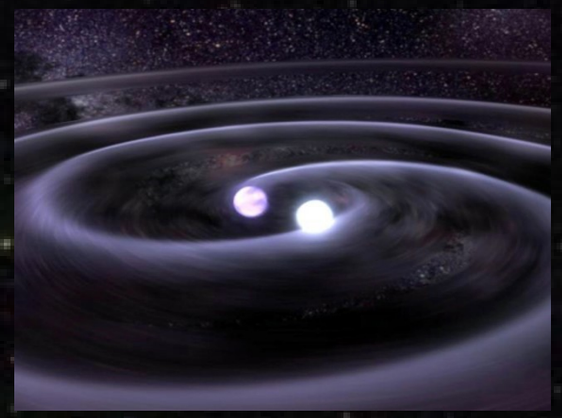
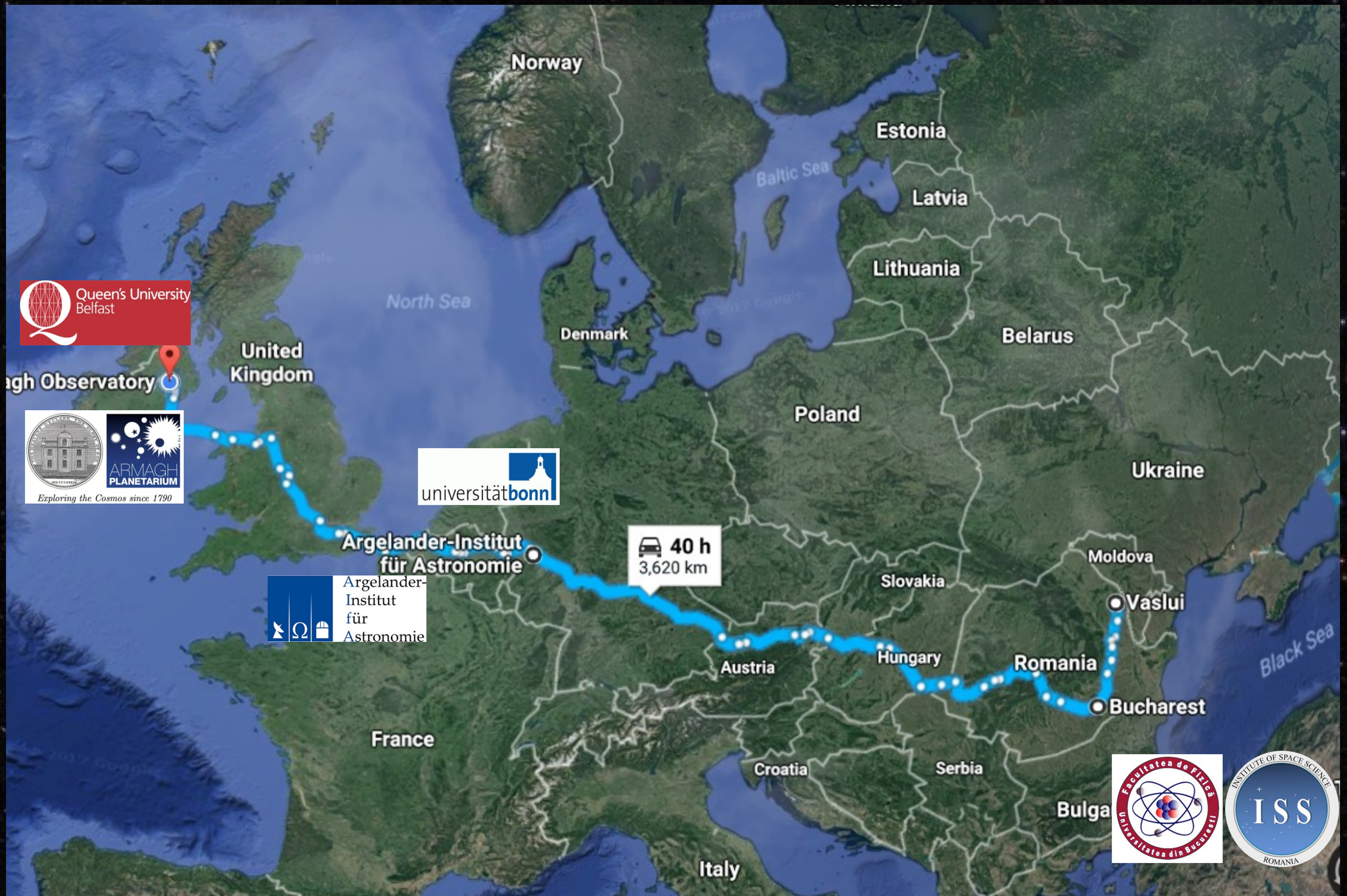
Short period variable stars in the OmegaWhite survey

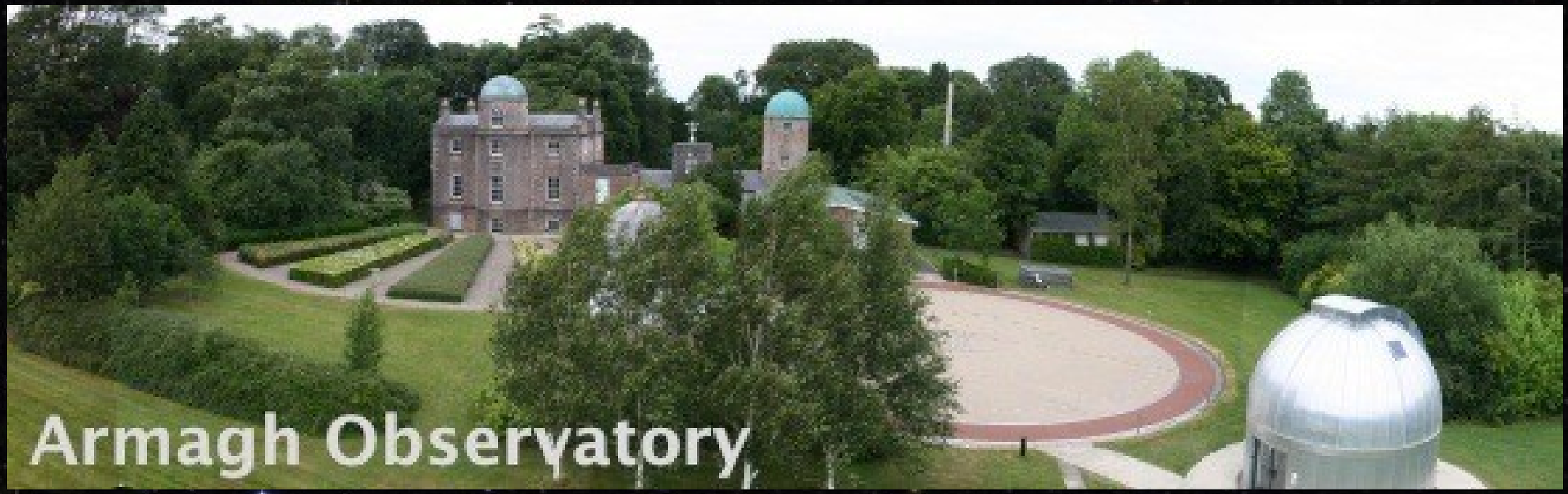


Ruxandra Toma, Gavin Ramsay, Simon Jeffery, Sally Macfarlane, Paul Groot, Patrick Woudt, Thomas Kupfer

Seminar, AIRA, Romania
12 Jan 2022
Online via zoom

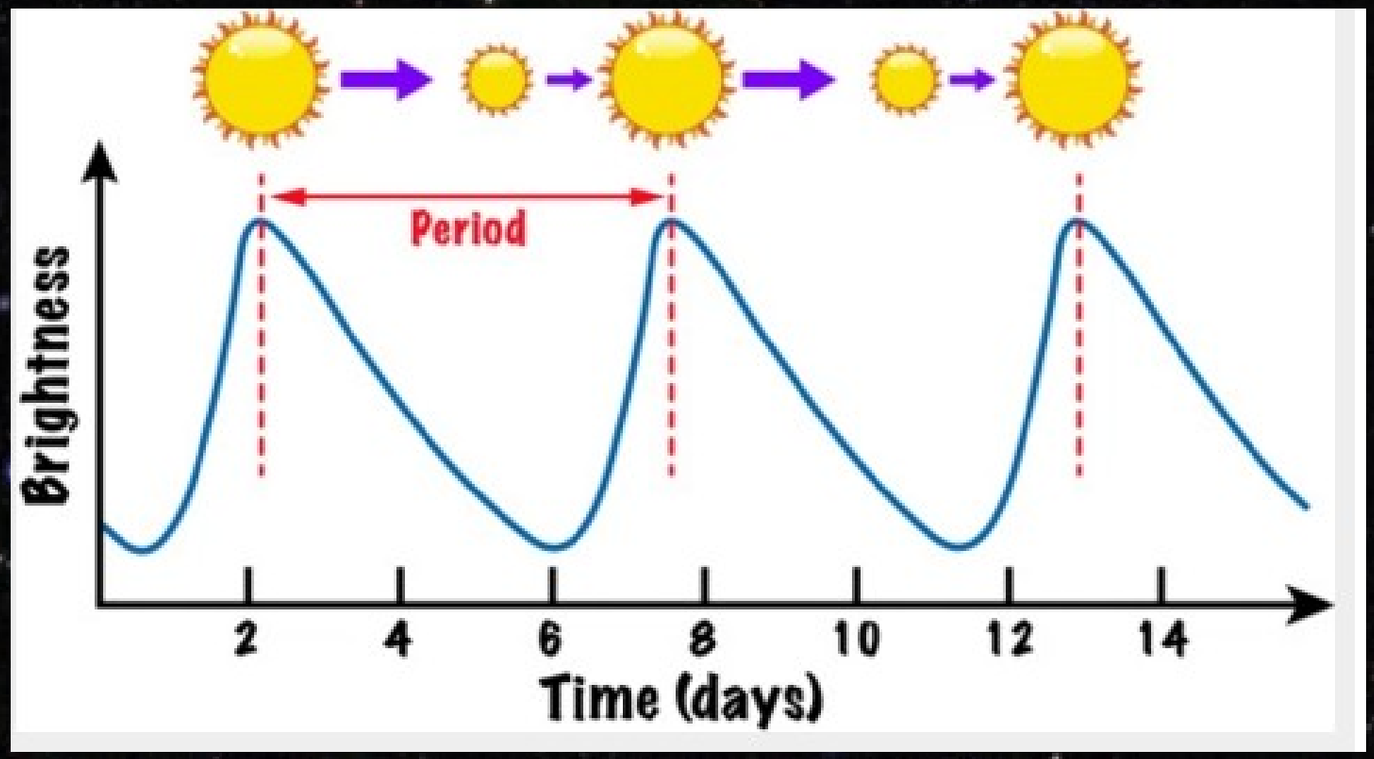
Who am I?

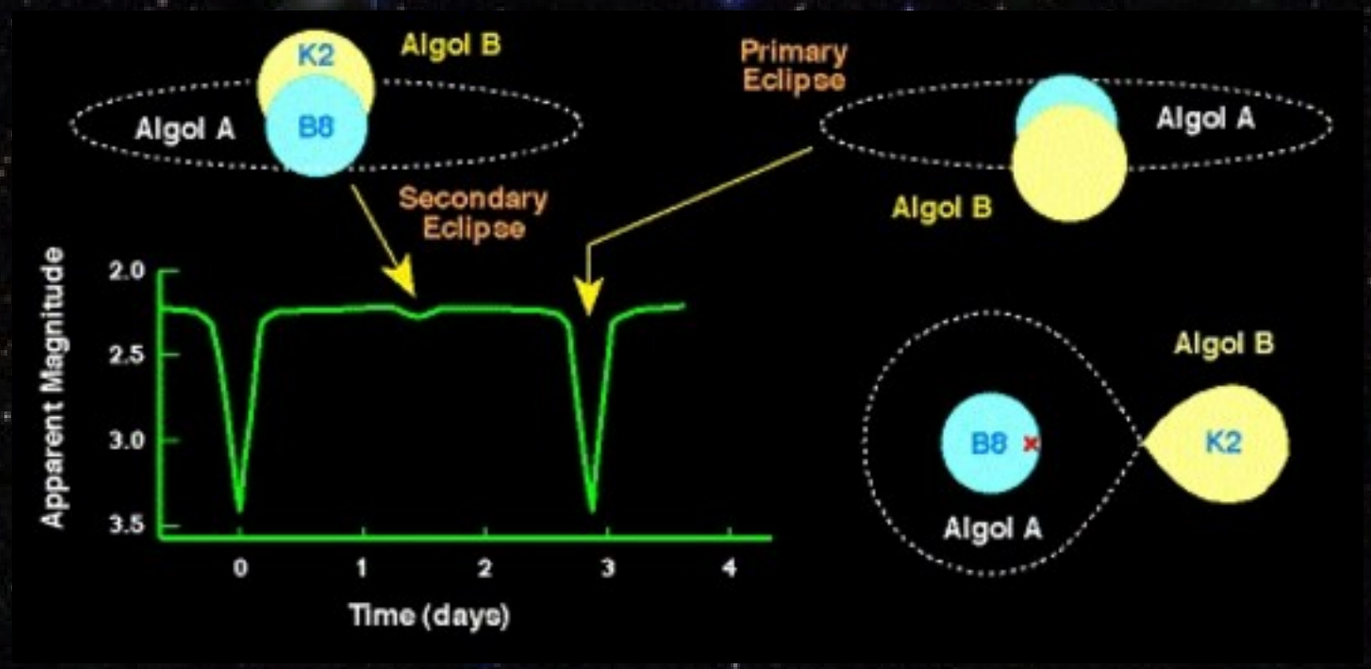

Norway
Estonia
Baltic Sea
Latvia
Lithuania
North Sea
Denmark
Belarus
United Kingdom
Queen's University Belfast
Poland
Ukraine
ARMAGH PLANETARIUM
Exploring the Cosmos since 1790
universitätbonn
Argelander-Institut für Astronomie
40 h
3,620 km
Slovakia
Moldova
Vaslui
Argelander-Institut für Astronomie
Hungary
Austria
Romania
Black Sea
Bucharest
France
Croatia
Serbia
Bulga
Italy
Facultatea de Fizică Universitatea din București
INSTITUTE OF SPACE SCIENCE
ISS
ROMANIA

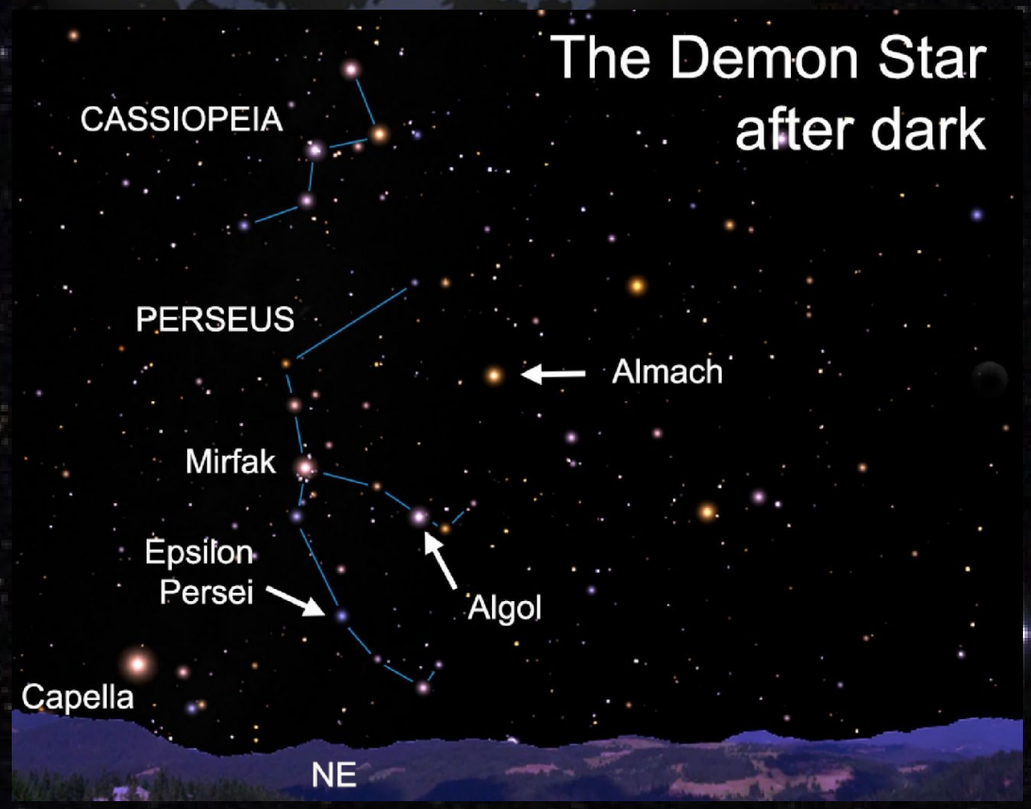

Armagh Observatory


Armagh
Planetarium
50

What are variable stars?

