

Symbiotic binaries at P. J. Šafárik University

Jaroslav Merc[1,2], Rudolf Gális[1] and collaborators

[1] Institute of Physics, P. J. Šafárik University in Košice, Slovakia
[2] Astronomical Institute of Charles University in Prague, Czech Republic

Outline

- **Symbiotic binaries**
  - Spectral appearance
  - Importance
- **Symbiotics at UPJŠ**
  - New Online Database of Symbiotic Variables
  - Z And-type symbiotics
  - Symbiotic candidates
  - New symbiotic stars
- **Conclusions**

21 „symbiotic“ publications in last 5 years (2015 – 2020)
+ 2 accepted (arXiv)
+ 1 submitted
+ 3 in preparation

Symbiotic binaries

- strongly **interacting binary** systems
  - mass transfer via stellar wind or Roche lobe overflow
  - open binaries
- consist of a **cool giant** and **hot compact star**, mostly a white dwarf
  - circumbinary envelope
- significant **variability,** „composite“ spectra

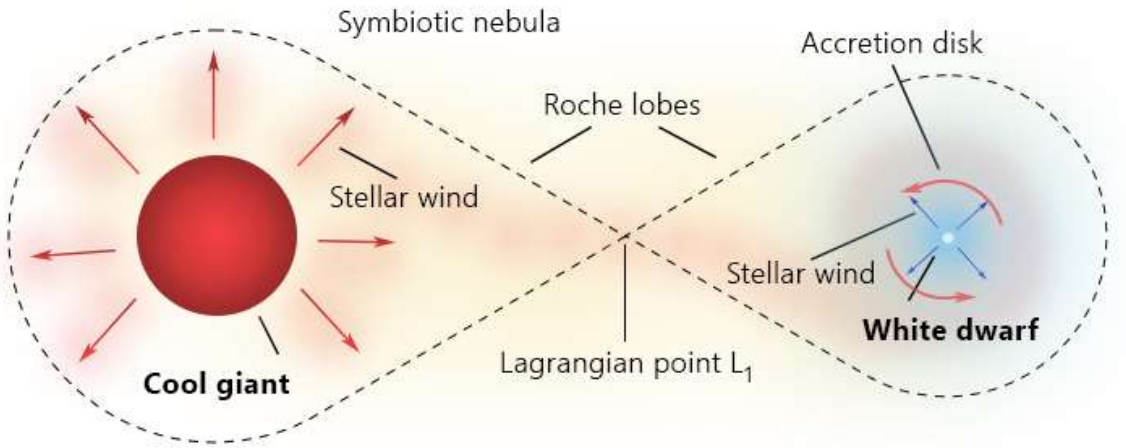


Figure: Simplified model of a symbiotic binary.

References:
Kenyon, 1986, The Symbiotic Stars
ISBN: 978-0521093316
Mikołajewska, 2012, Baltic Astronomy
doi: 10.1515/astro-2017-0352
Munari, 2019, Review in The Impact of Binary Stars on Stellar Evolution
arXiv:1909.01389
Merc et al., 2019, Astronomische Nachrichten
doi: 10.1002/asna.201913662

Symbiotic binaries
Spectra

CI Cyg observation:
ARAS Group

References:
Skopal et al., 2015, New Astronomy
doi: 10.1016/j.newast.2013.10.009
Teyssier, 2019, Contributions of the Astronomical Observatory Skalnaté Pleso

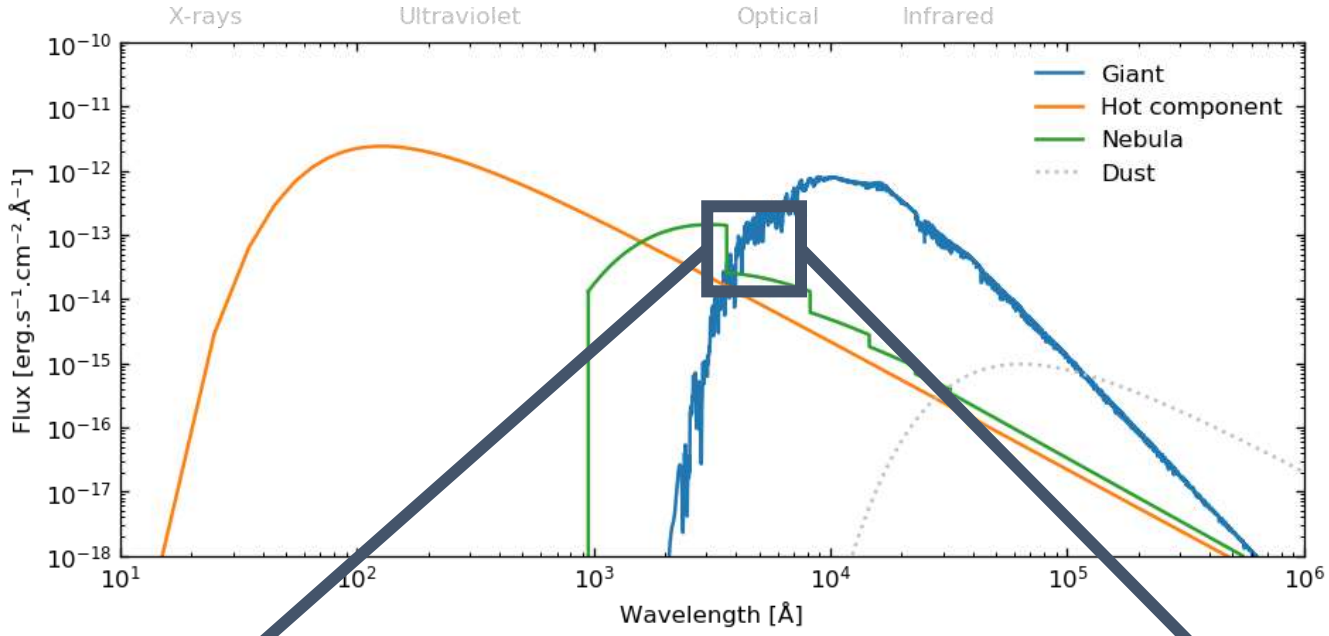


Figure: Radiation sources observed in symbiotic spectrum.

