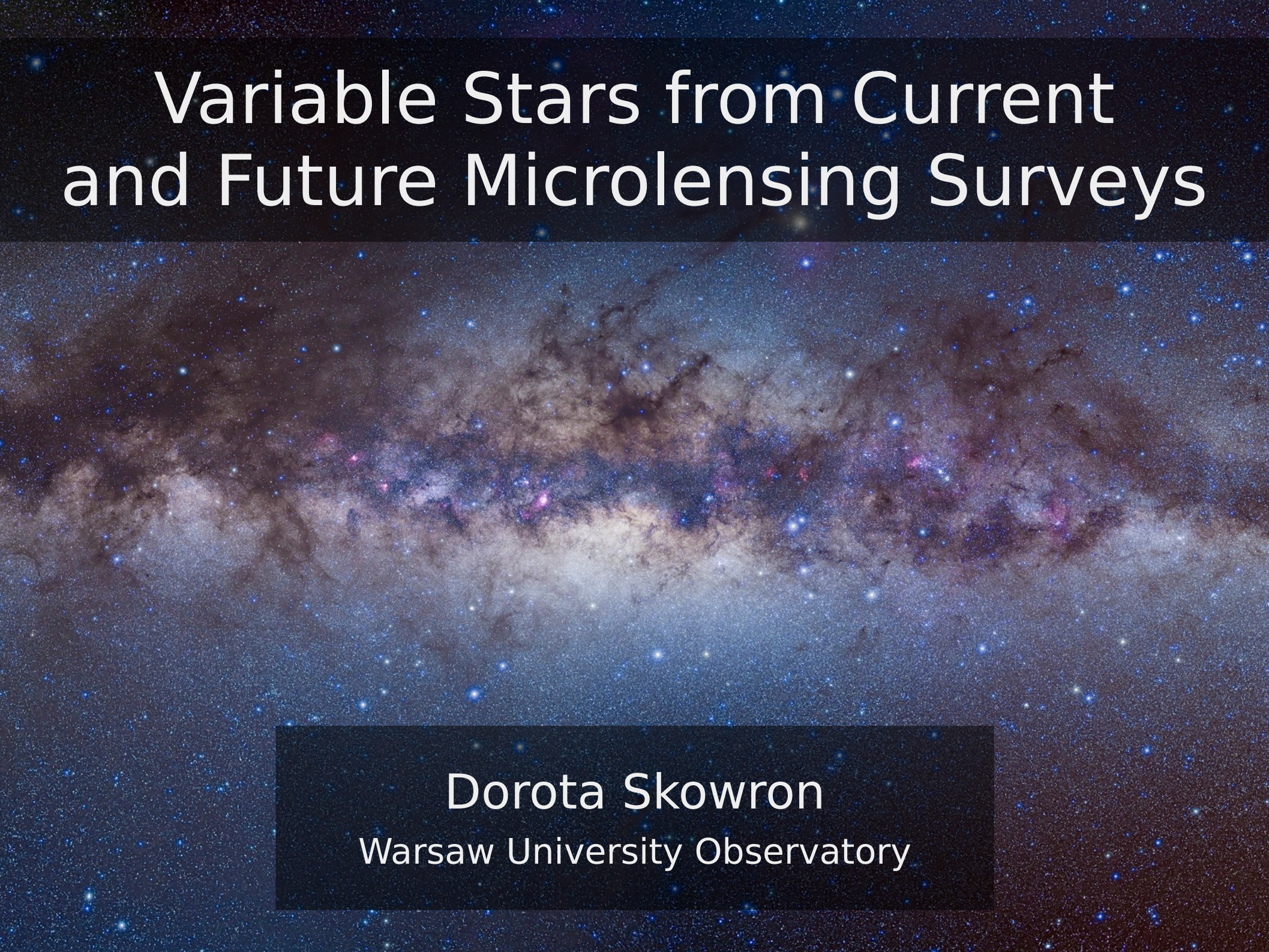
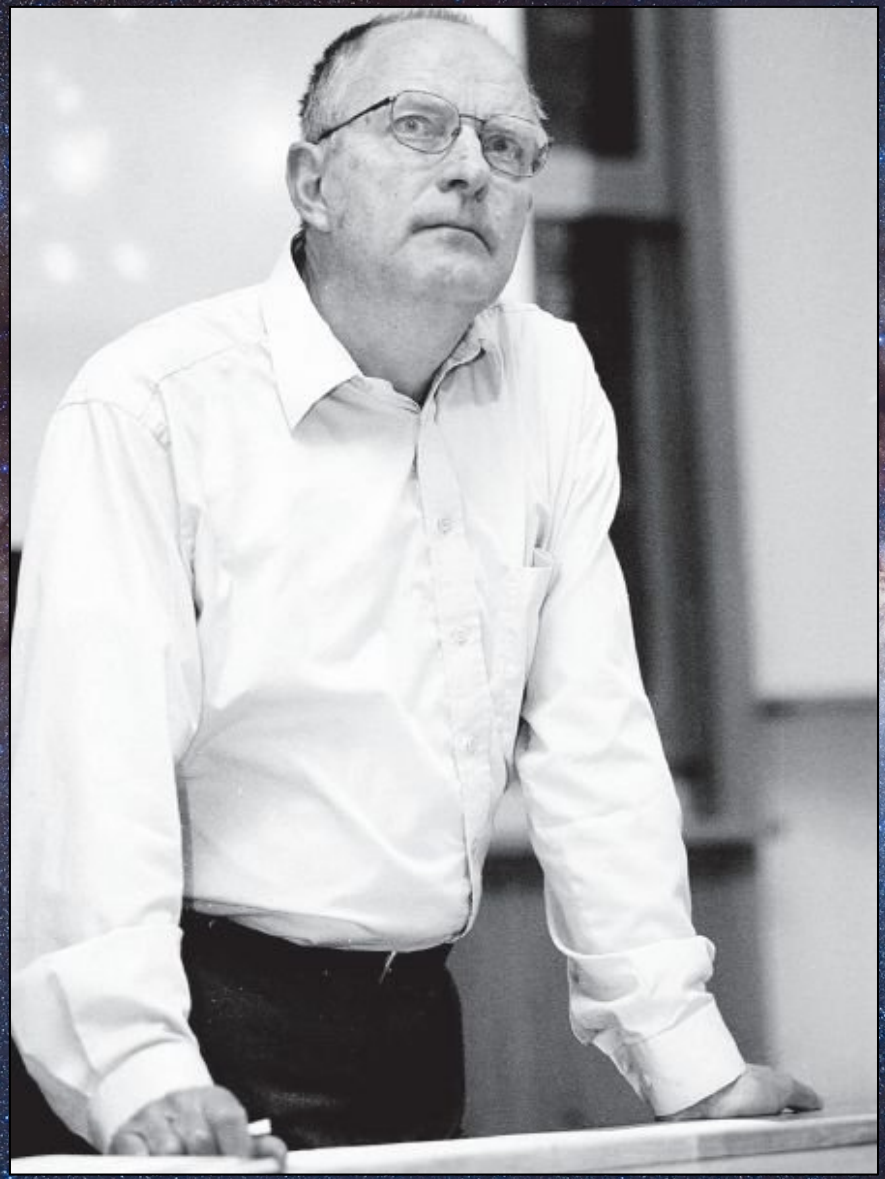
Variable Stars from Current and Future Microlensing Surveys



Dorota Skowron

Warsaw University Observatory

HISTORY OF MICROLENSING SURVEYS



Bohdan Paczyński
(1940-2007)

HISTORY OF MICROLENSING SURVEYS

THE ASTROPHYSICAL JOURNAL, **304**:1–5, 1986 May 1

GRAVITATIONAL MICROLENSING BY THE GALACTIC HALO

BOHDAN PACZYŃSKI[1]
Princeton University Observatory
Received 1985 August 1; accepted 1985 October 23

It is clear that the observational project is not simple, but one of its by-products, a systematic discovery of a large number of variable stars in a nearby galaxy, is attractive, even if no lensing events are discovered.

The last paragraph of the paper

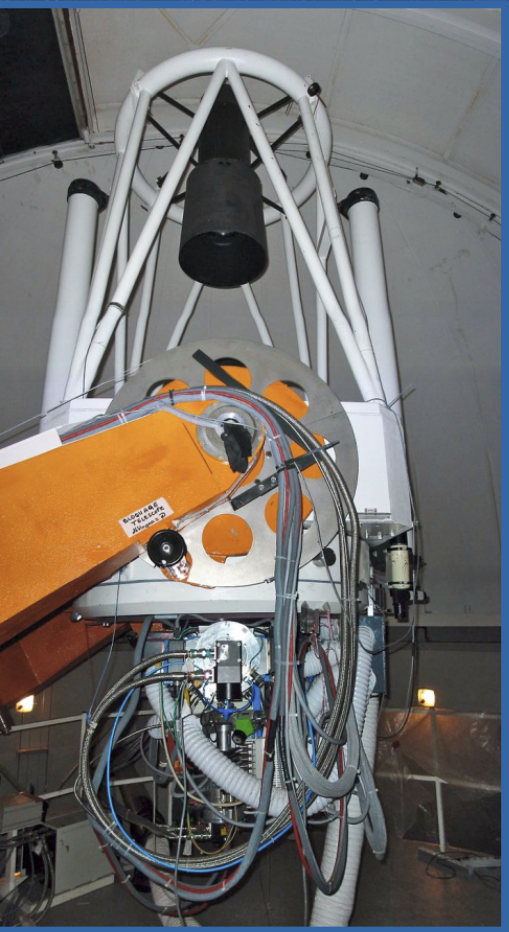
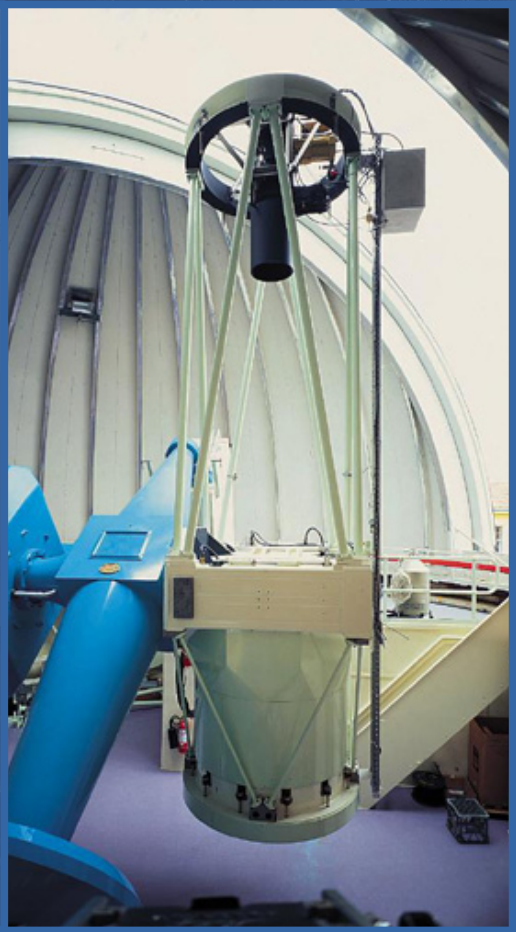
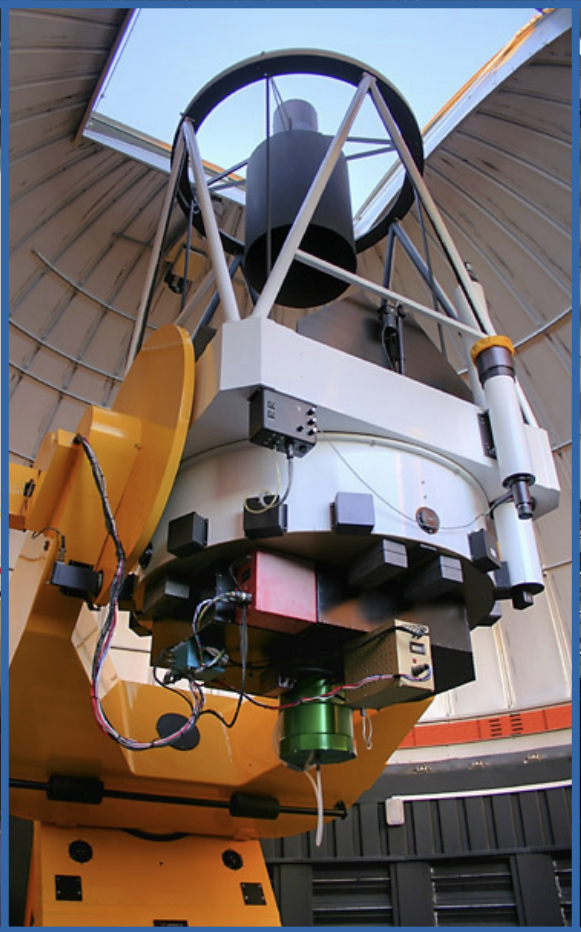
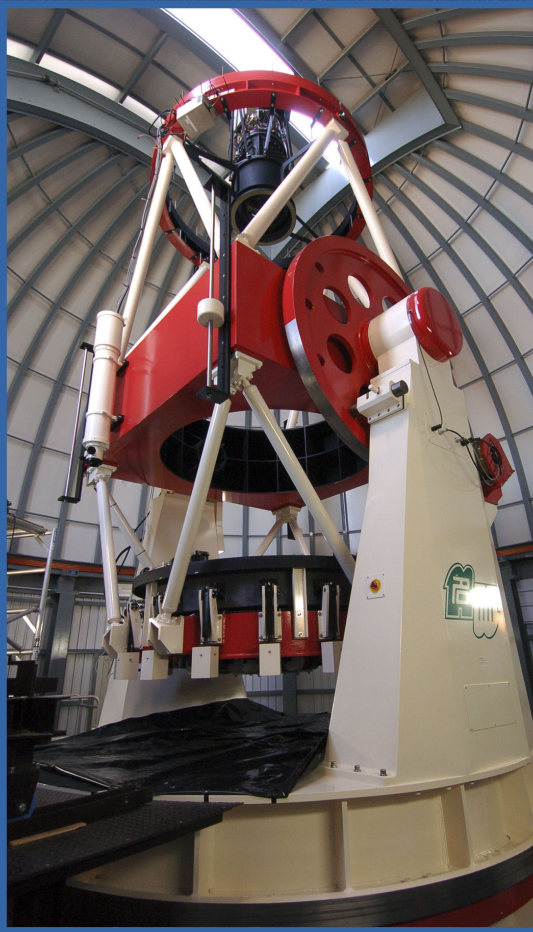
OUTLINE