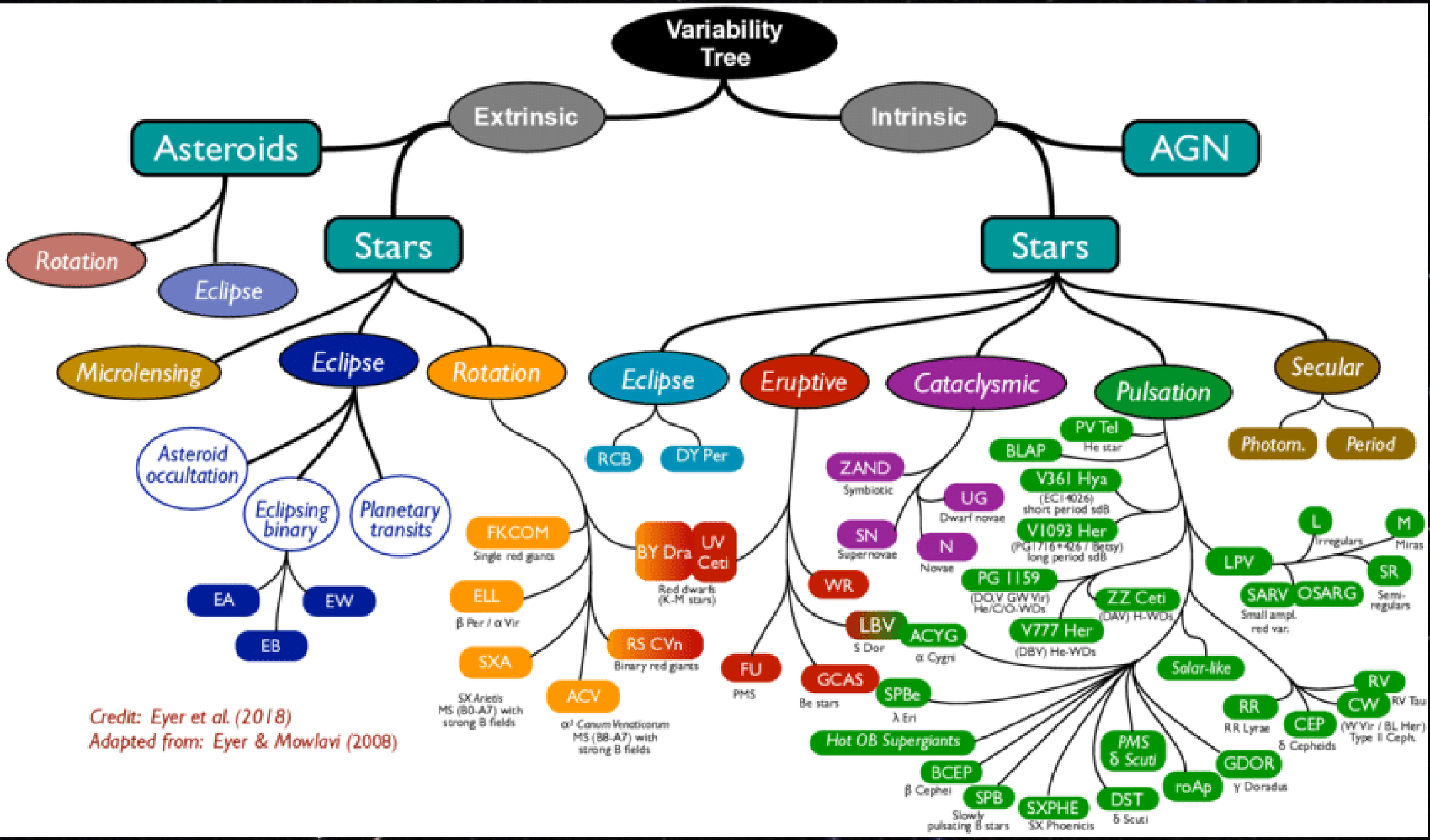




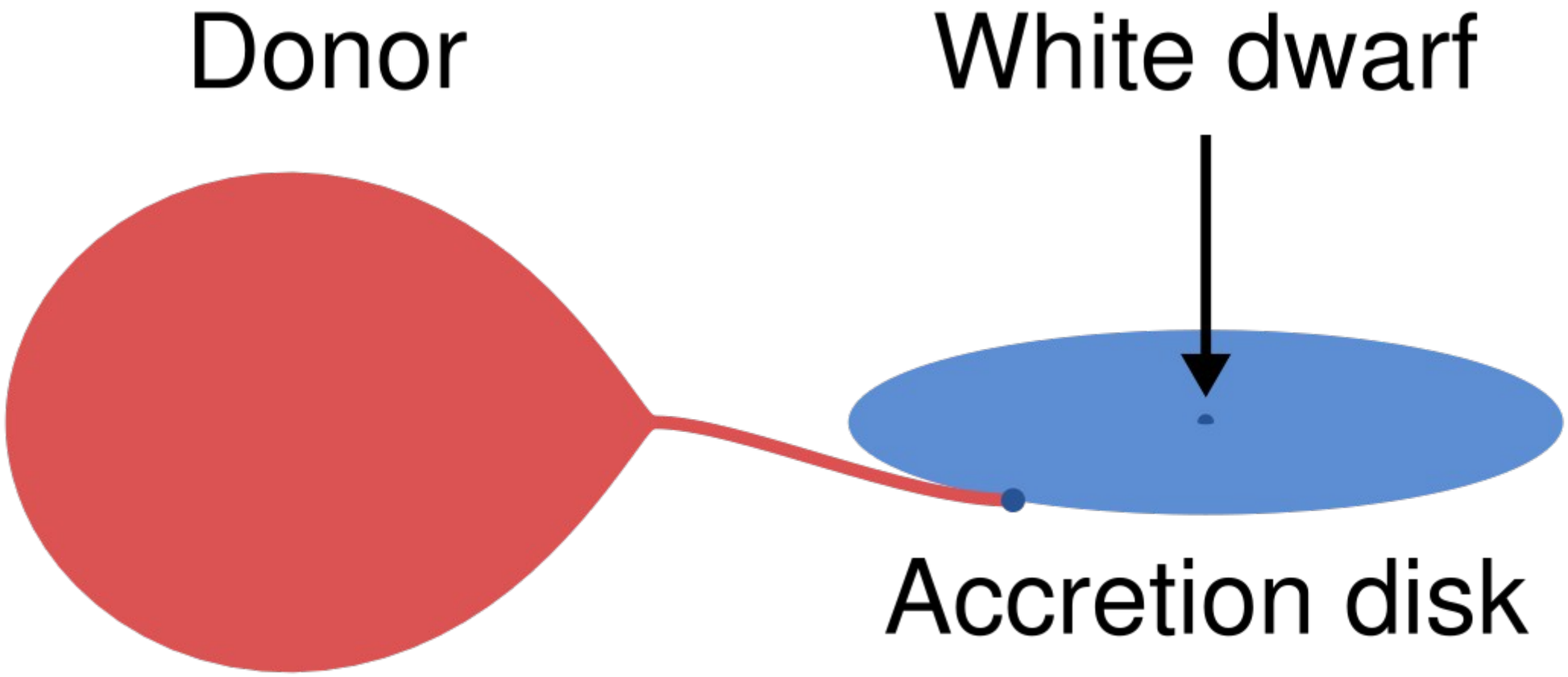


What are variable stars?

