

# A search for new variable stars using digitized Moscow collection plates

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# Talk plan:

- Intro to the Moscow plate collection
- Flatbed scanners we use
- Processing pipeline based on VaST
- Results

# MOSCOW COLLECTION OF ASTRONOMICAL PLATES (SAI)

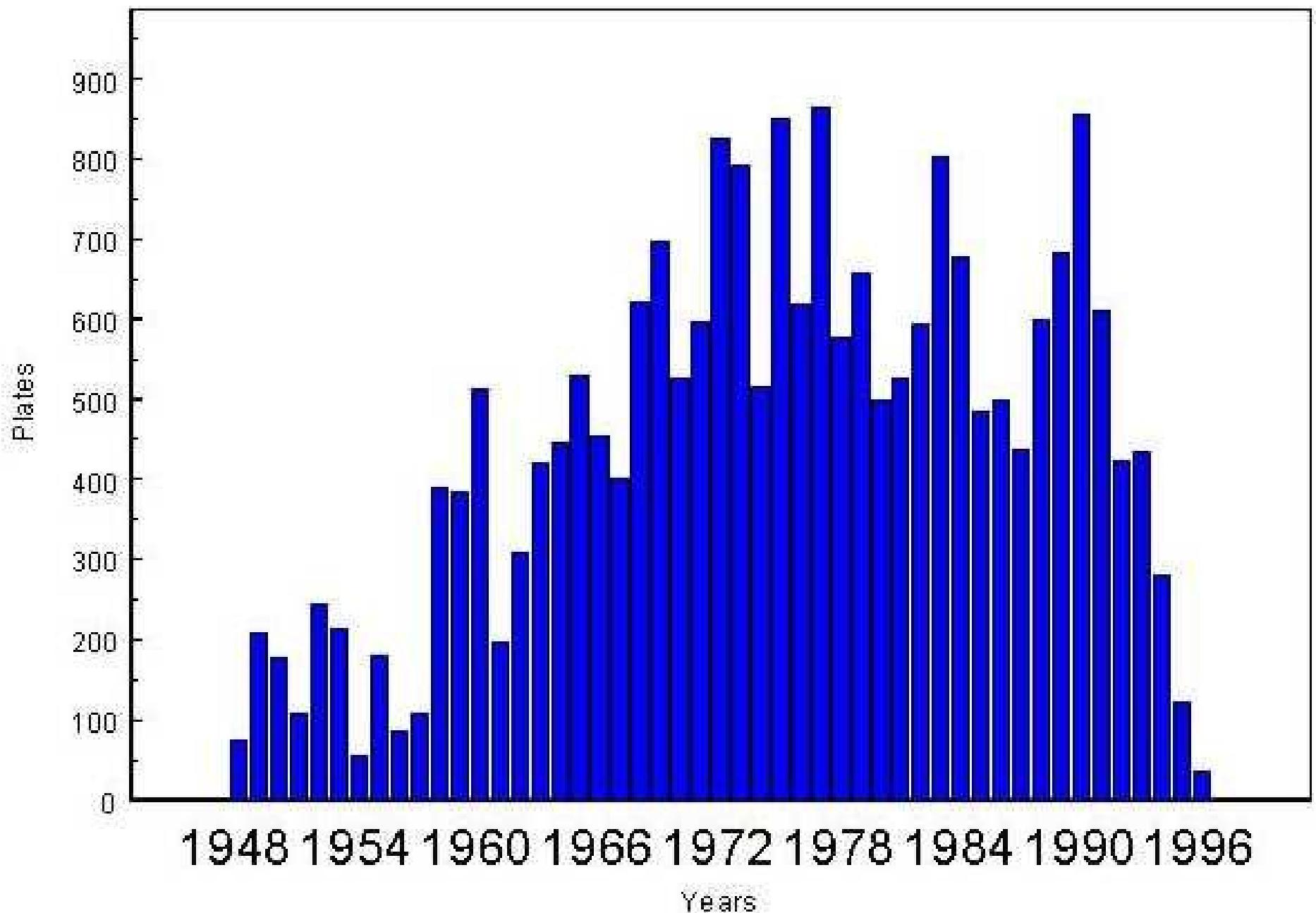
$D$ , cm	$F$ , cm	Field, degrees	$m_{\text{lim}}$	Years	$N$	Site
10	64	20×28	13–14	1895–1933	1100	Moscow
16	82	16×22	14	1933–1956	2700	Moscow
23	230	6×6		1955–1991	10000	Moscow etc.
38	640	1.4×1.4	14	1902–1972	6400	Moscow
40	160	10×10	17–18	1948–1996	22300	Kuchino, Crimea
50	200	3.5×3.5	18–19	1958–2004	10000	Crimea
50	200	Спектры		1959–2004	2300	Crimea
70	1050	0.6×0.6	13–18	1961–1995	9500	Moscow

Plus other plates and films of lower significance (after Shugarov, Antipin, Samus, and Danilkina, 1999, with corrections and additions).

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**Time distribution of 22300 40-cm-astrograph plates.**  
Typical exposure time: 45 min.;  $B_{\text{lim}} \sim 17.5$

# Motivation

- Originally these plates were obtained for variable star studies.
- Can we bring this work to a new level applying computers?
- *Utilize all information stored on plates* (not possible with traditional methods).

# The OLD scanners



**Resolution:**  
**2540 dpi**  
**(1.2"/pix)**

**Color depth:**  
**48 bit**  
**(16 bit/color)**

**Interface:**  
**SCSI**

**Can scan a  
30x30cm plate  
in 1h 20m**

**The CREO/Kodak EverSmart Supreme II scanners  
used at the Sternberg Institute in 2006 - 2011.**

# The NEW scanner



**Resolution:**  
**2400 dpi**  
**(1.4"/pix)**

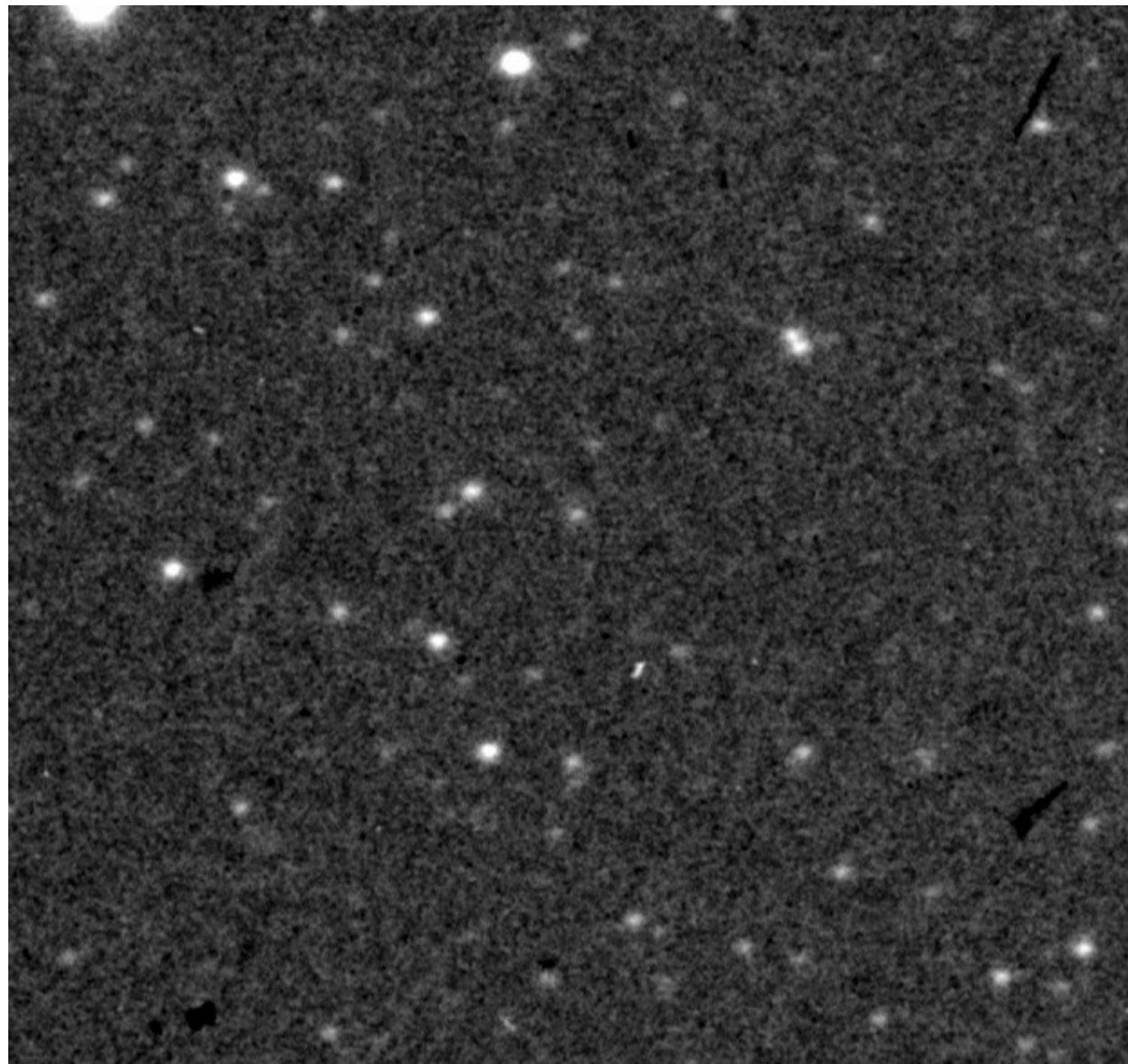
**Color depth:**  
**48 bit**  
**(16 bit/color)**

