Proposing

A Search for the Minutes-timescale Period White Dwarf Binaries

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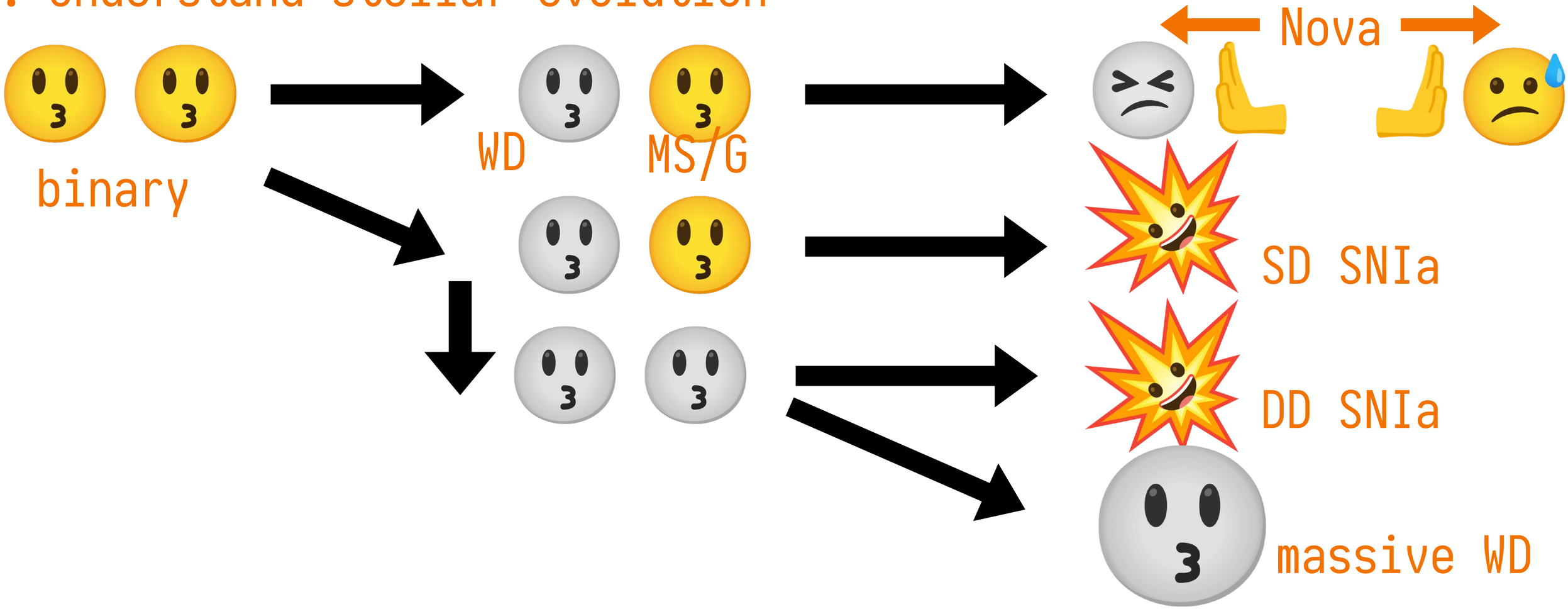
Kiso Schmidt Symposium 2024

1. Close White Dwarf Binary
2. Importance of High Cadence
3. Soft X-ray Candidates

White Dwarf binaries

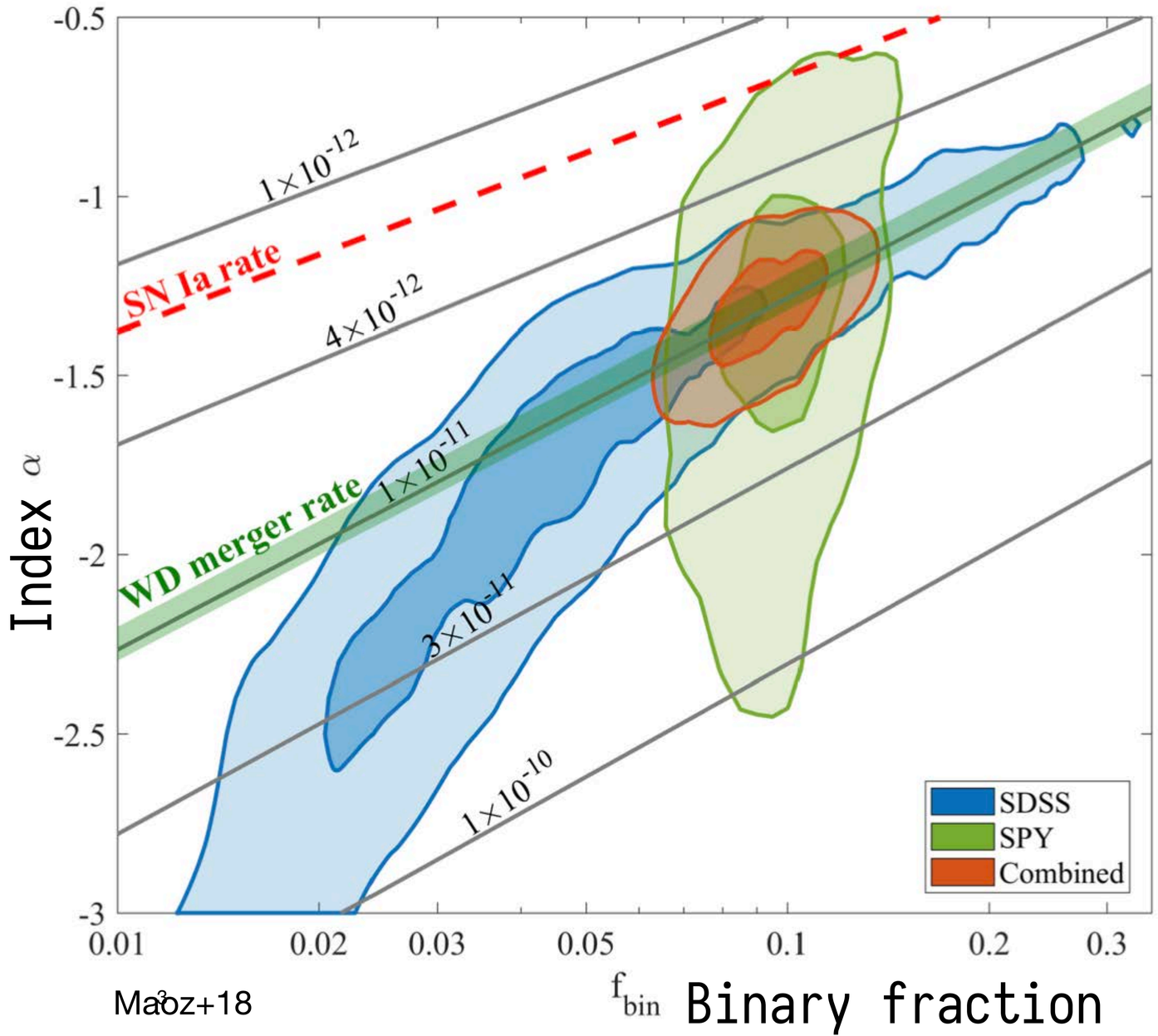
1. Understand stellar evolution



White Dwarf binaries

Separation (x) distribution N:

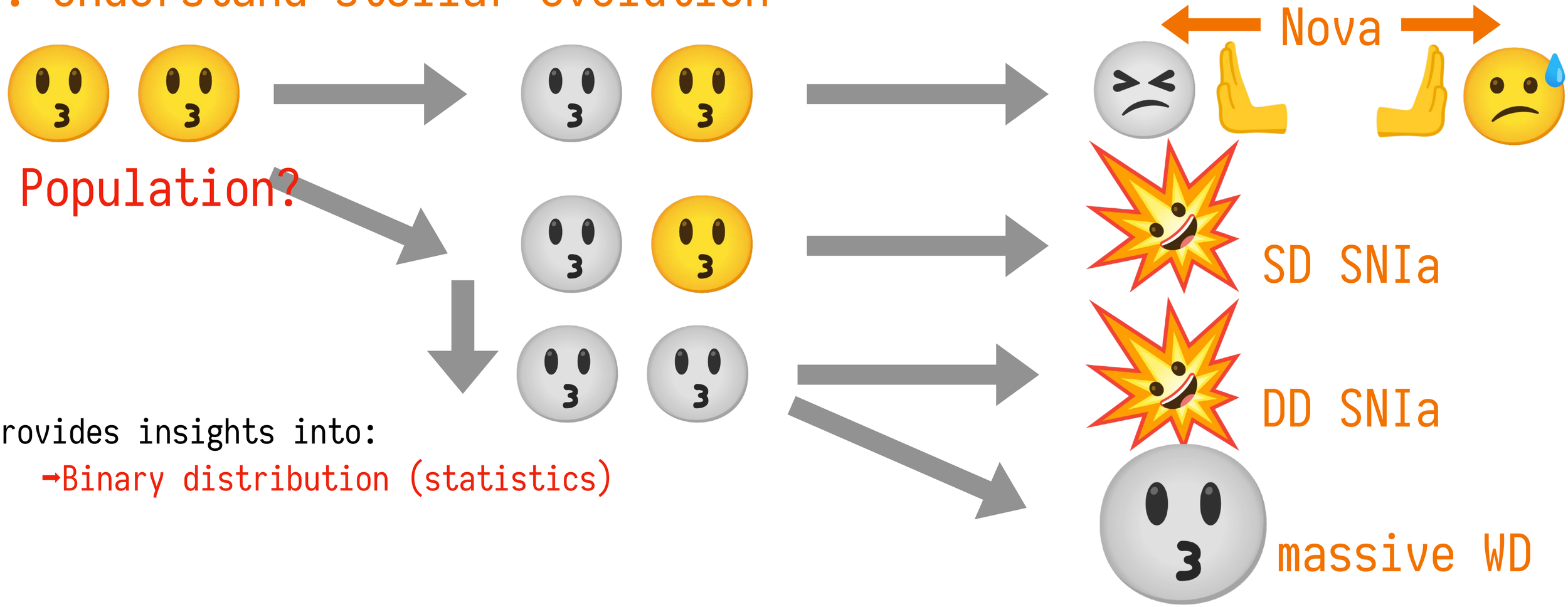
$$N(x) \sim x^{4+\alpha}\left[(1+x^{-4})^{(\alpha+1)/4}-1\right]$$



Maoz+18

White Dwarf binaries

1. Understand stellar evolution

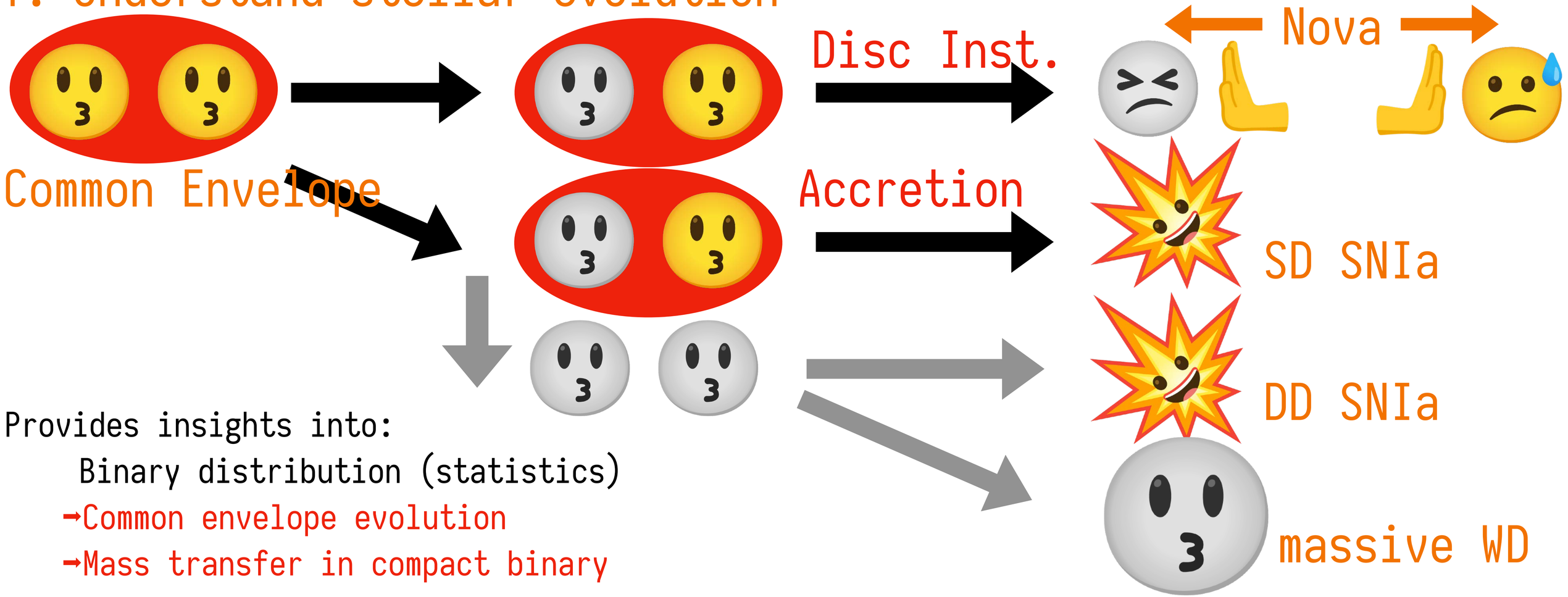


Provides insights into:

➡Binary distribution (statistics)

White Dwarf binaries

1. Understand stellar evolution



Provides insights into:

Binary distribution (statistics)

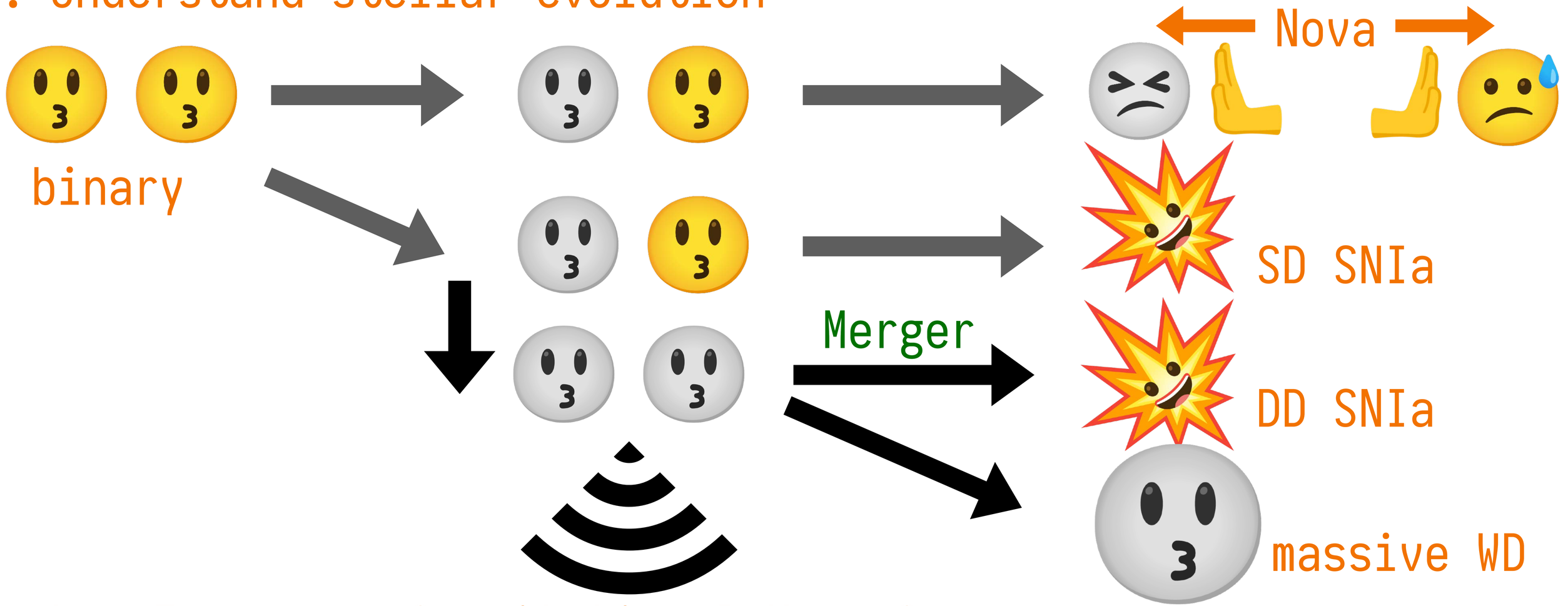
→Common envelope evolution

→Mass transfer in compact binary

Obs via Eclipsing and X-ray radiation

White Dwarf binaries

1. Understand stellar evolution



2. Low-Frequency Gravitational Wave Source

Space-based GW detector (e.g., LISA)

