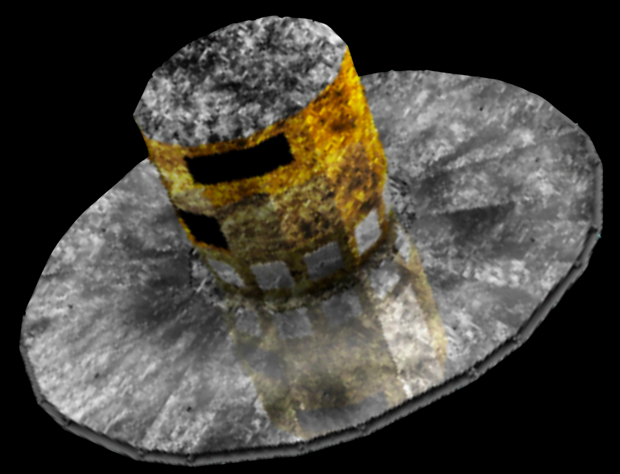


Studying close stellar interactions with Gaia

Nadejda Blagorodnova

Institute of Cosmos Sciences (ICCUB-IEEC)

The Milky Way Revealed by Gaia: The Next Frontier

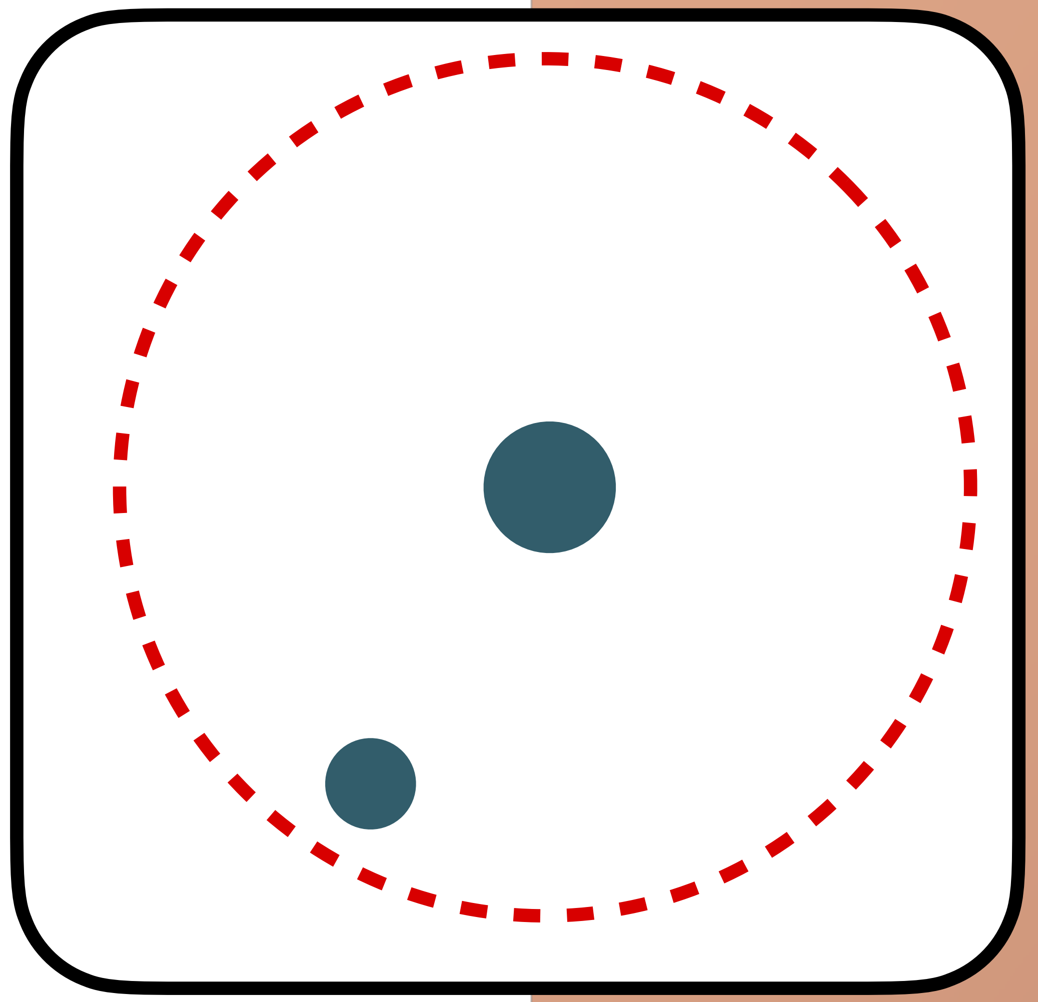
5th September 2023

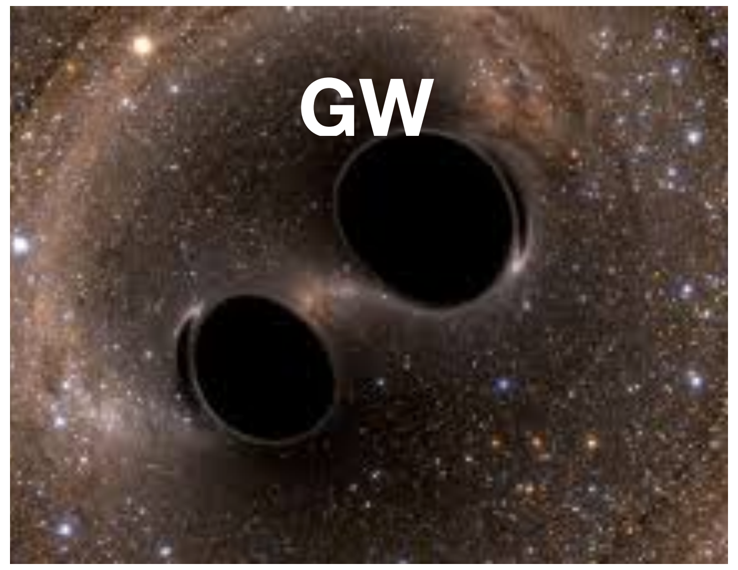
How close binary stars evolve?

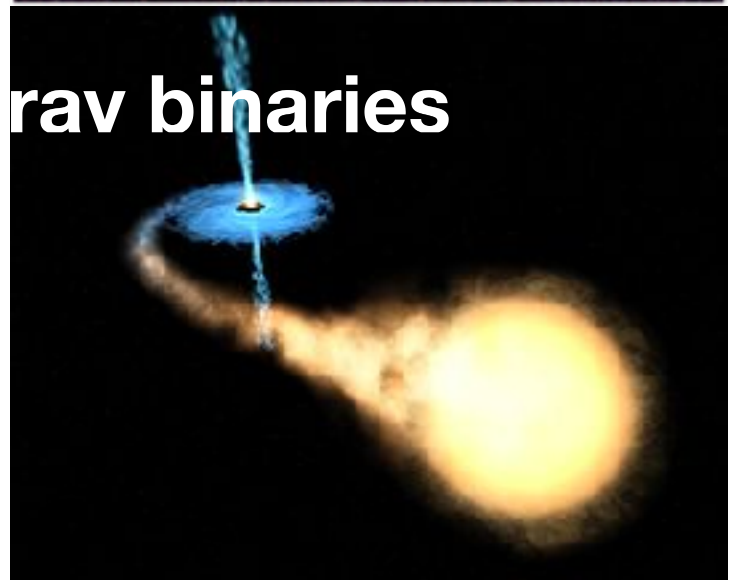
Before

During?

After







P ~days/year

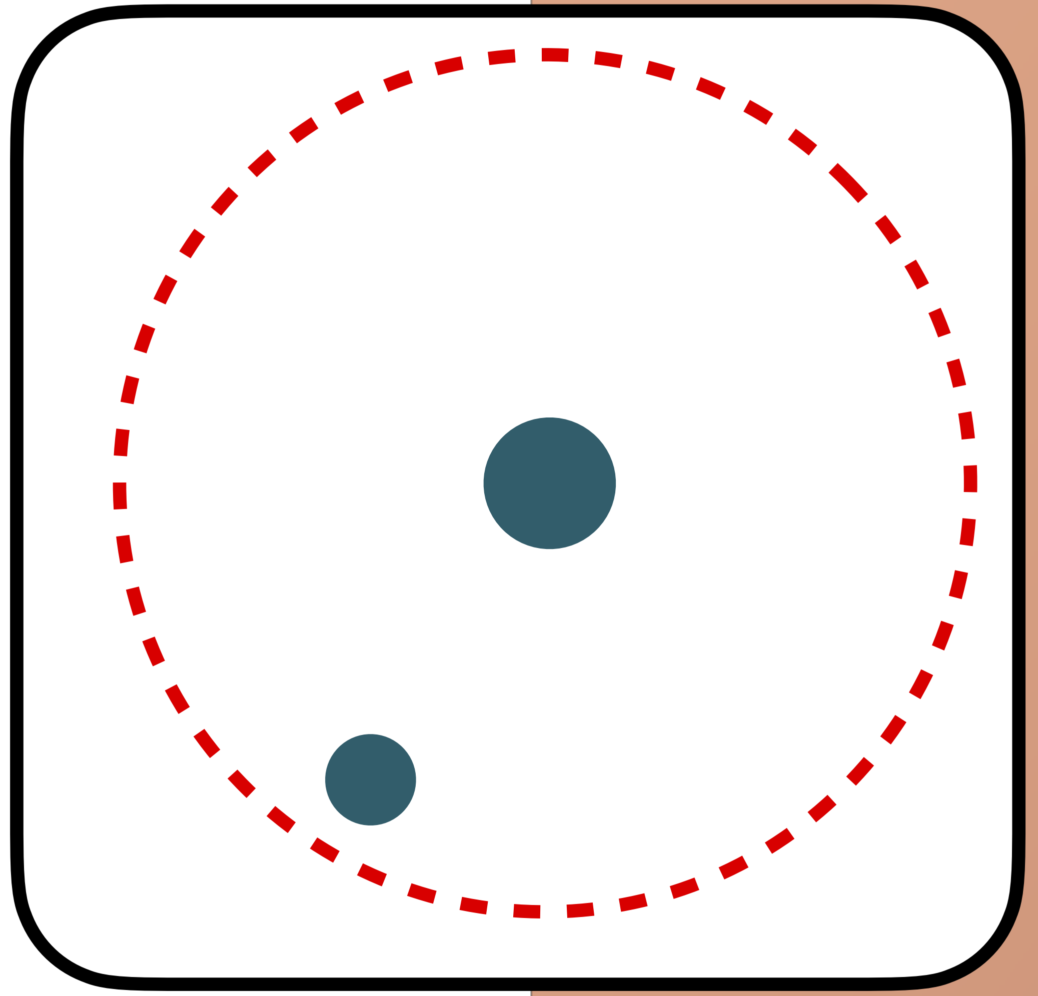
P ~ min

How close binary stars evolve?

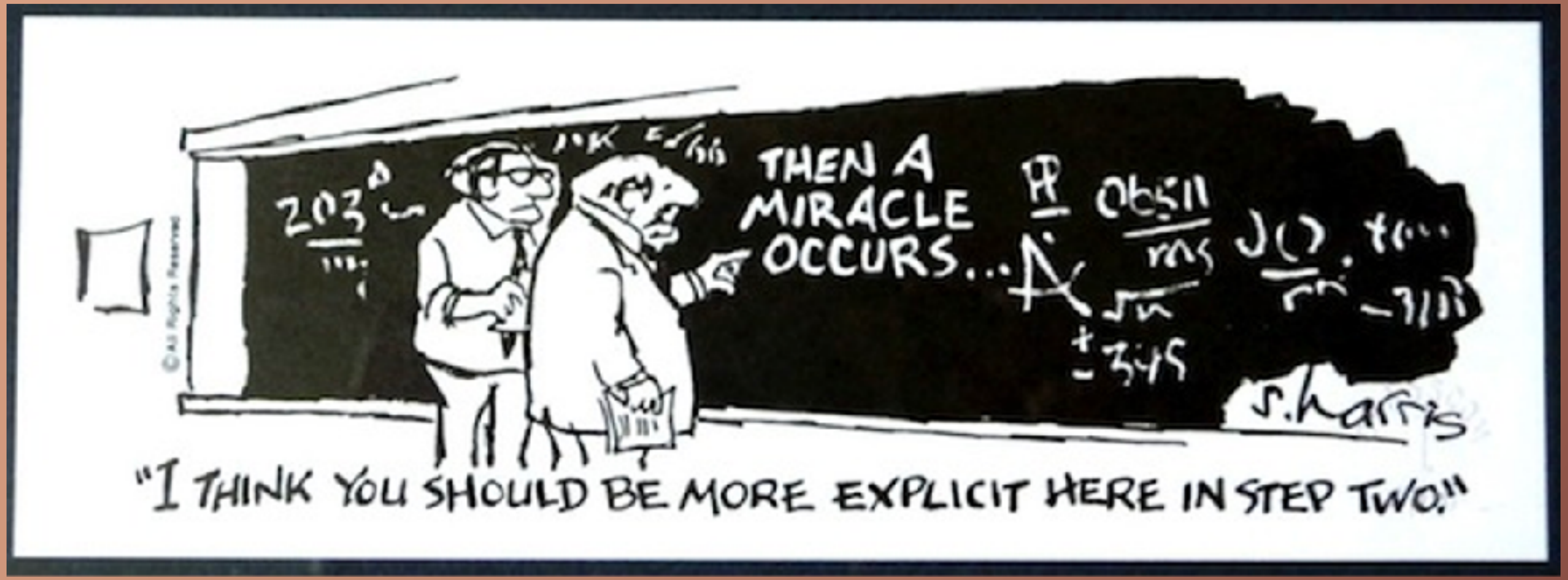
Before

During?

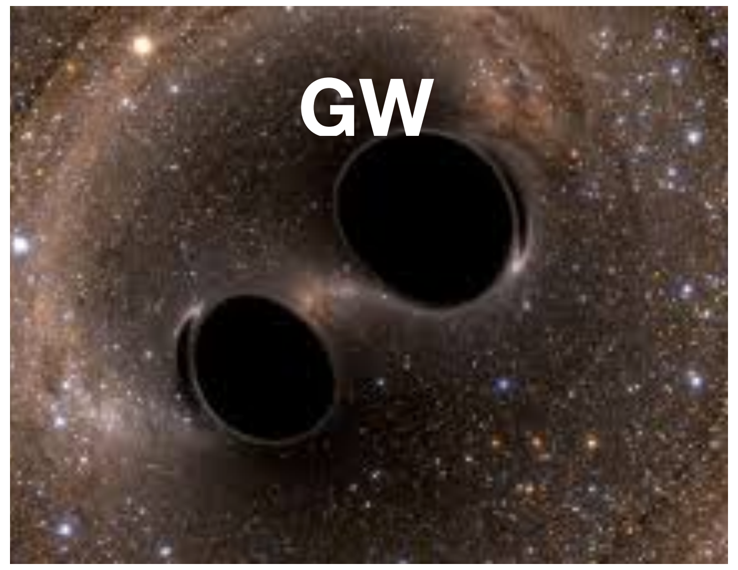
After

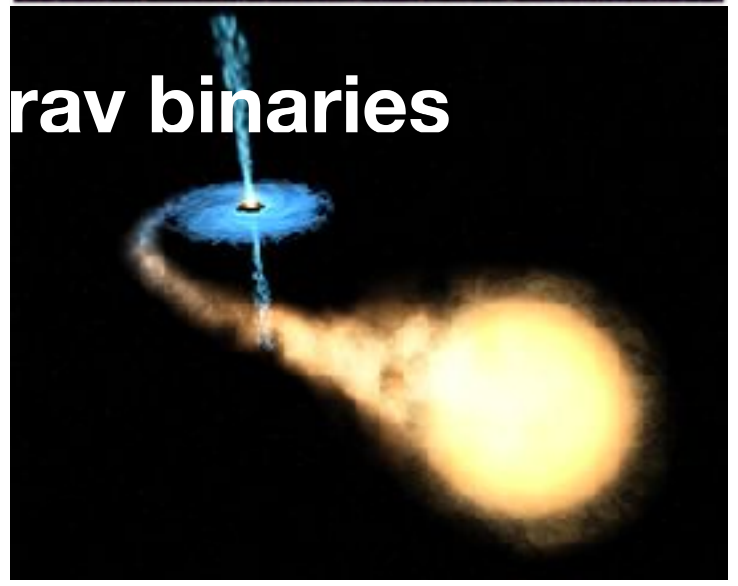


Common Envelope Evolution



e.g. Paczynski, 1976

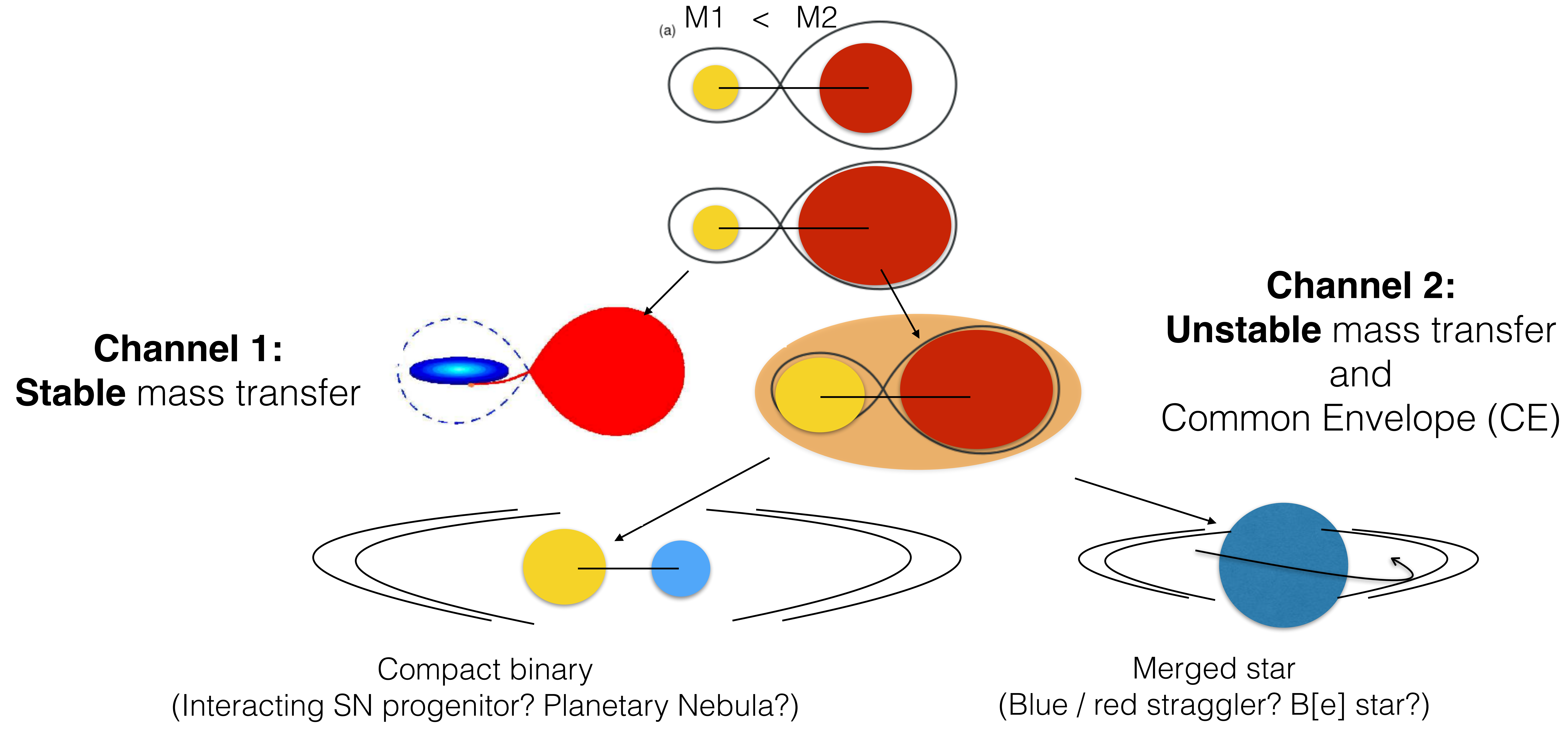




P ~days/year

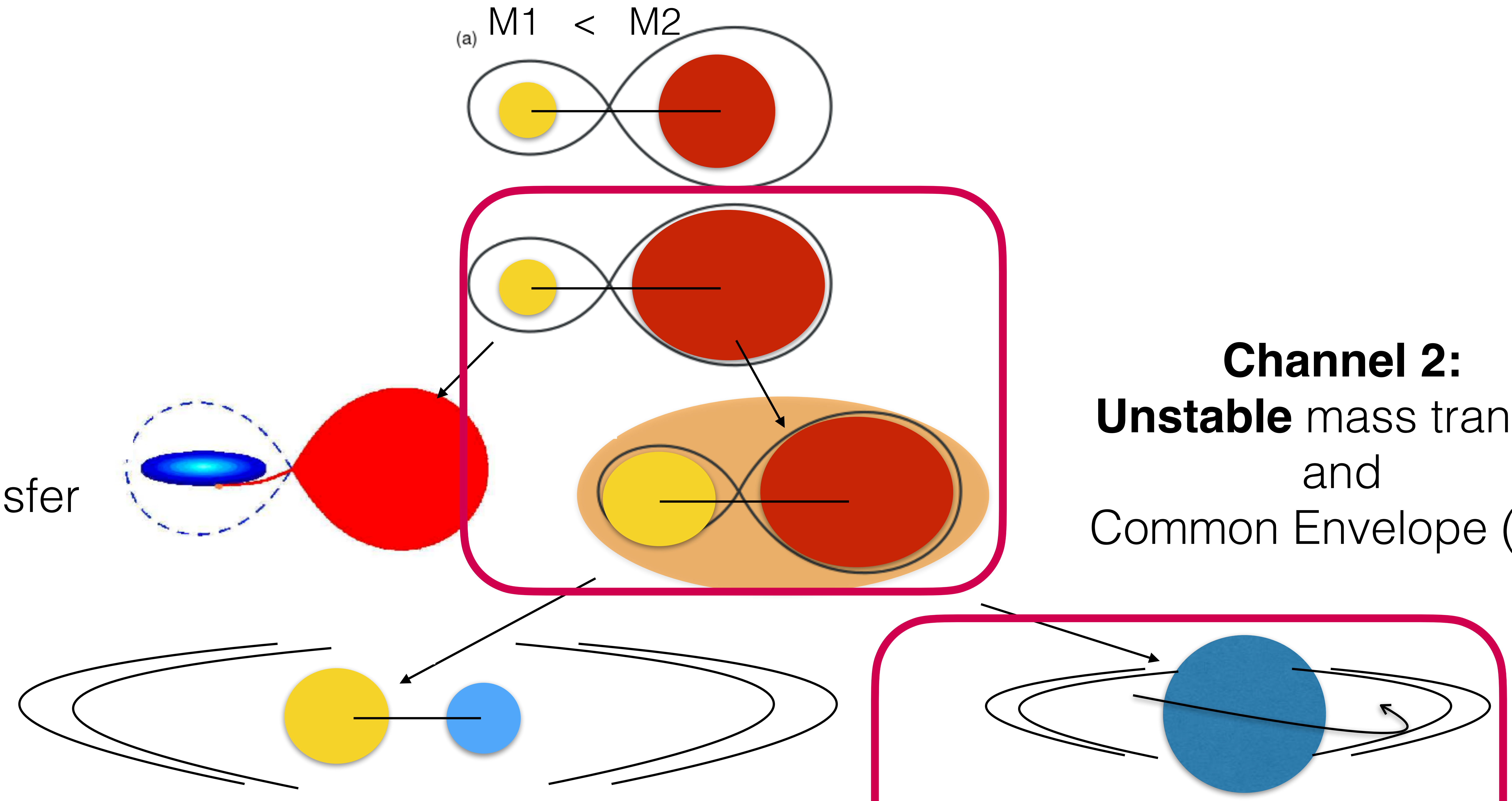
P ~ min

Pathways binary evolution



Pathways binary evolution

Channel 1:
Stable mass transfer



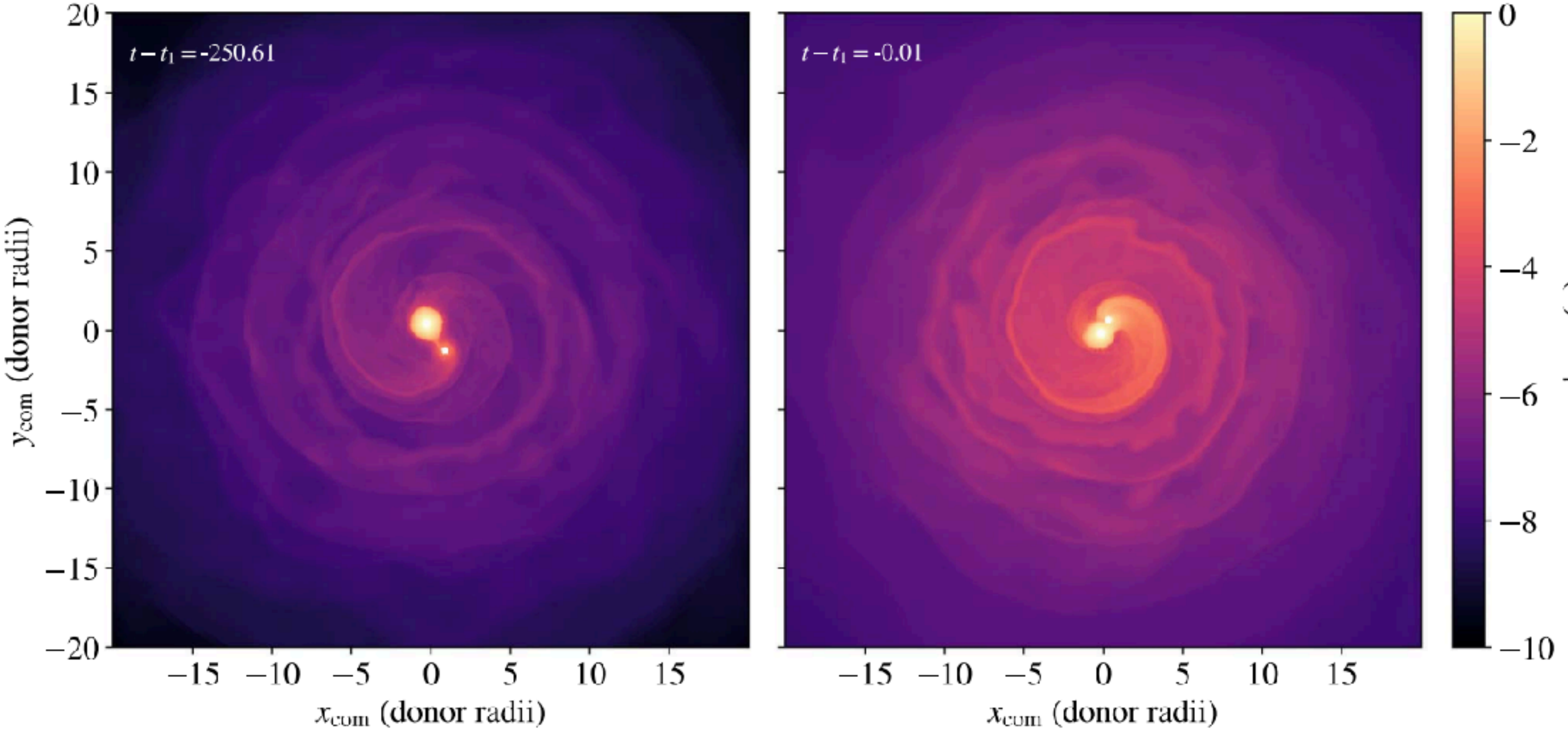
Channel 2:
Unstable mass transfer
and
Common Envelope (CE)

Compact binary
(Interacting SN progenitor? Planetary Nebula?)