**Interface:**  
**USB3**

**Can scan a  
30x30cm plate  
in 40m**

**The Epson Expression 11000XL installed at the Sternberg Institute in October 2013.**

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**Color depth:**  
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**Interface:**  
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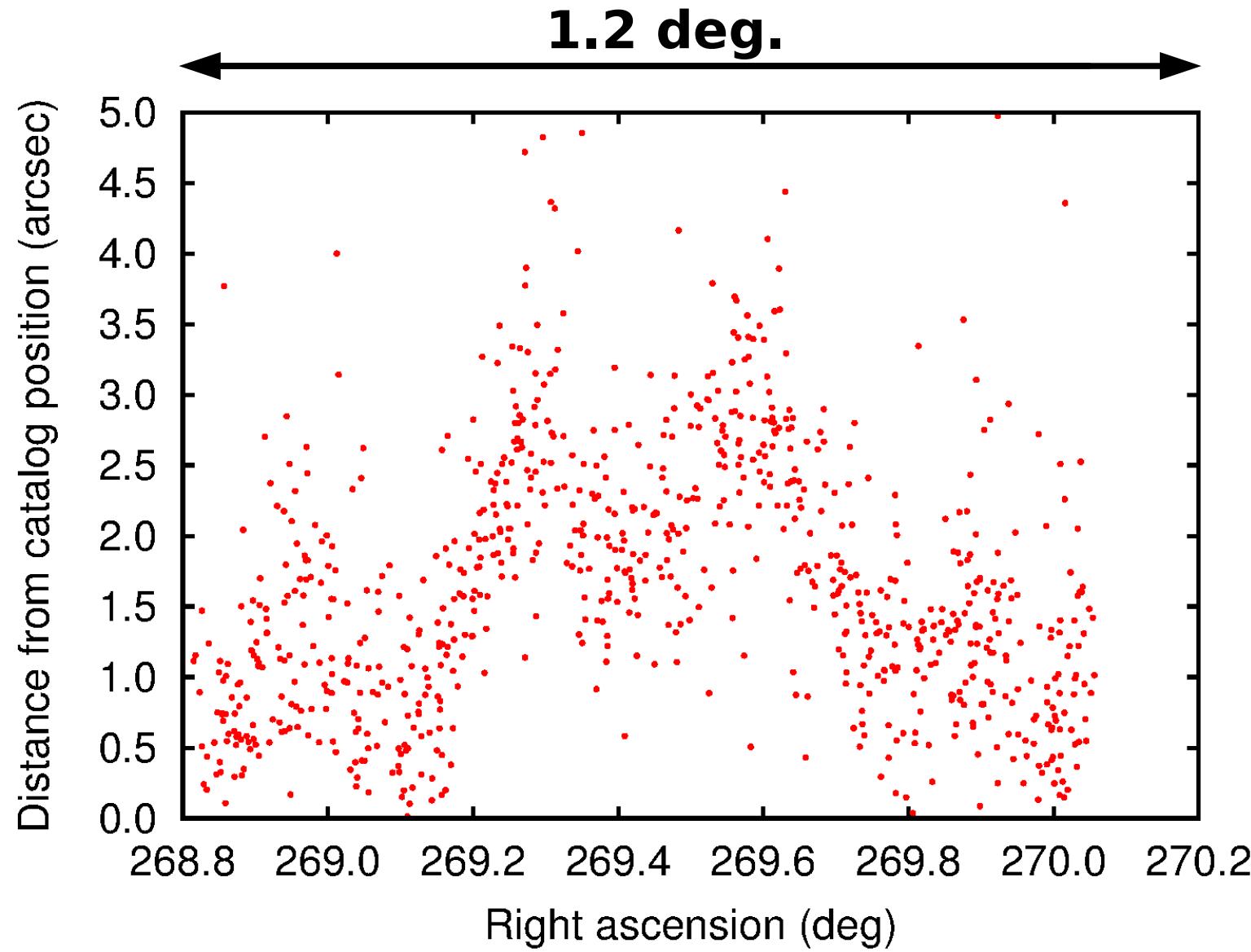
**Can scan a  
30x30cm plate  
in 40m**



**A 15'x15' field  
as an example**

# The NEW scanner

**is suffering from the irregular motion of the CCD  
problem, common to all flatbed scanners.**



# The workflow

1. Clean a plate and scan it to a **TIFF** image using software supplied with the scanner.
2. **TIFF** → inverted greyscale → **FITS**  
custom tiff2fits code available at <ftp://scan.sai.msu.ru/pub/software/tiff2fits/>
3. Insert **JD(mid. Exp.)** to FITS header
4. Determine a reference point at each image and cut the image into overlapping **subframes** ~1 deg. in size
5. Extract calibrated lightcurves using **VaST** (**SExtractor**, **Astrometry.net**, **USNO-B1.0**)
6. Search for variable stars among the lightcurves (**mag/RMS** plot, period search)

# The minimal FITS header

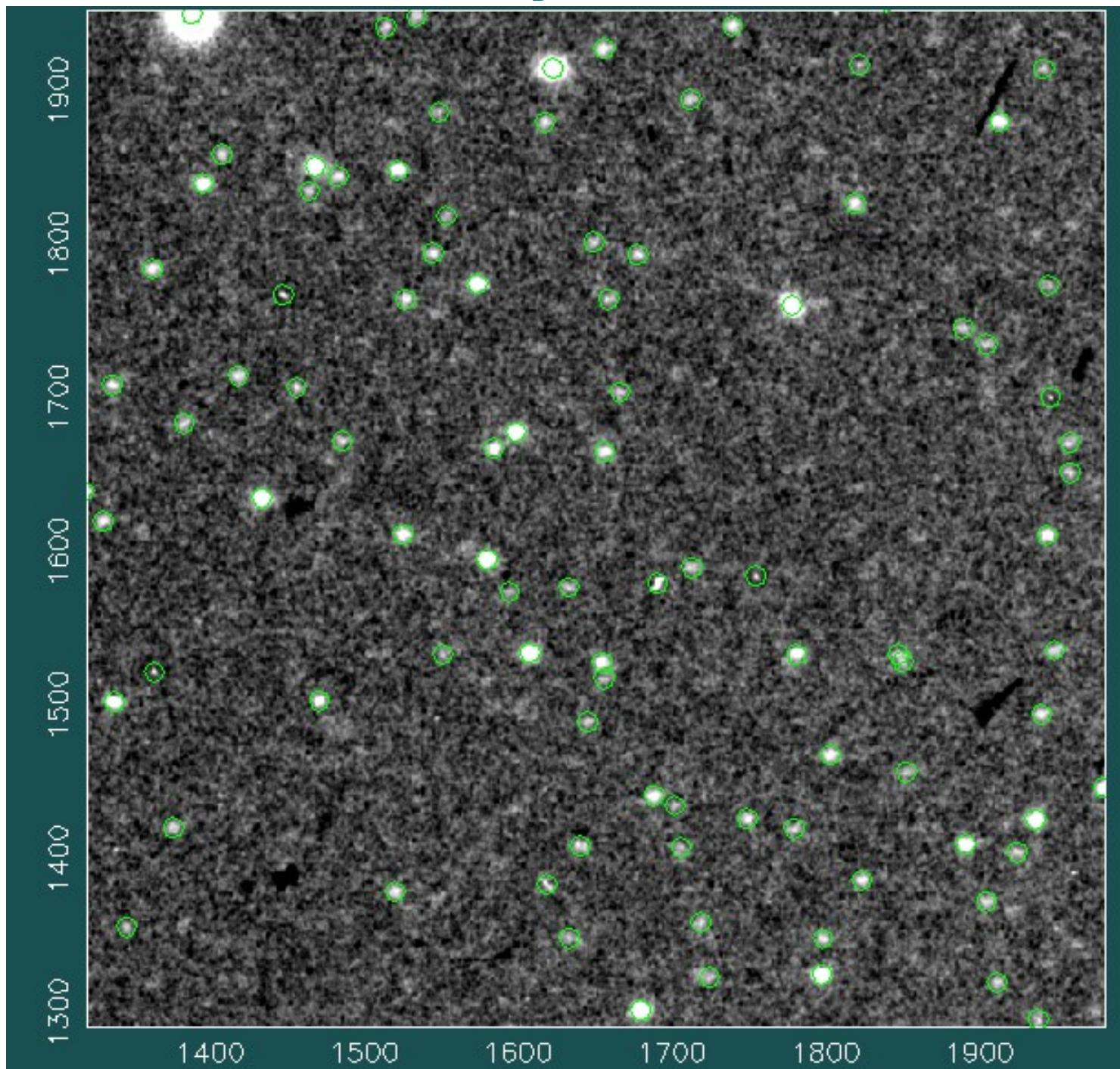
```
SIMPLE = T / file does conform to FITS standard
BITPIX = 16 / number of bits per data pixel
NAXIS  = 2 / number of data axes
NAXIS1 = 3307 / length of data axis 1
NAXIS2 = 3307 / length of data axis 2
EXTEND = T / FITS dataset may contain extensions
BZERO  = 32768 / offset
BSCALE = 1 / default scaling factor
JD      = 2442812.649
END
```