Known short periodic WDB

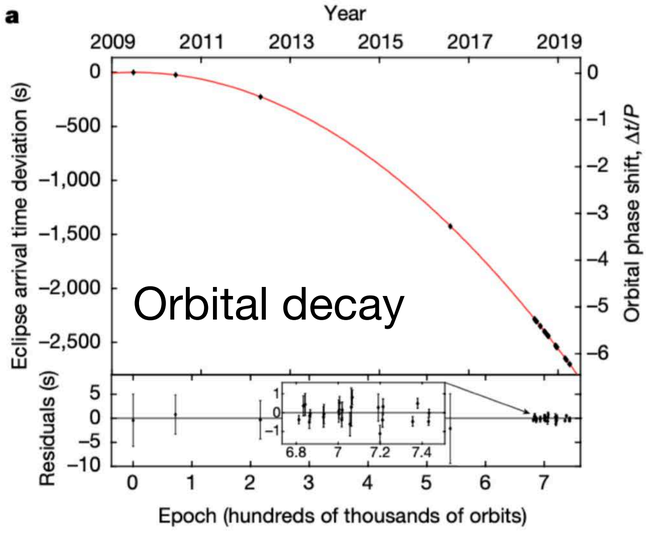
ZTF J1539+5027: Burdge+19

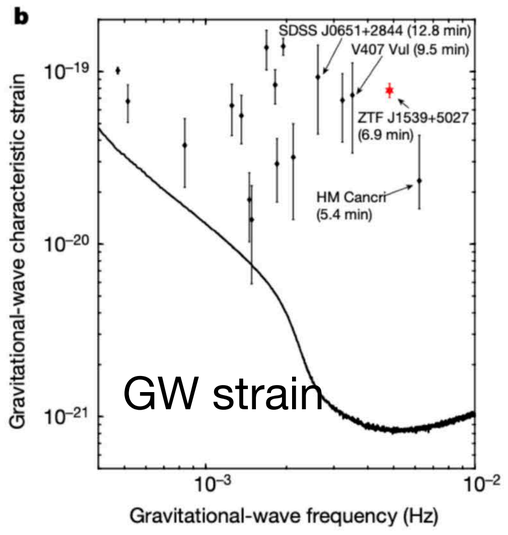
r = 20.5 mag detached WDB

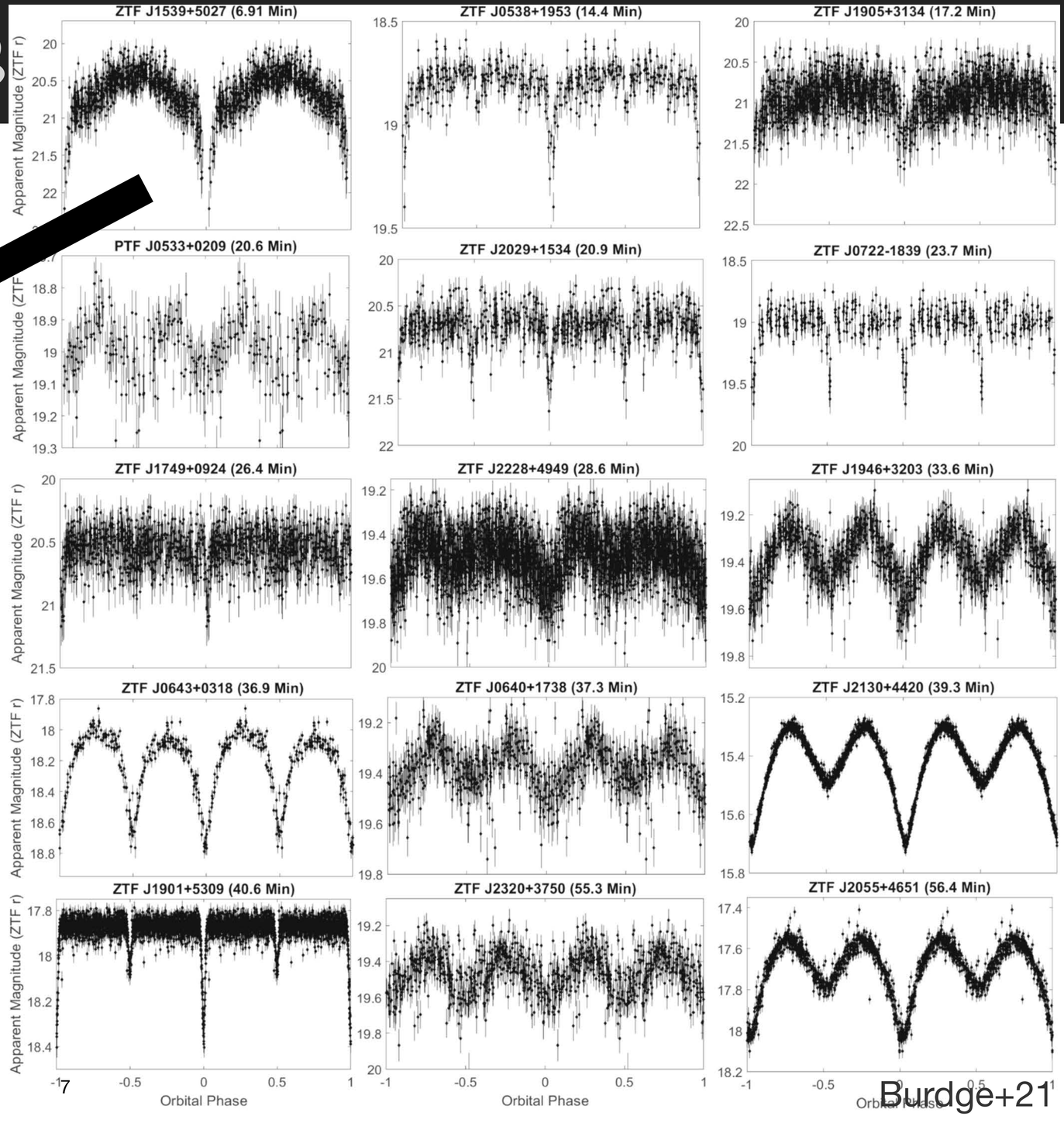
Shortest period (P = 6.91 min)

Found by ZTF all sky survey

Followed by CHIMERA and KPED







Burdge+21

Shorter period?

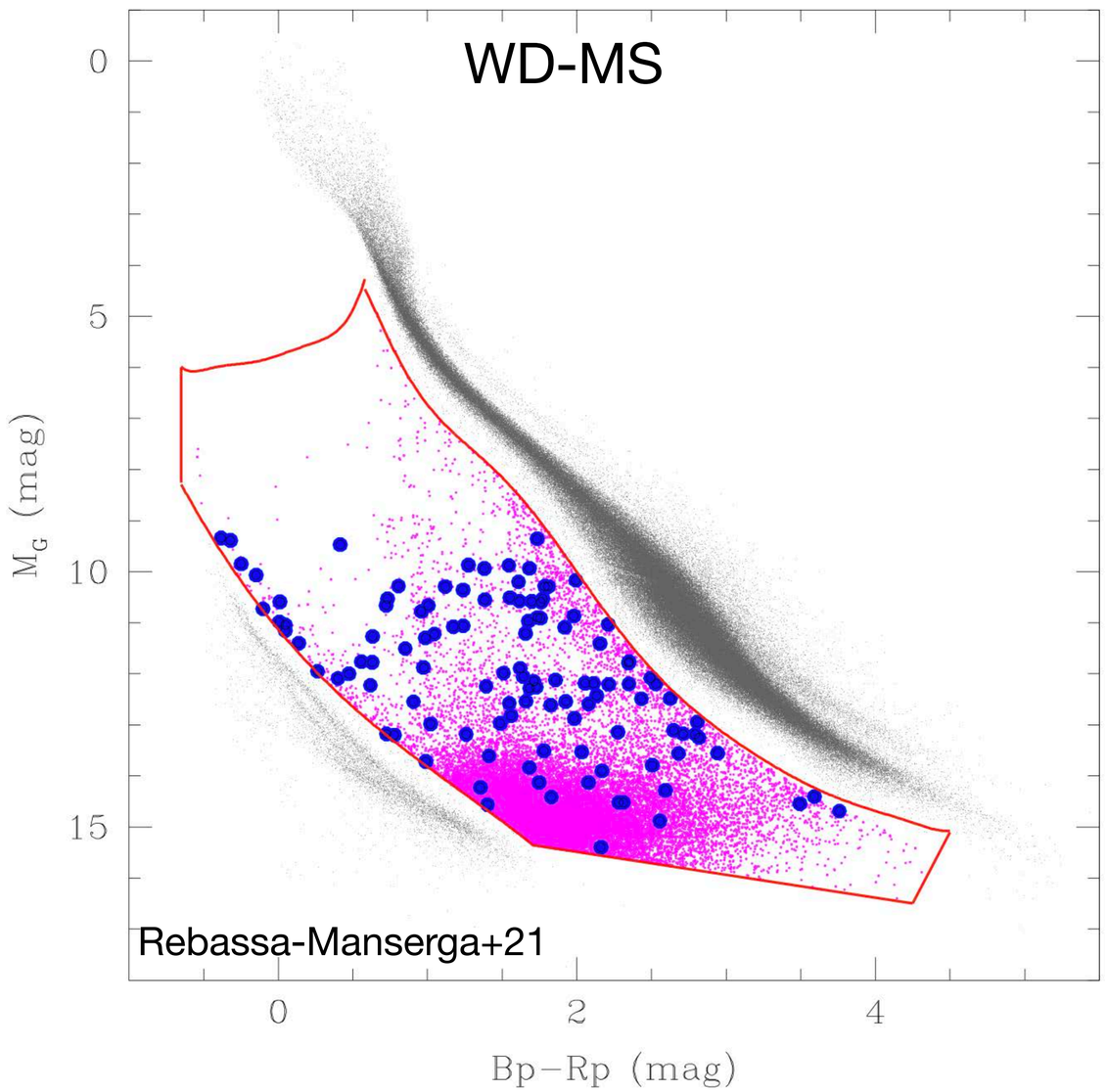
2 min for double (0.6 solMass) WDB:

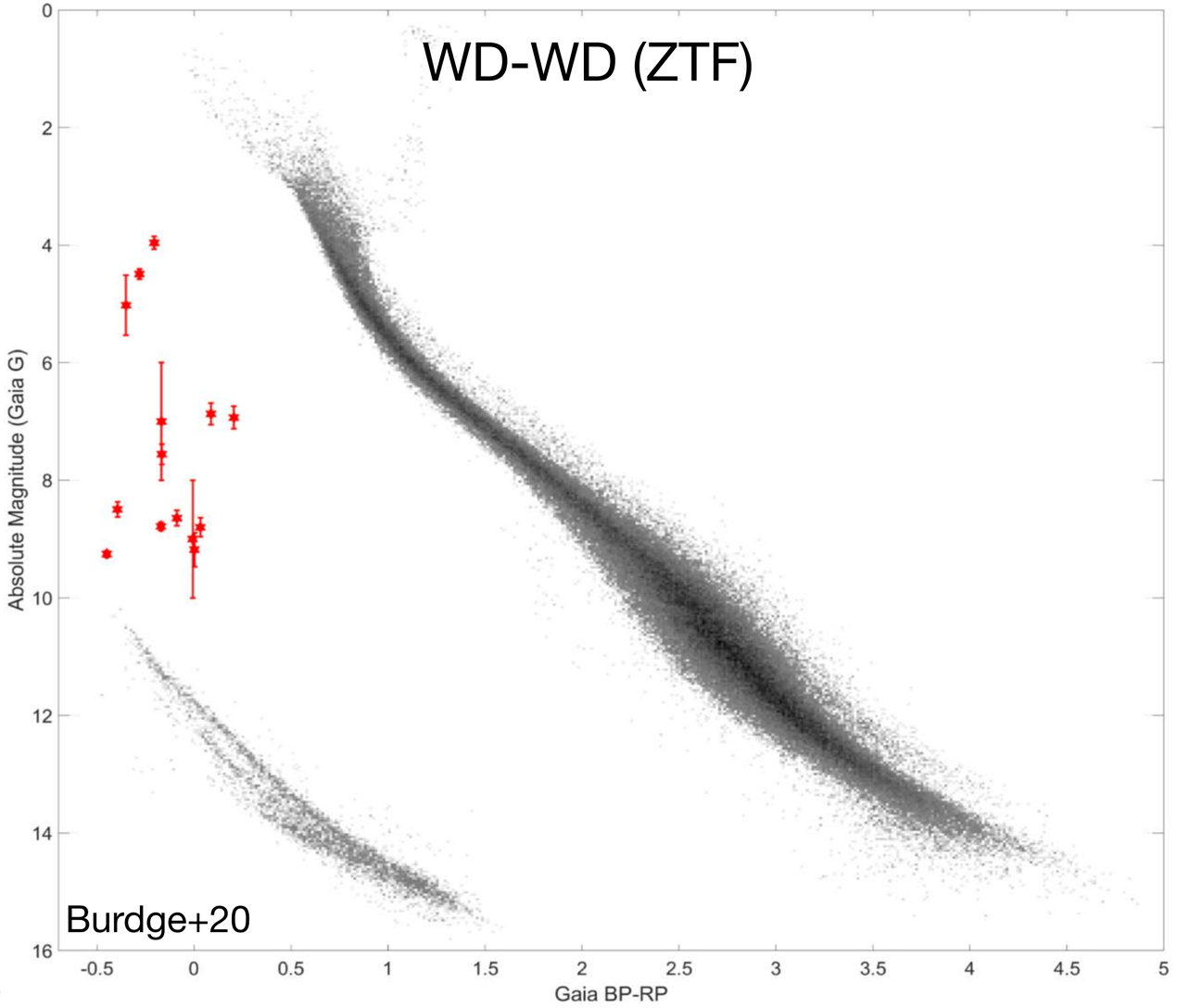
merge in ~3000 yr!

