Discovery of A New Blue Large-Amplitude Pulsator in the SkyMapper DR2: SMSS J184506.82-300804.7

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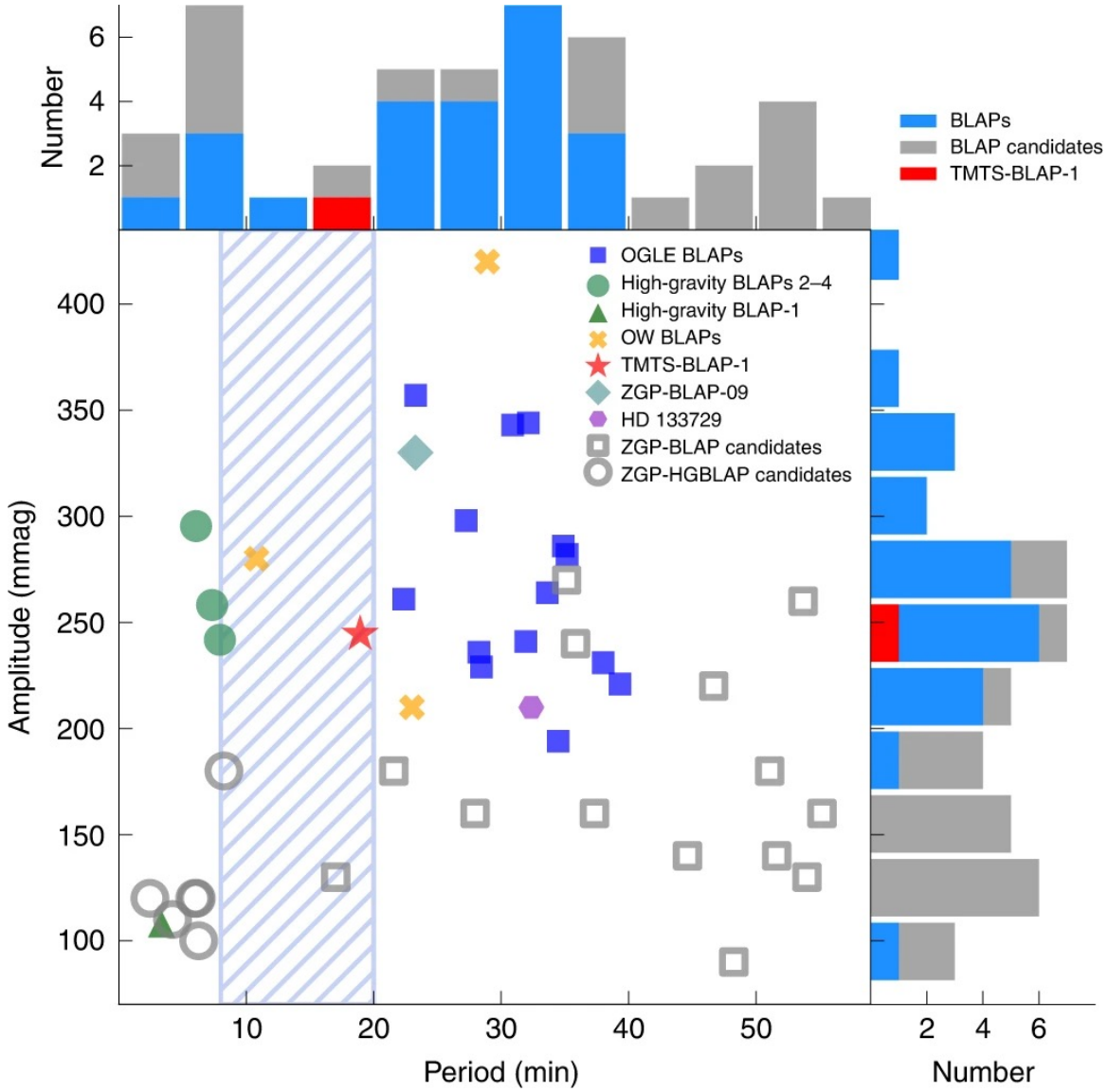
INTRODUCTION

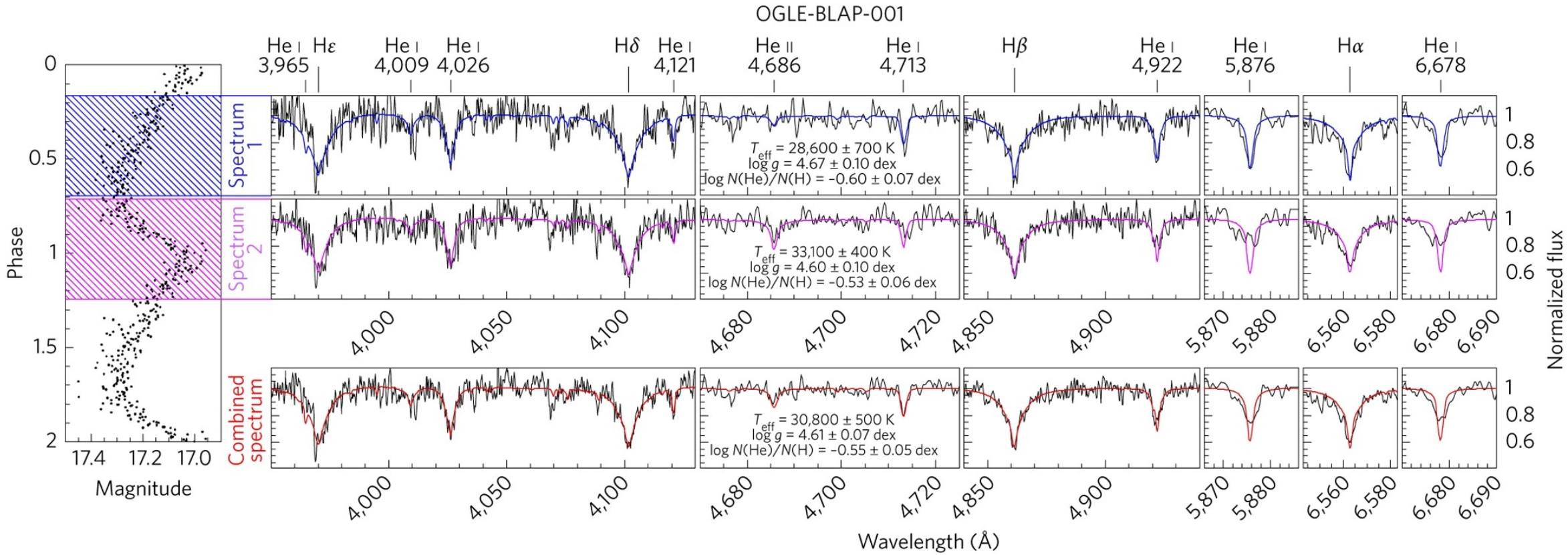
Blue Large-Amplitude Pulsators (BLAPs):

- A rare and striking class of short periodic (from a few to 40 minutes), luminous subdwarf stars with exceptionally large amplitude variations of 20–40%.
- They are pulsate with periods in the range ~ 20 − 40 min.
- The first BLAPs (OGLE-BLAP-001) discovered by Pietrukowicz with Optical Gravitational Lensing Experiment (OGLE) in 2017.