# Variability Search Toolkit (VaST)

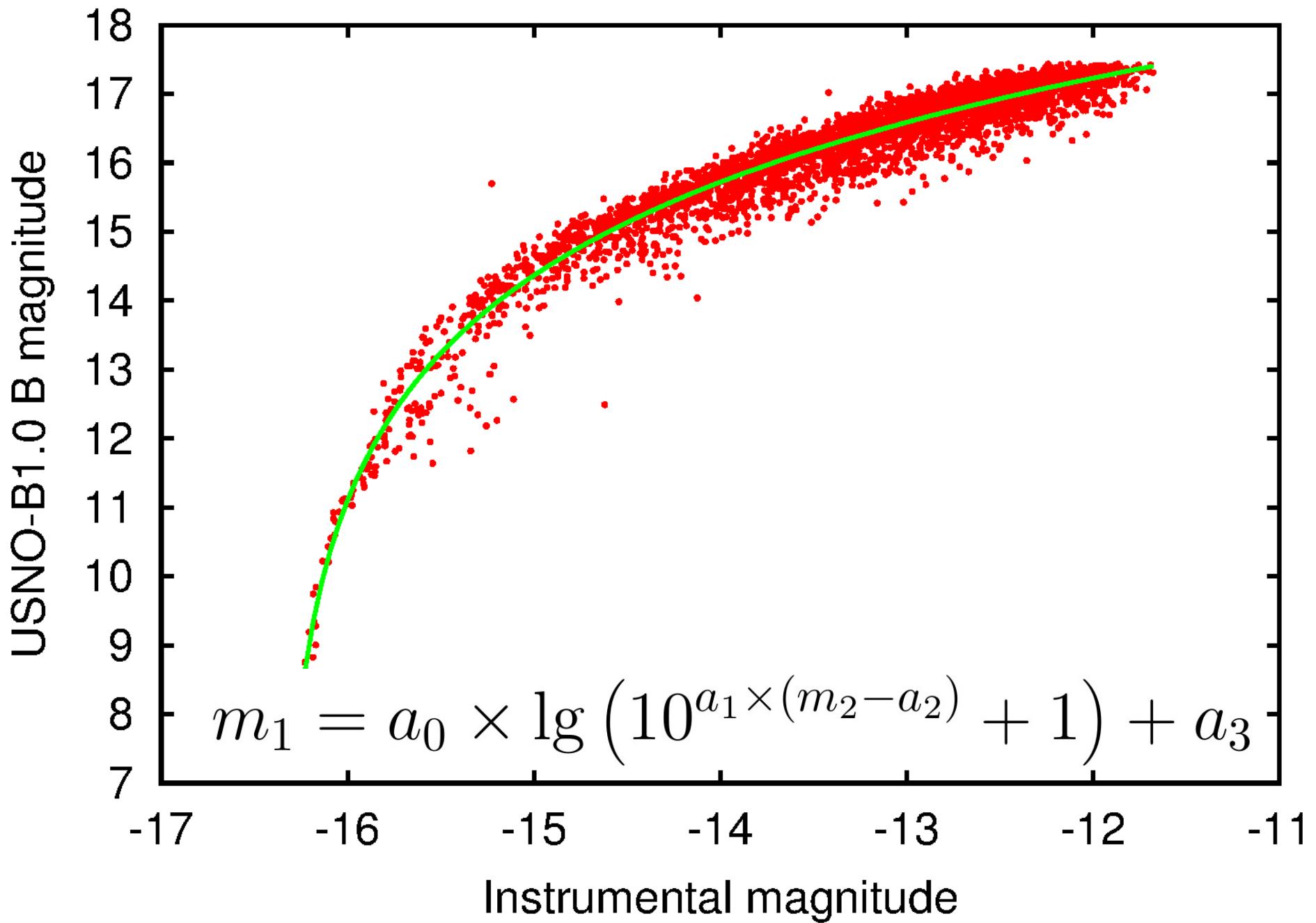
Open source general-purpose variability search software designed with photographic plates in mind:  
<http://scan.sai.msu.ru/vast/>

- Works on Linux and Mac OS.
- **SExtractor** (in CCD mode) for star detection and circular aperture photometry (aperture size adjusted for each image based on seeing)
- Star cross-matching and magnitude calibration
- Plate solution with **Astrometry.net** interface
- Absolute magnitude calibration with **cdstools**
- Integrated with online period-search tool  
<http://scan.sai.msu.ru/lk/>