Goals

1. **Shorter (<7 min) periodic WDBs?**

White Dwarf binaries in the H-R Diagram from Gaia





Goals

1. **Shorter (<7 min) periodic WDBs?**
2. **Homogenous rate/distribution studies for compact WDBs?**

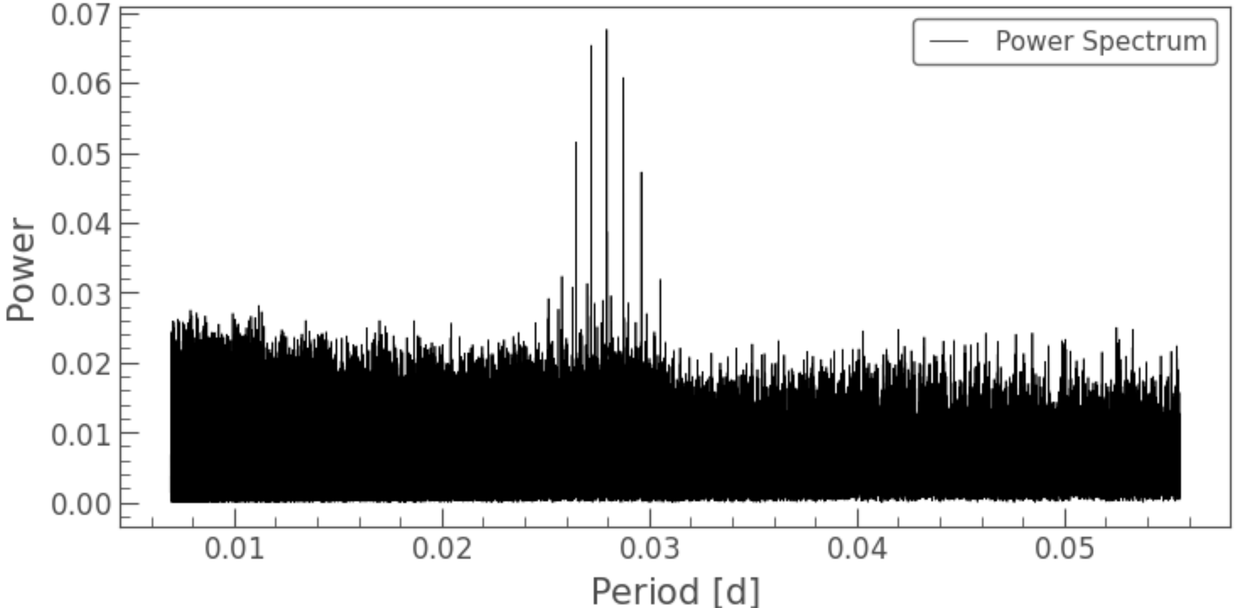
Methods

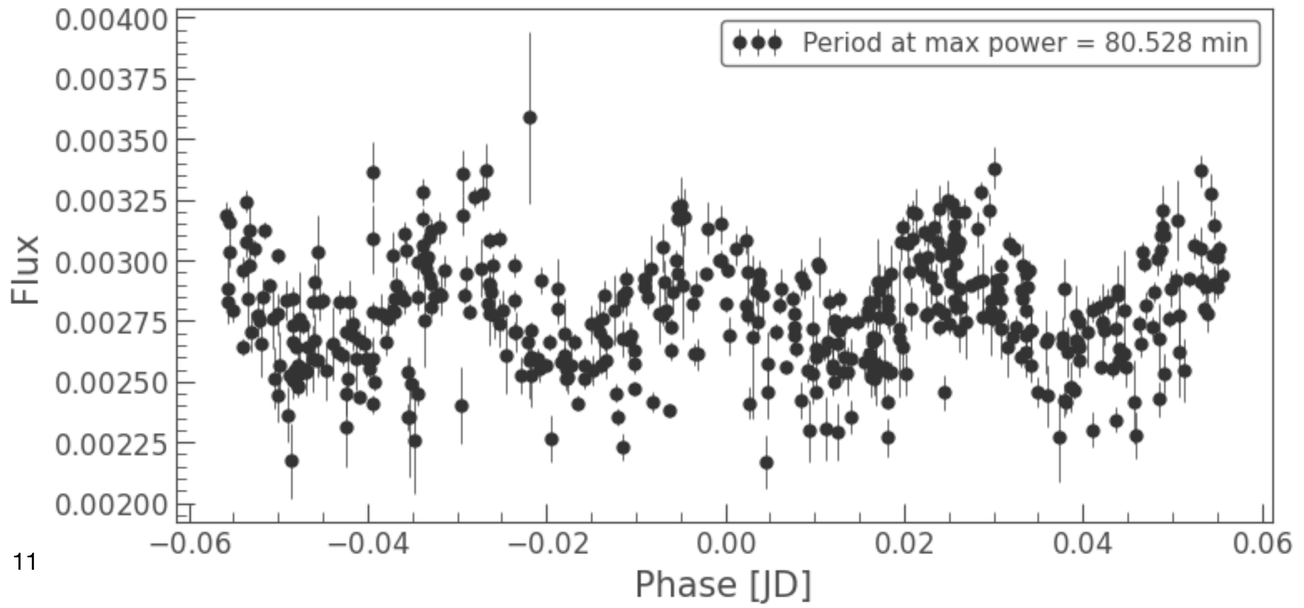
Step 1. Get light curve of the candidate stars

Step 2. Find period (via Lomb-Scargle…)

Step 3. Follow-ups (by Seimei, Gaia DR3…)

Quick Check: Tomo-e data reproduces ZTF-J0451+0104 (P=80.528 min)





Methods

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Where to get data?

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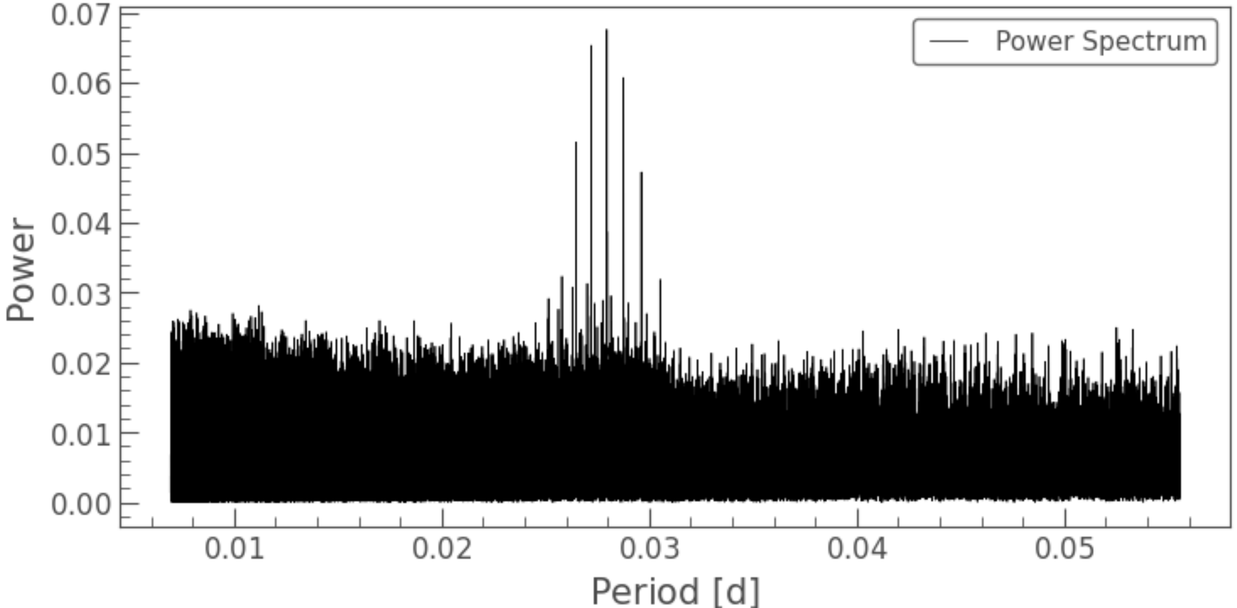
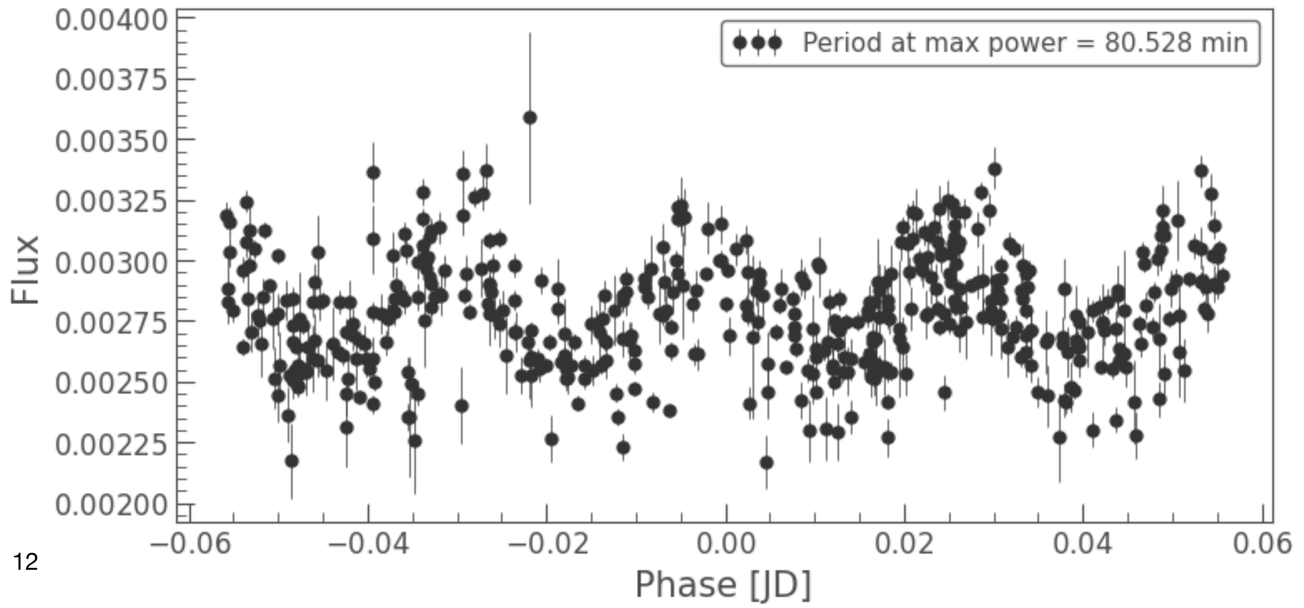




High vs Low Cadence Survey

1. ZTF northern-equatorial sky survey

   Coverage: 25,000 to 30,000 square degrees

   CCD, exposure time ~ 15s

   2-3 nights cadence

   Limiting magnitude: r ~ 20.5 mag

2. Tomo-e high cadence survey

   Coverage: > 5000 square degrees

   CMOS, exposure time (0.5s x 12 frames)

   Hour cadence, 3-5 visits per night

   Limiting magnitude ~ 17.5 mag

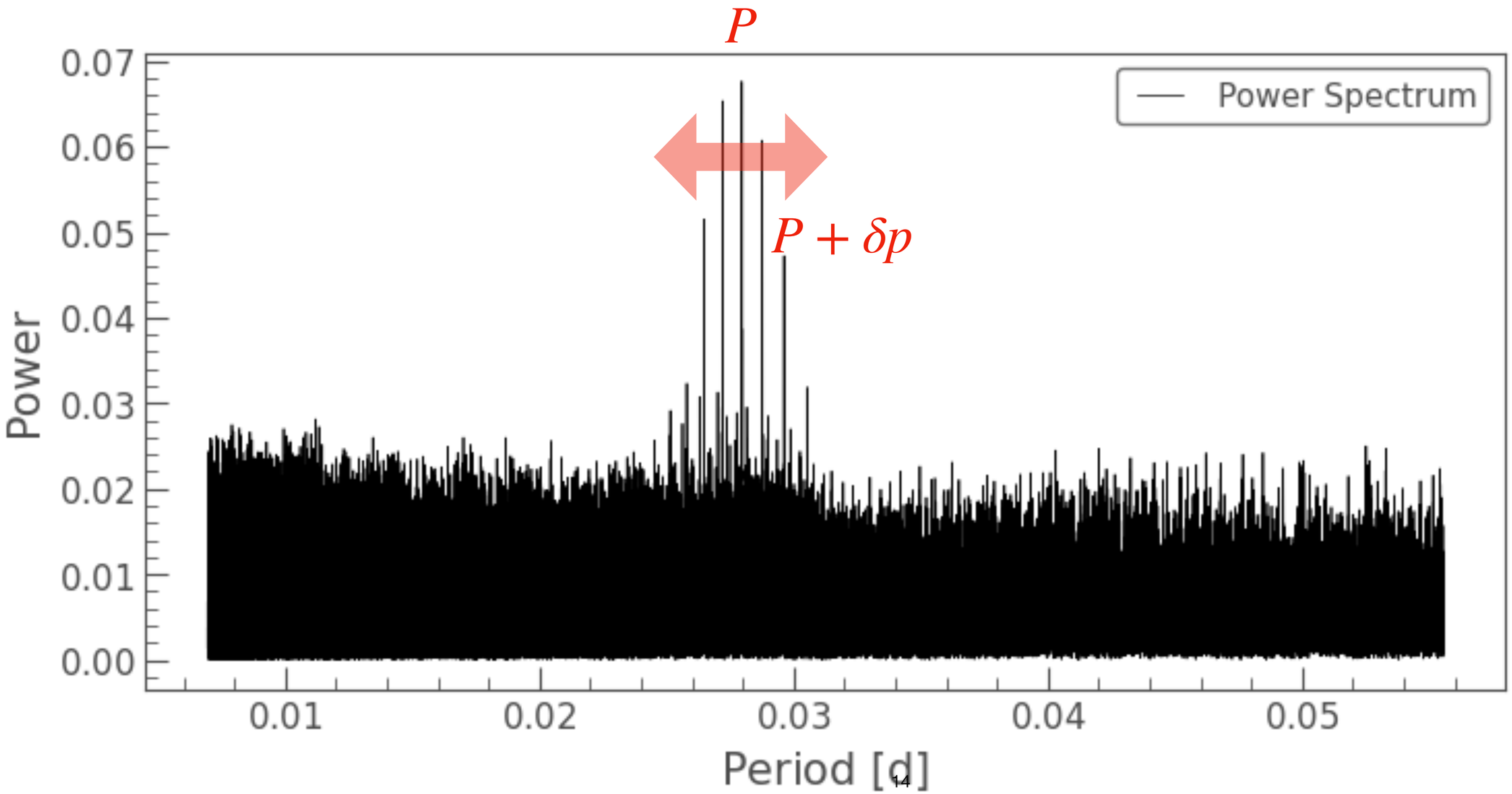
https://tomoe.mtk.ioa.s.u-tokyo.ac.jp/ja/

https://irsa.ipac.caltech.edu/data/ZTF/docs/releases/ztf_release_notes_latest

High vs Low Cadence Survey

Where to get data?

Consider period finding uncertainty!