Omega White

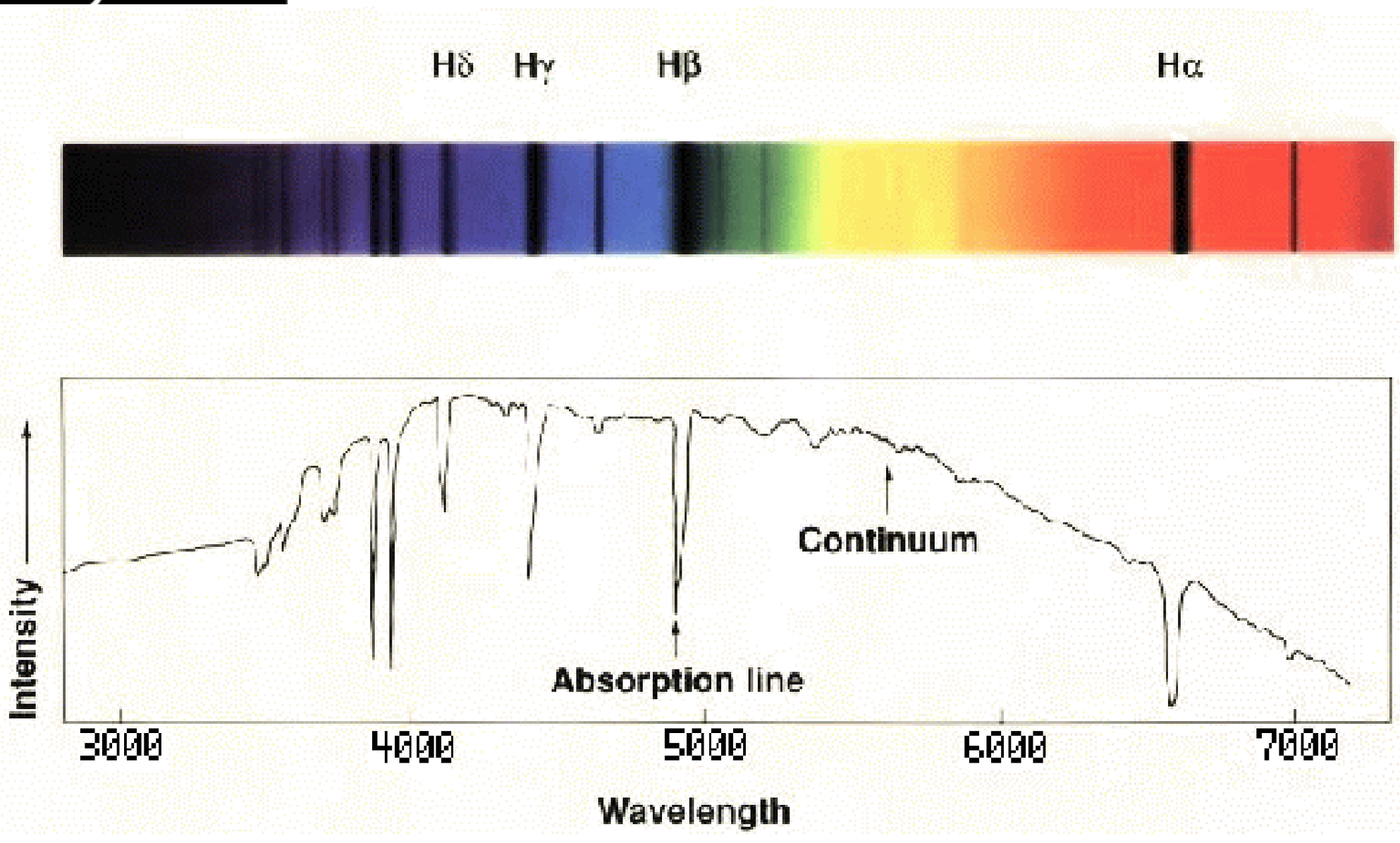


Cataclysmic variable stars

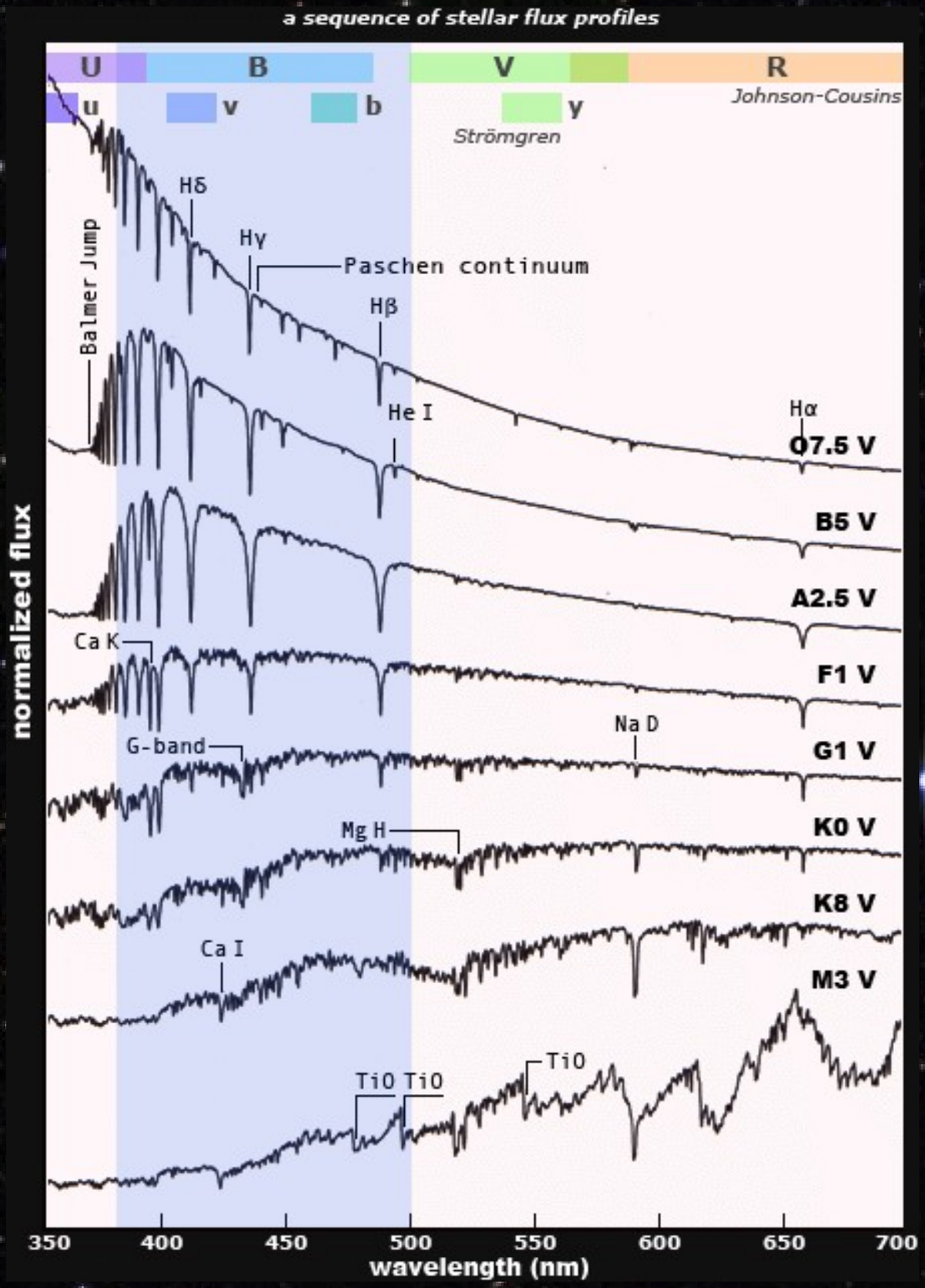


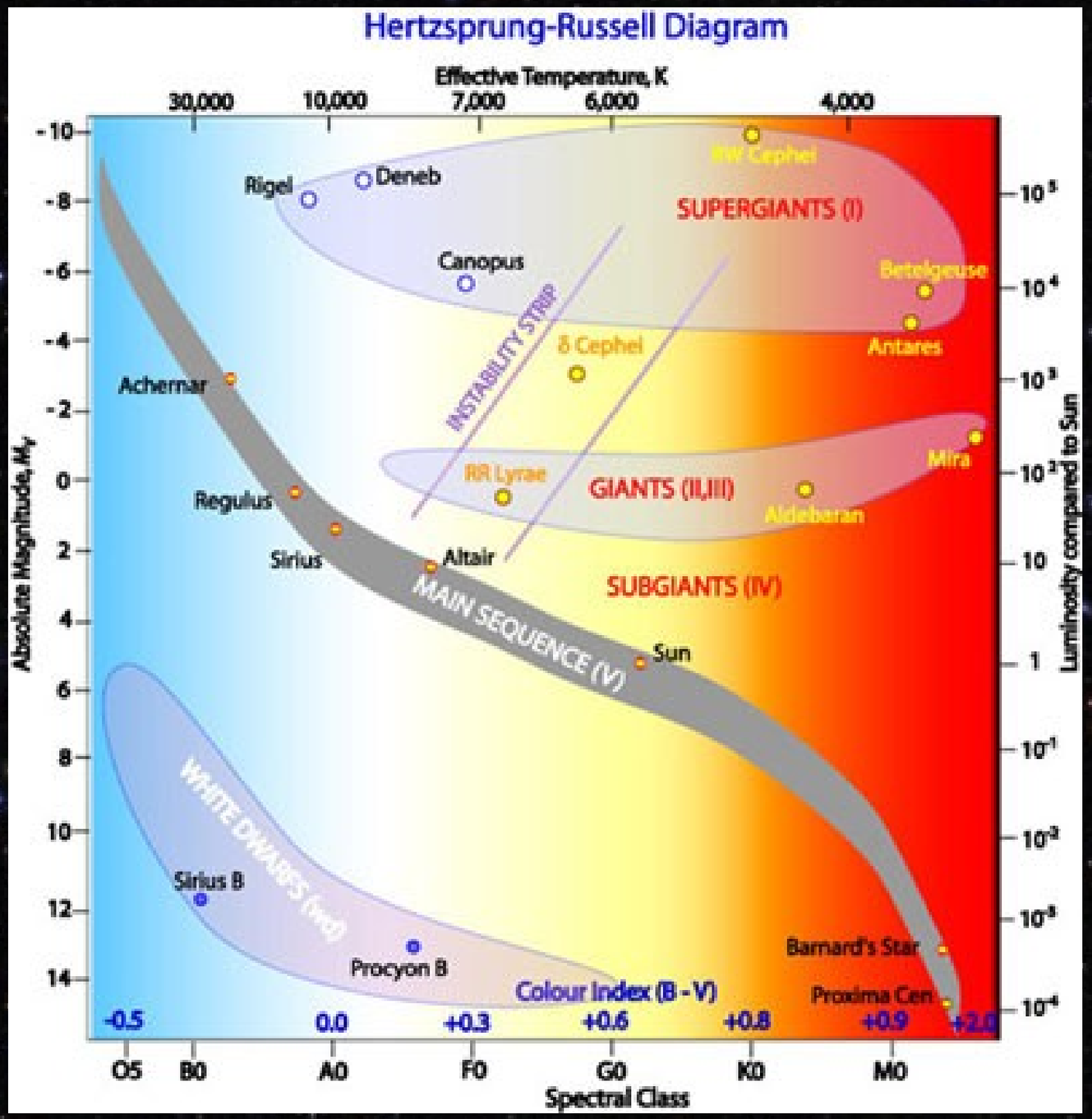
Stellar spectra

Omega White



Spectral classification of stars





What are ultra-compact binary systems?

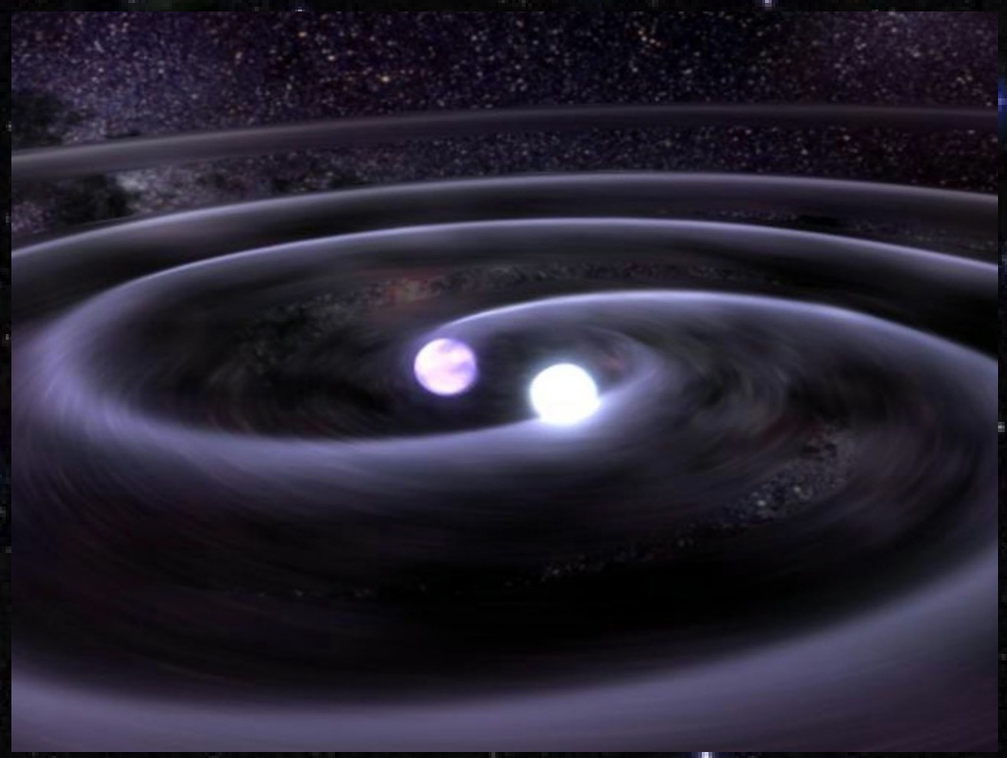
Omega White

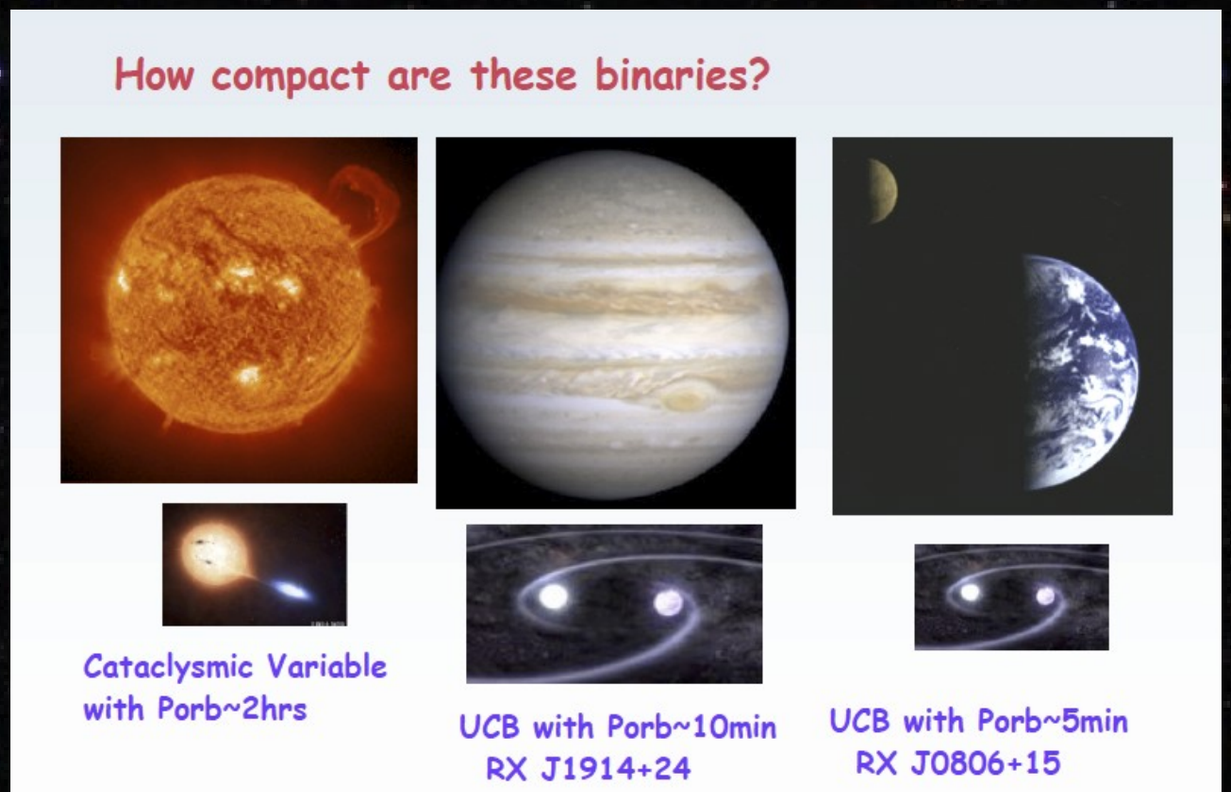
Ultra compact binaries (UCBs)

- **AM CVn system - interacting WD+WD; WD+He star**
- Porb < 1 h => small separation;
- blue objects; no H line, He lines

Why UCBs?

1) Stellar evolution - late phases
2) Progenitors of SN Ia - > Double vs single degenerate channels
3) GW - verification sources for LISA
4) Rare: ~50 AM CVns; **only 7 with P < 22 min**





The OmegaWhite survey

- Aim 1: AM CVns in MW -> space density
- Aim 2: rare interesting variable stars

How to find AM CVn systems?
- outbursts => transient (PTF)
- He emission lines (SDSS)
- **variability on short periods (P < 20 min)**

⇒new space: faint short per variables (succesor of RATS survey):

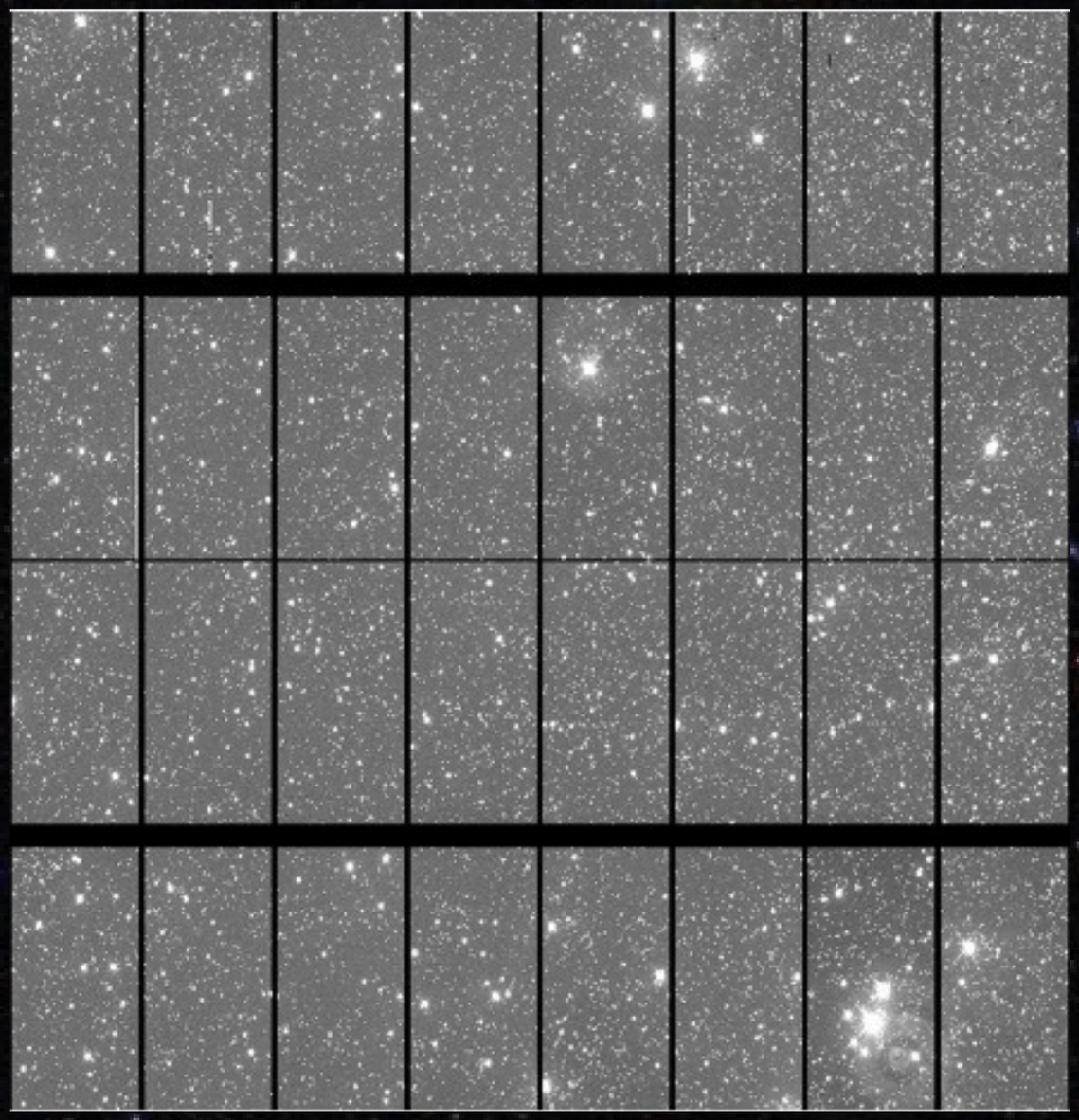
Strategy:

1. high cadence data - 3.5 min:

-> *g* band + data from VPHAS+
-> 38 exposures (**TEXP = 39s**) in 2 hours
-> **limit magnitude: *g* = 21.5 (10σ)**
-> aims to cover a sky area of **400 deg²**
-> Galactic plane: latitude: |b| <= 5°

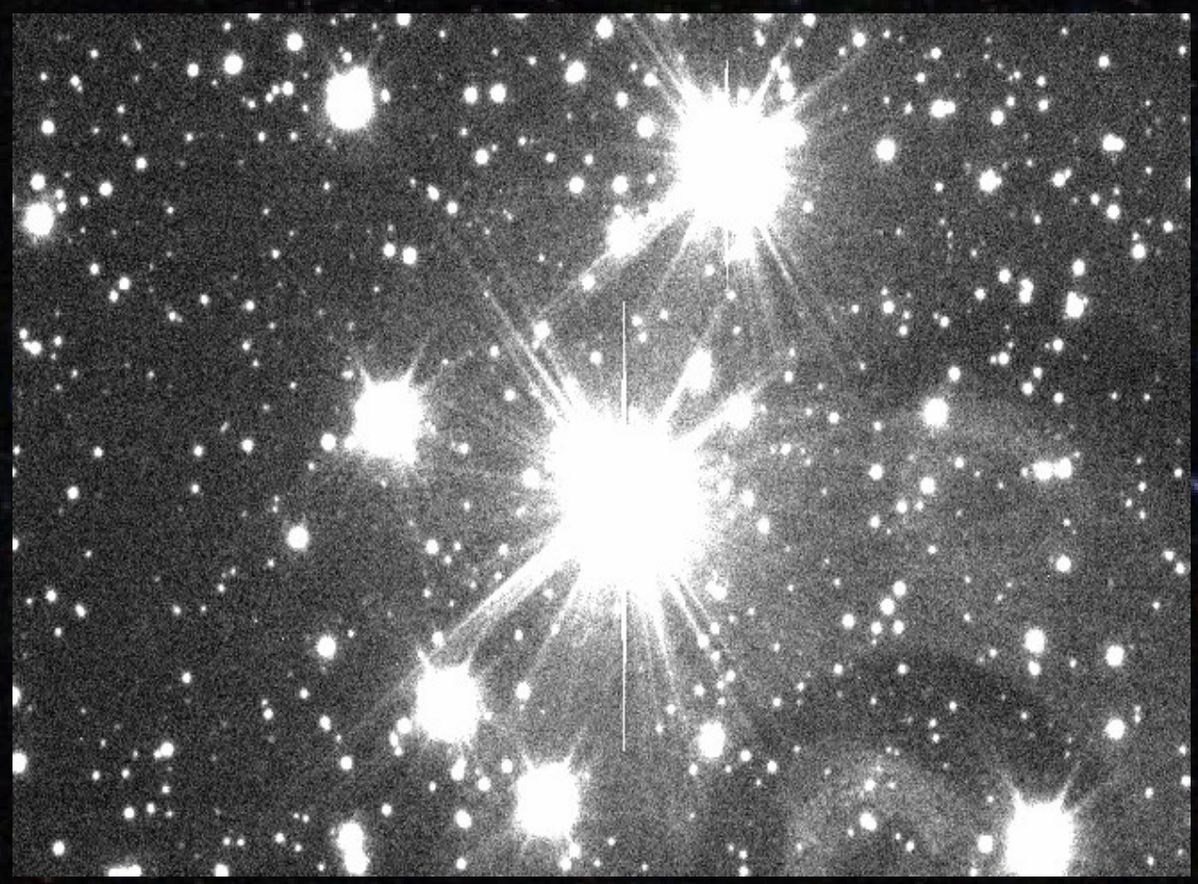
2. follow-up data for identification

- **OmegaCAM** @ **VST** (2.6m)
- FOV: 1 deg²



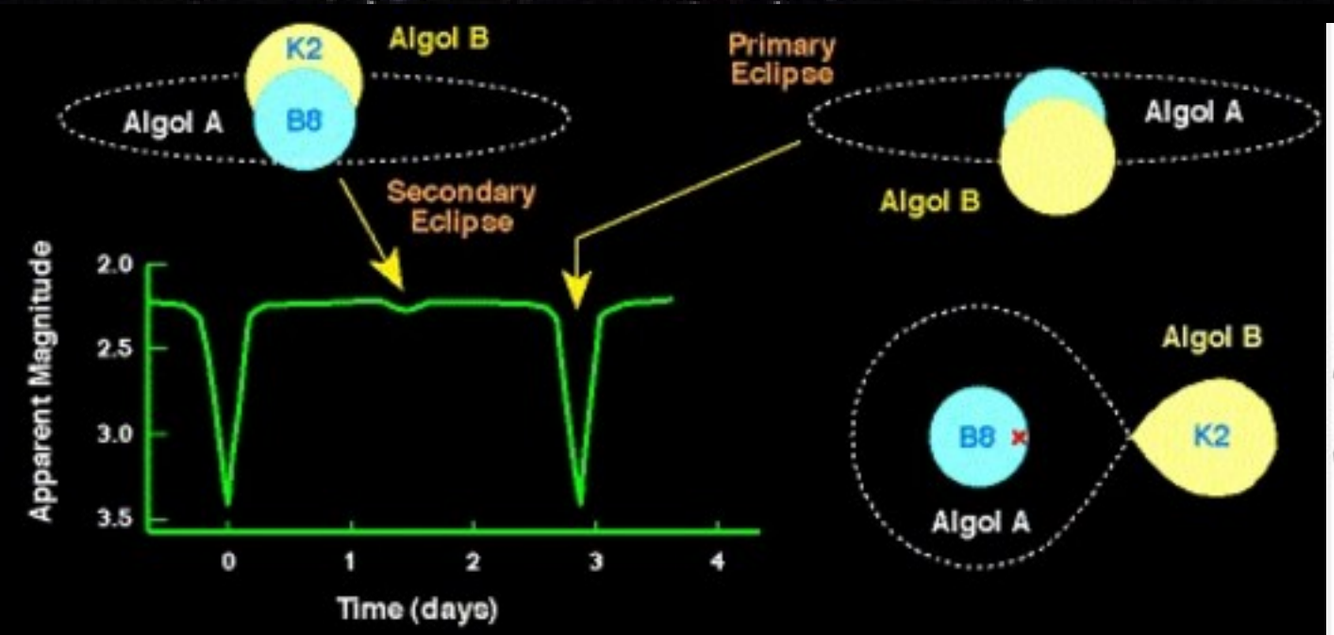
The challenge: false positive detections

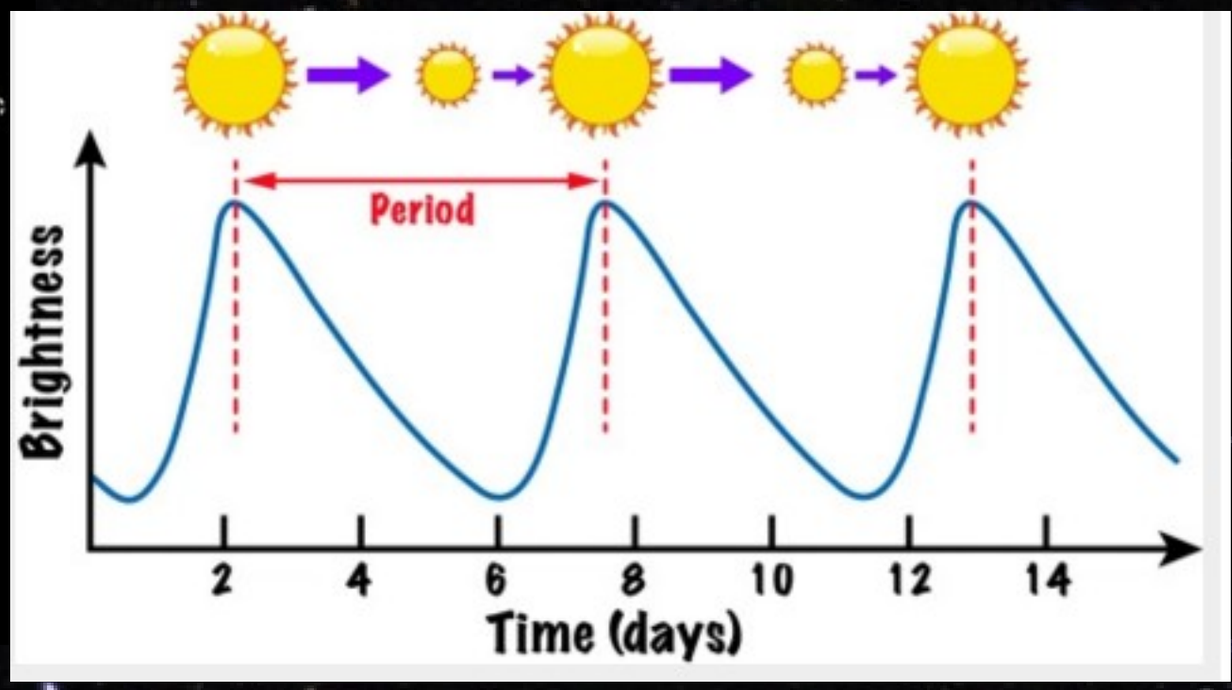
VST - altazimuthal mount = > rotating diffraction spikes
- > optimize the pipeline