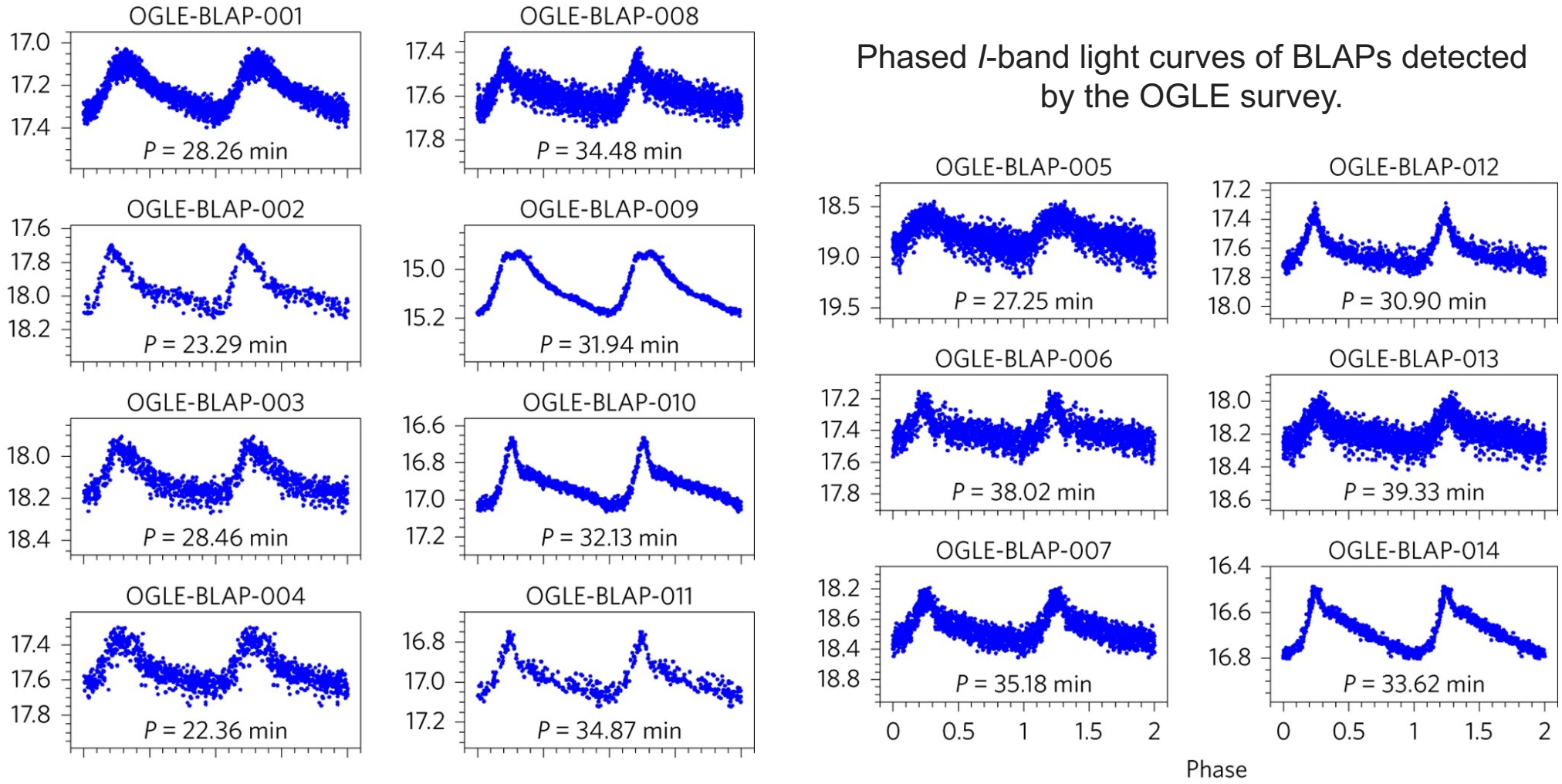
Lin et al. 2023 *Nature Astronomy*

- High effective temperatures of T_{eff} = 26,000 – 34,000 K ---------- significantly blue in colour;
- The spectrum of BLAPs also exhibits hydrogen and helium absorption lines corresponding to high effective temperatures;
- Spectra suggest surface gravity levels of *log g* ≈ 4 ~ 5.



Pietrukowicz et al. 2017 *Nature Astronomy*

The sawtooth shape of their phased light curve is not atypical compared to other classical pulsators (e.g., δ Scuti stars or Cepheids).



Phased *I*-band light curves of BLAPs detected by the OGLE survey.

Pietrukowicz et al. 2017 *Nature Astronomy*

Observationally, there are difficulties in searching for BLAPs in our Galaxy:

1. Nearly all confirmed BLAPs are located in low Galactic latitude regions (|b| < 10 deg ; mean $E(B-V) = 0.97 \pm 0.81$) where their observed photometry deviates from their intrinsic colour due to interstellar extinction and source confusion.

2. It is not easy to obtain an unbiased estimate of such short pulsational periods without support from minute-cadence (even sub-minute cadence) observations.

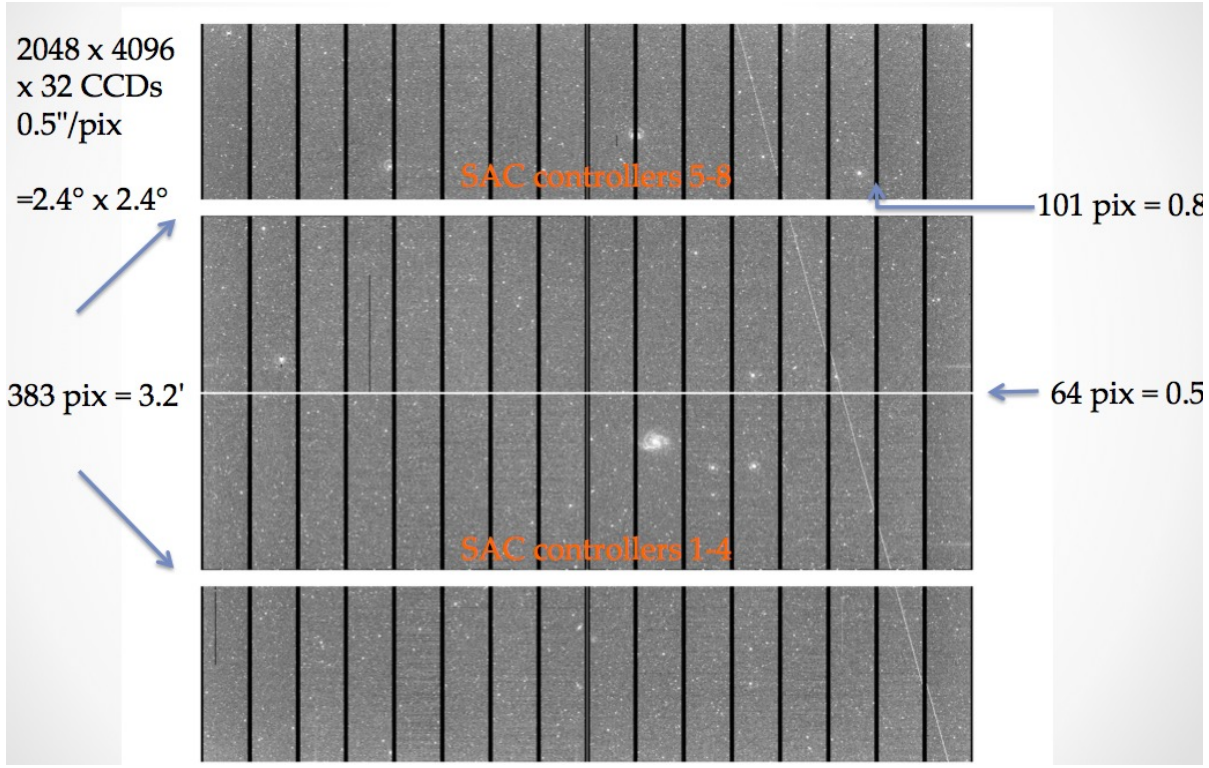
These difficulties may lead to a large discrepancy between model predictions and observations so far.