# Star detection by SExtractor/VaST

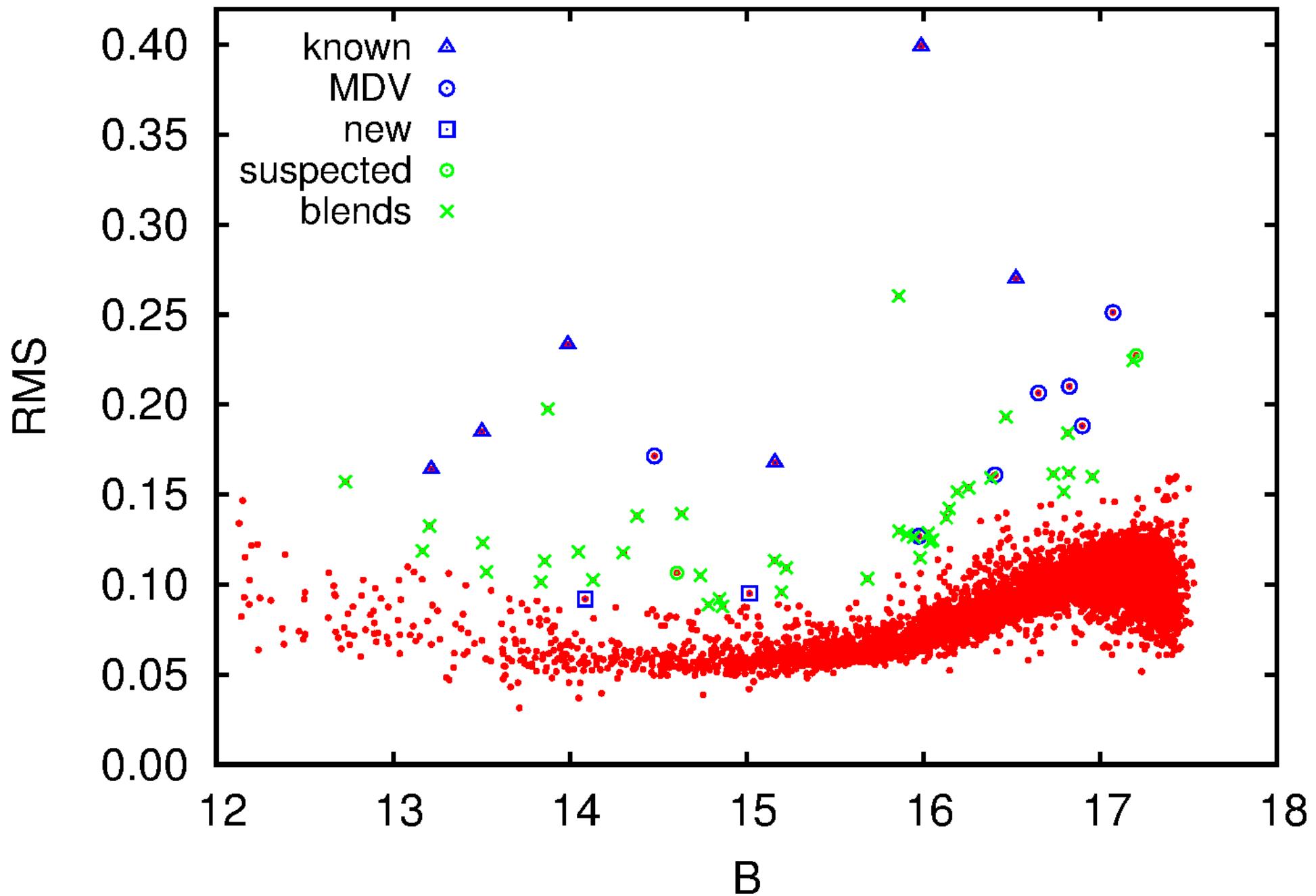


# Magnitude calibration

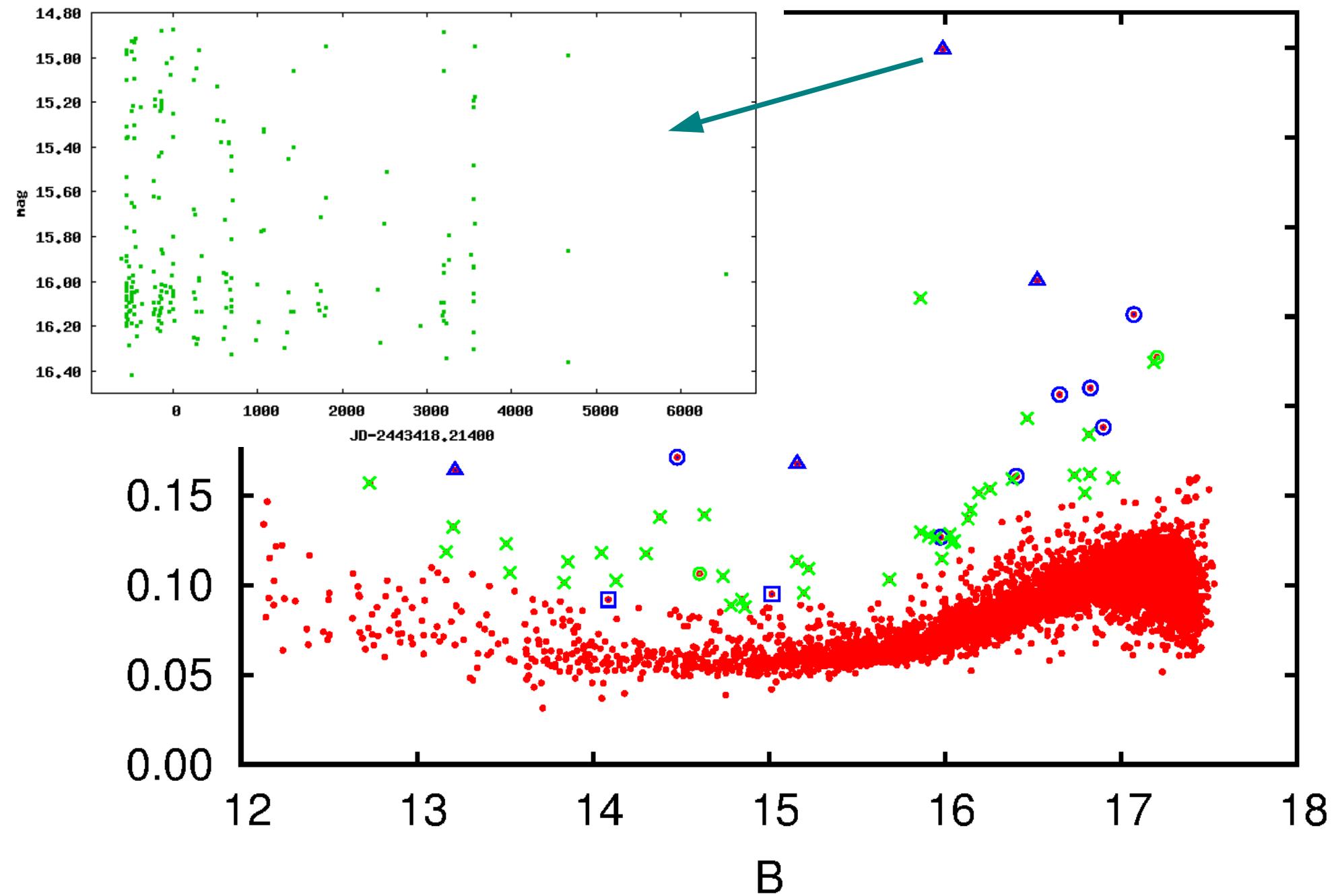


# Variable star search

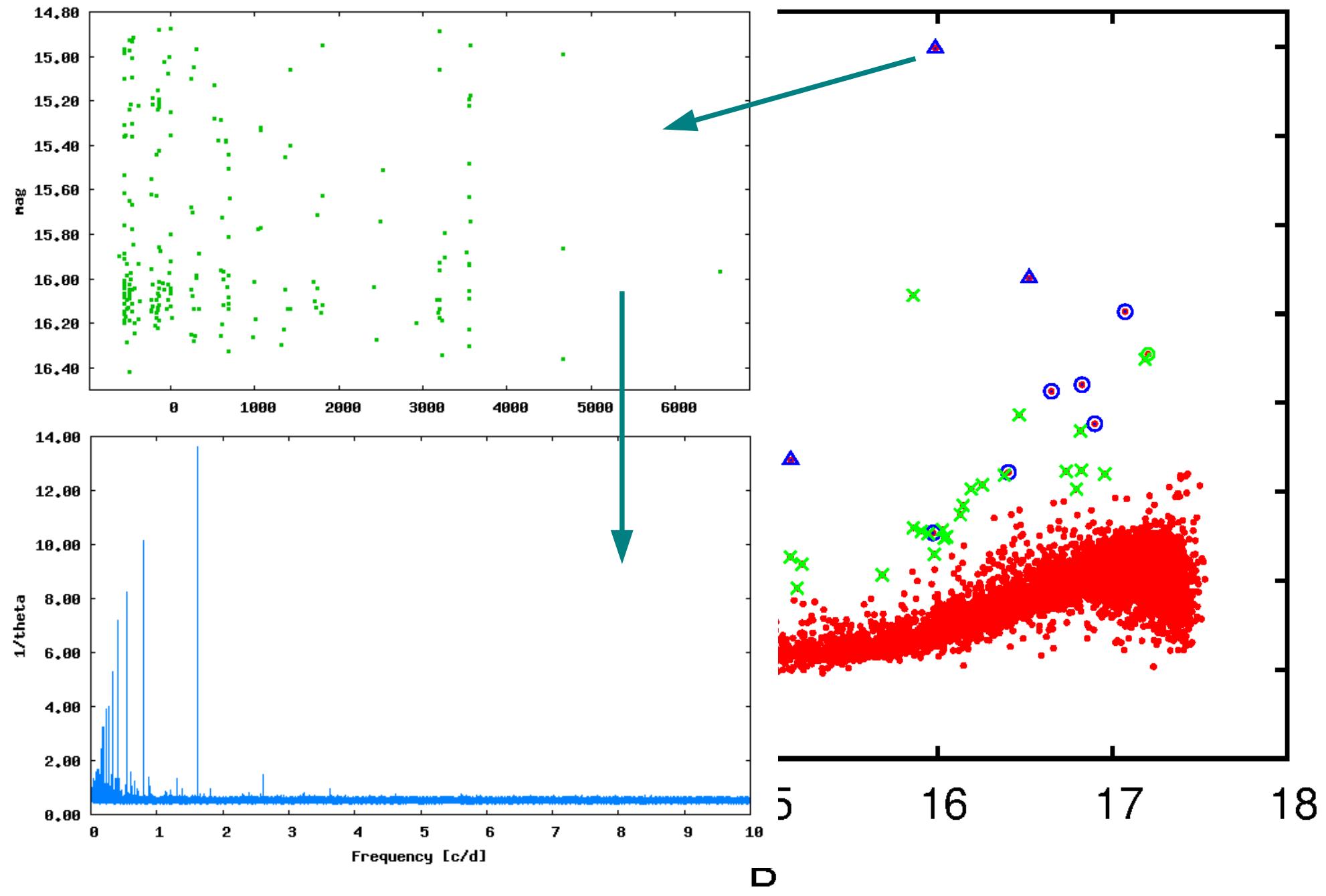
6300 stars in this 1.2x1.2 deg. field