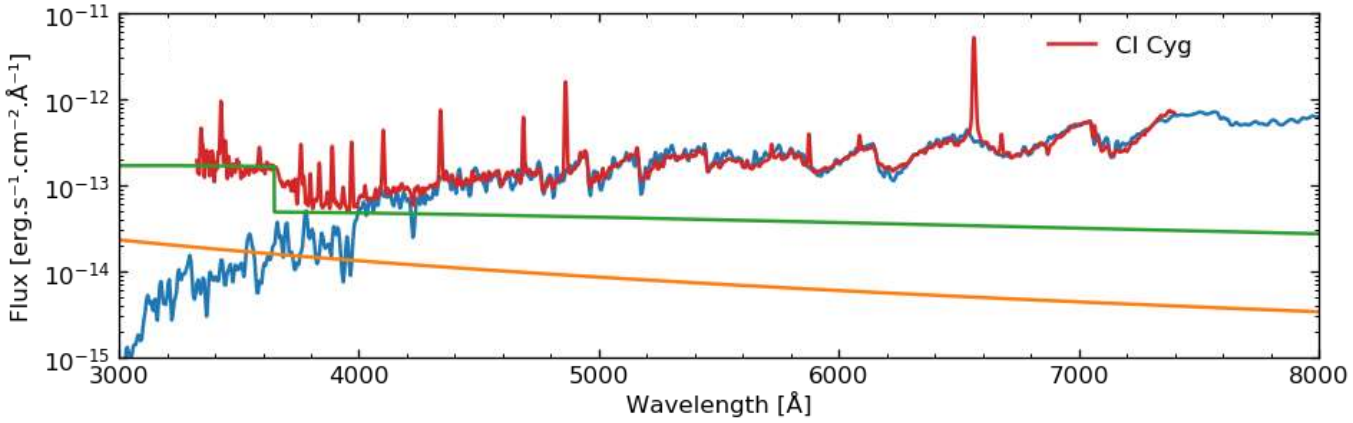


Figure: Optical and near-UV spectrum of CI Cyg.

Symbiotic binaries
Importance

- unique **astrophysical laboratories**
  - **stellar interaction** – mass transfer, accretion processes
  - stellar **winds** and their collision
  - formation and collimation of **jets**
  - **dust formation** and destruction
  - thermonuclear **outbursts**

- important in study of **stellar evolution**
  - **evolution** of binaries
  - possible **supernovae Ia** progenitors

References:
Kenyon, 1986, The Symbiotic Stars
ISBN: 978-0521093316
Mikołajewska, 2013, Proceedings of the International Astronomical Union
doi: 10.1017/S1743921312014925
Iłkiewicz et al., 2019, Monthly Notices of the Royal Astronomical Society
doi: 10.1093/mnras/stz760

New Online Database of Symbiotic Variables

References:

Merc et al., 2019, RNAAS
doi: 10.3847/2515-5172/ab0429

Merc et al., 2019, Astronomische Nachrichten
doi: 10.1002/asna.201913662

Merc et al., 2020, Contributions of the Astronomical Observatory Skalnaté Pleso
doi: 10.31577/caosp.2020.50.2.426

- more than **400** in the Milky Way
- concentration towards **Galactic plane**
- **New Online Database of Symbiotic Variables**

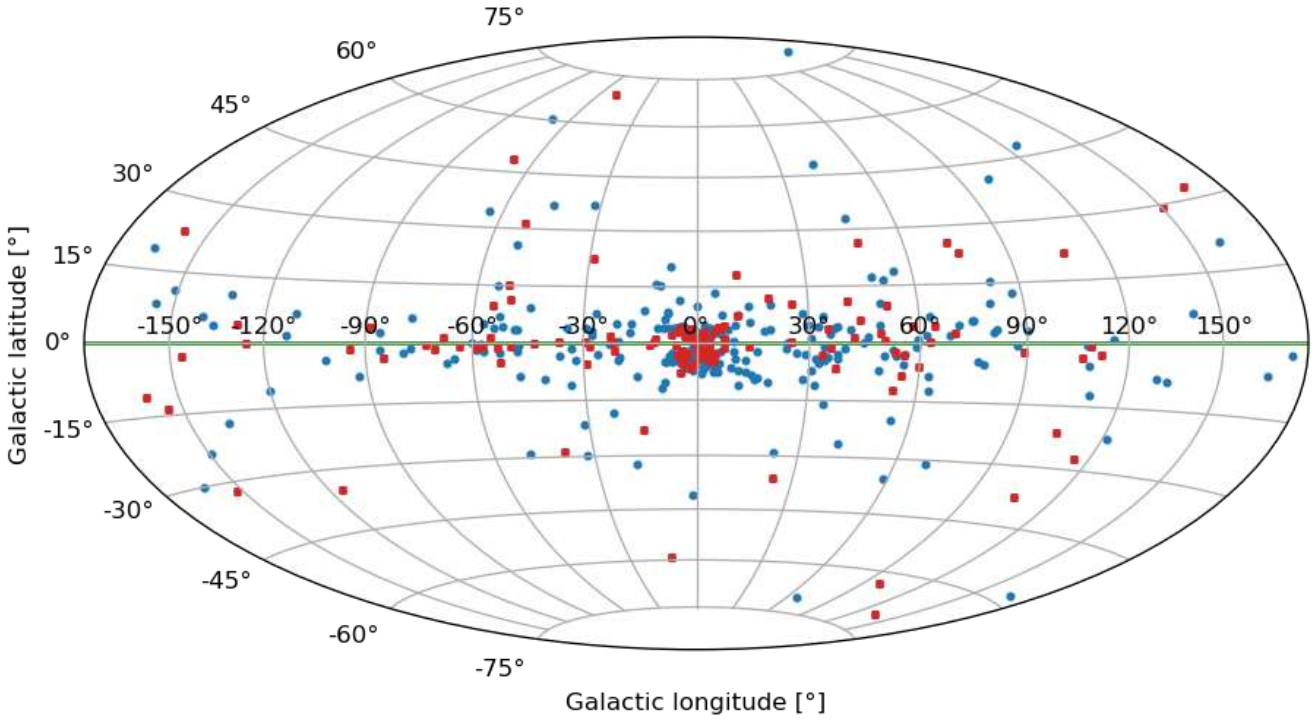


Figure: Distribution of the galactic symbiotic stars according to their galactic coordinates.

