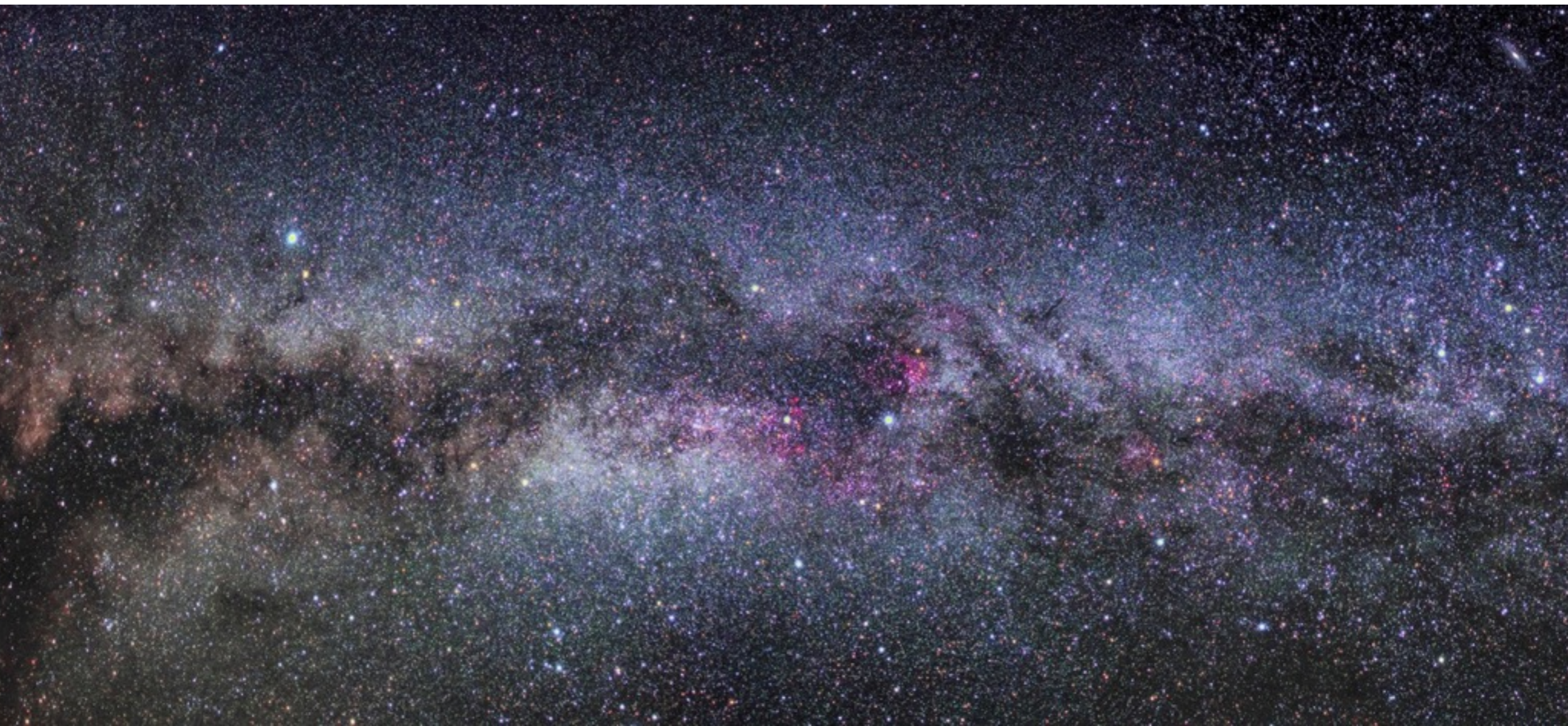


# ***The iPTF variability data and the iPTF Galactic Plane survey***



Thomas Kupfer

*California Institute of Technology*

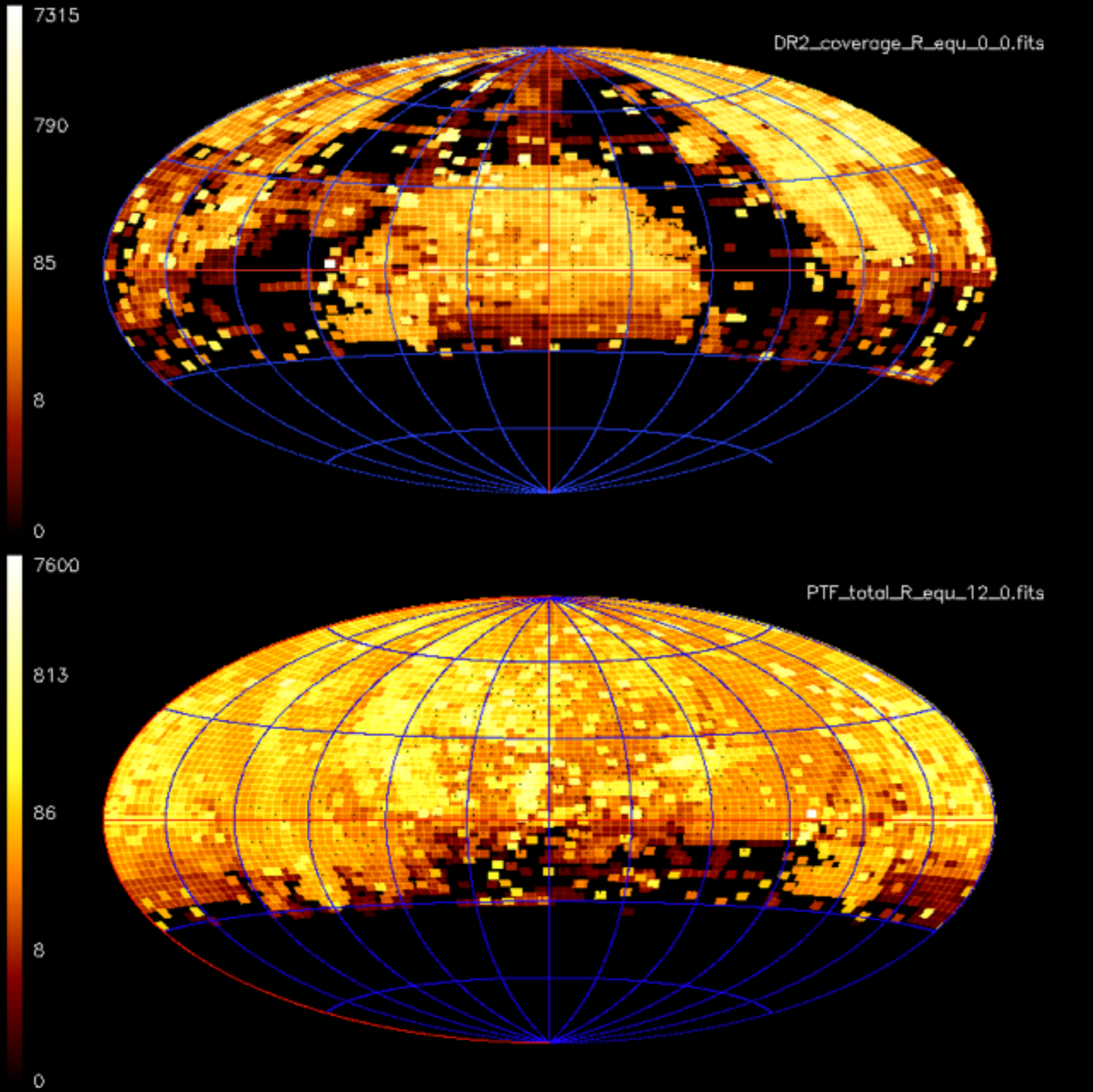
Eric C. Bellm; Thomas A. Prince; Shrinivas R. Kulkarni; Frank J. Masci; Russ Laher; David L. Shupe