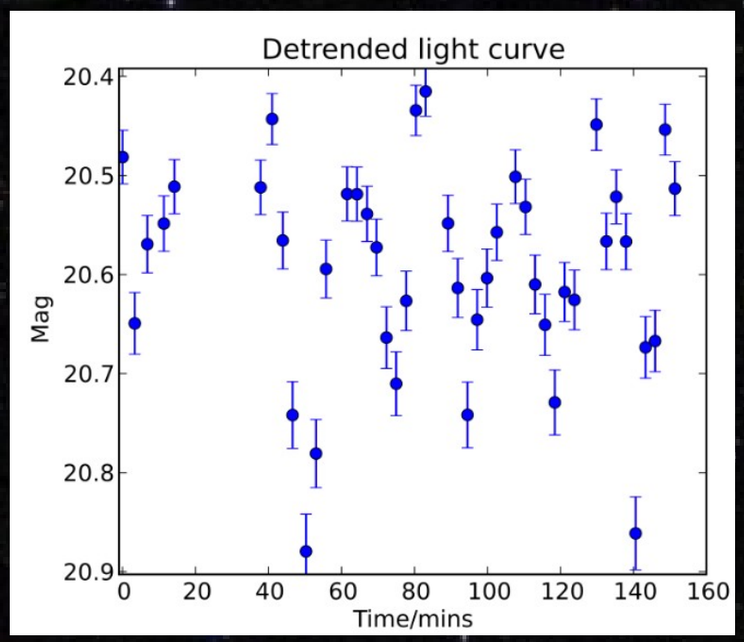


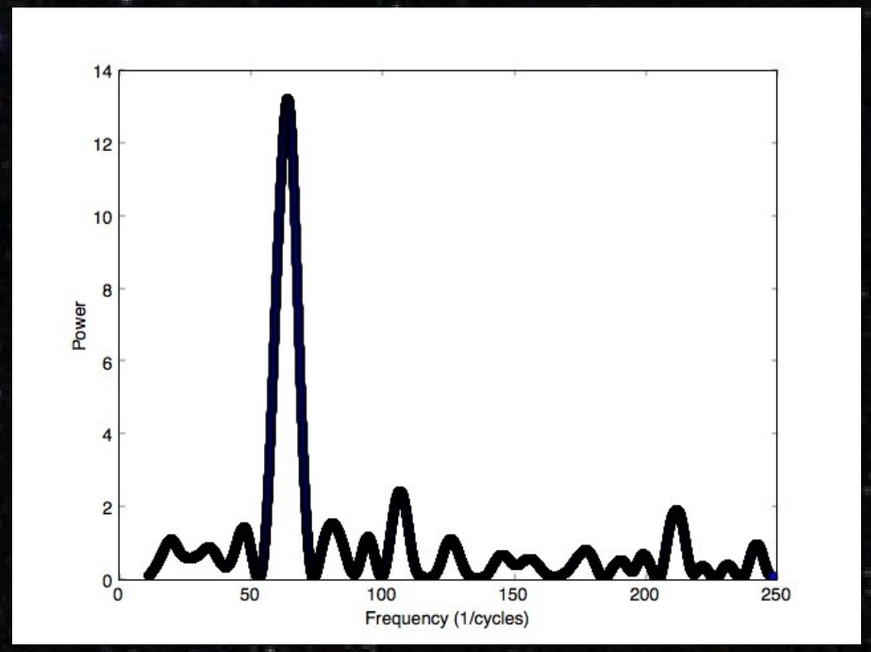
Light curves and power spectra

Omega White

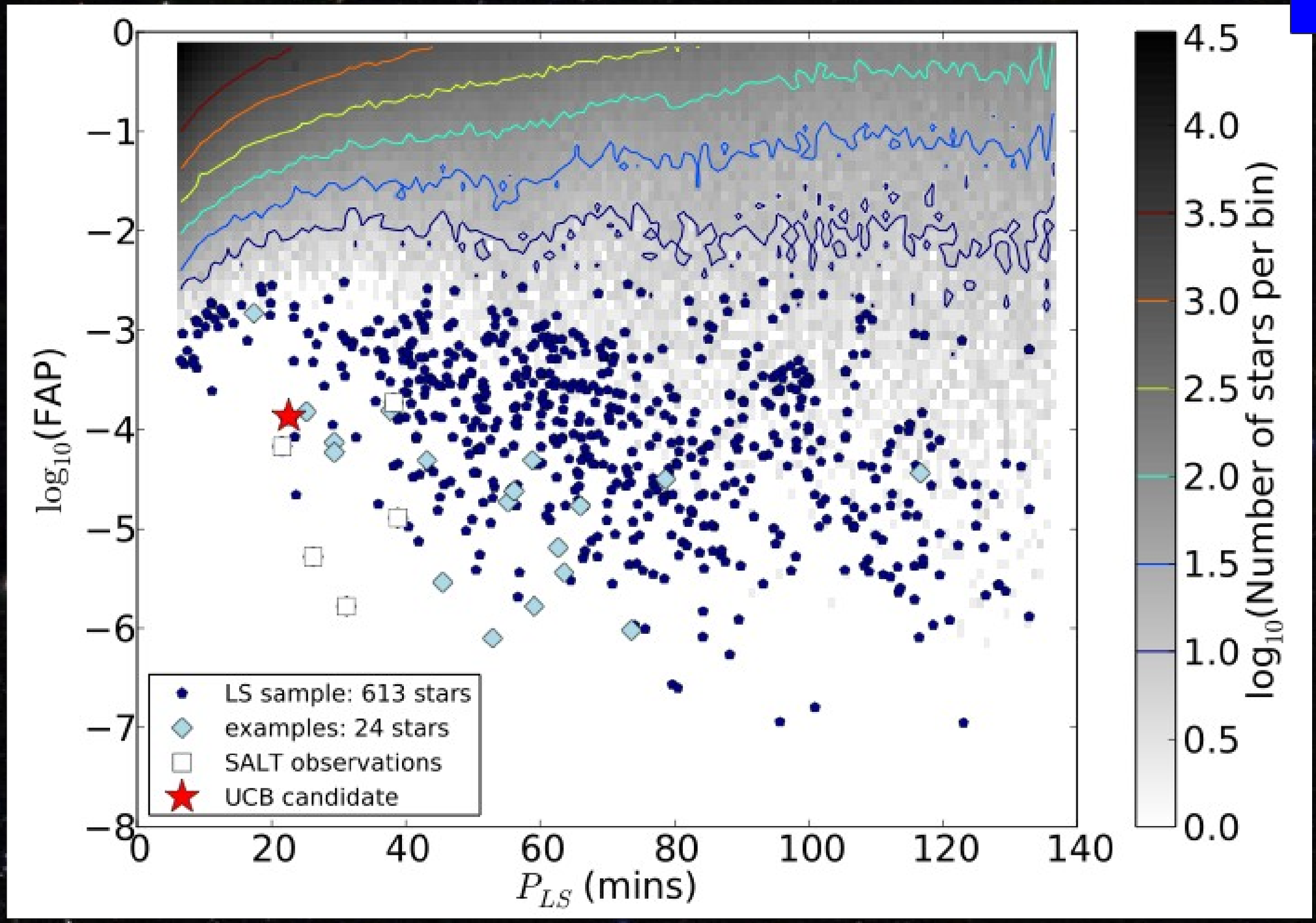








Results: Lomb Scargle periodogram

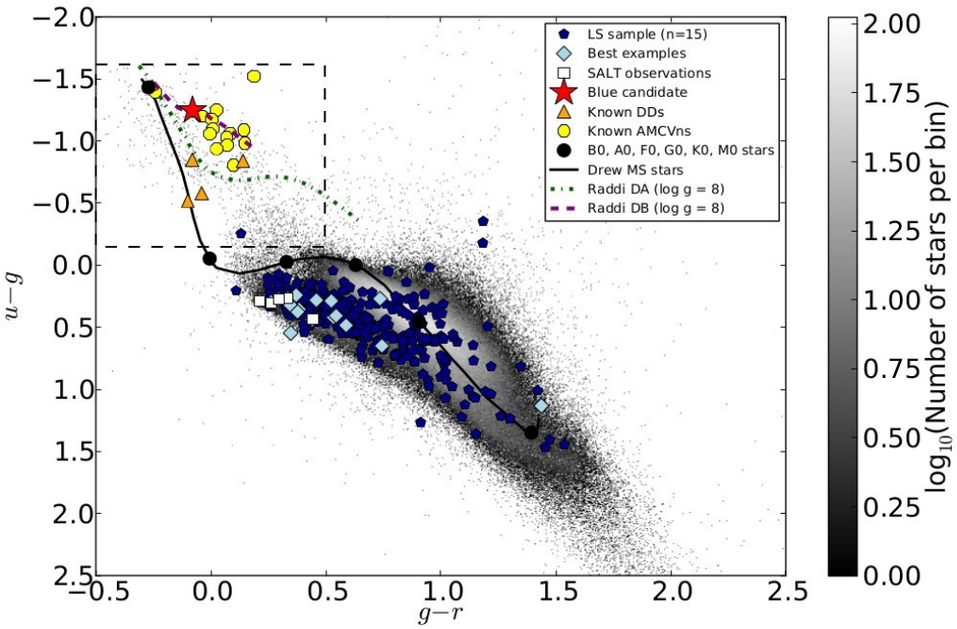


P88 - 26 fields: ~ 1.4×10^6 all stars

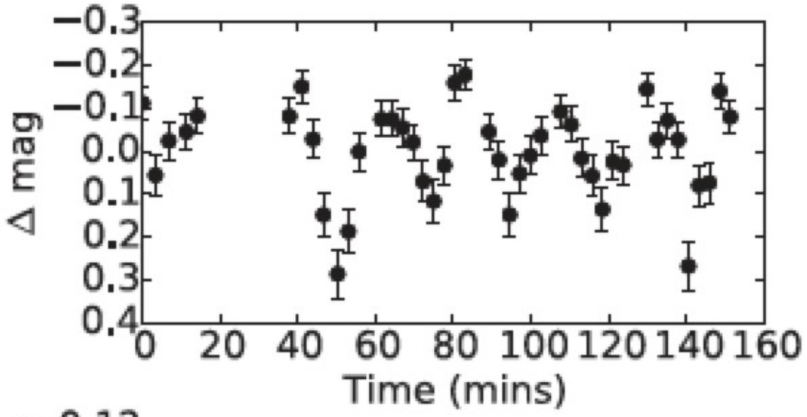
~ 50×10^3 stars/field ; (Macfarlane, Toma et al., 2015 – Paper 1)

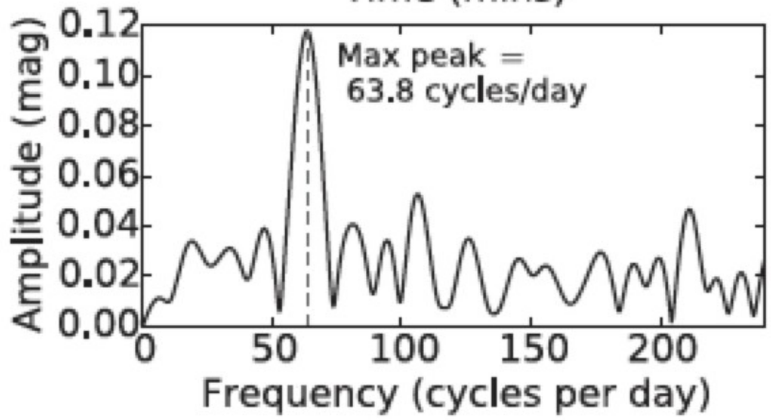
sample: 613 stars ~ 0.04%

OW J0741 - The bluest UCB candidate in P88 data - 22.6 min



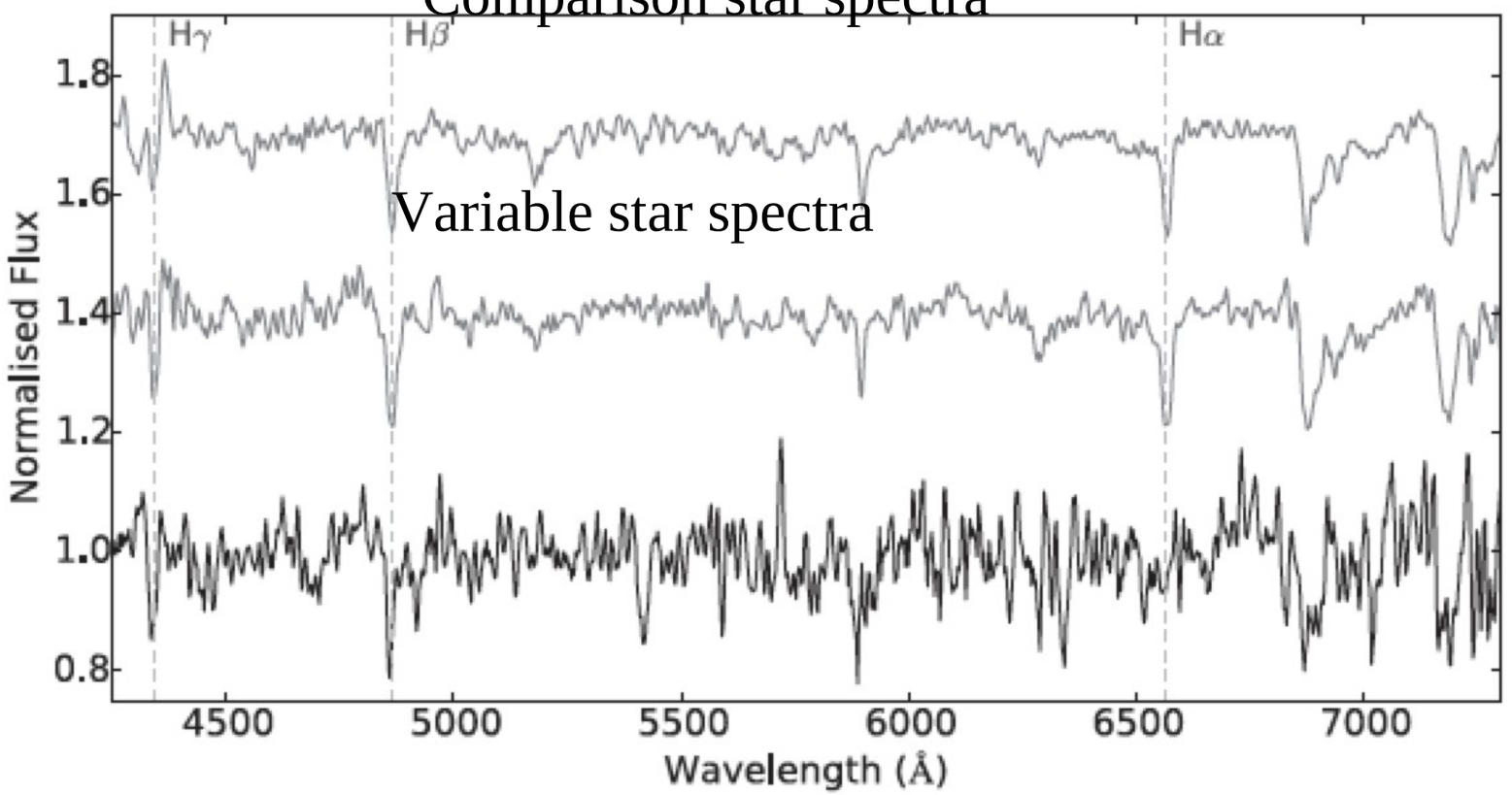
SALT: No Hα, but evidence of other Balmer lines.
→ pulsating subdwarf?