New Online Database of Symbiotic Variables

References:

Merc et al., 2019, RNAAS
doi: 10.3847/2515-5172/ab0429

Merc et al., 2019, Astronomische Nachrichten
doi: 10.1002/asna.201913662

Merc et al., 2020, Contributions of the Astronomical Observatory Skalnaté Pleso
doi: 10.31577/caosp.2020.50.2.426

- almost **160 objects** in the Local Group
- advantage in **known distance**

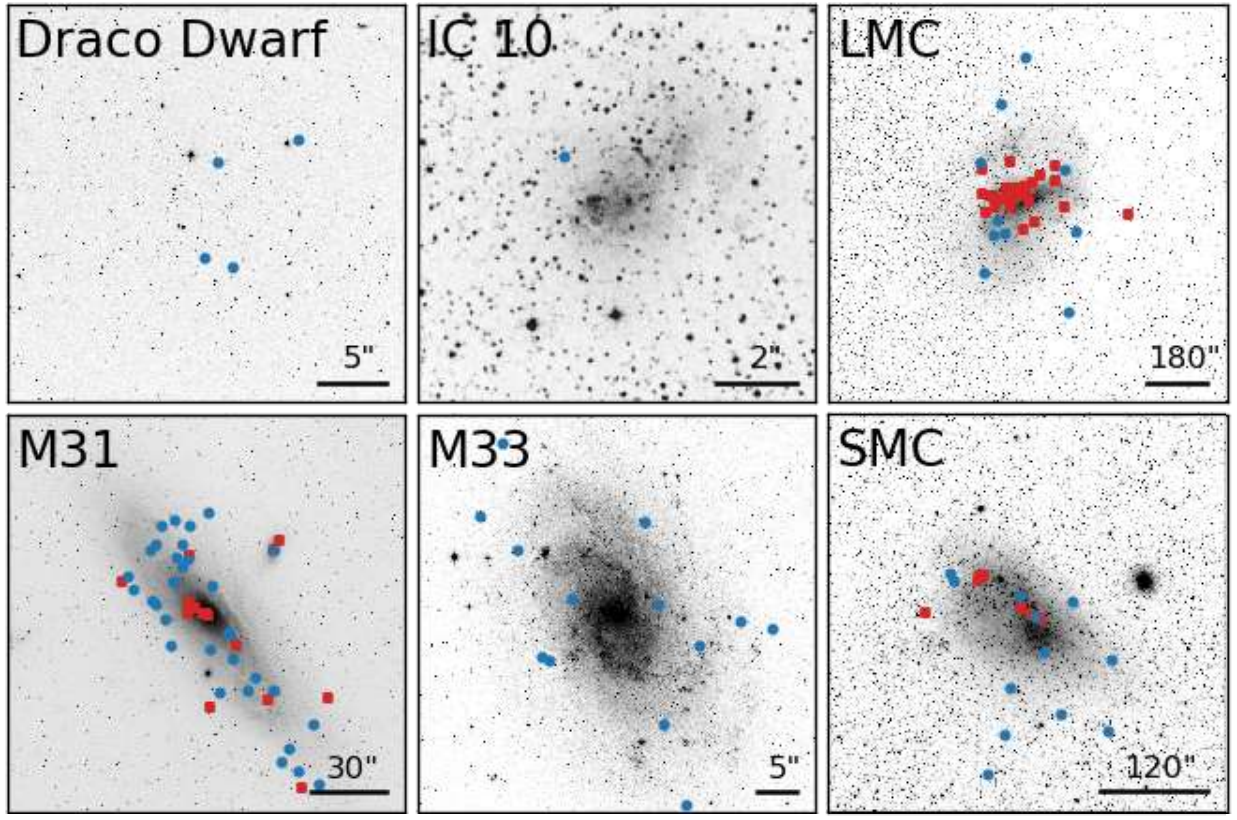


Figure: Position of extragalactic symbiotic stars in their host galaxies.

New Online Database of Symbiotic Variables

- **tables with data**
- **object pages**

http://astronomy.science.upjs.sk/symbiotics/

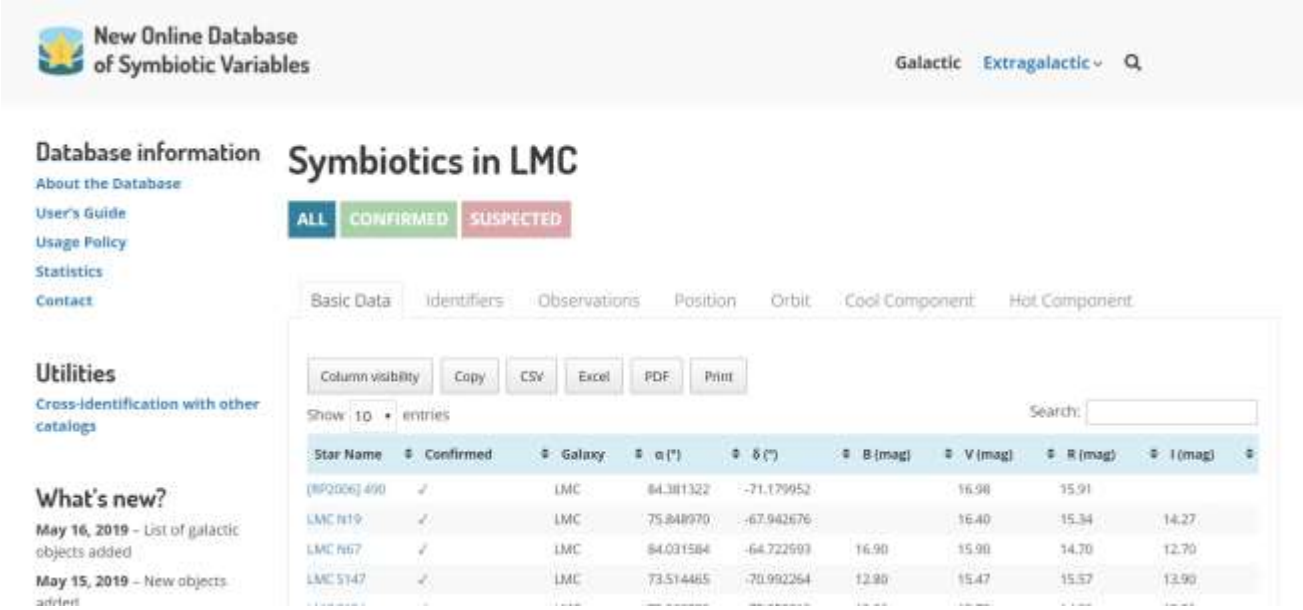


Figure: Catalog data for symbiotic stars in LMC.