Merged star
(Blue / red straggler? B[e] star?)

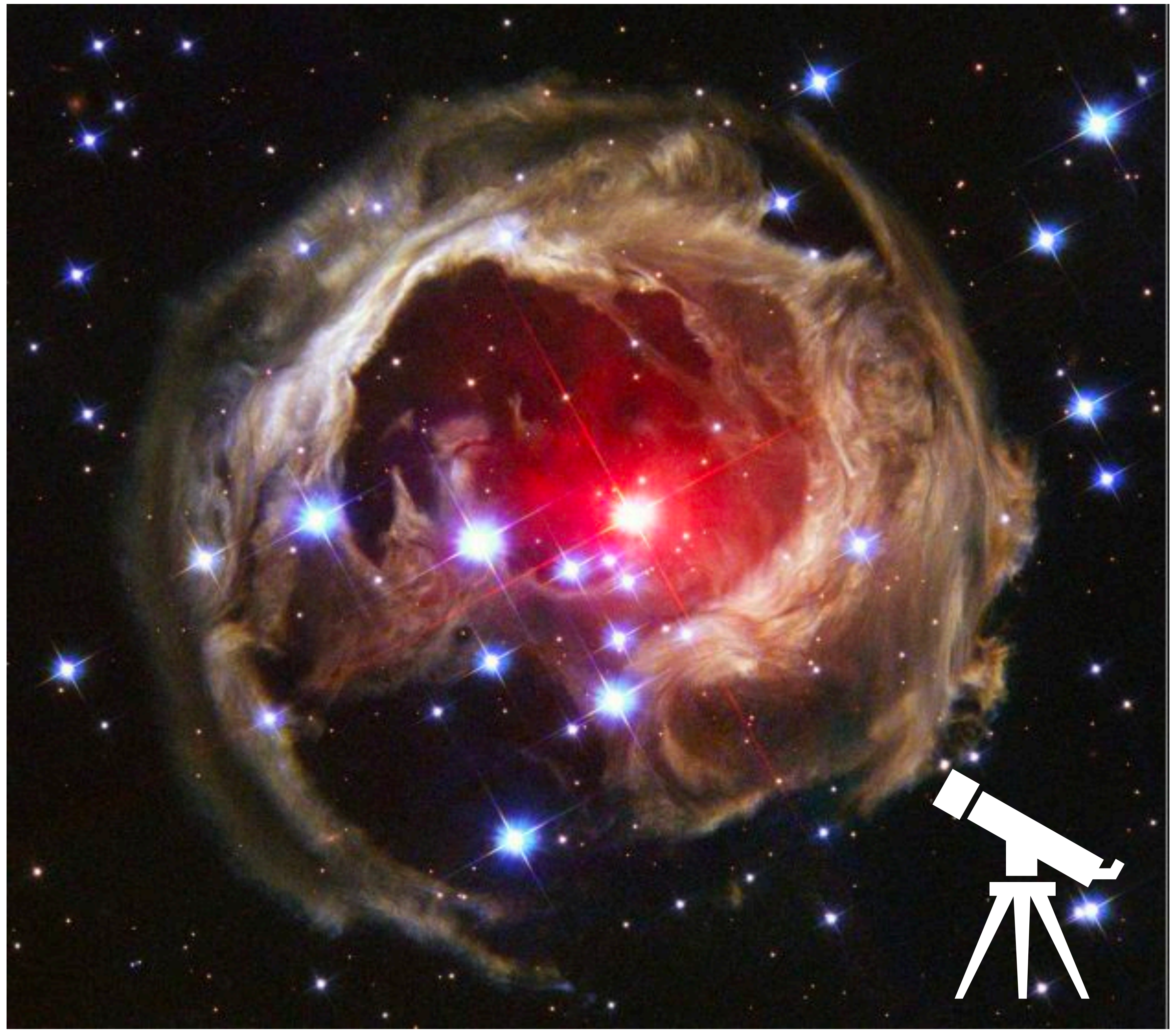
Approaches to the study of Common Envelope

Theory, simulations



MacLeod, Ostriker, Stone 2018

Observations

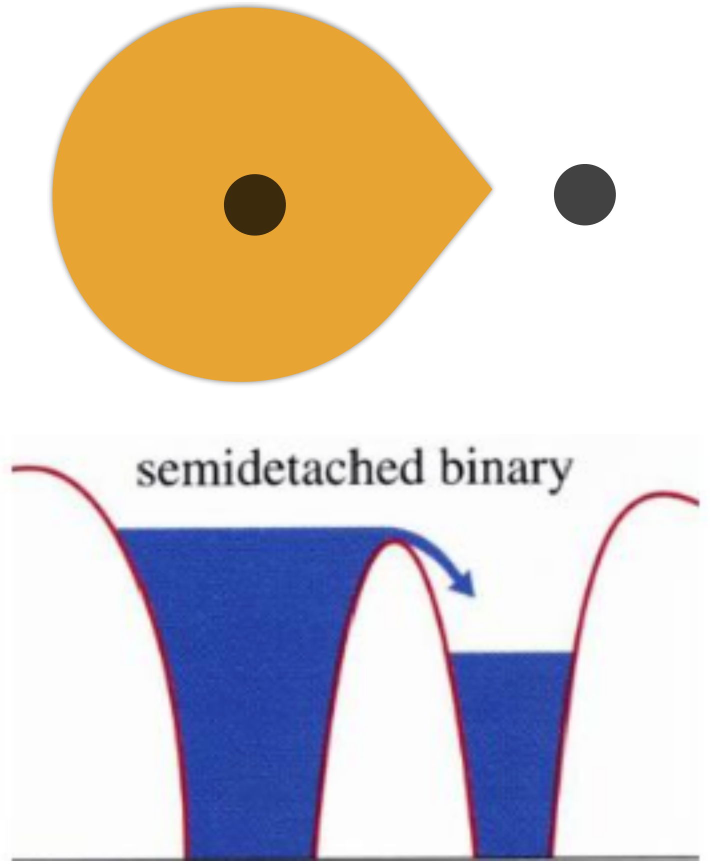


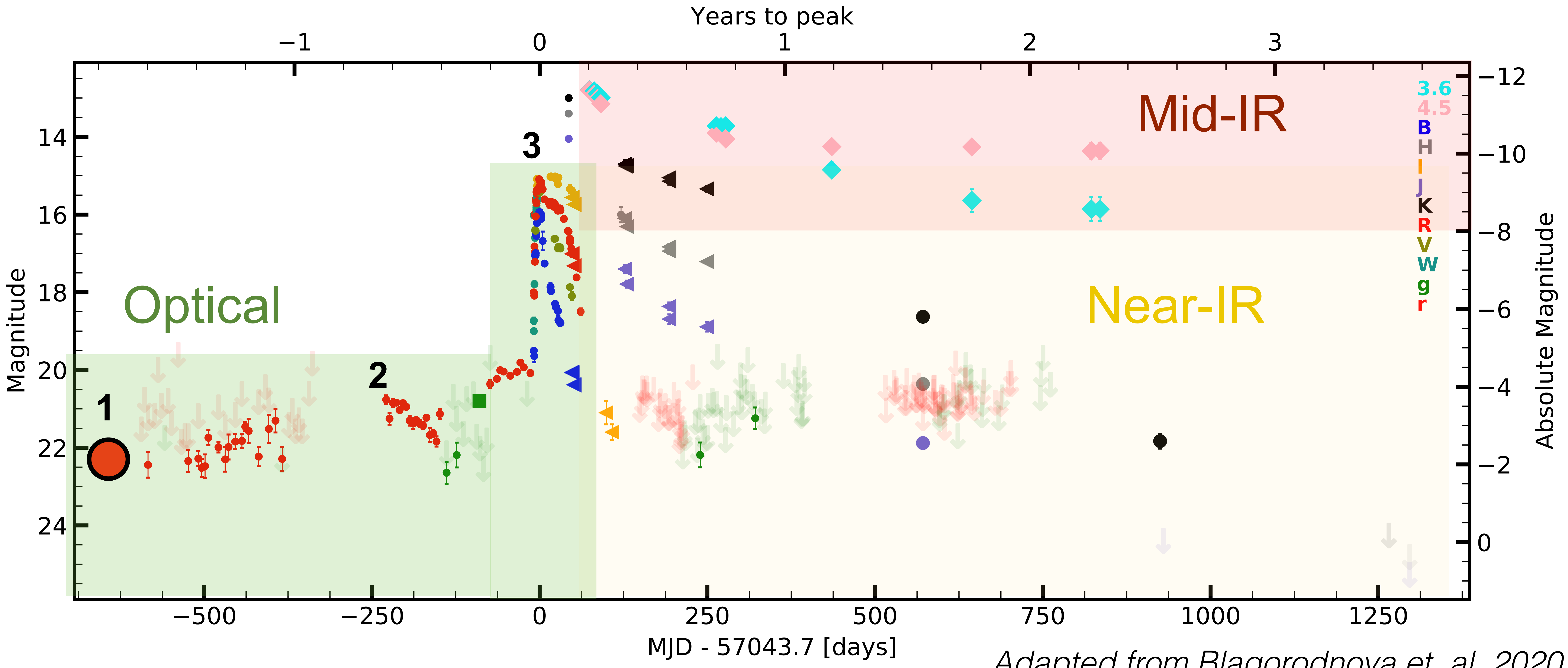
Astrophysical transients: **Luminous Red Novae (LRNe)**

Image: V838 Mon, Hubble Space Telescope

Time evolution of Luminous Red Novae

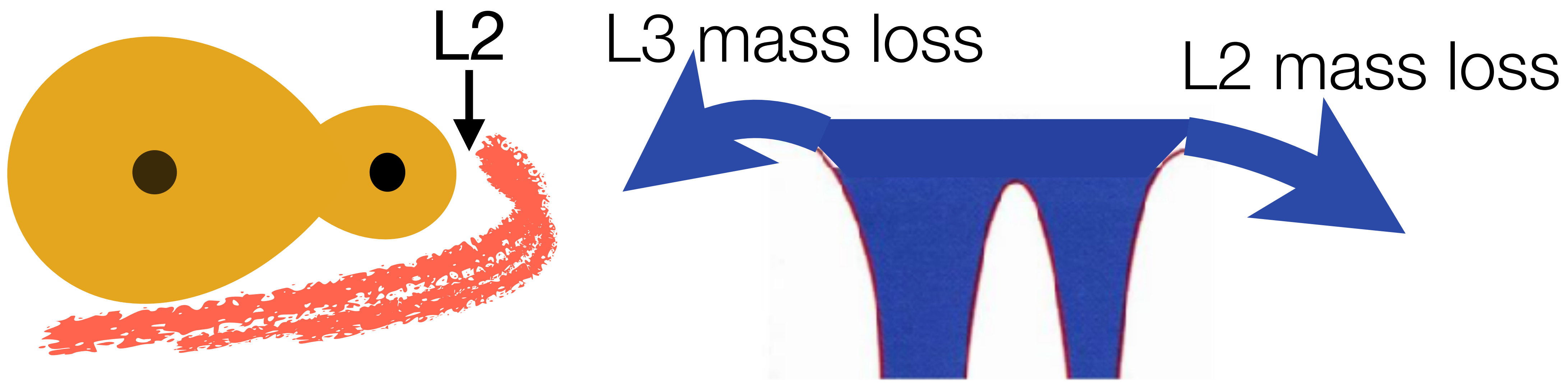
1 - Unstable mass transfer



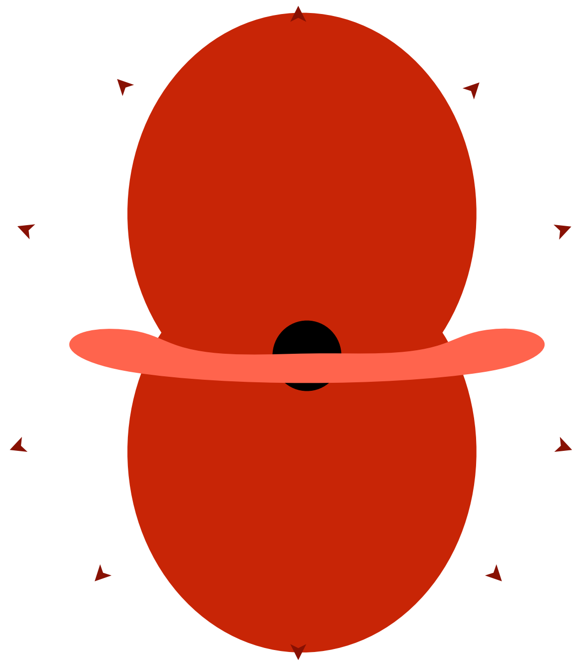


Adapted from Blagorodnova et. al. 2020

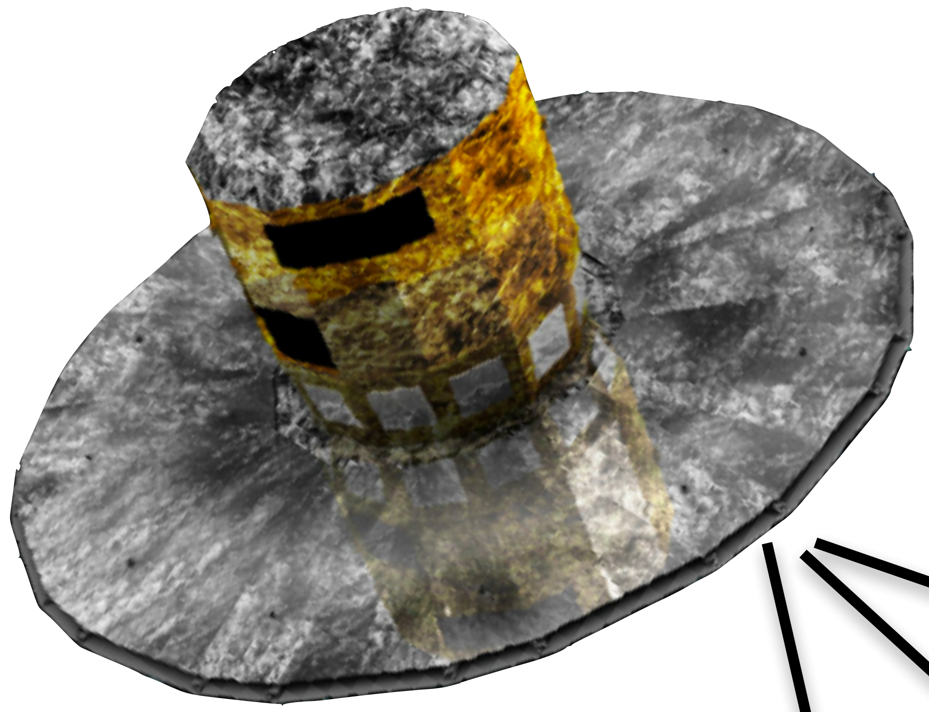
2 - L2/L3 mass loss



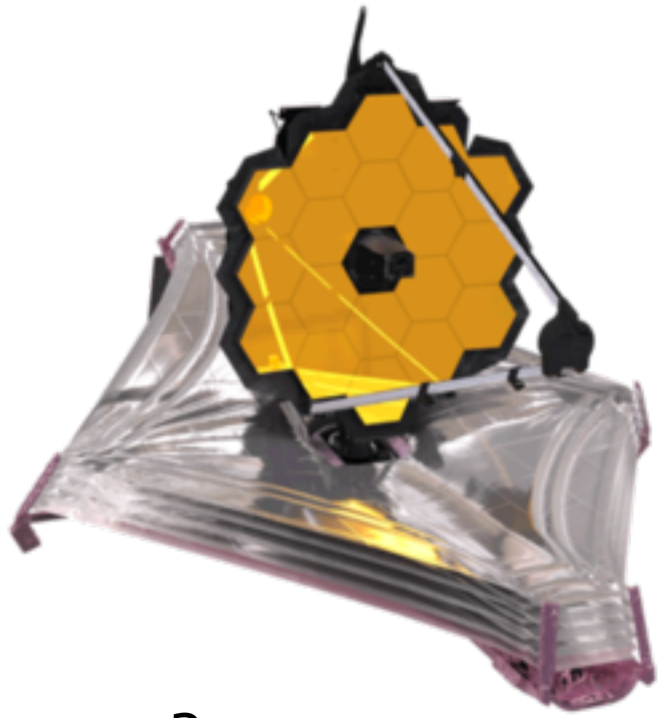
3 - Dynamical ejection & merger

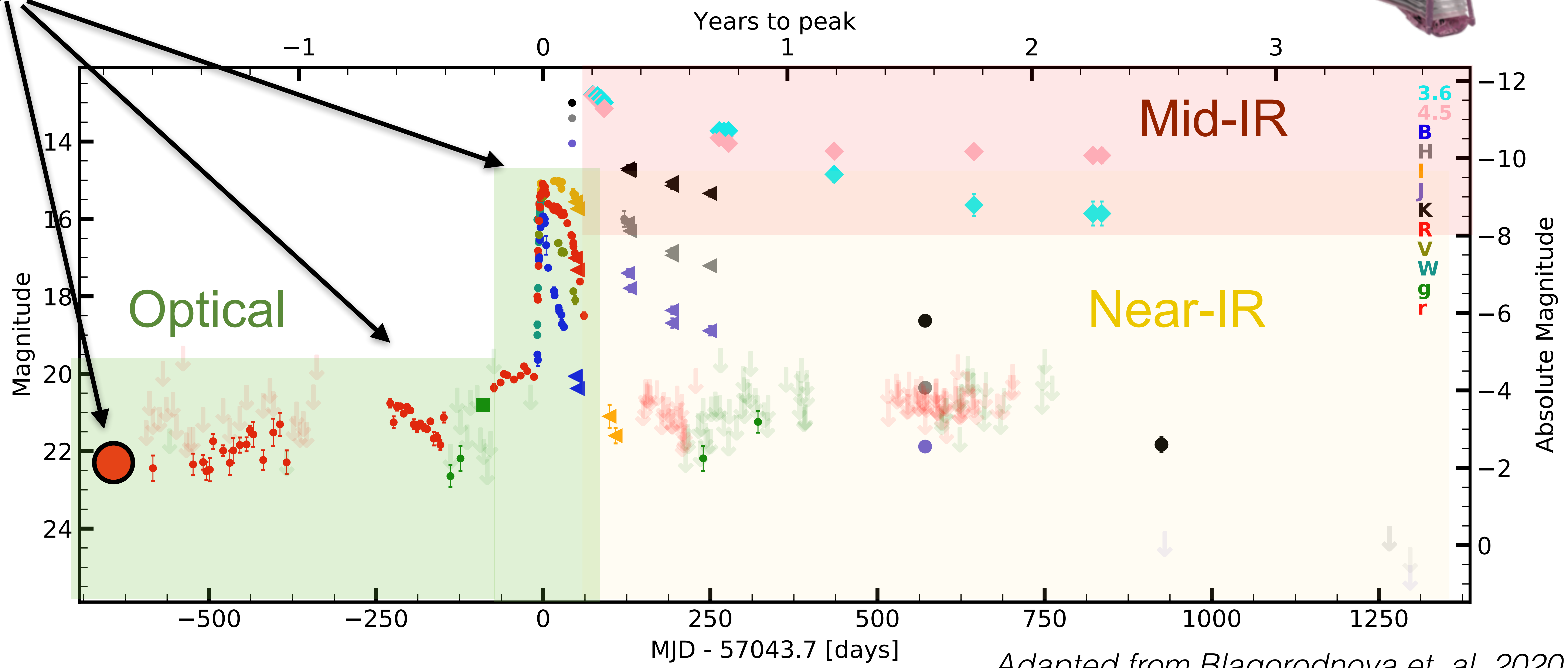


Luminous Red Novae: Gaia's contribution



1 - Outburst from Luminous Red Novae
2 - Pre-outburst brightening (precursor)
3 - Progenitors