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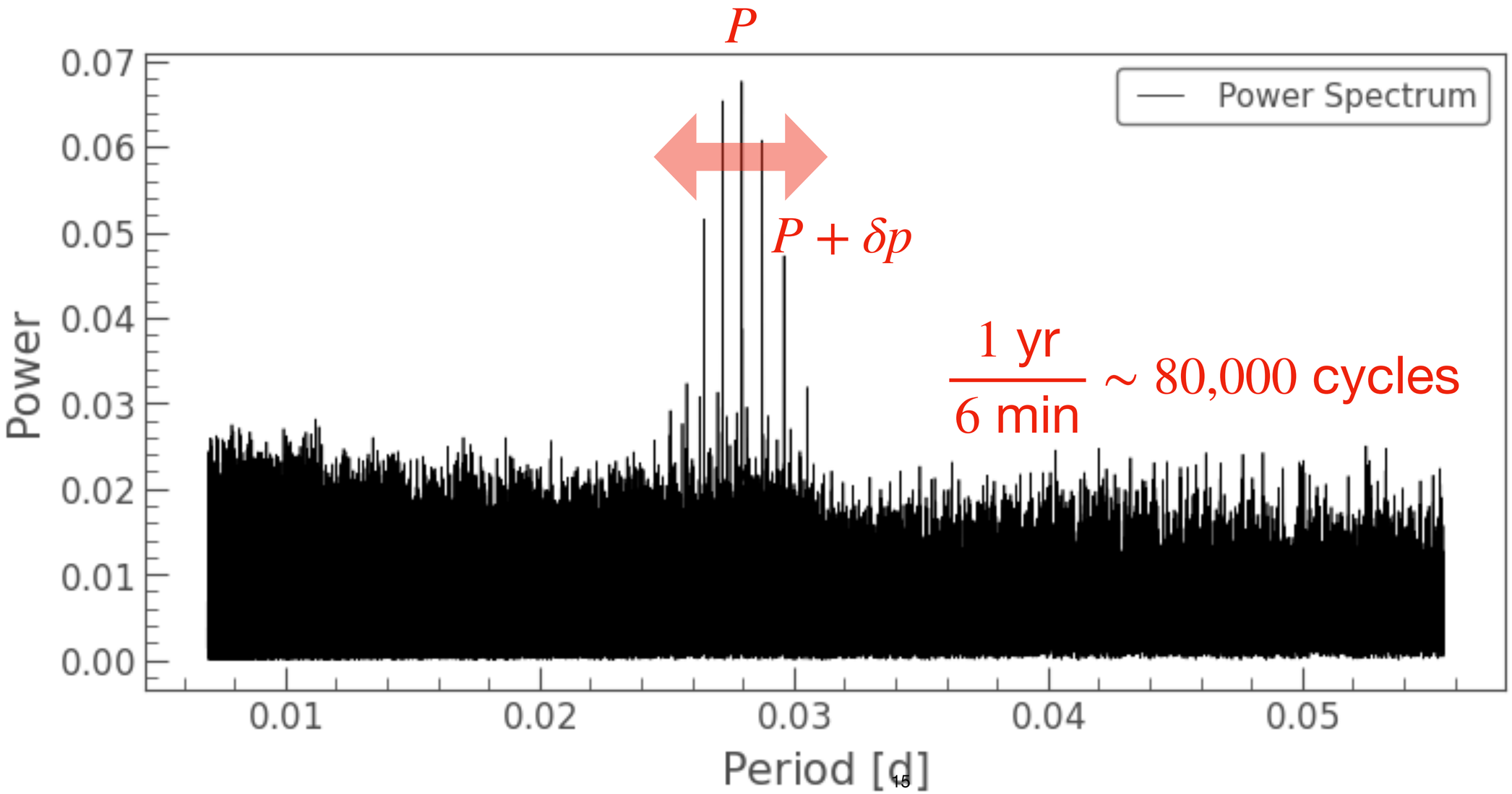


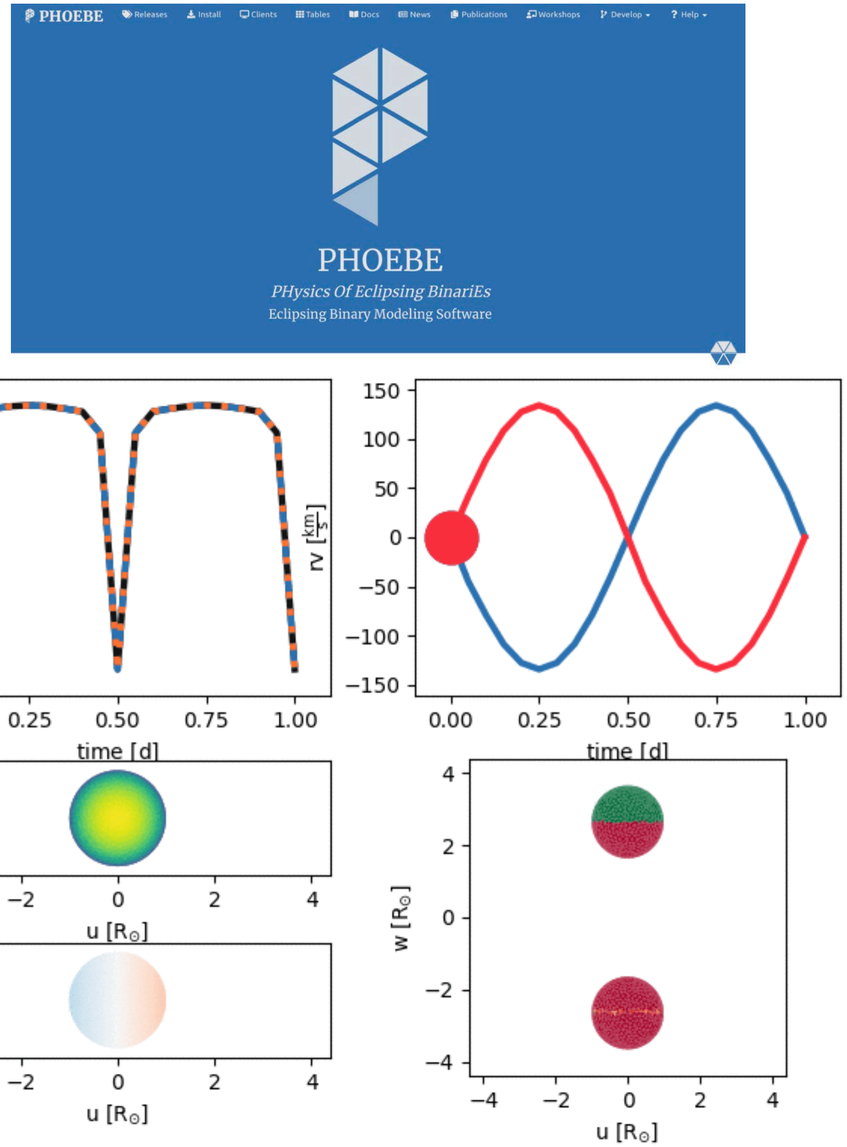
High vs Low Cadence Survey:Simulations

Settings:

q = m1/m2 = 0.8
Period = 6 min
Semi-axis-major = 1.2 SolRad
R1, R2 = 0.01 SolRad
m1 = 0.74 solMass
m2 = 0.59 solMass

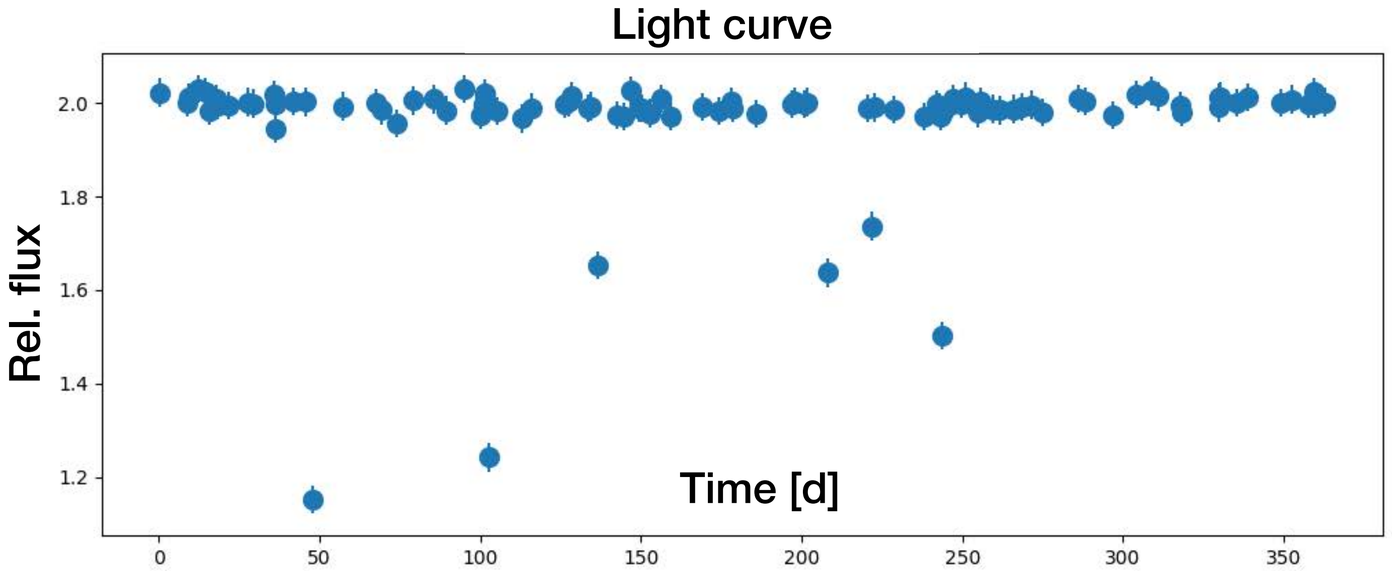
T1, T2 = 10,000 K

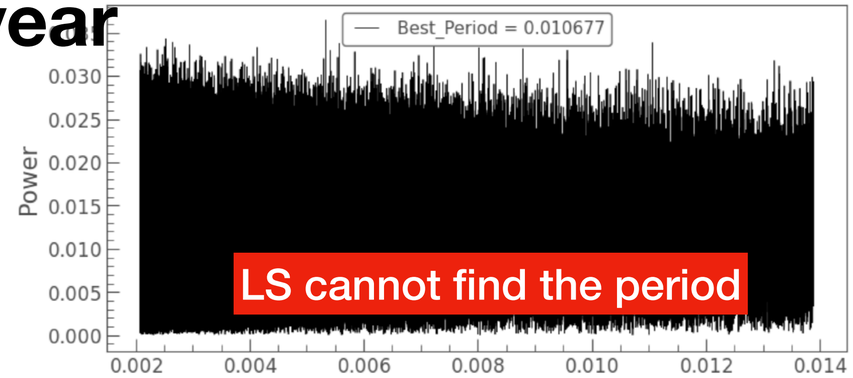
Inclination = 90 deg
Eccentricity = 0



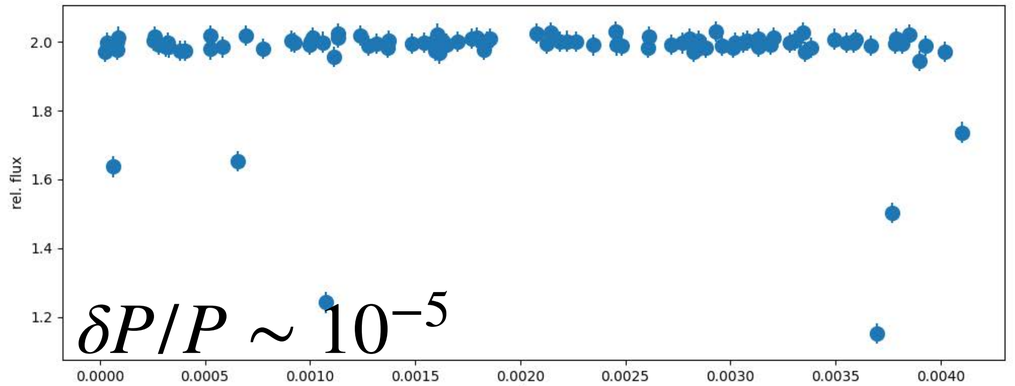
High vs Low Cadence Survey:Simulations

Case 1, uneven sampling, 100 detections from 1 year

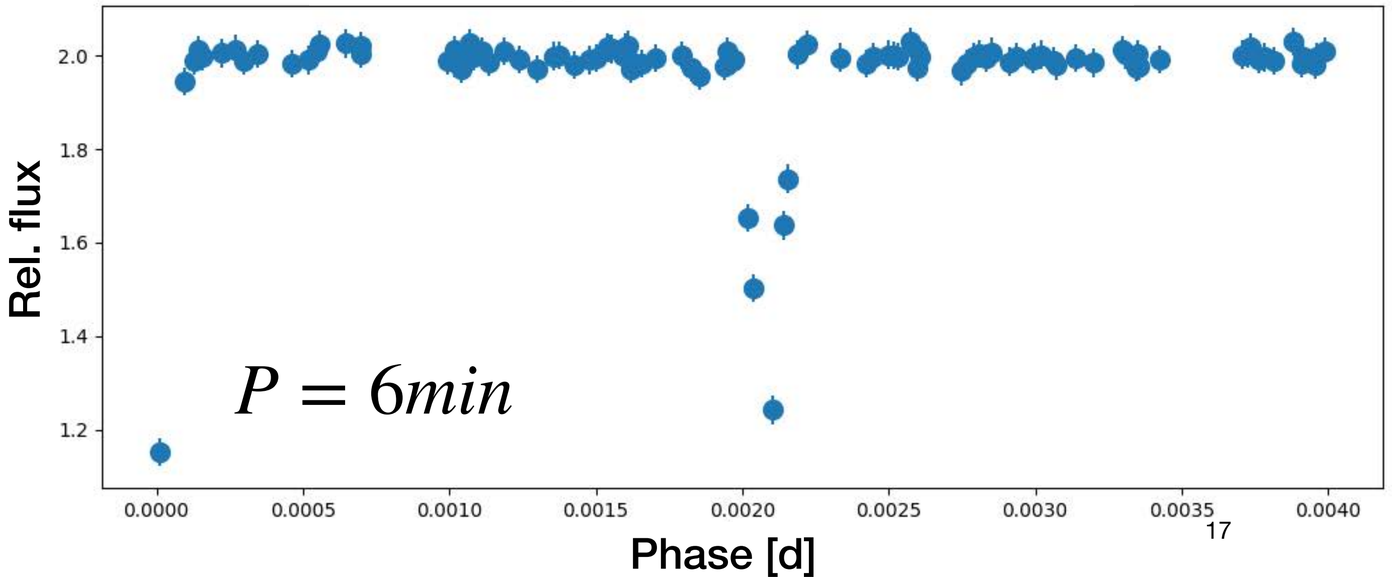




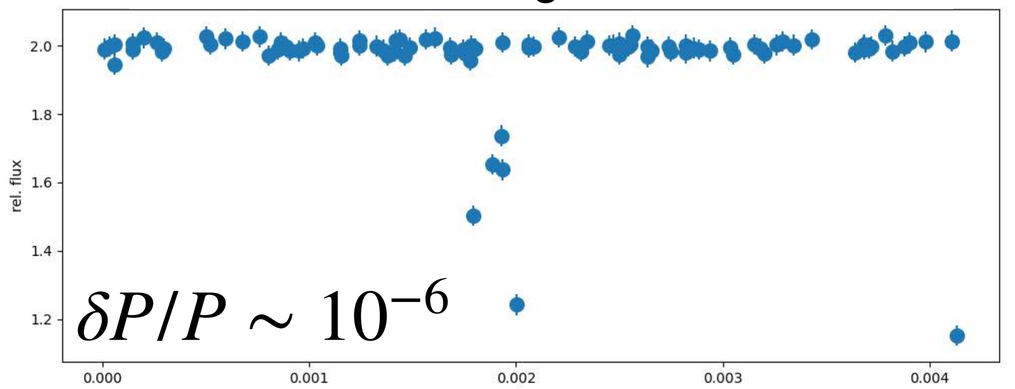
Folded light curve



Folded light curve at TRUE period



Folded light curve



High vs Low Cadence Survey:Simulations

Annual Orbital Decay

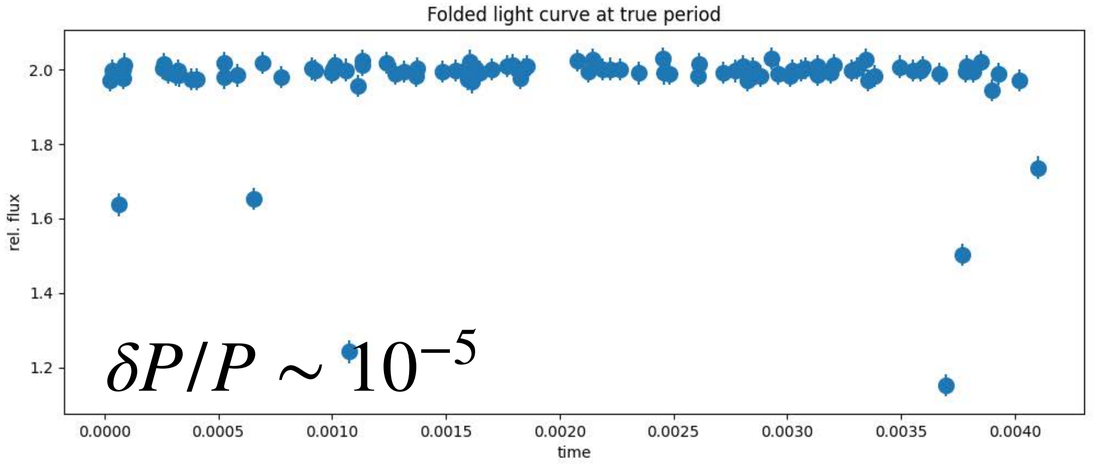
$$\frac{dP}{dt} = -\frac{192\pi}{5}\frac{m_1 m_2}{(m_1+m_2)^2}\left(\frac{2\pi G(m_1+m_2)}{c^3 P}\right)^{5/3}$$