CURRENT AND PAST MICROLENSING SURVEYS

VARIABLE STAR TYPES
AND WHY THEY ARE ATTRACTIVE

FUTURE MICROLENSING SURVEYS AND THEIR EXPECTED OUTCOME

CURRENT AND PAST MICROLENSING SURVEYS

EROS	MACHO	OGLE	MOA
			
1990-2003	1992-1999	1992 - …	1995 - …

CURRENT AND PAST MICROLENSING SURVEYS

	EROS	MACHO	OGLE	MOA
timespan	1990-2003	1992-1999	1992- ….	1995- ….
telescope	1 m at La Silla CHILE	1.3 m at Mount Stromlo AUSTRALIA	1.3 m at Las Campanas CHILE	1.8 m in New Zealand
targets	Galactic bulge,disk, Magellanic Clouds	Galactic bulge, Magellanic Clouds	Galactic bulge,disk, Magellanic Clouds	Galactic bulge, Magellanic Clouds
field of view	1 square degree	0.5 square degree	1.4 square degree	2.2 square degree
filters	Non-standard B, R	Non-standard B, R	**Standard V, I**	Non-standard Red
# of epochs	250-500	1000	50-12000	1000-6000
# of variable stars	**55 285**	**25 000**	**953 107**	**9 000**

Dorota Skowron, Warsaw University Observatory, dszczyg@astrouw.edu.pl

OGLE SKY COVERAGE

OGLE-IV phase since 2010

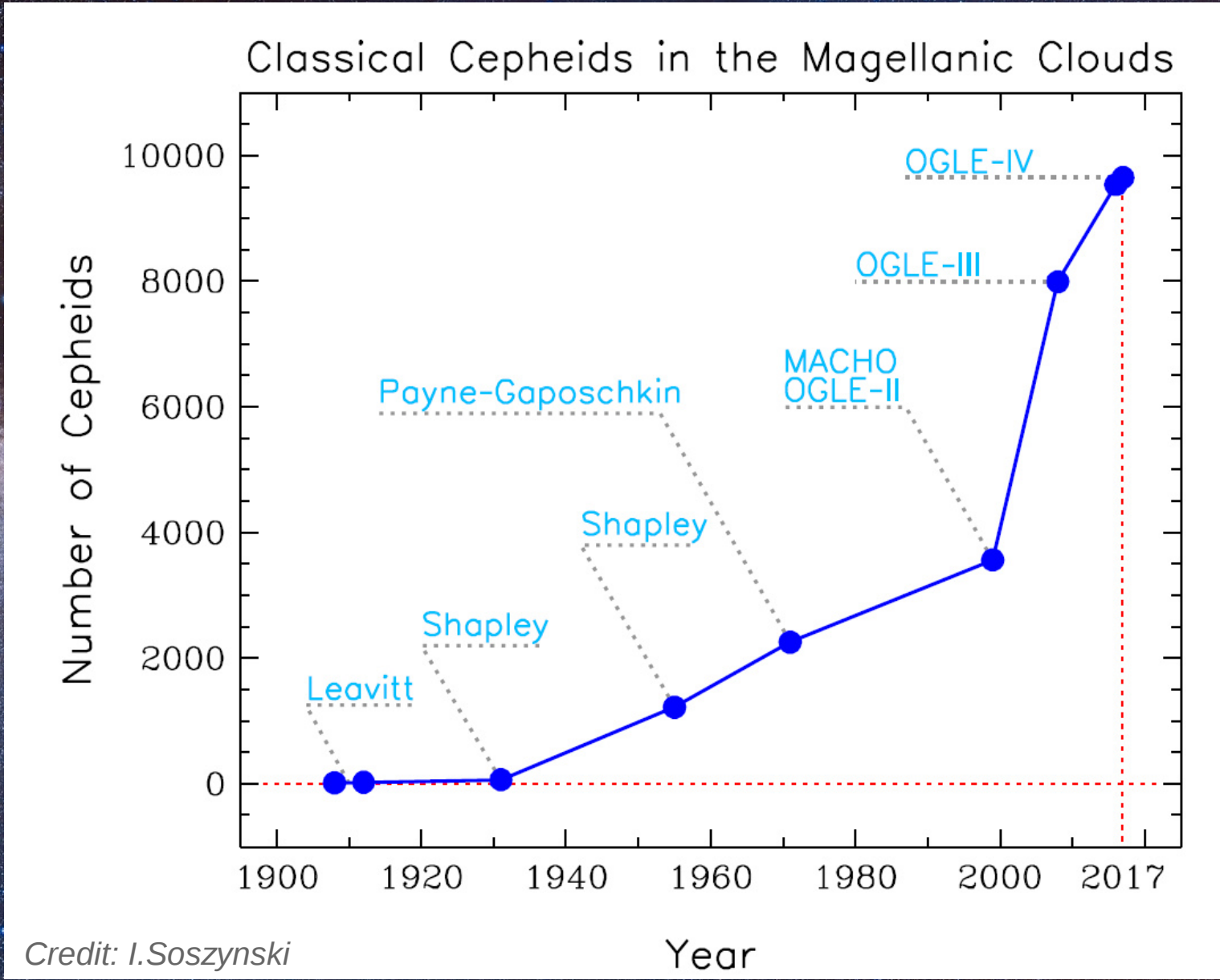
3500 square degrees

1.3 billion sources each night

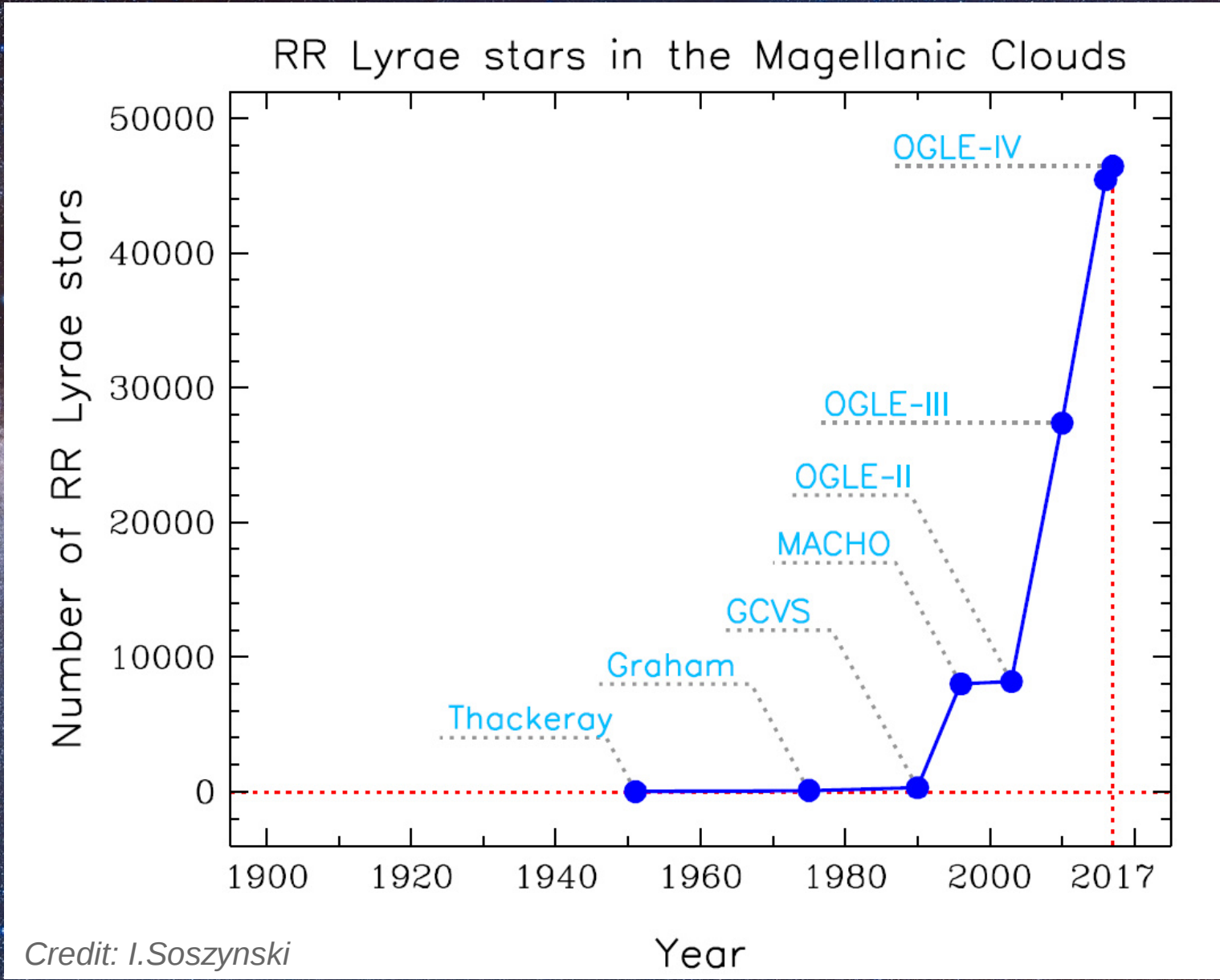
10^12 photometric measurements so far

Credit: J.Skowron

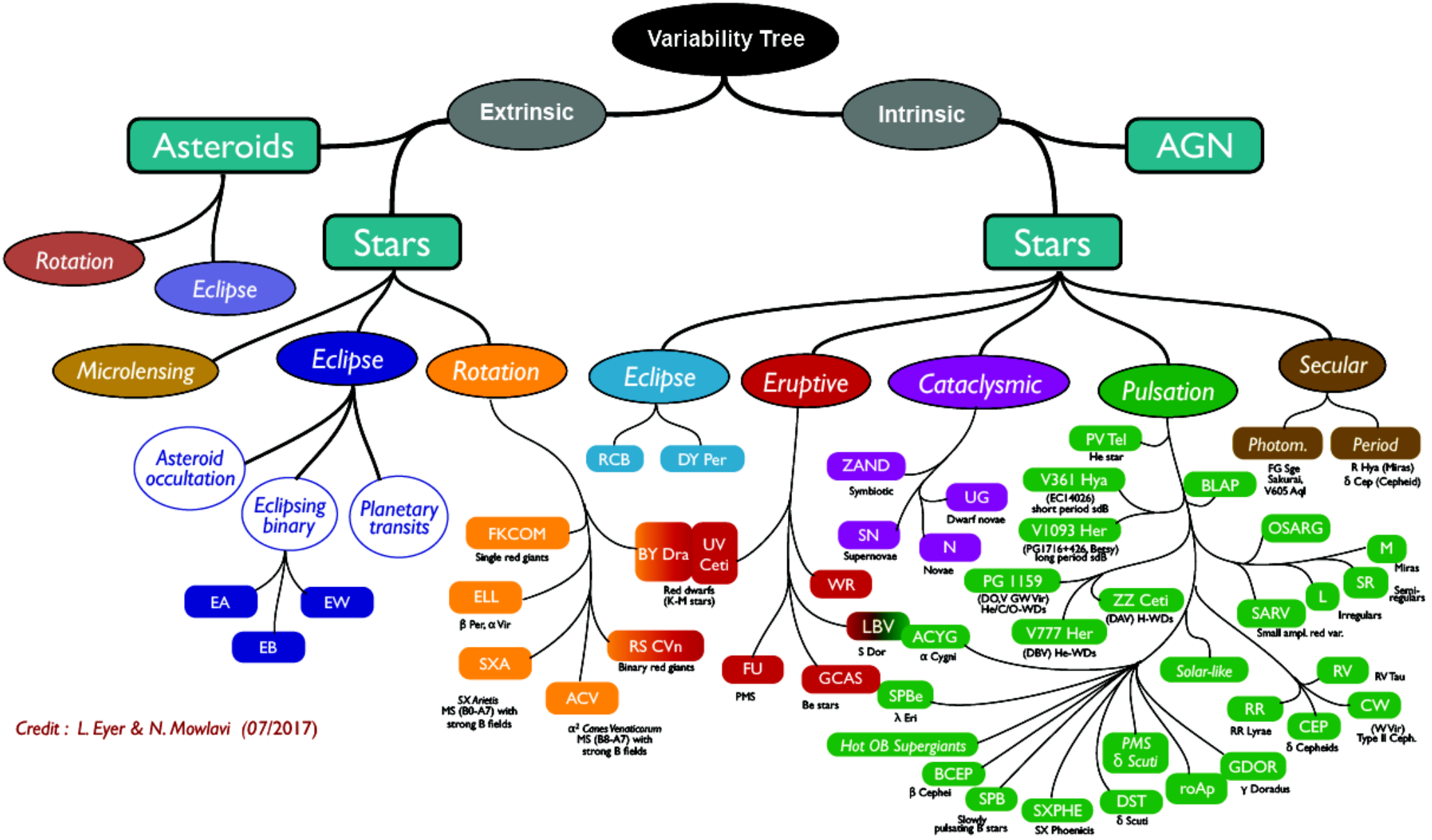
CURRENT AND PAST MICROLENSING SURVEYS



CURRENT AND PAST MICROLENSING SURVEYS

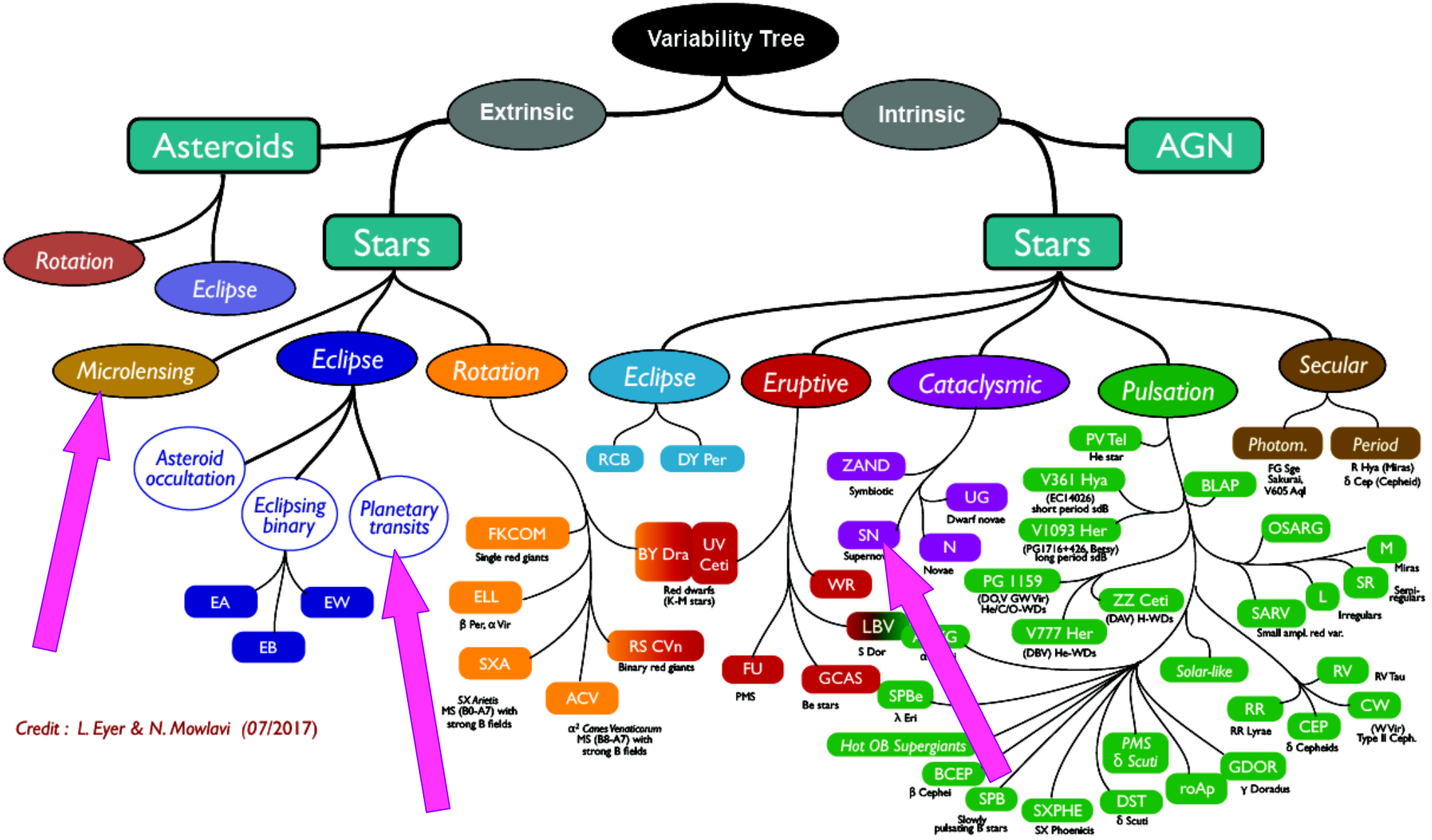


VARIABLE STAR TYPES



Credit : L. Eyer & N. Mowlavi (07/2017)