# *The Northern Plane has little variability coverage*

Survey	Bands	Limiting	Temporal	Sky coverage	Public?
ASAS	V, I	14	hundreds of	~all sky	yes
OGLE-IV	V, I	21	hundreds of	Bulge, Southern Plane,	no
VVV	Ks	18	tens of	Bulge, $ b  < 2$ section	yes
PS1 $3\pi$	g, r, i, z, y	22-23	tens of	entire Northern Sky	partial
IPHAS	r, i, H $\alpha$	20-21	~static	$ b  < 5$ , Northern Plane	yes
UVEX	U, g, r, He I	21	~static	$ b  < 5$ , Northern Plane	not yet
VPHAS+	u, g, r, i, H $\alpha$	20-21	~static	$ b  < 5$ , Southern Plane	partial
Gaia	G, R	20-21	tens of	all sky	partial

- The vast majority of stars reside in the Galactic Plane
  - regular monitoring of the plane can be expected to yield a treasure trove of new discoveries
- Galactic plane is not well studied by time domain surveys
  - However PanSTARRS/Gaia/UVEX/IPHAS is about to be released
  - iPTF is providing time-domain data for the Galactic Plane



# Palomar Transient Factory Data Release 2 (2009-2012)

intermediate  
Palomar Transient  
Factory  
current status

Average number of epochs: several hundred

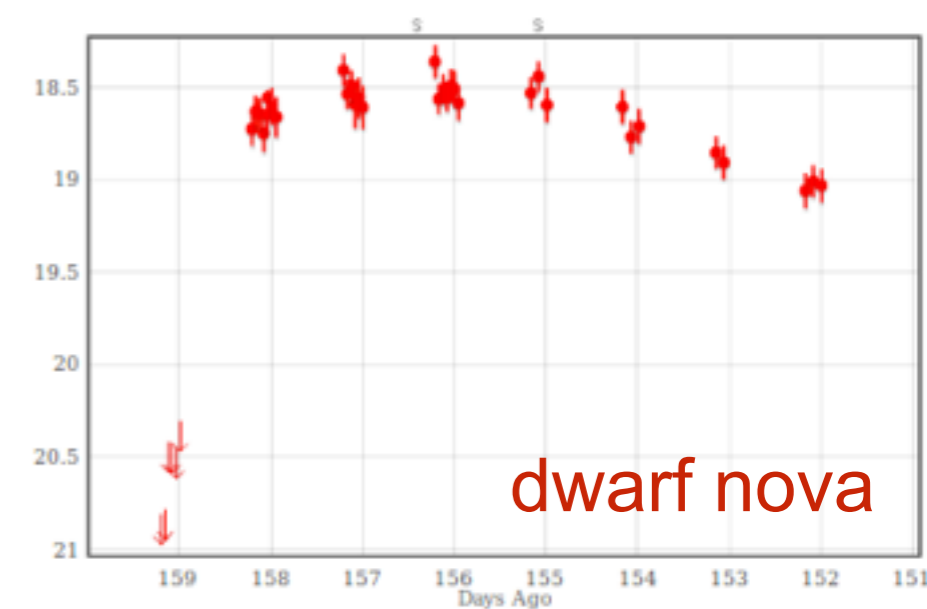
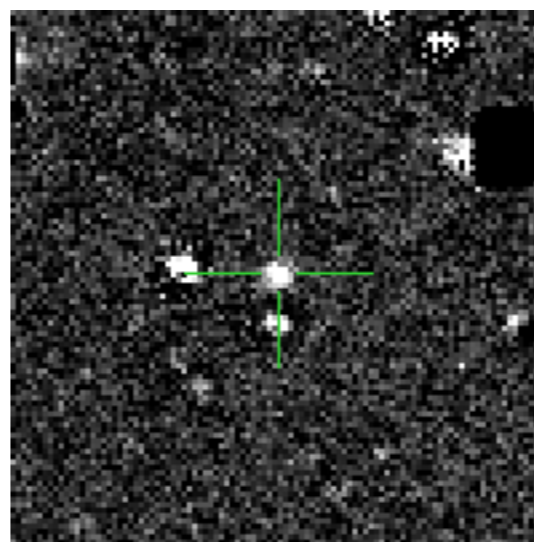
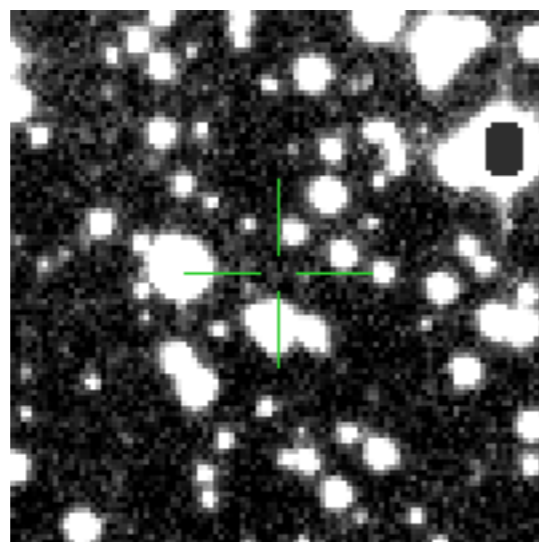
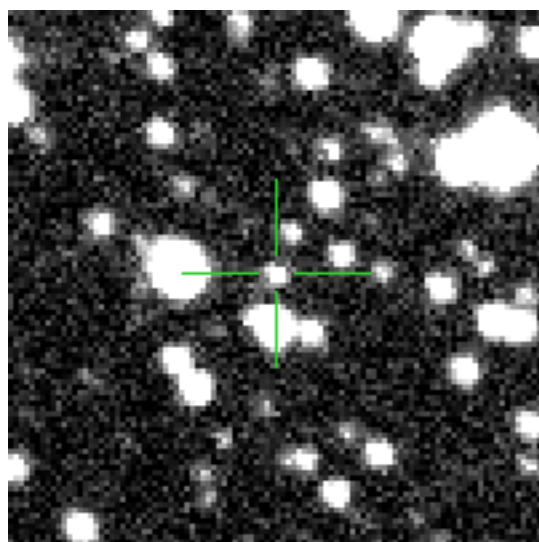
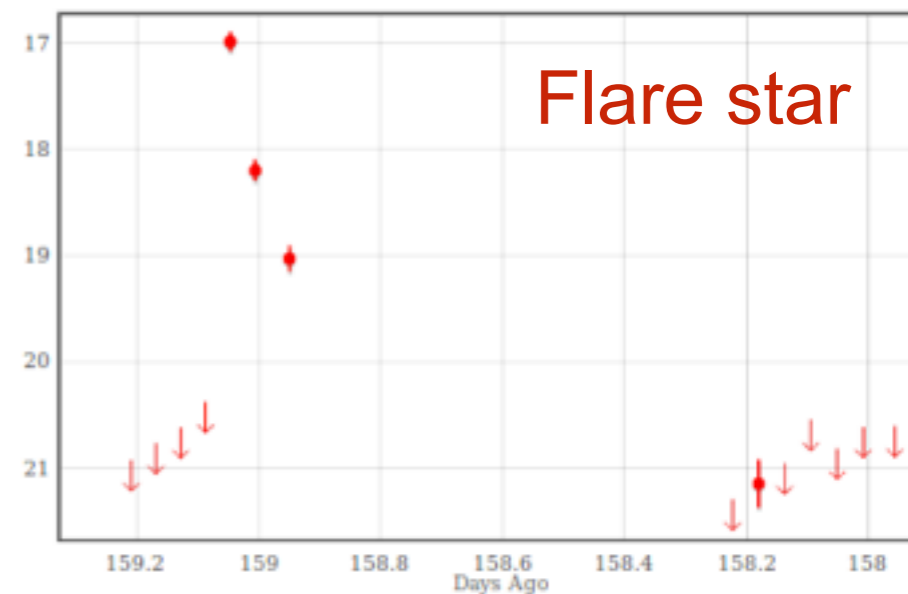
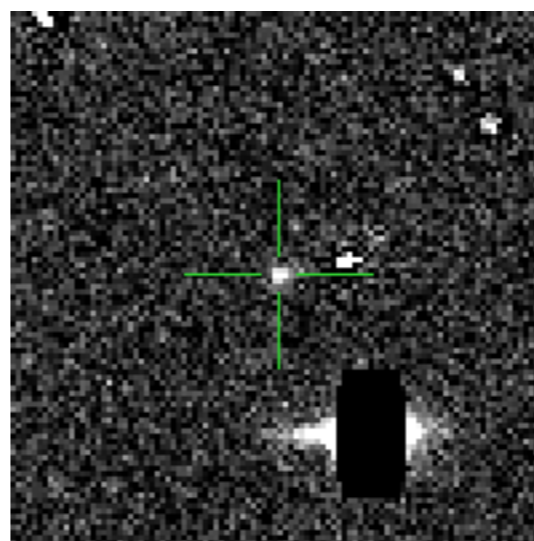
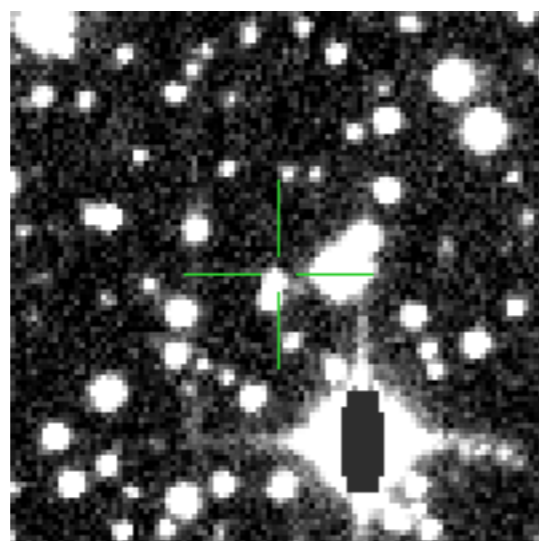
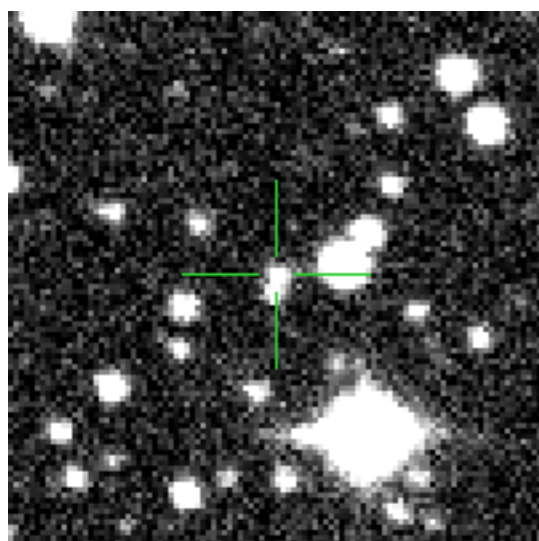
Average number of epochs in the northern Plane: about 50