References:
Merc et al., 2019, RNAAS
doi: 10.3847/2515-5172/ab0429
Merc et al., 2019, Astronomische Nachrichten
doi: 10.1002/asna.201913662
Merc et al., 2020, Contributions of the Astronomical Observatory Skalnaté Pleso
doi: 10.31577/caosp.2020.50.2.426

New Online Database of Symbiotic Variables

- **tables with data**
- **object pages**

http://astronomy.science.upjs.sk/symbiotics/

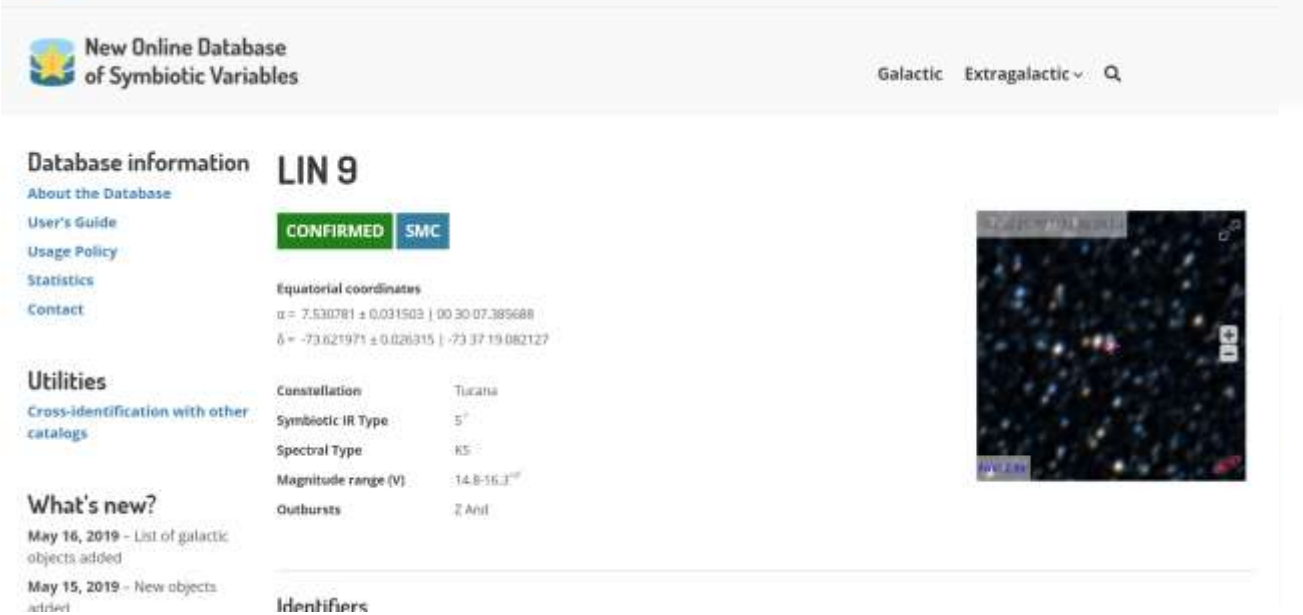
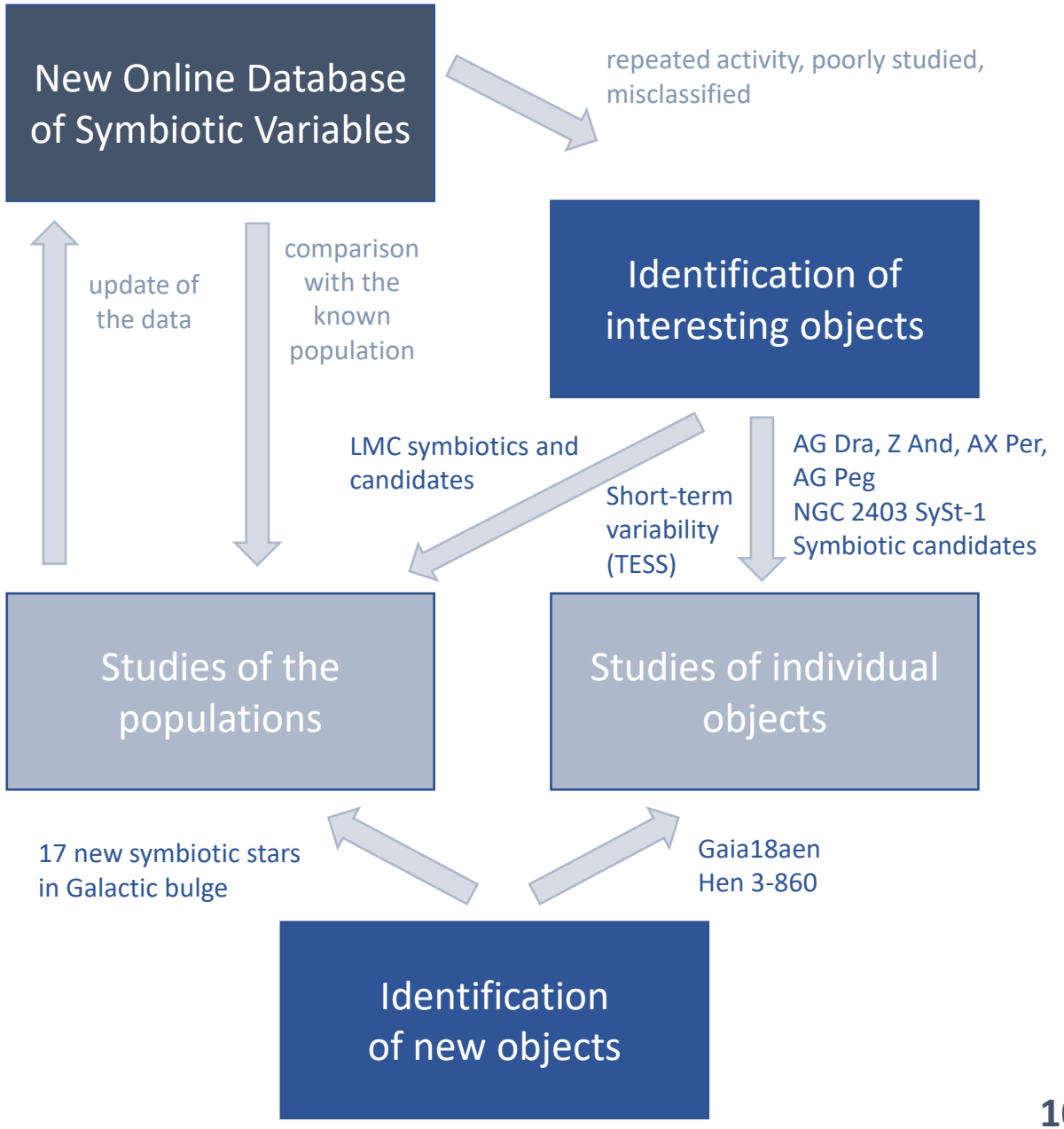


Figure: Example of the object page of symbiotic star LIN9.