VARIABLE STAR TYPES



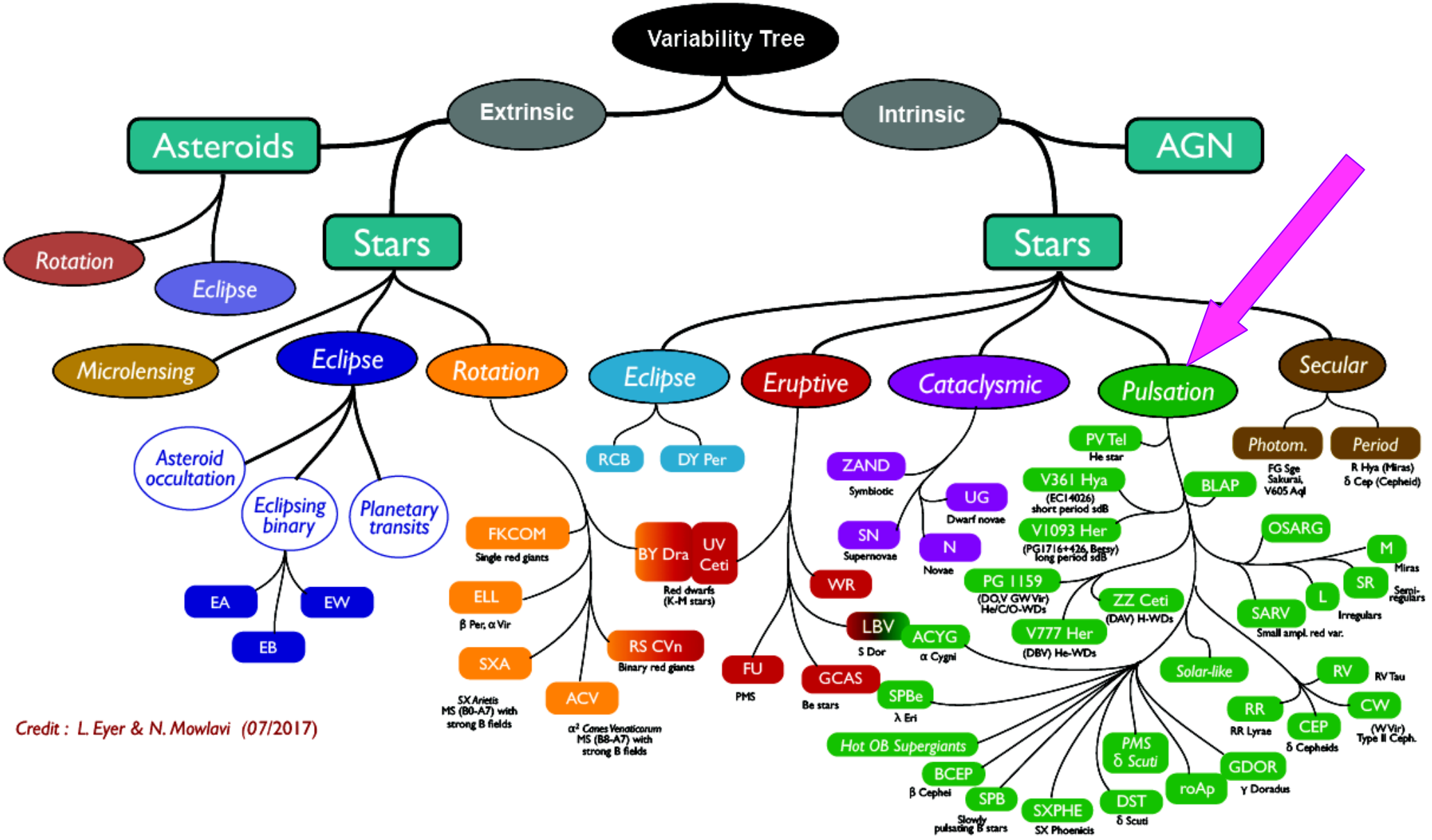
Credit : L. Eyer & N. Mowlavi (07/2017)

VARIABLE STARS – APPLICATIONS

LARGE SAMPLES OF VARIABLE STARS ALLOW US TO:

- investigate statistical and physical properties of stars
- study the structure and evolution of galaxies
- discover new objects and phenomena

VARIABLE STAR TYPES

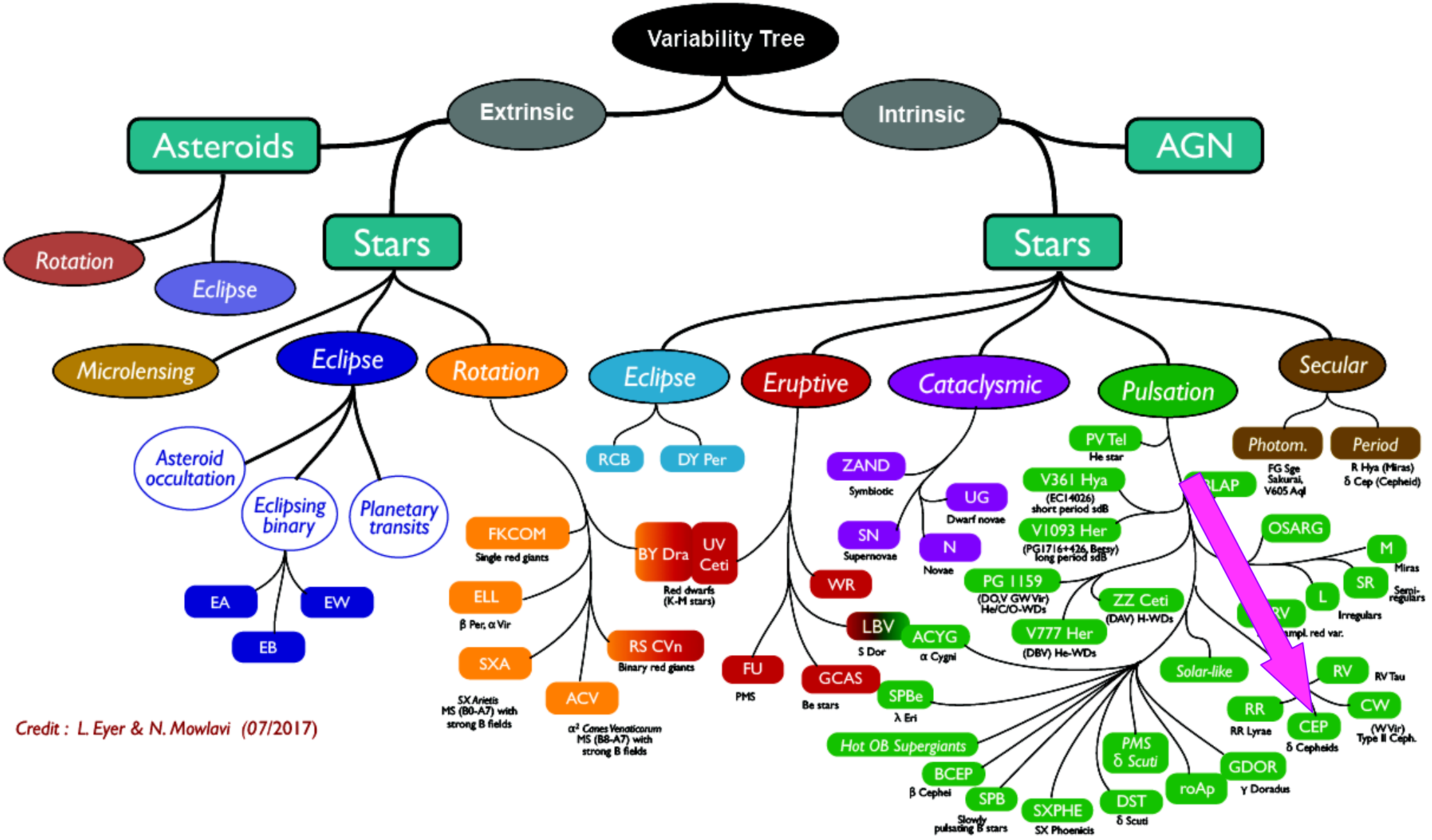


Credit : L. Eyer & N. Mowlavi (07/2017)

CLASSICAL PULSATING STARS

- Classical Cepheids (type I Cepheids or δ Cephei stars) and RR Lyrae type stars
- important distance indicators (the cosmic distance ladder)
- constrain stellar evolution and pulsation models
- tracers of the young (Cepheids) and old (RR Lyrae) stellar populations, used for galaxy structure and evolution studies

CLASSICAL CEPHEIDS



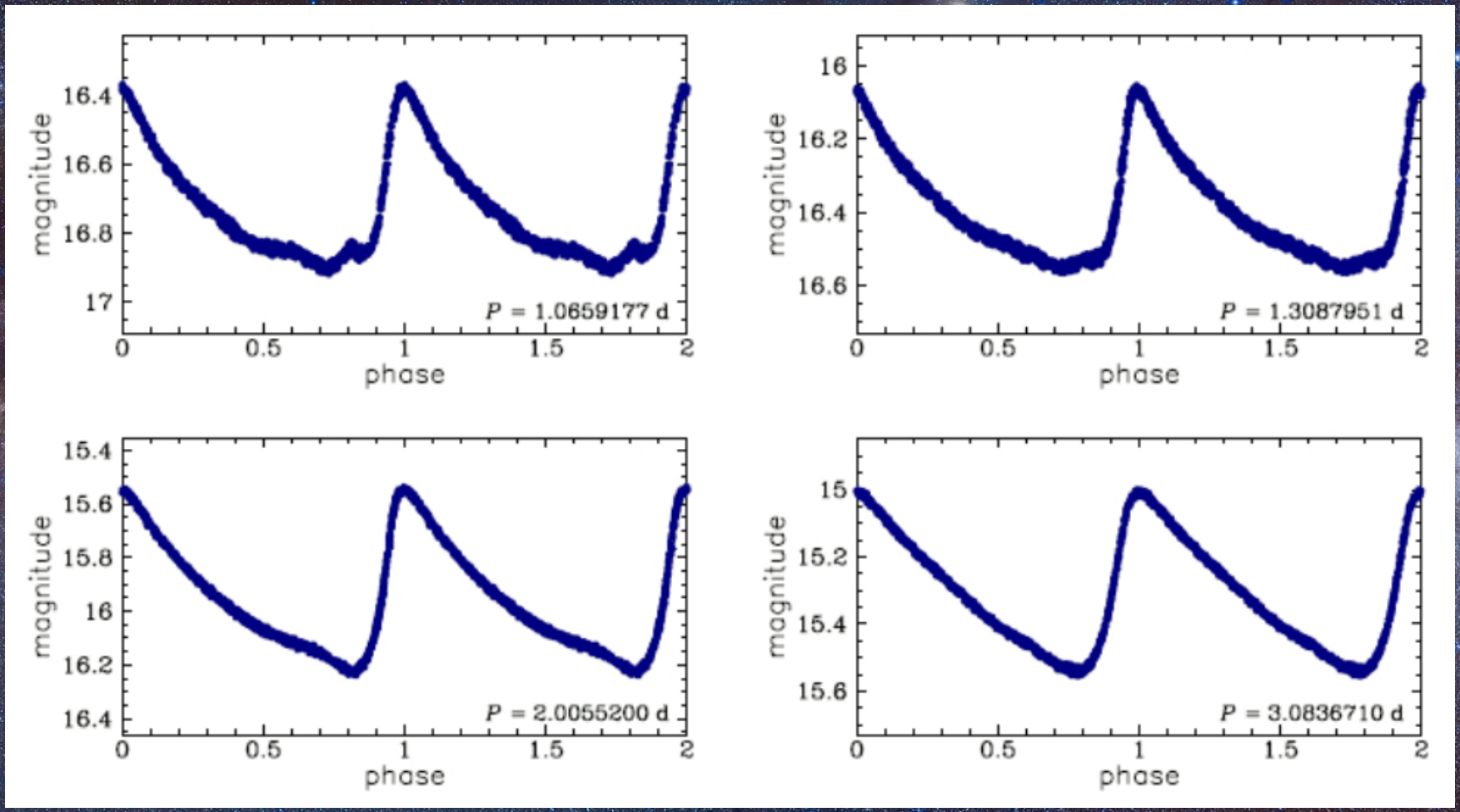
Credit : L. Eyer & N. Mowlavi (07/2017)

CLASSICAL CEPHEIDS

- relatively young and massive (yellow giants or supergiants with 5-20 $M_{\odot}$)
- pulsate radially, with periods from 1 to 200 days, typically a few days
- luminous – easy to locate in nearby galaxies
- tracers of the young stellar populations