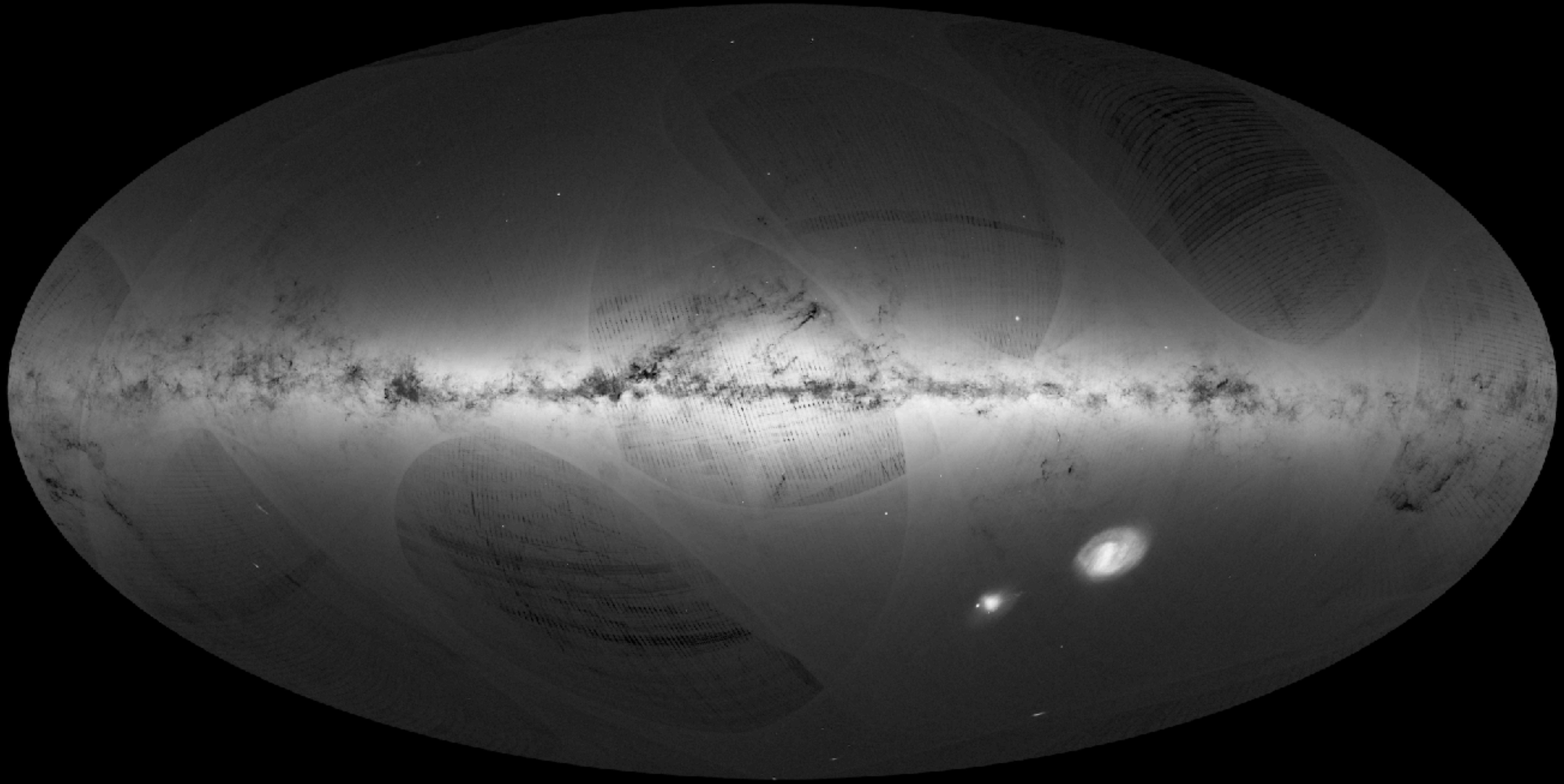


Adapted from Blagorodnova et. al. 2020

Detecting transients: Gaia Science Alerts

Survey Parameters

- **2 telescopes**
- **1 focal plane**
- **FOVs 1+2 sep by 106.5m**
- **spin period 6h**
- **precession period 70d**
- **Field revisited every ~30d**
- **1200 square degrees/day**
- **G=20.7**



Slide courtesy of Simon Hodgkin, IoA, Cambridge, UK

Alert Detection: Daily

2FoVs [40dy]

event type

new

brighter than 19 mag

- transients
- supernovae
- novae
- DNe
- TDE
- AGN flares
- GRB OT
- M-dwarf flares

old

RMS-based 6-sigma, 0.15 mag

or 3-sigma, 1 mag

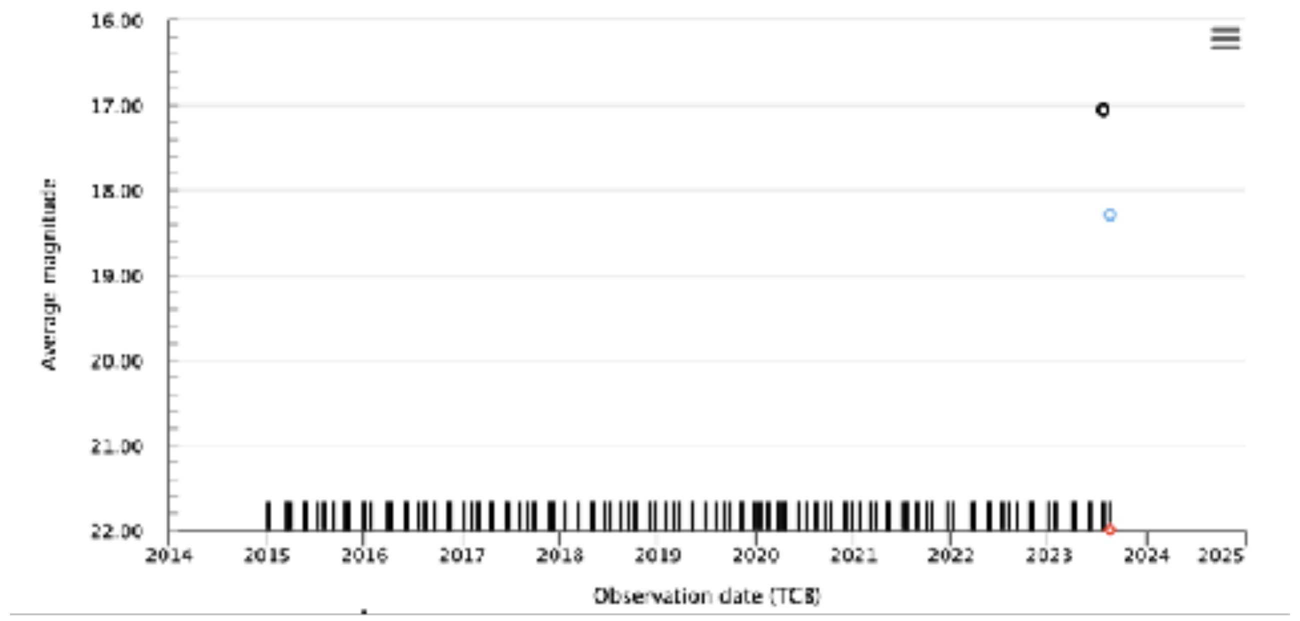
Skew-Von Neumann

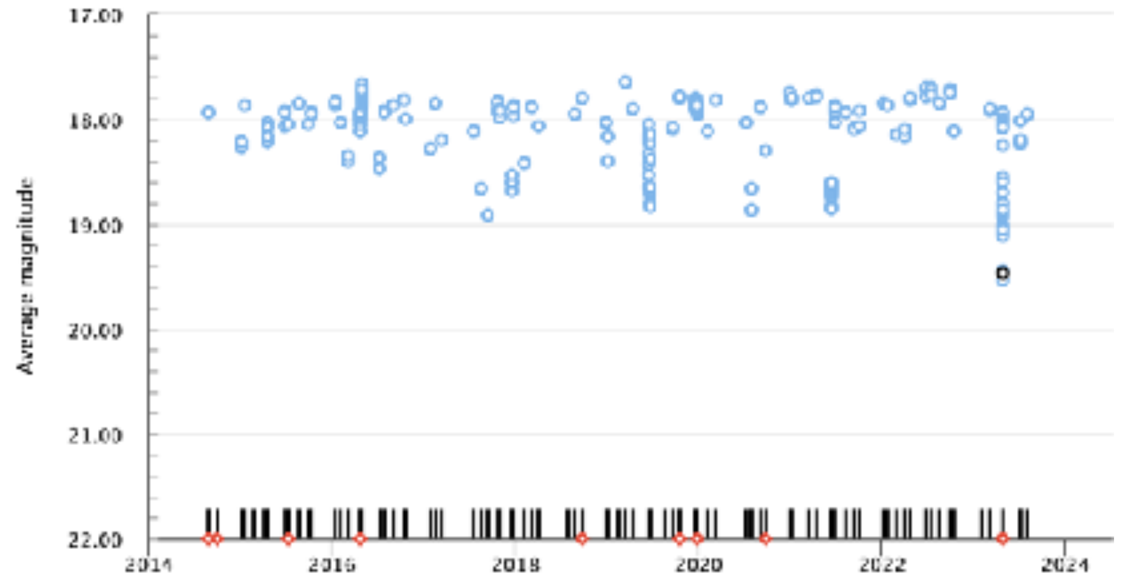
up

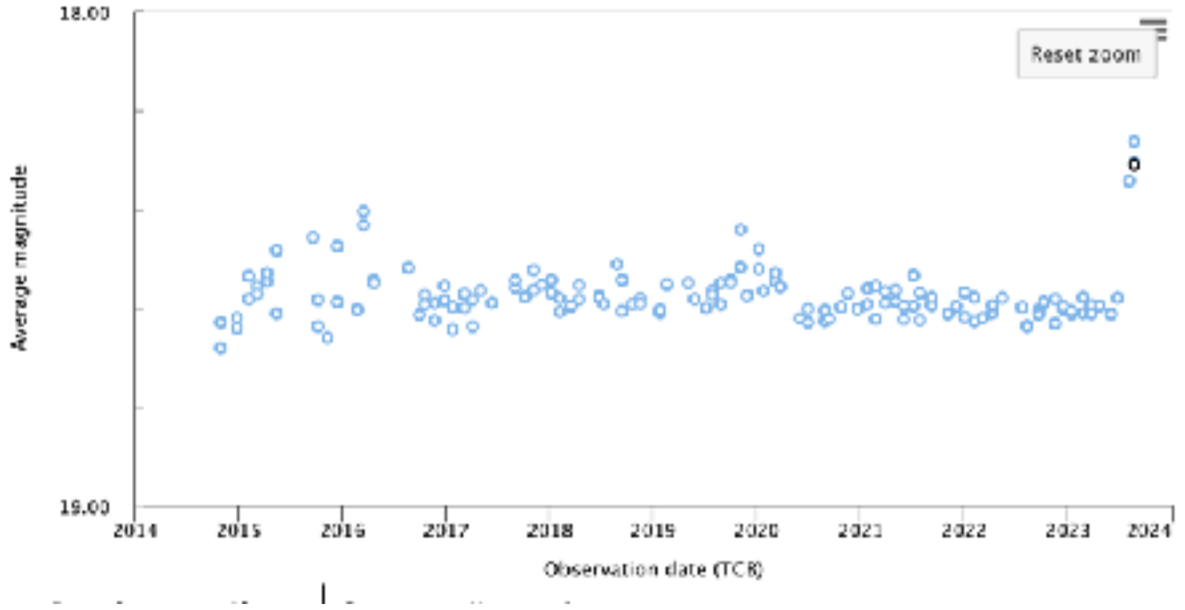
- microlensing
- dwarf novae
- SN on galaxy
- novae
- Be stars
- AGN flares
- FUOrs, EXOrs

down

- RCrB
- DY Per
- single eclipses
- dark clouds
- exoComets

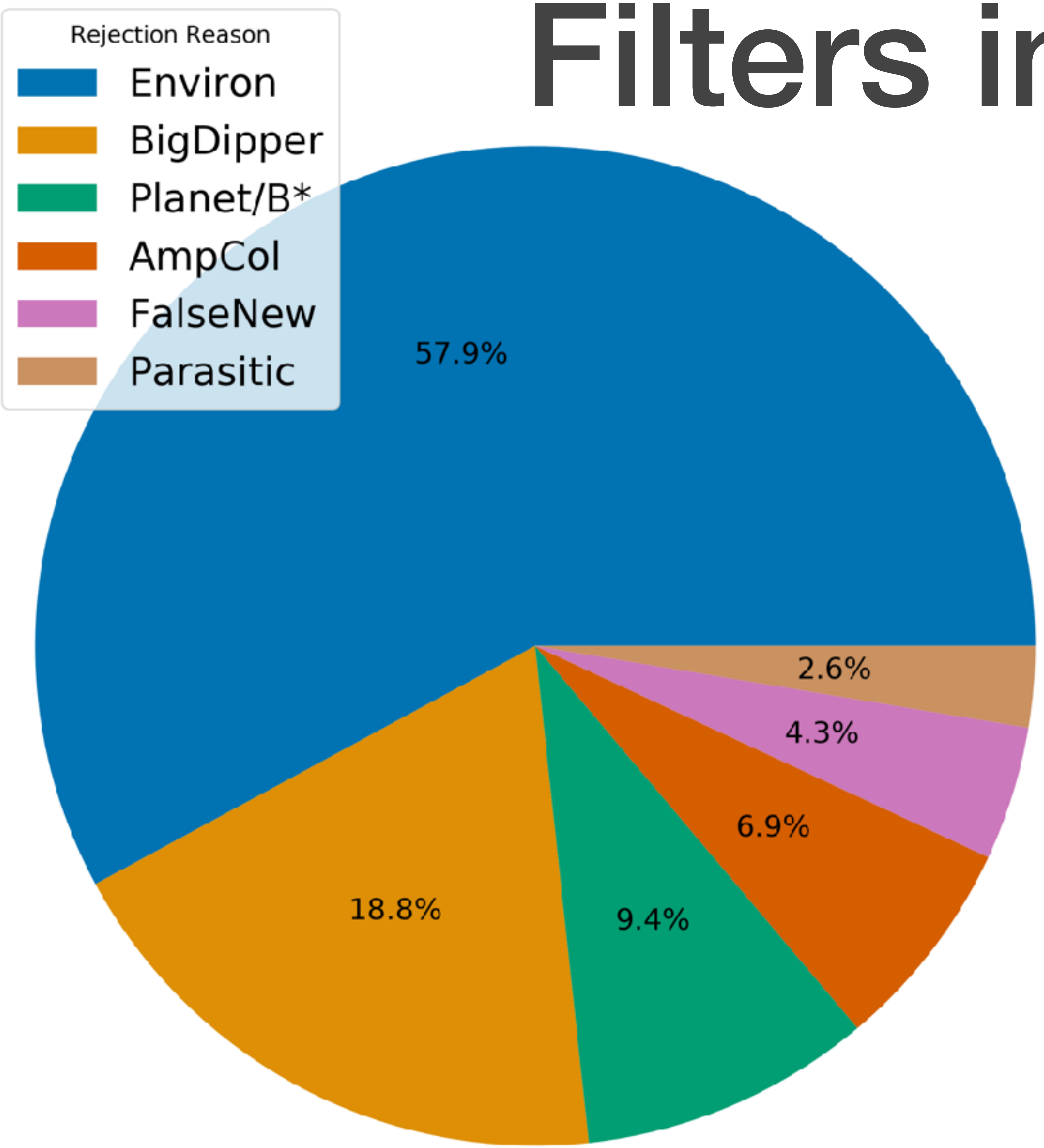






Slide courtesy of Simon Hodgkin, IoA, Cambridge, UK

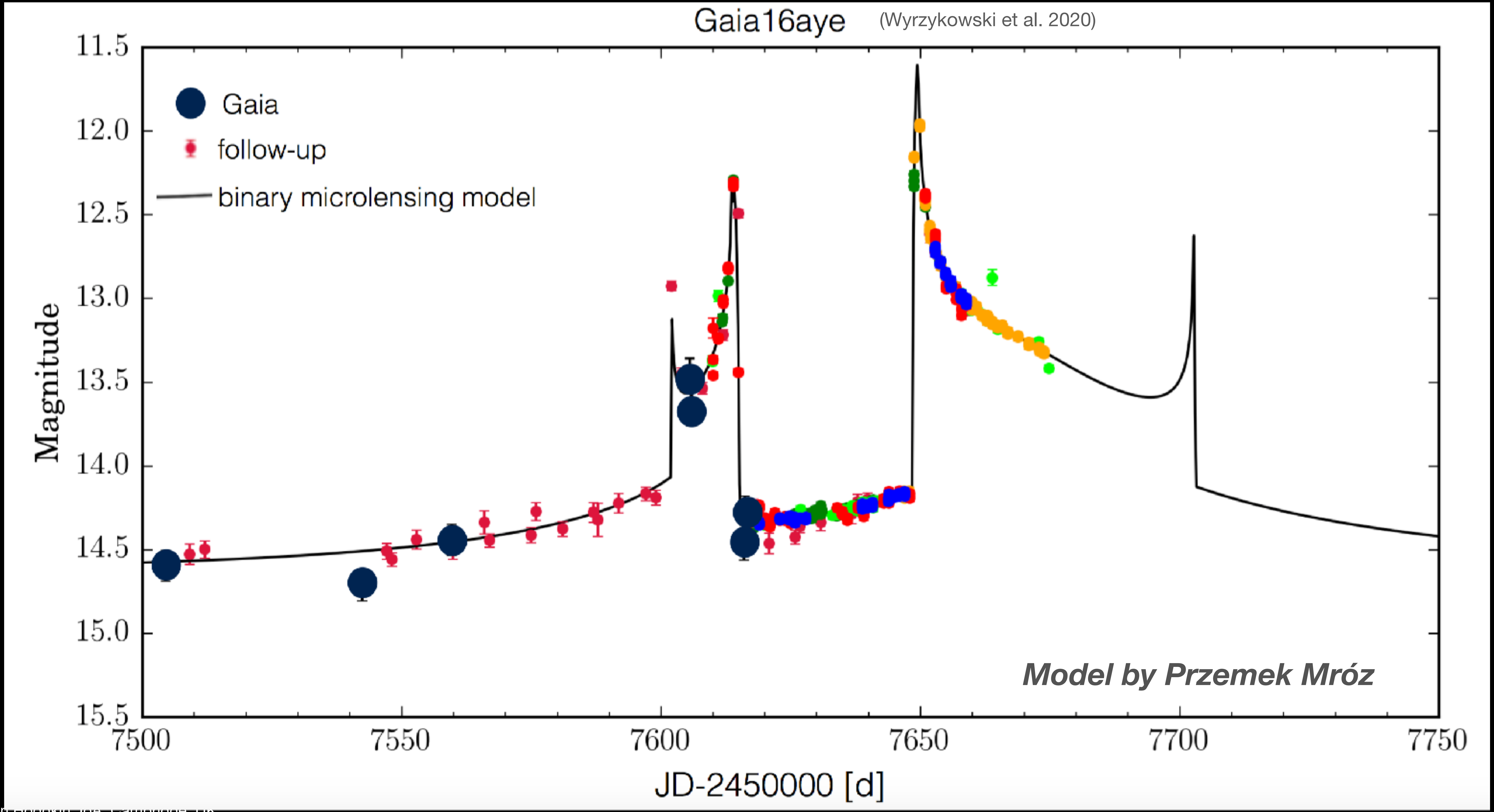
Filters in AlertPipe



1. Most false positives are environmental in origin, examples:
    1. wings of bright stars
    2. planet or bright stars close to pointing
    3. near neighbours
2. But we also classify/reject:
    1. Known SSOs
    2. Known DR3 variable stars
    3. High amplitude red variables

Slide courtesy of Simon Hodgkin, IoA, Cambridge, UK

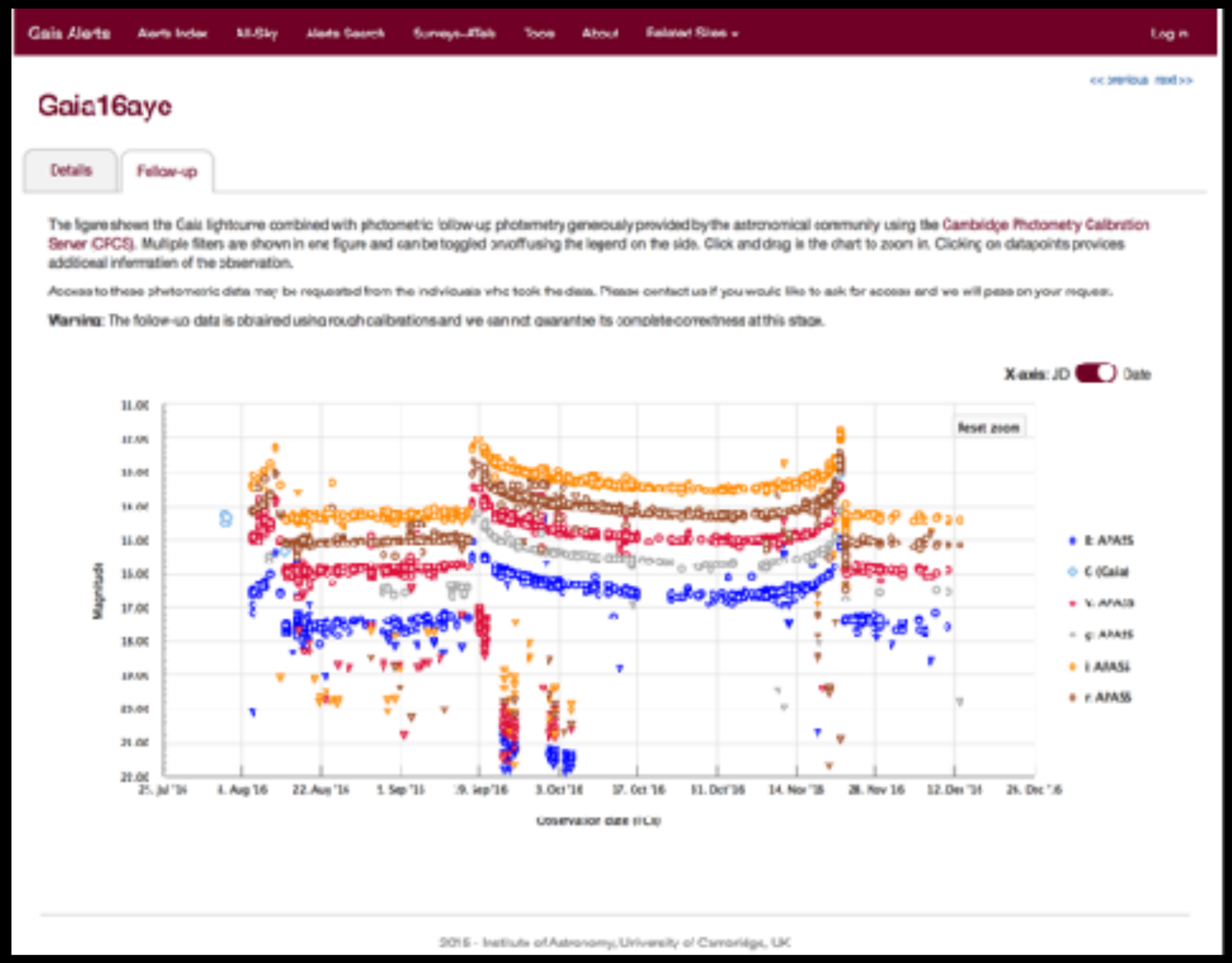
Ground-based follow-up: binary microlensing event



Slide courtesy of Simon Hodgkin, IoA, Cambridge, UK

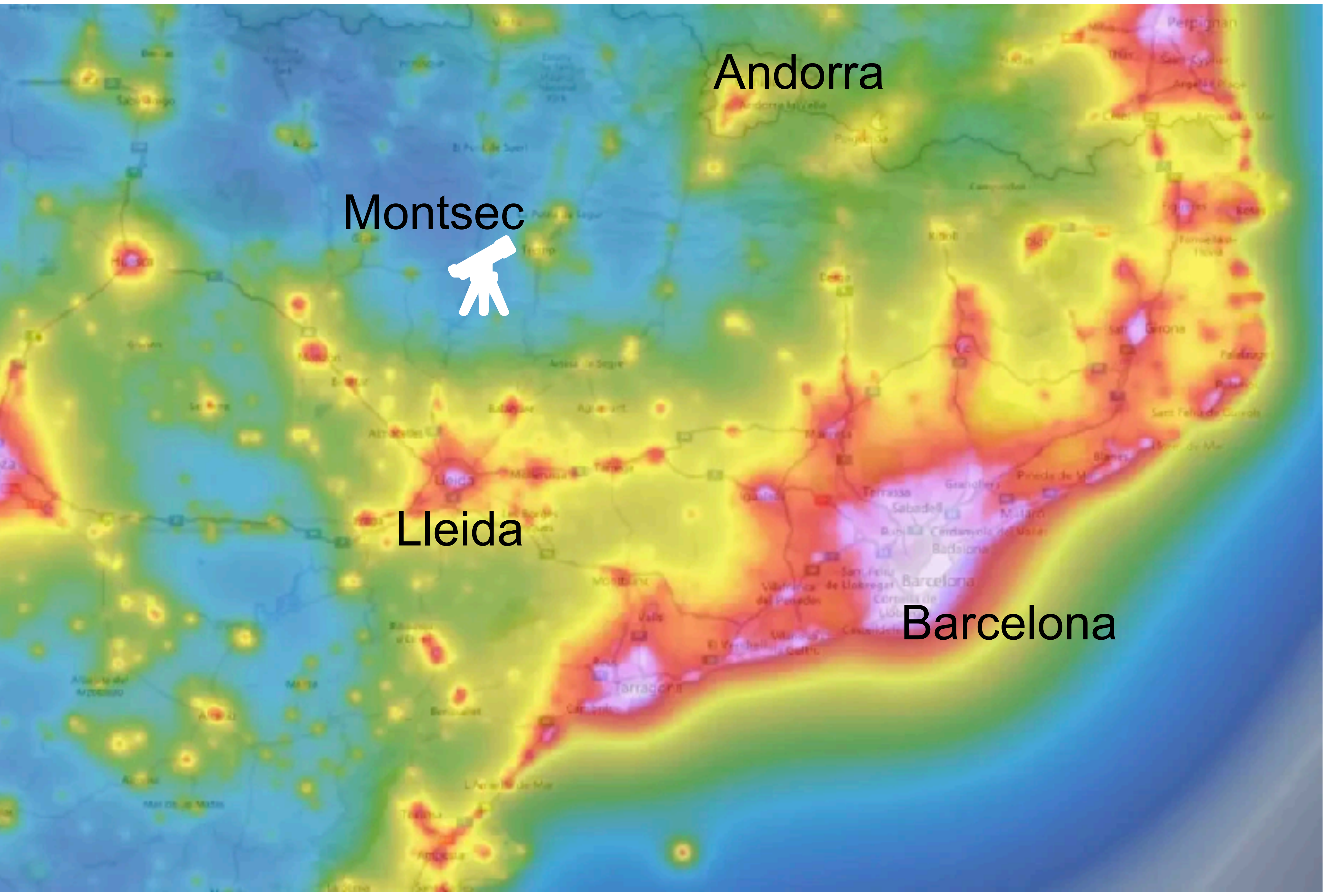
Cambridge Calibration Server

- observers upload astrometrically calibrated catalogues
- we apply photometric calibration from APASS, SDSS
- about 25% of published alerts have follow-up data
- >20000 measurements for Gaia16aye from 33 telescopes