References:
Merc et al., 2019, RNAAS
doi: 10.3847/2515-5172/ab0429
Merc et al., 2019, Astronomische Nachrichten
doi: 10.1002/asna.201913662
Merc et al., 2020, Contributions of the Astronomical Observatory Skalnaté Pleso
doi: 10.31577/caosp.2020.50.2.426

Symbiotics at UPJŠ
Workflow



AG Draconis

- **seven years of flat quiescence** following the 2006-08 major outbursts
- new activity **started in 2015**
- **four minor** outbursts
- returned to **quiescence** in 2018/2019

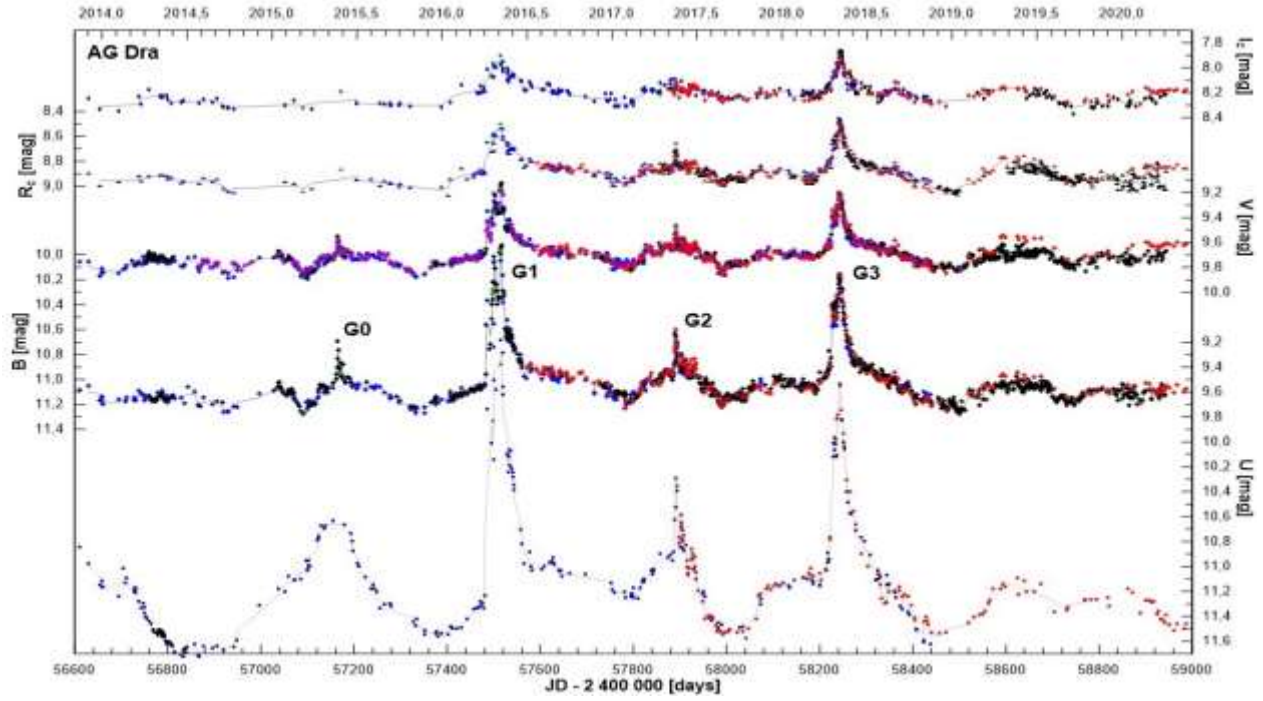


Figure: The recent light curves of AG Dra (2014 – 2020).

References:
Merc et al., 2017, Proceedings of Science
doi: 10.22323/1.315.0060
Gális et al., 2019, Contributions of the Astronomical Observatory Skalnaté Pleso
Merc et al., 2019, Contributions of the Astronomical Observatory Skalnaté Pleso
Gális, Merc, Leedjärv et al., in preparation

AG Draconis

References:
Merc et al., 2017, Proceedings of Science
doi: 10.22323/1.315.0060
Gális et al., 2019, Contributions of the Astronomical Observatory Skalnaté Pleso
Merc et al., 2019, Contributions of the Astronomical Observatory Skalnaté Pleso
Gális, Merc, Leedjärv et al., in preparation

- **spectroscopic campaigns** focused on the recent activity
- more than **750 spectra** (2014 – 2020)
  - various observers (many from the ARAS Group, recently M. Vrašťák)