- Only 8 stars have been further confirmed as BLAPs after the first discovery of 14 BLAPs by the OGLE survey.
- The formation channel and evolutionary path of BLAPs remains open.

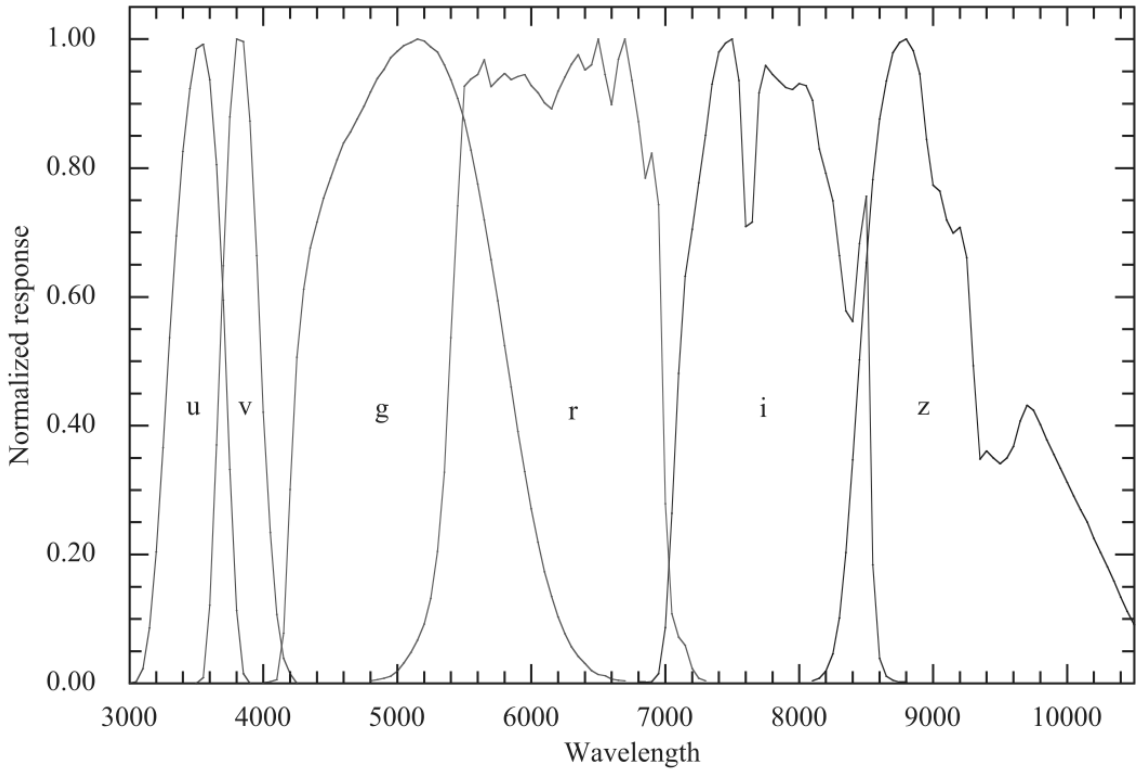
SkyMapper Southern Survey (SMSS):

SkyMapper telescope: 1.35m primary mirror, 0.71m secondary; at Siding Spring Observatory

SkyMapper mosaic camera



SkyMapper filter curves



The central wavelengths and width of *uv*-band are 350/43 nm and 384/31 nm, respectively.

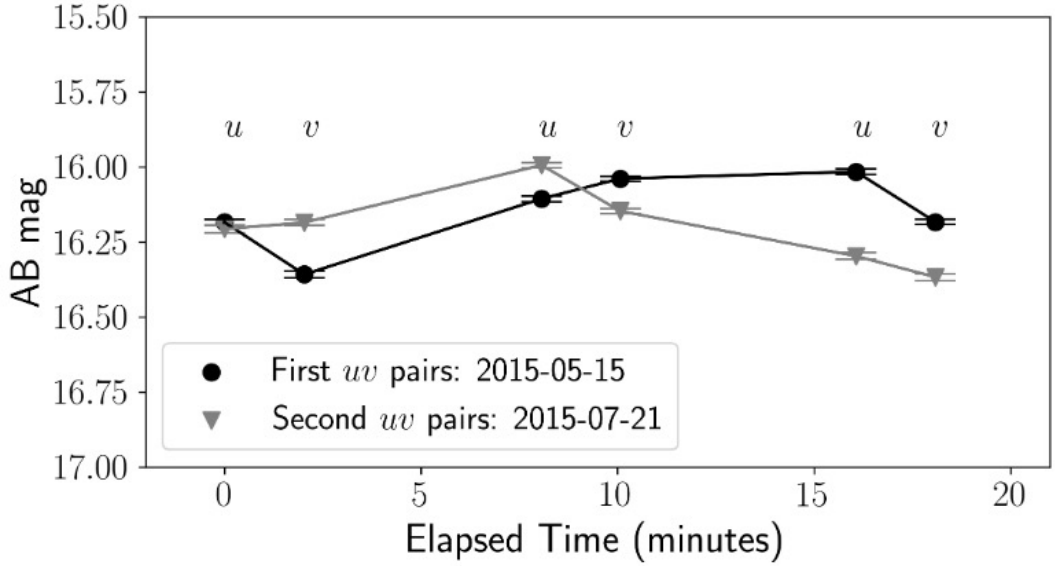
OBSERVATIONS

Discovery:

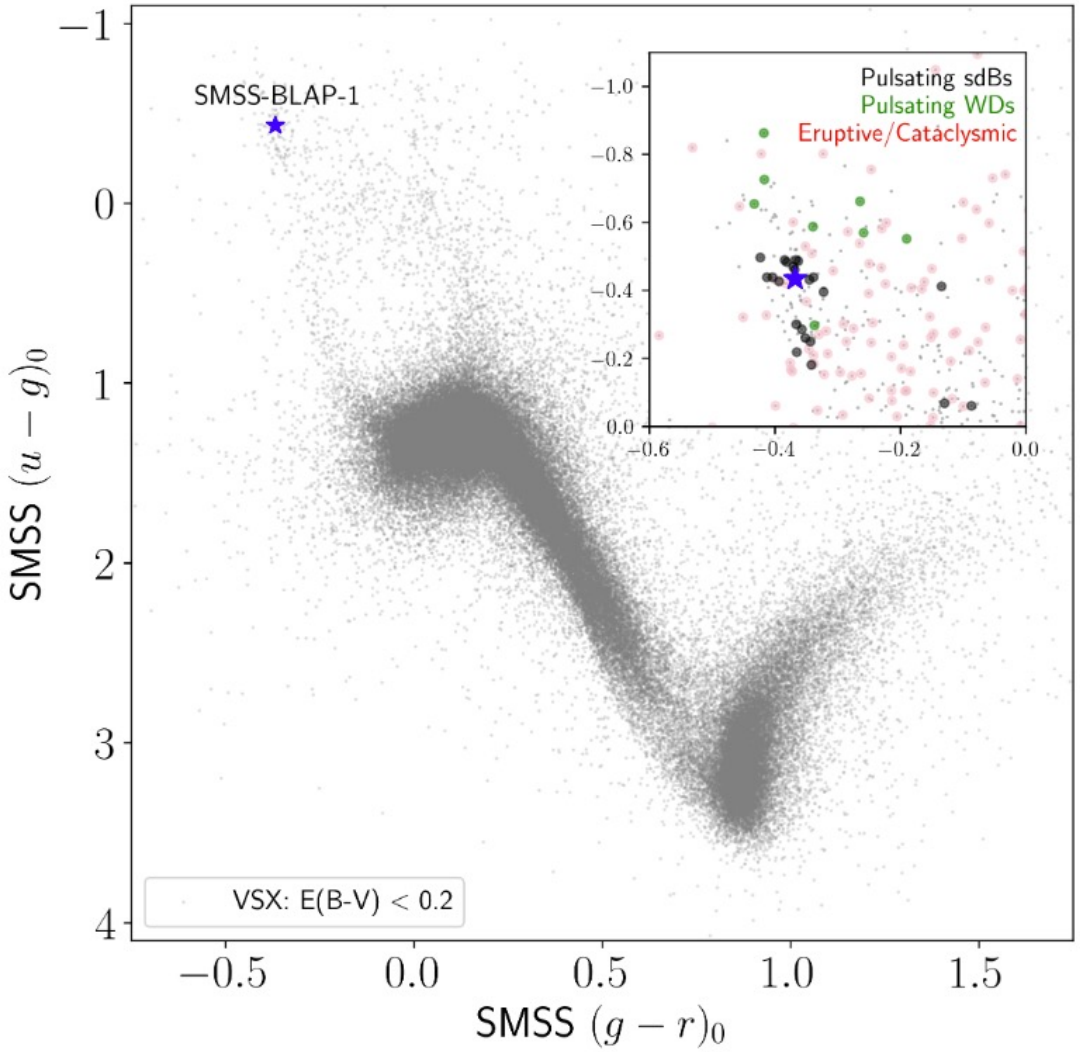
SMSS J184506.82-300804.7 (SMSS-BLAP-1)

G = 16.476 mag

They first identified SMSS-BLAP-1 during a search for short-term variable blue stars in the SMSS DR2



Exposure time of 100 seconds per image



127,660 known variable stars (grey points)

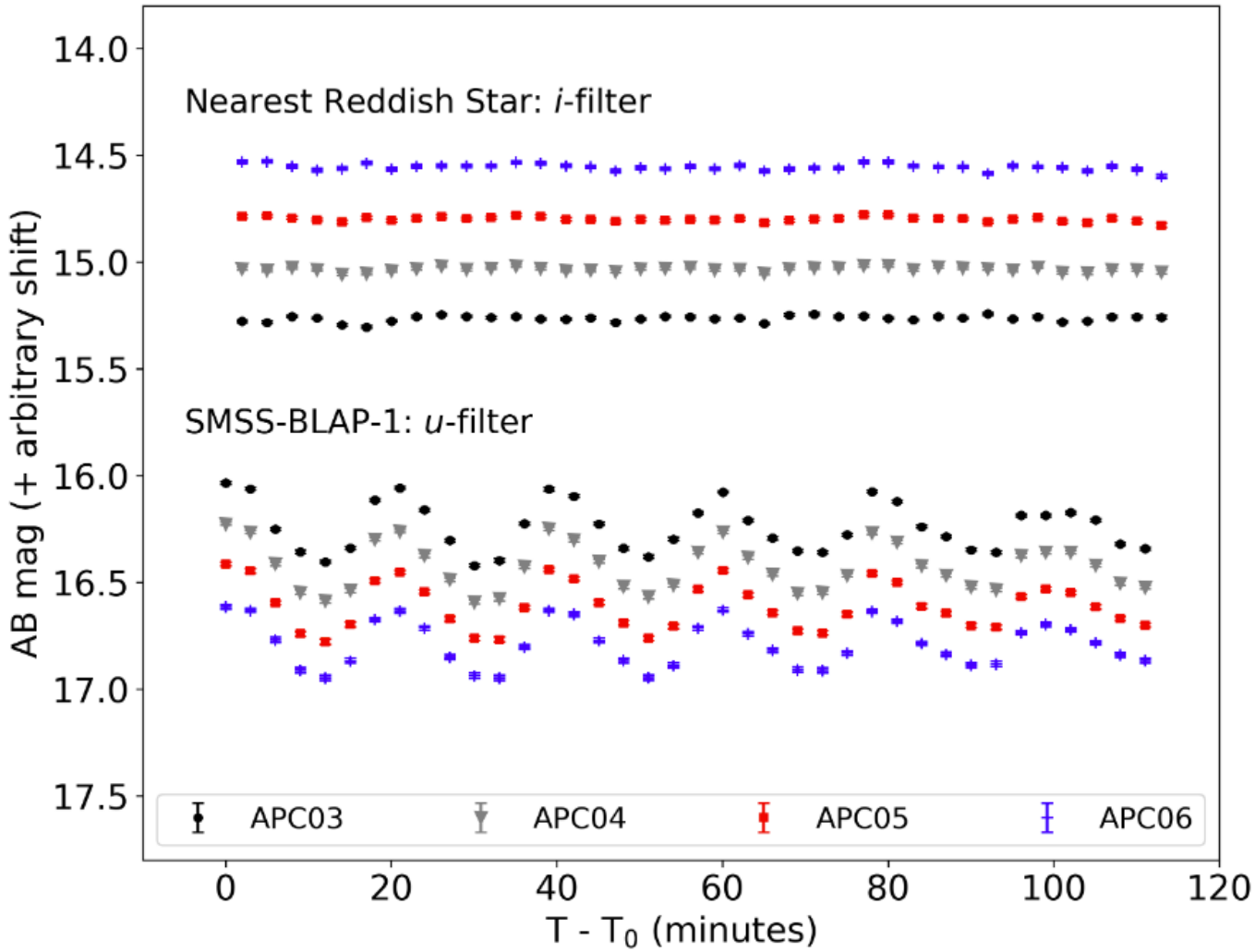
As shown in the insert figure, variable objects in the colour–colour plane around SMSS-BLAP-1 (-0.368, 0.435) are occupied by pulsating hot subdwarf stars and pulsating white dwarfs.

SkyMapper High-Cadence Photometry:

They conducted a high-cadence monitoring of the BLAP candidates to verify their pulsation periods.

They adopted a repeated filter sequence, alternating between a 100-sec *u* band and a 40-sec *i* band exposure.

- From 10 July 2019 to 27 August 2019 (15 nights);
- 283 *u* band and 240 *i* band images;
- Most images were obtained during bad-seeing time with a range of airmass between 1 and 1.4 through the program.