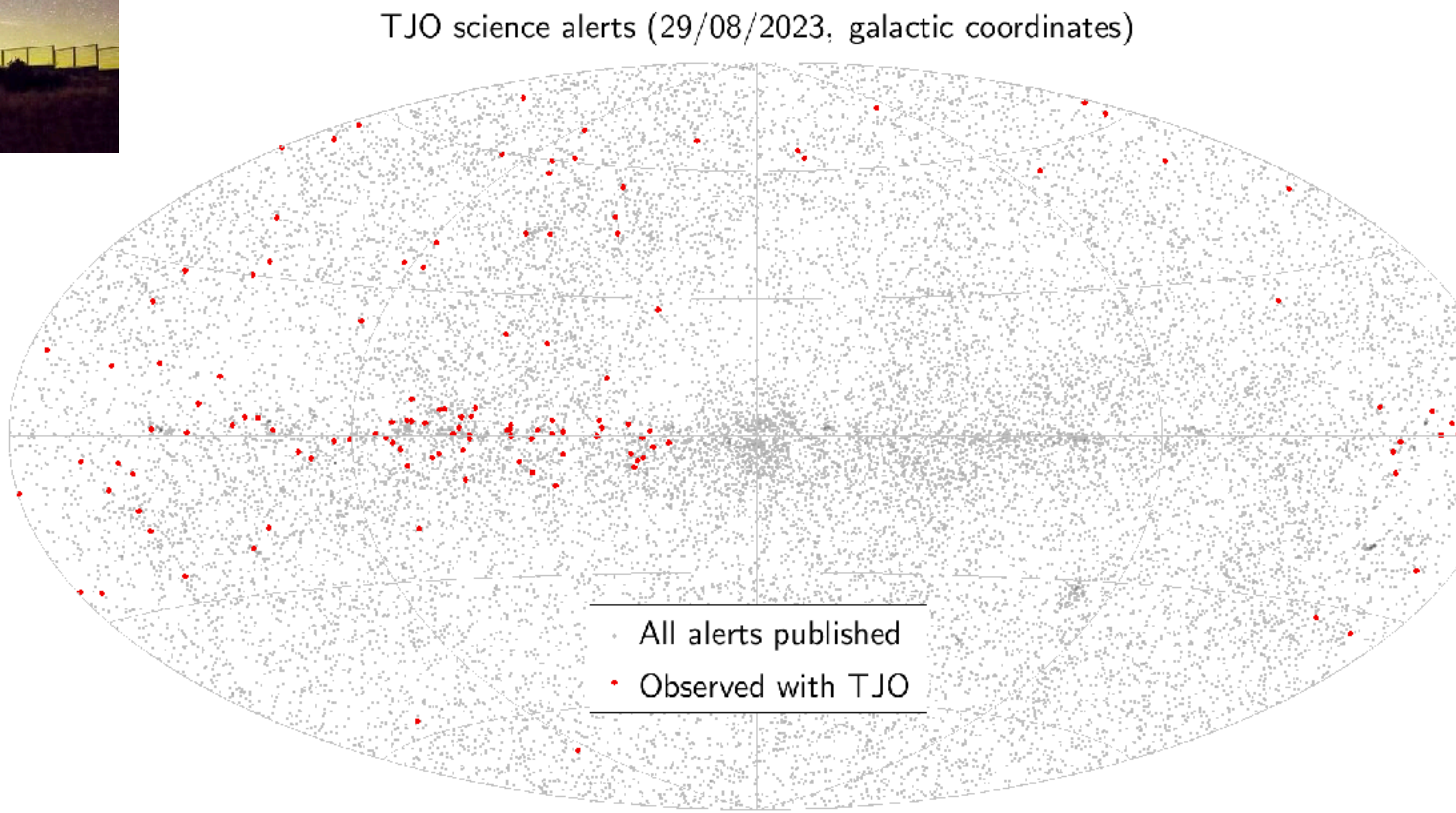
- AAVSO, USA
- APT2, Italy
- Aristarchos Telescope, Greece
- ASAS-SN, Hawaii, USA
- Asiago, Italy
- ASV, Serbia
- Bialkow, Poland
- Kryoneri, Greece
- Leicester University, UK
- LCOGT/SUPAscope network
- Liverpool Telescope, La Palma, Spain
- Loiano, INAF-OABO, Italy
- Joan Oró Telescope, Montsec, Spain
- Mercator, La Palma, Spain
- Montarrenti, Italy
- NOT, La Palma, Spain
- Ondrejov, Czechia
- OmicronC2PU, France
- Ostrowik, Poland
- Palomar 200-inch telescope (P200), Caltech, USA
- PIRATE, Tenerife, Spain
- pt5m, La Palma, Spain
- RTT150, Turkey
- SALT, South Africa
- Skinakas, Greece
- Sternberg Observatory, Russia
- T100, Turkey
- T60, Turkey
- UBT60, Turkey
- University College London, UK
- Watcher, South Africa
- Wise, Israel
- Yerkes-41, USA

Ground-based follow-up - Telescopi Joan Oró (PI Josep Ma Carrasco)



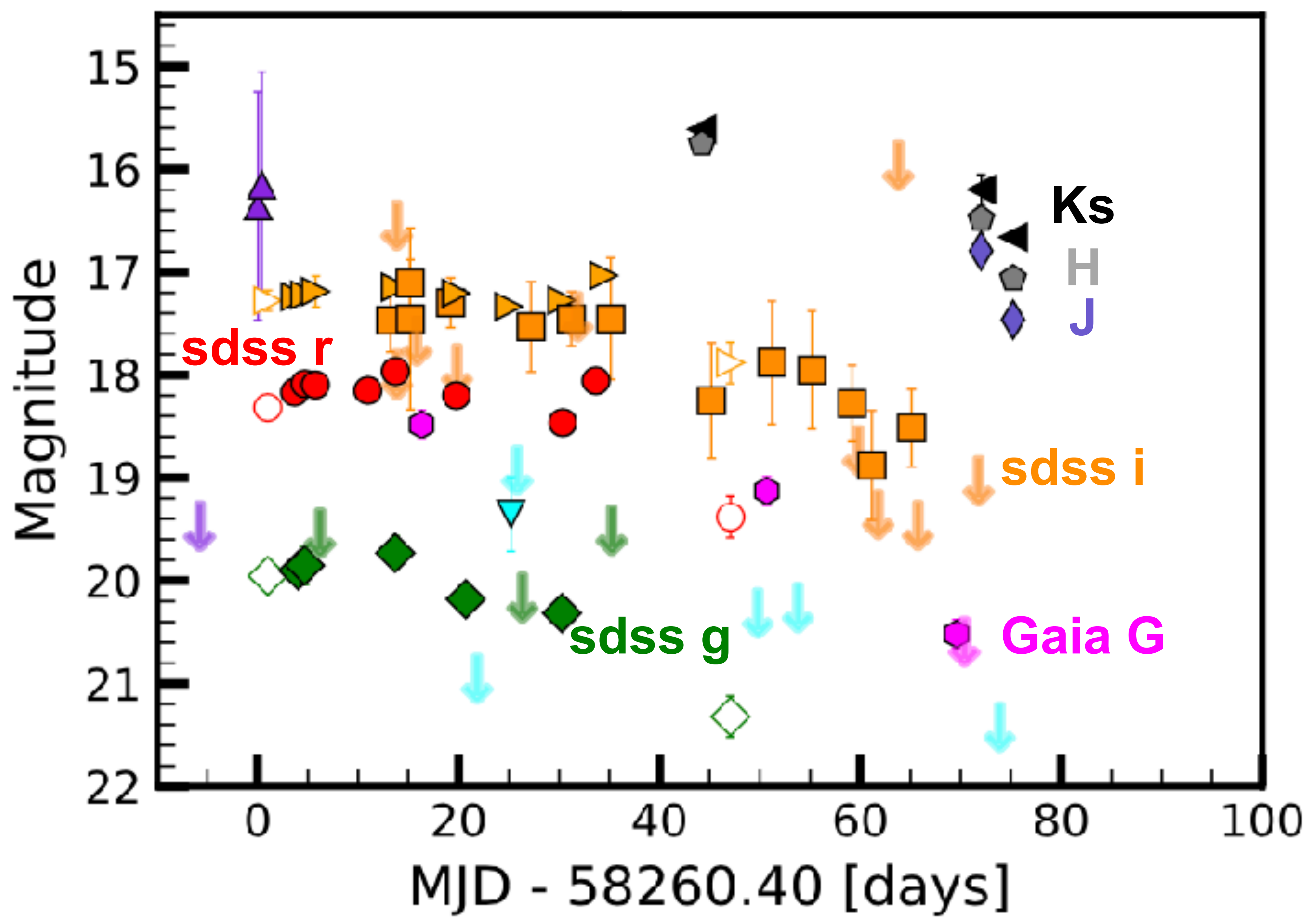
Alerts observed: 133
Images taken: 46,902

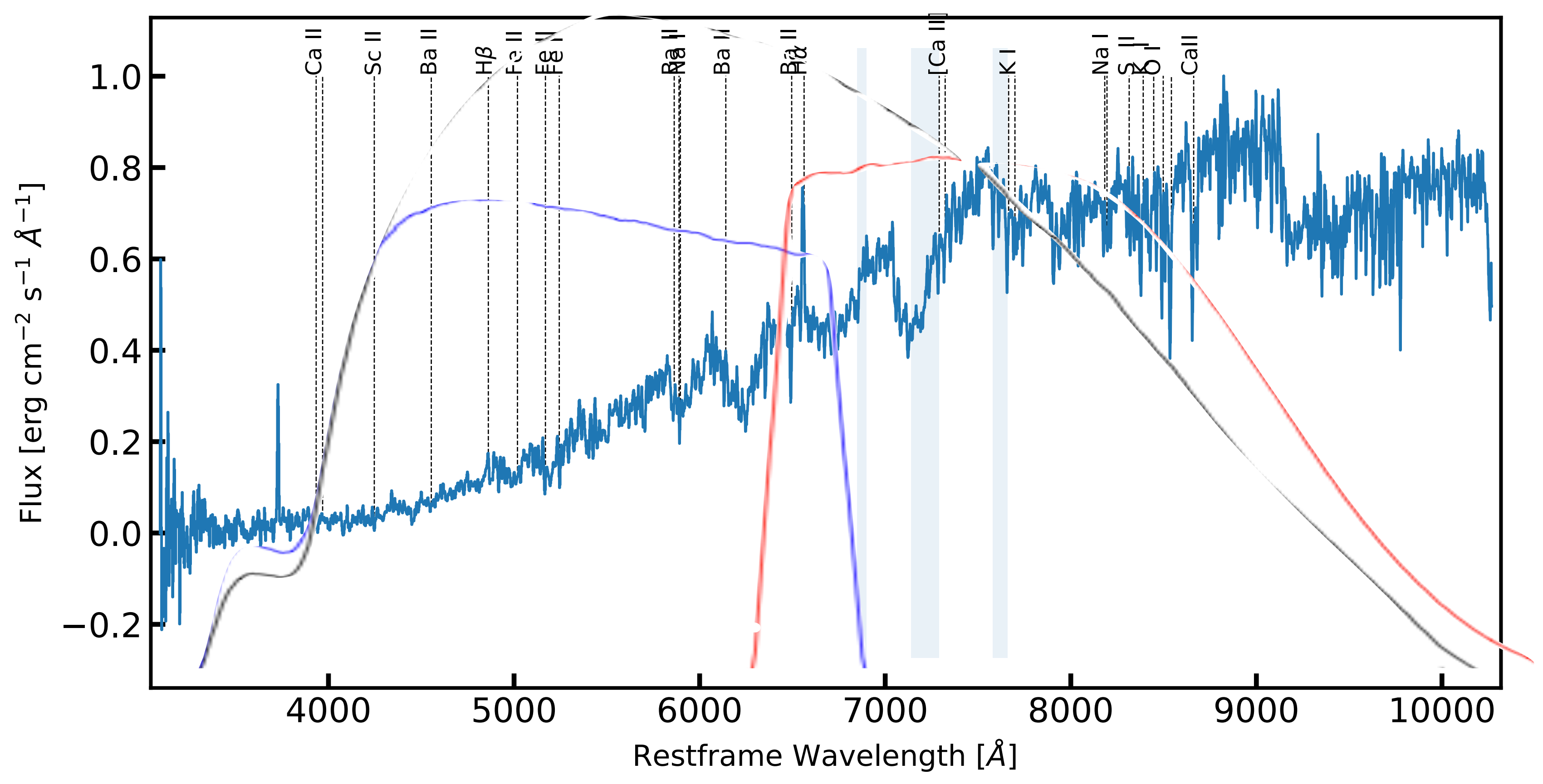
2nd contributor (after 0.5 La Palma)