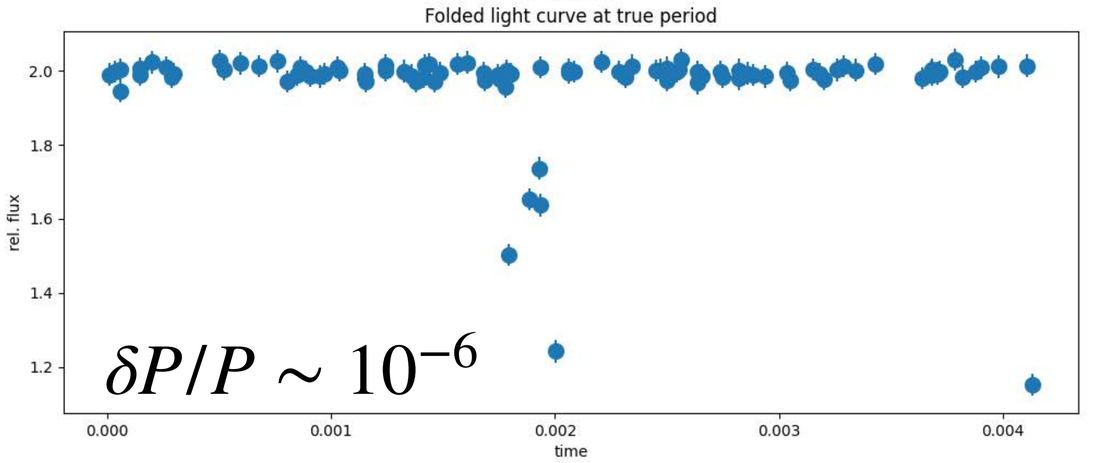
m1, m2 = 0.6 solMass

If P=6 min
$\dot{P} \sim 5 \times 10^{-6} P$ per year

P=3 min
$\dot{P} \sim -4 \times 10^{-5} P$ per year!

Case 1, 100 detections in 1 yr

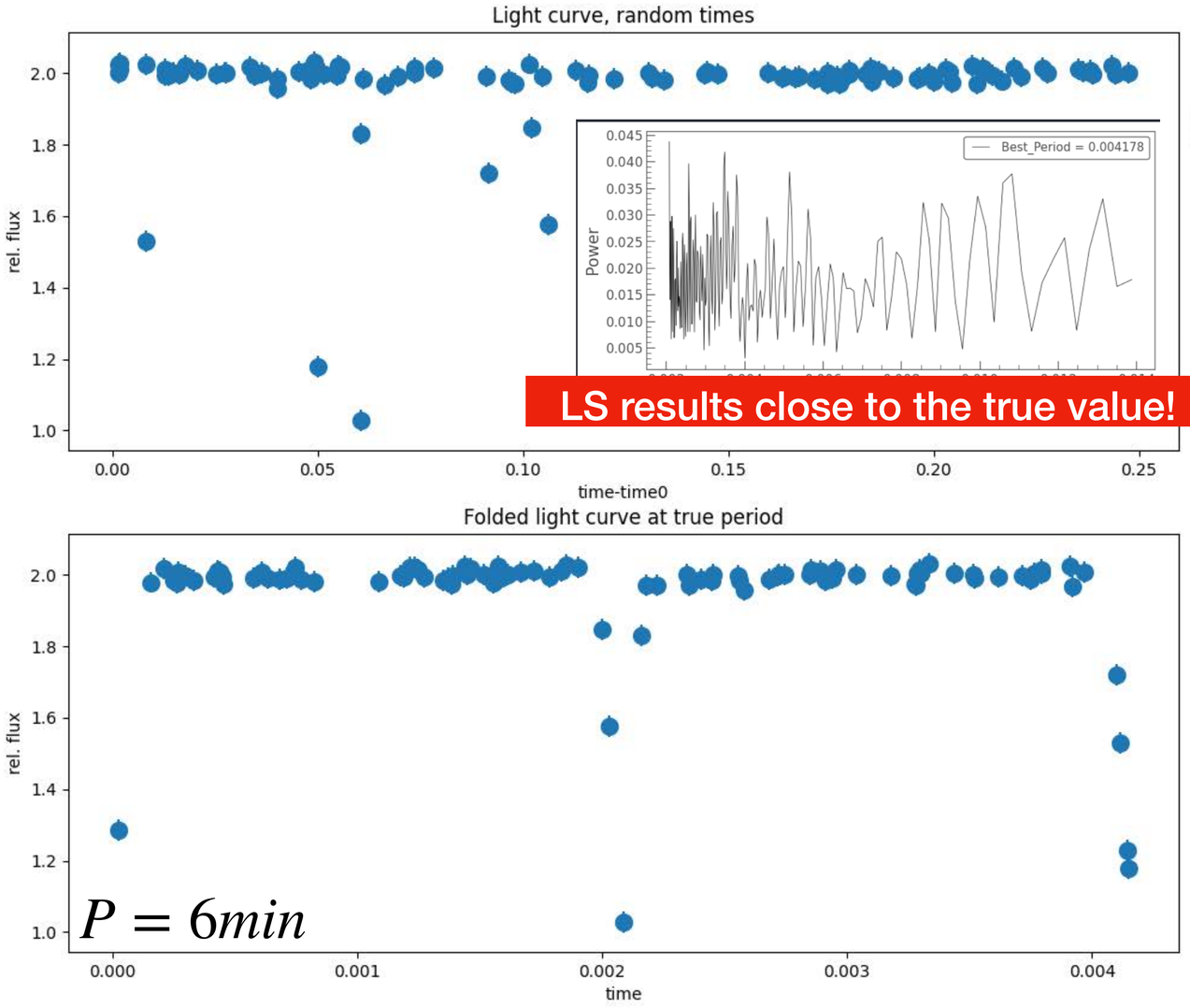




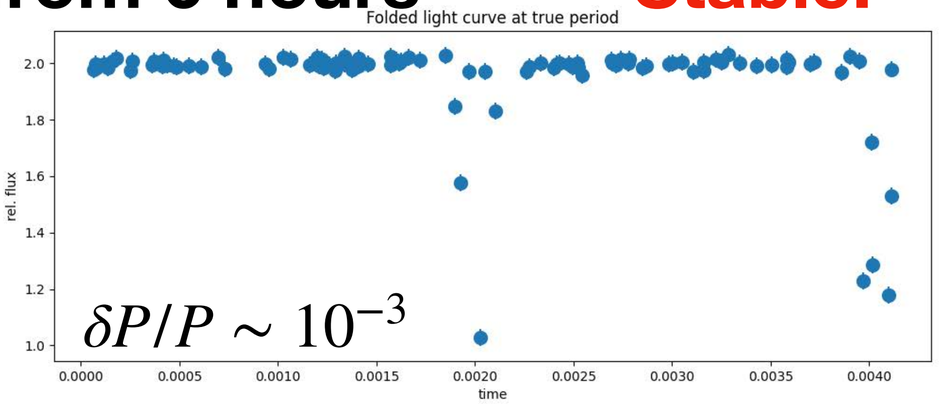
High vs Low Cadence Survey:Simulations

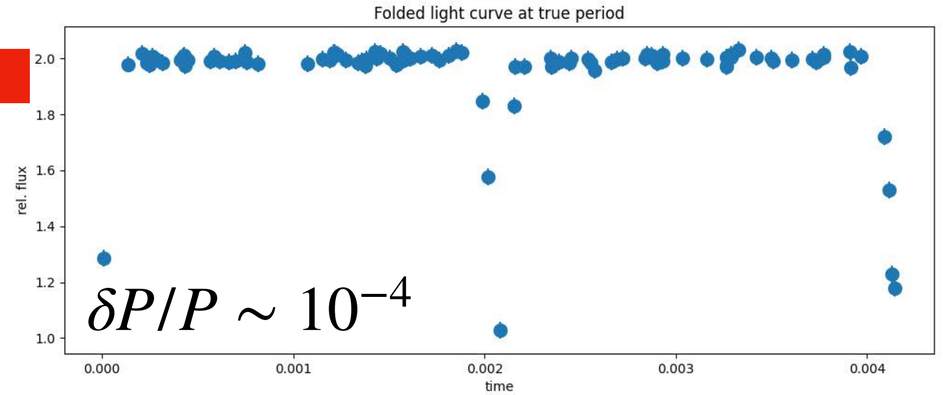
Case 2. uneven sampling, 100 detections from 6 hours

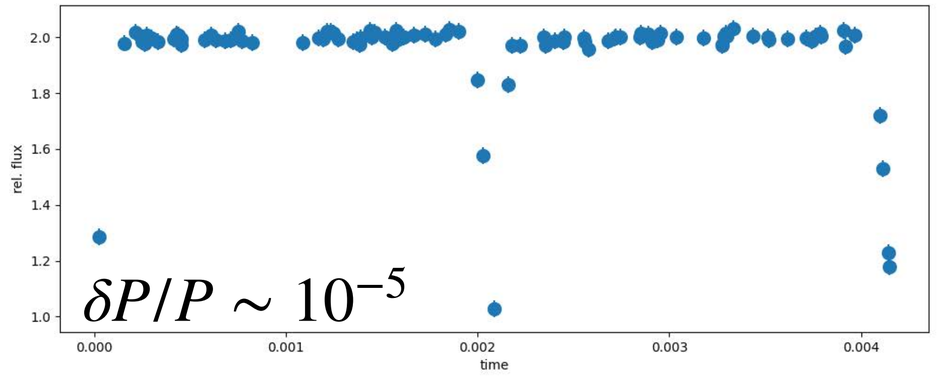
Stable!



LS results close to the true value!







High vs Low Cadence Survey

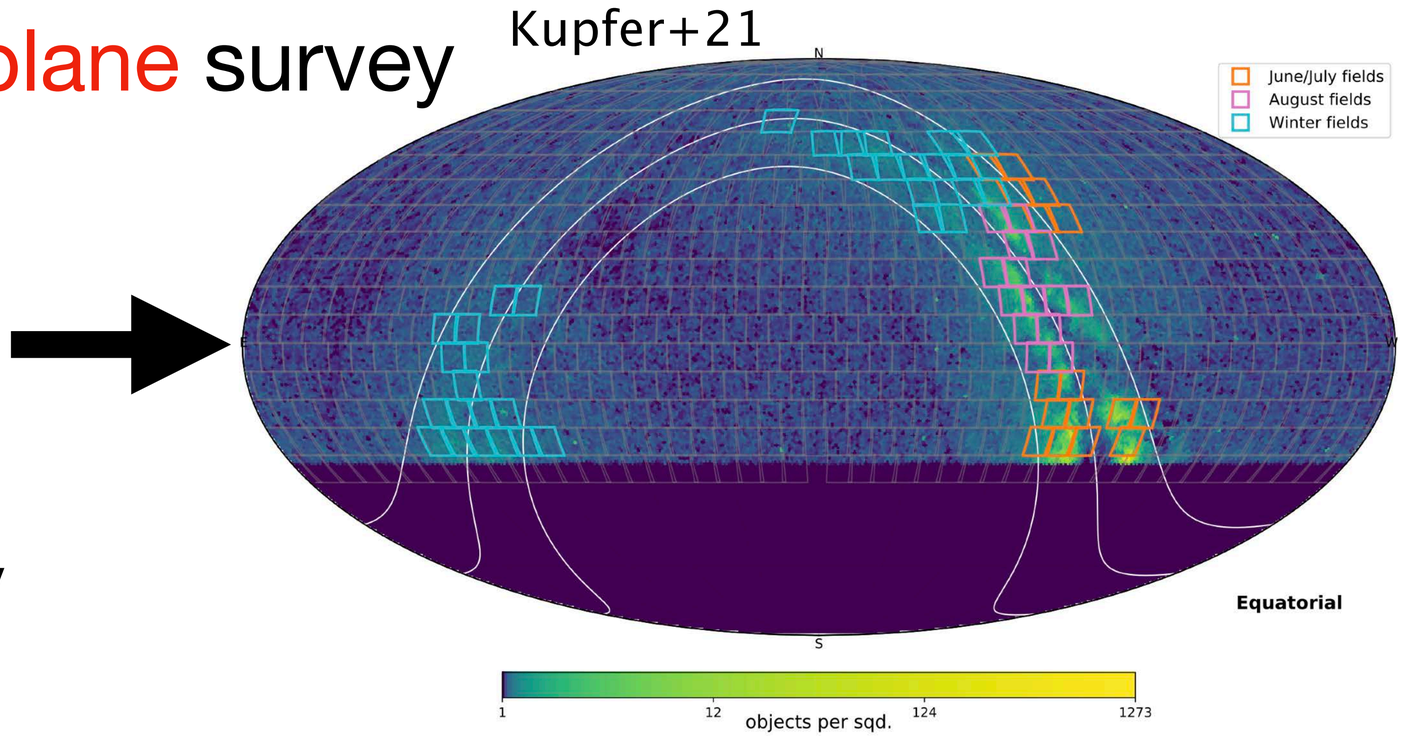
1. ZTF high cadence galactic plane survey

   Coverage: ~ 3000 square degrees

   CCD, exposure time ~ 15s

   40s cadence

   Limiting magnitude: r ~ 20.5 mag



2. Tomoe high cadence survey

   Coverage: > 5000 square degrees

   CMOS, exposure time (0.5s x 12 frames)

   Hour cadence, 3-5 visits per night

   Limiting magnitude ~ 17.5 mag

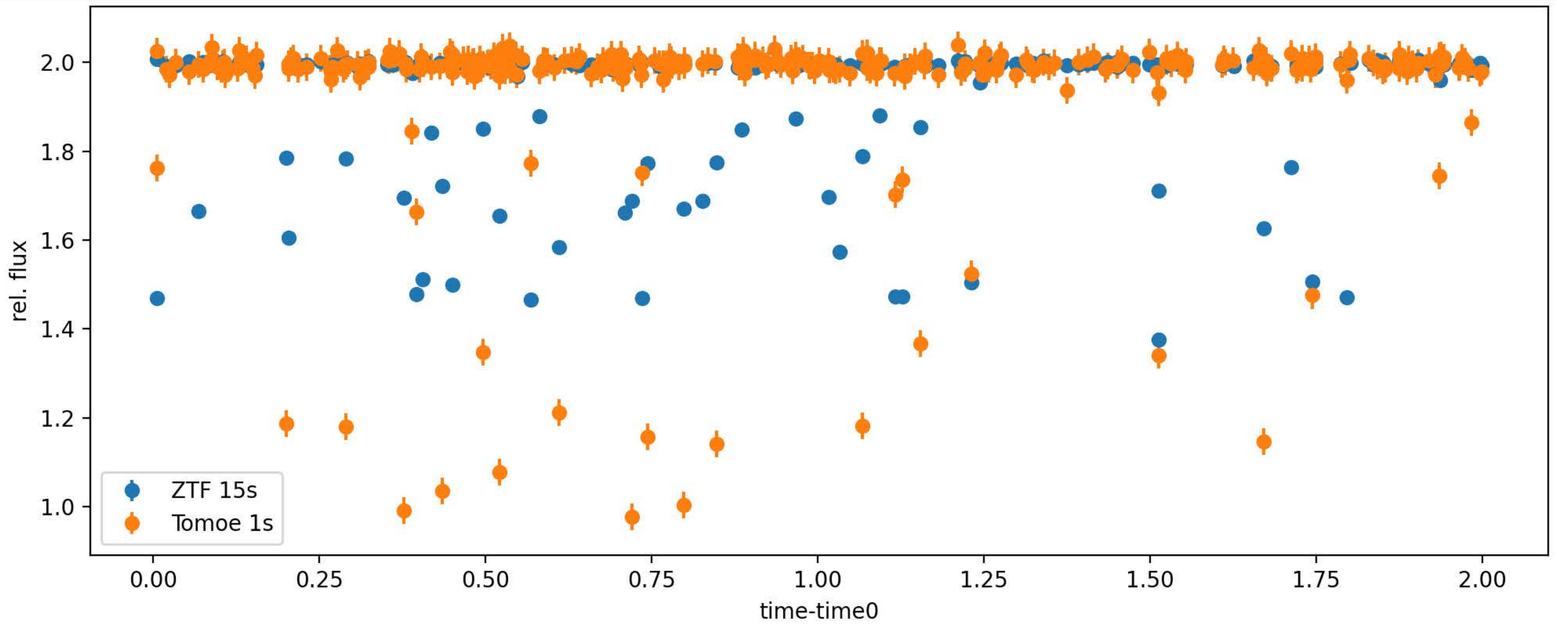
Close to the galactic plane?