The nearest DR2 object visible on SMSS images is a star at **3.6″** distance to the South-West.

ANU 2.3m Spectroscopy:

- Spectroscopic observations of the candidate were carried out with the Wide Field Spectrograph (WiFeS) on the ANU 2.3m-telescope at Siding Spring Observatory.

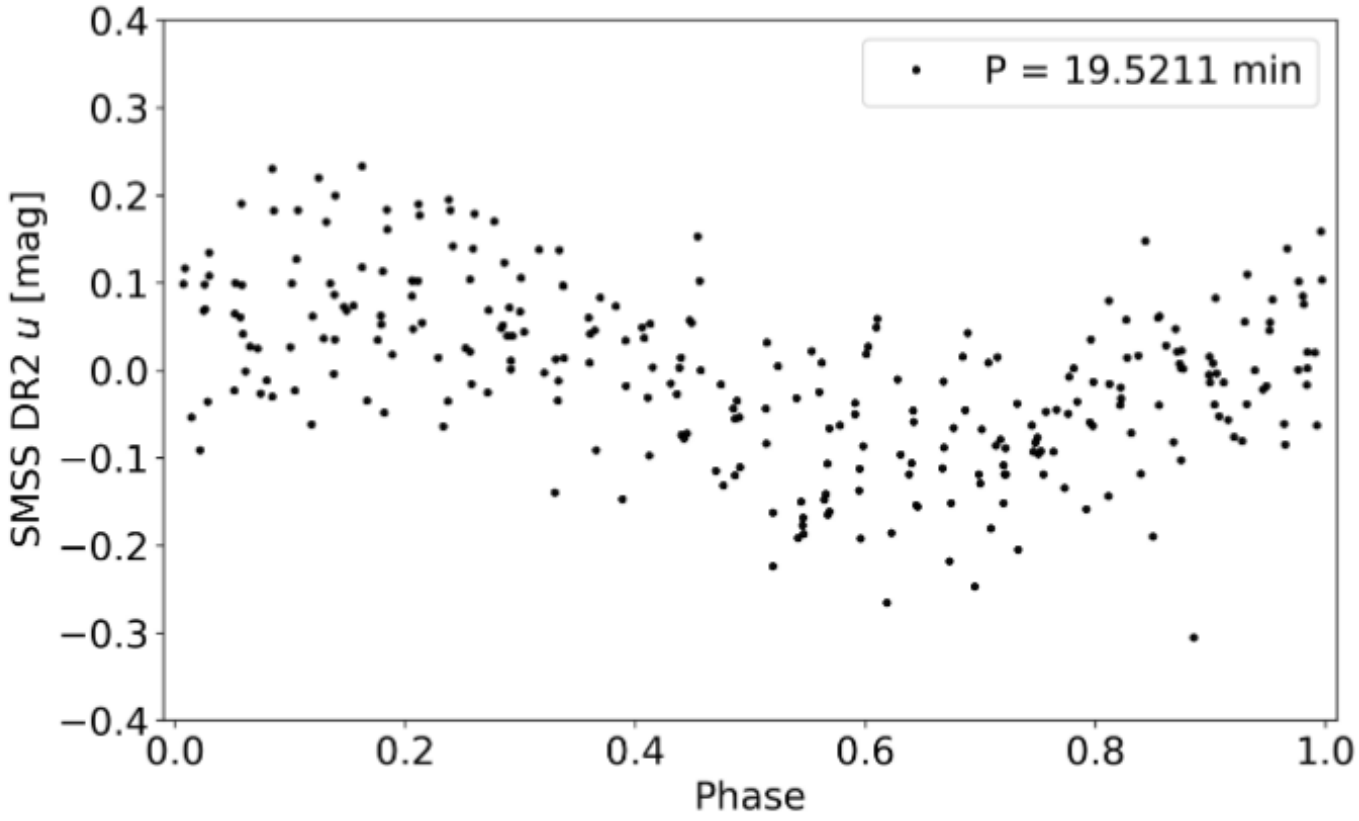
- They obtain nine 600-sec spectra with WiFeS on *9 June 2019* between *19 h12 m* and *20 h 46 m* sidereal time.

- The blue and red spectra cover the wavelength range of 3300–4370 and 5300–7040, respectively.

ANALYSIS

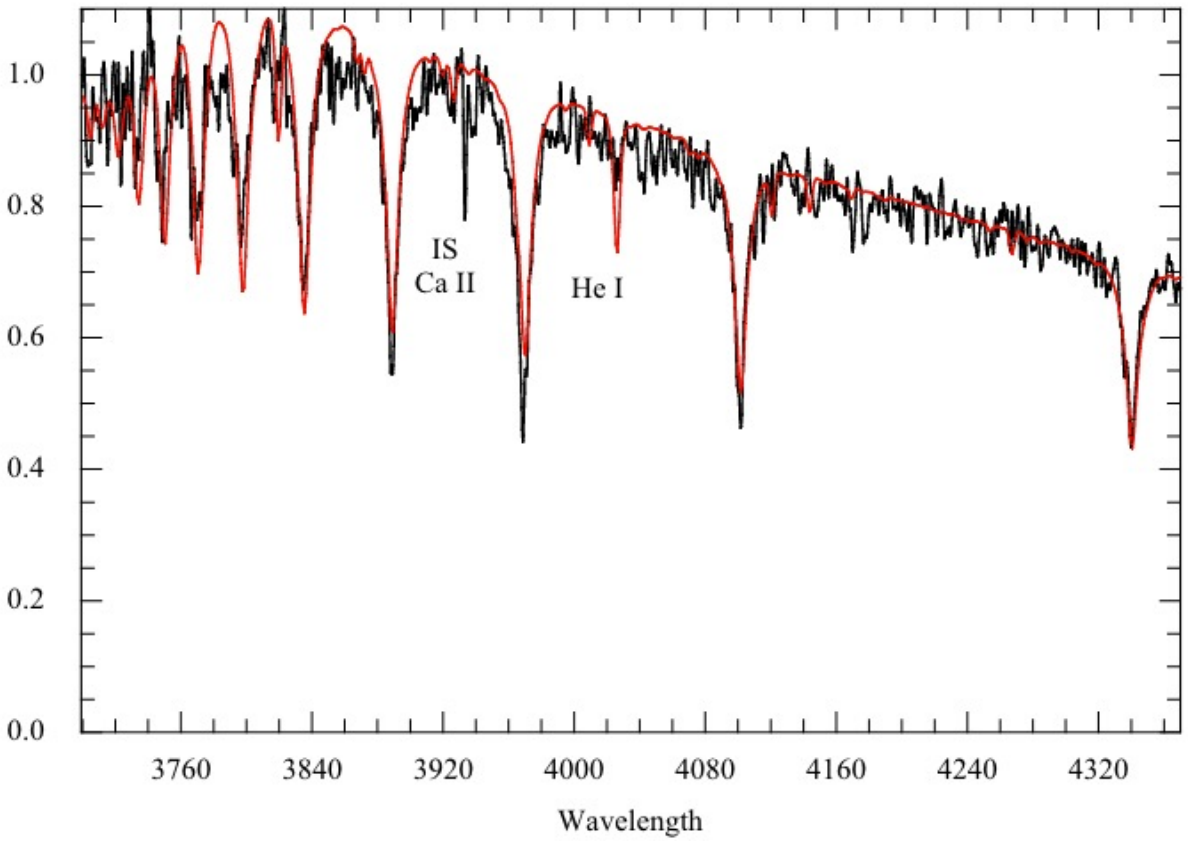
Pulsation Period:

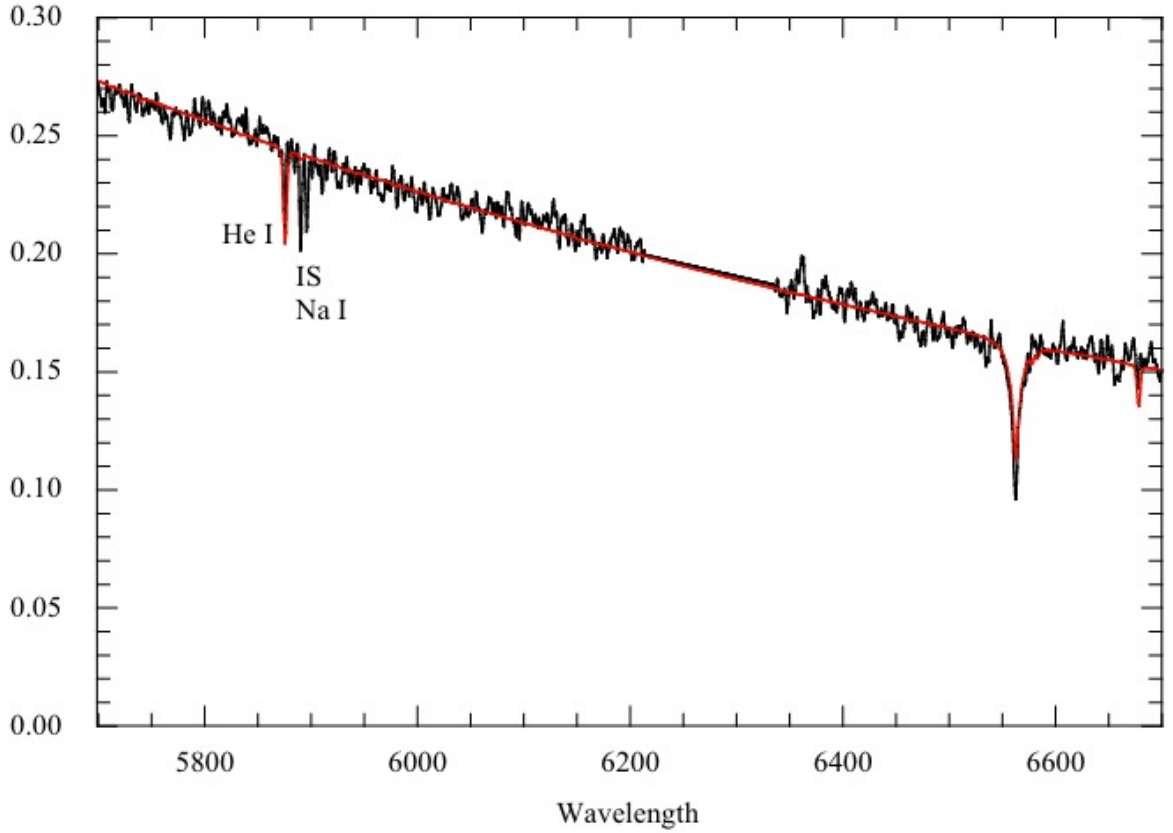
To identify a pulsation period and its amplitude, they perform a frequency analysis of the high-cadence lightcurve using the ***Period04*** and the ***Sigspec*** software.



To derive the effective temperature and surface gravity, they compare the fluxed blue spectrum with a grid of ***Munari synthetic spectra*** using the following criteria: 15,000 < Teff < 50,000, 3.5 < log g < 5.5, and -1.0 < [M/H] < 0.0 dex.

T_{eff} = 27,000 K, *log g* = 4.4, [*M/H*] = -1.0, *E(B − V)* = 0.128





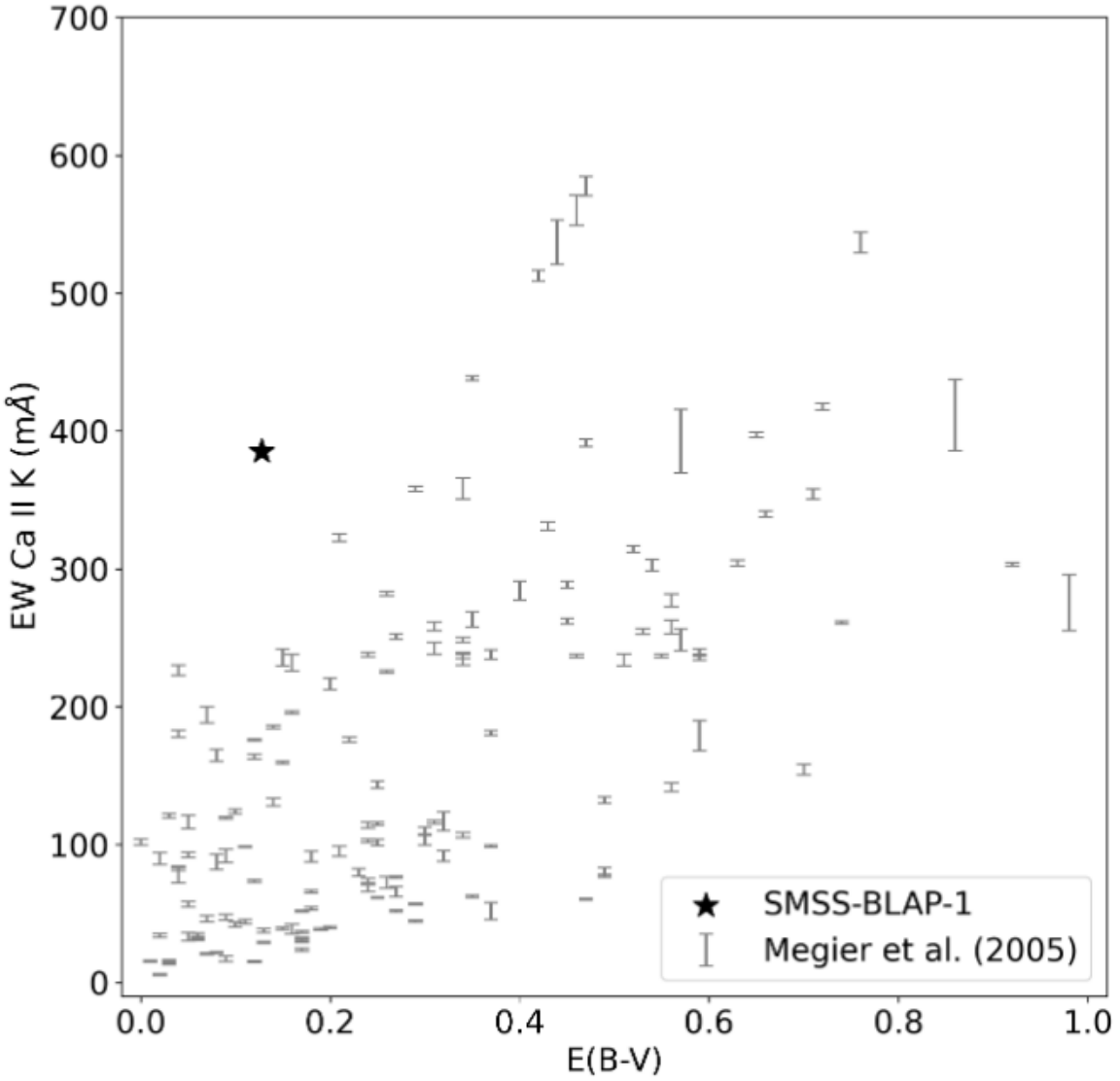
A prominent feature in the spectra are strong, narrow, interstellar lines of Ca II K (3933.7 Å) and Na I D (5889.95/5895.924 Å).