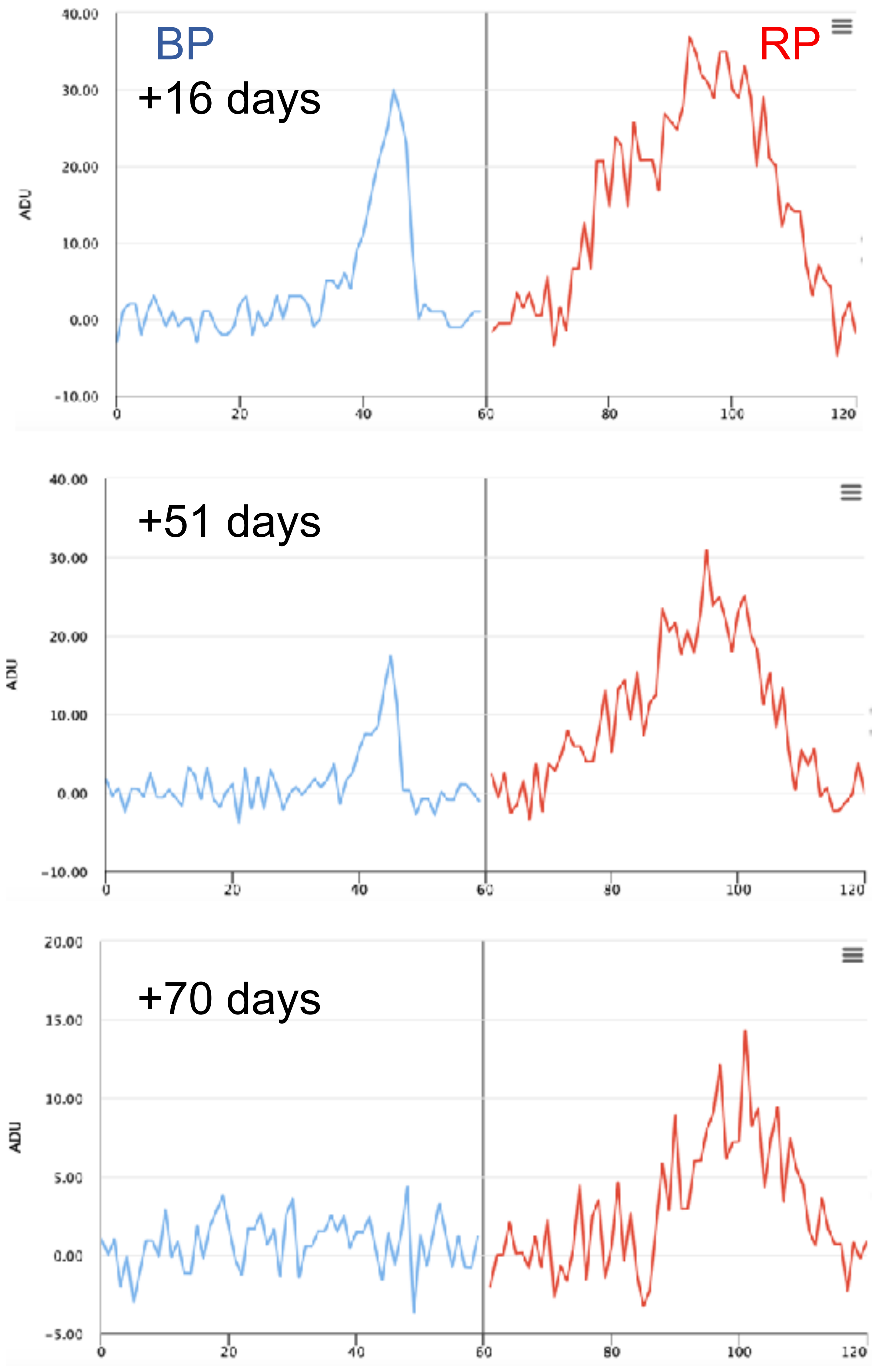


Gaia Science Alerts reported the Luminous Red Nova AT 2018bwo

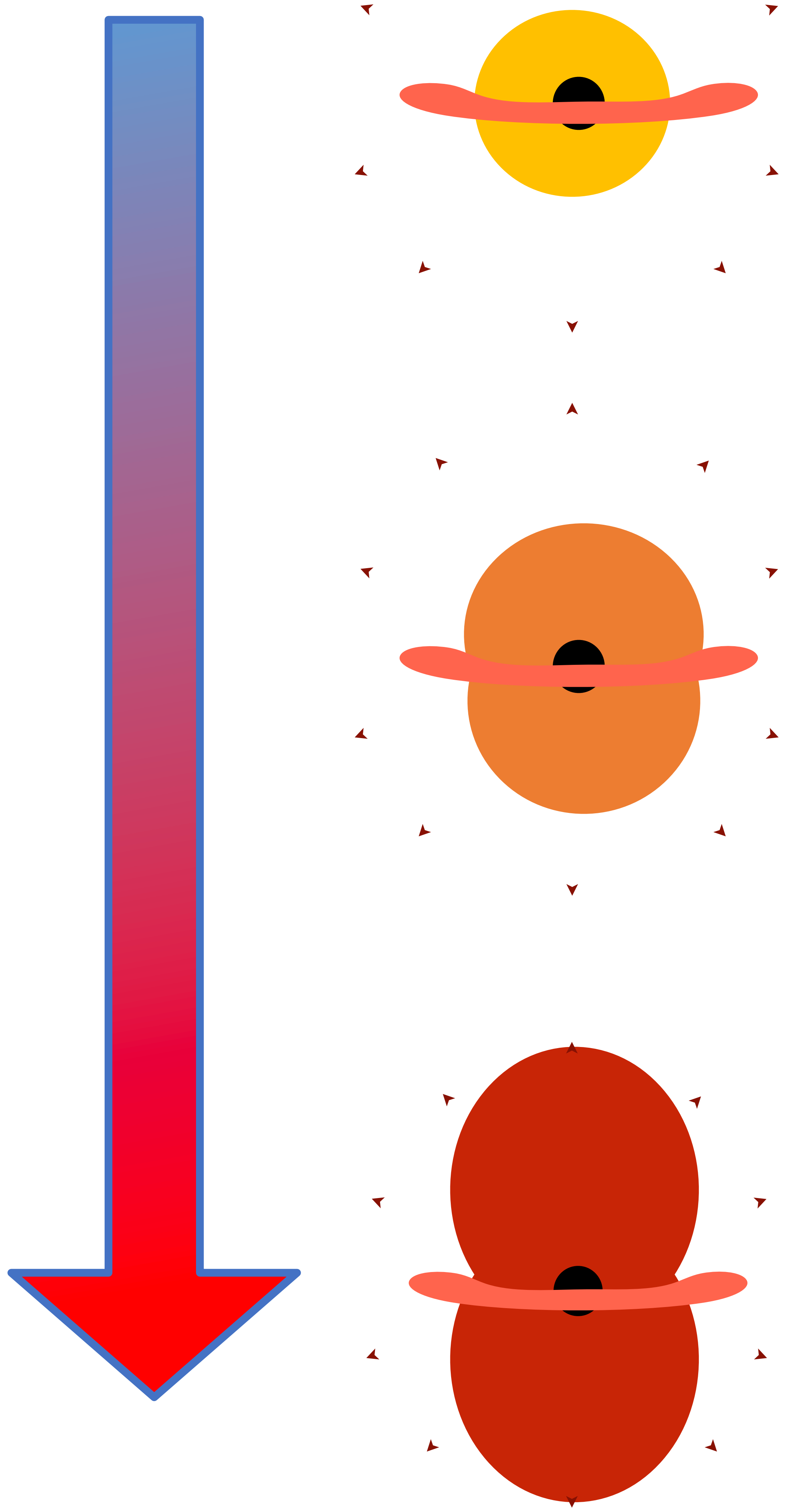
Blagorodnova et. al. 2021



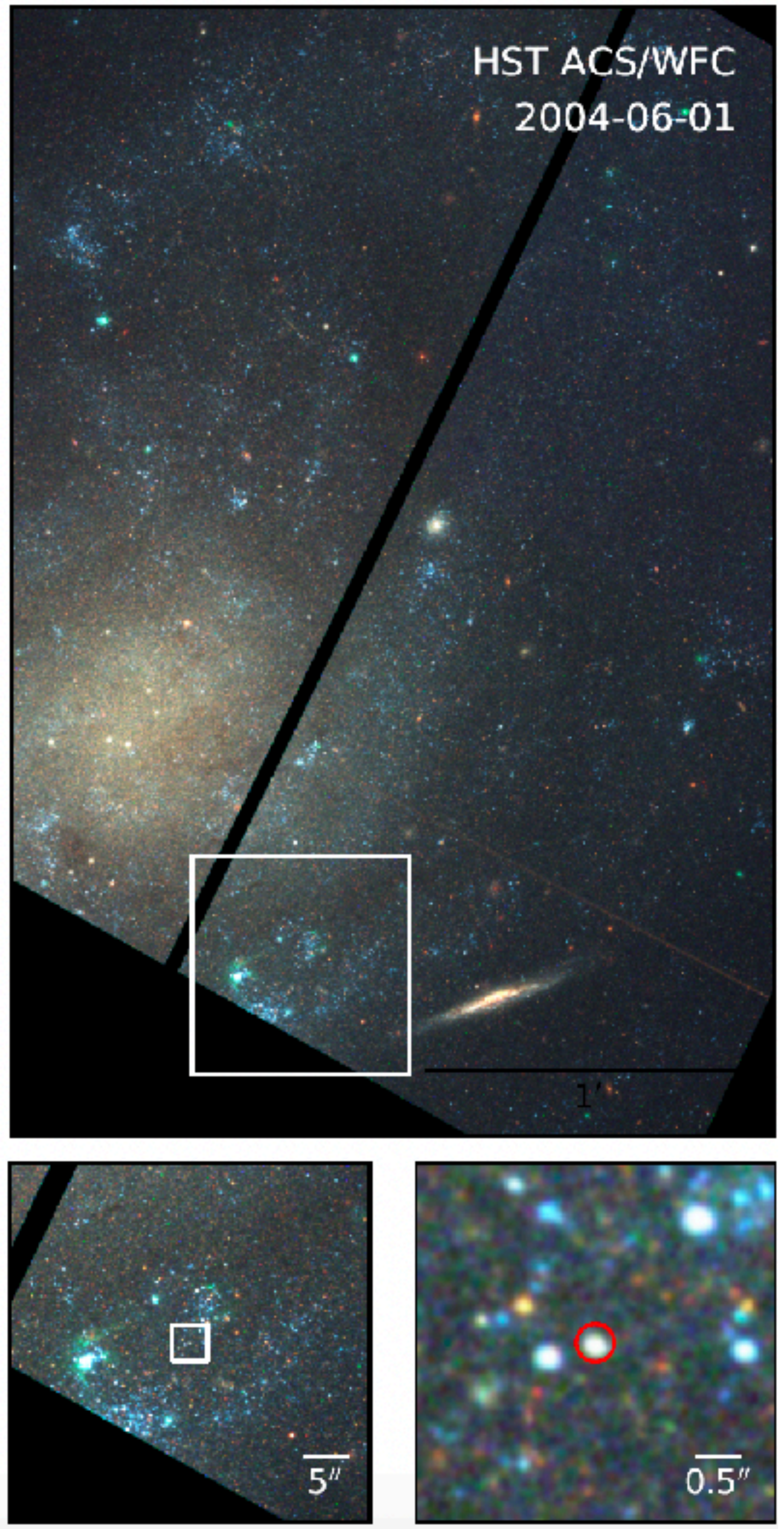


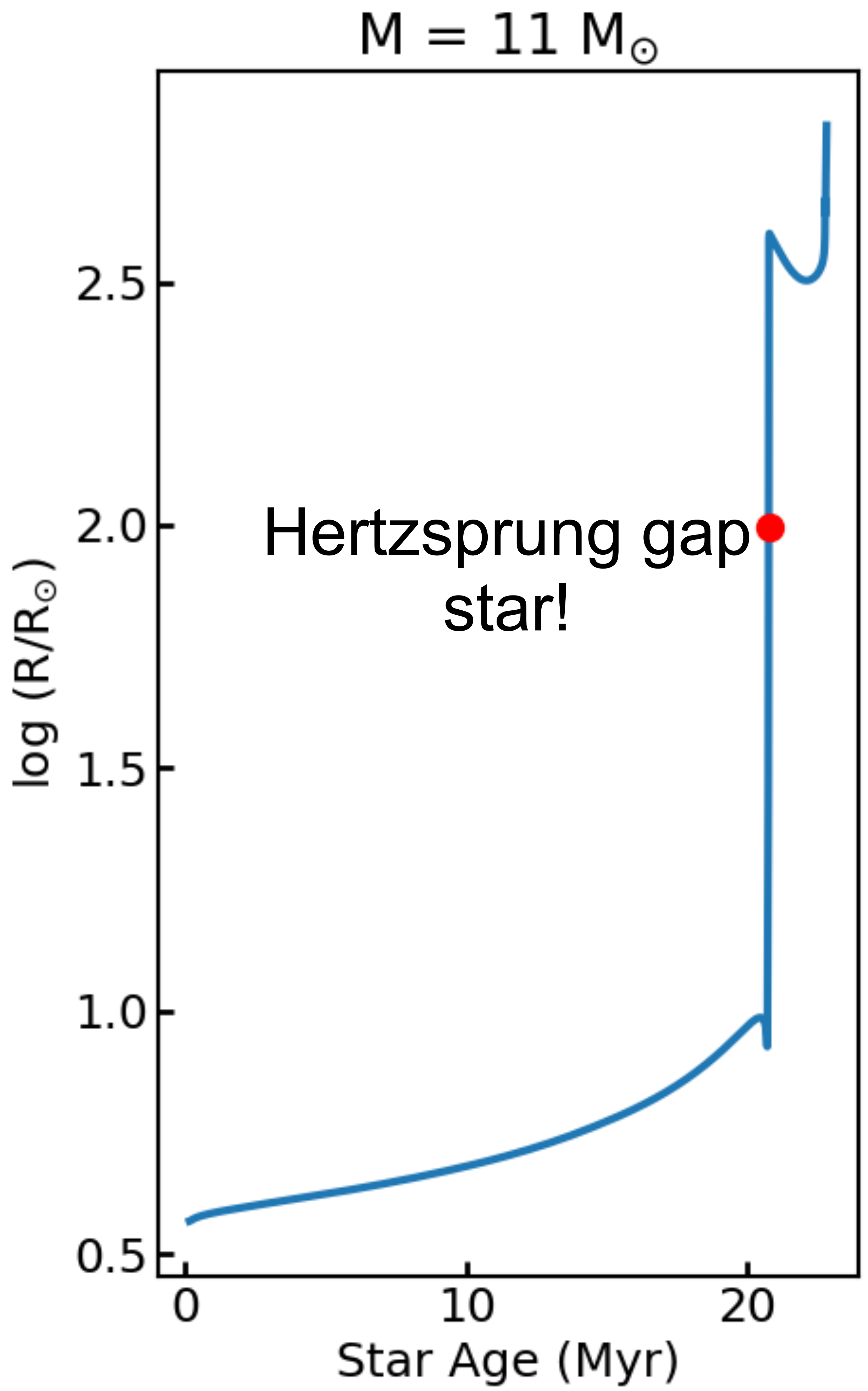


Ejecta becomes cooler (redder) with time

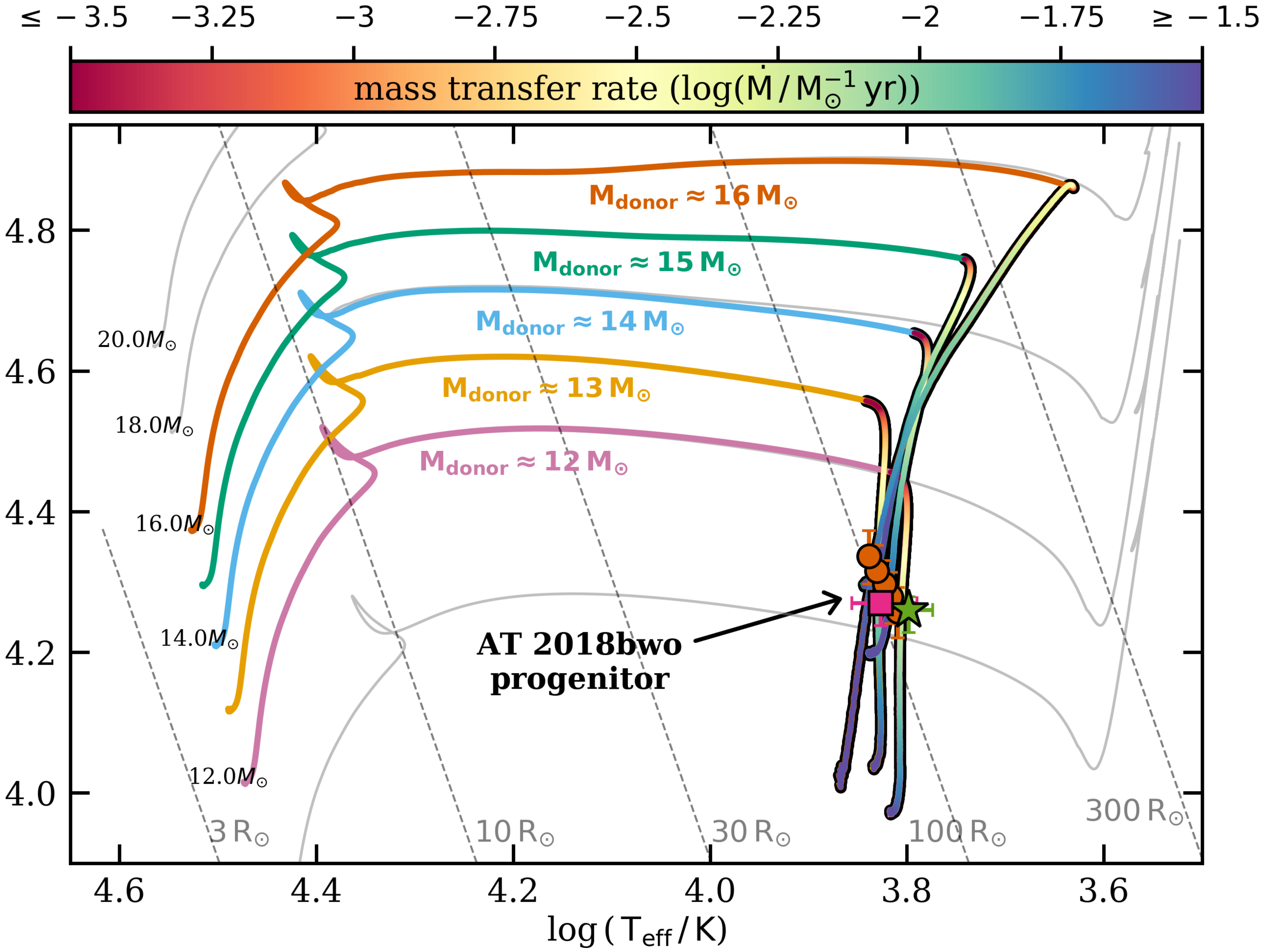


The progenitor of Luminous Red Nova AT 2018bwo





MESA binary stellar evolution model of the progenitor of LRN AT2018bwo

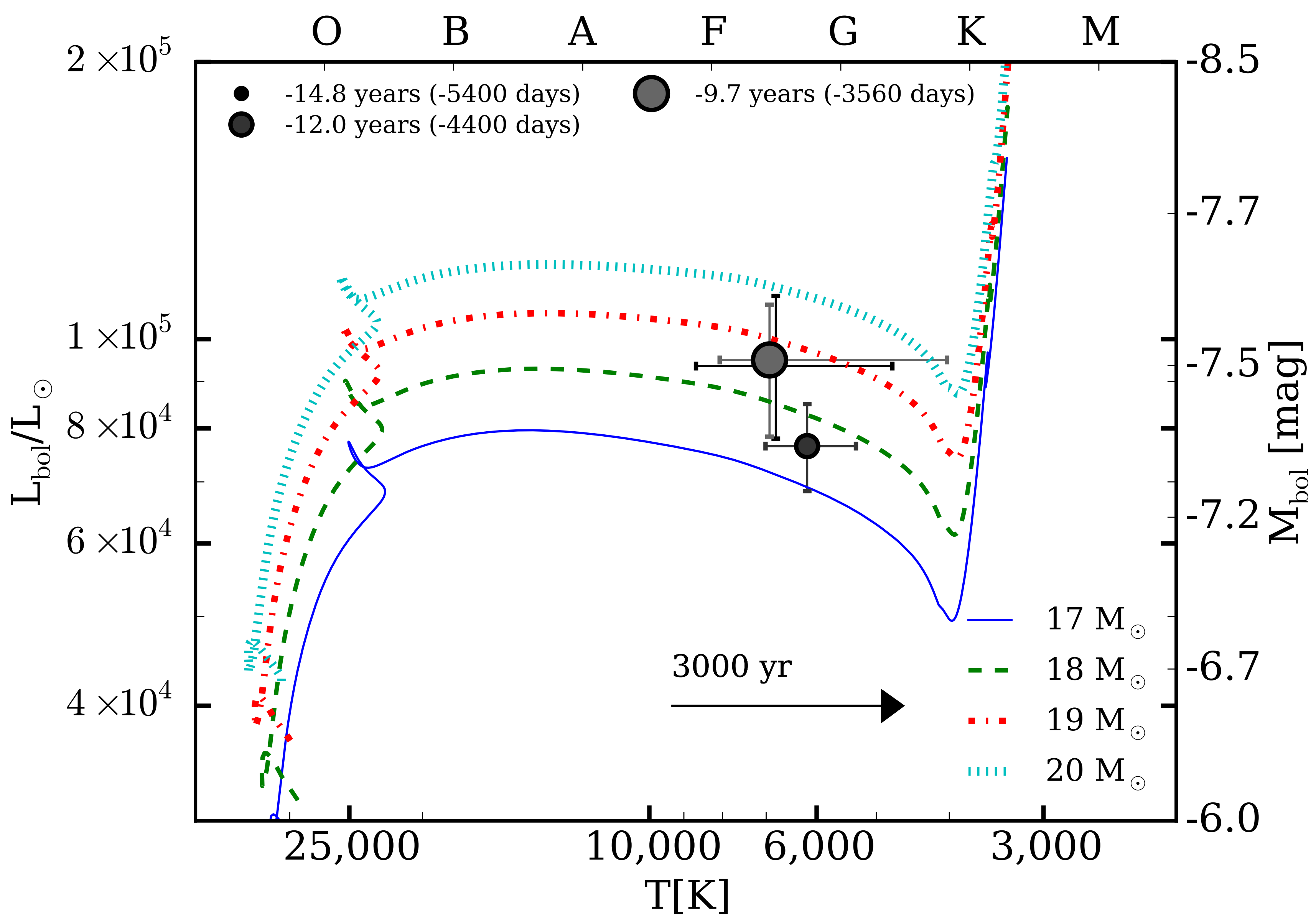


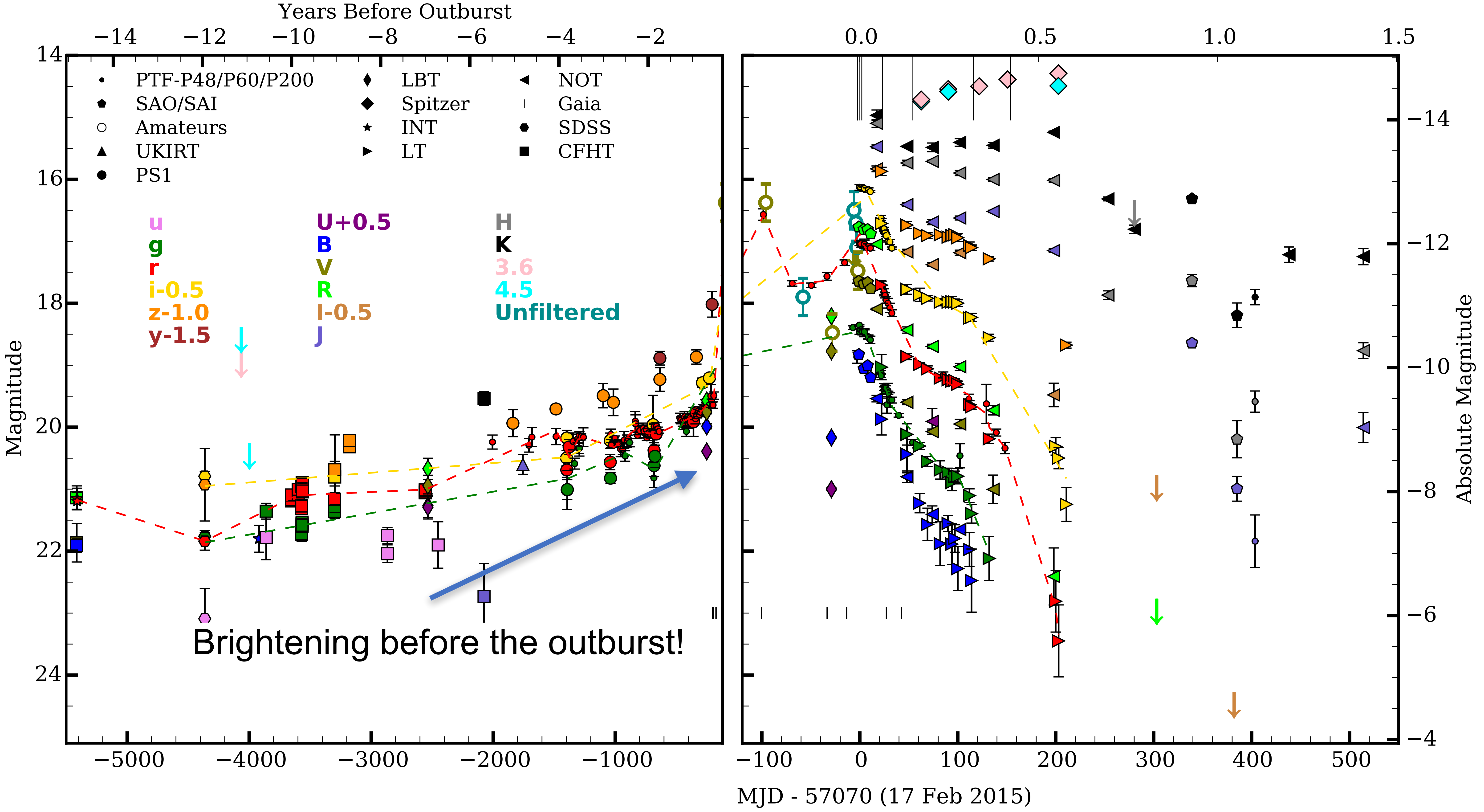
Blagorodnova et al. 2021

The progenitor and precursor of the Luminous Red Nova M101-2015OT

(also observed by Gaia, although not reported)

Progenitor of LRN M101-2015OT, another Hertzsprung gap star!