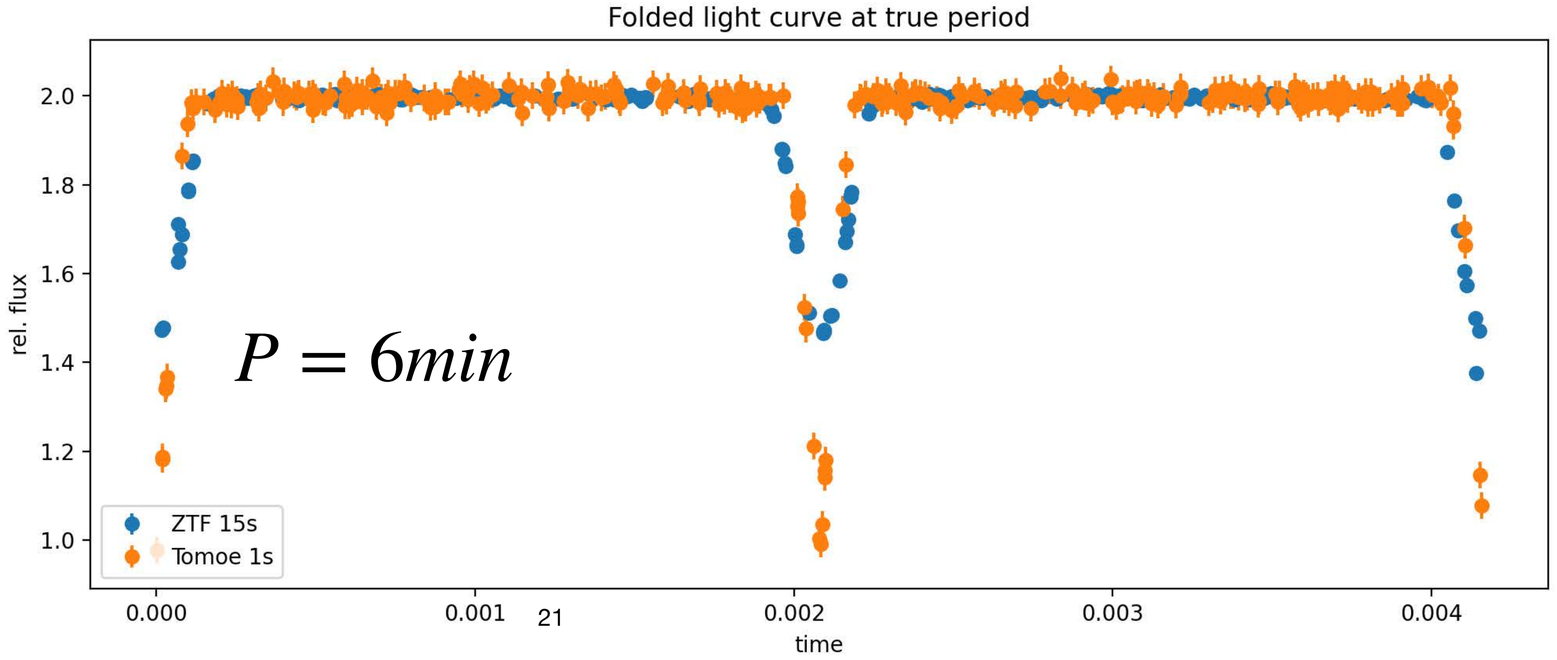
✓Retrieve half of the known short period candidates

✓Short periodic hot subdwarf pulsations

- No shorter periodic white dwarf binaries found

Exposure time?





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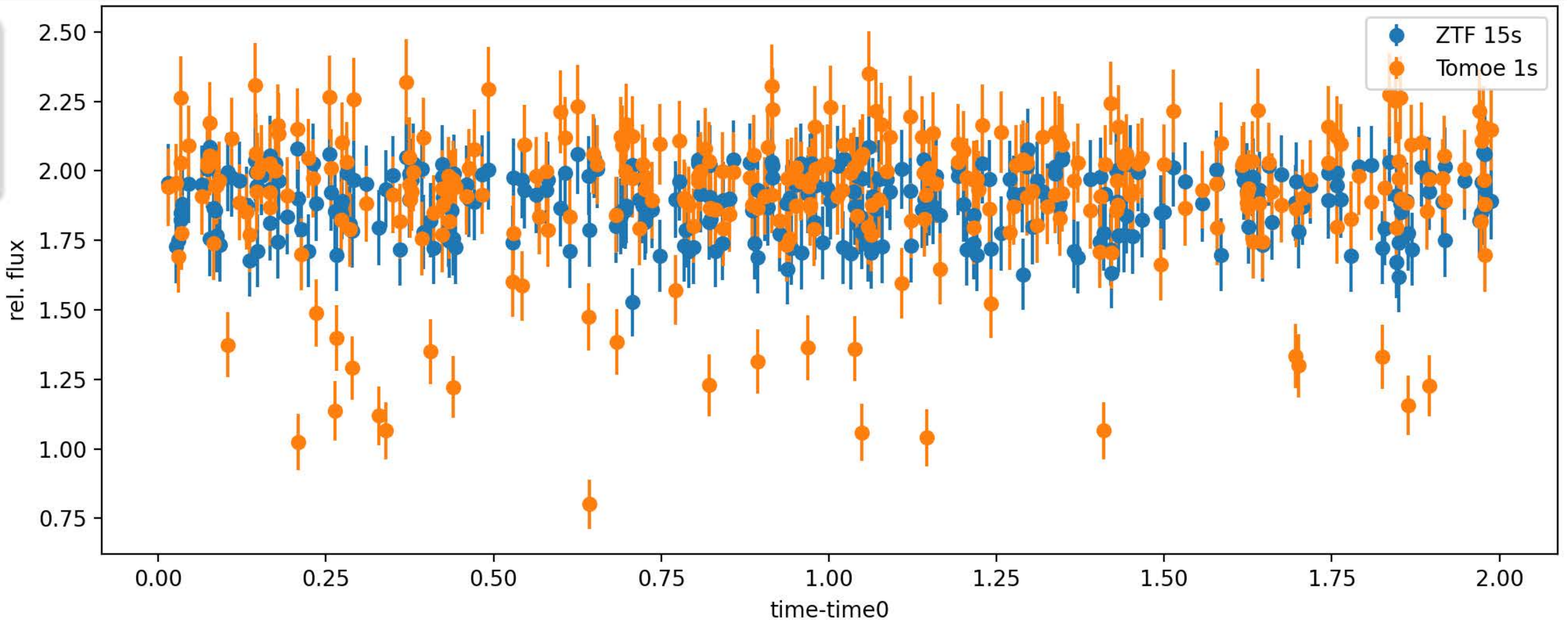
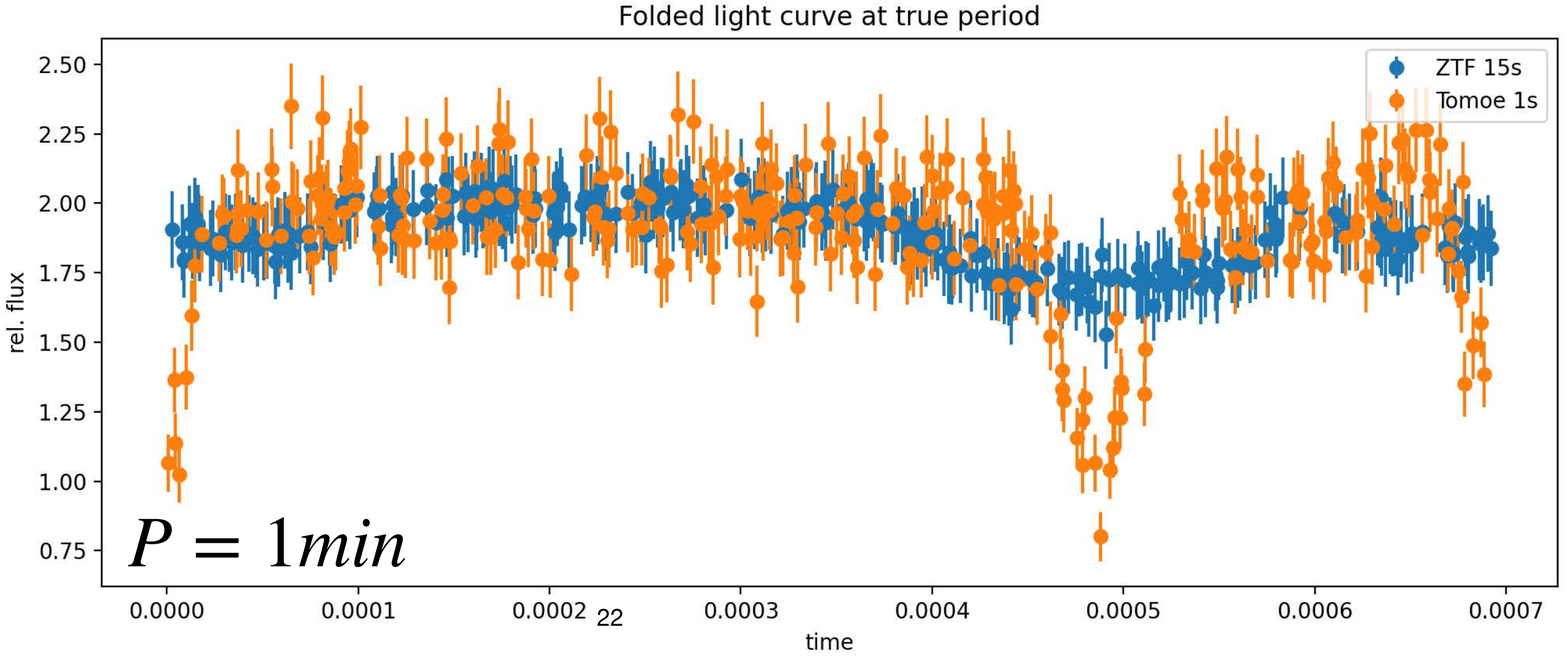
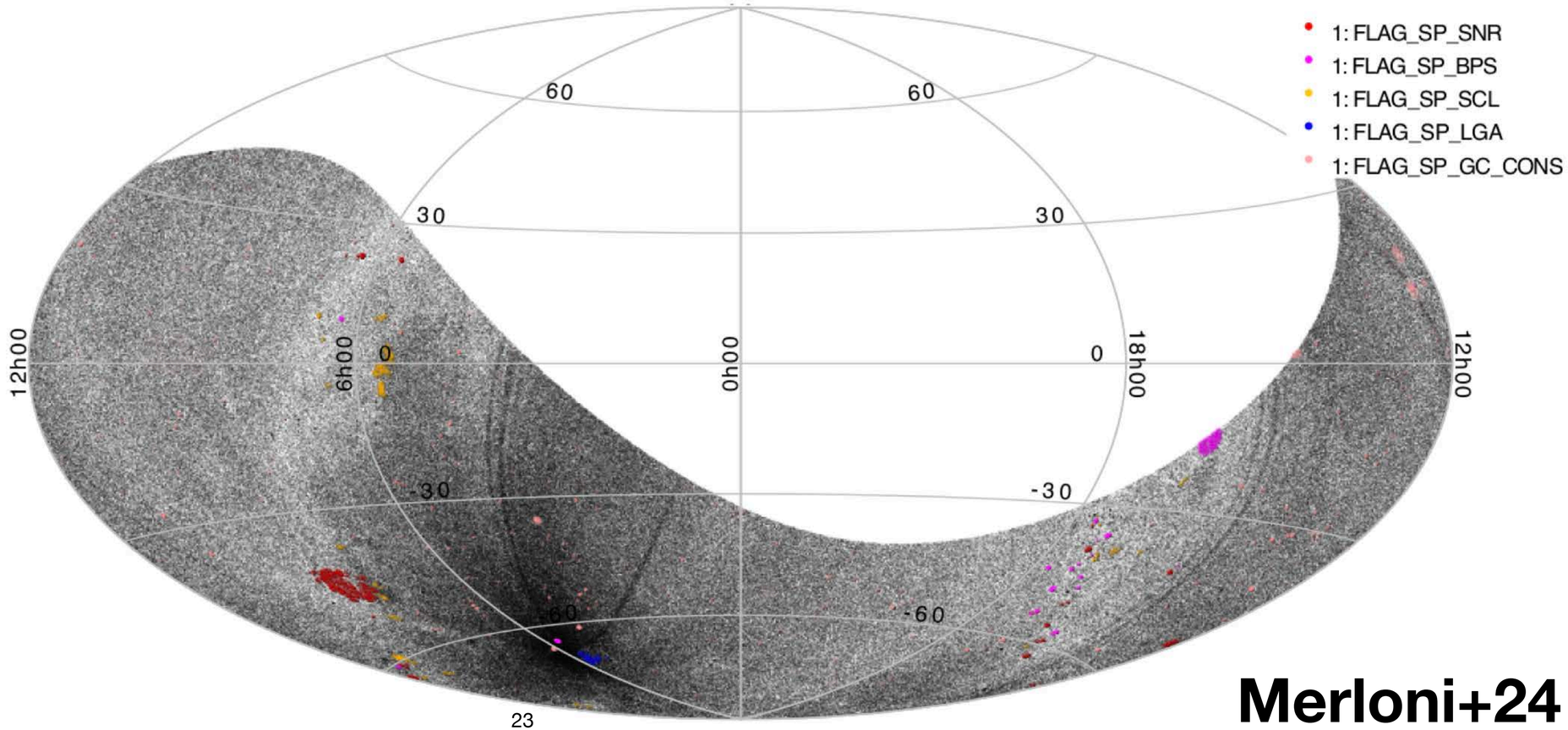




Any Candidates?