# Difference imaging finds variability even in crowded fields

New image

reference

subtracted



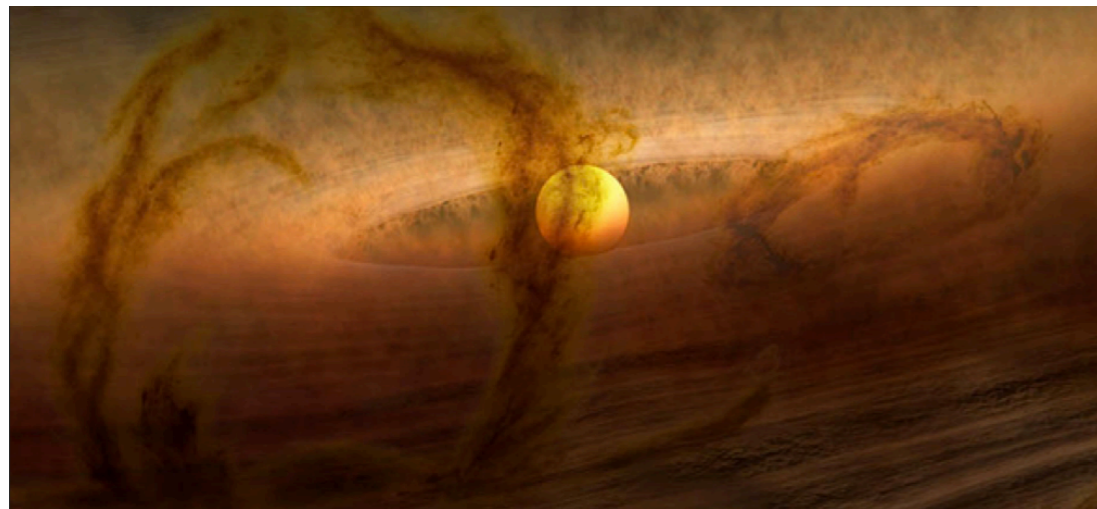
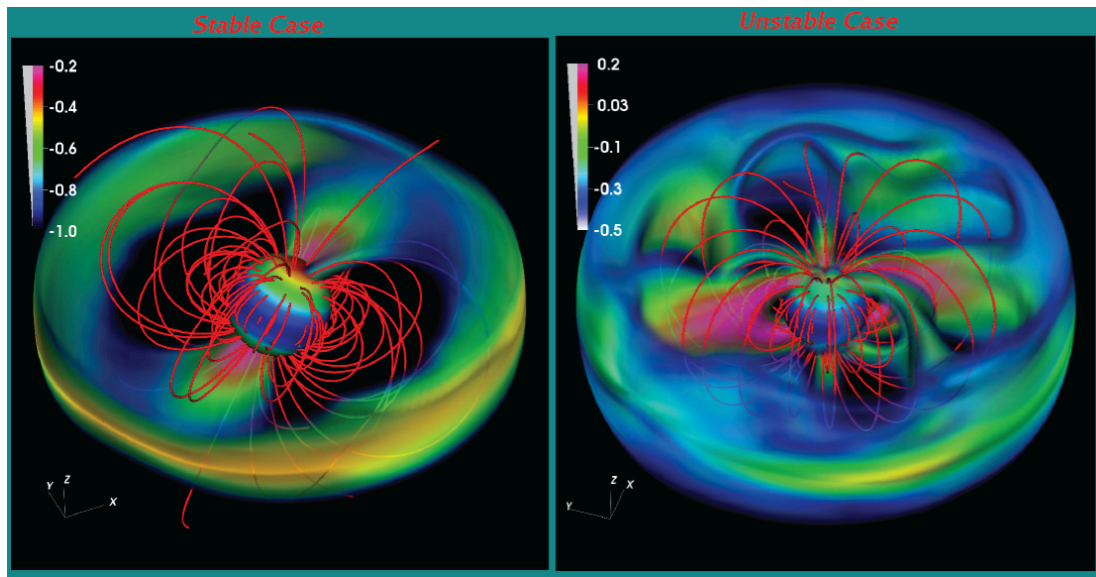
Variability studies of Galactic objects opens new frontier:

from young stellar objects to late stellar evolution, including microlensing, M-star flares, CV outbursts....