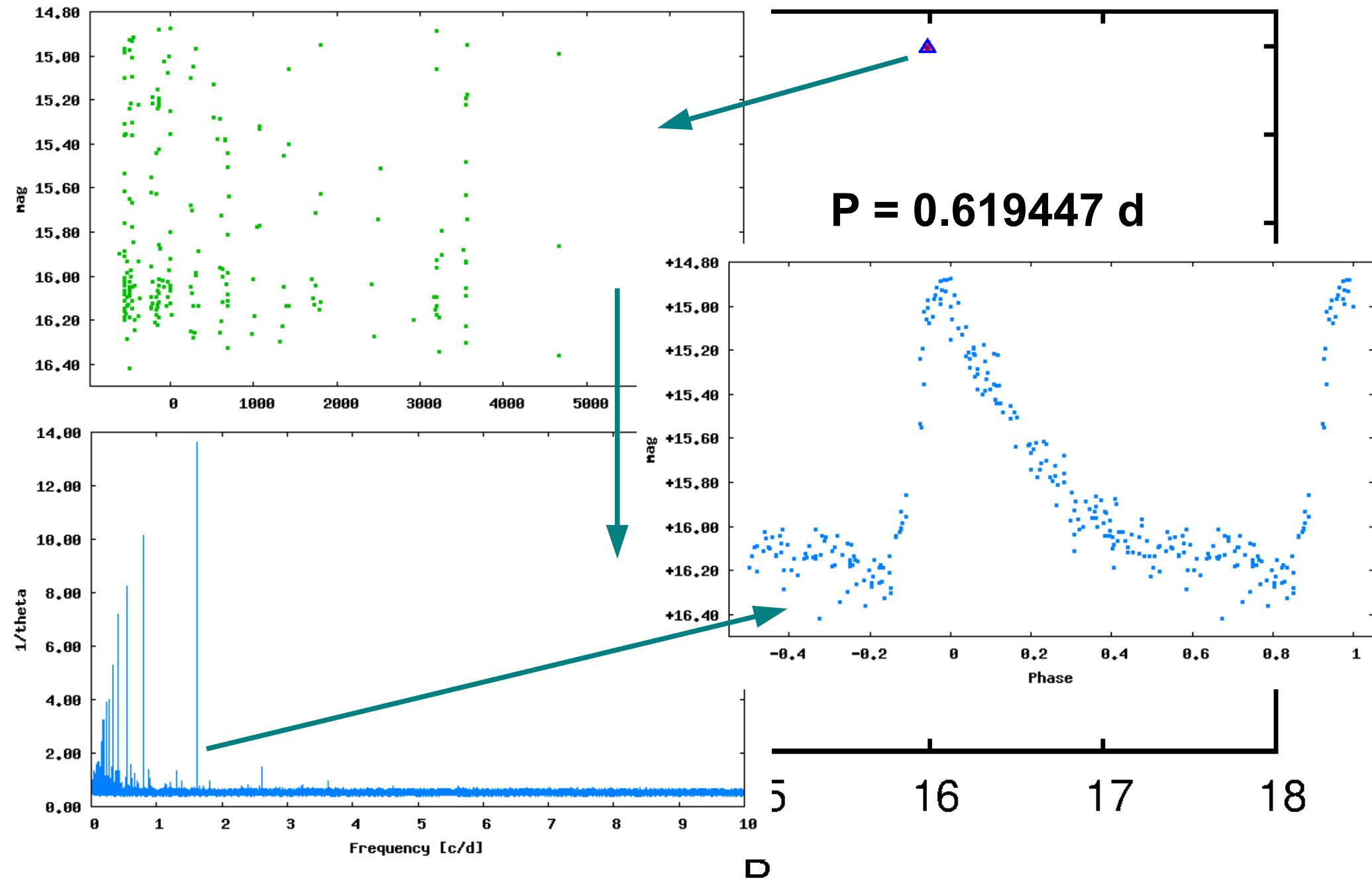
# V1013 Oph (RRAB type)



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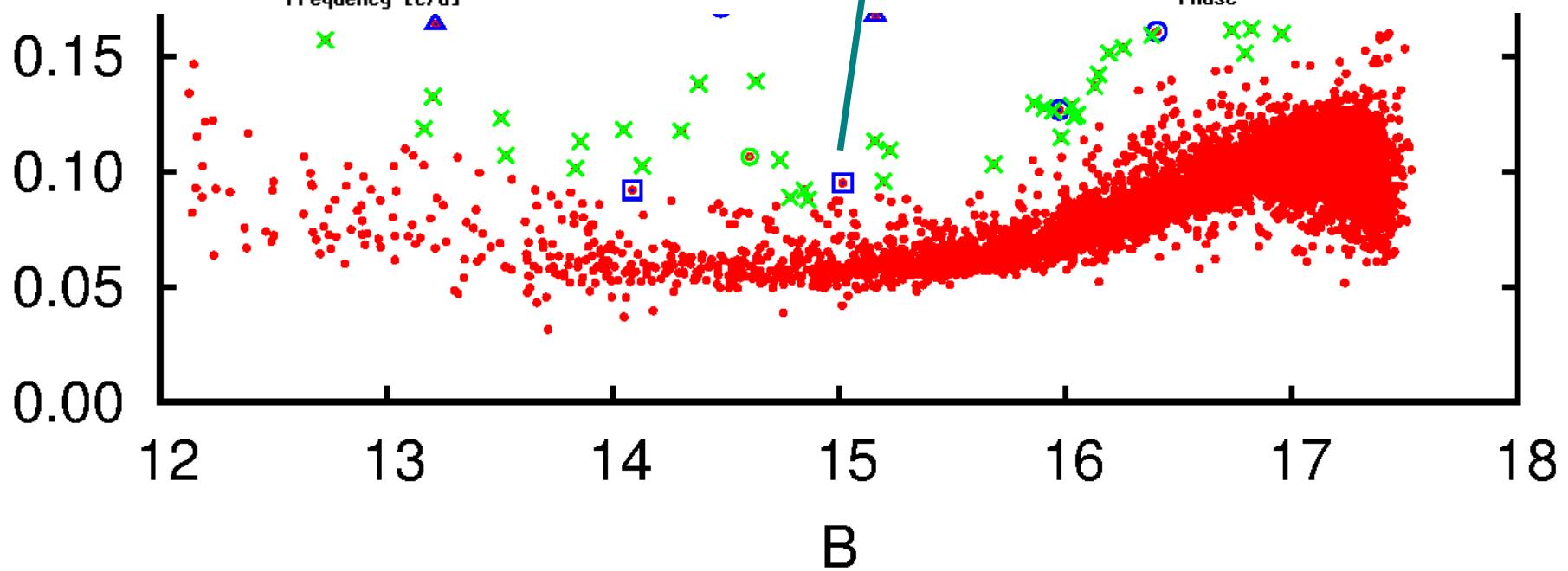
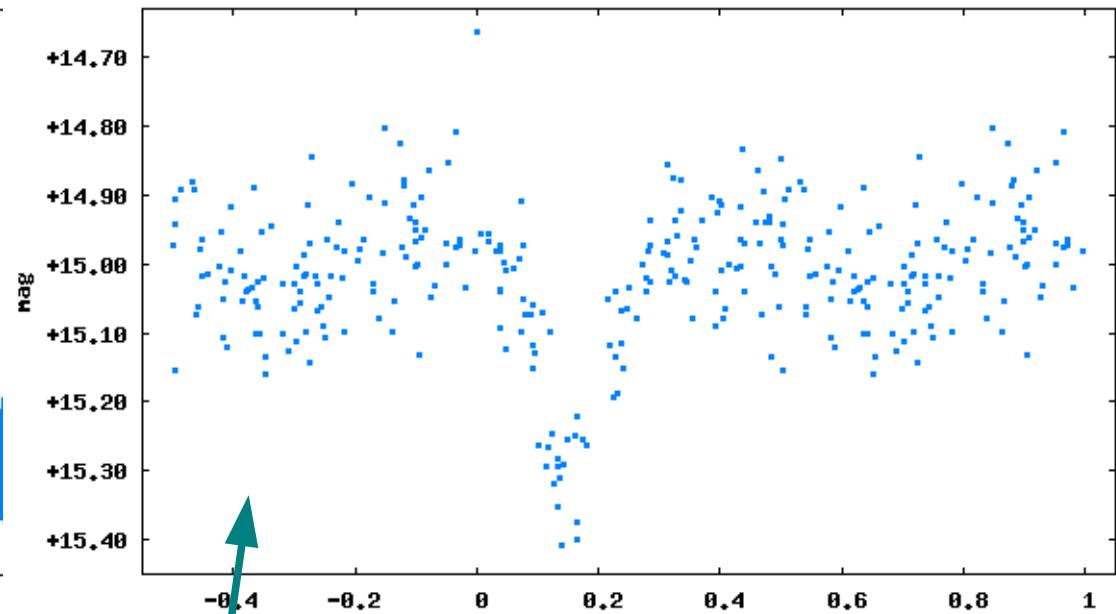
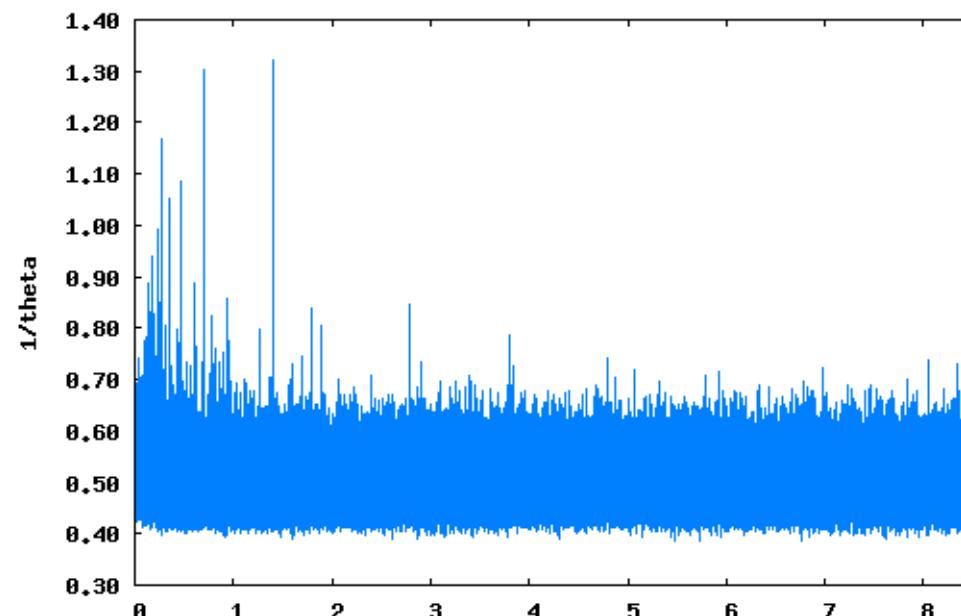