- Observations of Galactic field O and B stars by Megier et al. (2005) suggest that the measured strength of the interstellar lines in this object would correspond to an *E(B − V)* between 0.3 and 0.7, significantly exceeding the reddening estimates from Schlegel et al. (1998).

- Given this evidence, it is likely that most of the line EWs originate from CSM rather than ISM.

- The detection of significant CSM around BLAPs may constrain their recent evolutionary history.

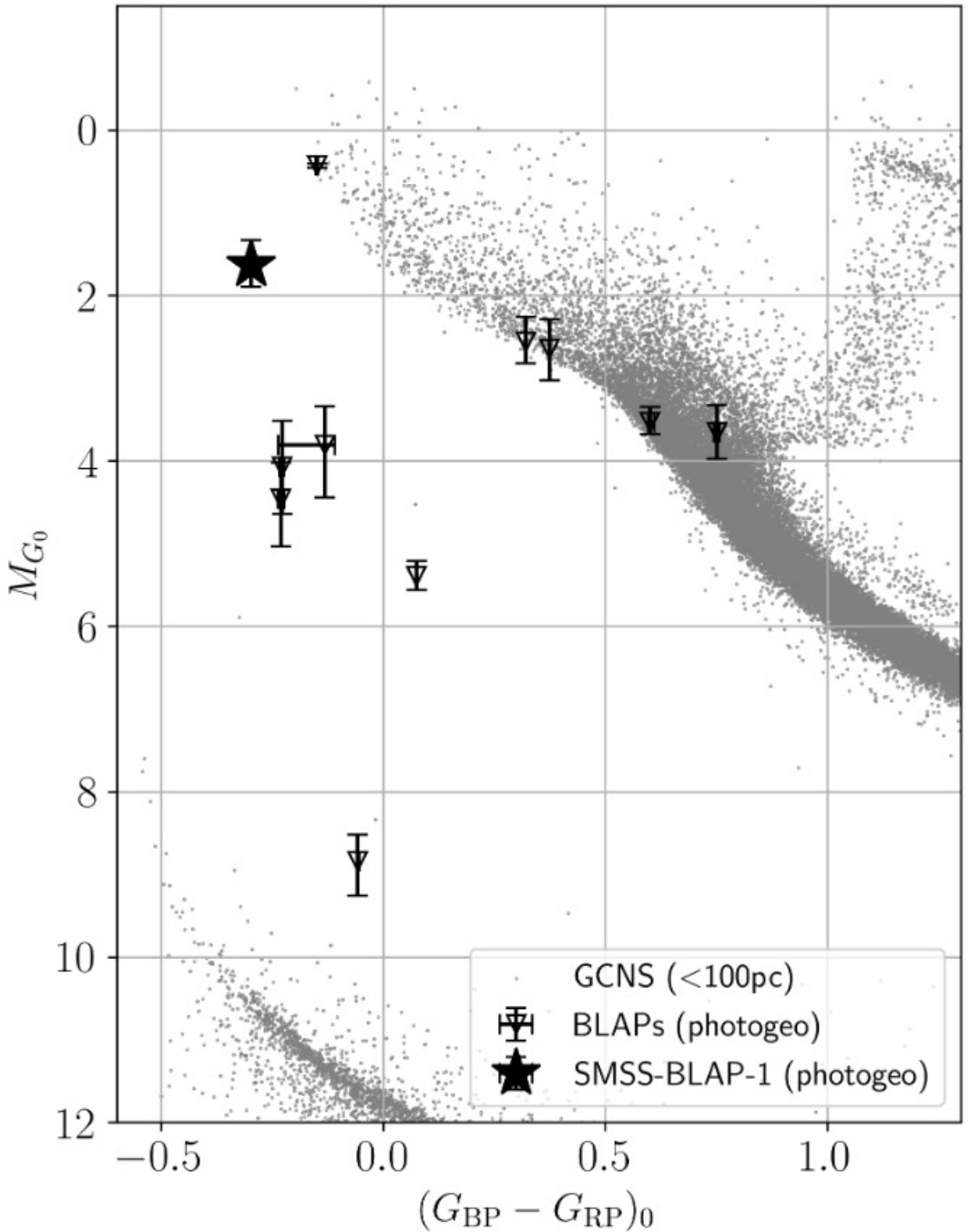
Relation between Ca II K line strength and E(B −V) for OB stars in our Galaxy (Megier et al. 2005) and SMSS-BLAP-1 (star).



GAIA DR3 VIEW OF BLAPS

Hertzsprung-Russell diagram of BLAPs:

The known BLAPs cover a very wide range of colour and luminosity in the CaMD, implying the difficulty of searching for new BLAPs wihtout light curves.



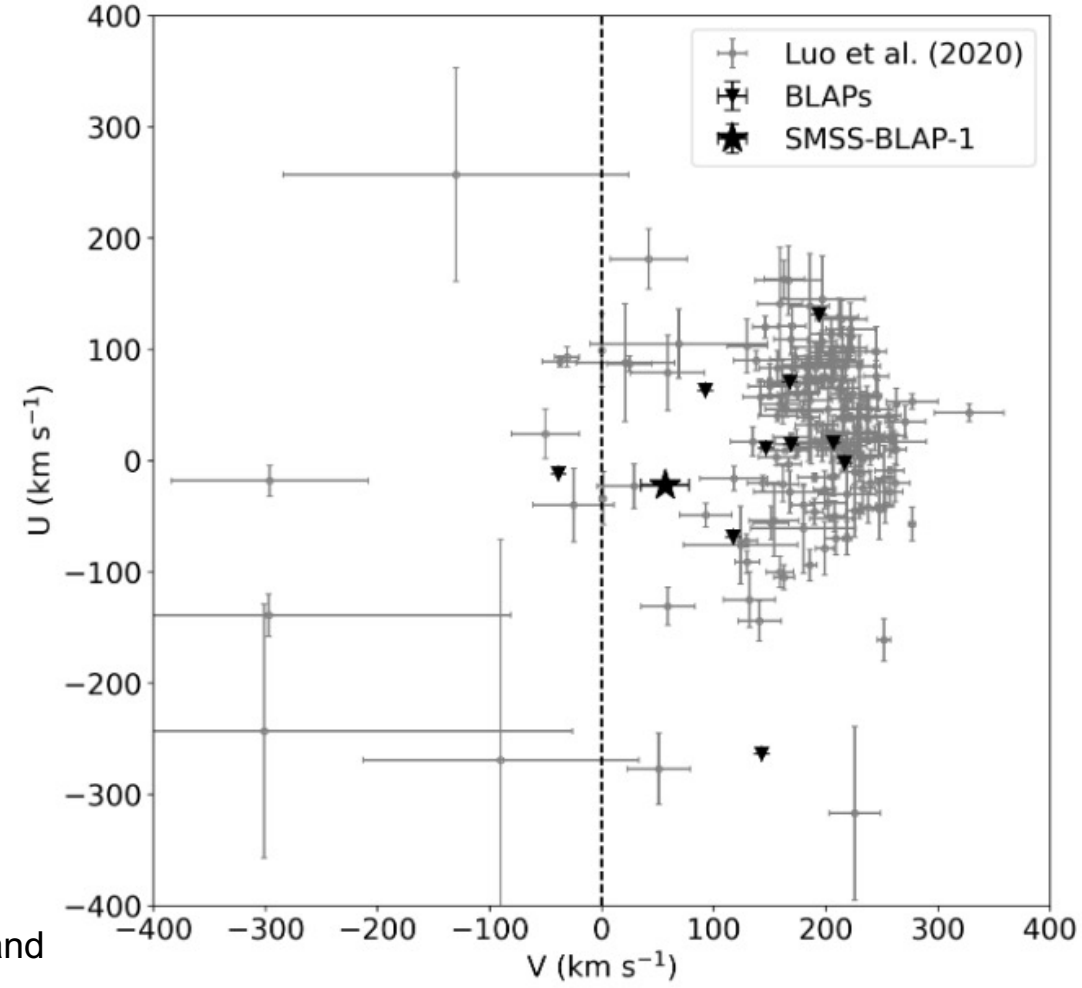
Known 10 BLAPs (open inverse triangle), SMSS-BLAP-1 (star), and nearby stars within 100 pc (grey).