# Young stars in the Palomar Transient Factory

Kurosawa, Romanova

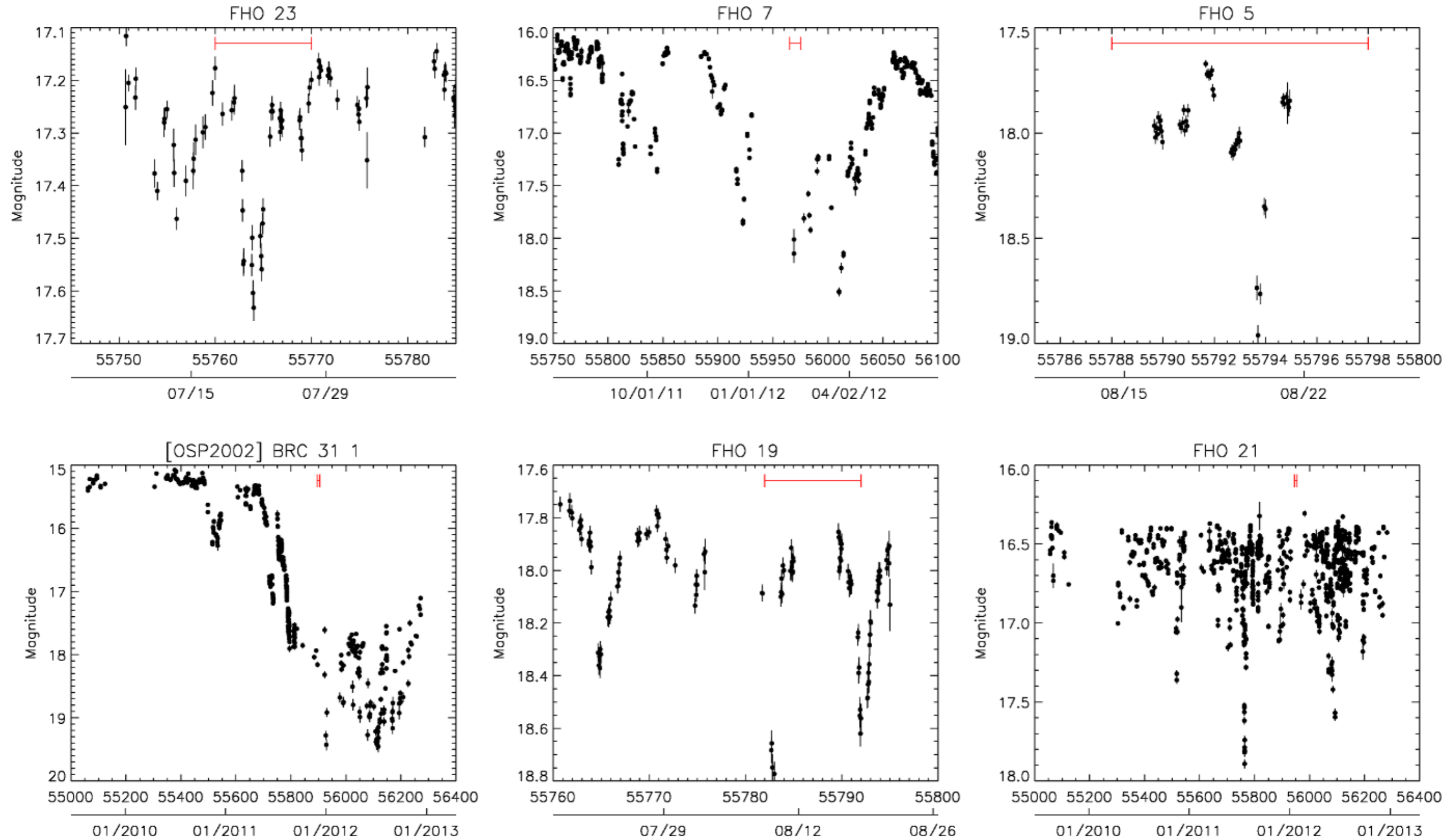


- Variability attributed to:
  - time variable magnetic activity on star
  - rotation of stellar surface inhomogeneities e.g. cool or hot spots
  - possible pulsation phenomena
  - time variable accretion from disk to star
  - disk inhomogeneities e.g. orbiting warps or vertical circulation
  - binary phenomena.
- Amplitudes range from  $<0.01$  mag to  $>5$  mag, typically 0.1-0.2 mag.
- Time scales range from hours to years, typically 0.5-2 days.

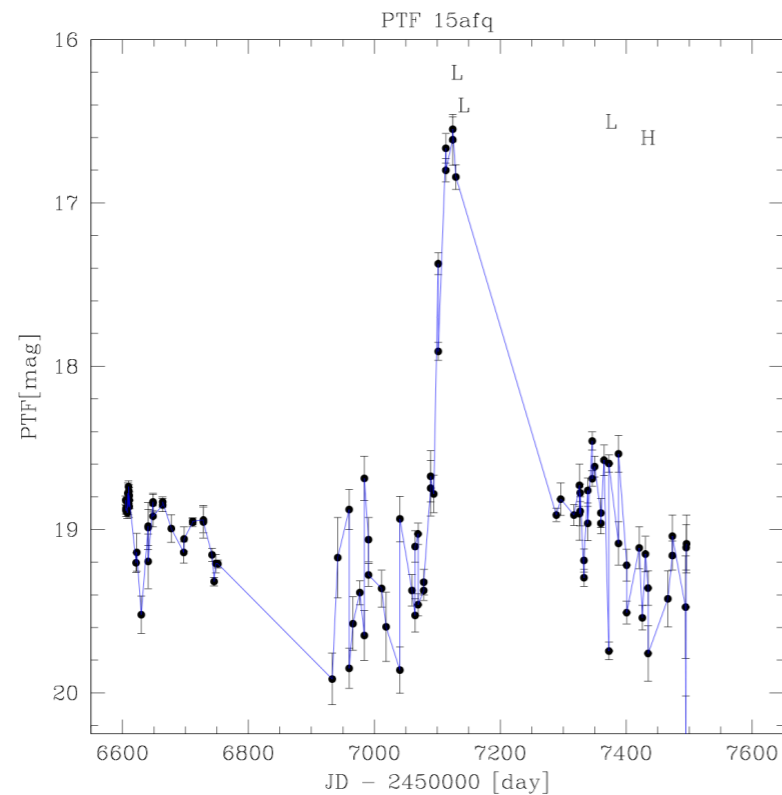
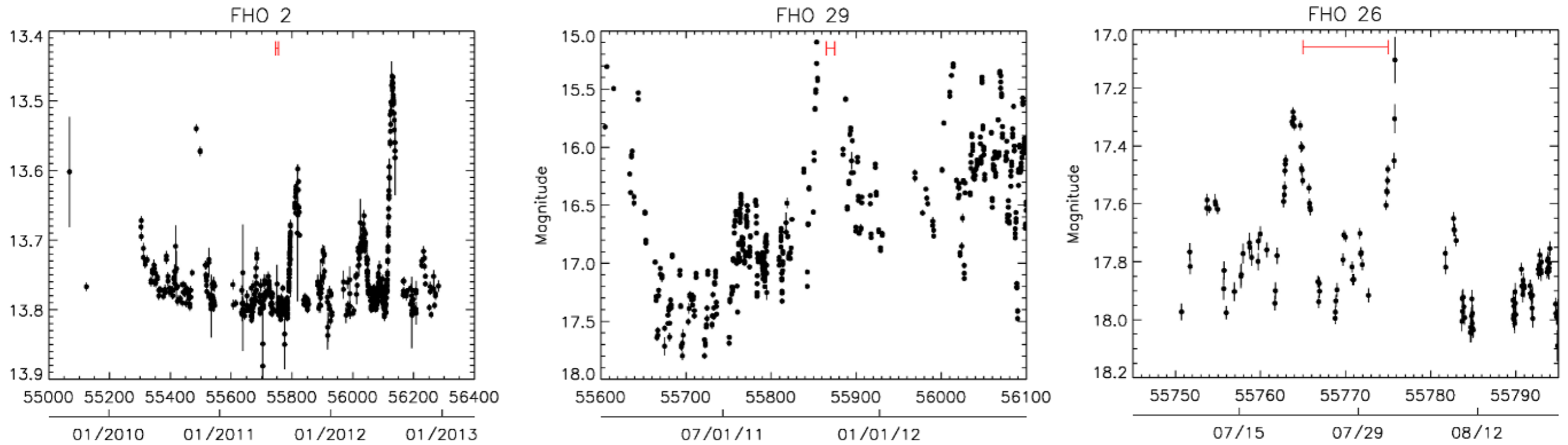
PTF survey data fills a gap among existing YSO data sets given the long duration at intermediate cadence.