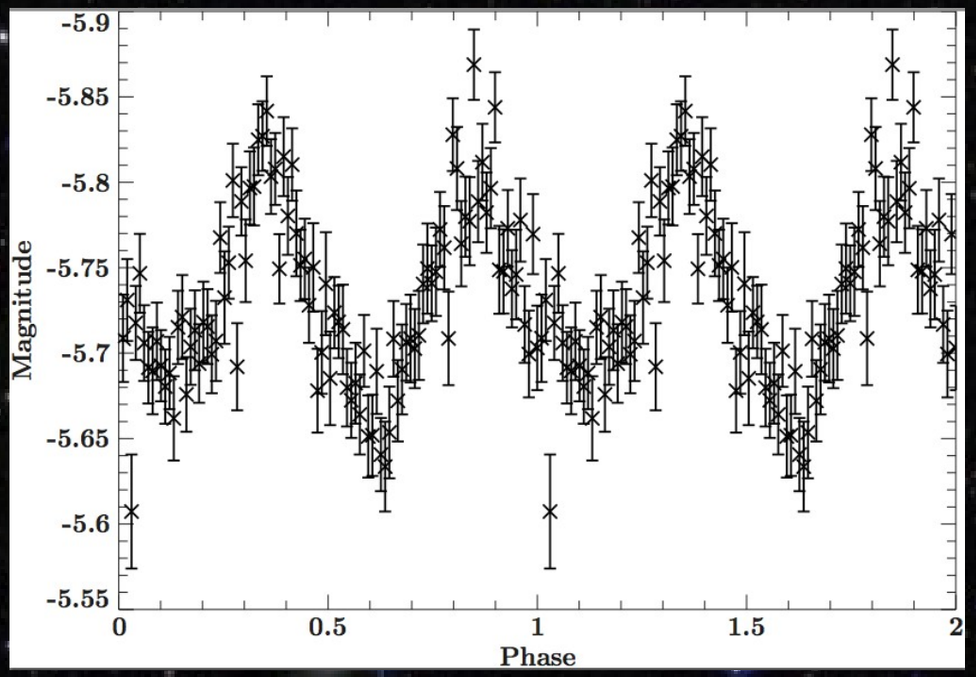
Comparison star spectra

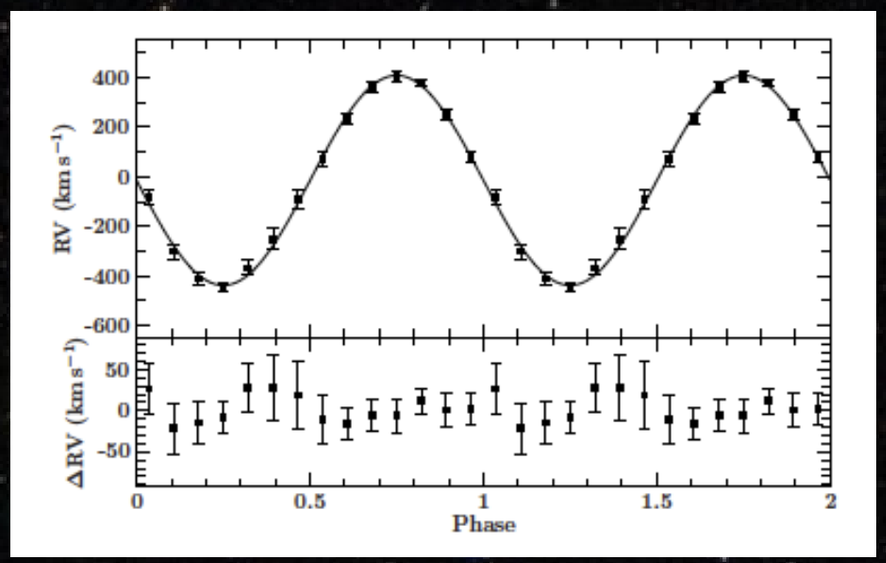
Variable star spectra



Macfarlane, Toma et al. 2015, MNRAS, Paper 1

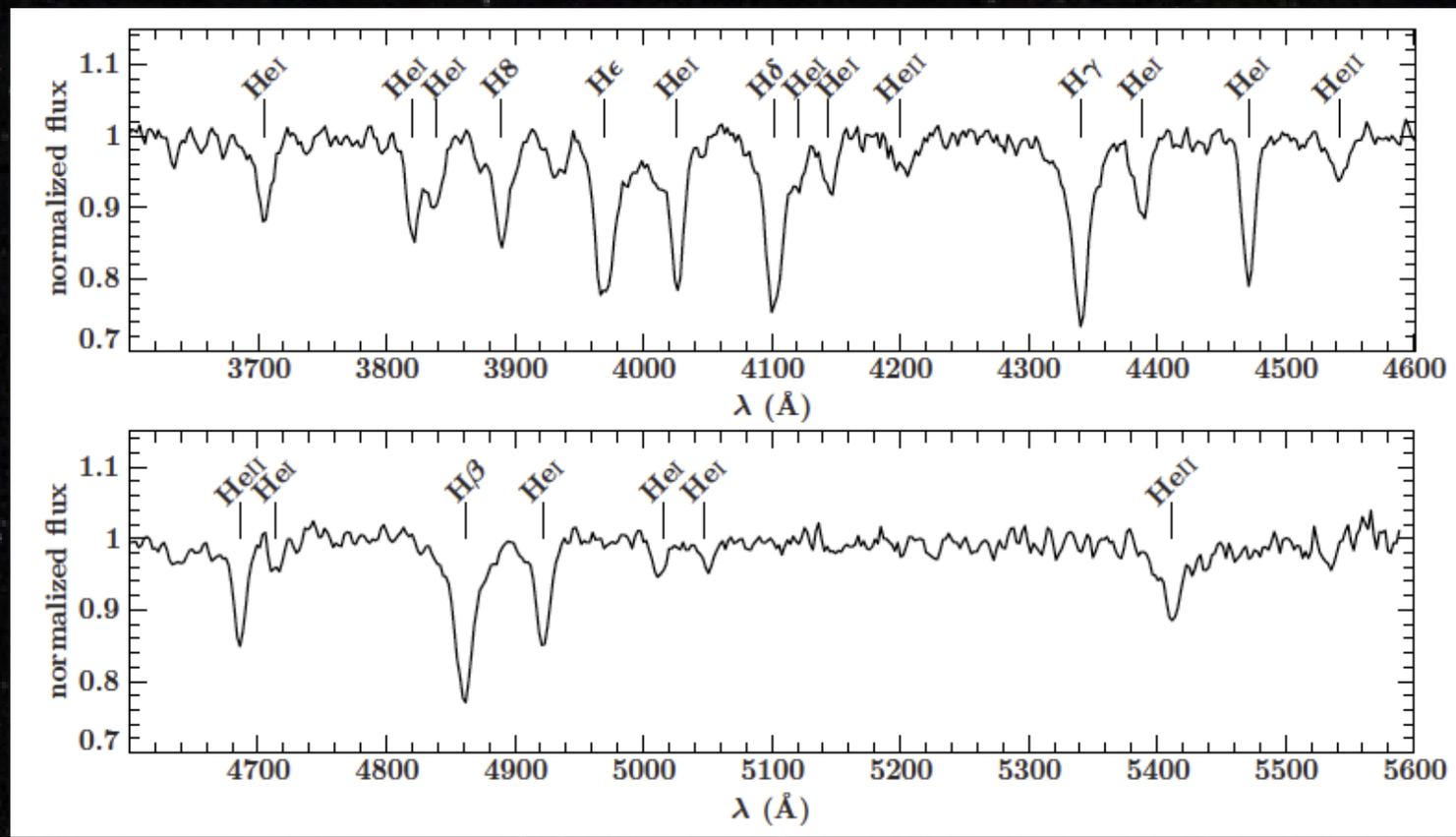
Follow-up data => OW J0741 - First UCB Shortest SdOB + WD

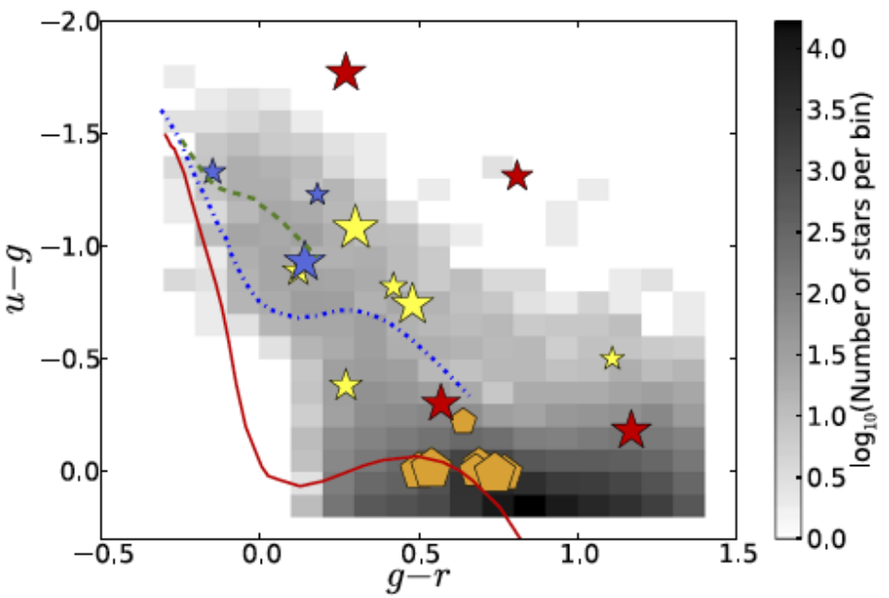




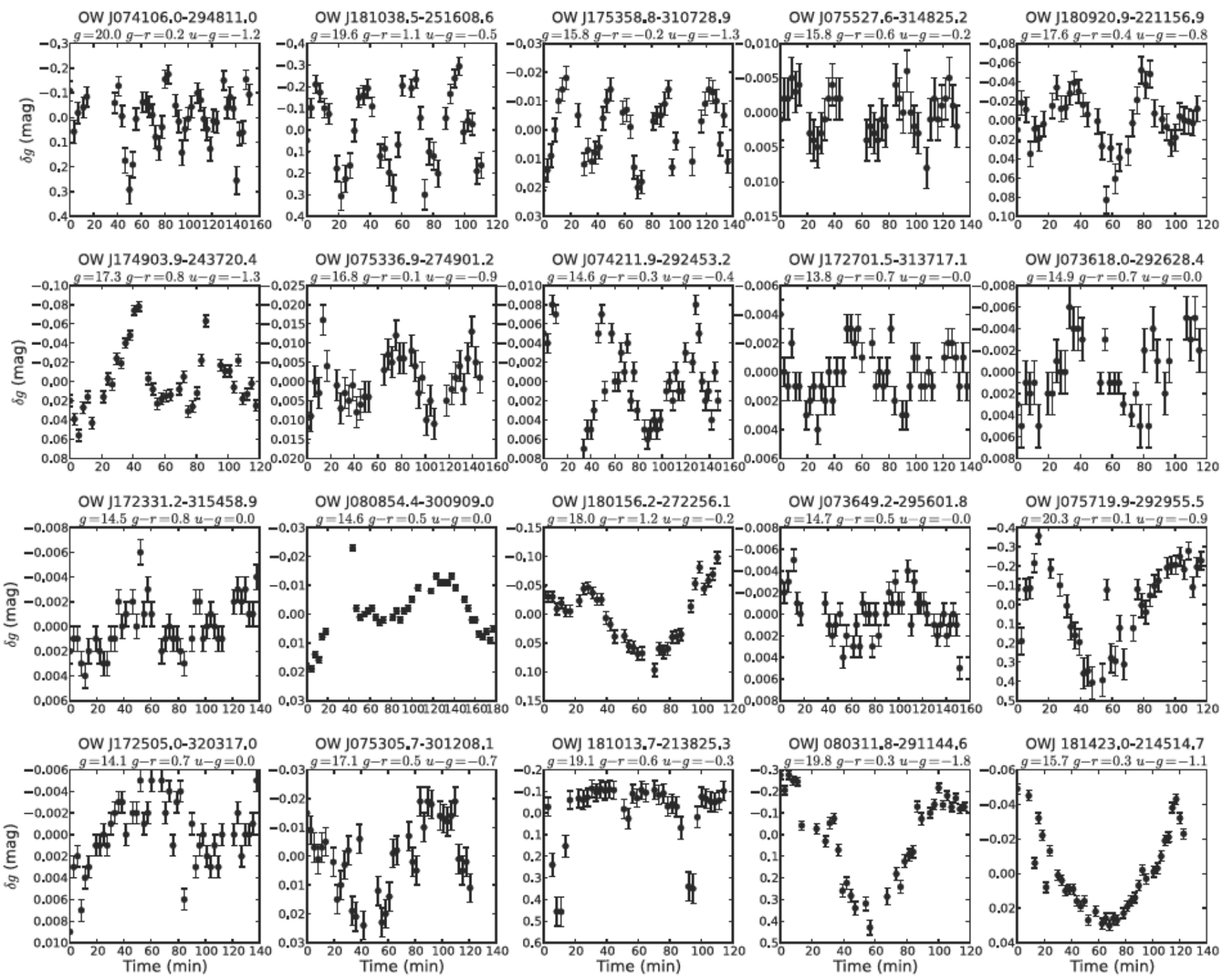
PLS= 22.6 min
Keck Rv shift= 200 km/s (5 min apart)
=> binary system, unseen massive WD
Porb = 44 min - > ellipsoidal variation

(Kupfer et al., 2017, ApJ – Paper 5)





The 20 bluest variable stars: *u-g* < 0.0 2011-2015

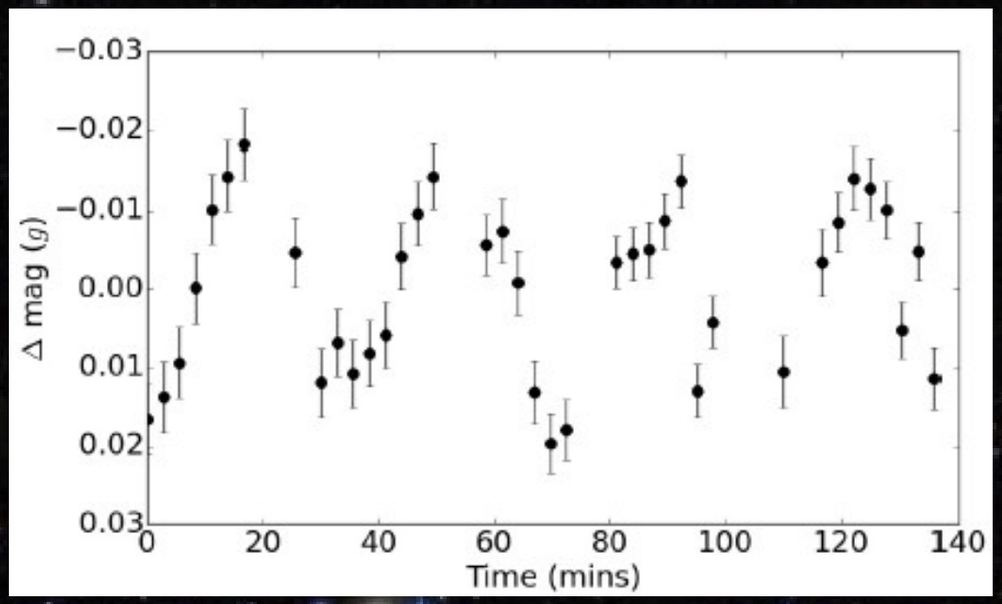


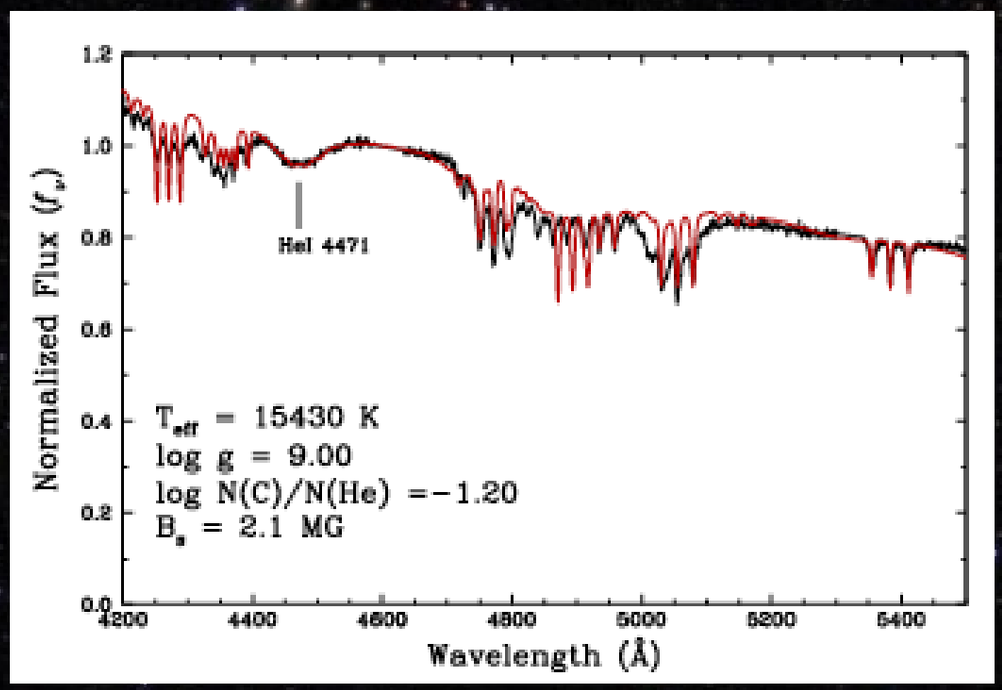
Many types of variable stars:
- blue: UCB cand
- red: CVs, acreeting, eclipsing
- yellow: unknown
- poligons: delta Scutis
(Toma et al 2016, MNRAS, Paper 2)