CLASSICAL CEPHEIDS

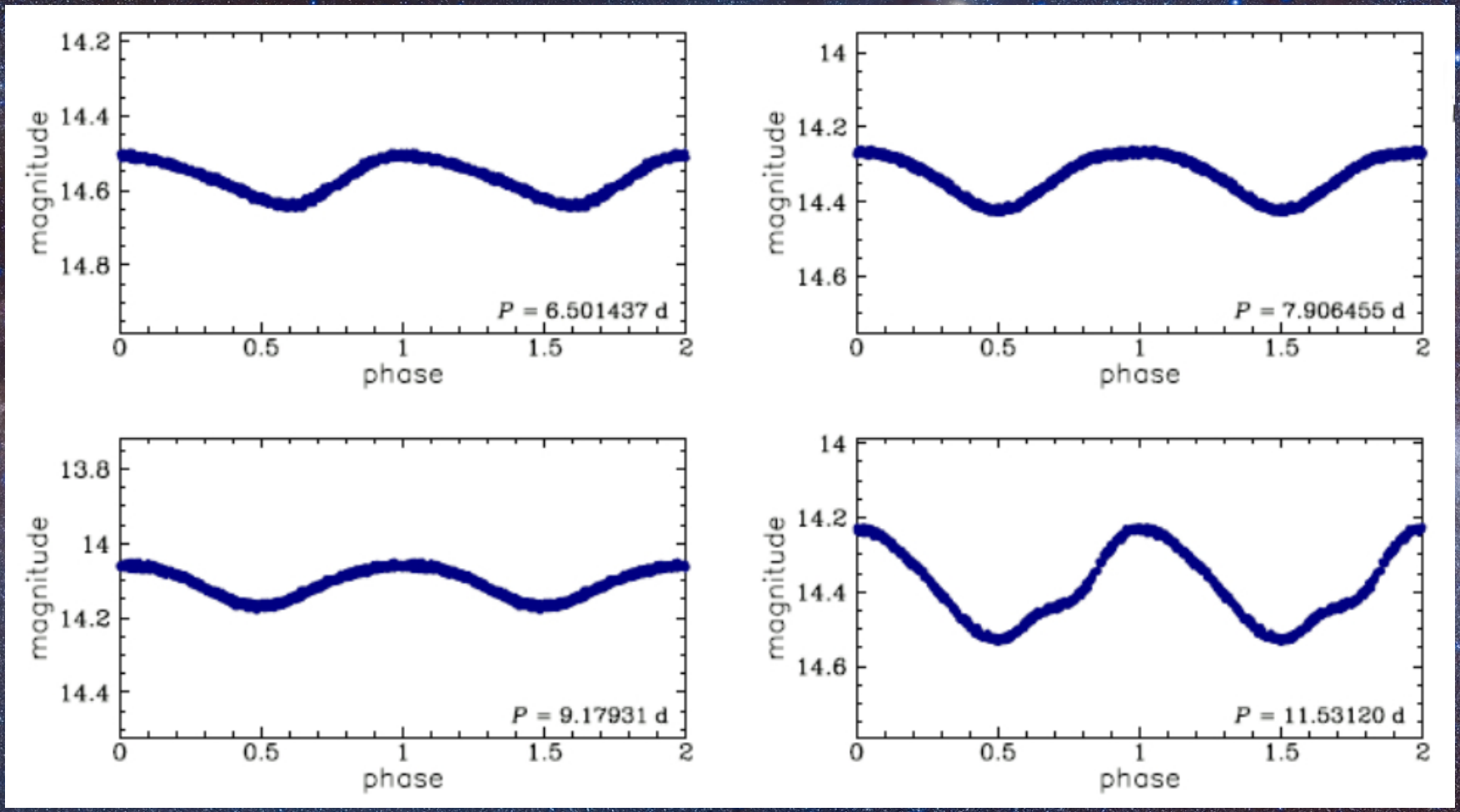
FUNDAMENTAL MODE



http://ogle.astrouw.edu.pl/atlas/

CLASSICAL CEPHEIDS

FIRST OVERTONE



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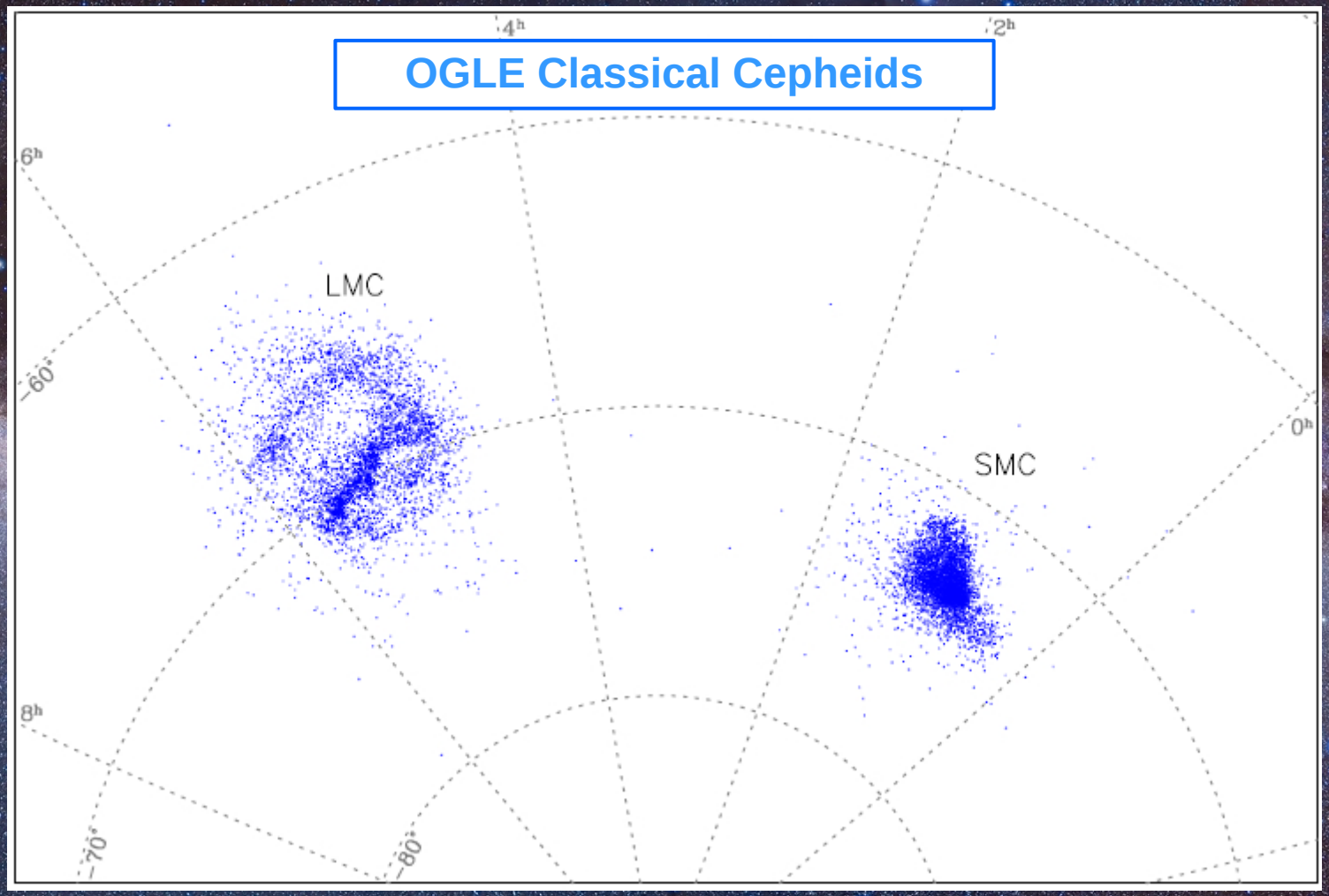
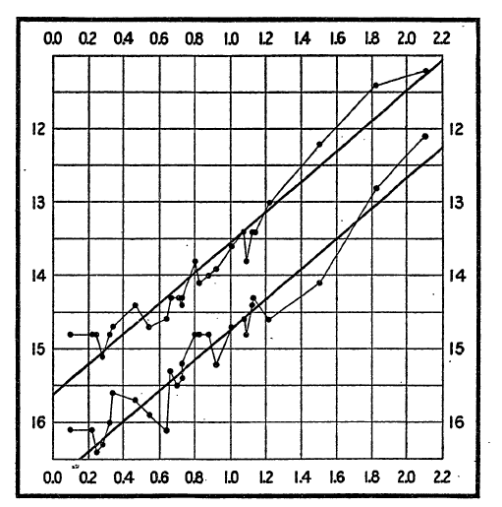
CLASSICAL CEPHEIDS IN THE MAGELLANIC SYSTEM



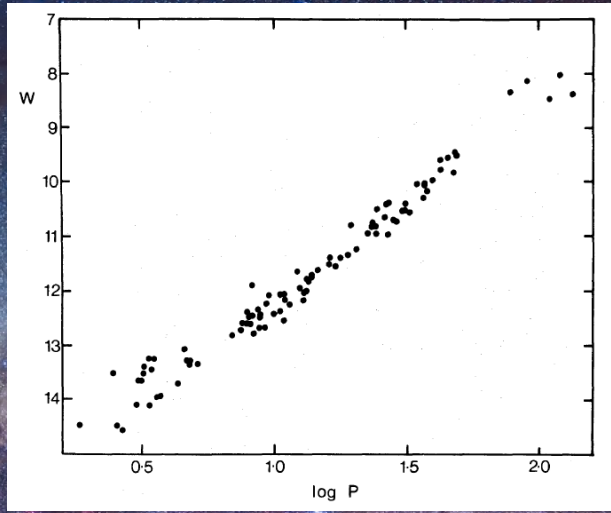
Soszynski et al. (2015)

CLASSICAL CEPHEIDS – PL RELATIONS

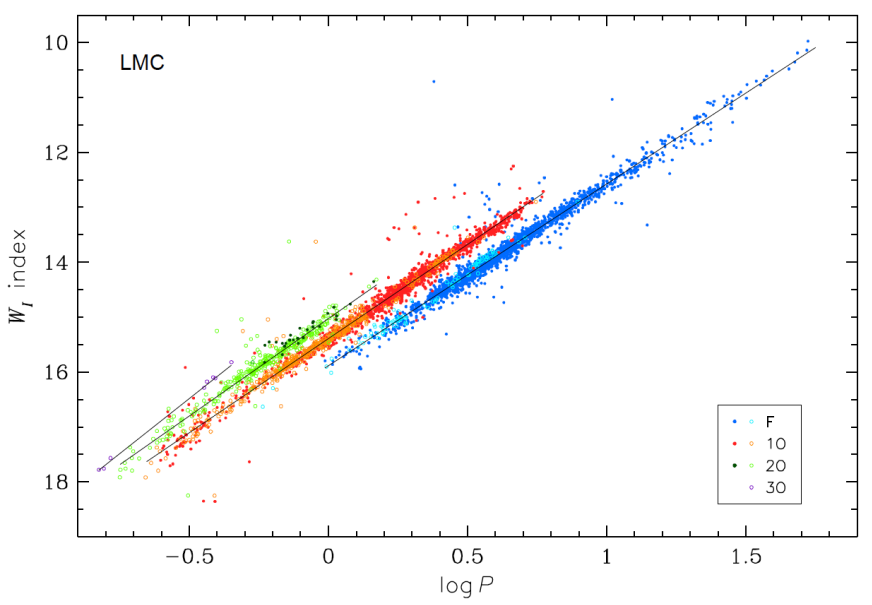
Leavitt (1912)



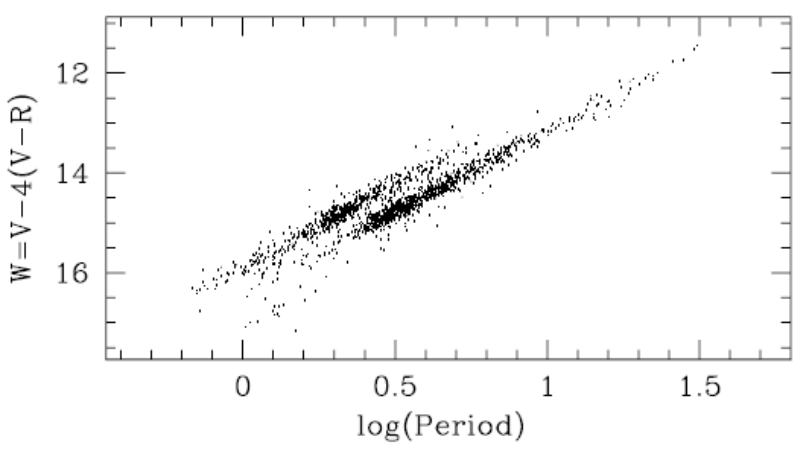
Madore (1982)



Soszynski et al. (2015)

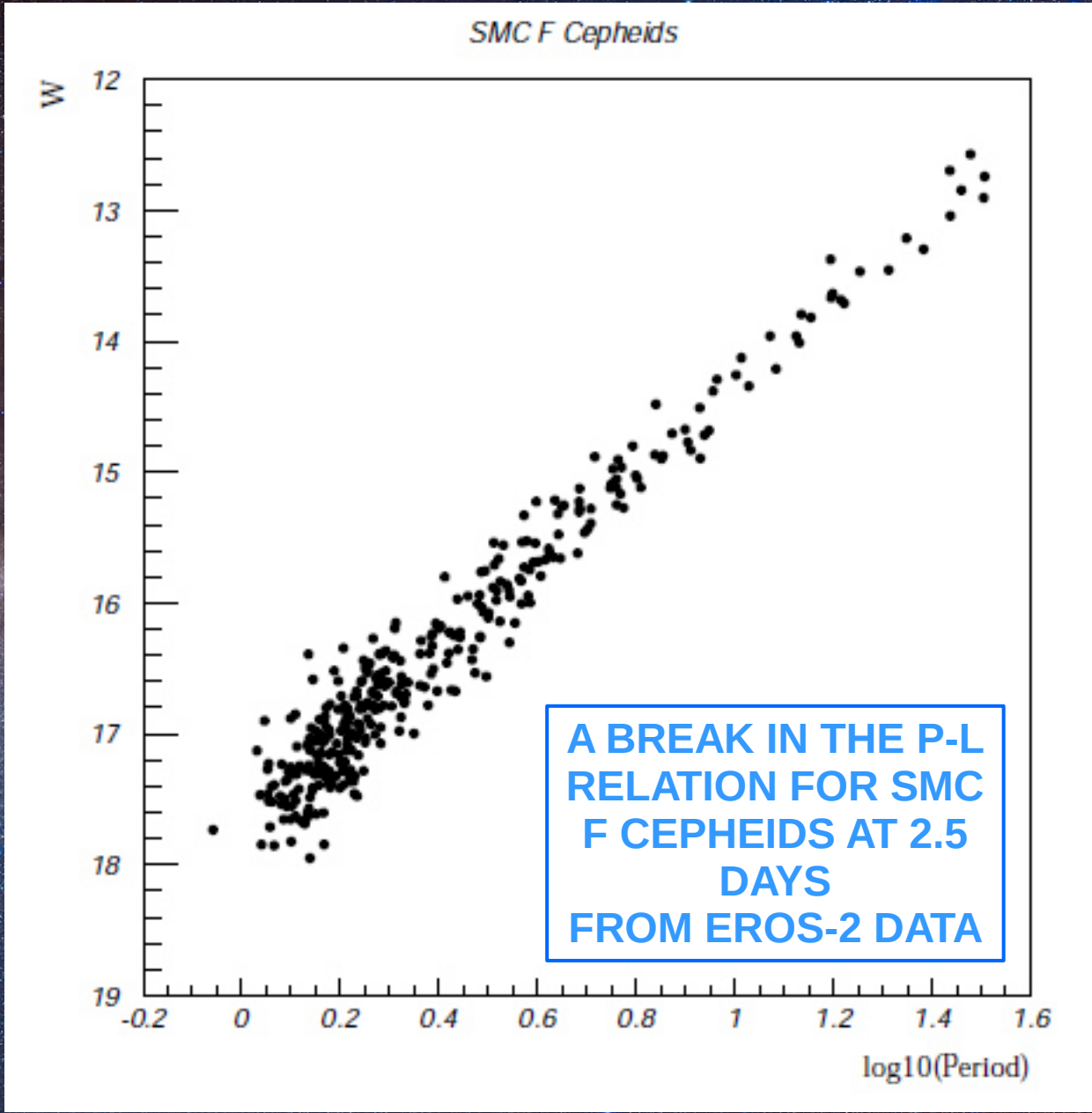


Alcock et al. (1999)