- ~20 star forming regions targeted.
- ~150-200 epochs over 3 years, up to 1300 epochs over 7 years.

# *A variety of fading young stars*



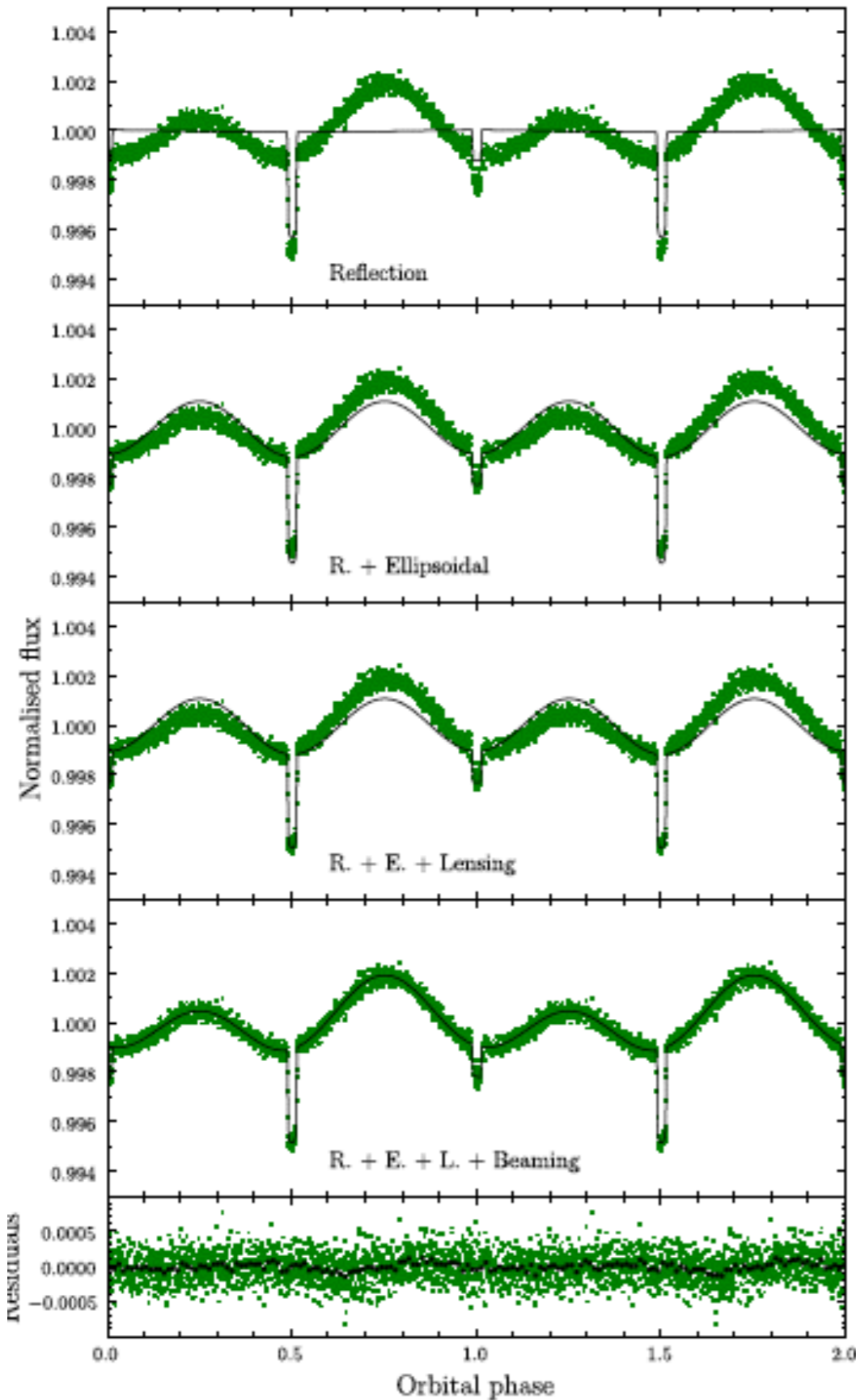
# A variety of bursting young stars



Increase in disk accretion rate caused ~3 mag brightening for several months

# Compact binary evolution with *iPTF*

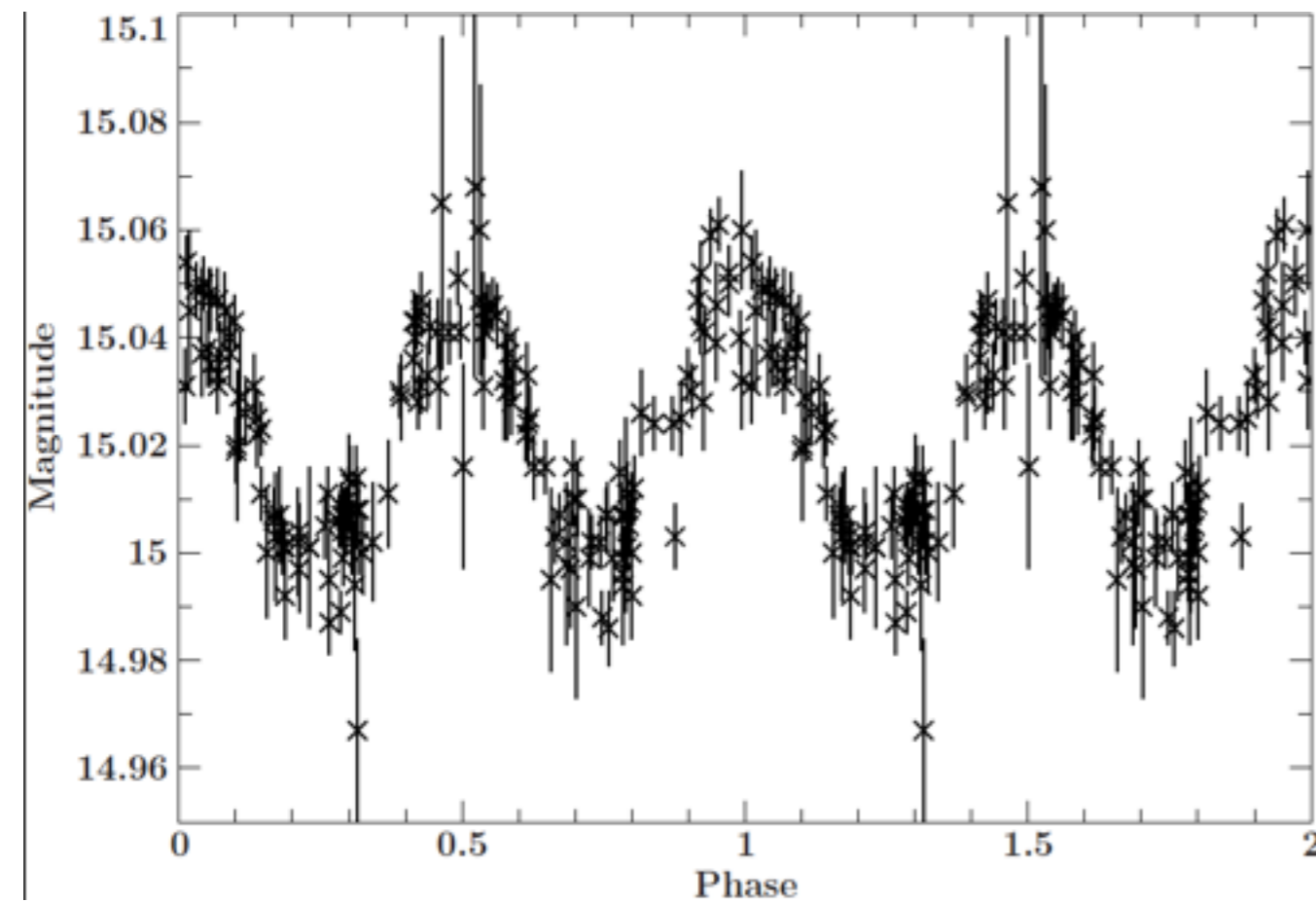
- Identification of white dwarf/He-star binaries in compact orbits  $P_{\text{orb}} < \text{few days}$