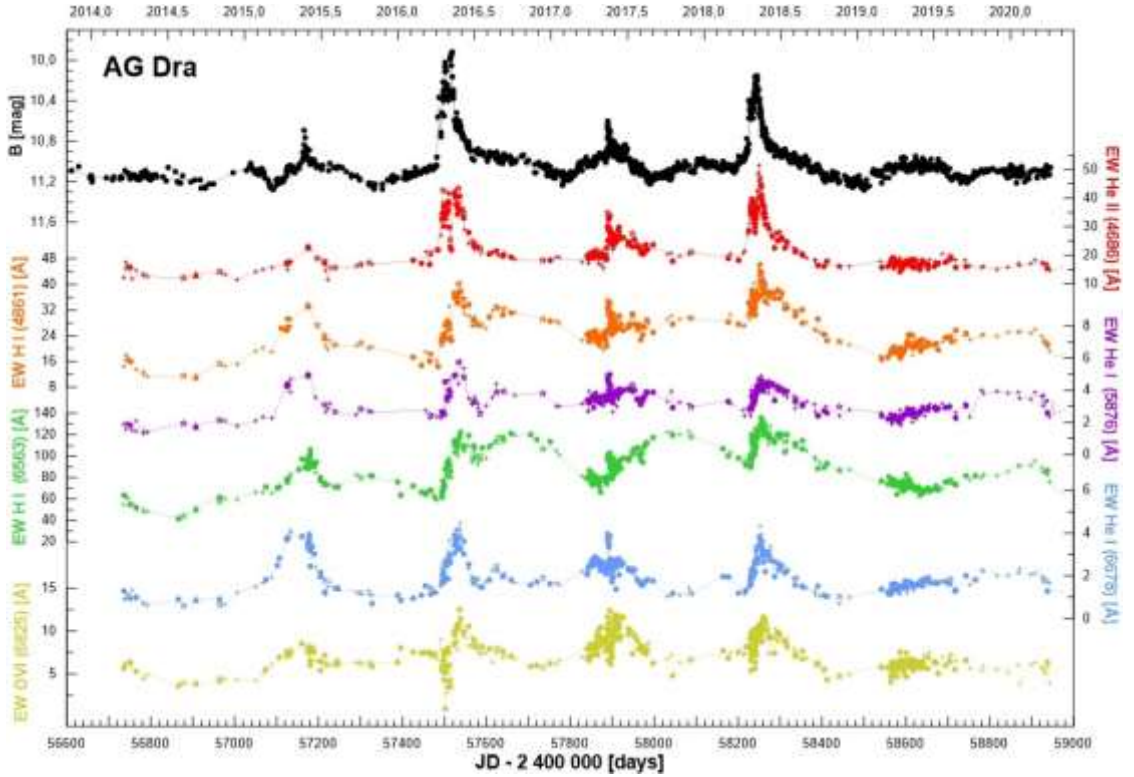


Figure: EWs of selected emission lines.

Z Andromeda

- current activity **started in 2000**
  - recent outburst recorded at the turn of **2017 and 2018**
- Z And is **one of few** symbiotic stars producing **jets**
  - observed during maxima **in 2006 and 2009-2010**
  - **not during** the recent outburst

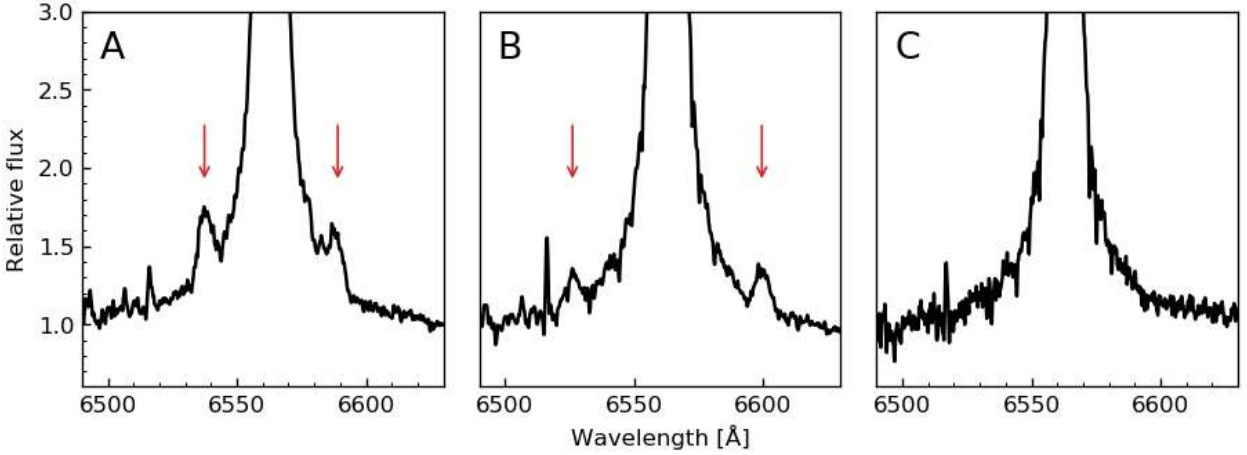


Figure: The jet components (marked with red arrows) of the Hα emission line. The spectra are from 2006 (A), 2010 (B) and from 2018 (C).

References:

Skopal et al., 2018, Astrophysical Journal *doi: 10.3847/1538-4357/aabc11*

Merc et al., 2019, Open European Journal on Variable Stars

Merc et al., 2019, Contributions of the Astronomical Observatory Skalnaté Pleso

AG Pegasi

- **slowest** symbiotic nova
- showed Z And-type outburst **165 years after** its nova-like flare-up
  - **transition** from symbiotic nova **to classical symbiotic star**
  - also some other had gone **through this evolution?**

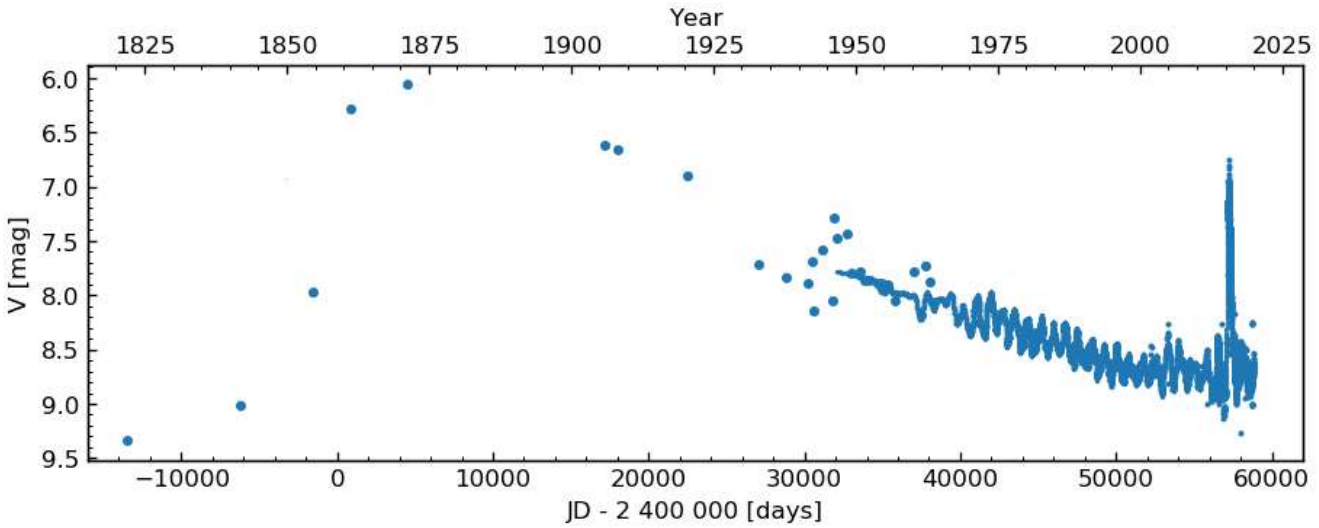


Figure: The historical light curve of AG Peg covering the period of 1821 to 2020.