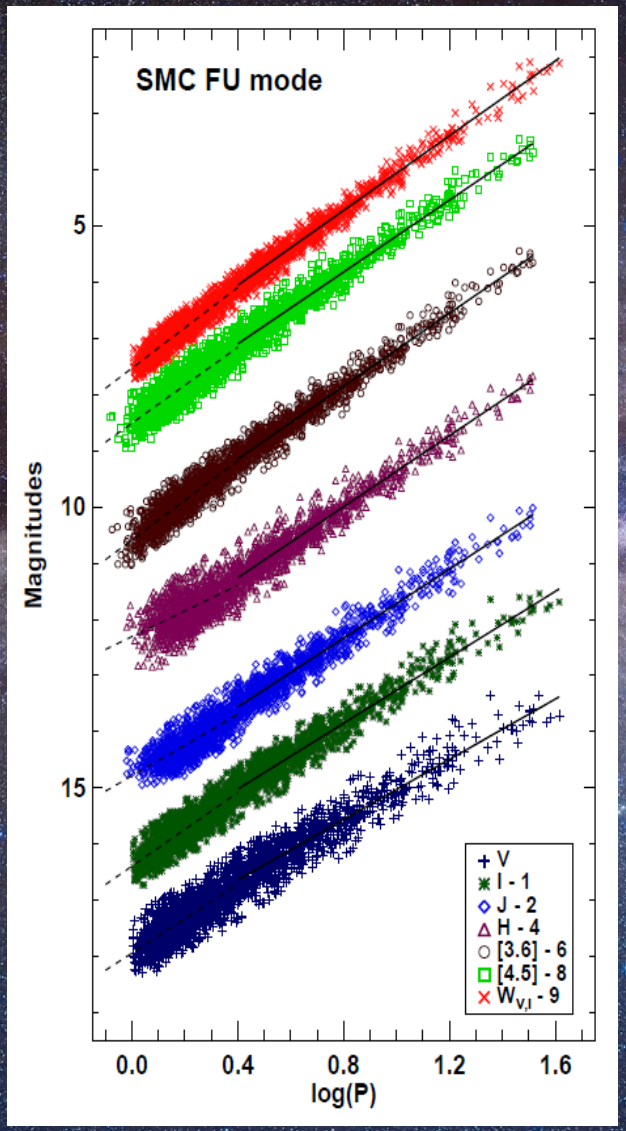
Credit: I.Soszynski

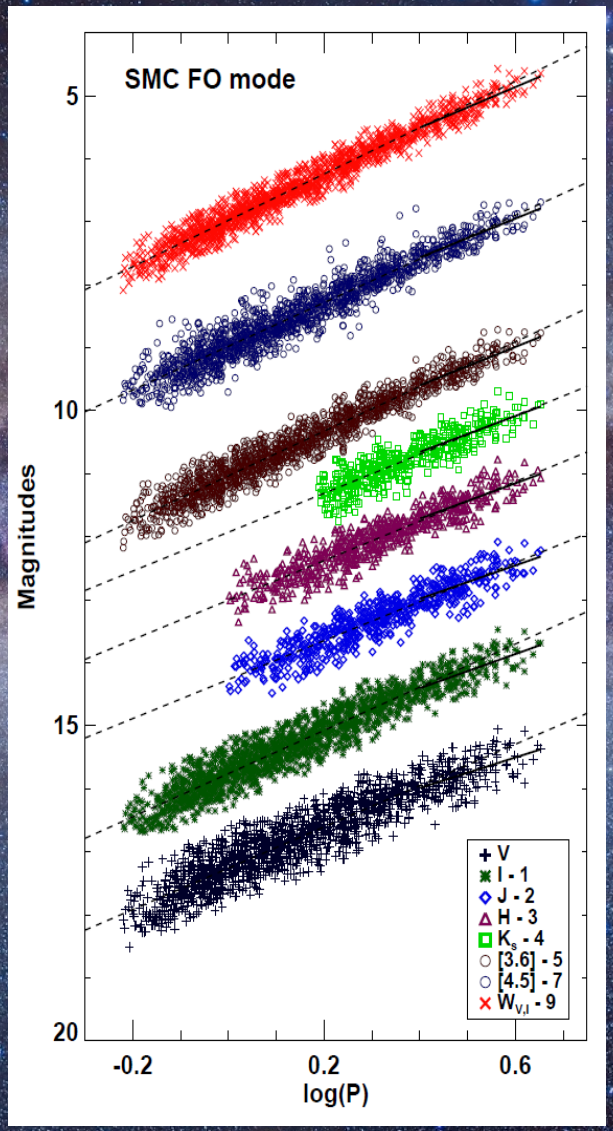
CLASSICAL CEPHEIDS – PL RELATIONS



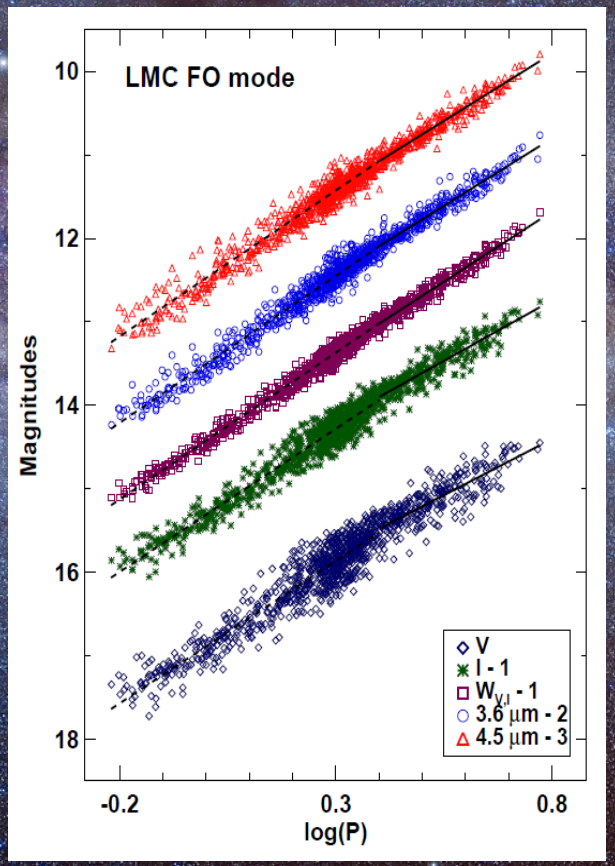
Bauer et al. (1999)

CLASSICAL CEPHEIDS – PL RELATIONS



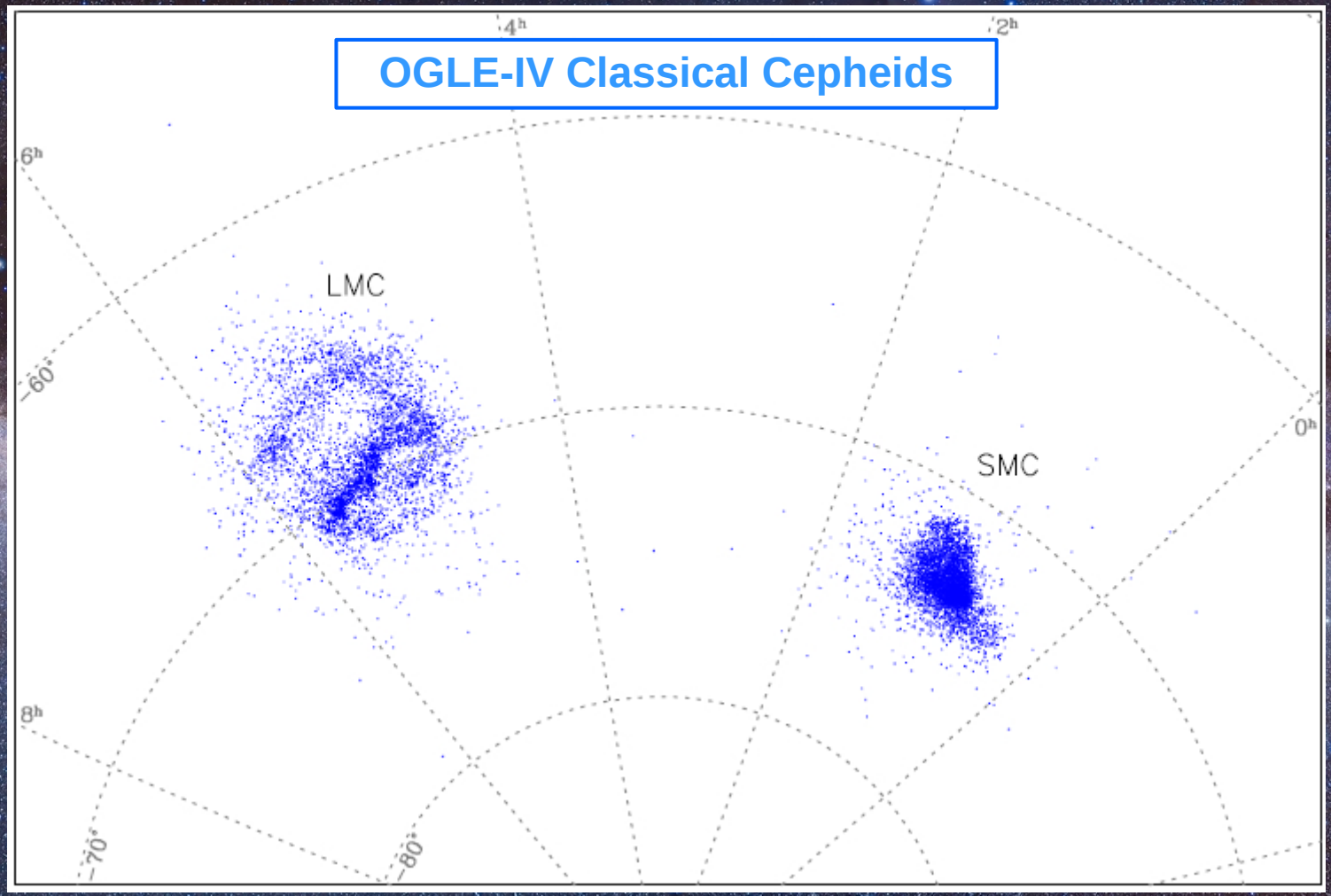


TESTS OF P-L RELATIONS IN THE MAGELLANIC CLOUDS



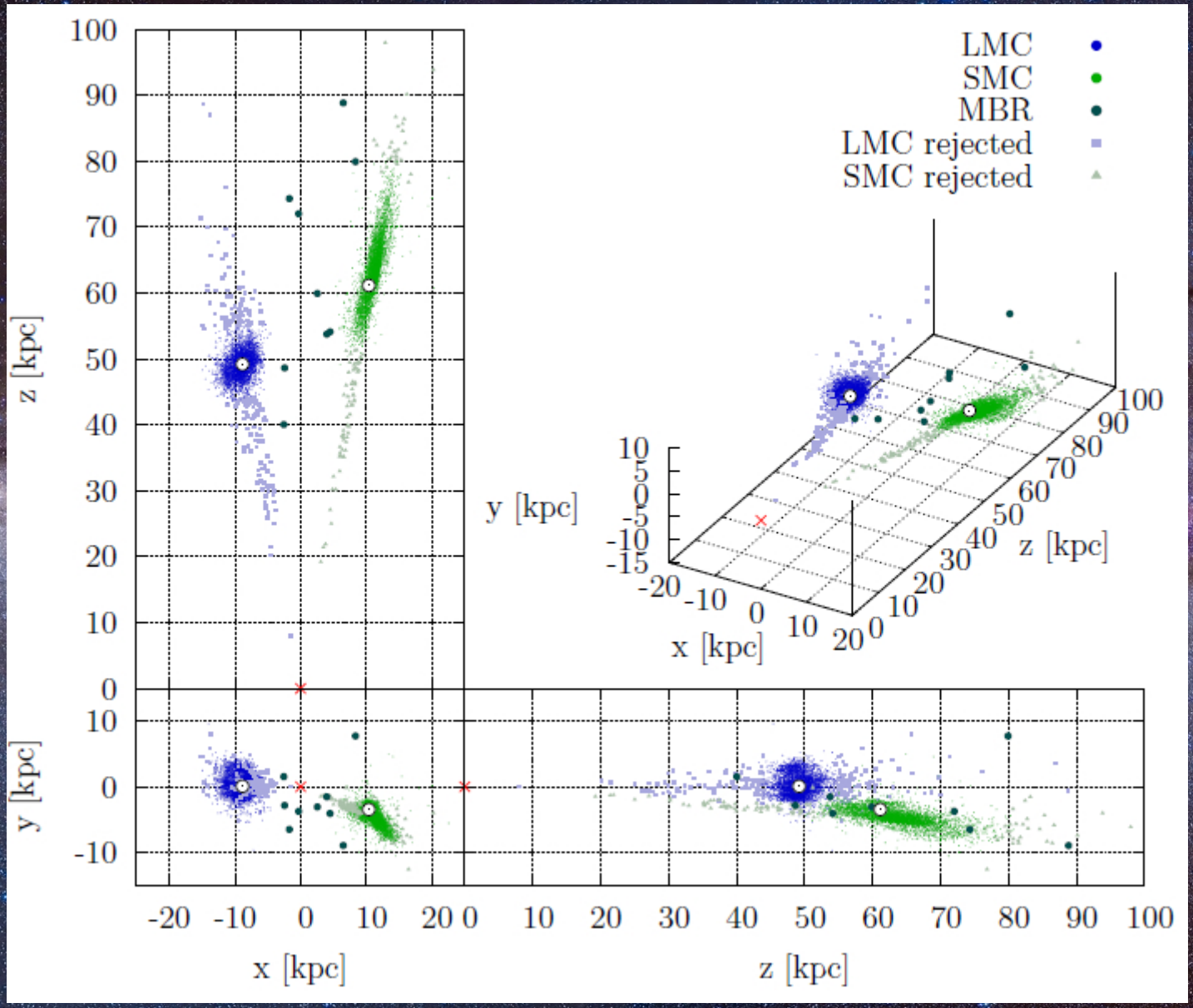
Bhardwaj et al. (2016)