- Variability caused by:
  - Tidal deformation
  - Heating of the companion
  - Eclipses
  - Beaming
  - Accretion disc variability



# *The second most compact detached He-star binary*

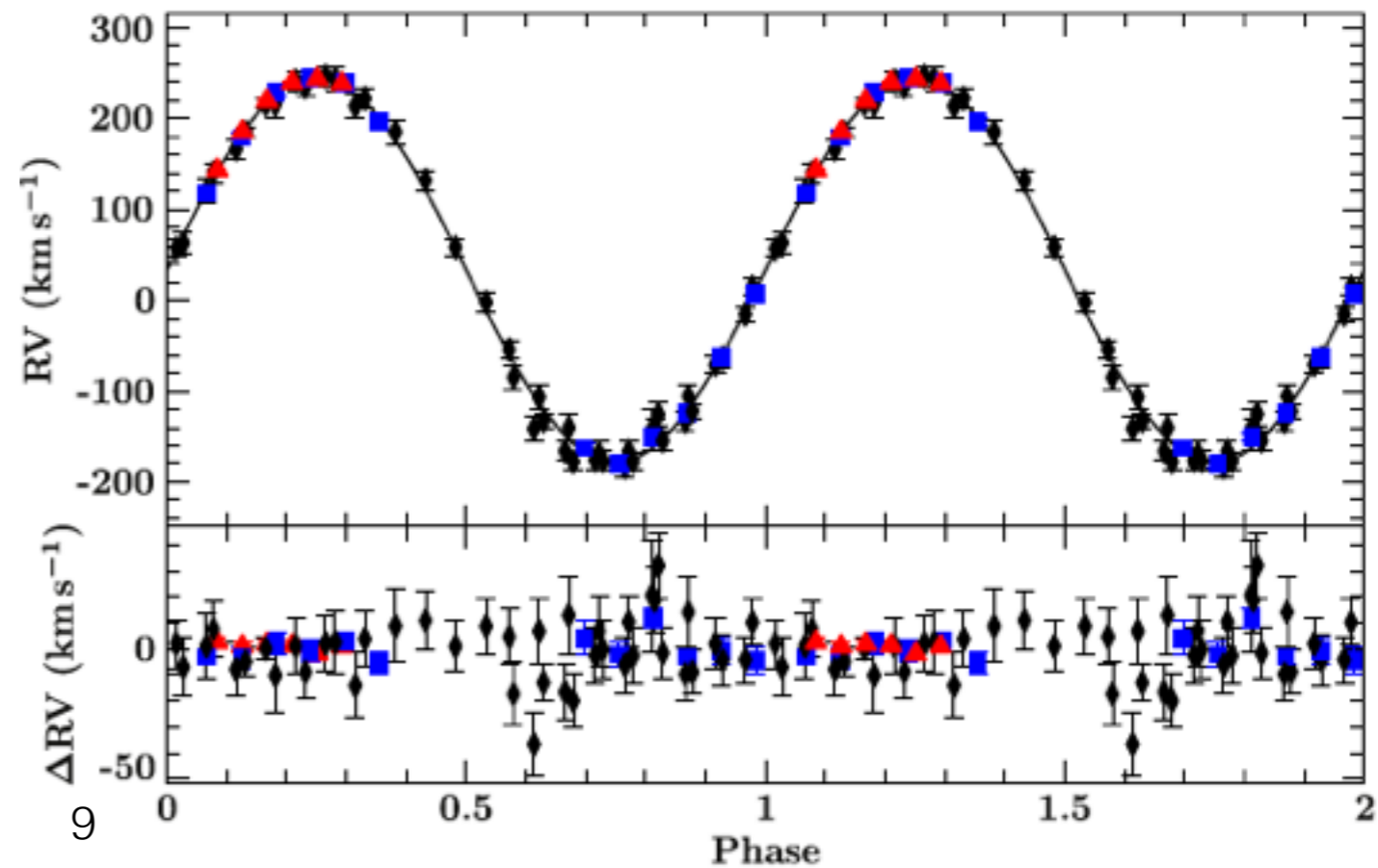


**PTFS1 J0823 - an ultracompact  
He-star with WD companion**  
 *$P_{orb} = 87 \text{ min}$*

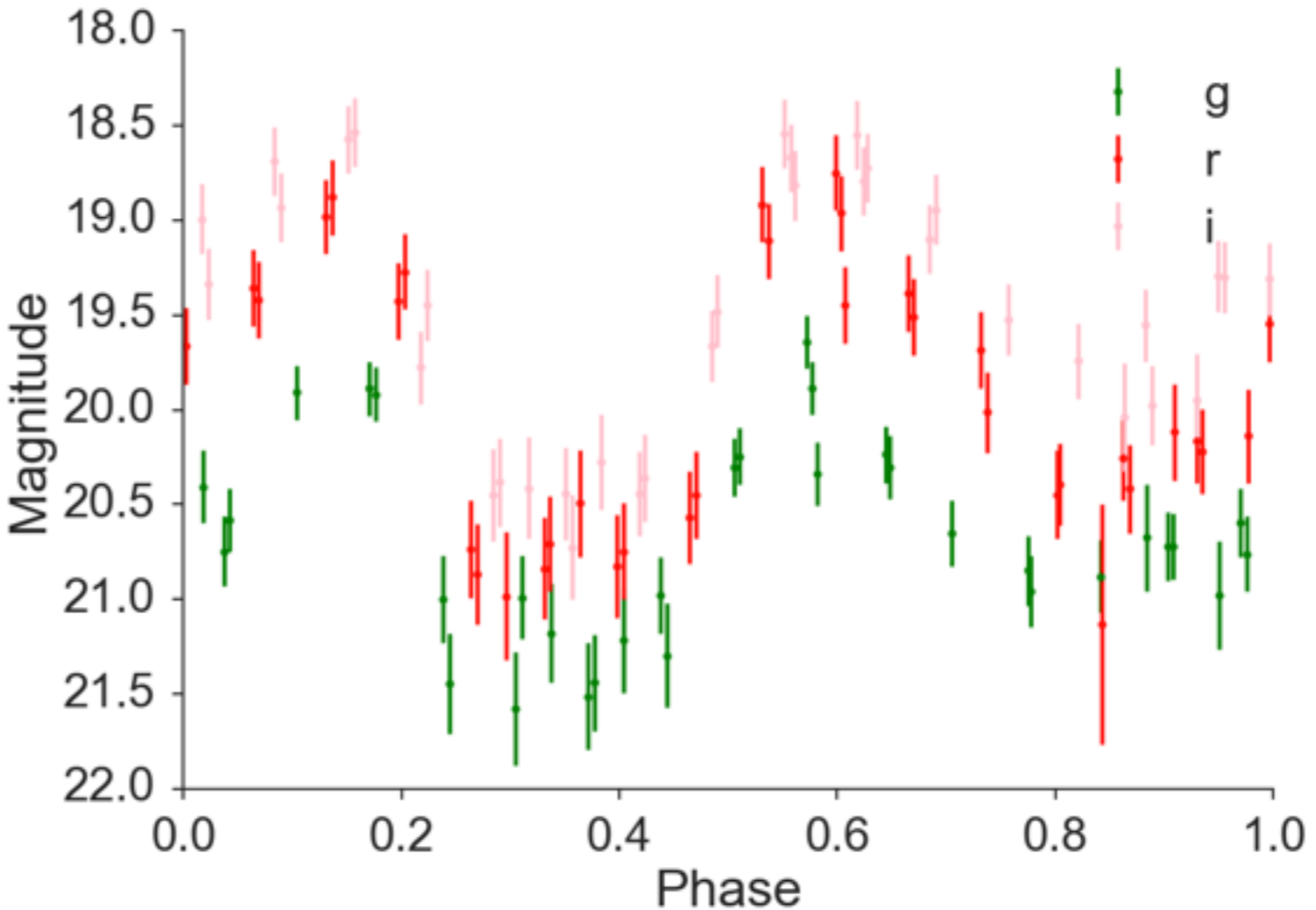
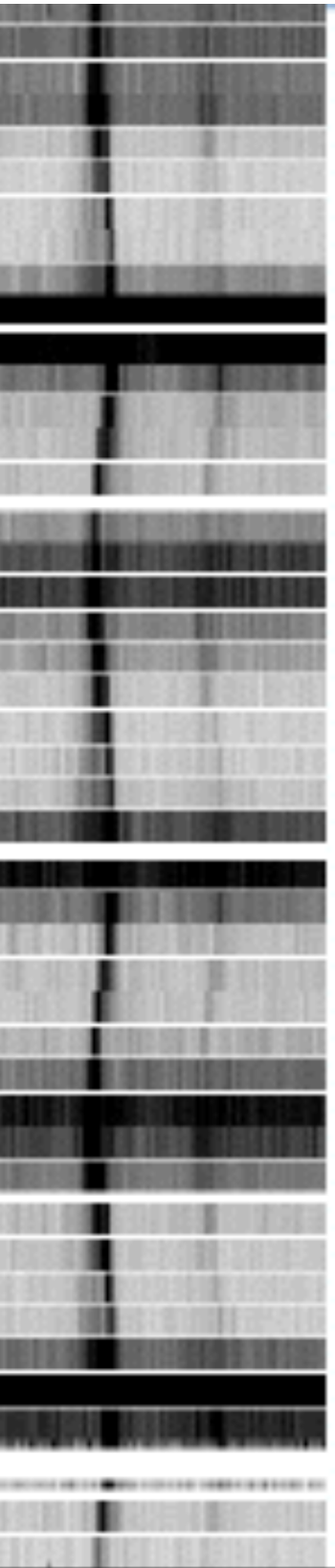
