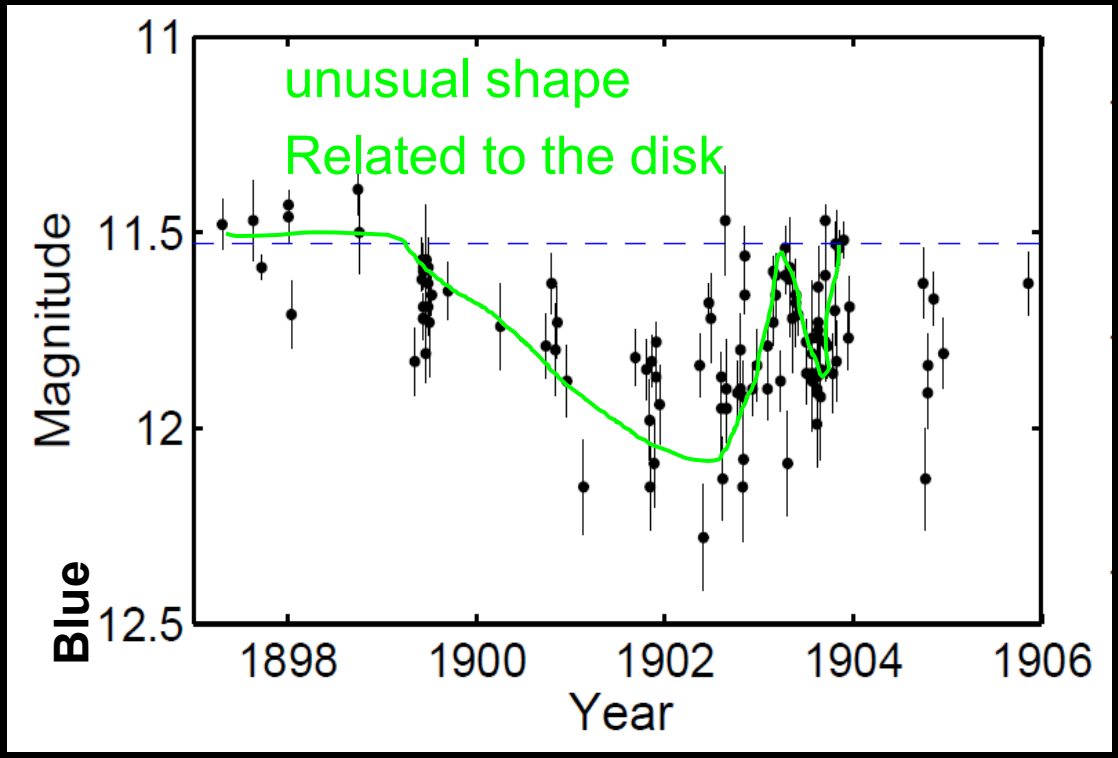
~ 10^{-4} are variables with amplitude >~0.5 mag

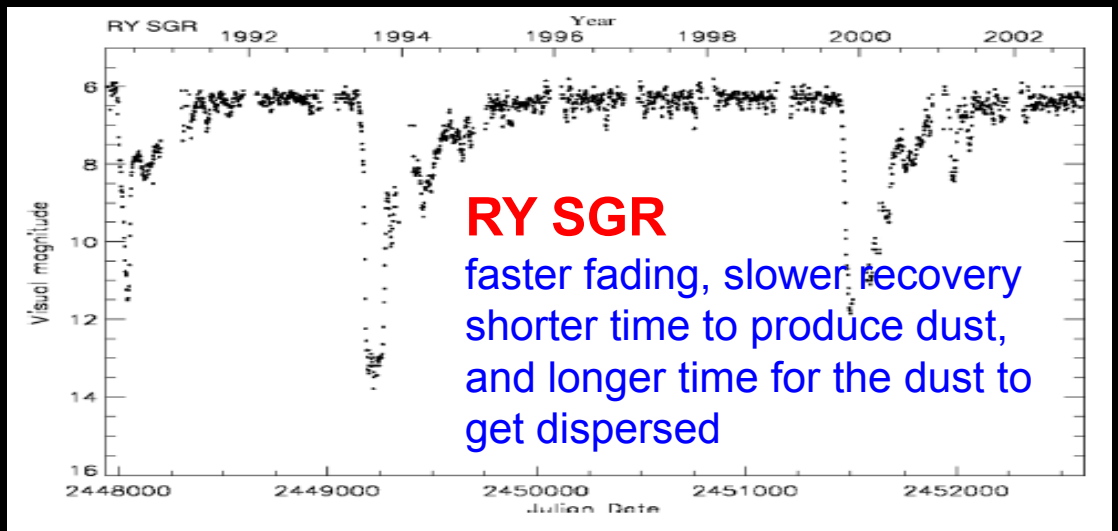
Demographics of DASCH Variables

In M44 field



KU Cyg: 5-yr dust accretion event





Tang et al. 2011, ApJ, 738, 7

Algol-type eclipsing binary

3.85 $M_\odot$ F star + 0.48 $M_\odot$ K5III

(*Smak & Plavec 1997*)

Slow Fading: accretion timescale

Increased mass transfer => increased disk mass => larger optical depth (dust extinction and neutral hydrogen scattering) => fading

Fast brightening:

Dust evaporates when moves closer to the F star => brightening

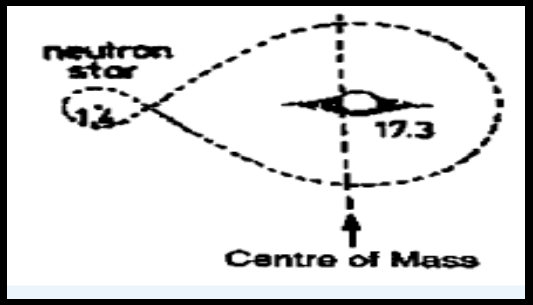
Fluctuations:

Dust condensation

Accretion energy release on the boundary layer

A group of large amplitude Be variables: Be X-ray binaries? (Be + NS)

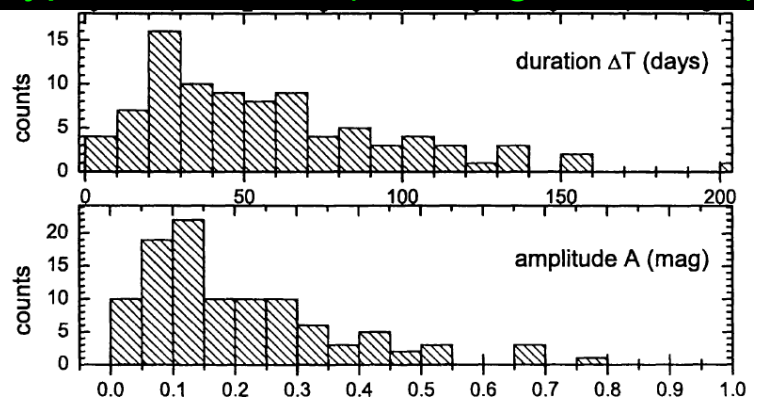
excretion disk



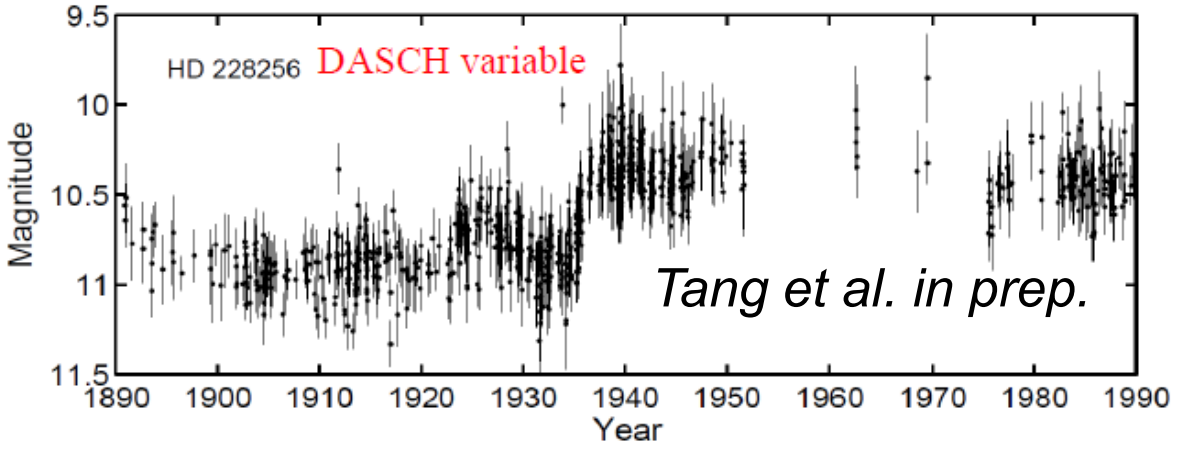
X-ray obs. needed (SWIFT)

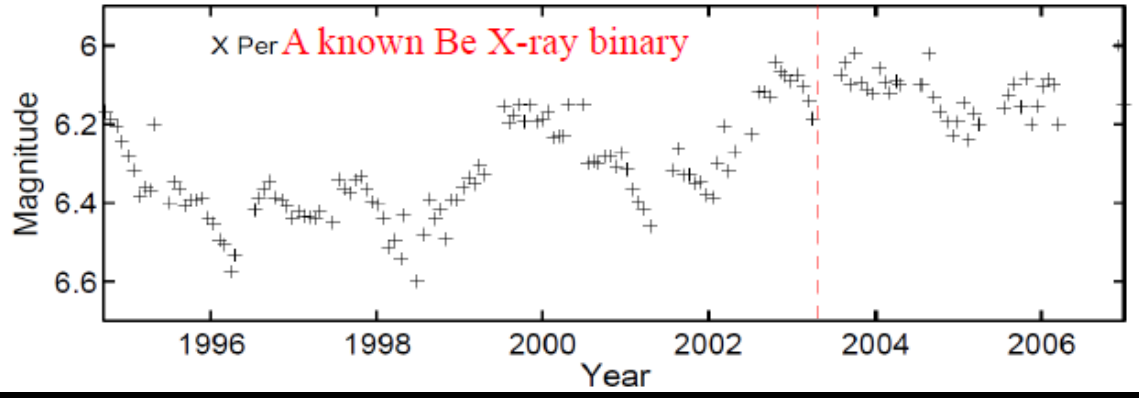
Normal Be stars: amplitude <~0.3 mag (Mennickent et al. 2003)