CLASSICAL CEPHEIDS IN THE MAGELLANIC SYSTEM



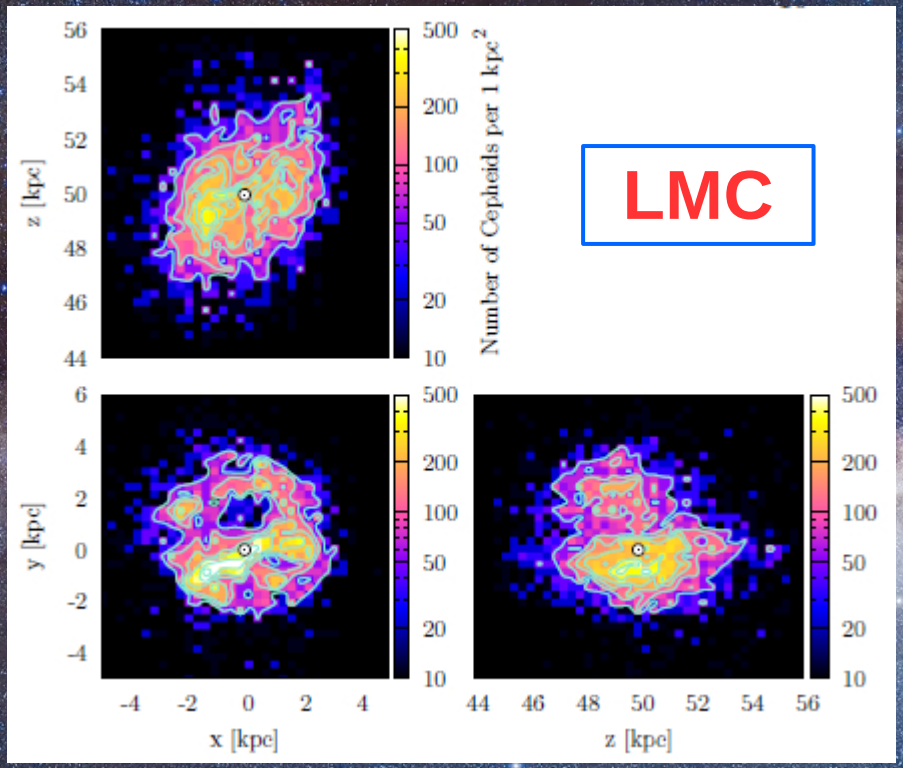
Soszynski et al. (2015)

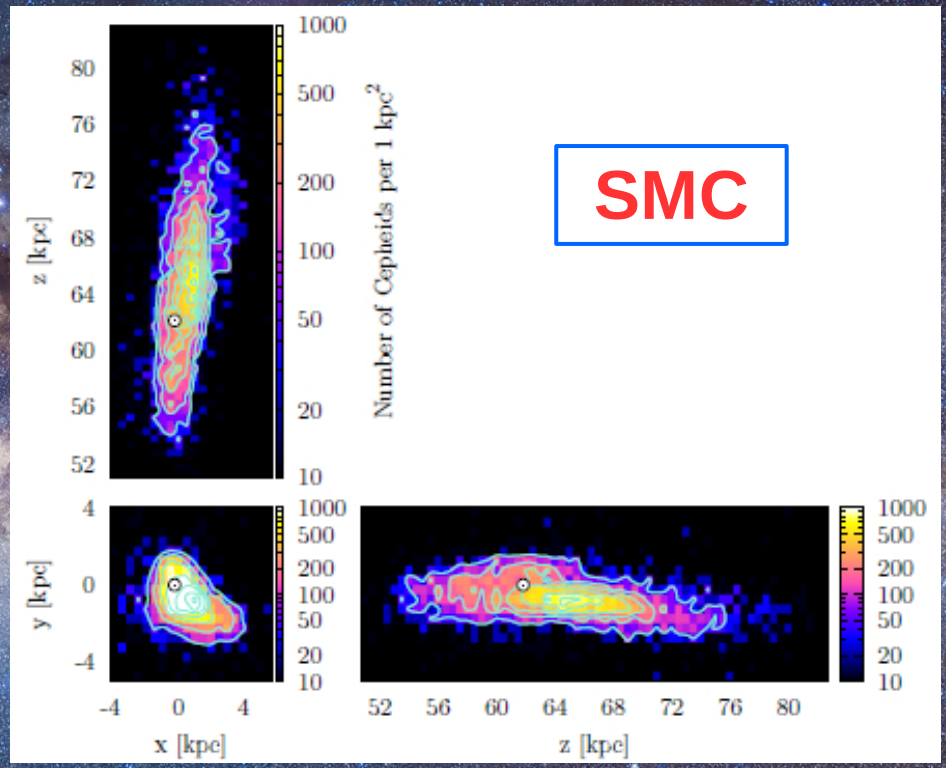
CLASSICAL CEPHEIDS IN THE MAGELLANIC SYSTEM



Jacyszyn-Dobrzeniecka et al. (2016)

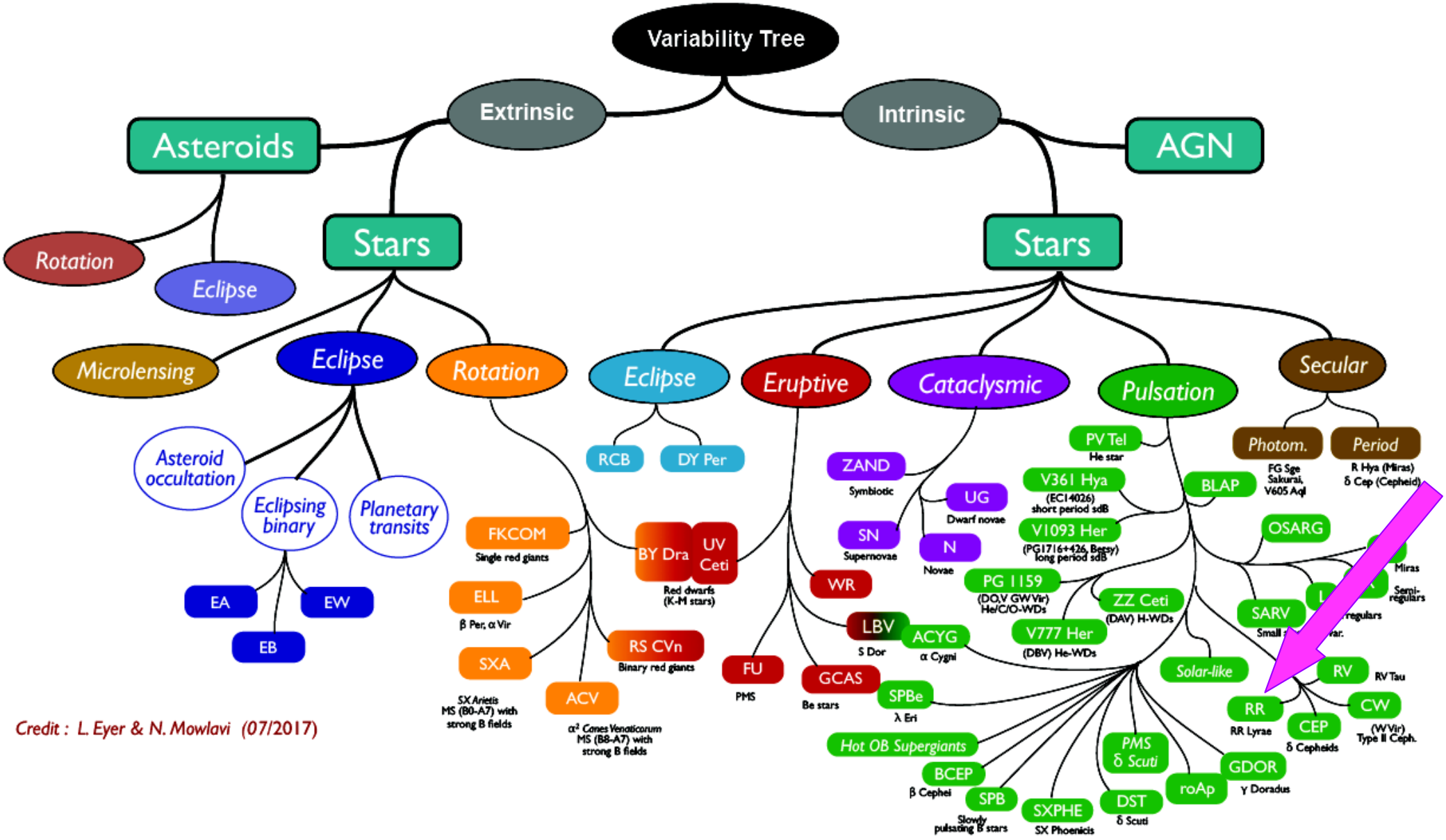
CLASSICAL CEPHEIDS IN THE MAGELLANIC SYSTEM





Jacyszyn-Dobrzeniecka et al. (2016)

VARIABLE STAR TYPES

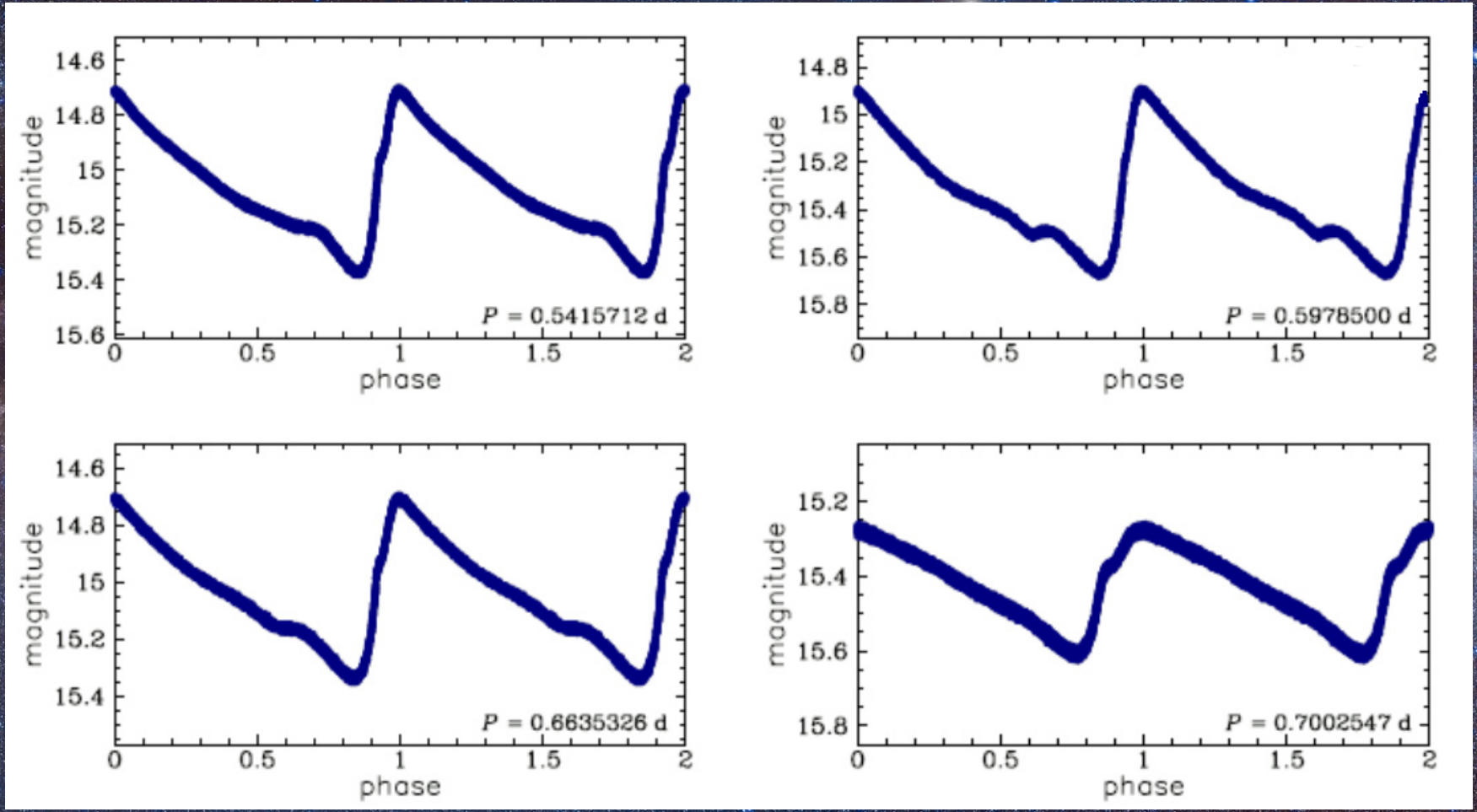


RR LYRAE STARS

- old (>10 Gyr), low mass stars, that populate galactic halos, thick disks and globular clusters
- pulsate radially, with periods from 0.2 to 1 days
- small magnitude range – good standard candles
- tracers of the chemical and dynamical properties of the oldest observable population of stars (give insight into the earliest history of galaxies)