1. **Variables Catalog in Tomo-e**
2. **Soft X-ray catalog (by eRosita)**



Merloni+24

https://www.mpe.mpg.de/eROSITA

Soft X-ray candidates

SRG/eRosita (Merloni+24)

Soft x-ray sources

Point source catalog

Dec > -25

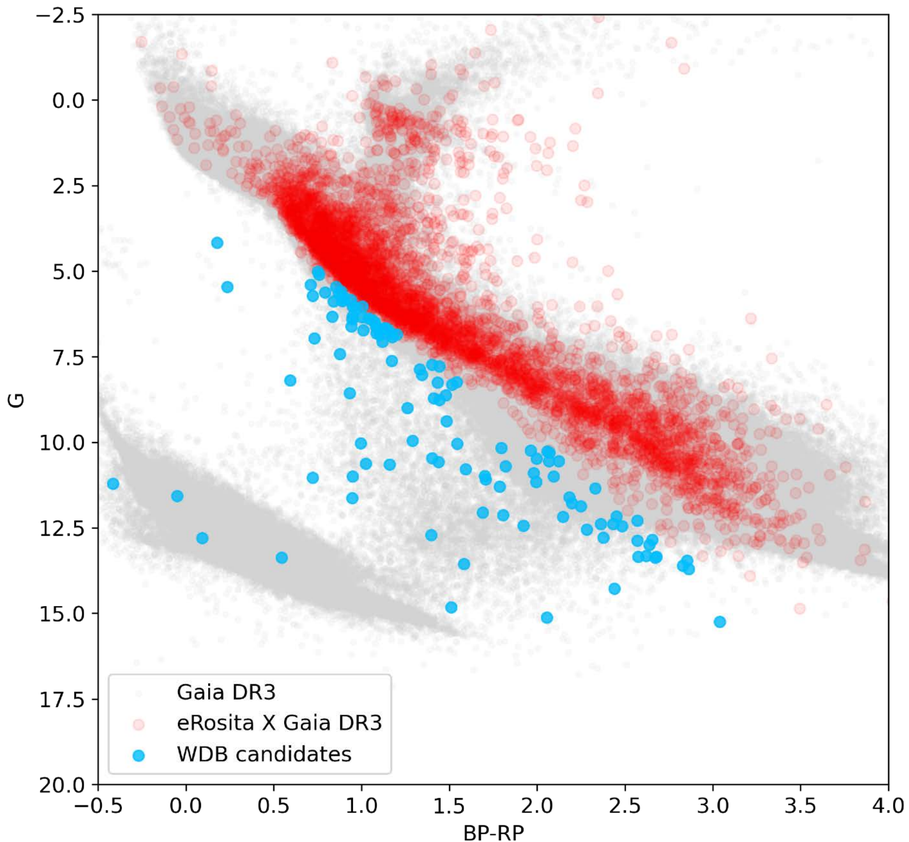
144, 313 candidates

RA, Dec uncertainty ~ 5 asec

Gaia DR3

- Radius 5 asec
- Parallax SNR > 5
- Proper Motion > 0

Candidates



Soft X-ray candidates

SRG/eRosita (Merloni+24)

Soft x-ray sources

Point source catalog

Dec > -25

144, 313 candidates

RA, Dec uncertainty ~ 5 asec

Gaia DR3

- Radius 5 asec
- Parallax SNR > 5
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X-ray sources with **at least one galactic obj:**

All candidates: 4623

4088 objs, < 18 mag (TriCCS)

3474 objs, < 17 mag (Tomoe)

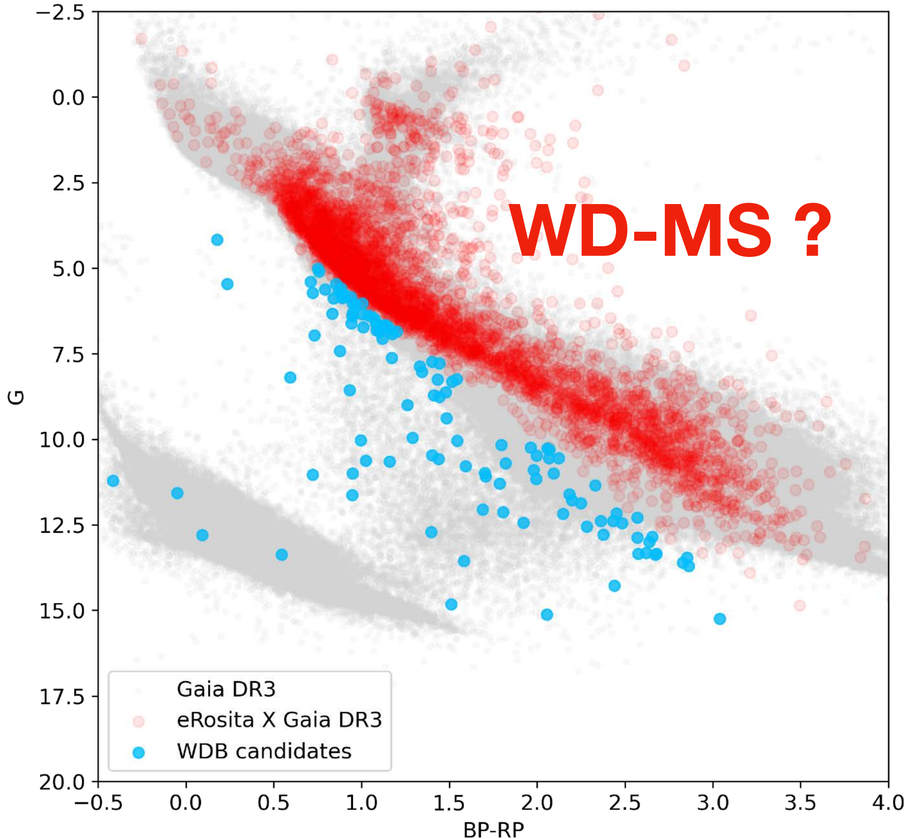
1252 objs, <14 mag (Tomoe MS-WD)

below main sequence: 115

62 objs, < 18 mag (TriCCS)

32 objs, < 17 mag (Tomoe)

7 objs, <14 mag **Only 18/115 are known!**



Summary

1. Propose for searching for short period WDBs
   Variables catalog?
   Photometry; Period finding
2. High cadence survey is needed
   Target on/near to the galactic plane?

3. New candidates identified by eRosita… To be confirmed!

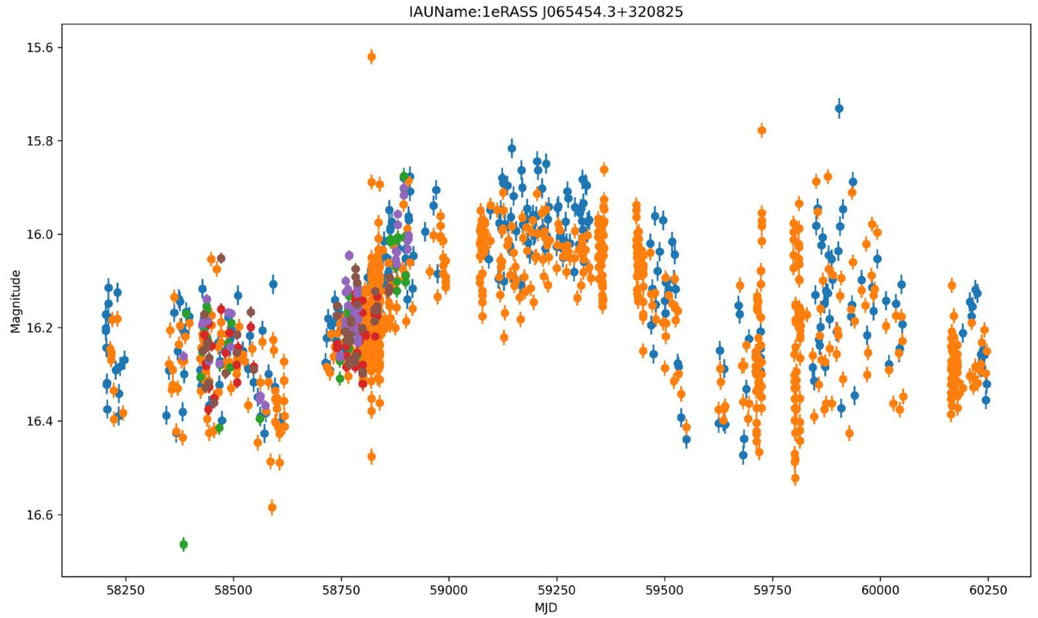
below main sequence: 115

3 objs near galaxies (PS1 image)

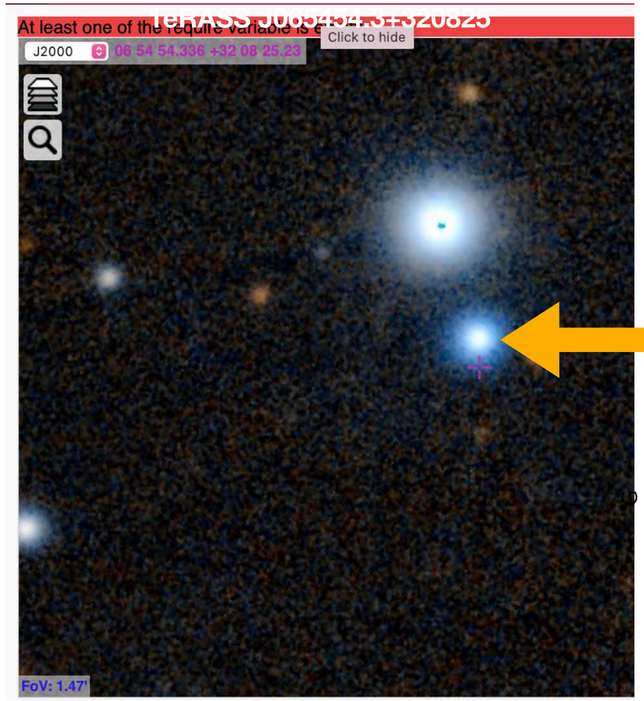
18 objs are known (nearest galactic obj < 5 asec)
-> 1 Nova, 1 hot subdwarf, 1 RR Lyr

IAUName	RA_ICRS	DE_ICRS	nearest_obj_asec	type
1eRASS J065454.3+320825	103.7264512	32.141071	0.1	V* DN Gem/Nova
1eRASS J065748.2+253253	104.4517868	25.54753433	0	LAMOST J065748.42+253251.1/Hot Sd
1eRASS J051702.0-082832	79.258557	-8.477089788	0.2	RR Lyr

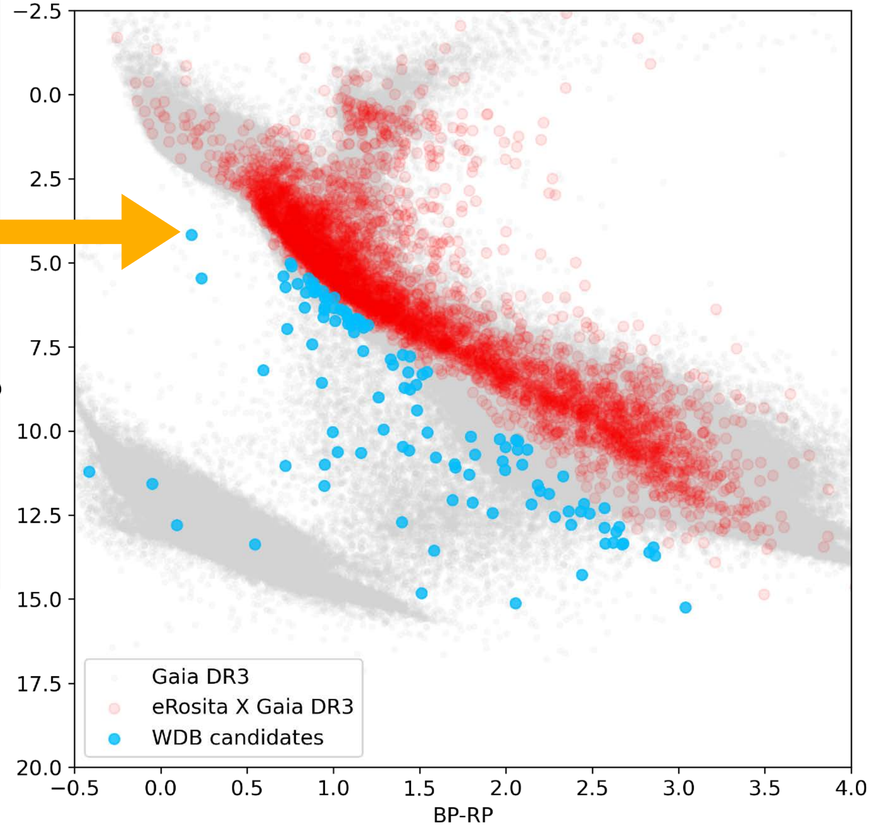
Nova



ZTF



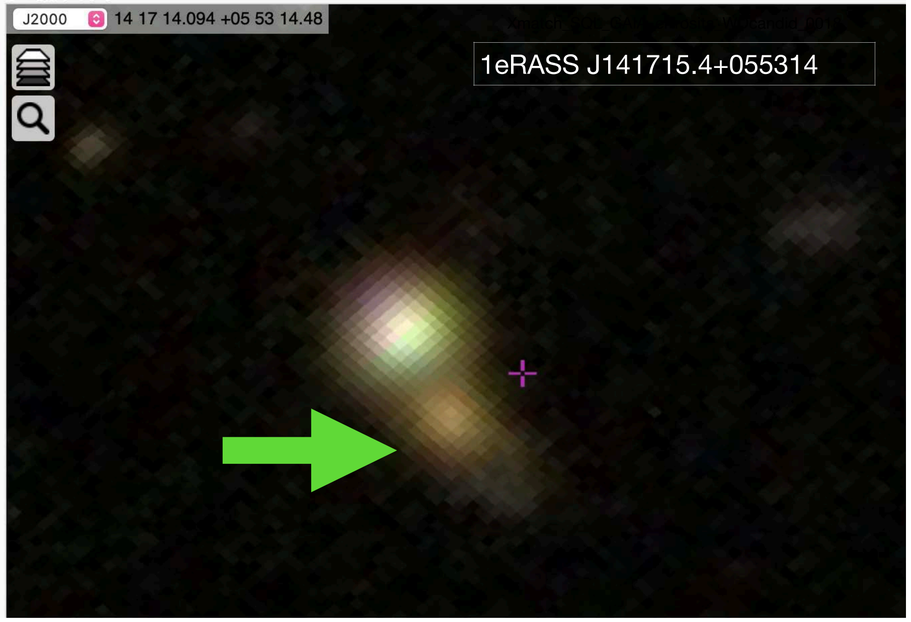
PS1



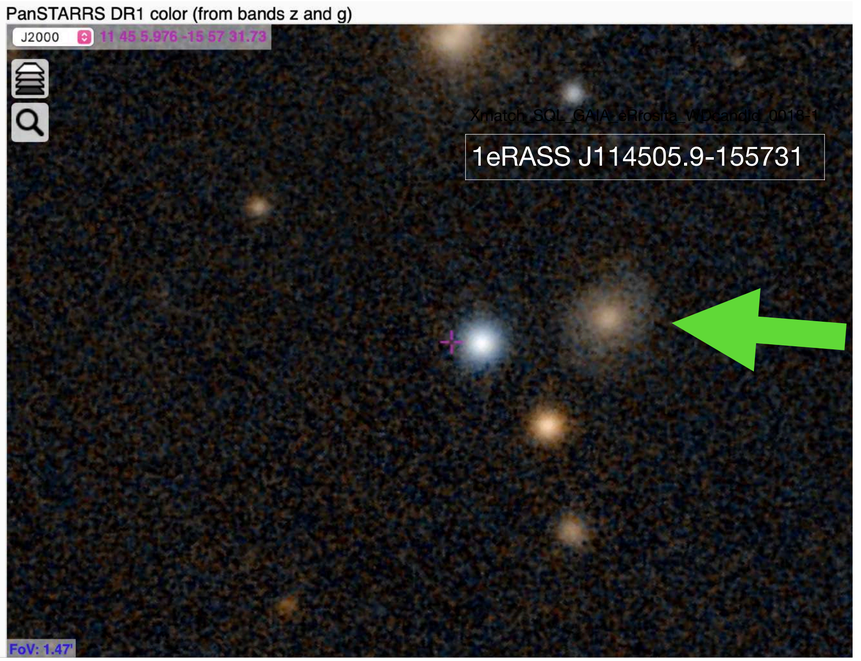
Gaia

Galaxy?