Type 1 Be stars (showing outbursts)

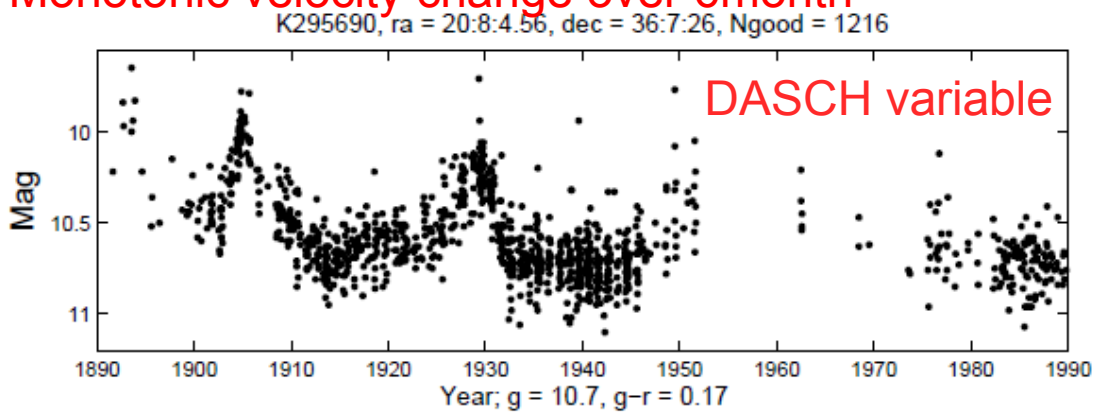


Within the error circle of a Fermi source: pulsar + Be?





Monotonic velocity change over 6month



Discovery of new type of variable stars: 3 unusual long-term K giant variables; ALL K2III

An unknown phase of RGB/AGB evolution with dust production?

Tang et al. 2010, ApJL, 710, L77

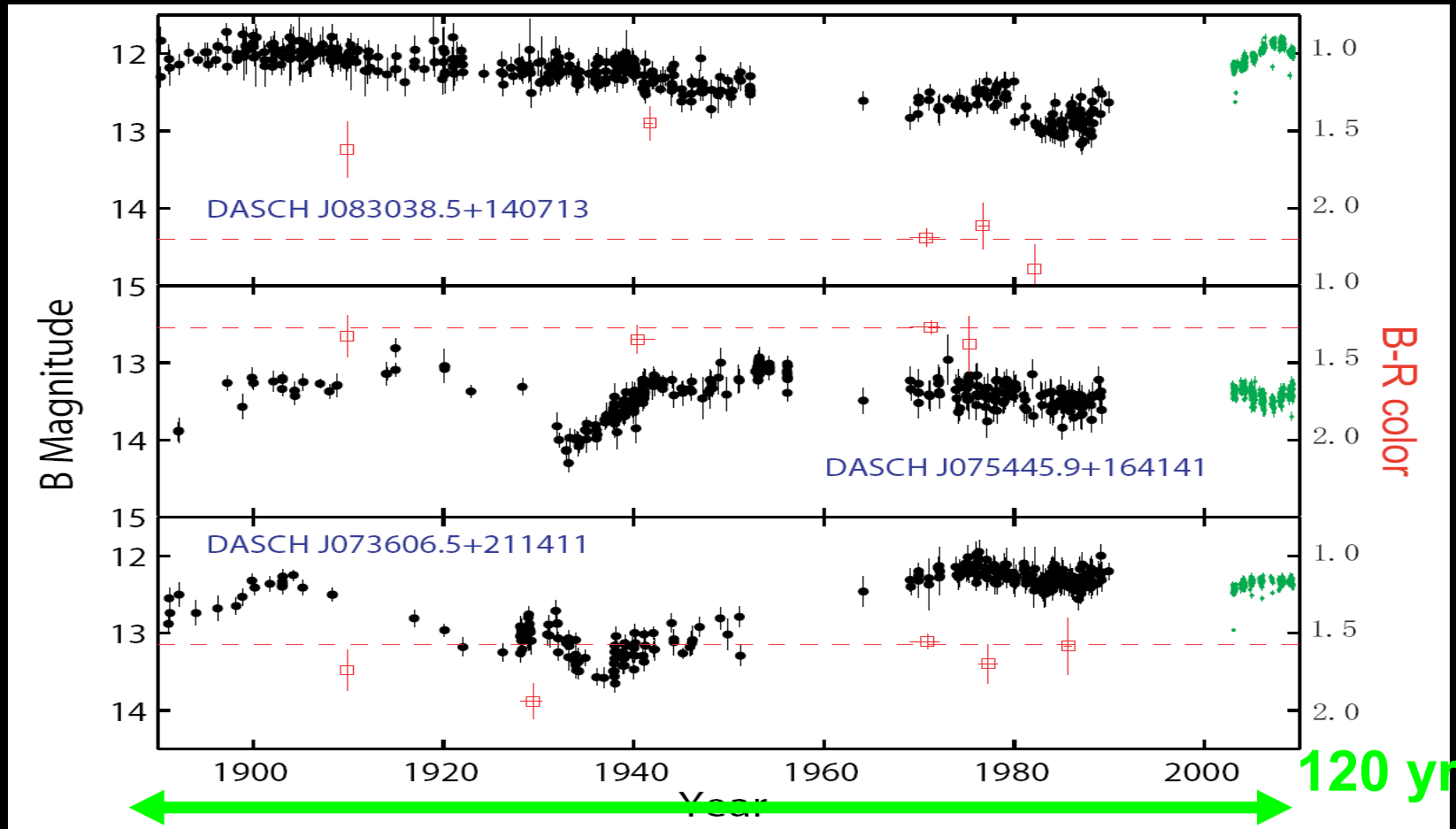
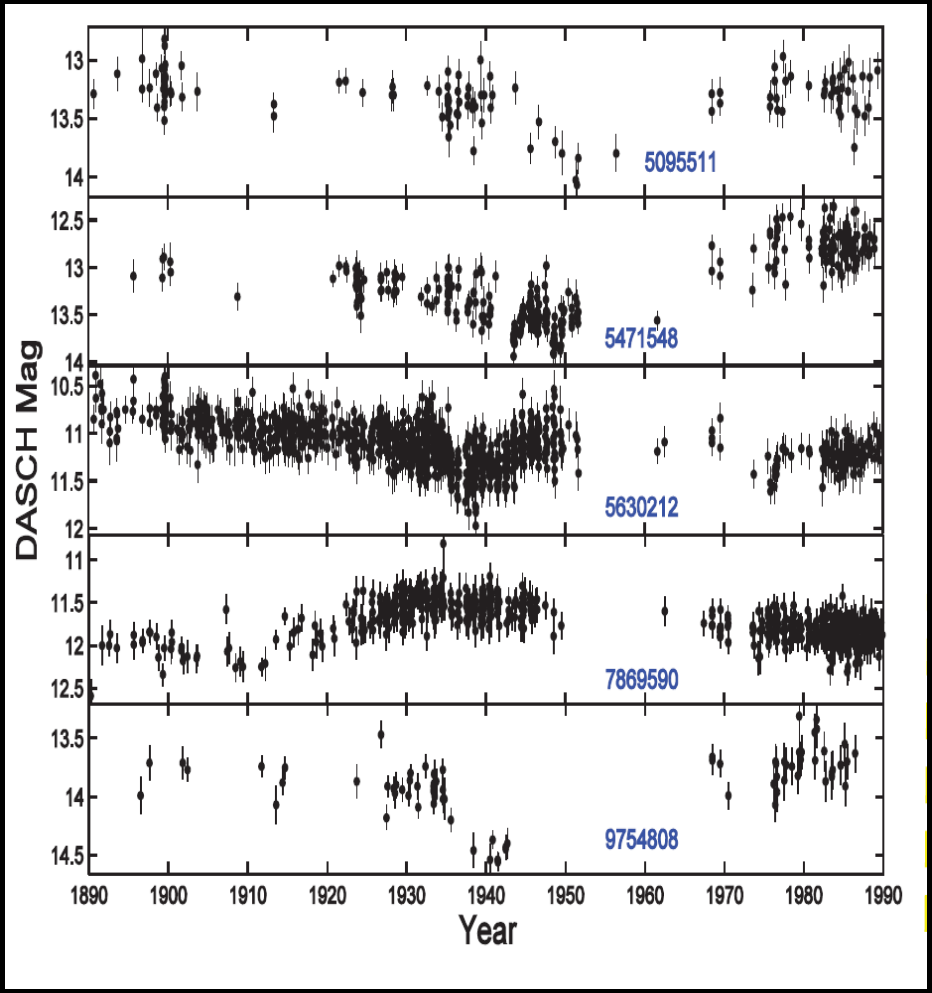


FIG. 1.— Lightcurves and color evolution of 3 unusual long-term variables which were found in DASCH scans near M44. Black dots with errorbars are the lightcurves from DASCH, small green dots are the lightcurves from ASAS. Since ASAS data are in V band, while DASCH magnitudes are blue, we added 1.16 mag 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.