RR LYRAE STARS

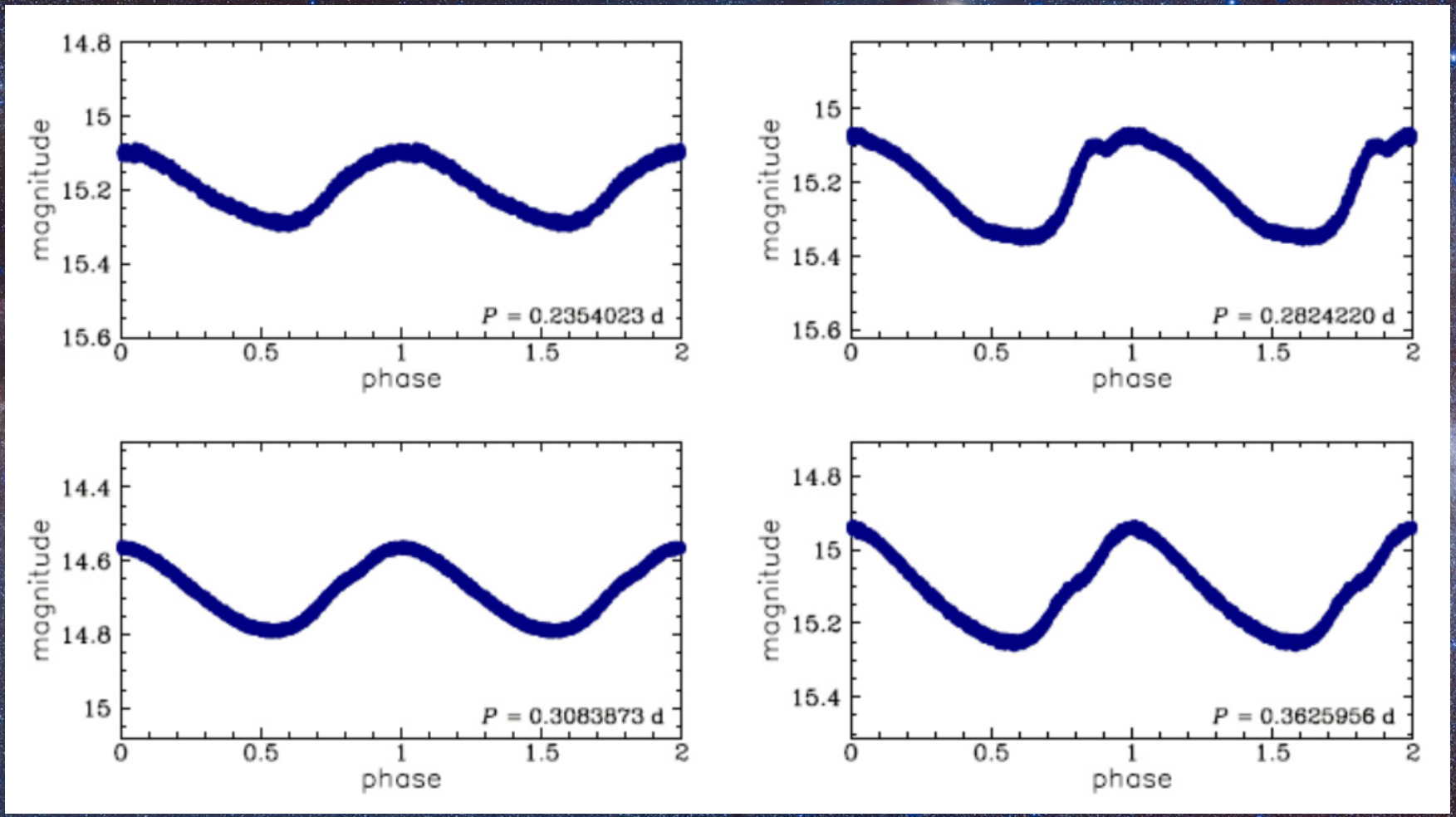
FUNDAMENTAL MODE



http://ogle.astrouw.edu.pl/atlas/

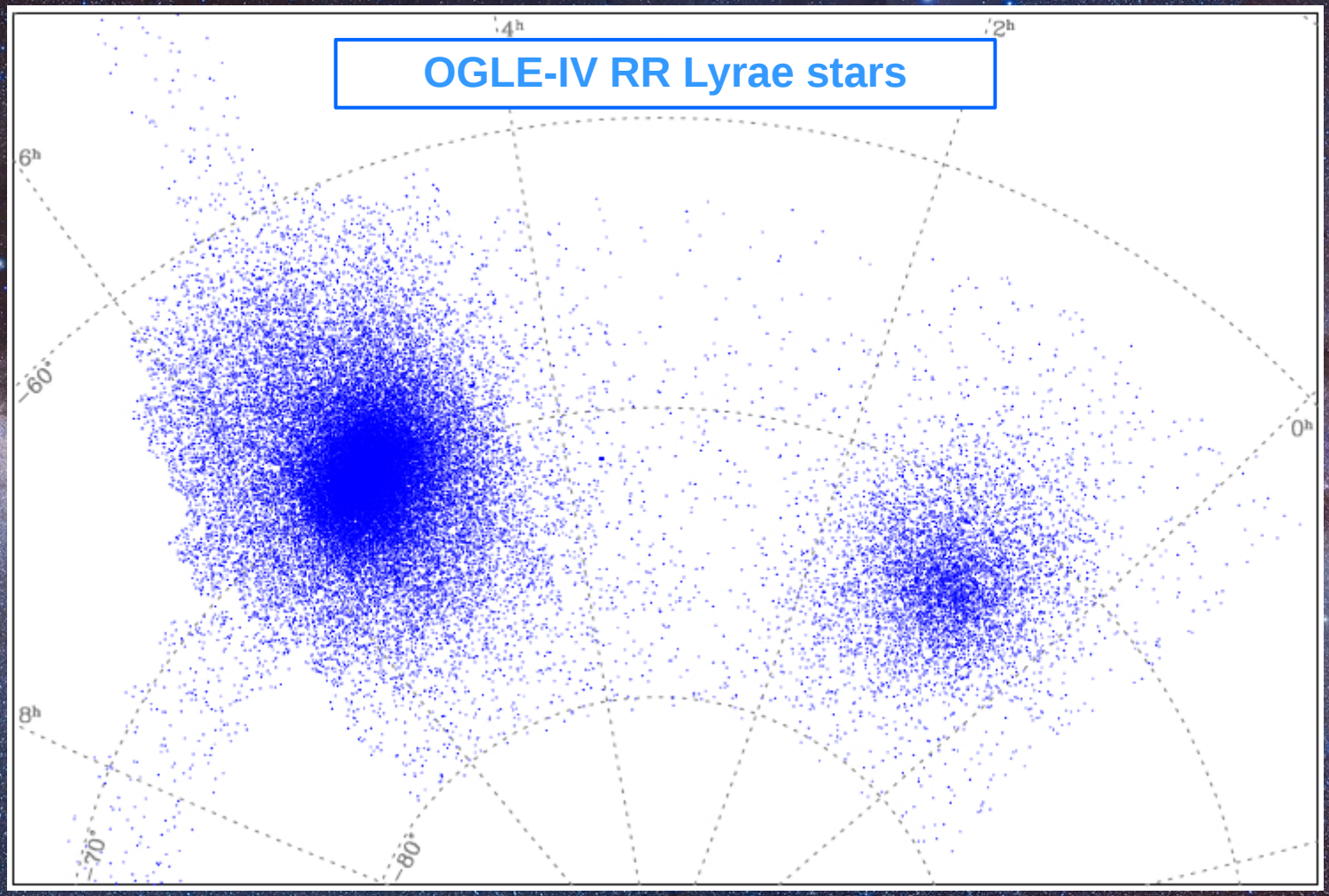
RR LYRAE STARS

FIRST OVERTONE



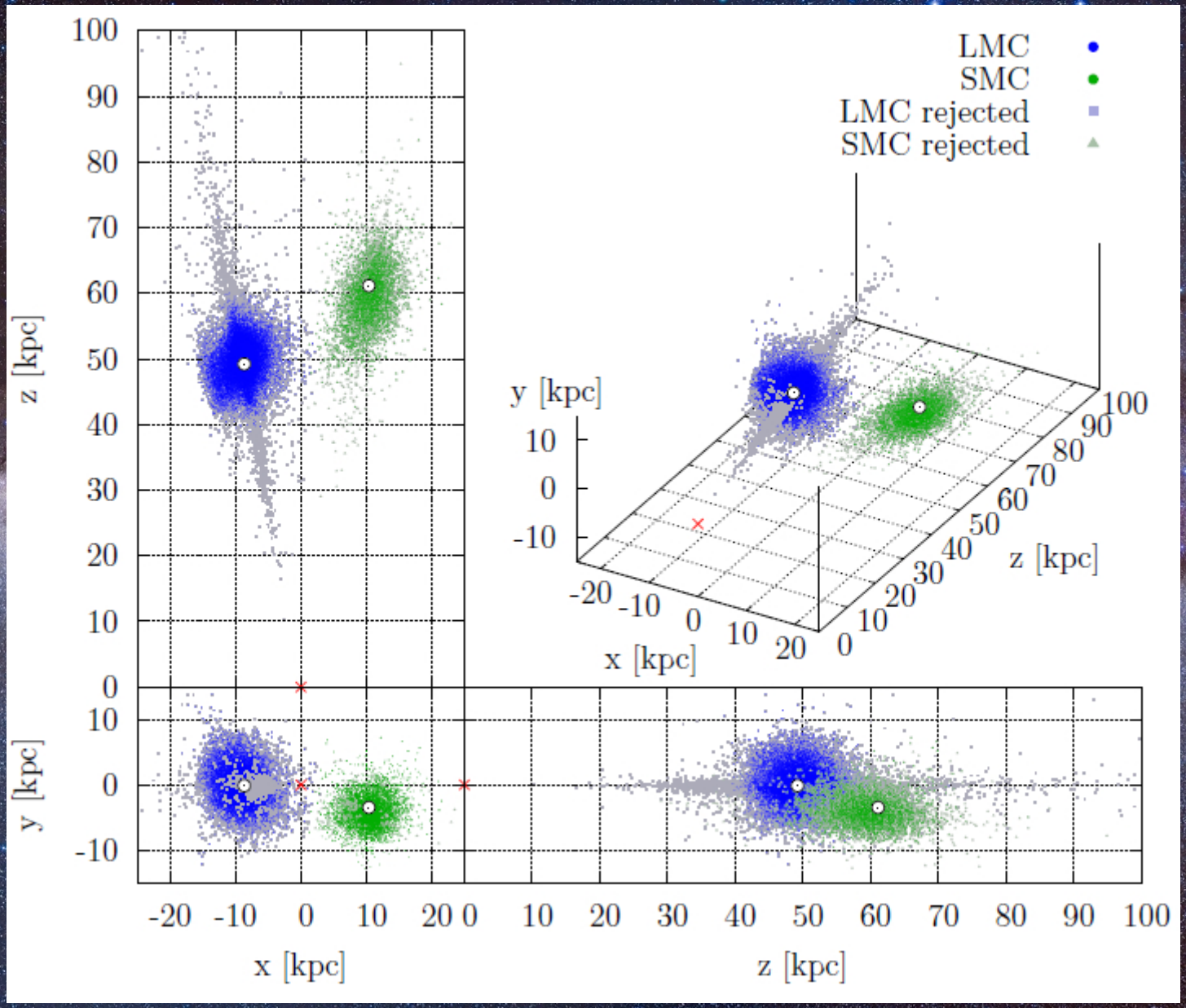
http://ogle.astrouw.edu.pl/atlas/

RR LYRAE STARS IN THE MAGELLANIC SYSTEM



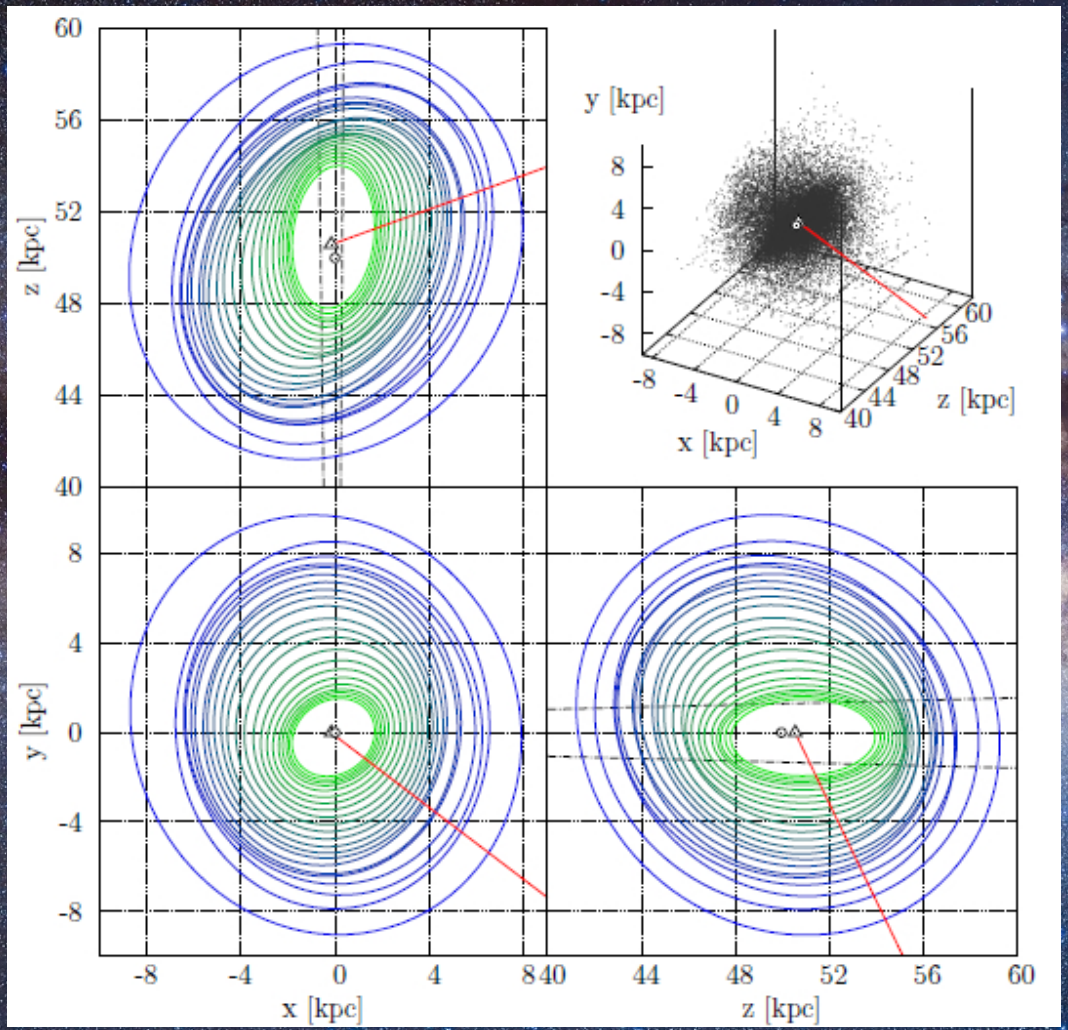
Soszynski et al. (2016)