- iPTF lightcurve shows 5% variability due to deformation of the He-star

$M_{\text{He-star}} = 0.49 M_{\text{sol}}$ ;  $M_{\text{WD}} \sim 0.46 M_{\text{sol}}$

*System will merge in about 100 Myr*



# A new accreting binary coincident with a Fermi and a ROSAT source at $b=4.9^\circ$ .

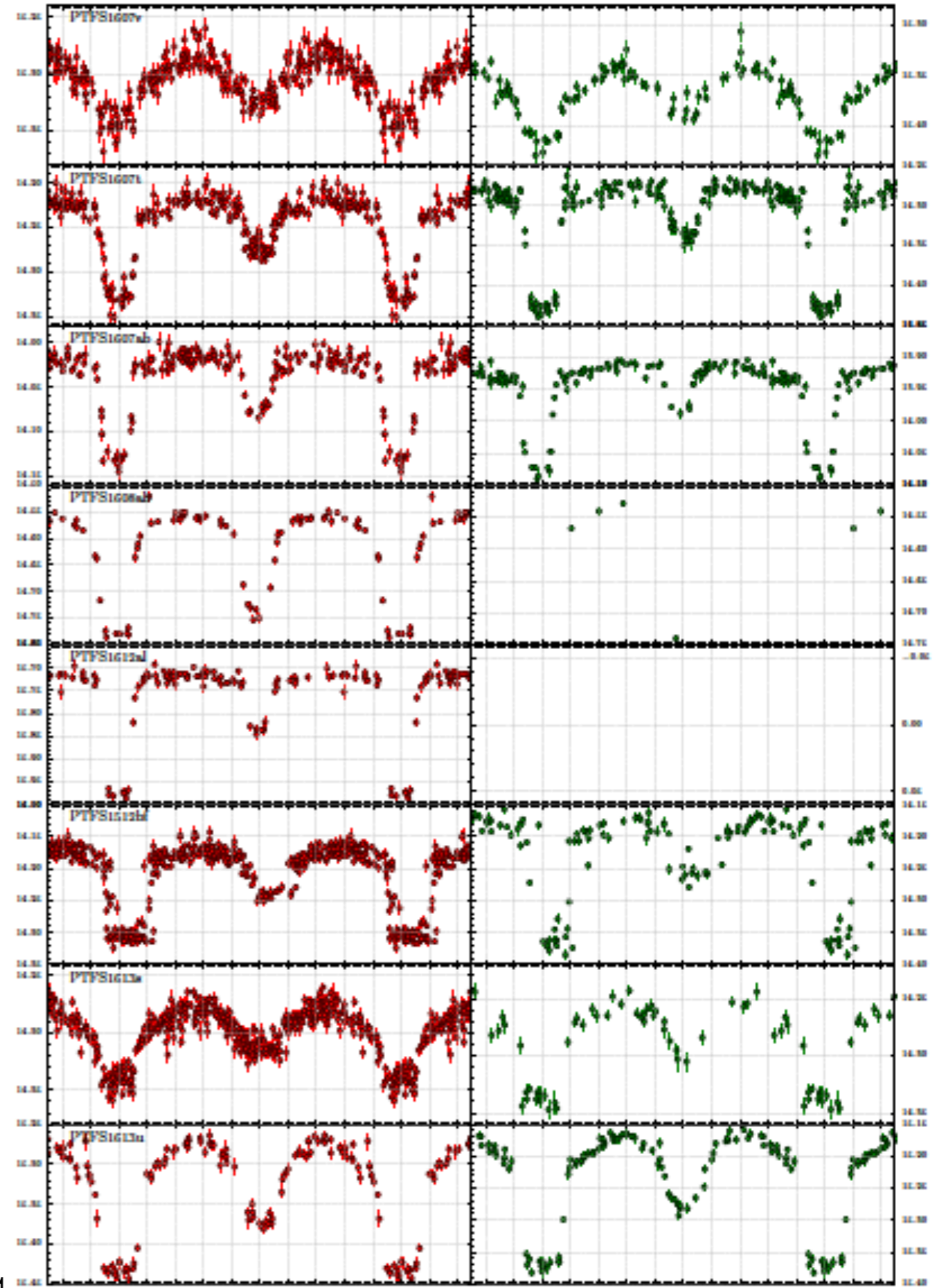
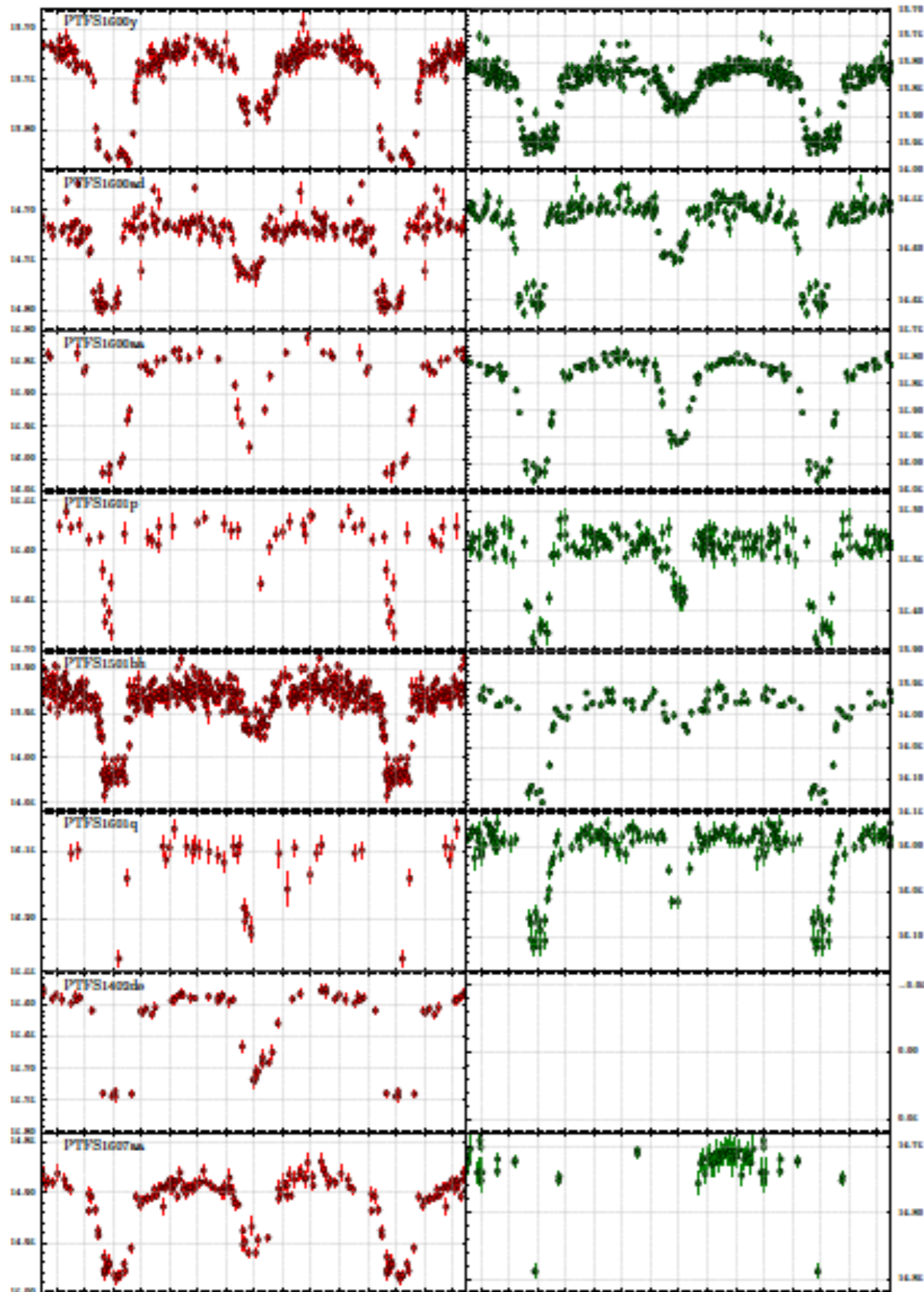