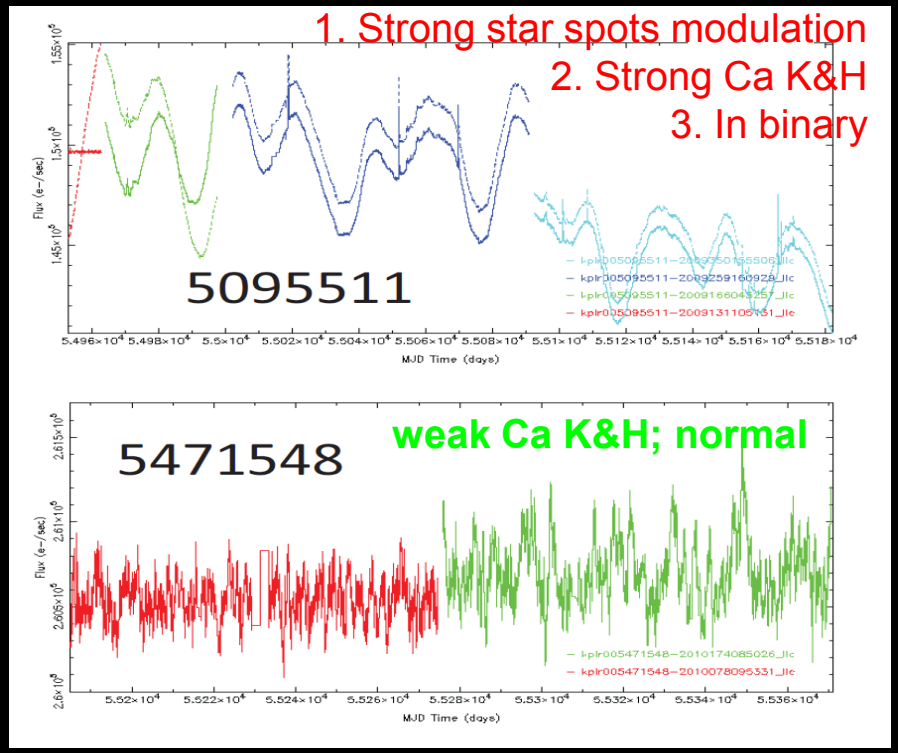
New K giants variables in the Kepler field

Tang et al. 2012c

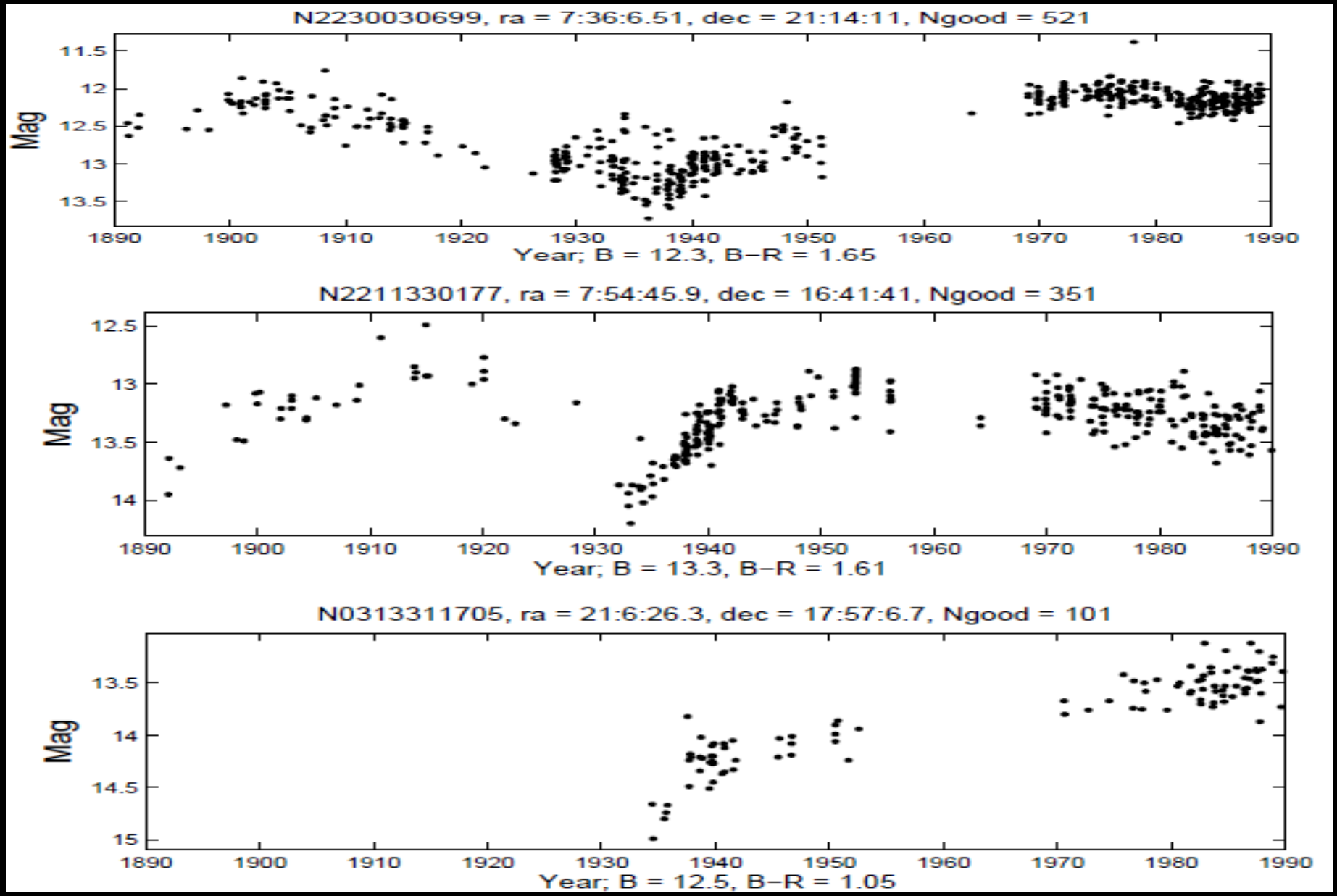


Probably a mix of two subgroups:

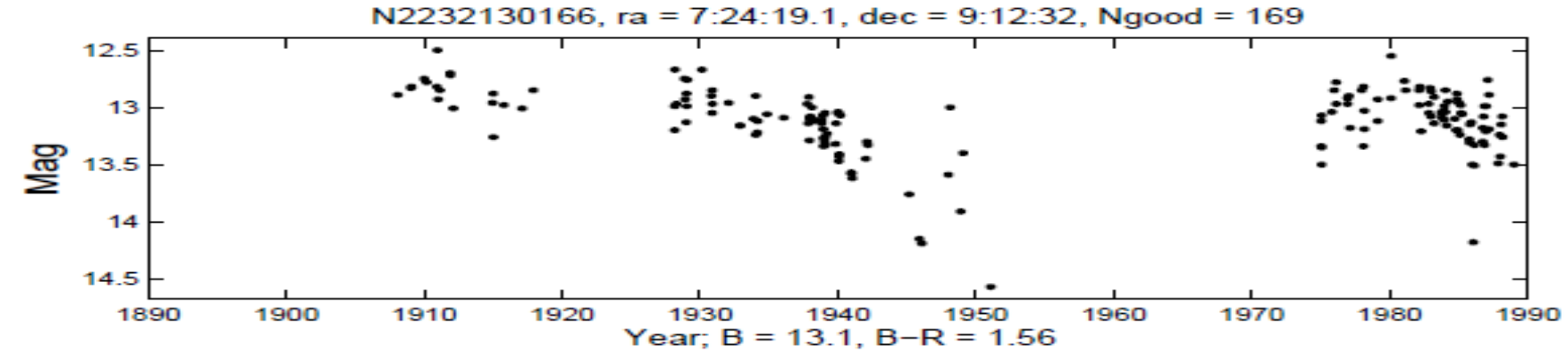
1. extreme RS CVn binaries with strong magnetic activities induced by binary interaction; variations may be related to ultra strong star spots activity.
2. Single stars; variations may be caused by novel dust formation processes during a certain evolutionary stage.