# V1013 Oph (RRAB type)

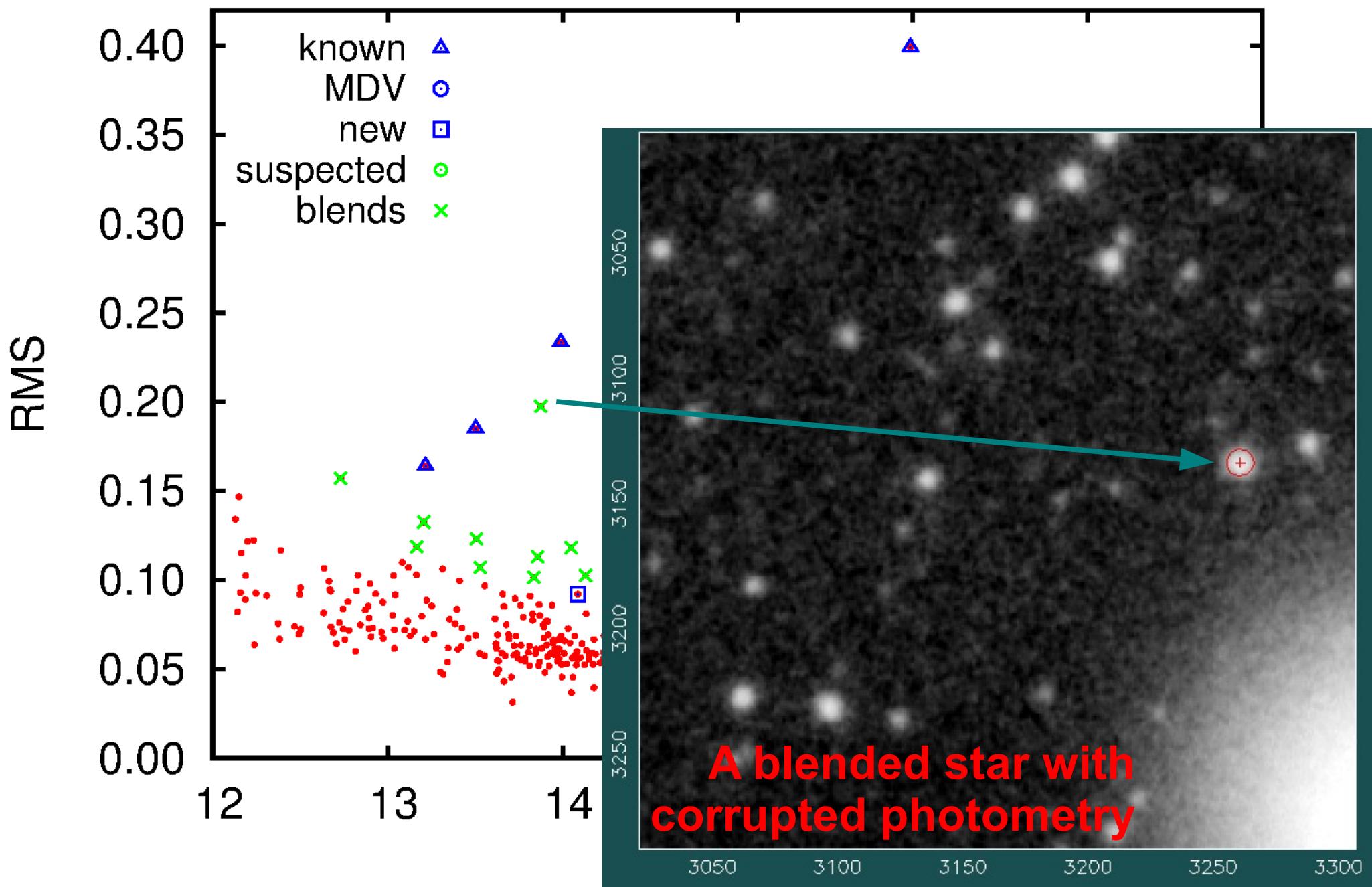


# New EA binary

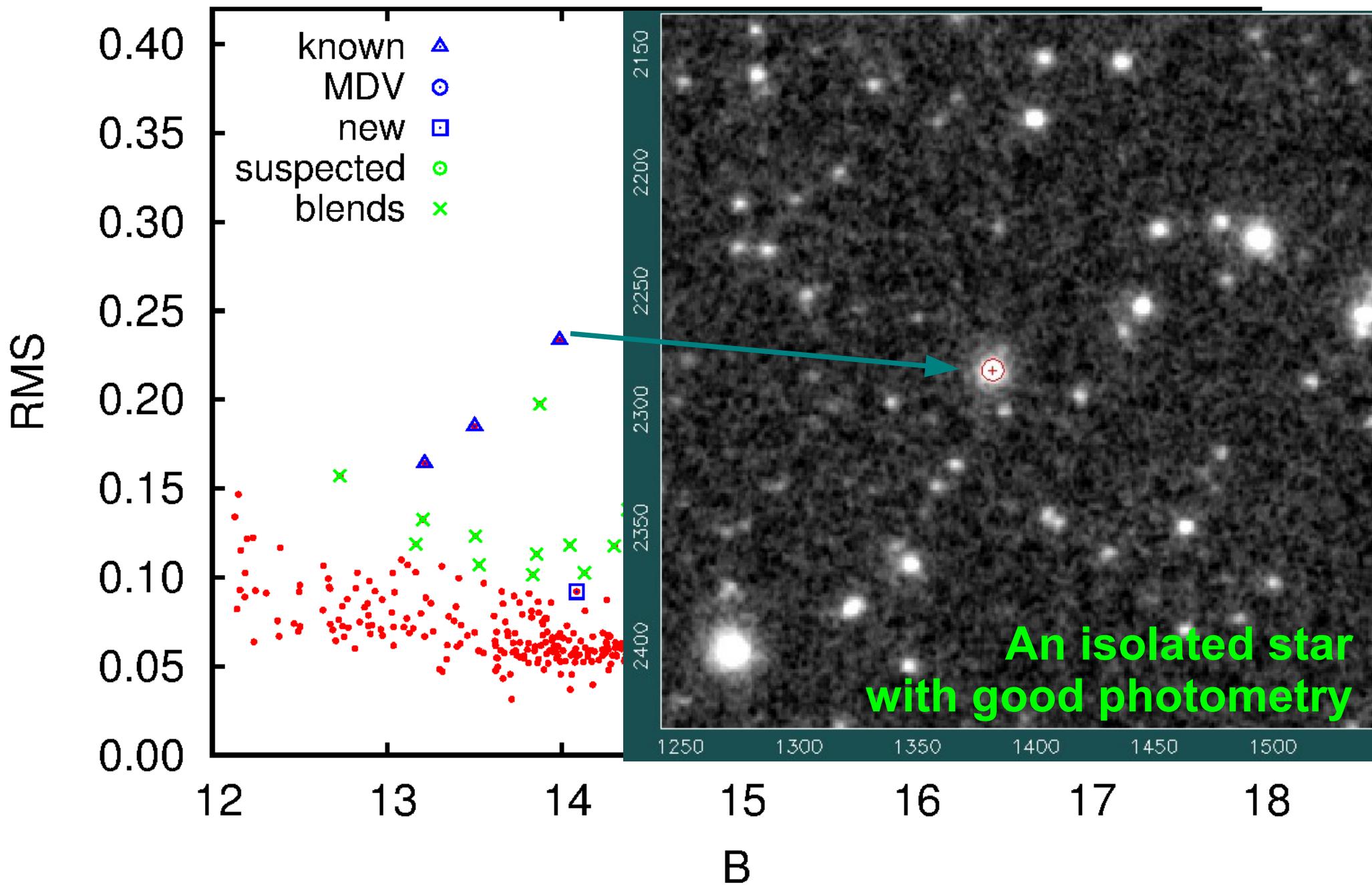
$P = 0.716296 \text{ d}$