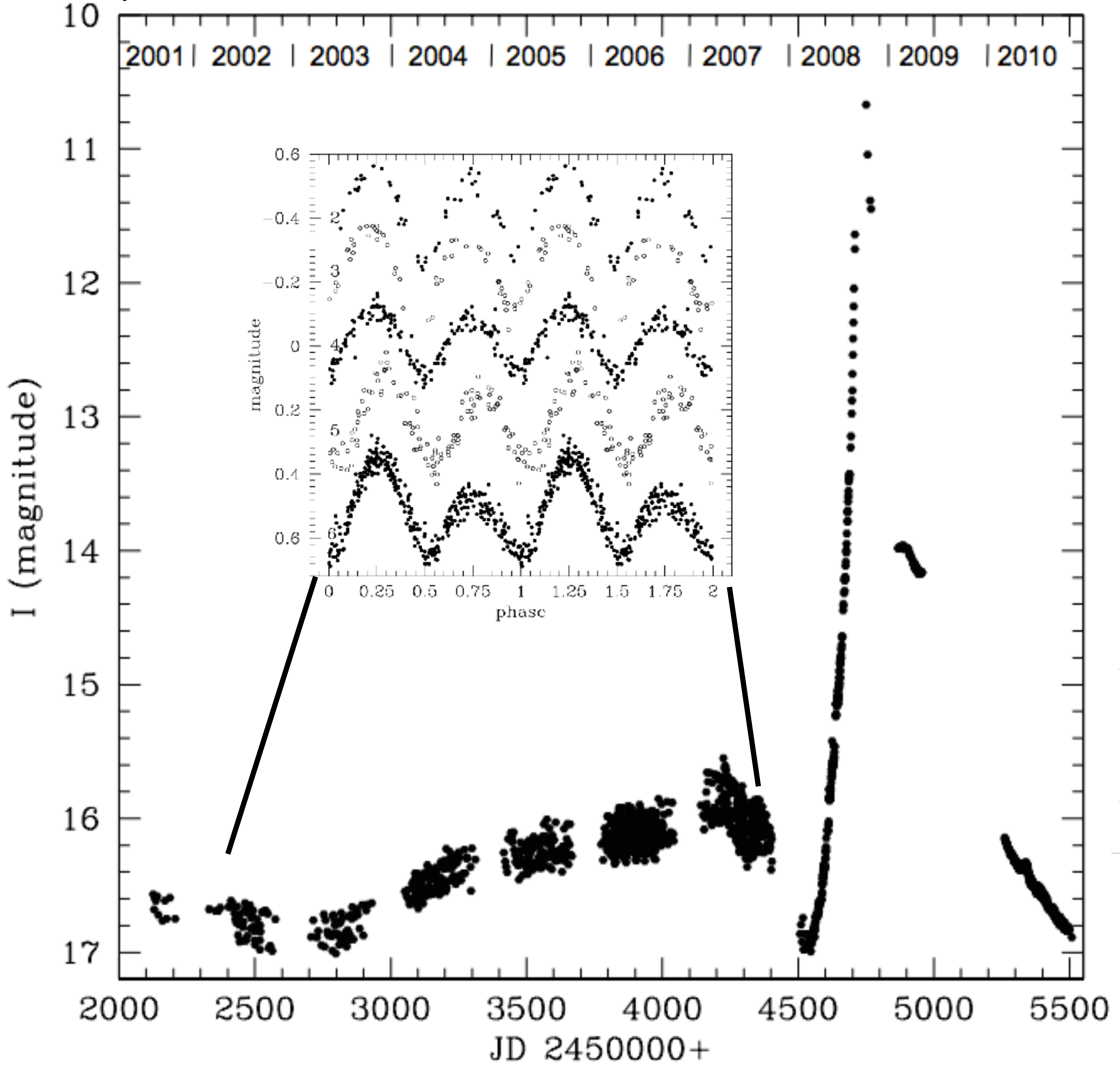




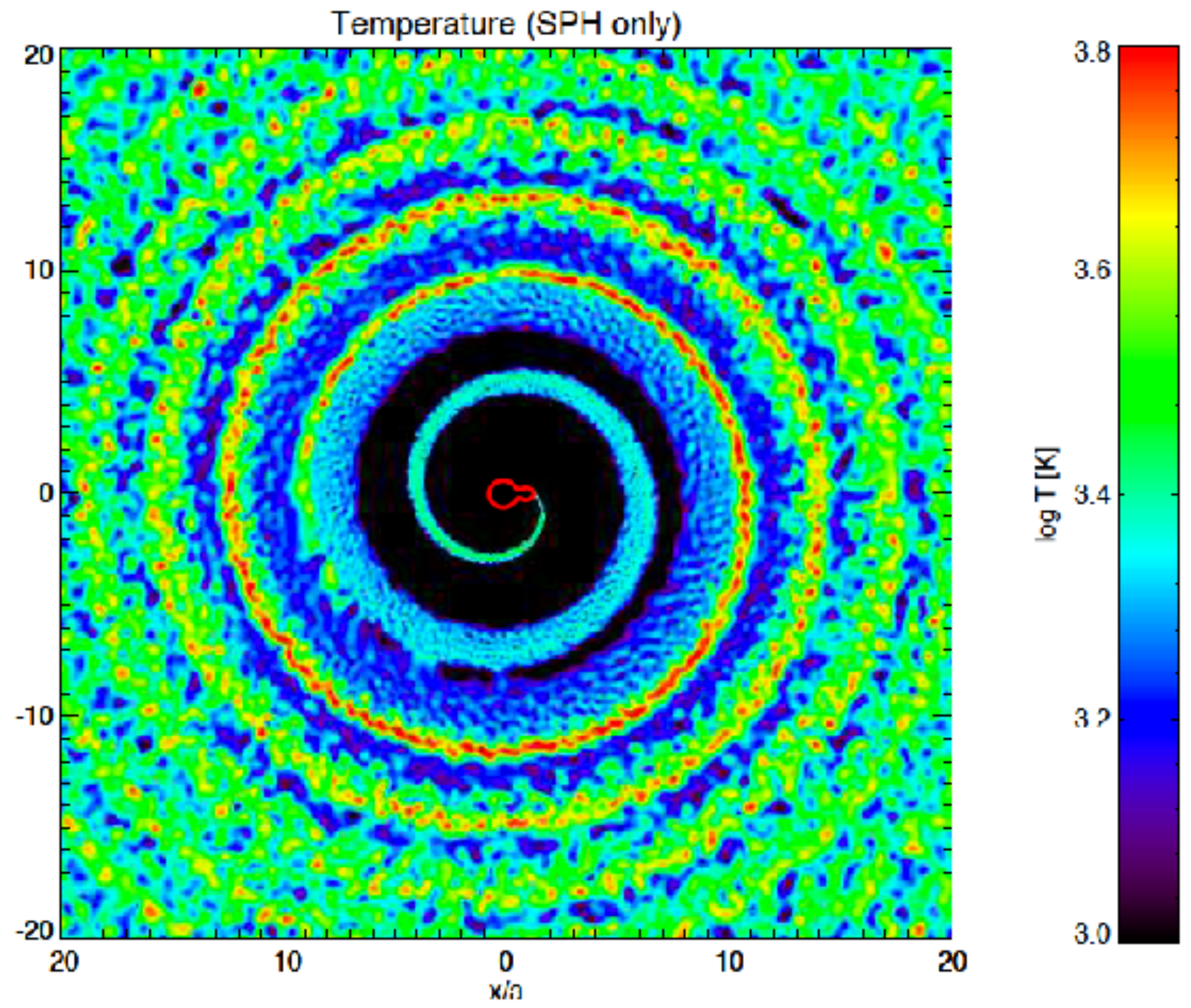
Blagorodnova et al. 2017

Precursor brightening as mass loss from the binary

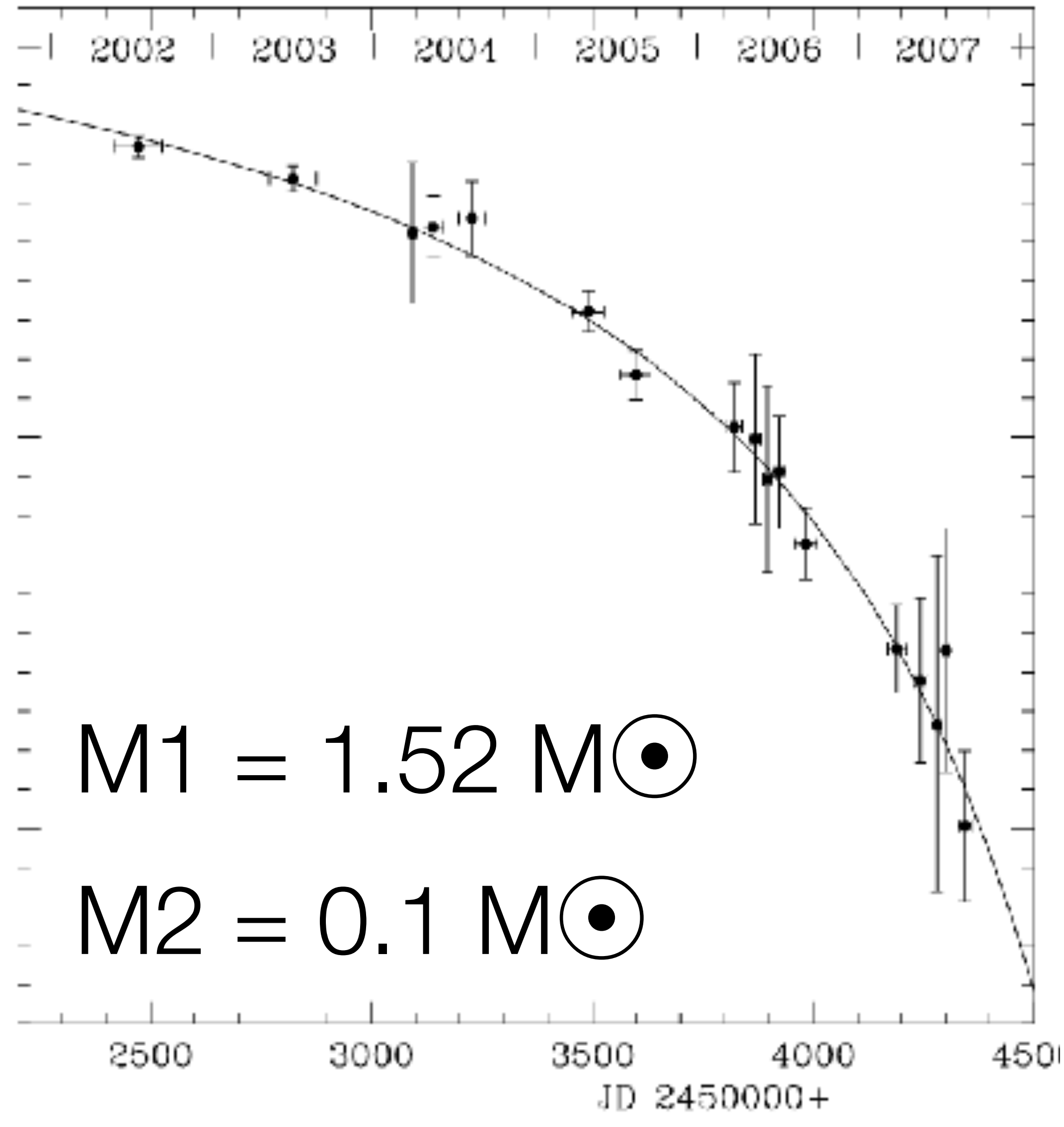
Tylenda et. al., 2011



Mass loss shrinks the binary!

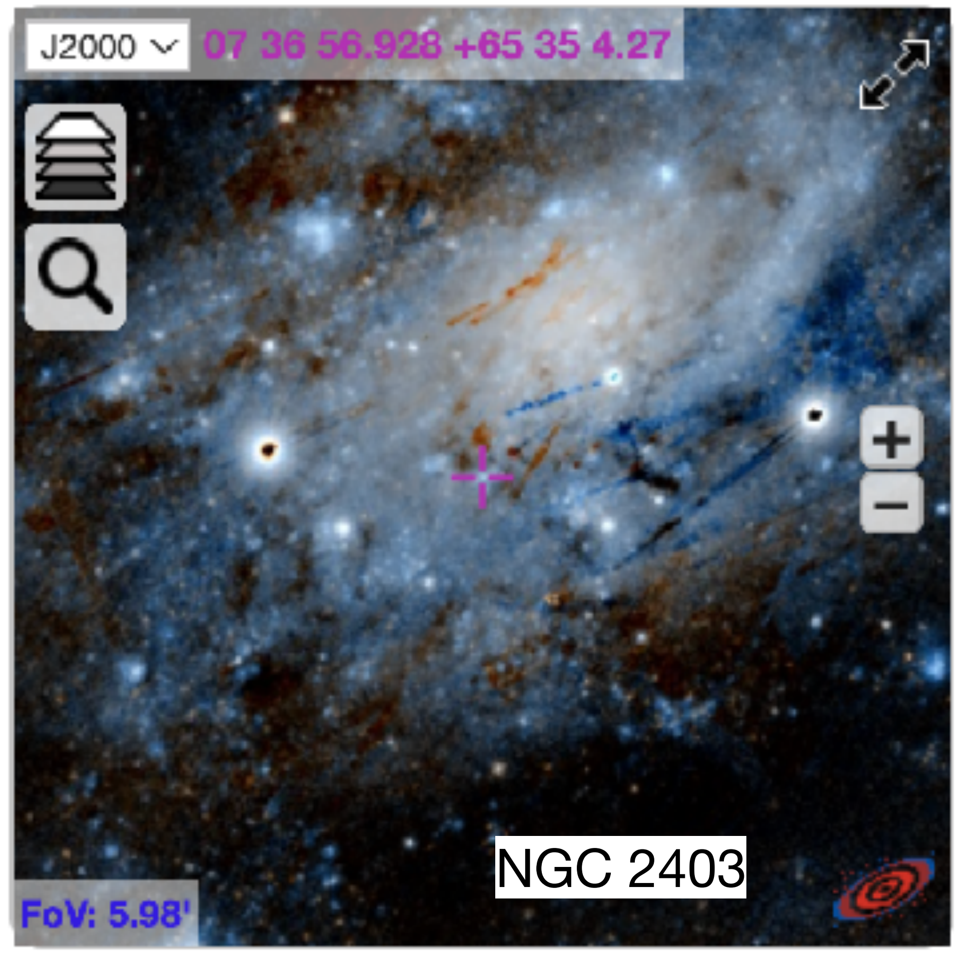


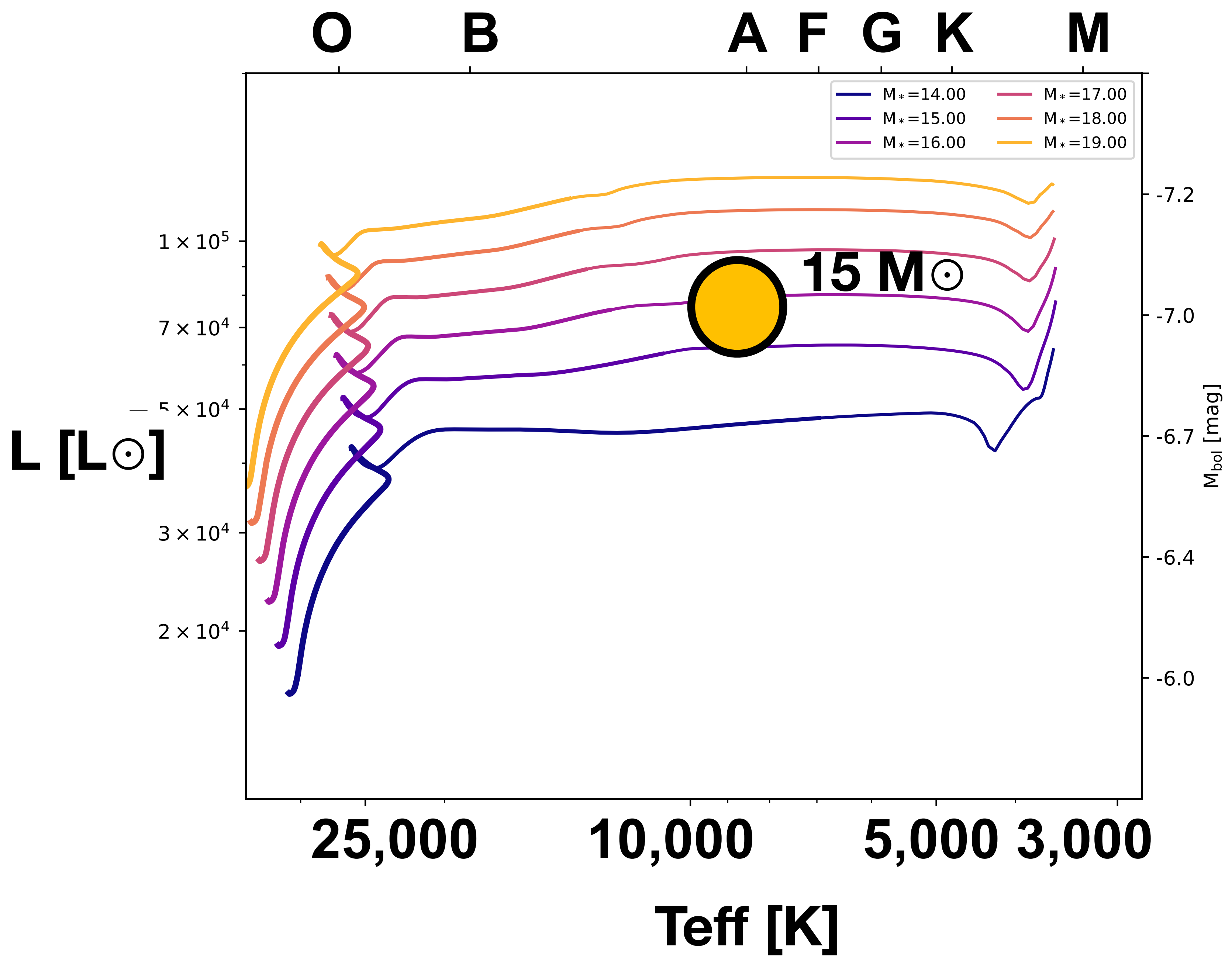
Pejcha et al. 2016a



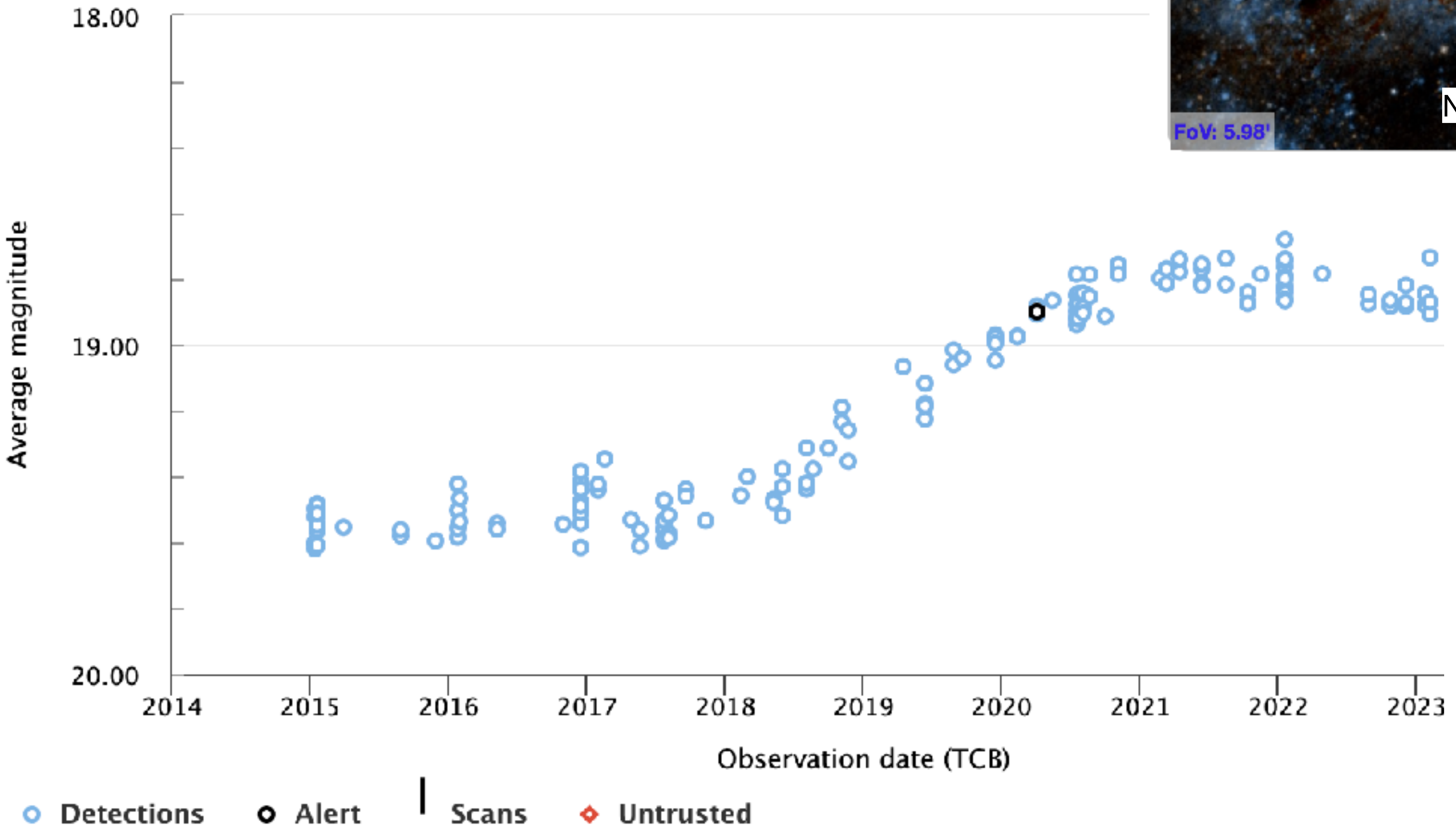
Tylenda et. al., 2011

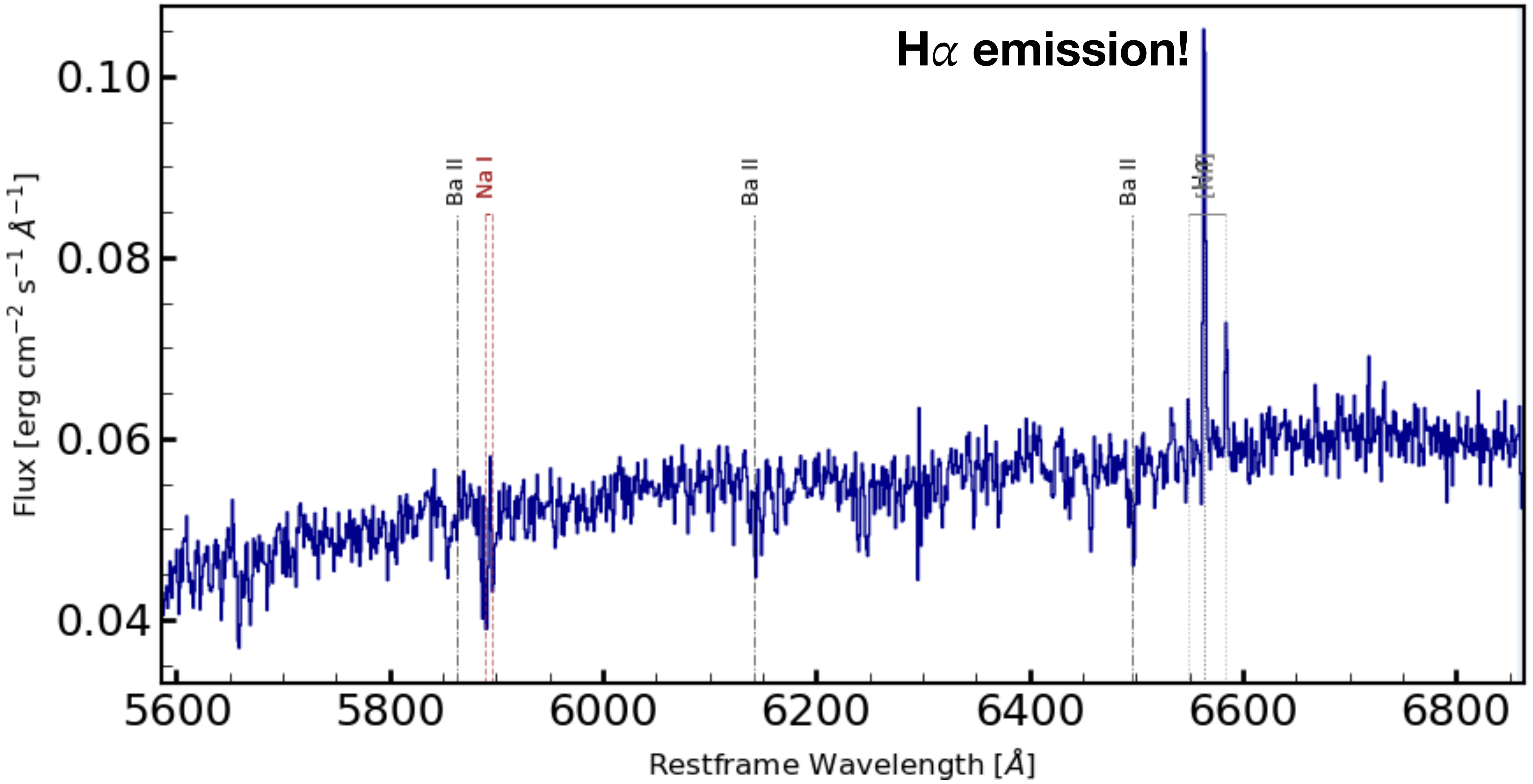
A likely LRN precursor from Gaia





Gaia20bsc / AT2019aabm

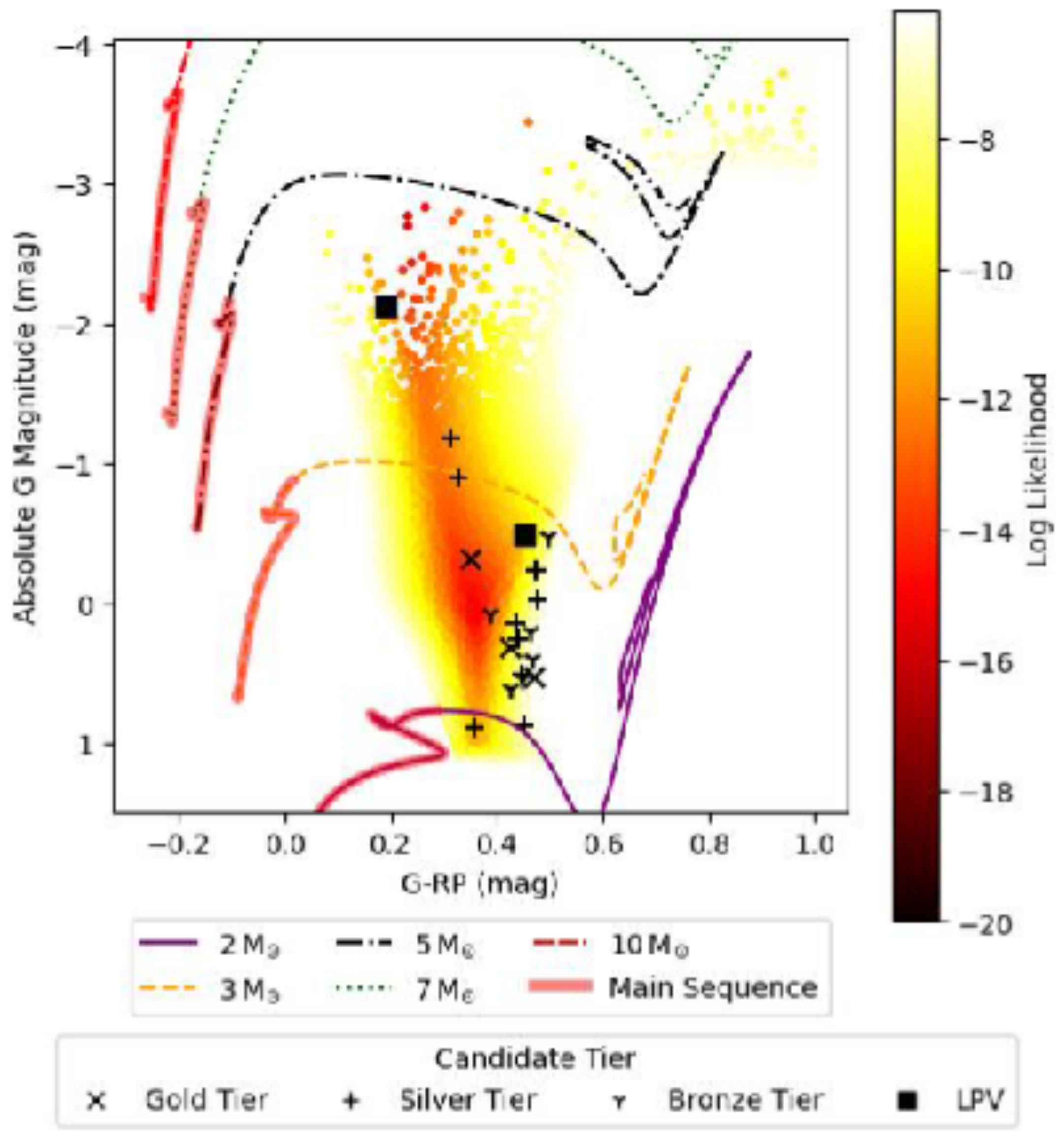




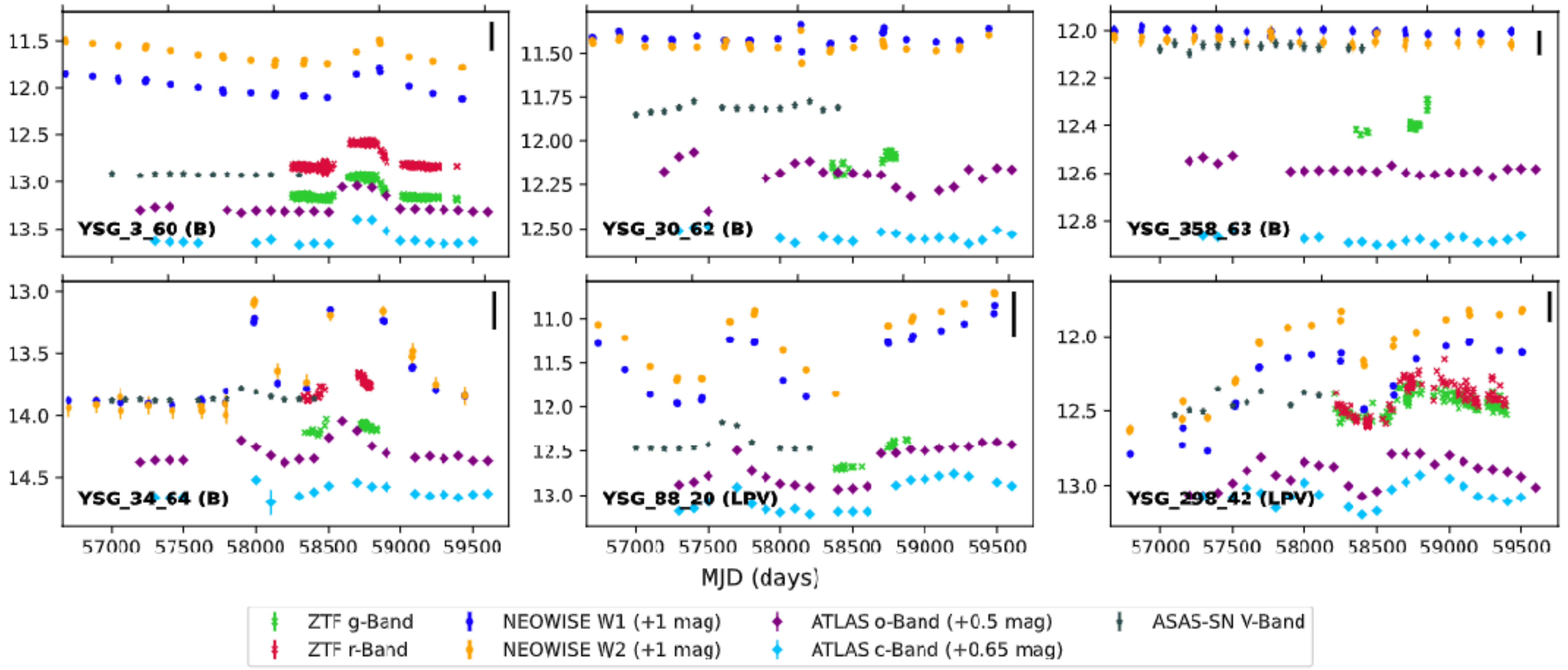
Can we predict a LRN… in the MW?