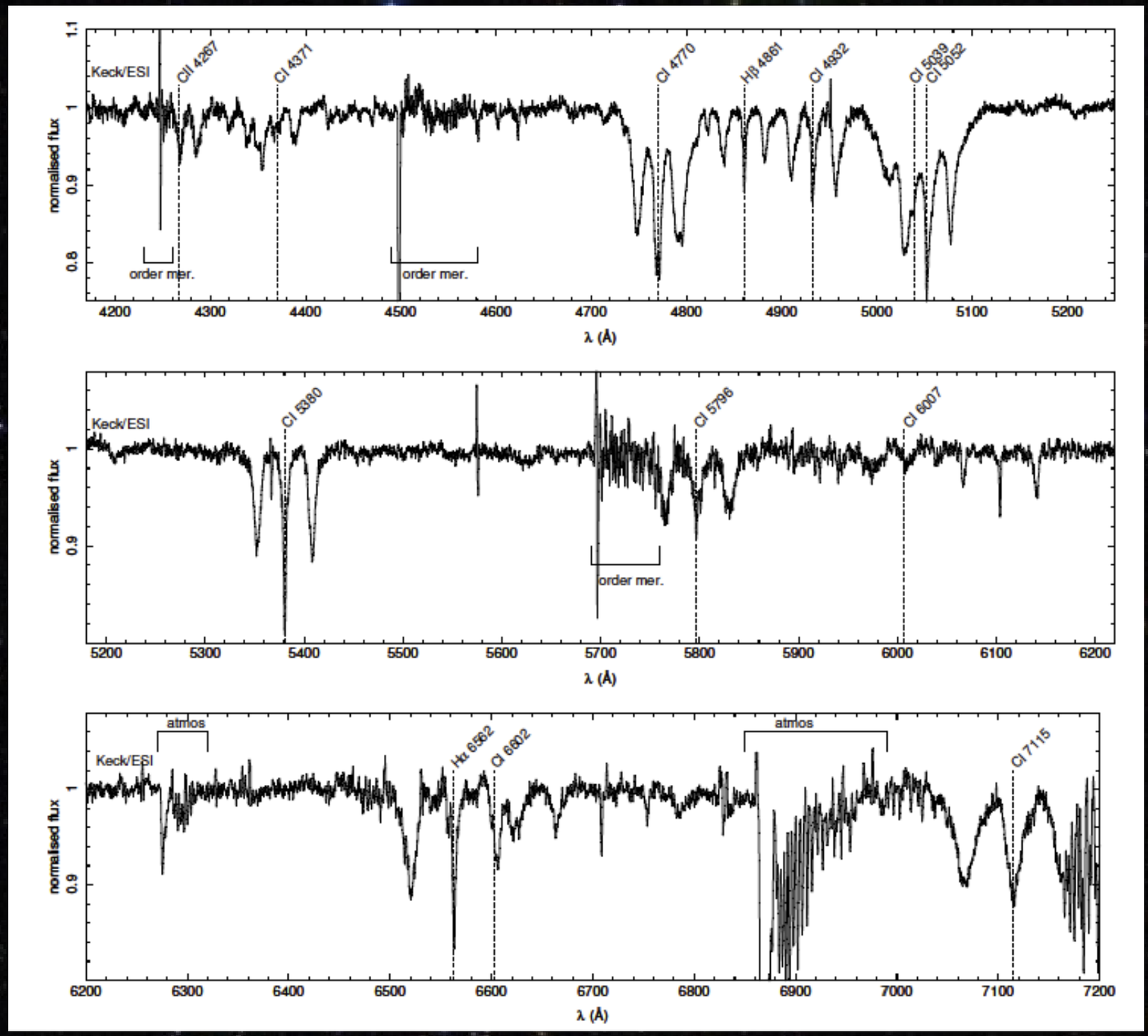
Omega White

OW J1753 - The second magnetic warm DQ WD

P = 35.2 min
rapid rotator? (Macfarlane et al., 2017b, MNRAS, Paper 4)



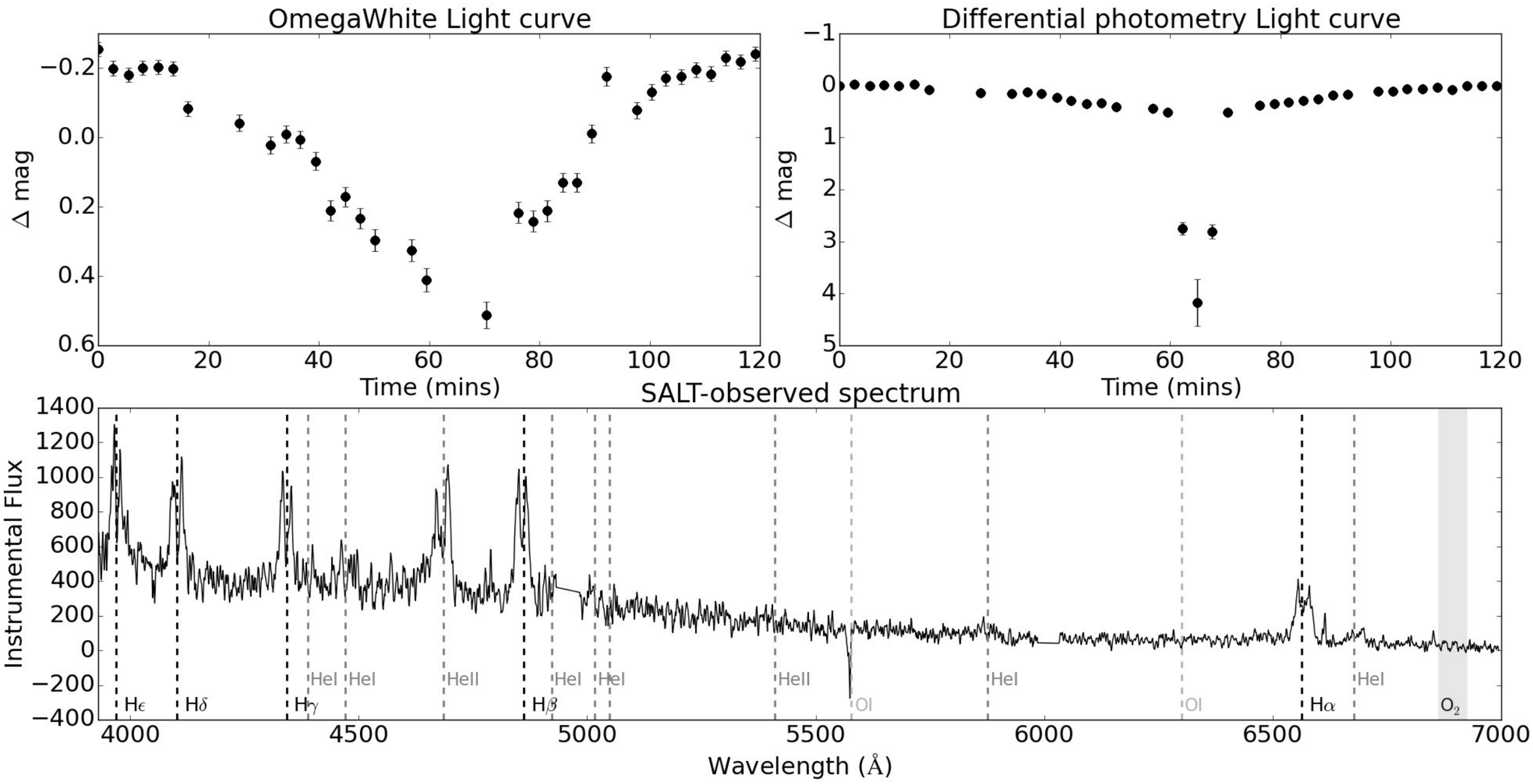




New eclipsing dwarf nova

DIA photometry

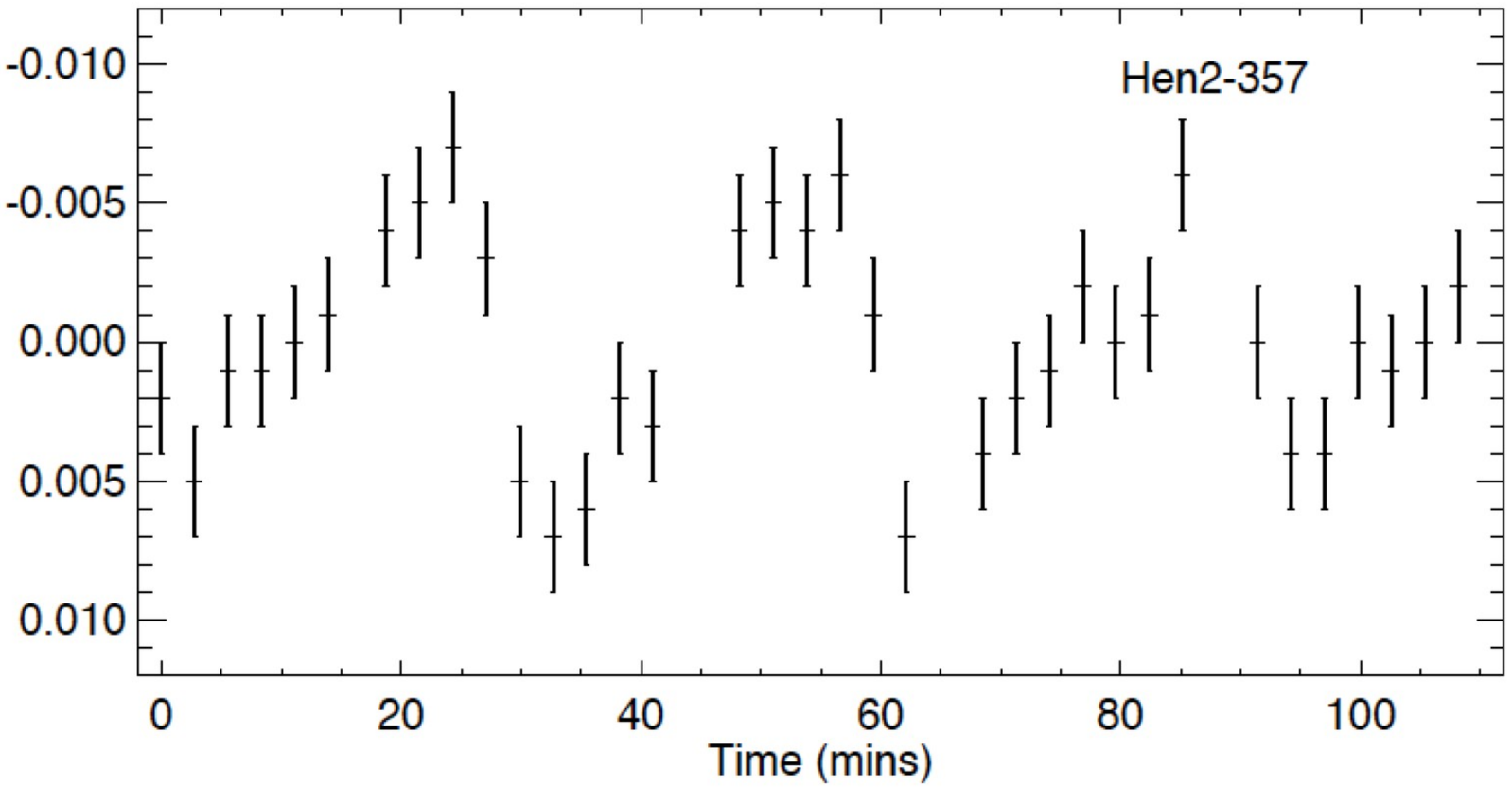
Differential Aperture photometry



Toma et al. 2016, MNRAS (Paper 2) & Macfarlane et al. 2017a, MNRAS (Paper 3)

Hen2-357 - a symbiotic binary with a magnetic field?

OmegaWhite light curve - 31.7 min



Z And — the only other magnetic symbiotic binary (28 min).

Toma et al. 2016, MNRAS (Paper 2) & Macfarlane et al. 2017a, MNRAS (Paper 3)

Variable stars in open clusters

Why?
- Cluster parameters known -> var stars known => test theories
- Short, faint variable space: not studied before in open clusters

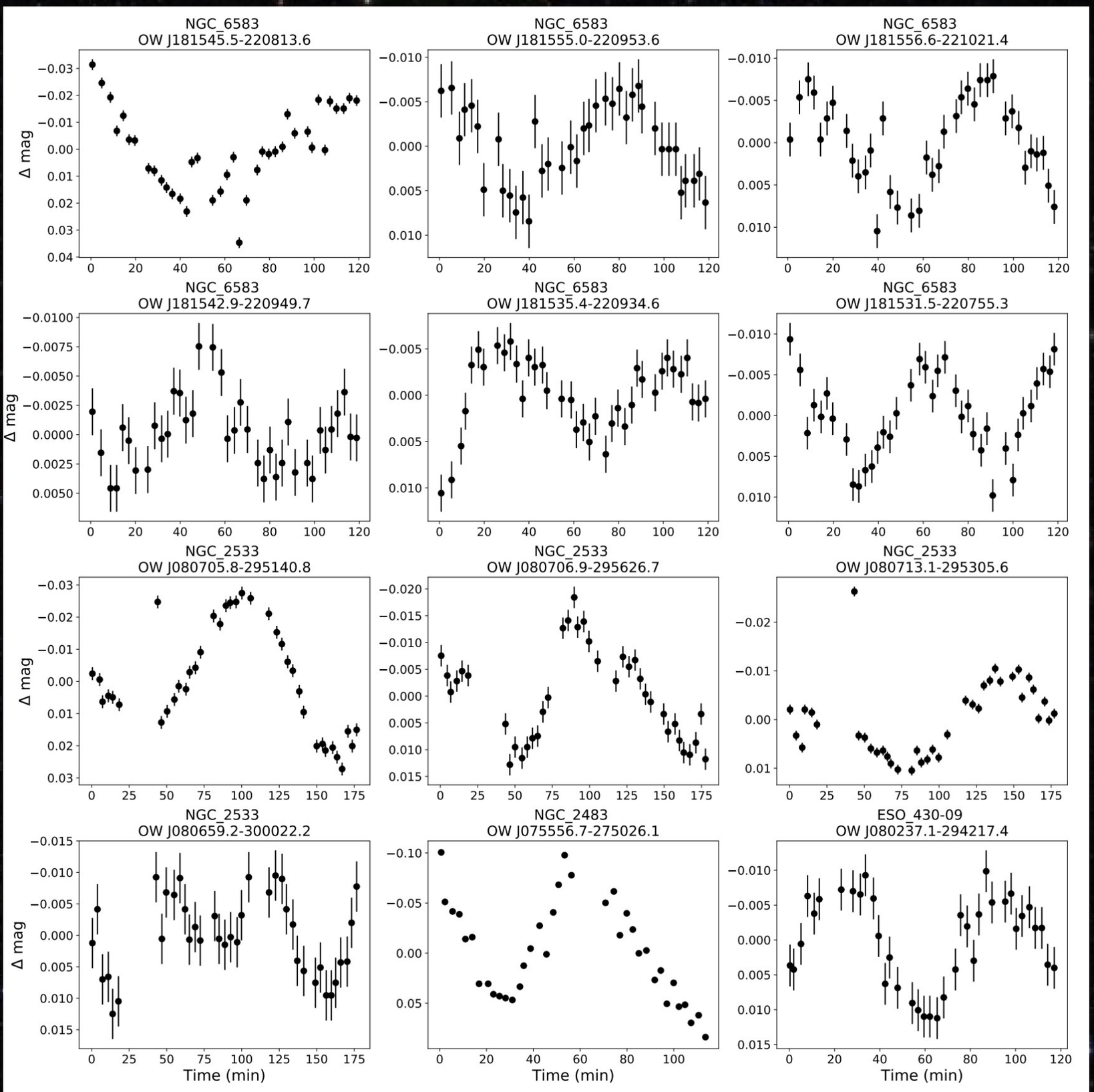
Use MWSC Catalogue and GAIA-DR3
-> Global Survey of star clusters in the MW (Kharchenko, 2013)

Results:
OW data => 62 open clusters; 20 complete data; 4! in GAIA data
217 candidates; 92 variable stars, 10 members, 2 high probable;
5 P < 60 min; 1 P = 29.8 min