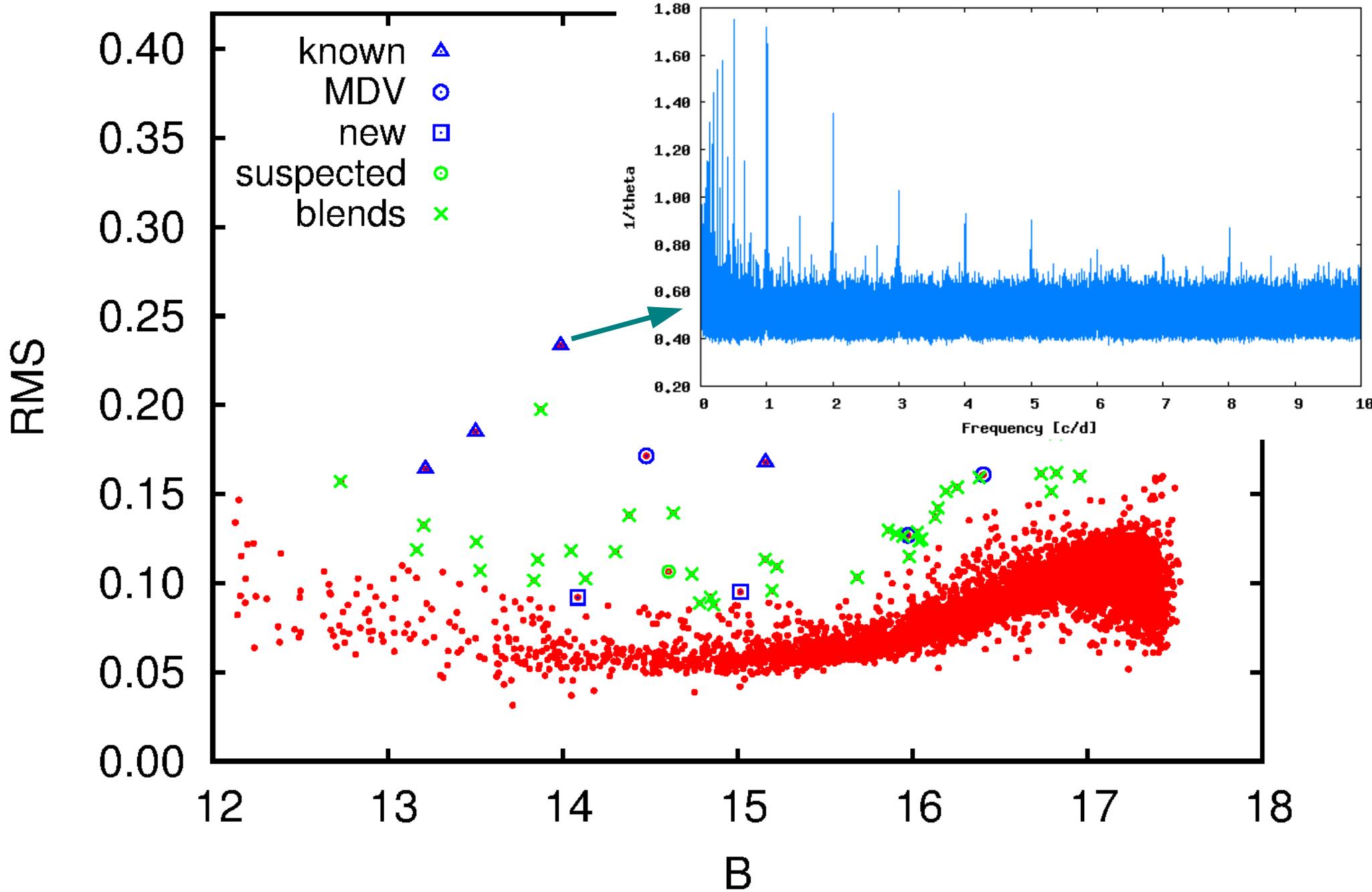
# A typical false alarm



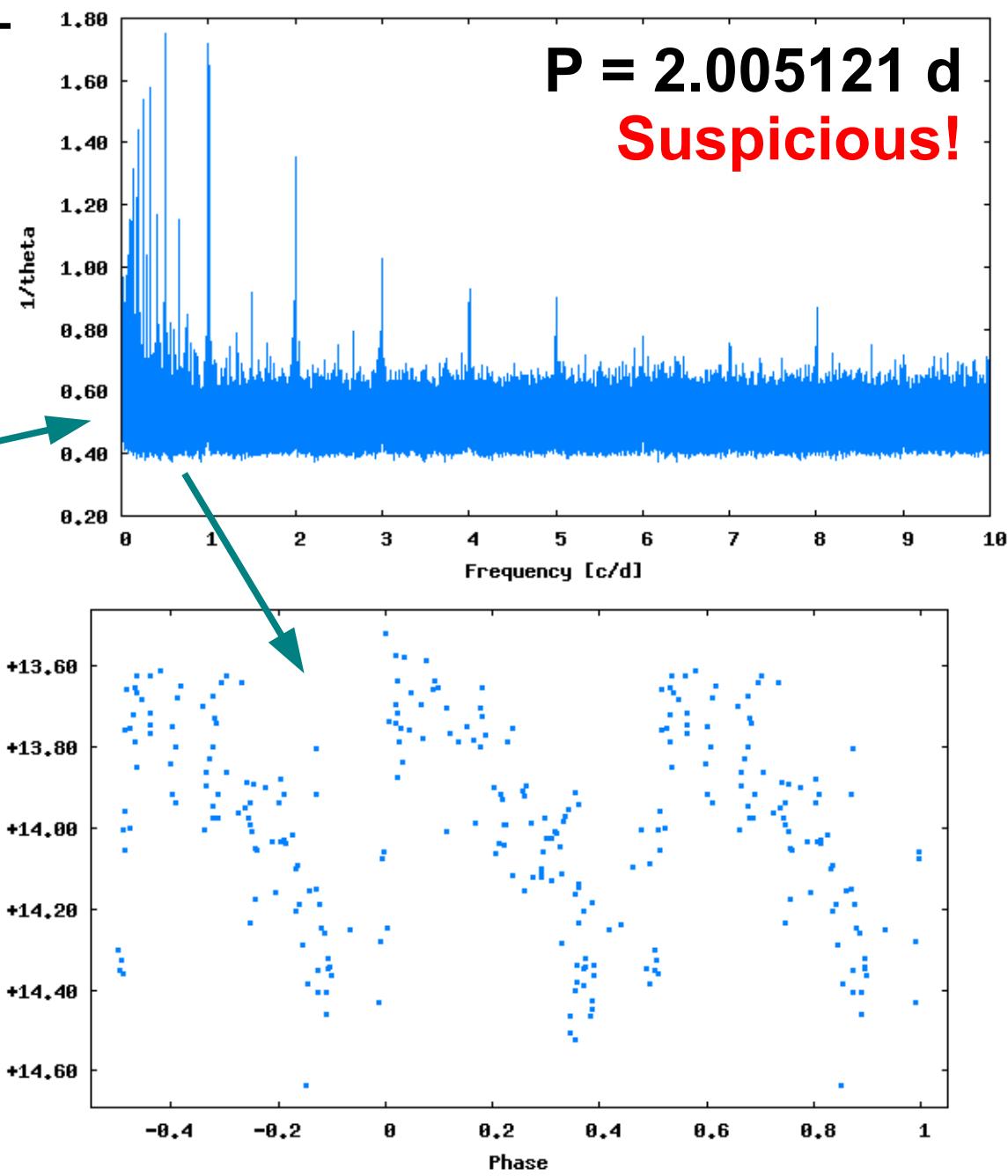
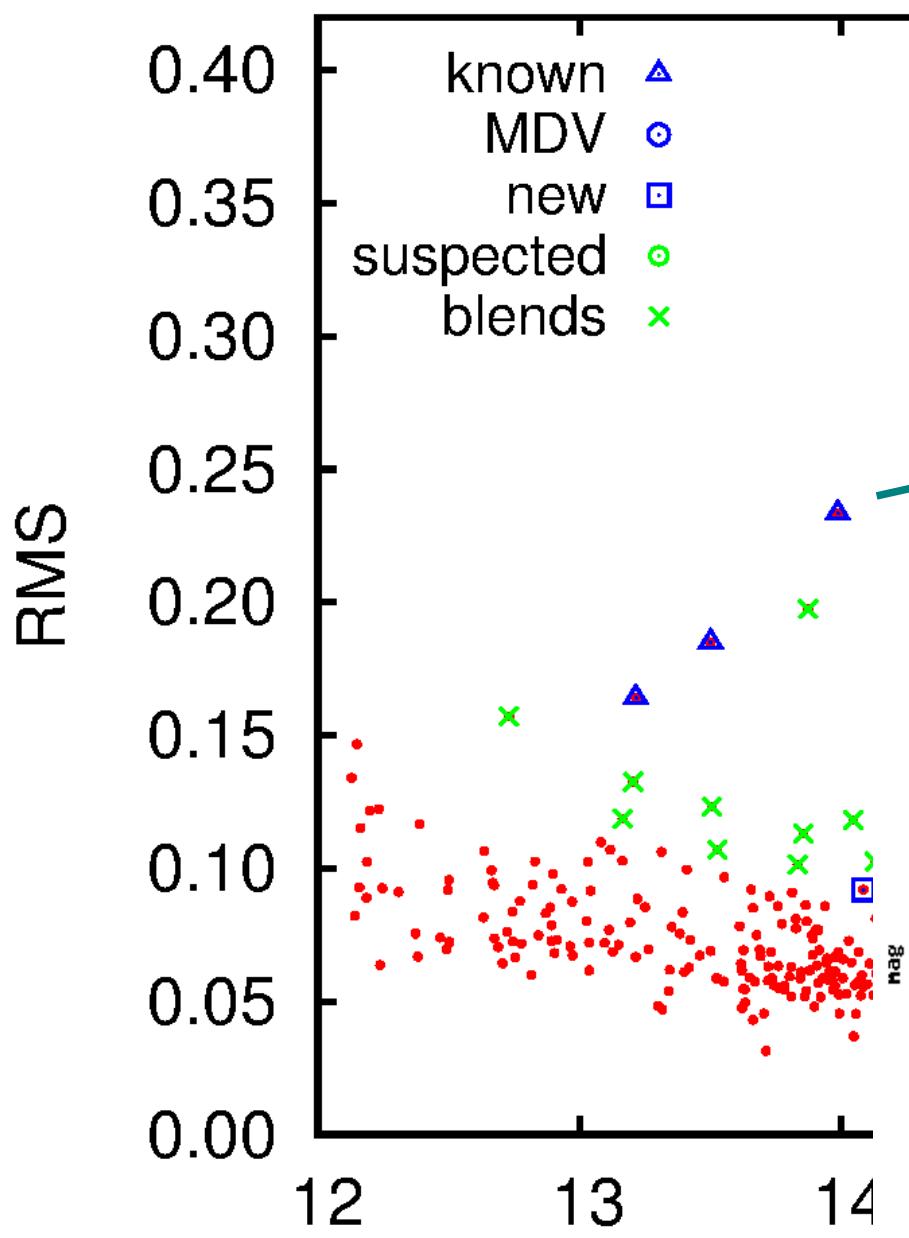
# ASAS J175719+0445.6 (L type)