Addison, Blagorodnova et al. 2022

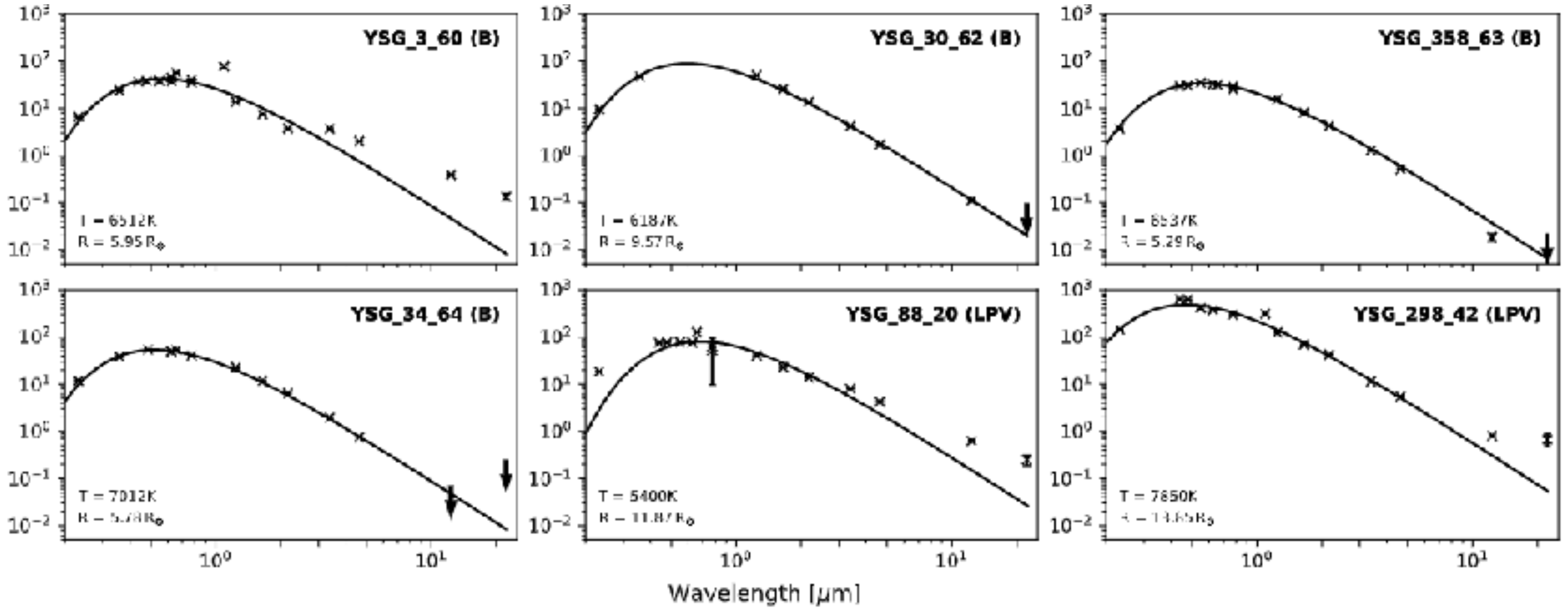
1 - Search for Gaia sources in "the gap"



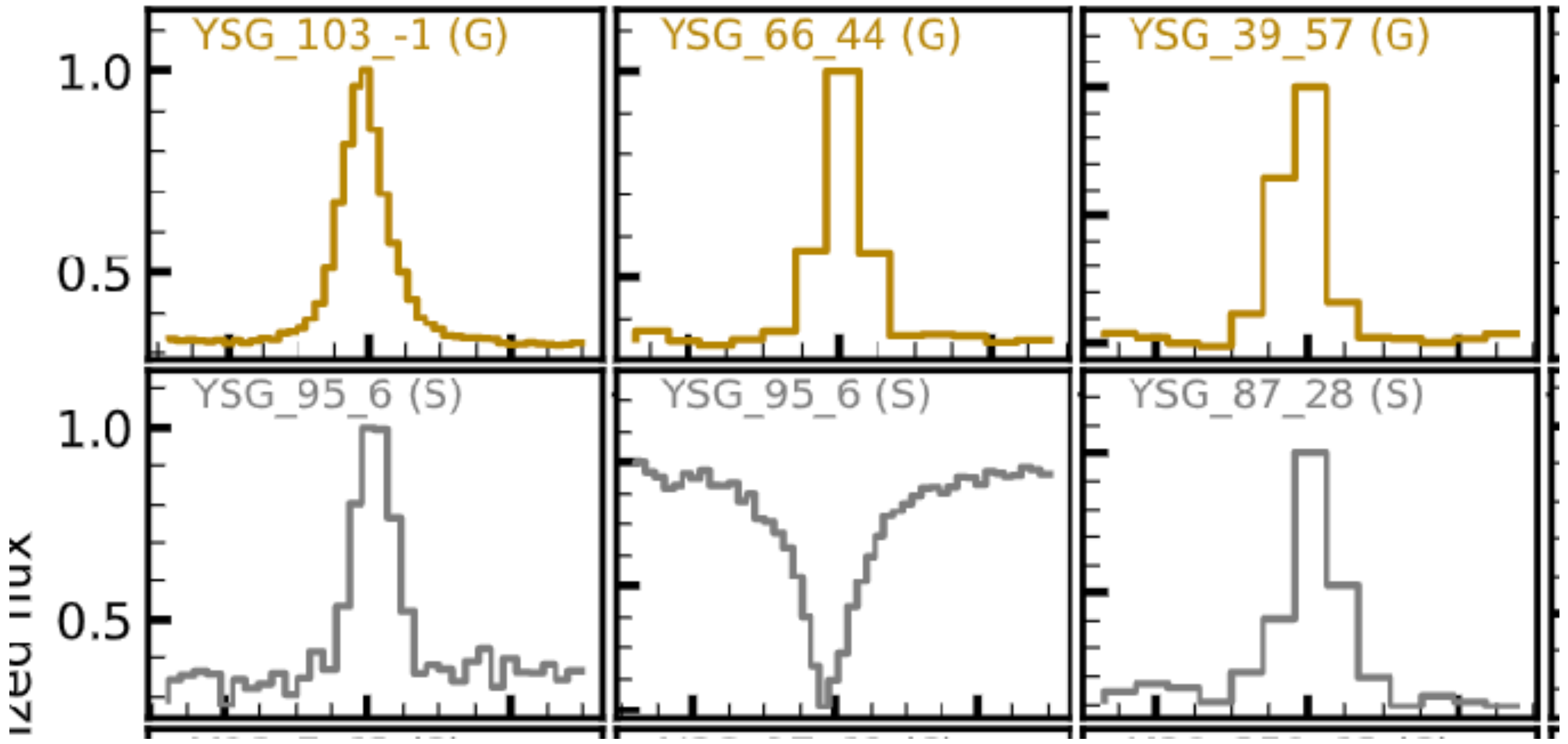
2 - variability study



3 - characterisation: IR excess



Hα emission



Can we predict a LRN… in the MW?

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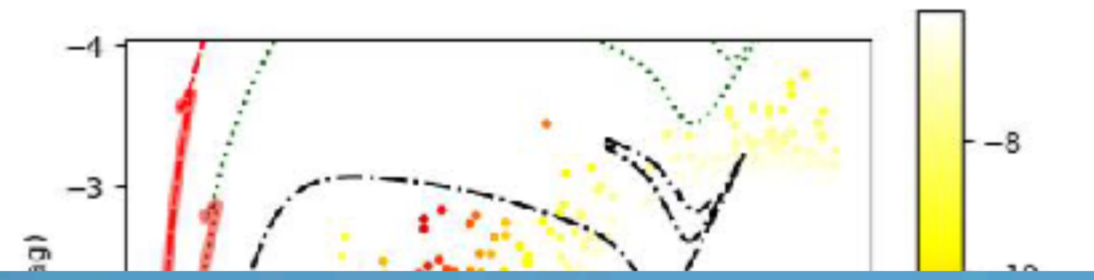

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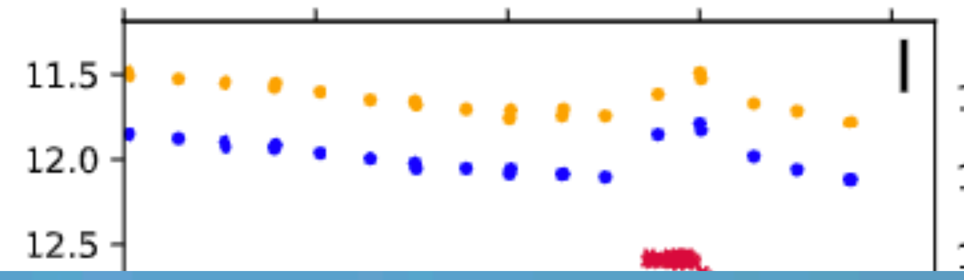
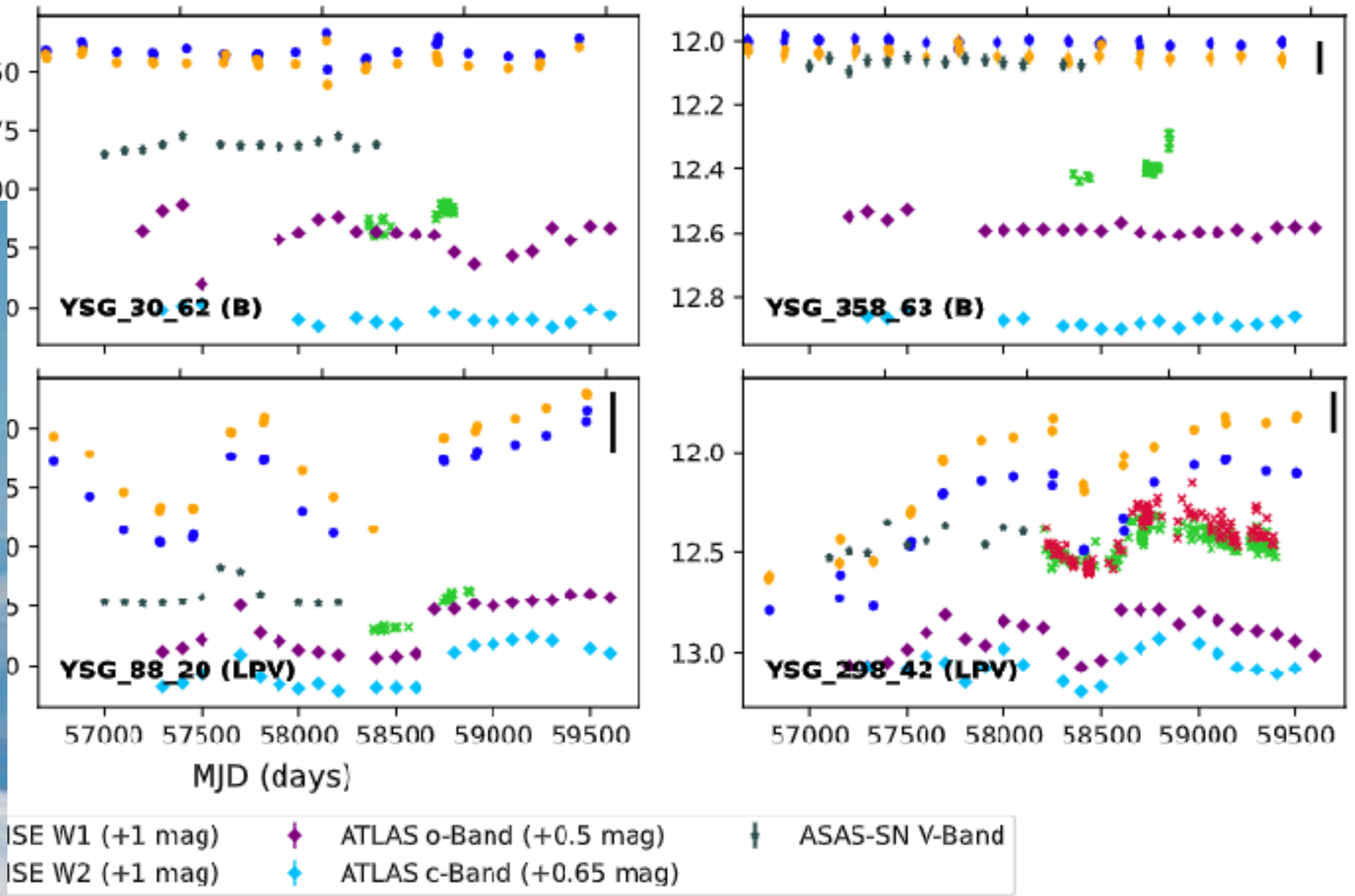
Addison, Blagorodnova et al. 2022

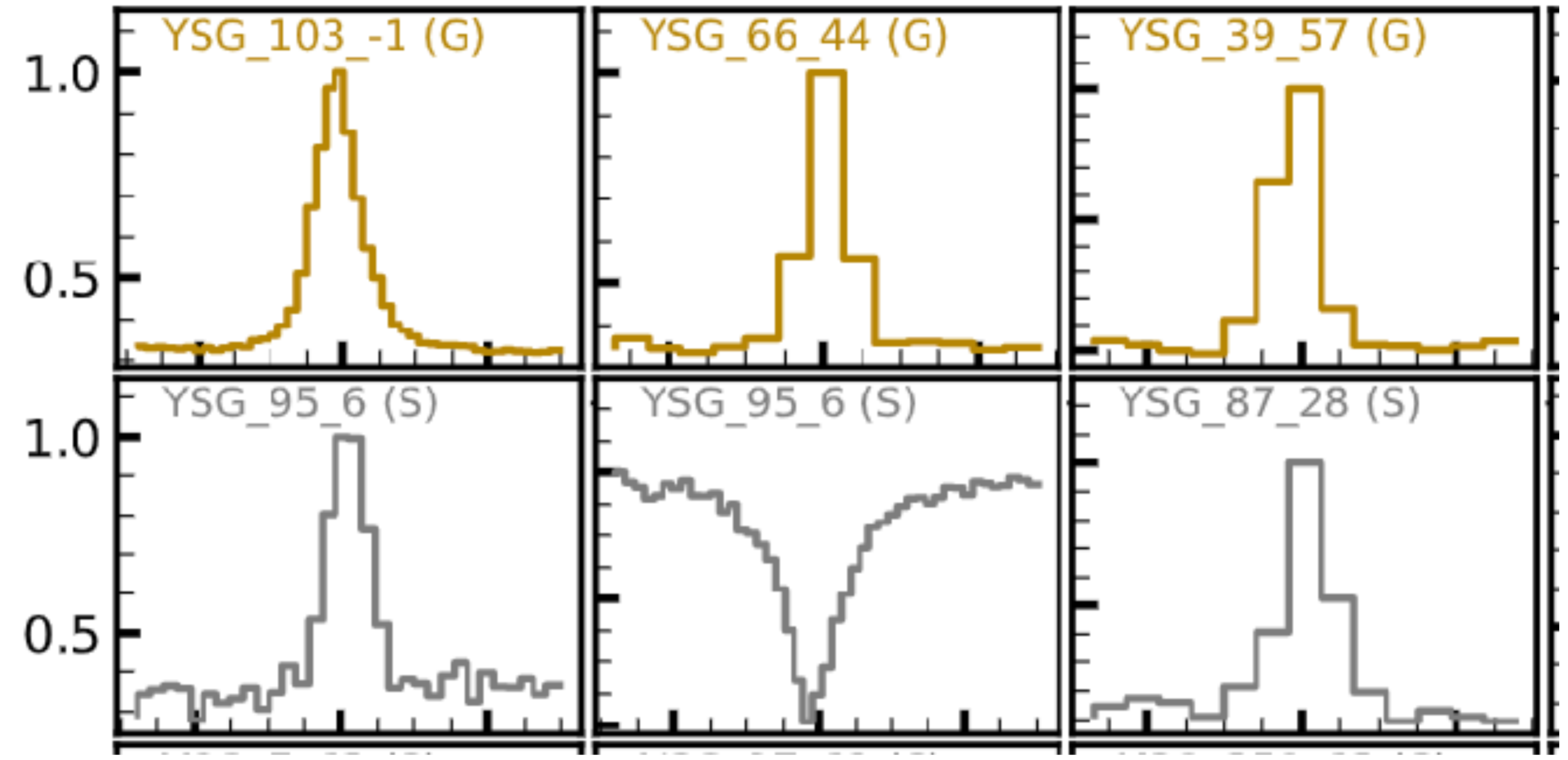


Coming soon…

NOT/FIES high-resolution spectroscopy for the characterisation of the 21 candidates



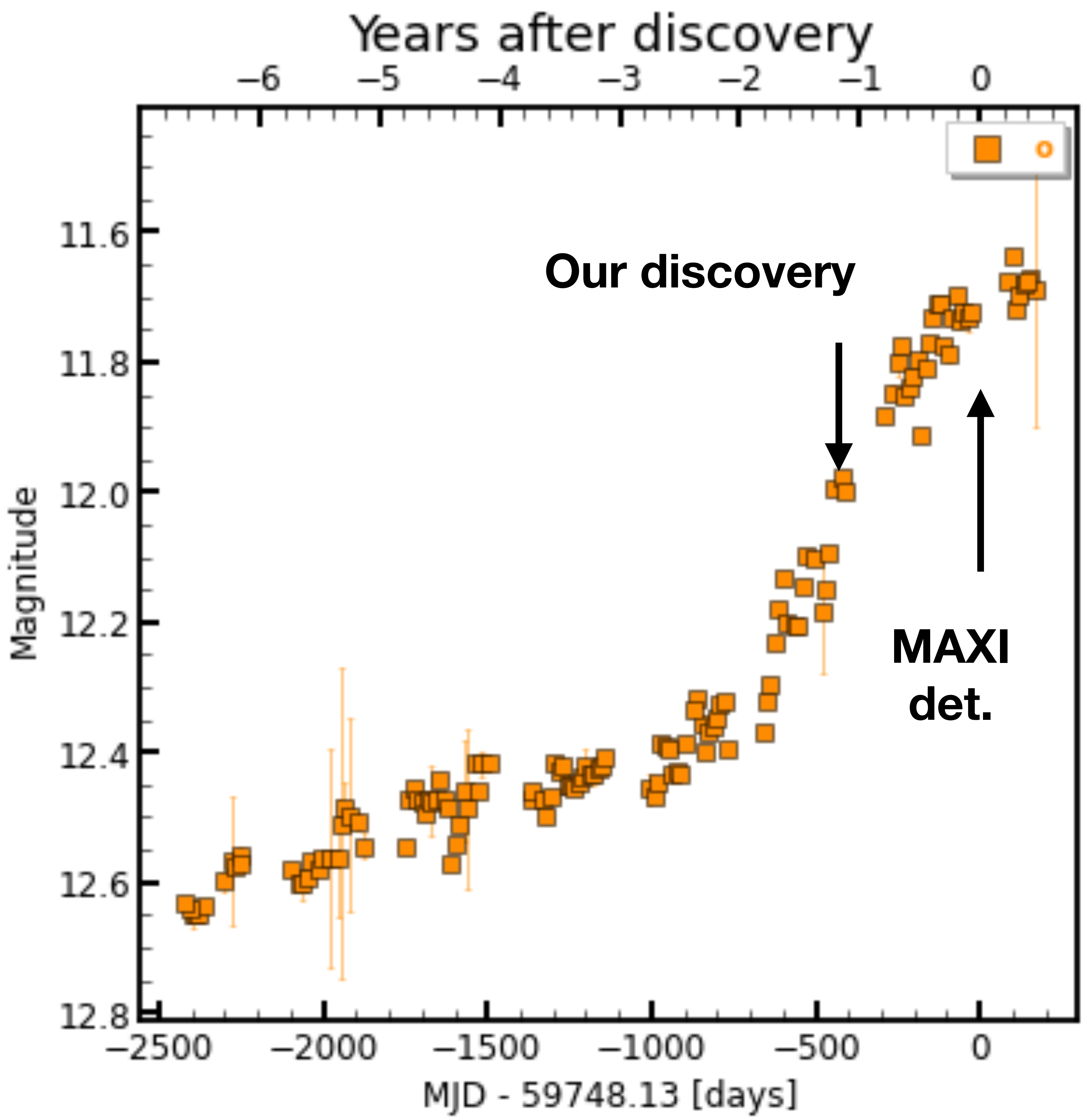
Hα emission

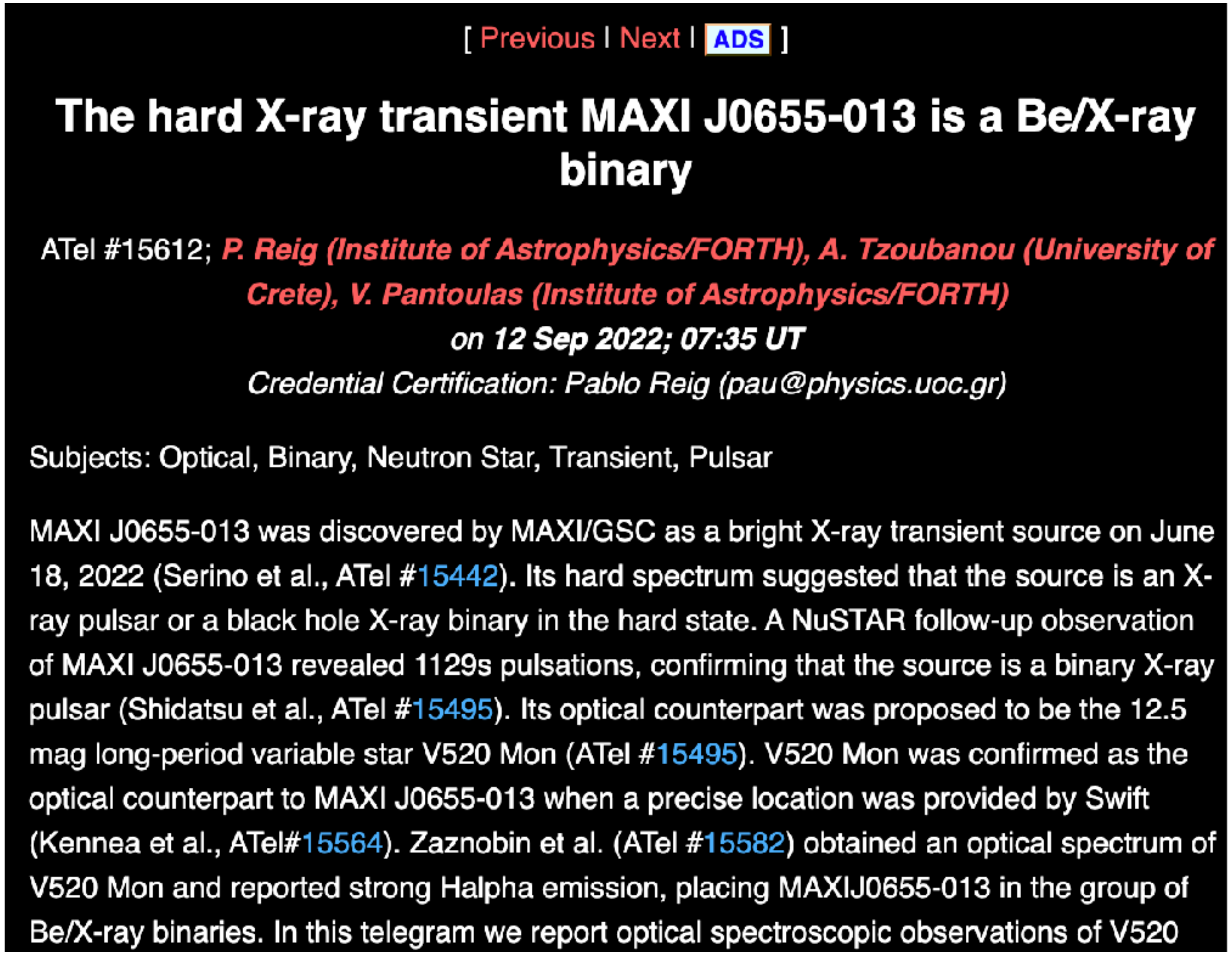


Wavelength [μm]

but… We predicted an X-ray binary outburst!