References:
Skopal et al., 2017, Astronomy & Astrophysics *doi: 10.1051/0004-6361/201629593*
Merc et al., 2019, Contributions of the Astronomical Observatory Skalnaté Pleso

NGC 2403 SySt-1

References:
Merc, Gális, Kára et al., 2020, accepted in Monthly Notices of the Royal Astronomical Society
arXiv: 2009.14784

- classified as a **possible symbiotic binary**, cataclysmic variable, supernova remnant, H II region
  - located **in the field of NGC 2403**
  - **X-ray source**
- our **multiwavelength analysis** proved that this object is **an active, young red dwarf**
  - data from Gaia, TESS, ASAS-SN, ZTF, XMM-Newton, Chandra, Swift, 2MASS, WISE

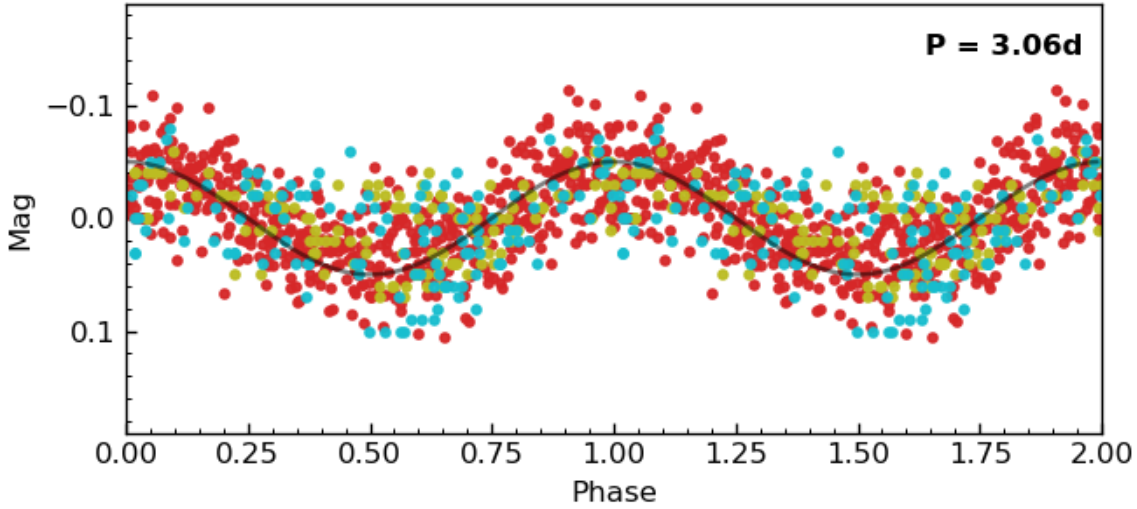


Figure: Phased light curve of NGC 2403 SySt-1.

Hen 3-860

Spectrum:
P. Velez, ARAS Group

References:
Merc, Gális, Velez et al., in preparation

- selected for spectroscopic campaign based on the **peculiar light curve**
  - **outburst in 2018 – 2019 (ASAS-SN)**
  - **eclipse-like** features
- spectrum **confirmed** the symbiotic nature
  - **M2 III continuum**, emission lines of H I, He I, He II
- orbital period of **550 days**
- **two** or three **outbursts** in past

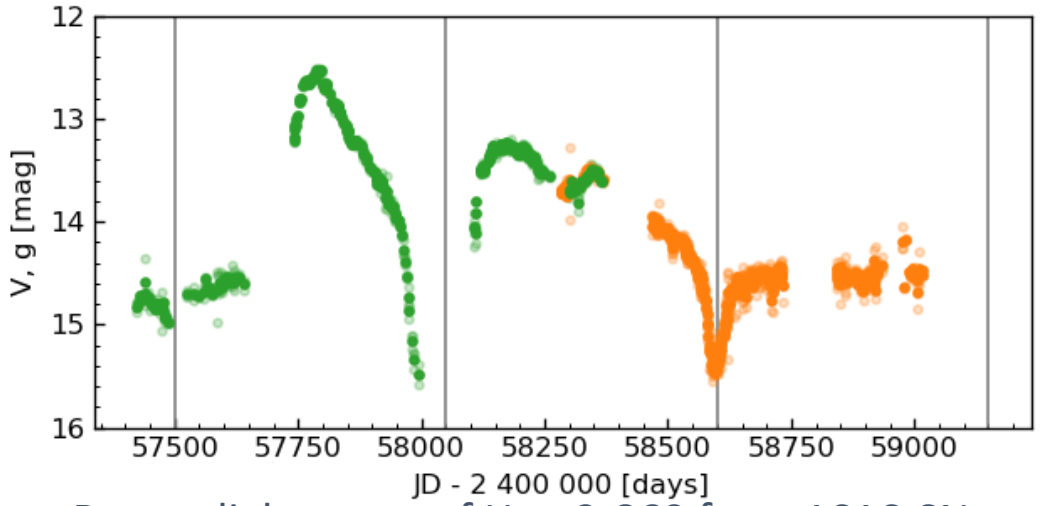


Figure: Recent light curve of Hen 3-860 from ASAS-SN survey.

Hen 3-860

Spectrum:
P. Velez, ARAS Group

References:
Merc, Gális, Velez et al., in preparation

- selected for spectroscopic campaign based on the **peculiar light curve**
  - **outburst in 2018 – 2019 (ASAS-SN)**
  - **eclipse-like** features
- spectrum **confirmed** the symbiotic nature
  - **M2 III continuum**, emission lines of H I, He I, He II
- orbital period of **550 days**
- **two** or three **outbursts** in past

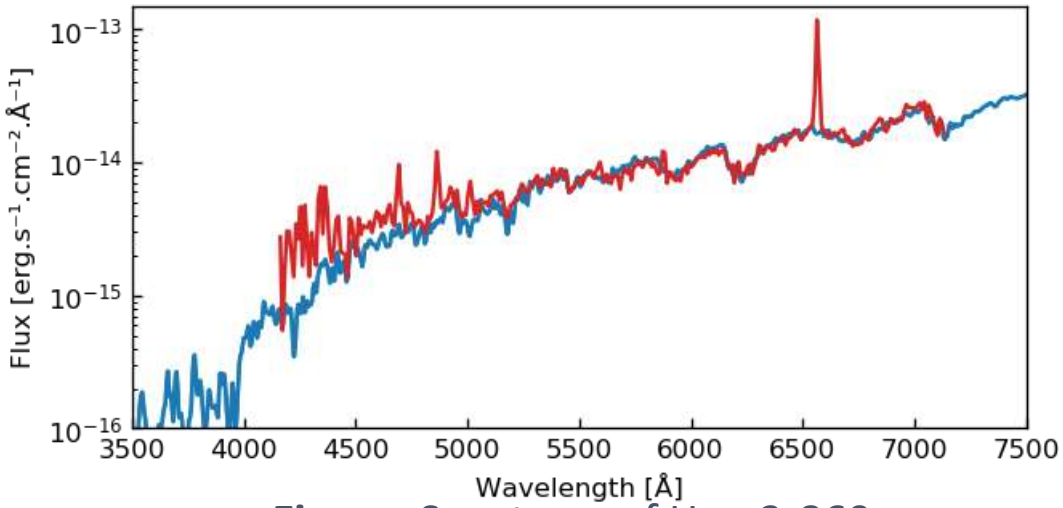


Figure: Spectrum of Hen 3-860.