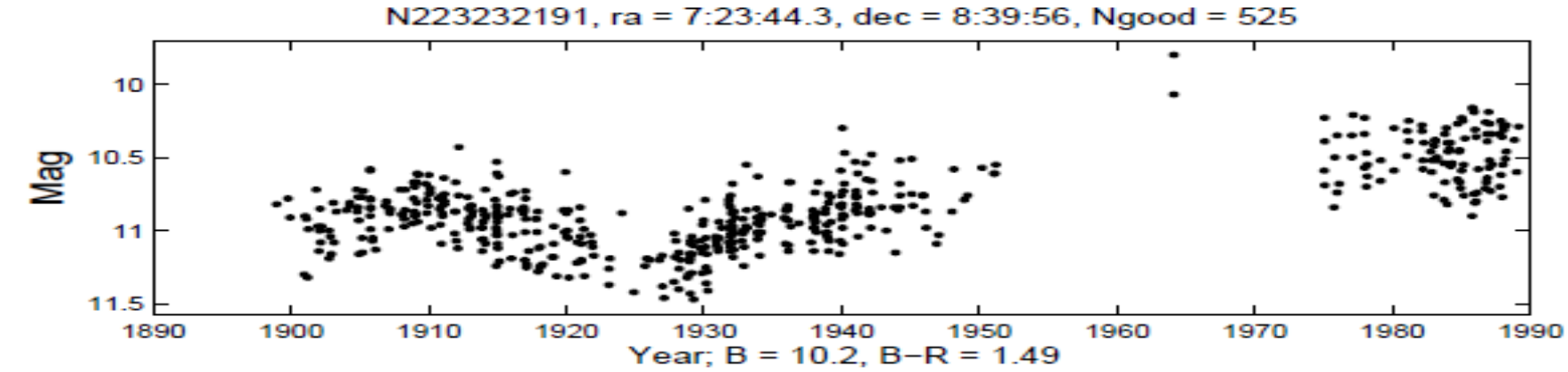


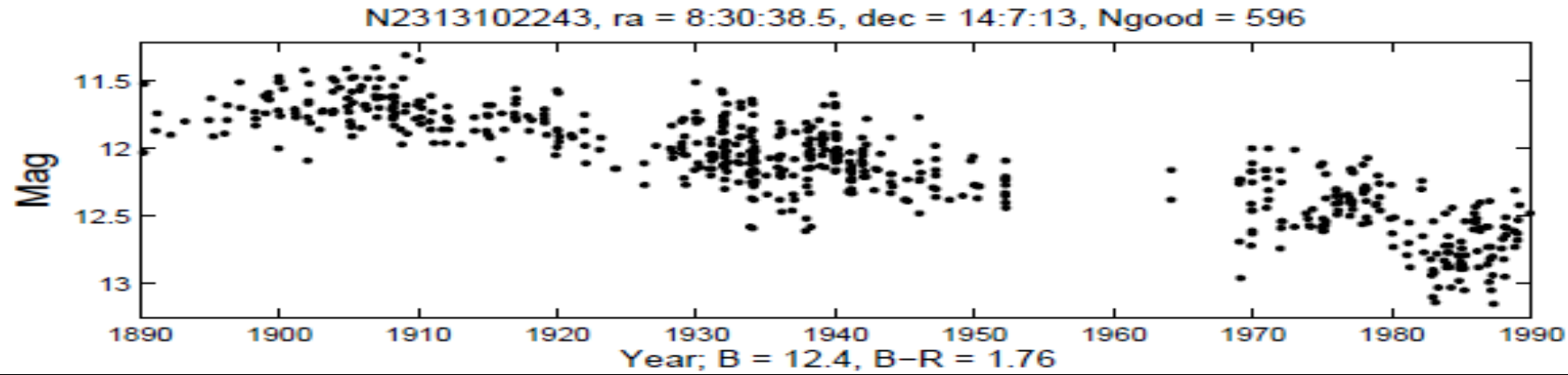
K giants in Binaries



Single K giant Stars (T~4700-5000 K, logg~3-3.5)

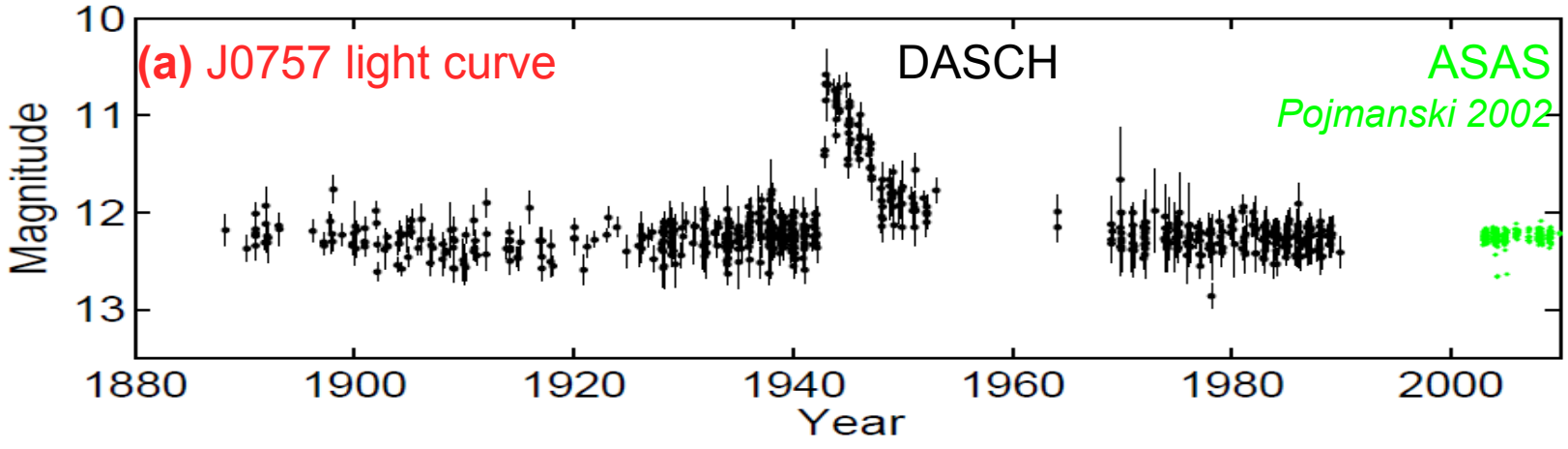


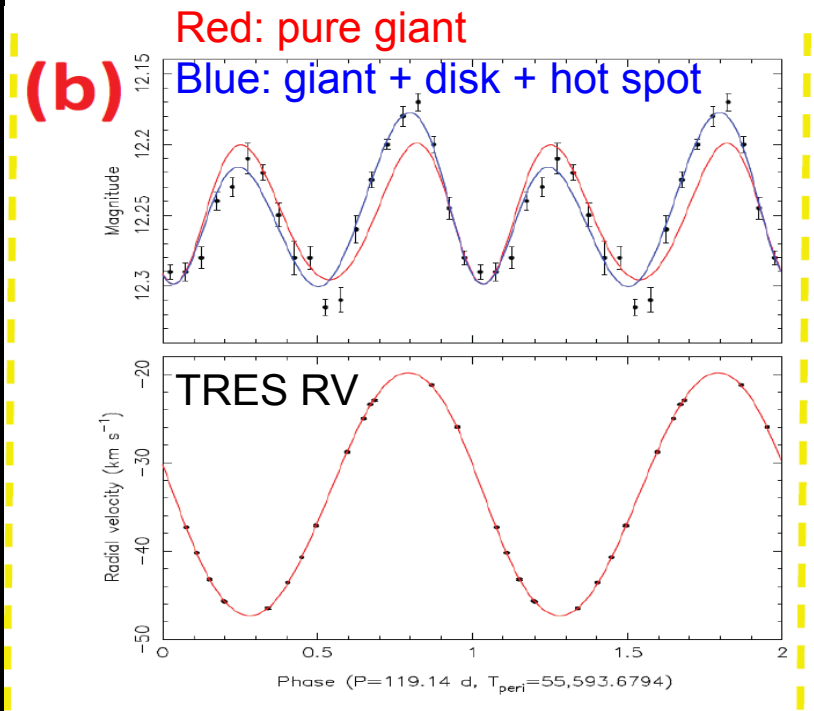


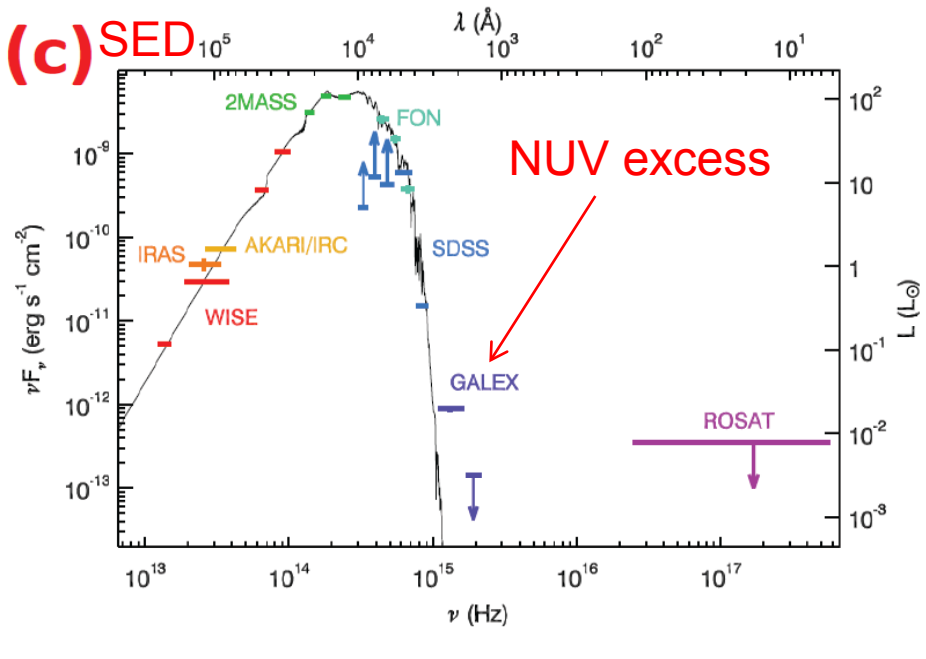


A peculiar 10-yr outburst

Tang et al. 2012a, ApJ, submitted
arXiv:1110.0019



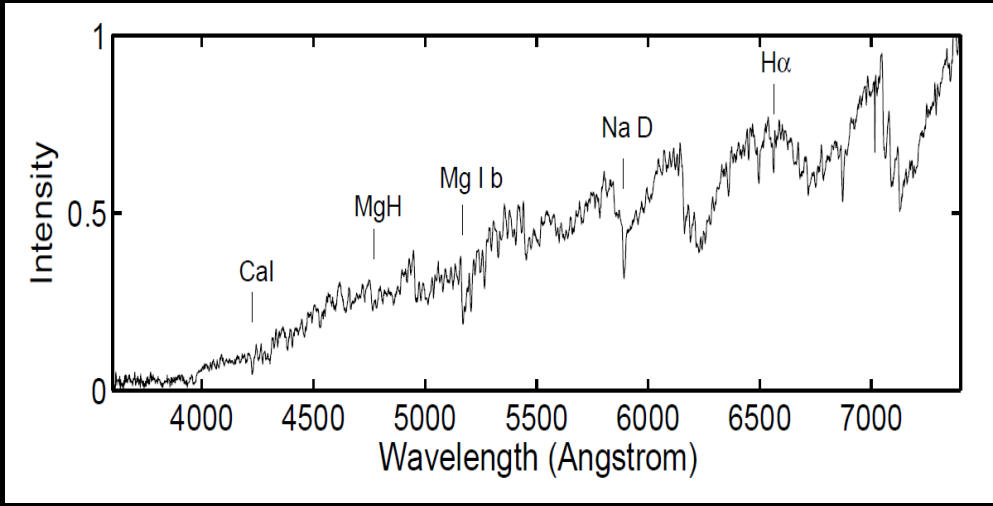




DASCH J0757, list of properties:

From atmosphere fitting (Bob Kurucz), radial velocity & ellipsoidal variation

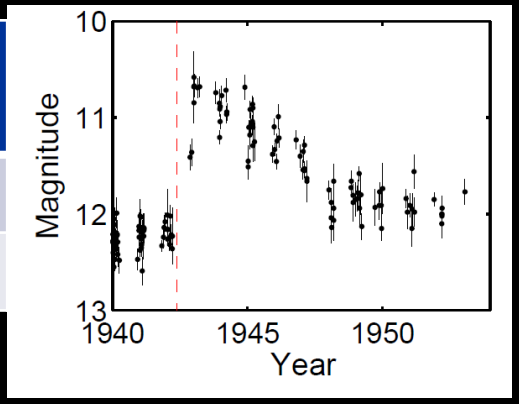
Spectra: normal M0 giant, no emission line



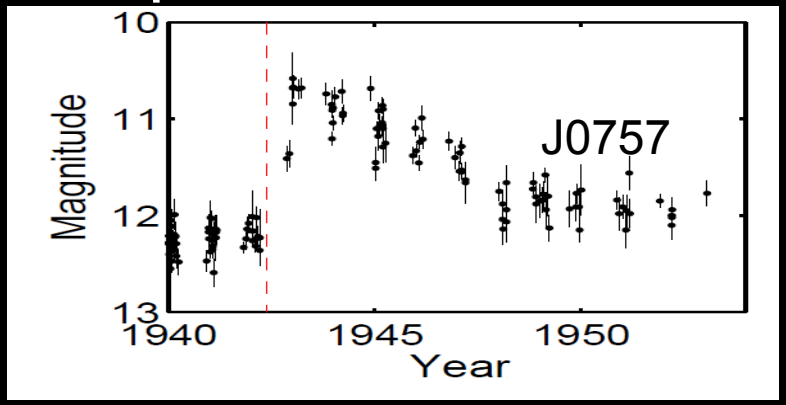
Spectral type	M0III
Orbital Period	119.18d+-0.07
Eccentricity	0.025+-0.01
M_giant	1-1.3 $M_\odot$
M_WD	~0.6 $M_\odot$
Distance	~1 kpc
L_giant	250 $L_\odot$
L_hot, quiescence Mdot	~2 $L_\odot$ 10^{-9} $M_\odot/yr$
M_B quiescence	~2
M_B outburst	~1
RL lobe filling factor	0.5-0.8

Properties of the outburst:

T_eff	L ($L_\odot$)	Mdot ($M_\odot/yr$) Accretion powered	Mdot ($M_\odot/yr$) H-burning powered
8000	~150	**10^{-7}**	-
10^5	10^4	-	**10^{-7}**



What powered the outburst?



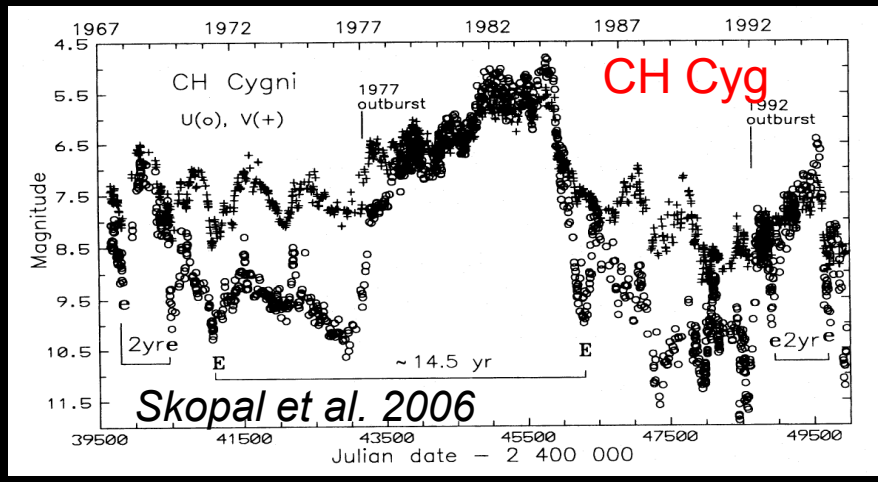
- **Accretion?**

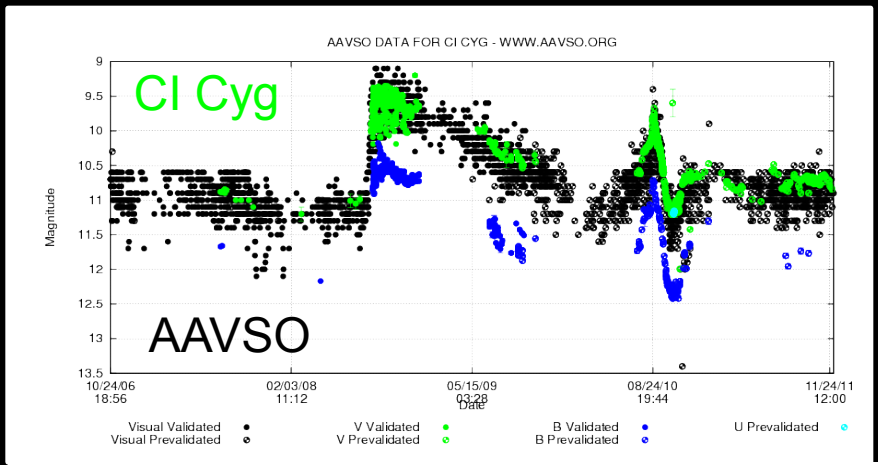
  Light curve of J0757 doesn't look like the accretion powered systems, such as CH Cyg.

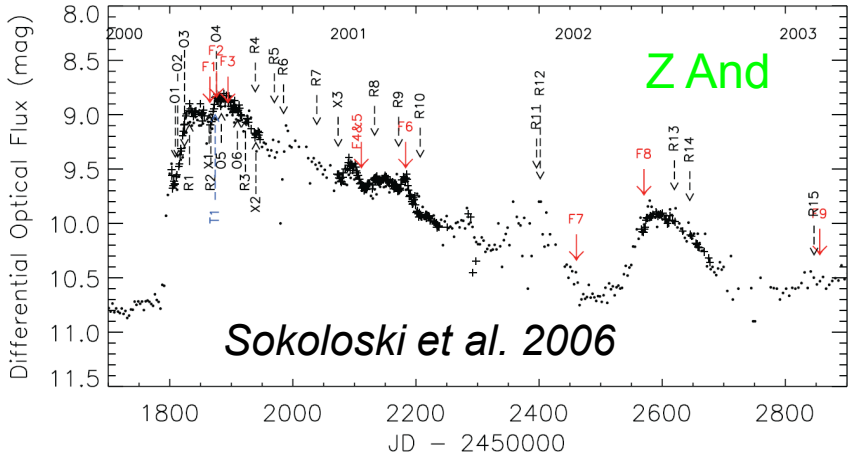
- **Nuclear burning?**

  The outburst profile of J0757 more closely resembles that of Z And and CI Cyg, which are believed to have gone through nuclear burning powered outbursts (Mikolajewska 2003, et al. 2002). However, Z And and CI Cyg are hot and luminous during quiescence (H-burning in both quiescence & outburst).

If nuclear burning without significant mass loss (no emission line in the spectra) => WD grows =?> SN Ia?



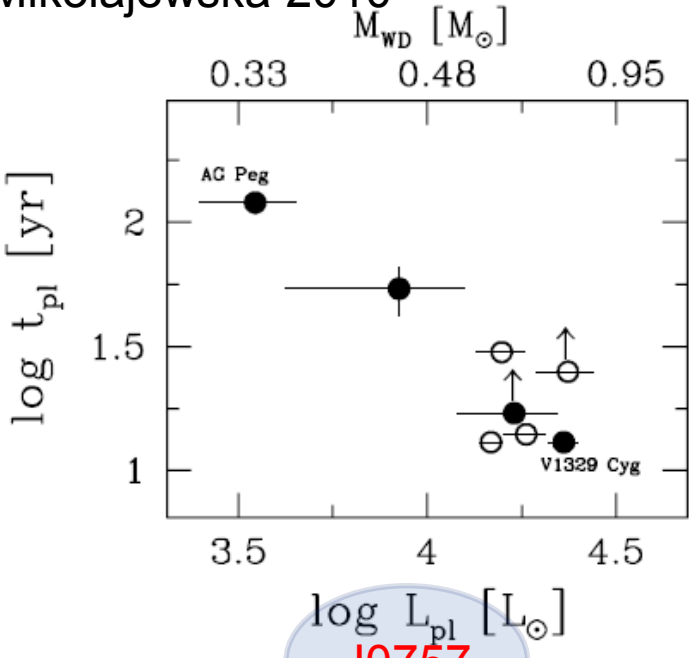




Symbiotic novae?