V520Mon





[Previous | Next | ADS]

The hard X-ray transient MAXI J0655-013 is a Be/X-ray binary

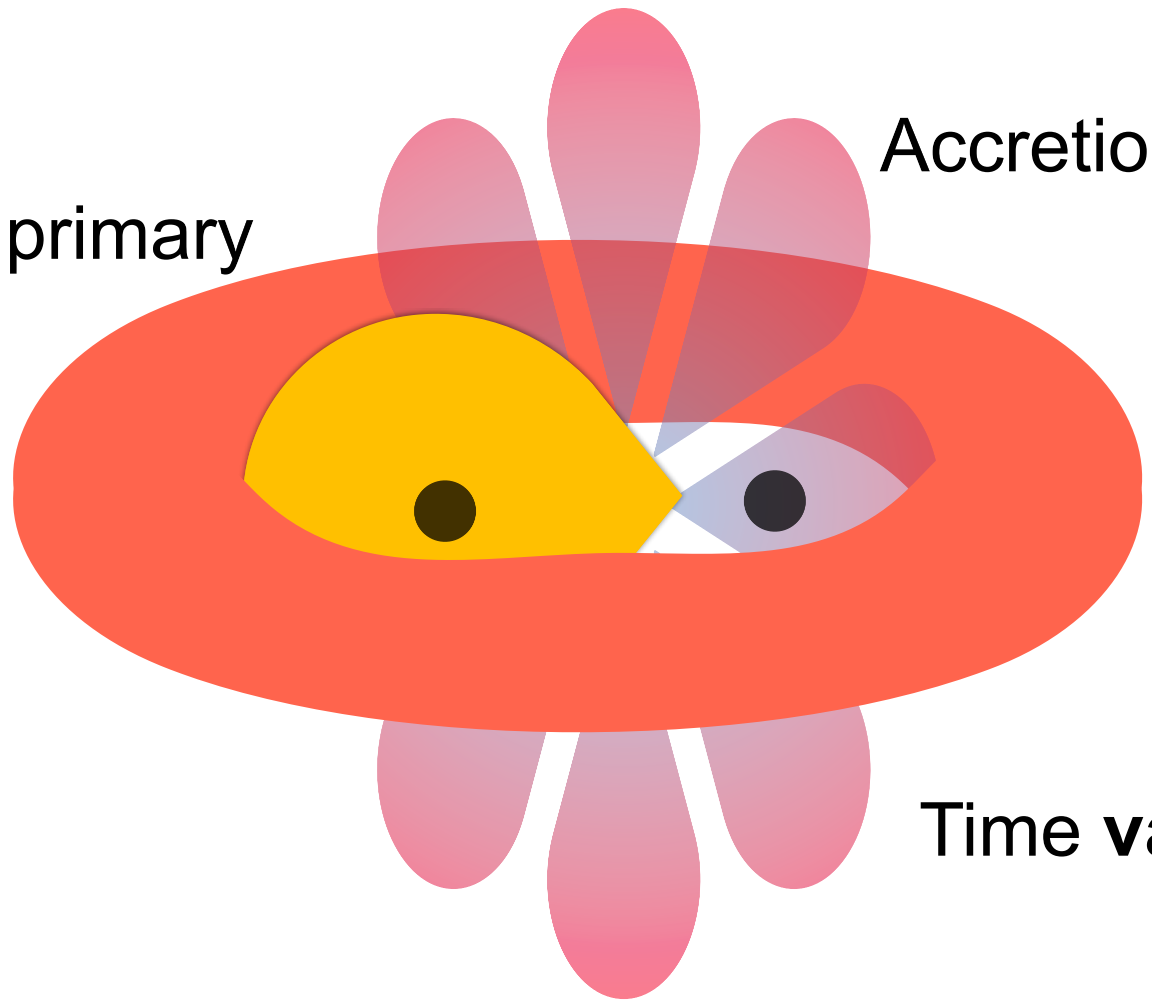
ATel #15612; *P. Reig (Institute of Astrophysics/FORTH), A. Tzoubanou (University of Crete), V. Pantoulas (Institute of Astrophysics/FORTH)*
on 12 Sep 2022; 07:35 UT
Credential Certification: Pablo Reig (pau@physics.uoc.gr)

Subjects: Optical, Binary, Neutron Star, Transient, Pulsar

MAXI J0655-013 was discovered by MAXI/GSC as a bright X-ray transient source on June 18, 2022 (Serino et al., ATel #15442). Its hard spectrum suggested that the source is an X-ray pulsar or a black hole X-ray binary in the hard state. A NuSTAR follow-up observation of MAXI J0655-013 revealed 1129s pulsations, confirming that the source is a binary X-ray pulsar (Shidatsu et al., ATel #15495). Its optical counterpart was proposed to be the 12.5 mag long-period variable star V520 Mon (ATel #15495). V520 Mon was confirmed as the optical counterpart to MAXI J0655-013 when a precise location was provided by Swift (Kennea et al., ATel#15564). Zaznobin et al. (ATel #15582) obtained an optical spectrum of V520 Mon and reported strong Halpha emission, placing MAXIJ0655-013 in the group of Be/X-ray binaries. In this telegram we report optical spectroscopic observations of V520

searching for LRN progenitors among Hertszprung gap Hα emitters

Hertszprung gap primary

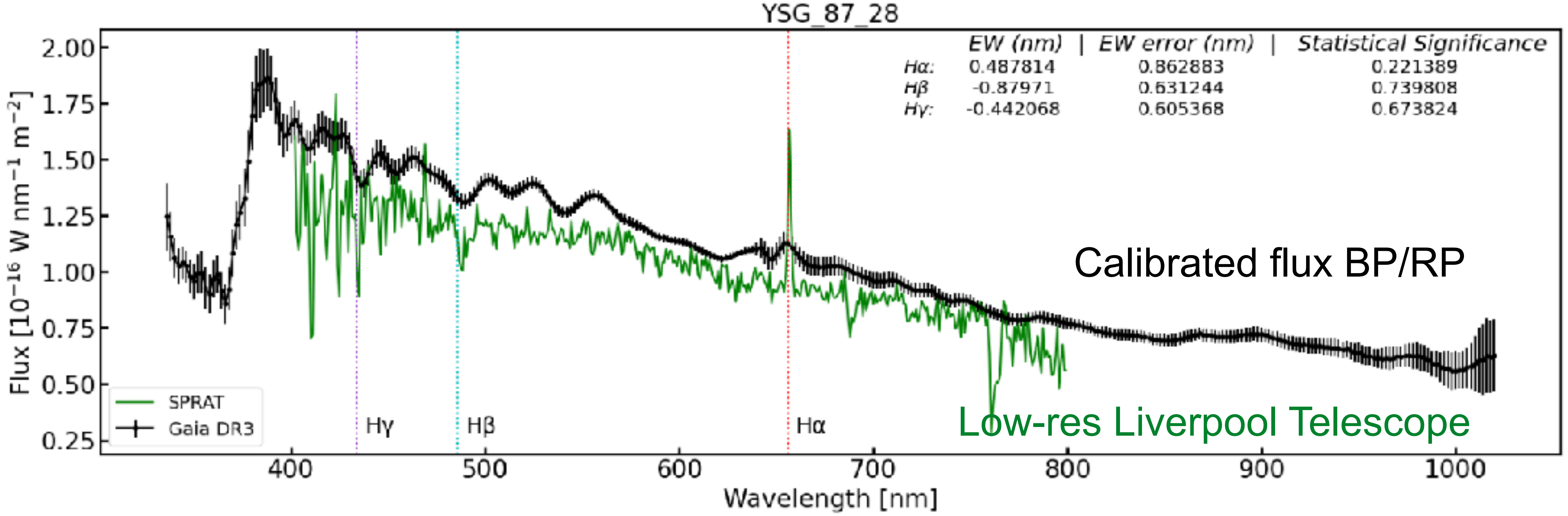


Accretion & outflows: **emission lines**

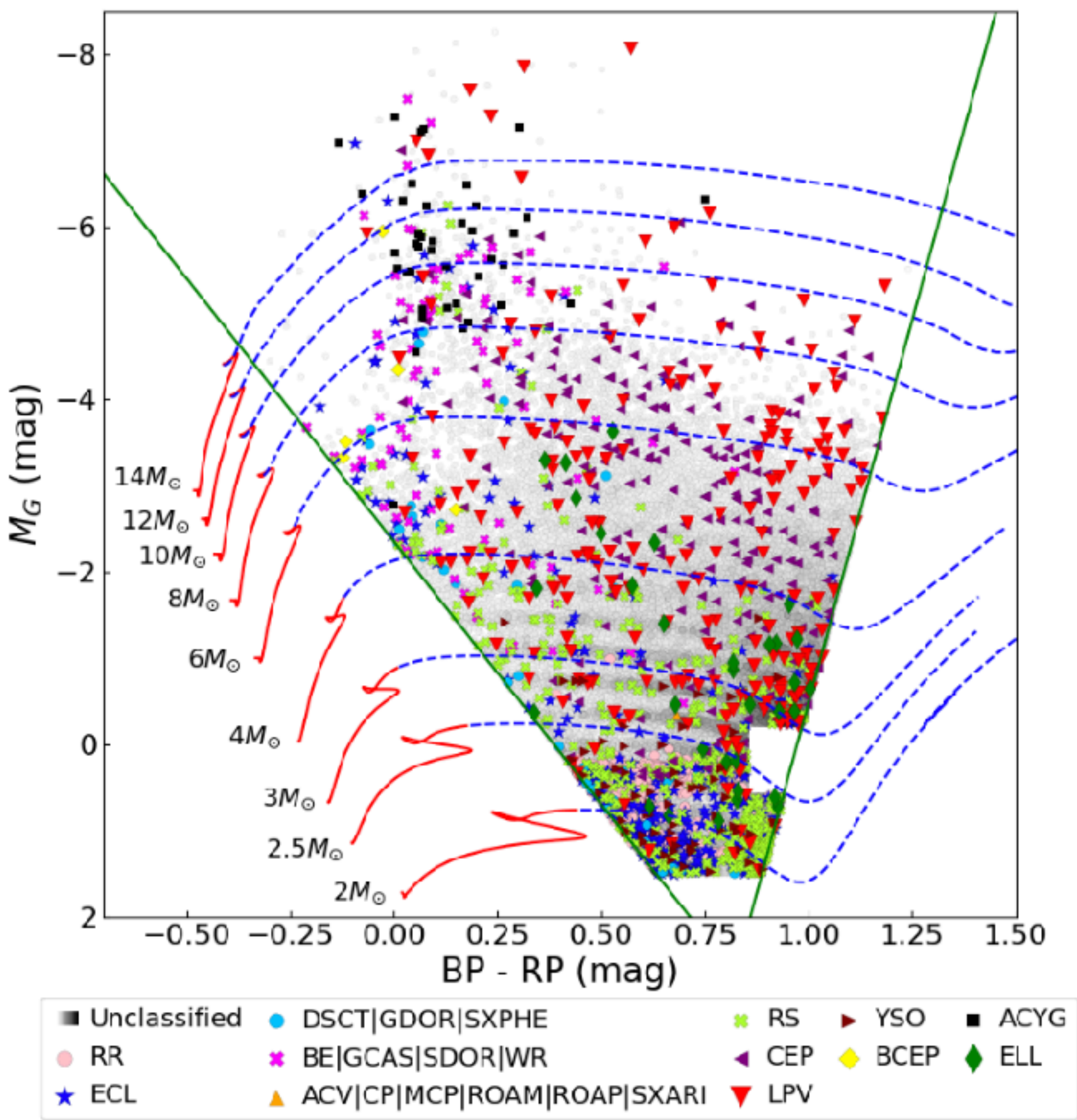
IR emission from dusty disk

Time **variability** in brightness

Gaia DR3 provides Bp/Rp spectrophotometry! —> search for **Hα emission**



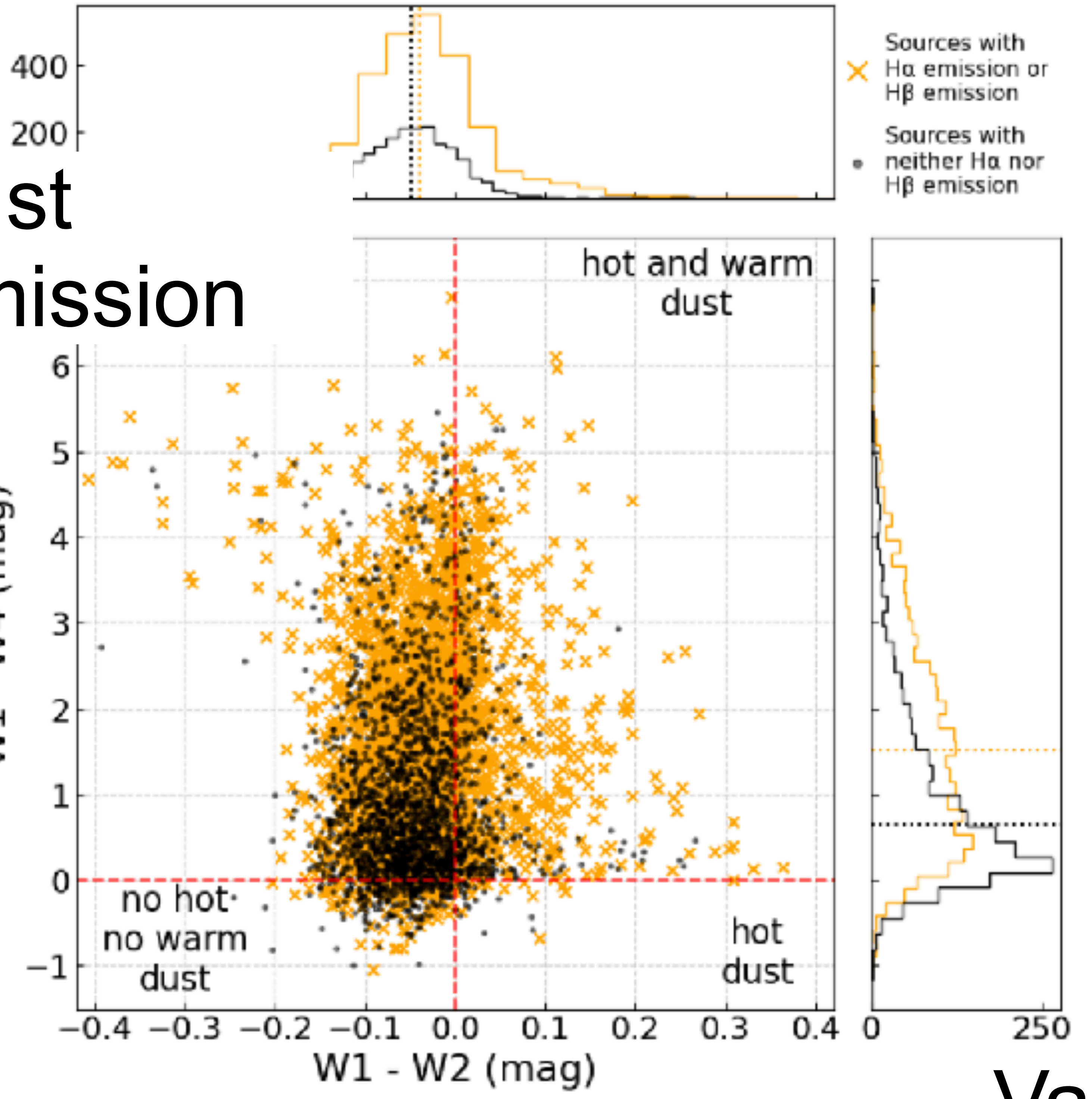
Hertszprung gap primary star



Undergraduate thesis, Gerard Garcia Moreno, Universitat de Barcelona

Interesting candidates

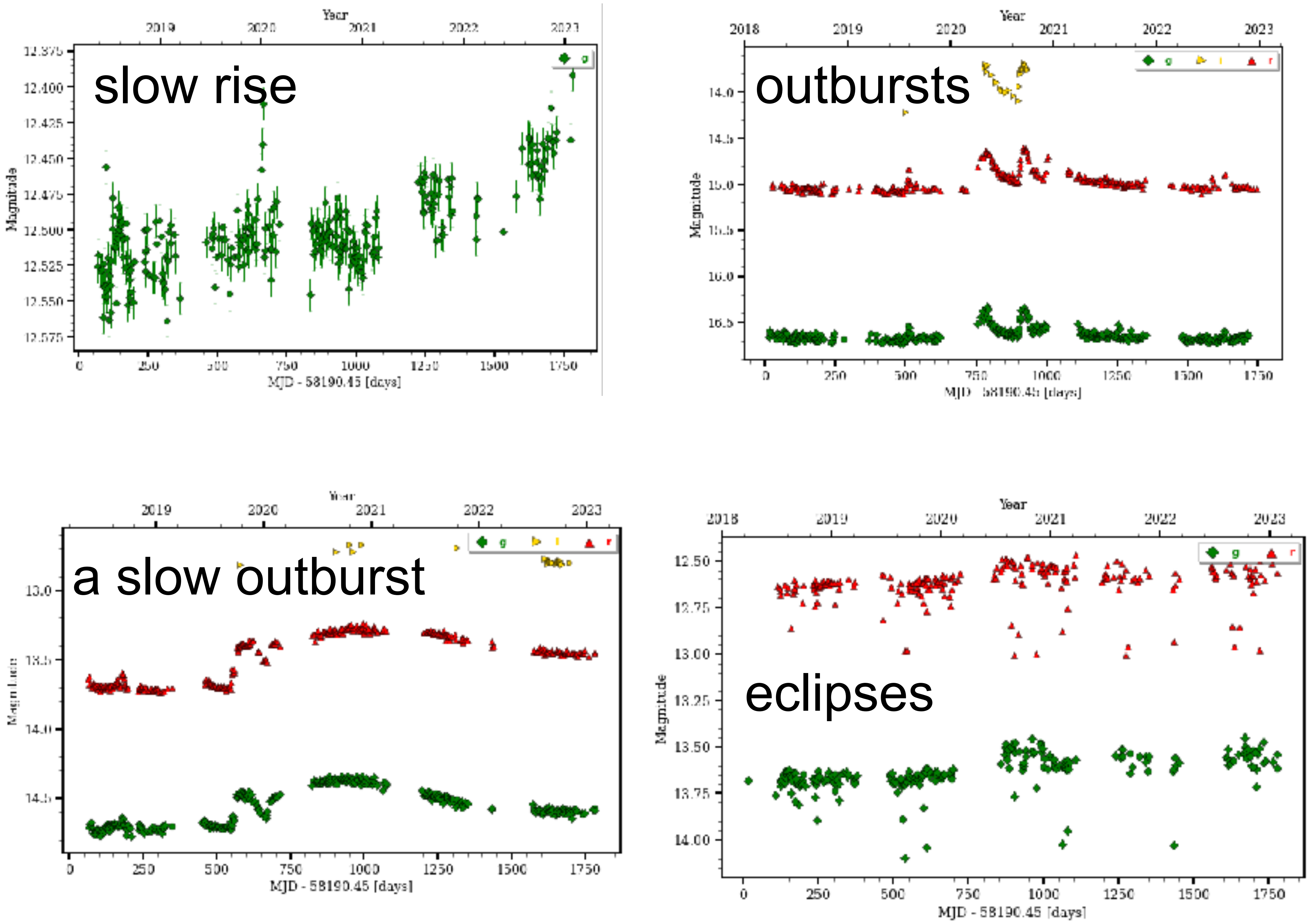
dust emission



Cross-match NEOWISE.

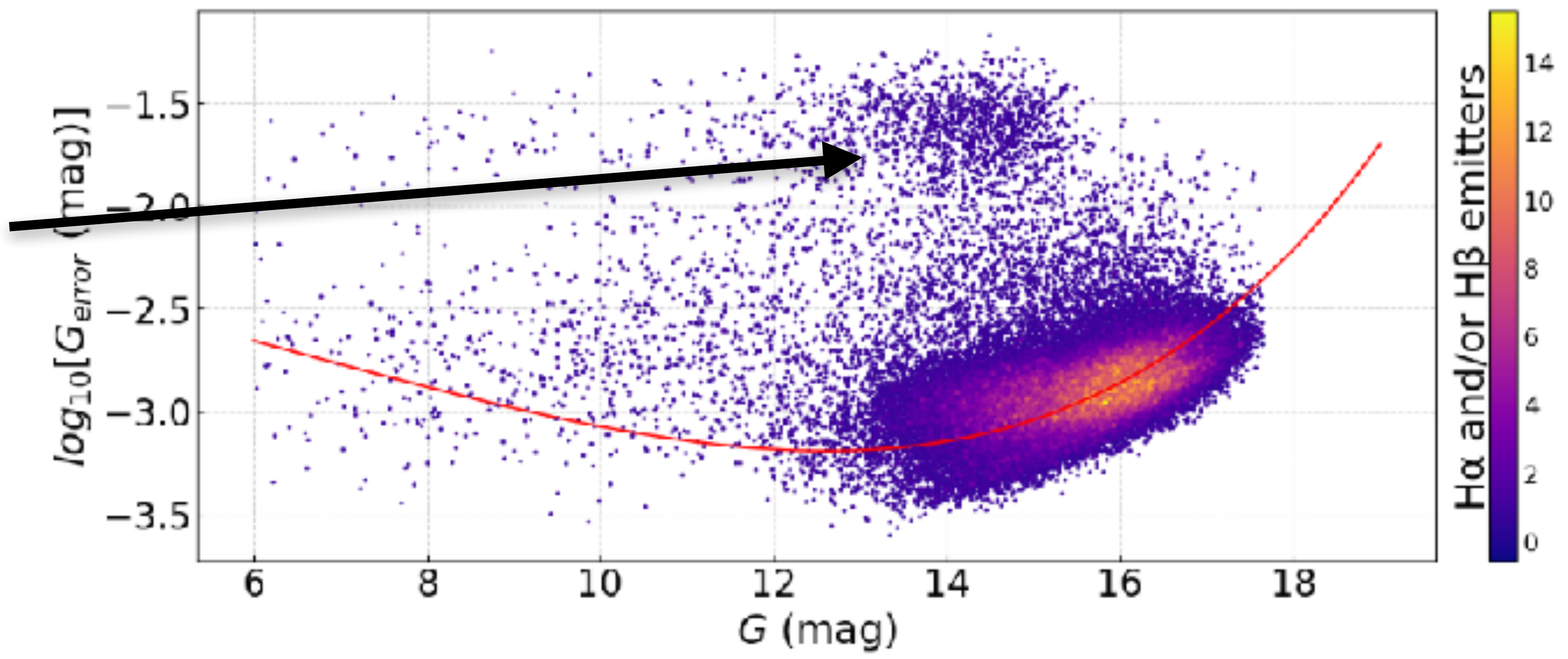
Hα emitters have more dust

g and r-band lightcurves from Zwicky Transient Facility



Variability

Excess photometric error G-mag



Conclusions

- **Common Envelope** is a **critical**, but **poorly understood** phase in binary evolution - each part is studied separately.
  - Observations are needed to connect the pieces.
- Luminous Red Novae (LRNe), as **Common Envelope Transients**, allow us to *directly observe the CE phase* in binary systems
- Gaia's contribution consists in:
  - Better understanding the LRN progenitor systems
  - Combined with time-domain data
    - Detecting the outbursts based on time-domain information
    - Predicting outbursts for LRNe in the MW and beyond.