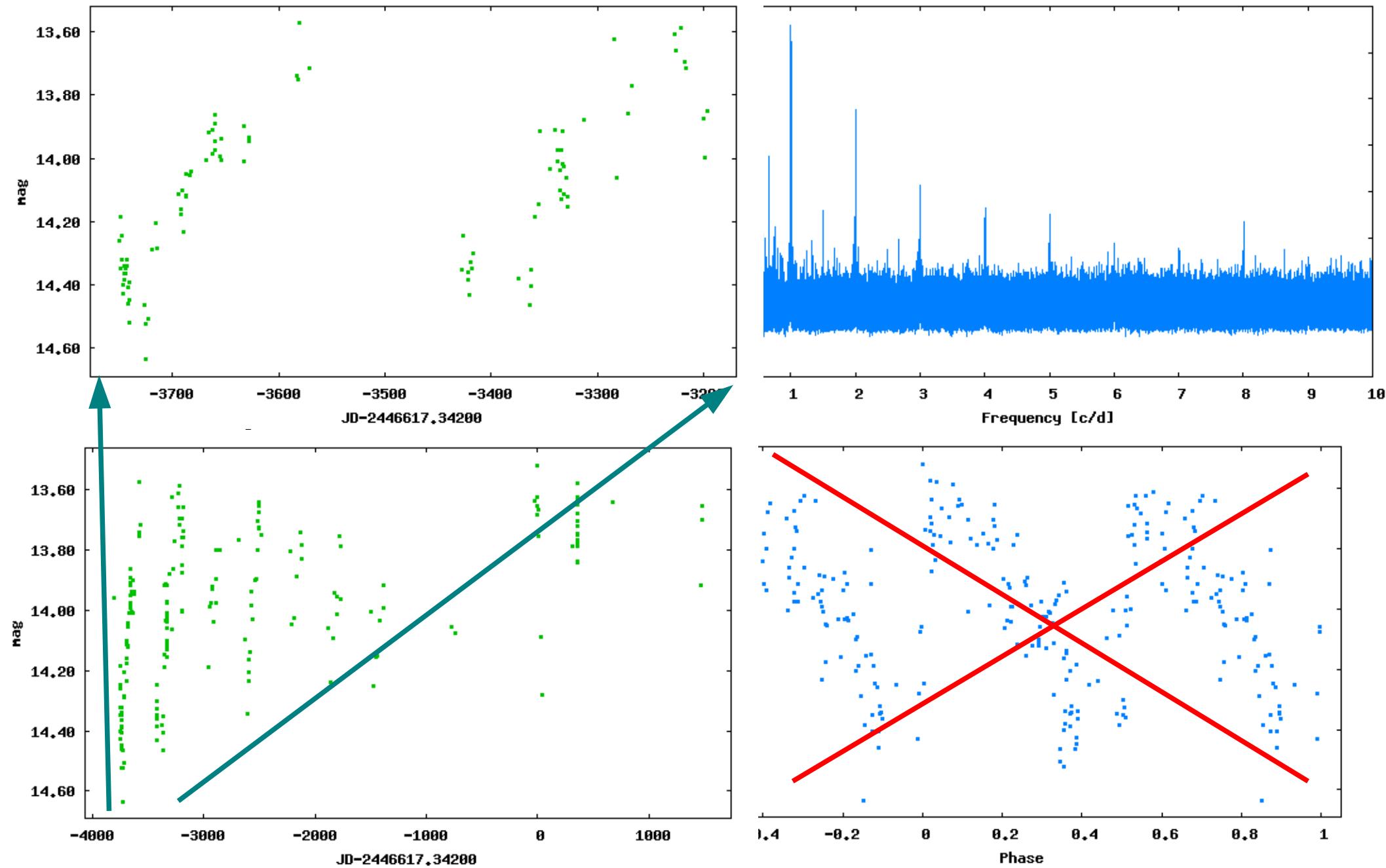
# ASAS J175719+0445.6 (L type)



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# ASAS J175719+0445.6 (L type)



# Results 1/2

Three 10x10 deg. fields are digitized using the OLD scanners:

- 66 Oph (254 plates exposed in 1976-1995)
- BD+60°636 (182 plates, 1949-1989)
- β Cas (391 plates, 1964-1994)

Search for variable stars using a combination of mag./RMS plot and period search completed in the first two fields: 557 new variable stars including 6 Cepheids (Type I and II), 147 RR Lyrae type variables, 12 HADS, 168 red (types SR and L) variables, 222 eclipsing binaries, 2 BY Dra.

# Results 2/2

Preliminary results - 50% of the  $\beta$  Cas field (391 plates, 1964-1994): 604 variable stars (454 new) among  $\sim 51000$  stars:

- $1.2 \pm 0.1\%$  of the stars show detectable light variations
- $0.7 \pm 0.1\%$  of the stars are eclipsing binaries ( $64 \pm 4\%$  of them are EA type,  $22 \pm 2\%$  are EW type and  $14 \pm 2\%$  are EB type)
- $0.3 \pm 0.1\%$  of the stars are red variable giants and supergiants of M, SR and L types