P60 photometry folded at 90 minute period.

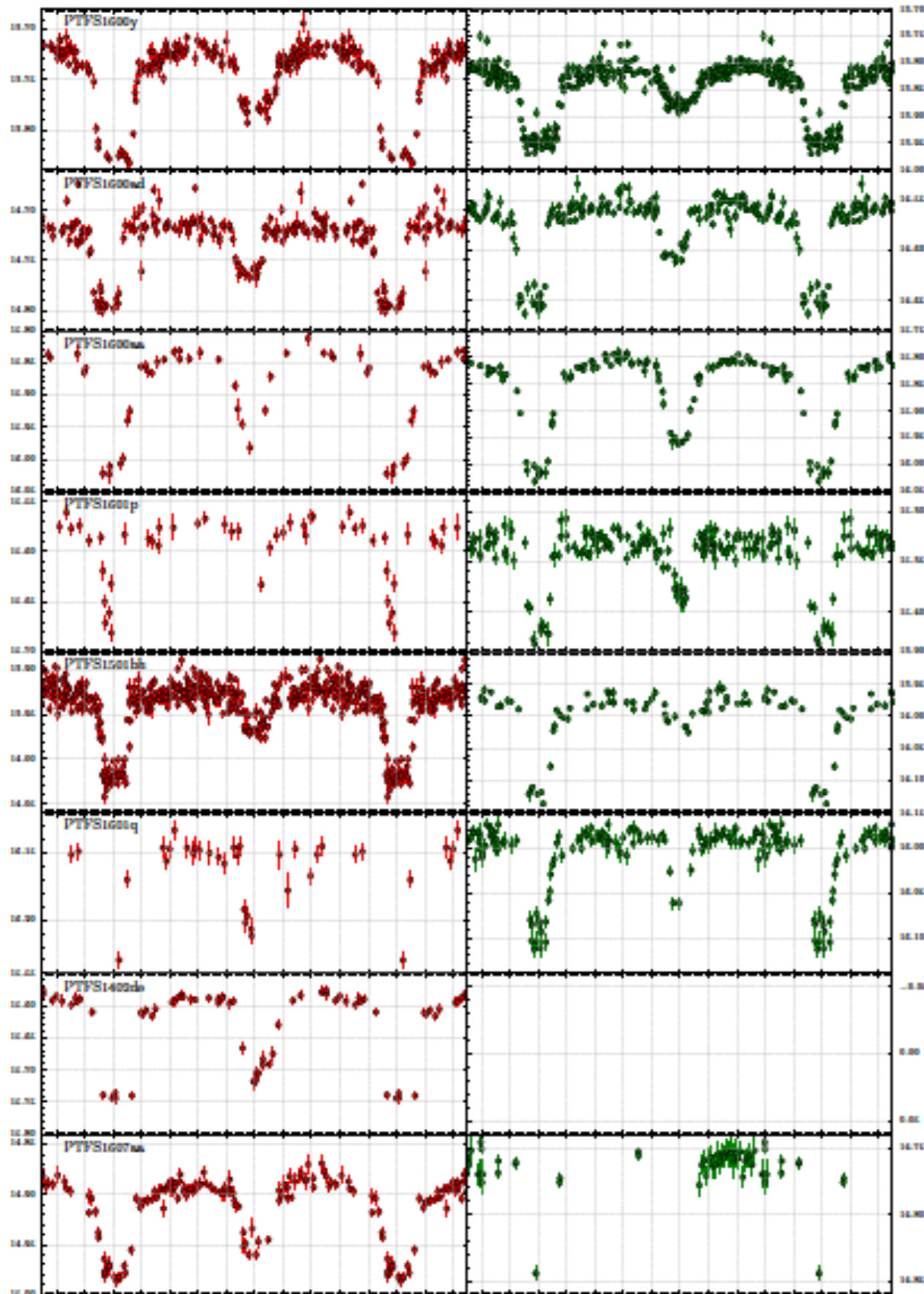
LRIS trailed H-alpha and Hel.  
~400 km/s RV amplitudes



# Population studies with *i*PTF



# Population studies with *iPTF*



- ELCVn binaries:
  - short period post-common envelope binaries
  - **low-mass white dwarf + main sequence companion**
- We discovered 30 new ELCVn type binaries using machine learning techniques
- Tripled the number of known systems
- *Now, population studies are possible*





iPTF provides a large variability dataset for the whole northern hemisphere

The Galactic Plane is the variability frontier.

iPTF has the best variability dataset for the Northern Plane.

ZTF will conduct an extensive public Plane Survey.