- Symbiotic novae: thermonuclear runaways in symbiotic systems; only 9 symbiotic novae known so far (e.g. Kenyon 1986)
- Orbital period >2 yr, slow & quiet wind-accreting ; strong emission lines
- Our object: period 119 days, NO emission line , NO indication of wind

Mikolajewska 2010



J0757

Iben 2003

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

DASCH J0757 is a rare and new class of symbiotic variables:

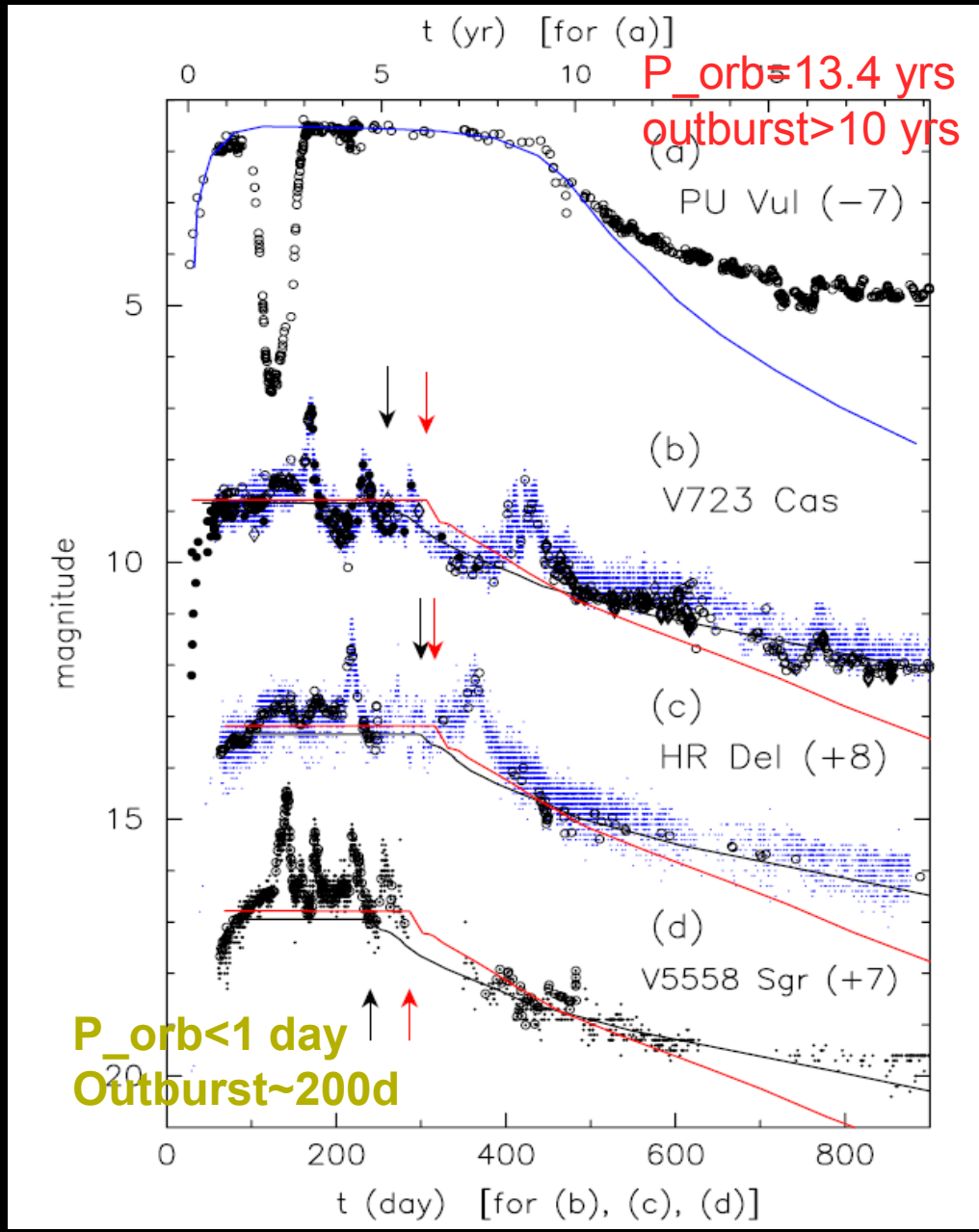
A missing part of symbiotic family?

Its current photometric and spectroscopic properties is not different from a normal red giant binary. It would not be picked out without the capture of its long outburst in 1940s on DASCH plates.

What sets the nuclear outburst timescale?

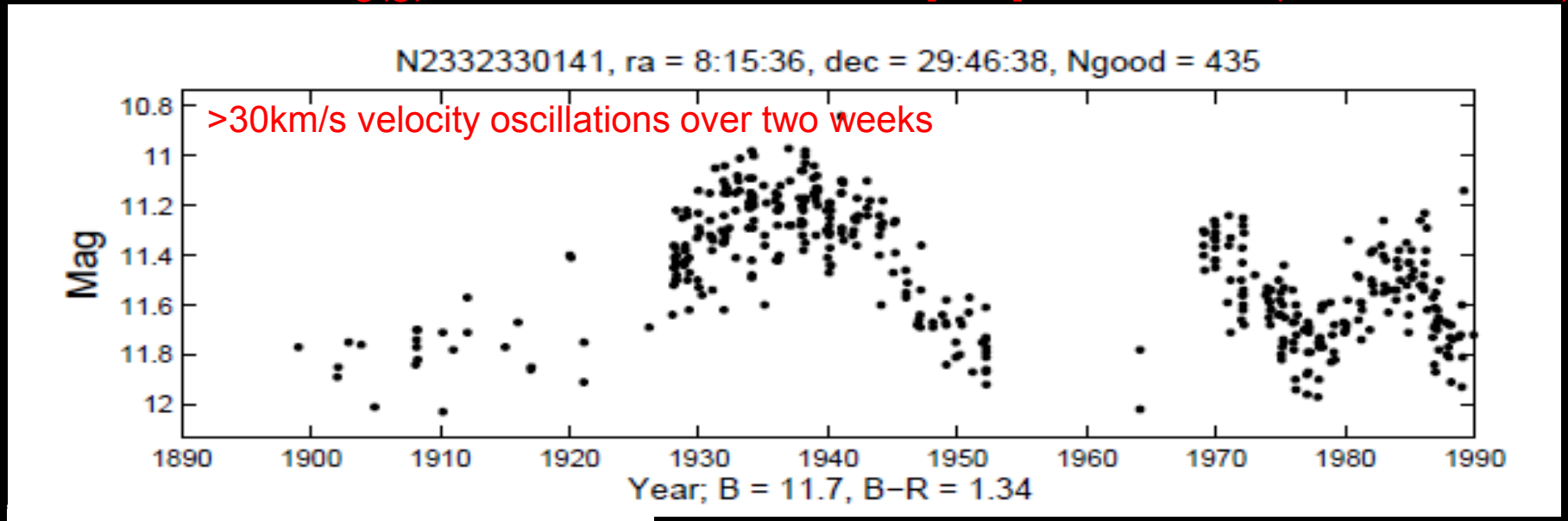
- Companion may play an important role (Kato & Hachisu 2011): a closer companion helps drive wind loss => shorter timescales
- With P=119 days, J0757 is at the valley between symbiotic novae (P>2 yr) and novae in close binaries (P<1 day)

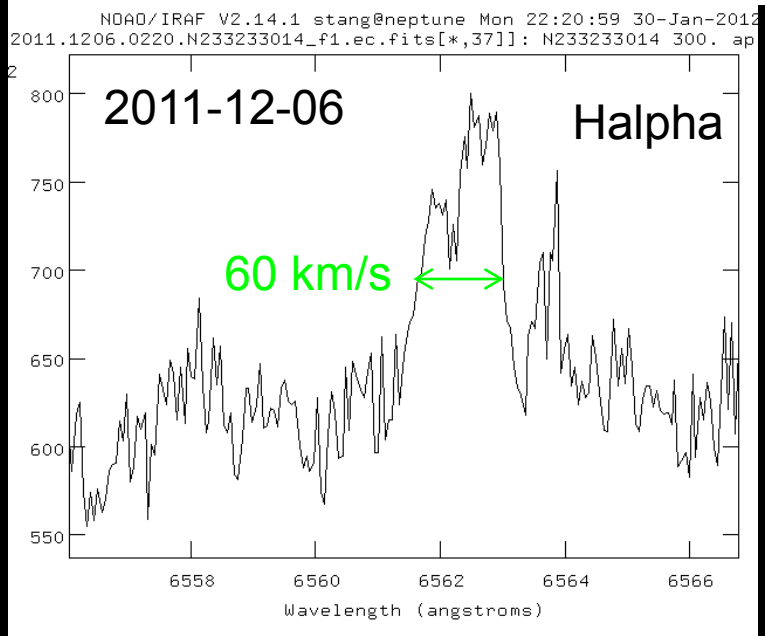
Kato & Hachisu (2011): all w/ 0.6 Msun WD

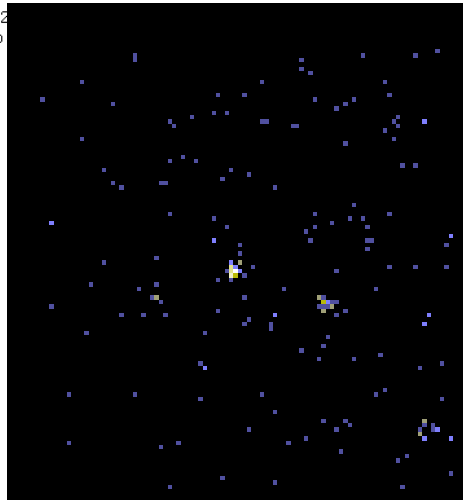


A G8-K0 dwarf binary with variations over decades

Teff=5250+/-125, log(g)=4.50+/-0.25, Vrot=16+/-2, [m/H]=0.00+/-0.25 (Lars Buchhave)