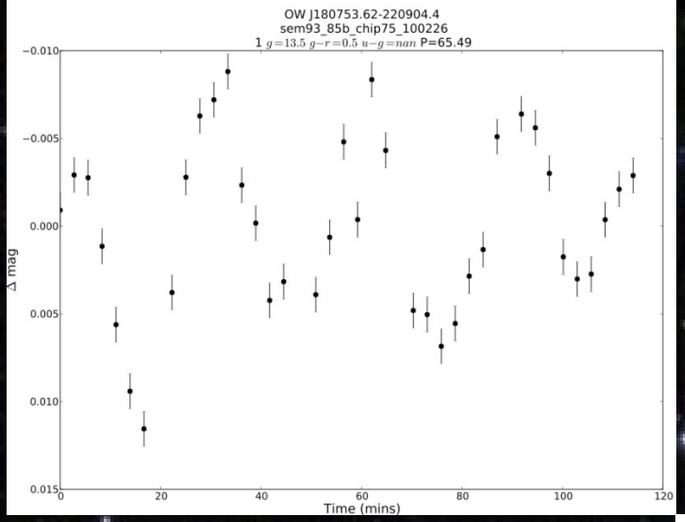
M103 - Christmas Tree

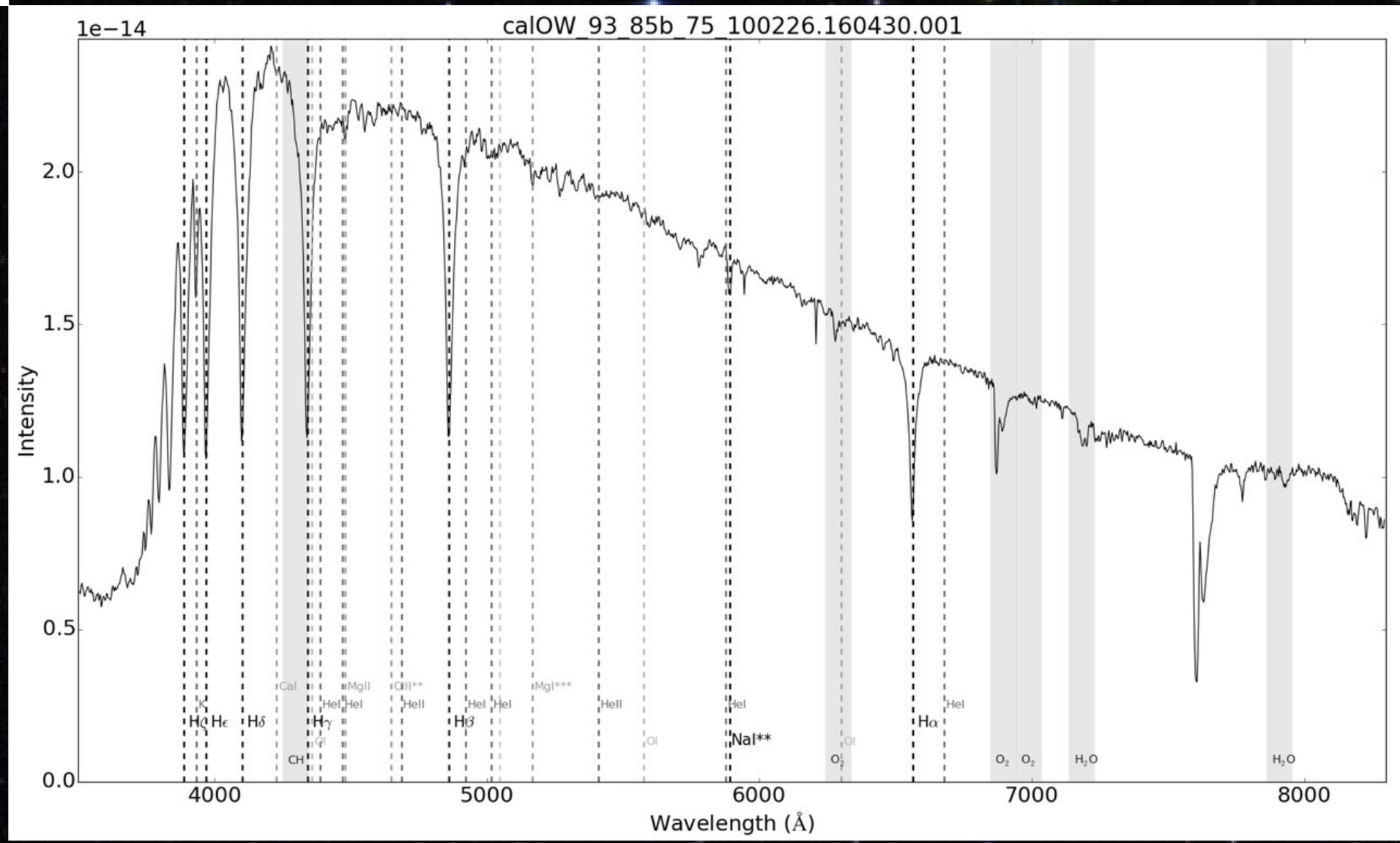
M11 - Wild duck

Members of open clusters



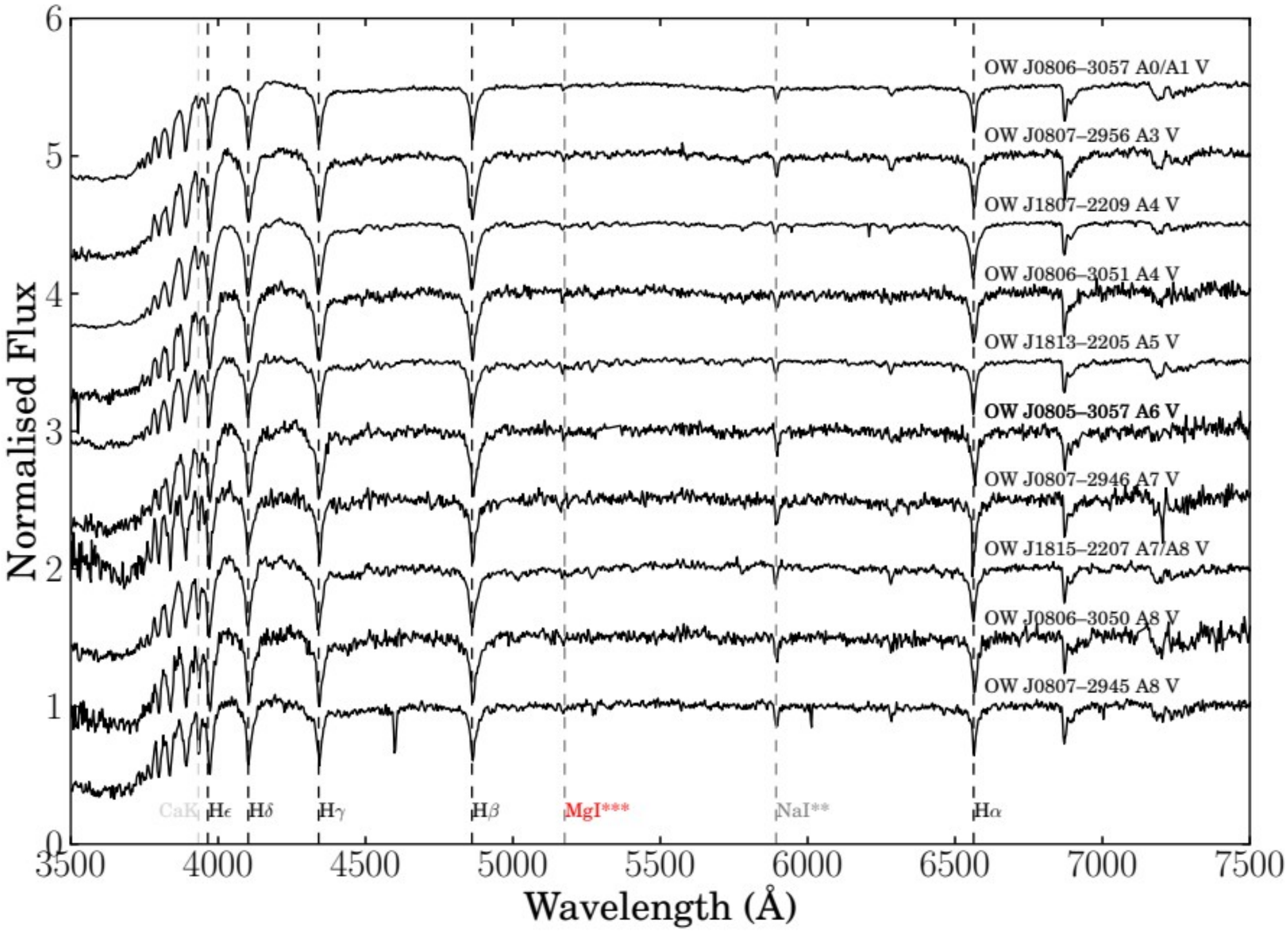
Toma et al., Paper 6
MNRAS, accepted





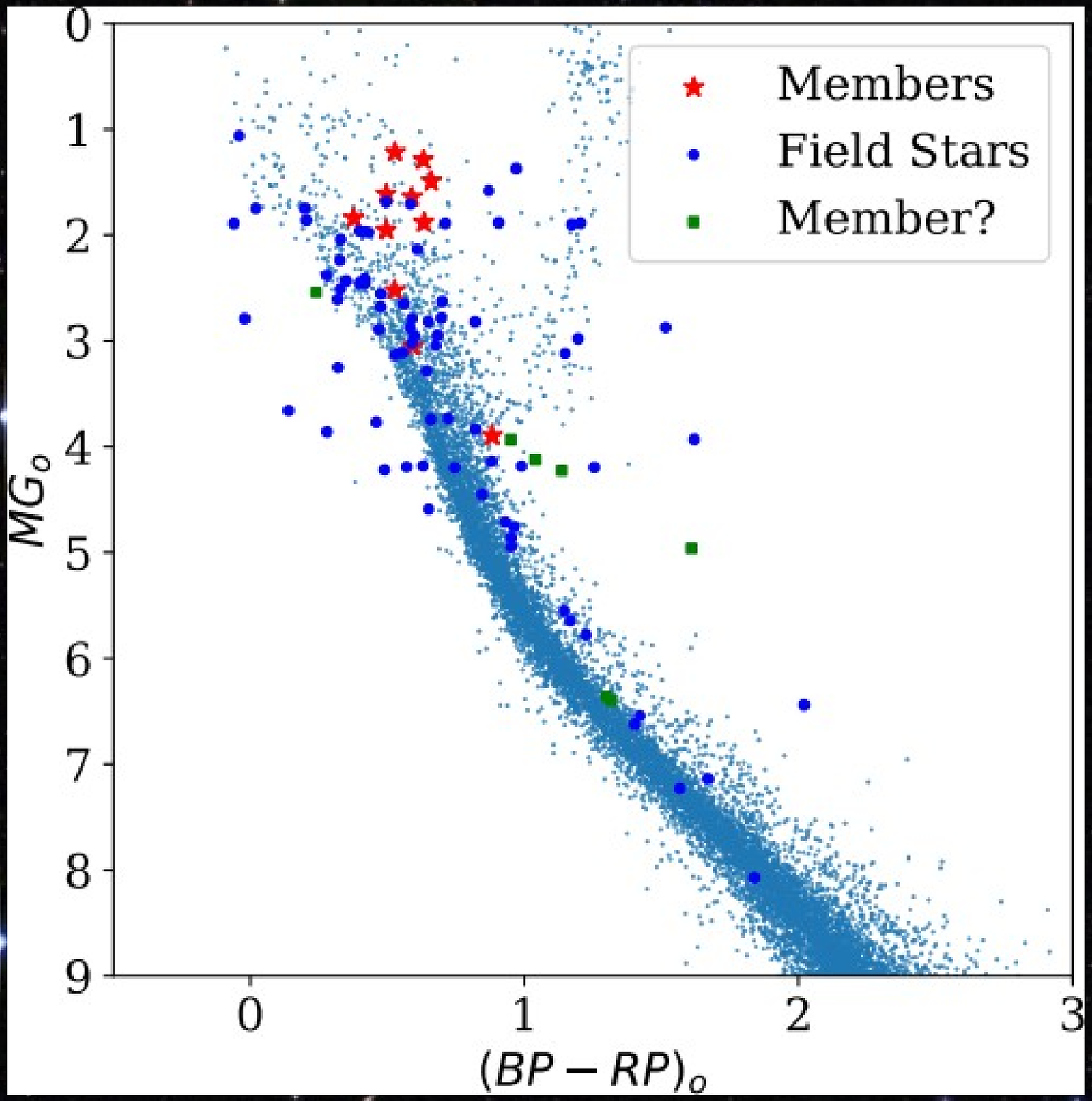
ASCC 93, 16 Myr;
OW J1807: 30 min delta Scuti: A4V type, P = 66 %
(Toma et al., Paper 6, MNRAS, accepted)

Spectra of variable stars



Toma et al, Paper 6, MNRAS, accepted

Variable stars on GAIA EDR3 HR Diagram



Toma et al., Paper 6
MNRAS, accepted

Conclusions

- 1000s short period variable stars;

- Many rare examples of unusual stars;

Question:
- Wide field synoptic surveys are either not best means to identify AM CVn binaries with P < 30 min - or they are quite rare;

- Follow-up photometric and spectroscopic observations
–> essential steps;

- indicates - objects expected to be found by similar surveys:
Ongoing: ZTF, GOTO
Future: LSST, BlackGEM, MeerLICHT, etc.

Contact: ruxandra.toma85@gmail.com, ruxandra.toma@aira.astro.ro

Aknowledgements

The study of variable stars in open clusters is supported by funds from the project „Big Data for Small Bodies” (BD4SB), a project funded by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project number PN-III-P1-1.1-TE-2019-1504, within PNCDI III.

Thank you for your attention!

Omega White

Extra slides - details

RATS and OmegaWhite

Rapid Temporal Survey (RATS)
(2003 - 2010)

- wide field, synoptic survey
- **Aim**: space density of AM CVns in Milky Way => test population synthesis models
- new parameter space: P < 20 mins

> - WFC@INT (2.5m)
  - WFI@MPG/ESO-2.2m

Strategy:
-> white light observations + (BVI, U*g'r'*HeII)
-> **high cadence - 1 min**
-> 77 exposures (**TEXP = 30s**) in 2 hours
-> **limit magnitude: *g'* = 23**
-> low galactic latitude: |b| <= 10°

> covered a sky area of **40 deg²**

The OmegaWhite Survey
(2011 - present)

- wide field, synoptic survey
- **Aim**: space density of UCBs in MW: => test population synthesis theory
- new parameter space: P < 20 mins

-> OmegaCAM @ VST (2.6m)

Strategy:
-> *g* band + data from VPHAS+
-> **high cadence - 3.5 min**
-> 38 exposures (**TEXP = 39s**) in 2 hours
-> **limit magnitude: *g* = 22.5 (10σ)**
-> low galactic latitude: |b| <= 5°
-> aims to cover a sky area of **400 deg²**
10x => better constraints on space density

LS False alarm probability (FAP)

A power spectrum is composed of:
- periodic signal
- Gaussian noise

$$X(t_i) = X_0 \sin(\omega_0 t_i + \phi) + R(t_i), \quad i=1,2,...N_0$$

- FAP = probability of detecting a peak in the periodogram caused by random noise. For a frequency interval [z, z+dz]:

$$FAP=1 - (1 - e^z)^N$$

where N - number of independent frequencies in the sample (Scargle, 1982).

- Median absolute deviation of the median (MAD) of FAP ($x_i = FAP_i$):

$$MAD_n = b\ med_i|x_i - med_j x_j|, \quad i=1,2, \ldots n \quad \text{(Hampel, 1974)}$$