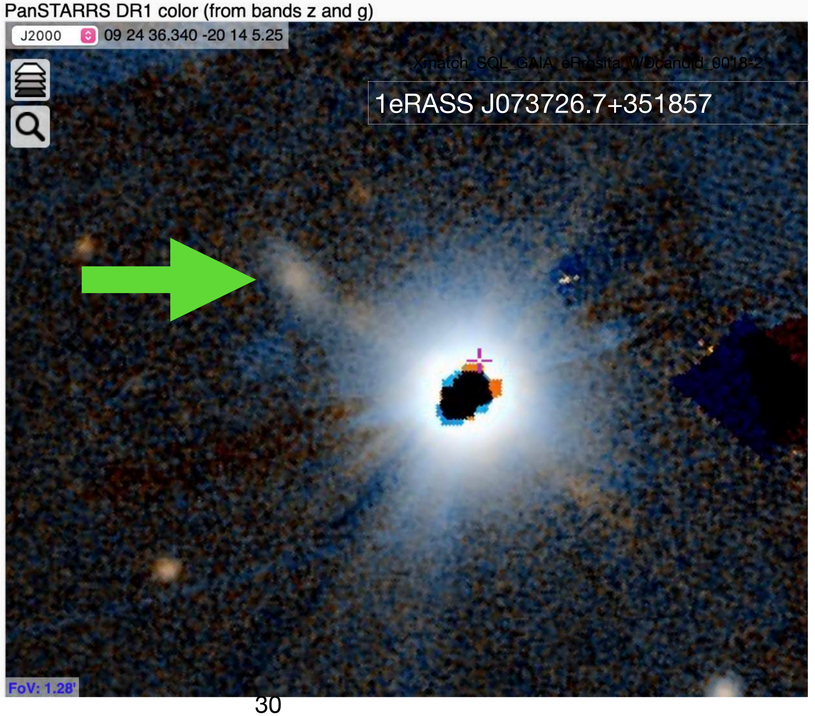
SDSS9 color



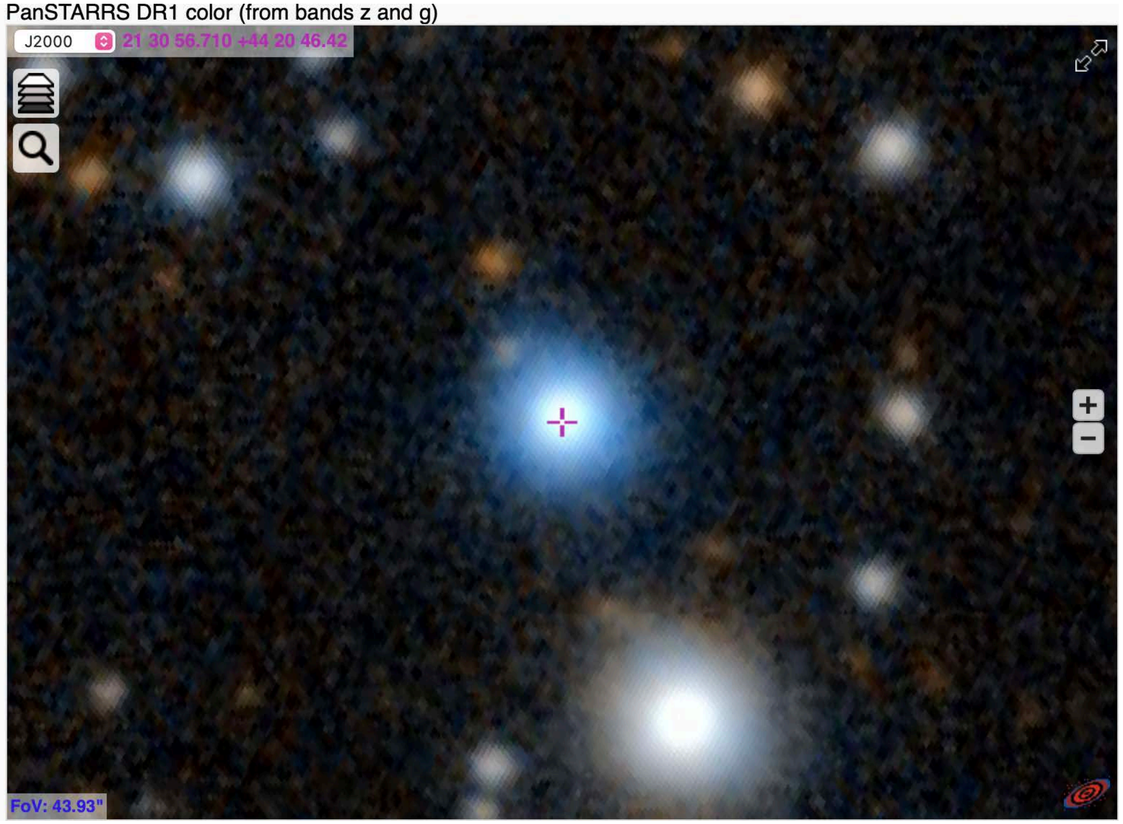
PanSTARRS DR1 color (from bands z and g)

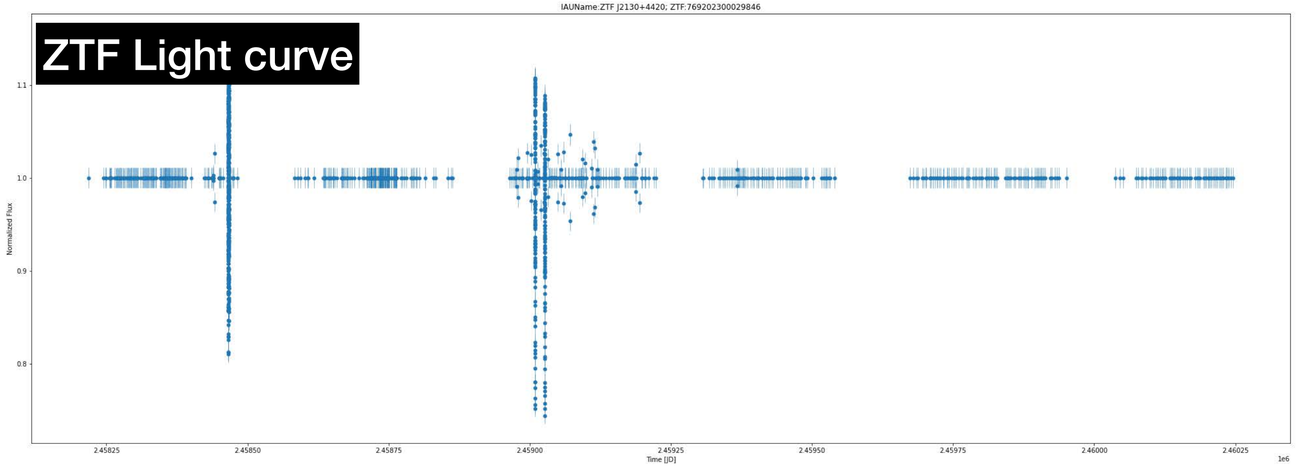


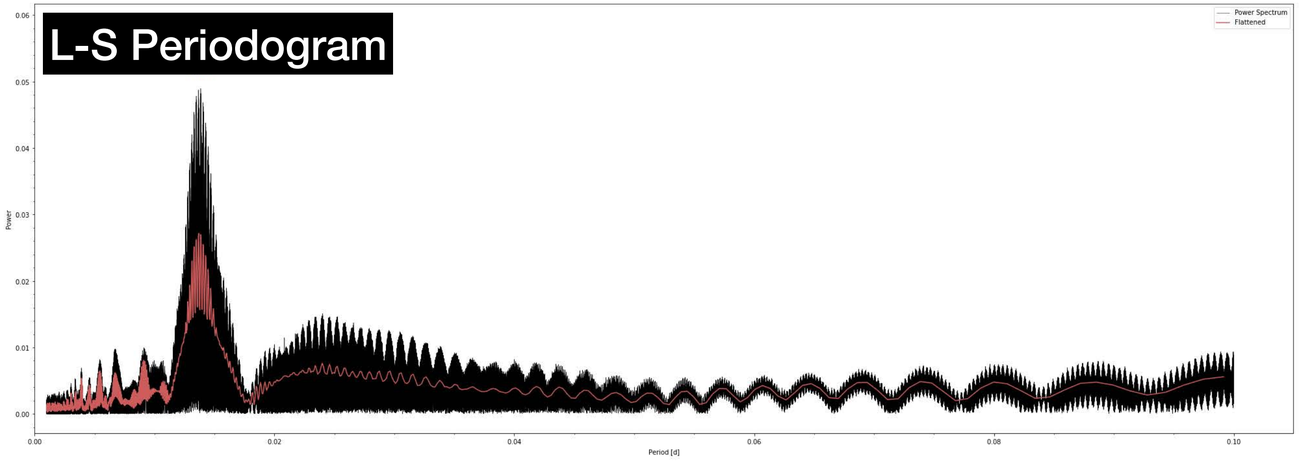
PanSTARRS DR1 color (from bands z and g)

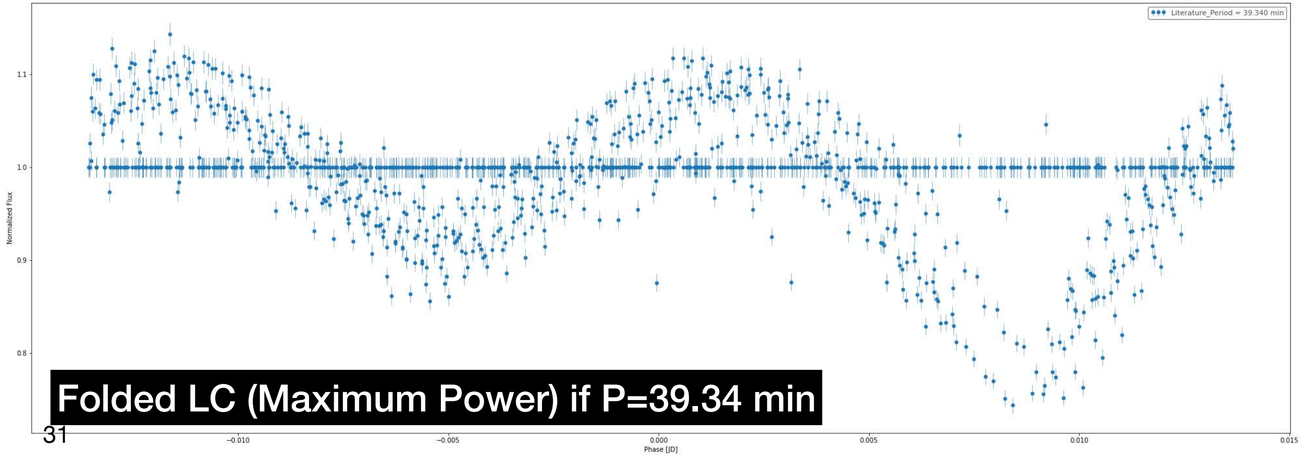


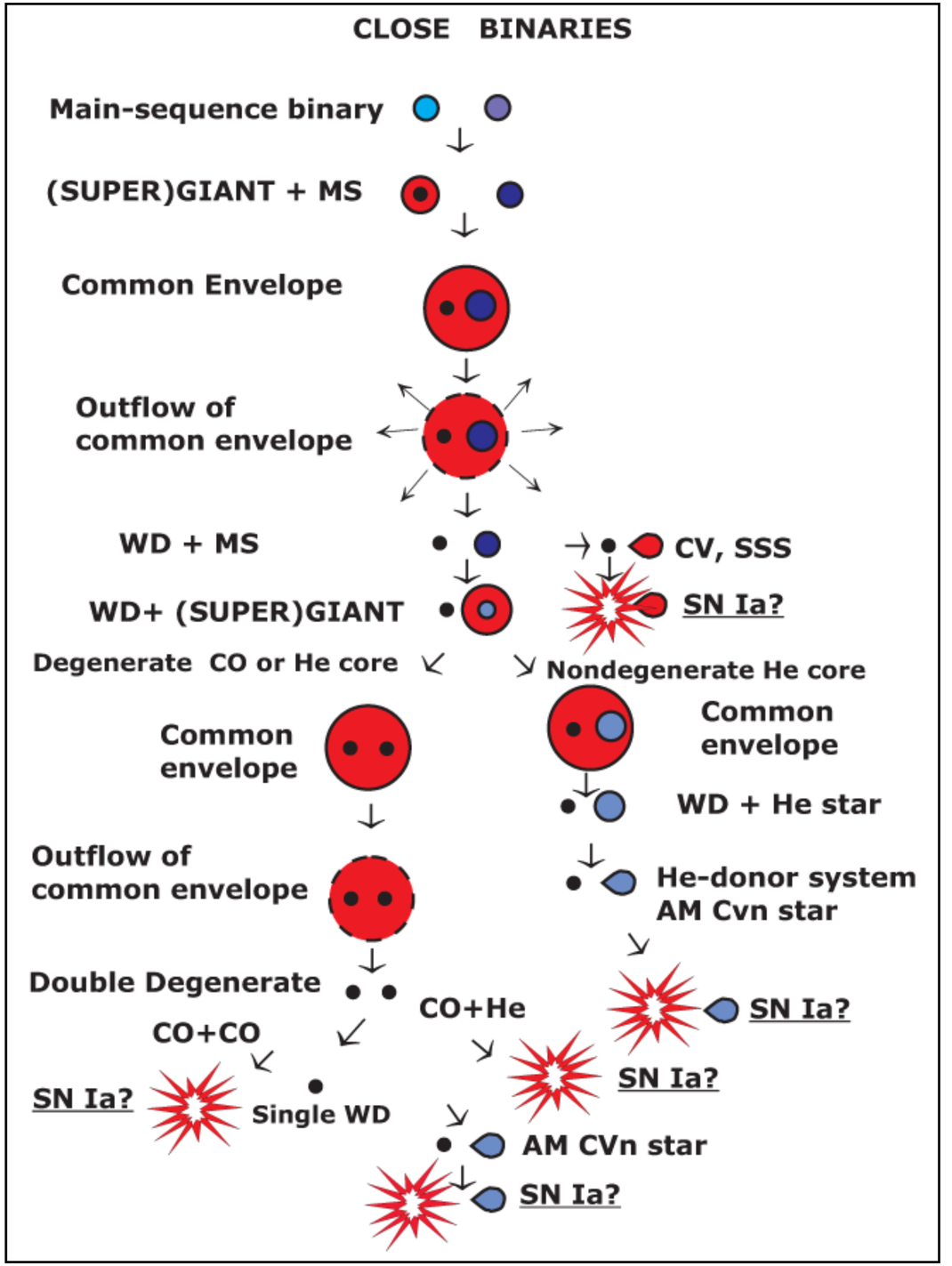
Period finding (ZTF example)










CLOSE BINARIES
Main-sequence binary
(SUPER)GIANT + MS
Common Envelope
Outflow of common envelope
WD + MS
CV, SSS
WD+ (SUPER)GIANT
SN Ia?
Degenerate CO or He core
Nondegenerate He core
Common envelope
Common envelope
WD + He star
Outflow of common envelope
He-donor system AM Cvn star
Double Degenerate
CO+He
SN Ia?
CO+CO
SN Ia?
SN Ia?
Single WD
AM CVn star
SN Ia?