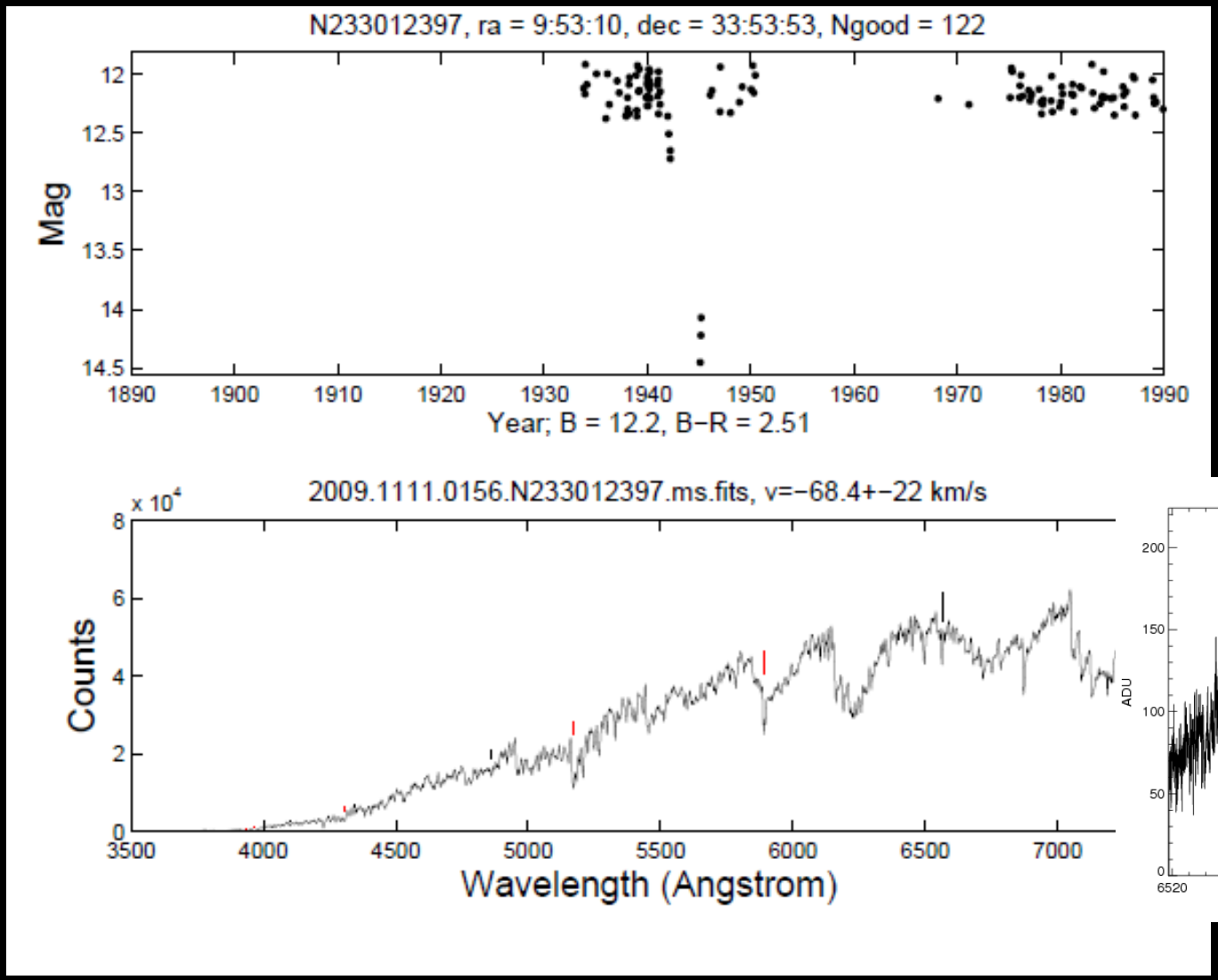




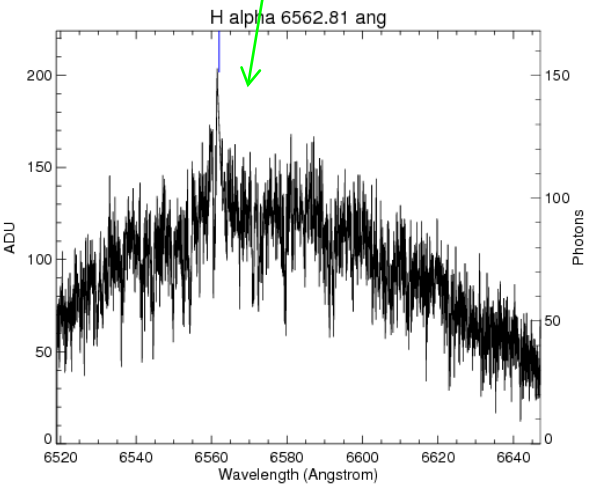
RASS 75'x75'

Also a ROSAT source
0.1 cts/s =>
L(0.1-2.4 keV)=4x10^{30} erg/s
(Sun: L_X~10^{27}-10^{28} erg/s)

An M0III star with a 2yr+ dimming event:



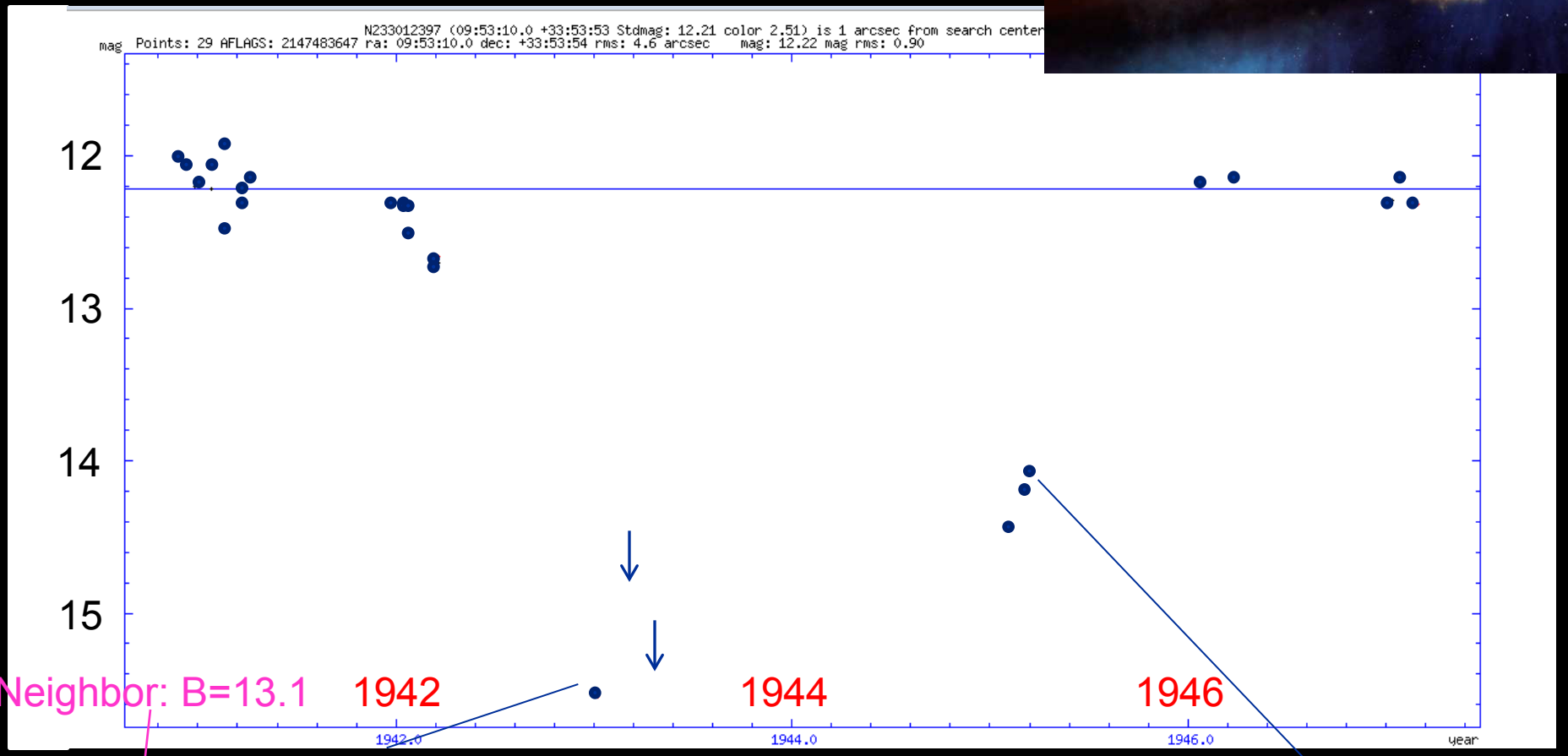
Halpha emission?



Dust process? ε Aurigae-like (8 AU disk)?