Hen 3-860

Spectrum:
P. Velez, ARAS Group

References:
Merc, Gális, Velez et al., in preparation

- selected for spectroscopic campaign based on the **peculiar light curve**
  - **outburst in 2018 – 2019 (ASAS-SN)**
  - **eclipse-like** features
- spectrum **confirmed** the symbiotic nature
  - **M2 III continuum**, emission lines of H I, He I, He II
- orbital period of **550 days**
- **two** or three **outbursts** in past

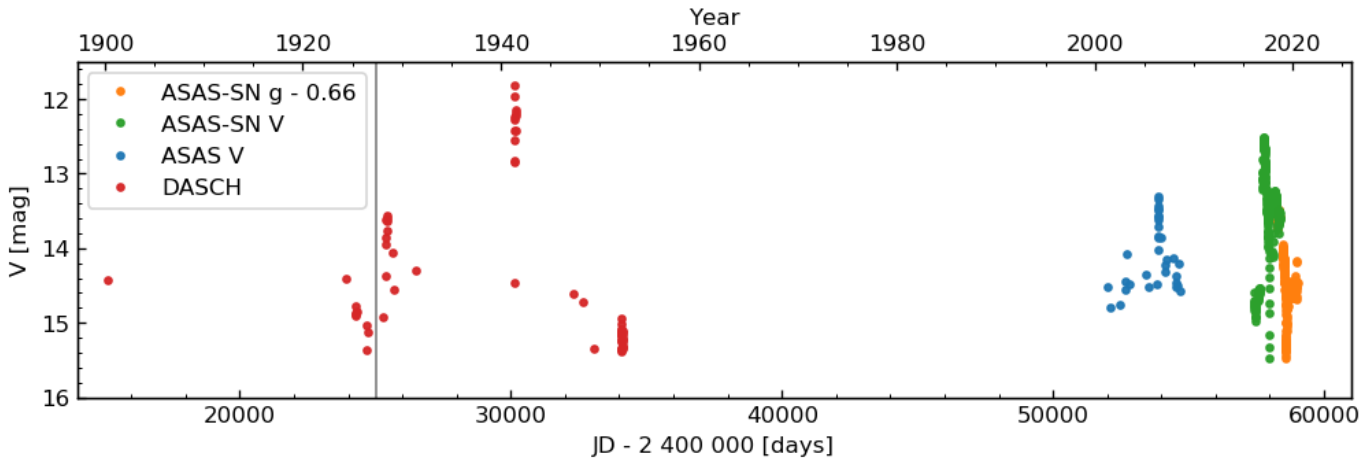


Figure: Historical light curve of Hen 3-860.

Gaia18aen

- at the beginning of 2018, *Gaia* detected the **brightening of Gaia18aen**
  - soon classified as a ‘nova?’
  - light curves and the spectra **confirmed** the **symbiotic** nature
  - **first ever symbiotic star** discovered by *Gaia*

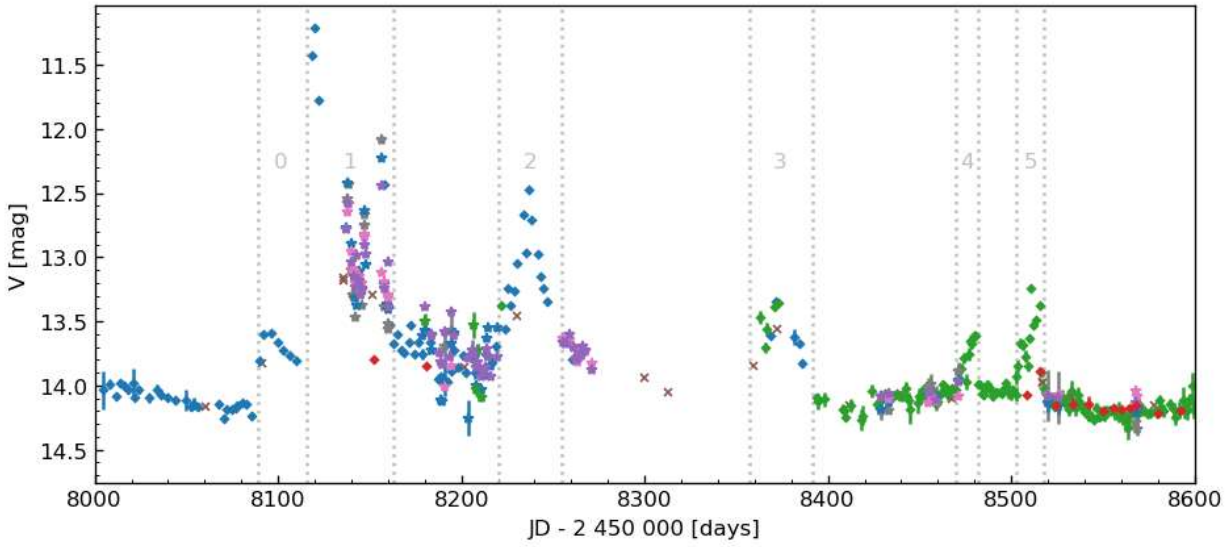


Figure: The light curve of Gaia18aen.

References:
Merc, Mikołajewska, Gromadzki et al., 2020, accepted in Astronomy & Astrophysics
arXiv: 2009.14709

Conclusions
Why to bother?

Thank you for your attention.

Acknowledgements:
This work was supported by the Charles University, project GA UK No. 890120 and by the internal grant VVGS-PF-2019-1047 of the Faculty of Science, P. J. Šafárik University in Košice.

Why?

- **basic** research – expanding our **knowledge**
- **unique** astrophysical laboratories
  - accretion processes, winds or jets
- important for **evolutionary models**
  - binary evolution
  - possible progenitors of supernovae Ia

How?

- studies of **individual systems**
  - long-term monitoring
  - understanding of the processes
  - parameters of the components
- **systematic** studies
  - population of symbiotic stars