Kinematic properties of BLAPs:

(U , V , W) are positive in the direction toward the Galactic Centre, Galactic rotation and North Galactic Pole

Name	X (kpc)	Y (kpc)	Z (kpc)	U (km s^{-1})	V (km s^{-1})	W (km s^{-1})	$v_{\rm tan}$ (km s^{-1})
SMSS-BLAP-1	$0.415^{+1.127}_{-1.105}$	$0.766^{+0.099}_{-0.097}$	$-1.855^{+0.238}_{-0.243}$	$-22.075^{+2.643}_{-2.593}$	$56.7766^{+21.585}_{-22.001}$	$43.9594^{+3.260}_{-3.198}$	156.282

Slow rotational velocity prograde motion (V > 0)

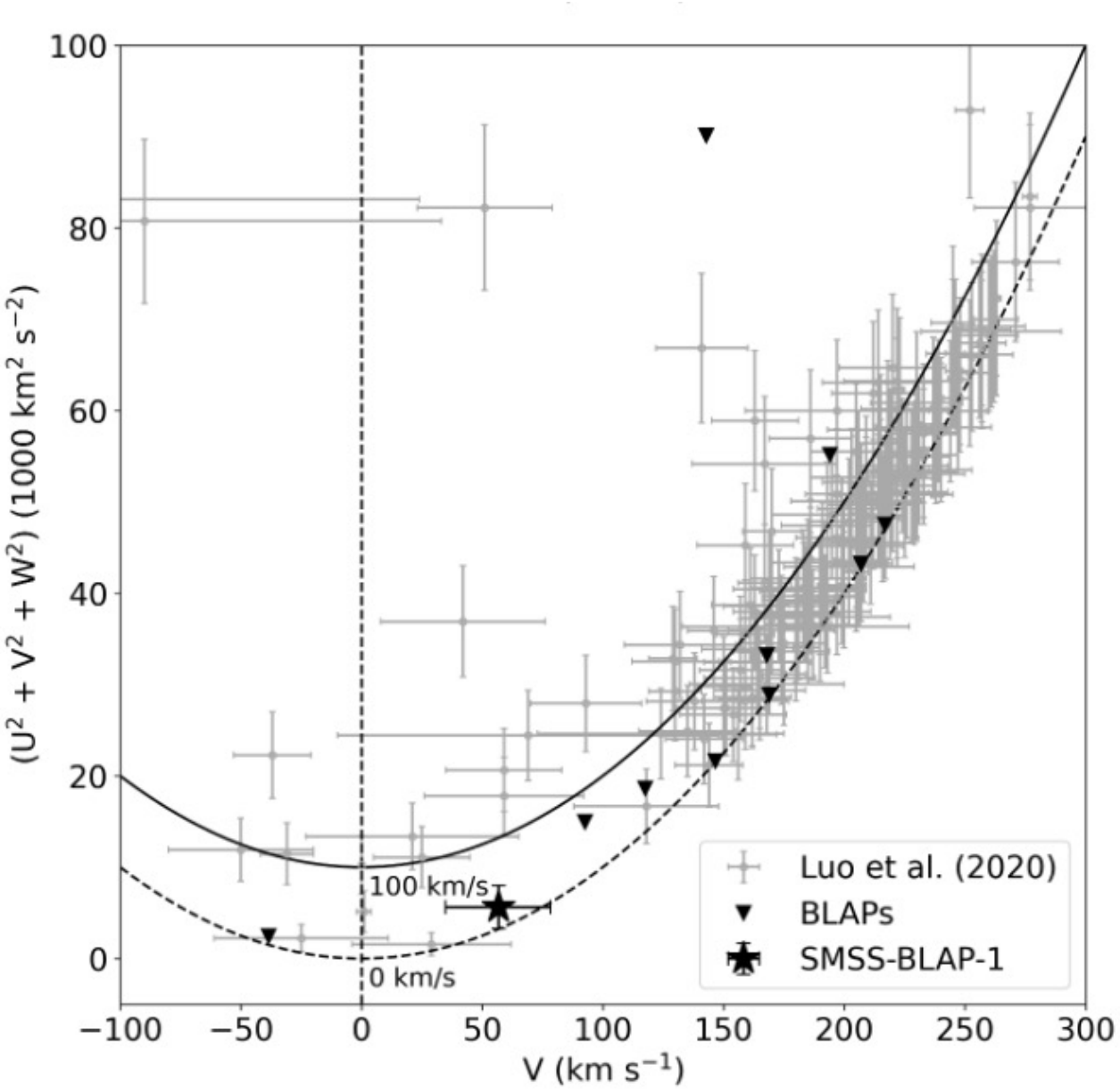


182 hot subdwarfs from Luo et al. (2020) and BLAPs.

Low value of its total kinetic energy,

circular orbit,

Kinematically cool star



SUMMARY

1. **Discovery of a New BLAP:** A new BLAP, named SMSS J184506-300804, was discovered in the SMSS DR2.
2. **Observation Techniques:** The discovery was made possible by the short cadence of *u* band exposure pairs in the survey.
3. **Pulsation Period:** The BLAP exhibits a pulsation period of 19.5211 minutes in the *u* band, a rare observation for stars in the 8–20 minute period gap.
4. **Estimated Parameters:** The star's estimated effective temperature is 27,000 K and surface gravity is 4.4, classifying it as a low-gravity BLAP. However, these values are not precise due to pulsation phase variations and insufficient signal-to-noise ratio in the spectra.
5. **Excess Absorption Features:** There is excess absorption in the Ca II K and Na I D lines, suggesting the presence of CSM.

Thanks for your attention !