Eclipsed by a foreground cloud? 4yr x 10km/s = 8 AU

No significant 2MASS (JHK) & AKARI/IRC(9micron) flux excess



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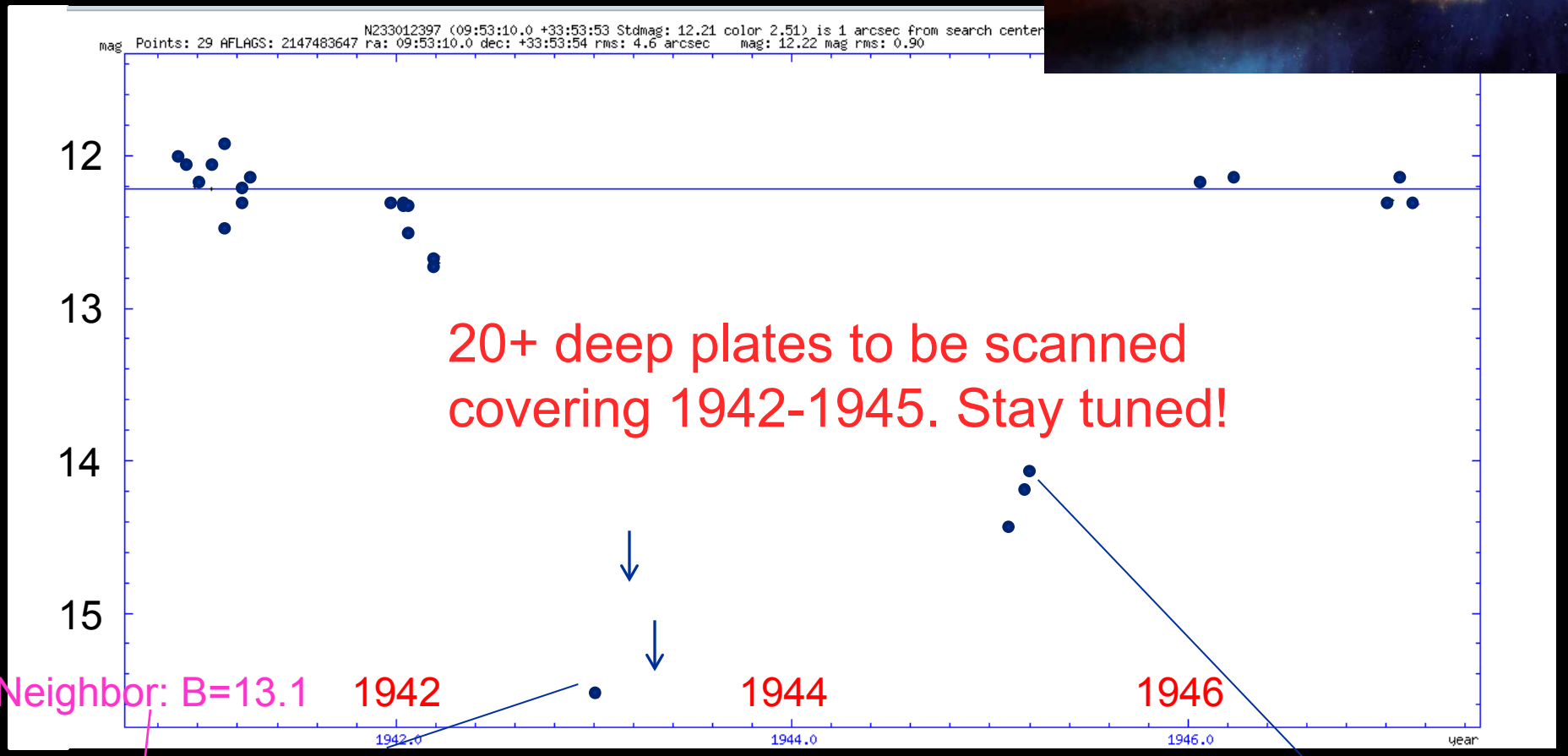
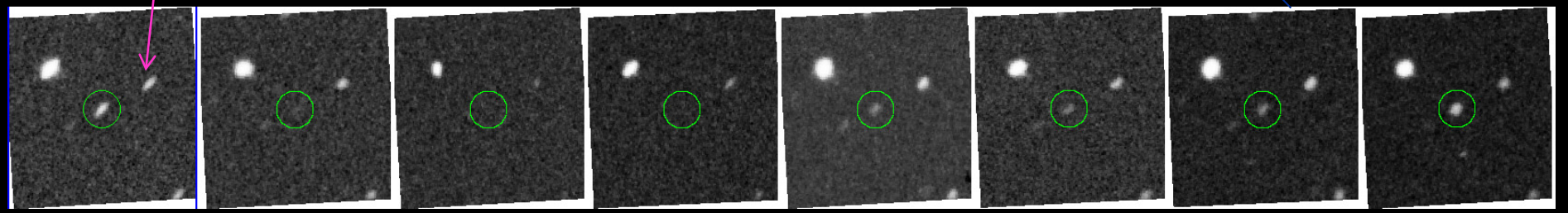
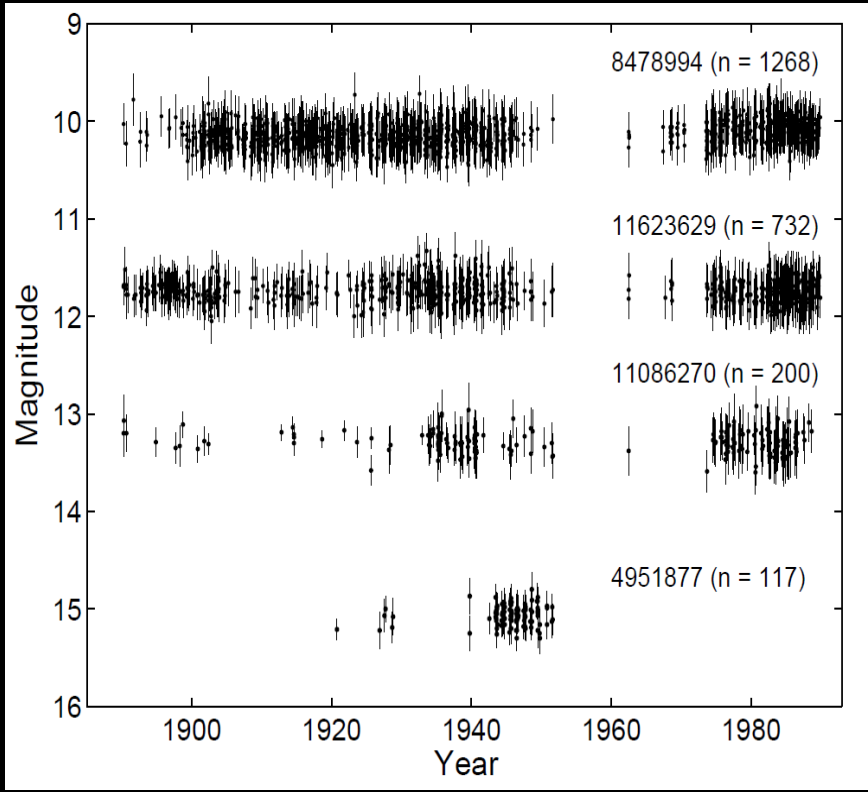


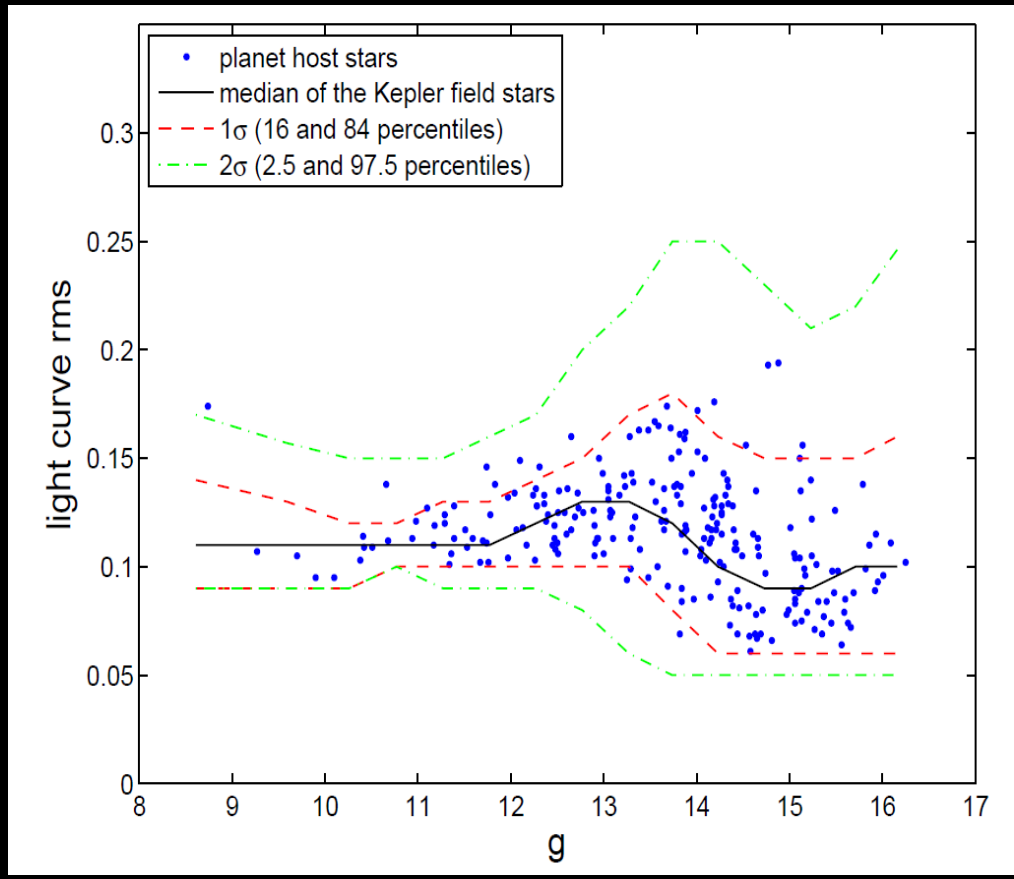


Kepler planet-candidate host stars

Tang et al. 2012b

Example light curves:





No variation detected for bright ones with good DASCH coverage

Agree with the assumption that these are MS stars (support the hypothesis that the transit signals not due to background giant binaries).

And good news for the habitability of the plants.

Summary

We have developed DASCH photometry and variable search pipeline, which enables us to explore stellar variations over decades.

DASCH discoveries:

- A 5-yr dust-accretion event in KU Cyg: first evidence of dust transportation and evaporation in an accretion disk
- A group of large amplitude Be variables which might be Be X-ray binaries (Be + Neutron star); opens a new window of hunting for high mass X-ray binaries
- Long-term K giant variables with ~1 mag variations over decades: provide new insights into dust formation processes or extreme magnetic activities on stars
- DASCH J0757: a peculiar outburst in a peculiar symbiotic system, may be powered by nuclear burning without significant mass loss and thus the WD could grow.
- Another long-term variable may be a weird CV
- A candidate of Epsilon Aurigue-like system
- And many new variables…

Long-term variability of stars is a poorly-explored area
We found more UNKNOWNS than KNOWNS