RR LYRAE STARS IN THE MAGELLANIC SYSTEM

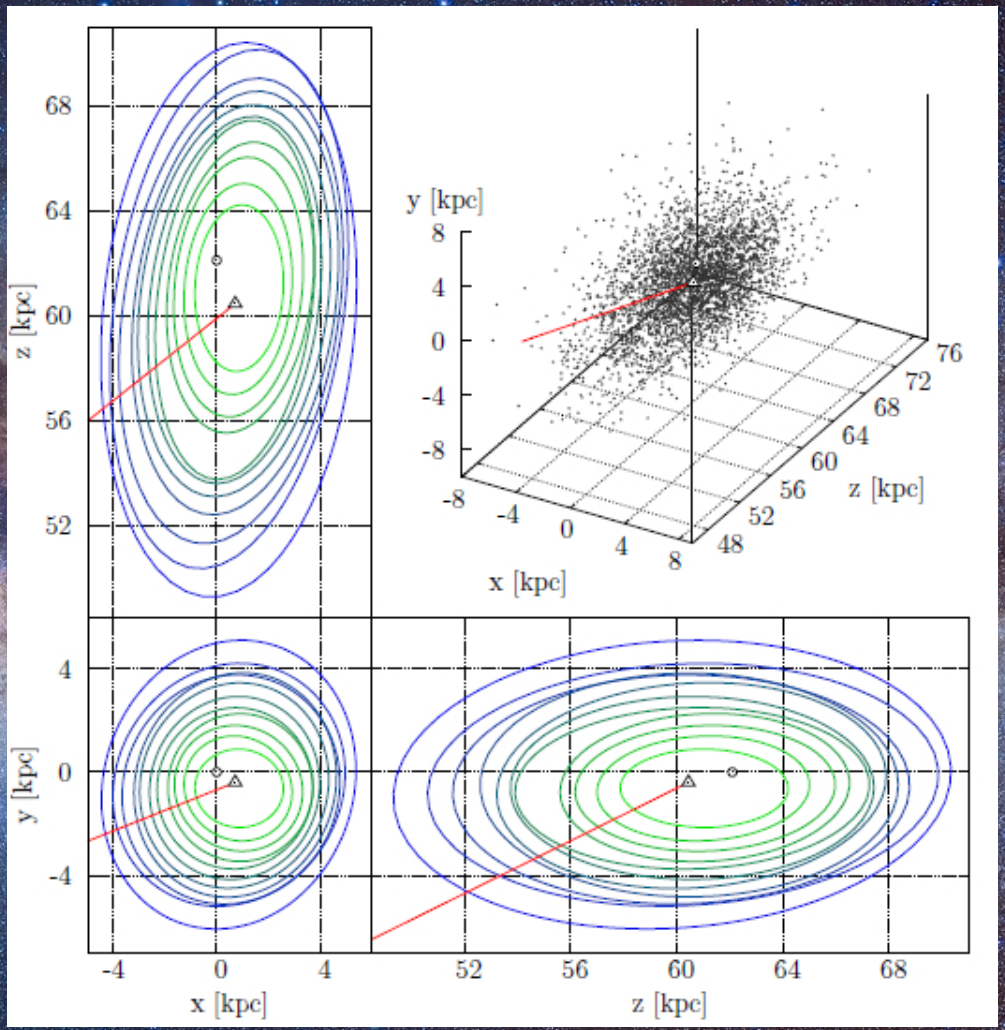


Jacyszyn-Dobrzeniecka et al. (2017)

RR LYRAE STARS IN THE MAGELLANIC SYSTEM



LMC

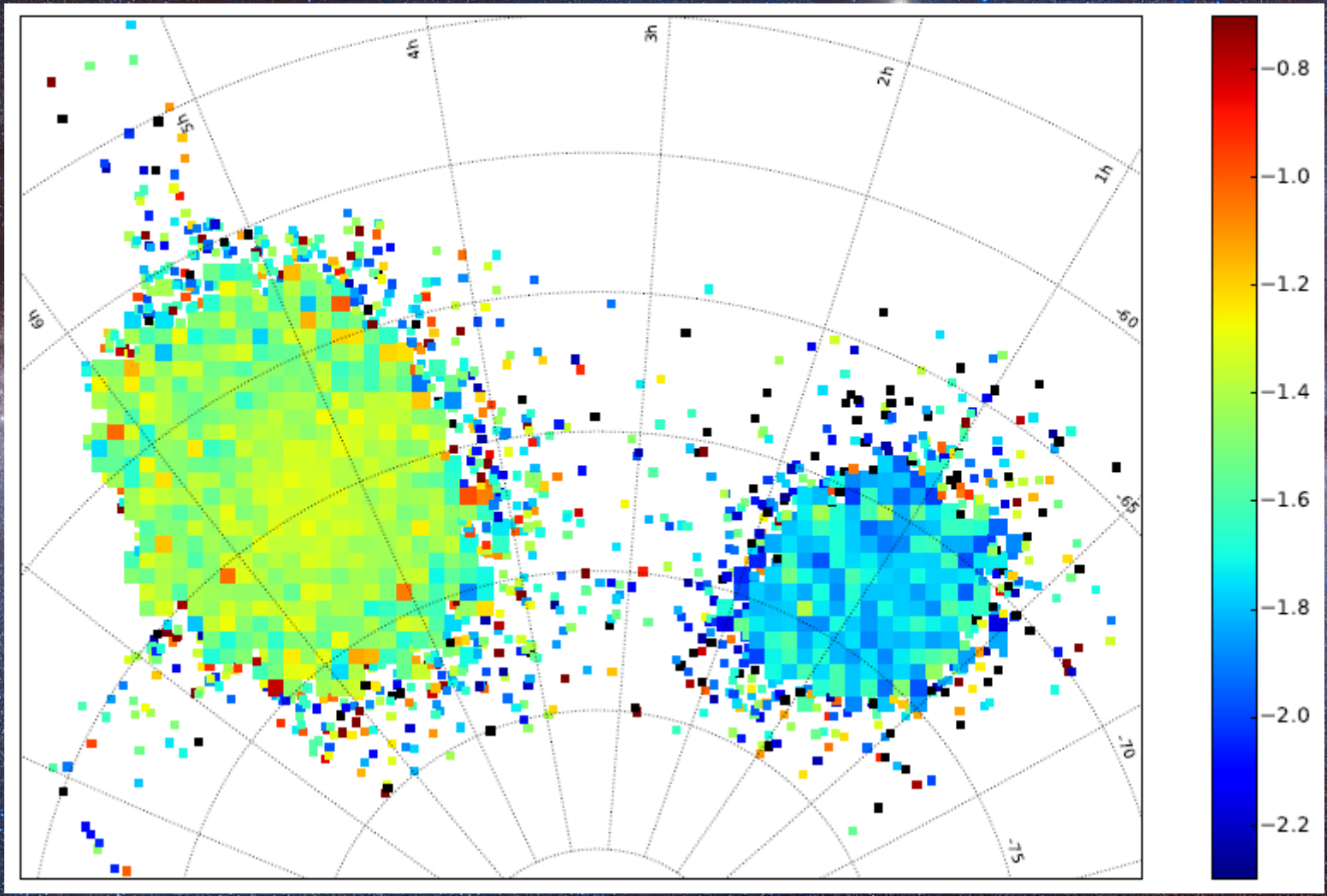


SMC

Jacyszyn-Dobrzeniecka et al. (2017)

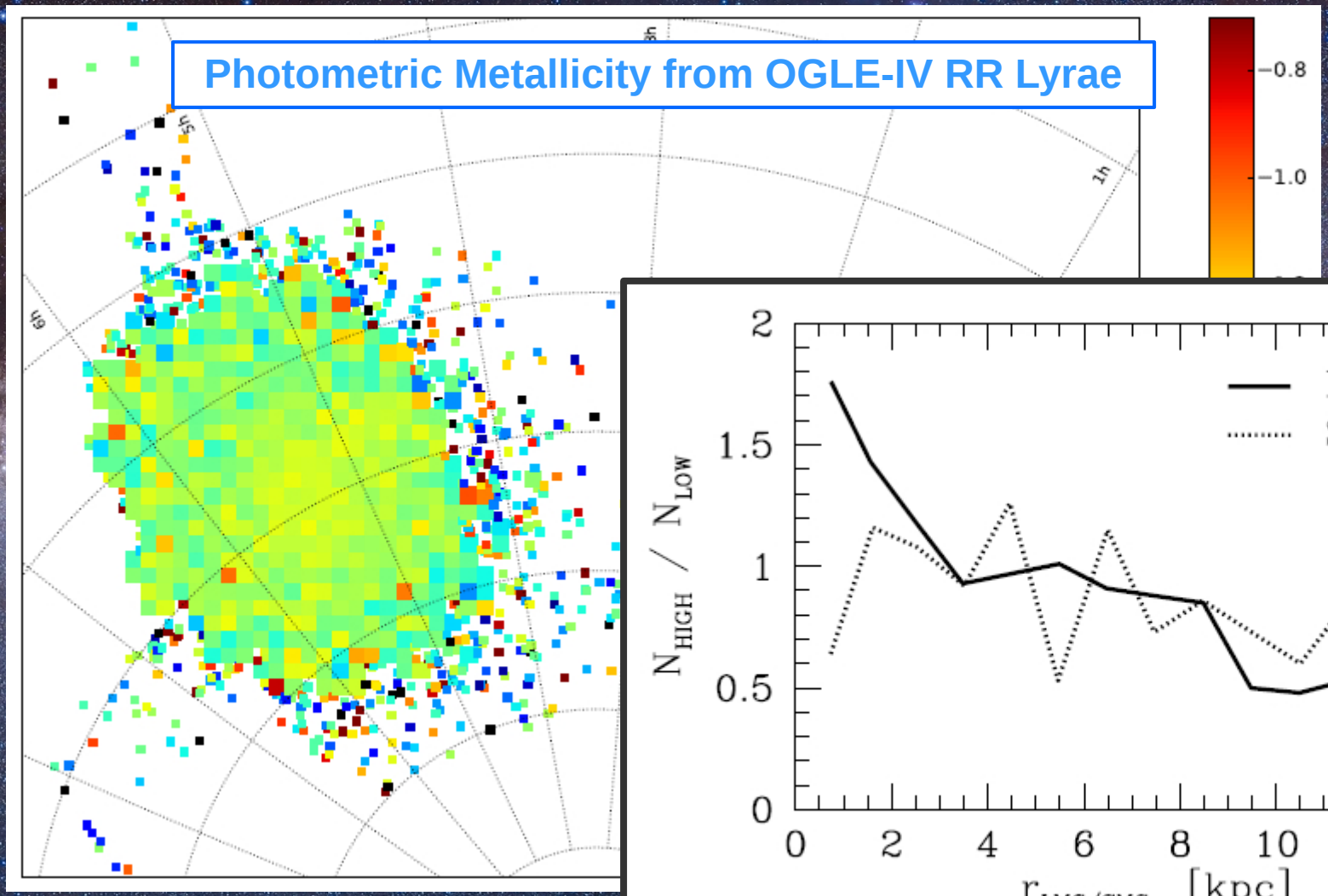
RR LYRAE STARS IN THE MAGELLANIC SYSTEM

Photometric Metallicity from OGLE-IV RR Lyrae



Skowron et al. (2016)

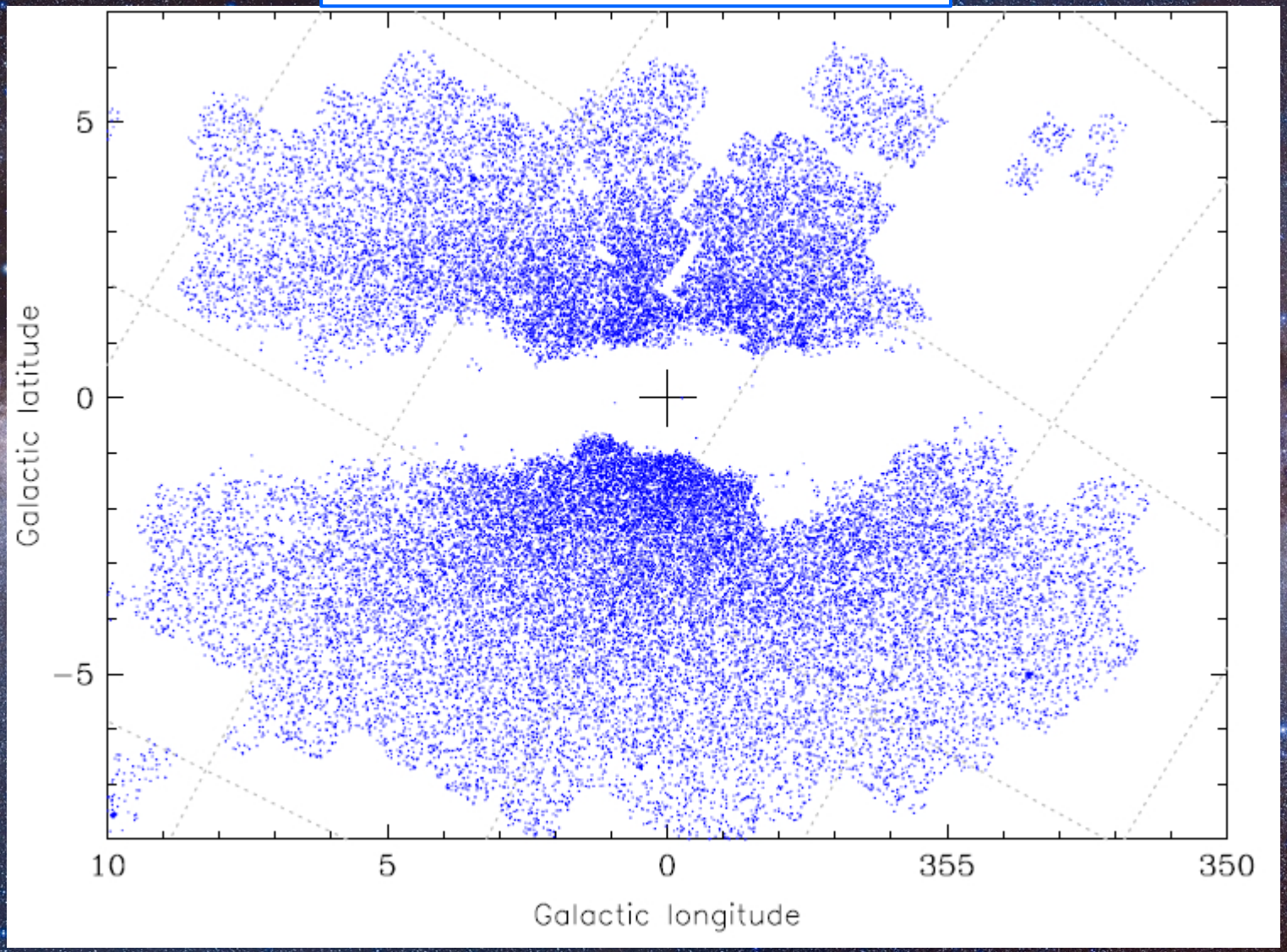
RR LYRAE STARS IN THE MAGELLANIC SYSTEM



Skowron et al. (2016)

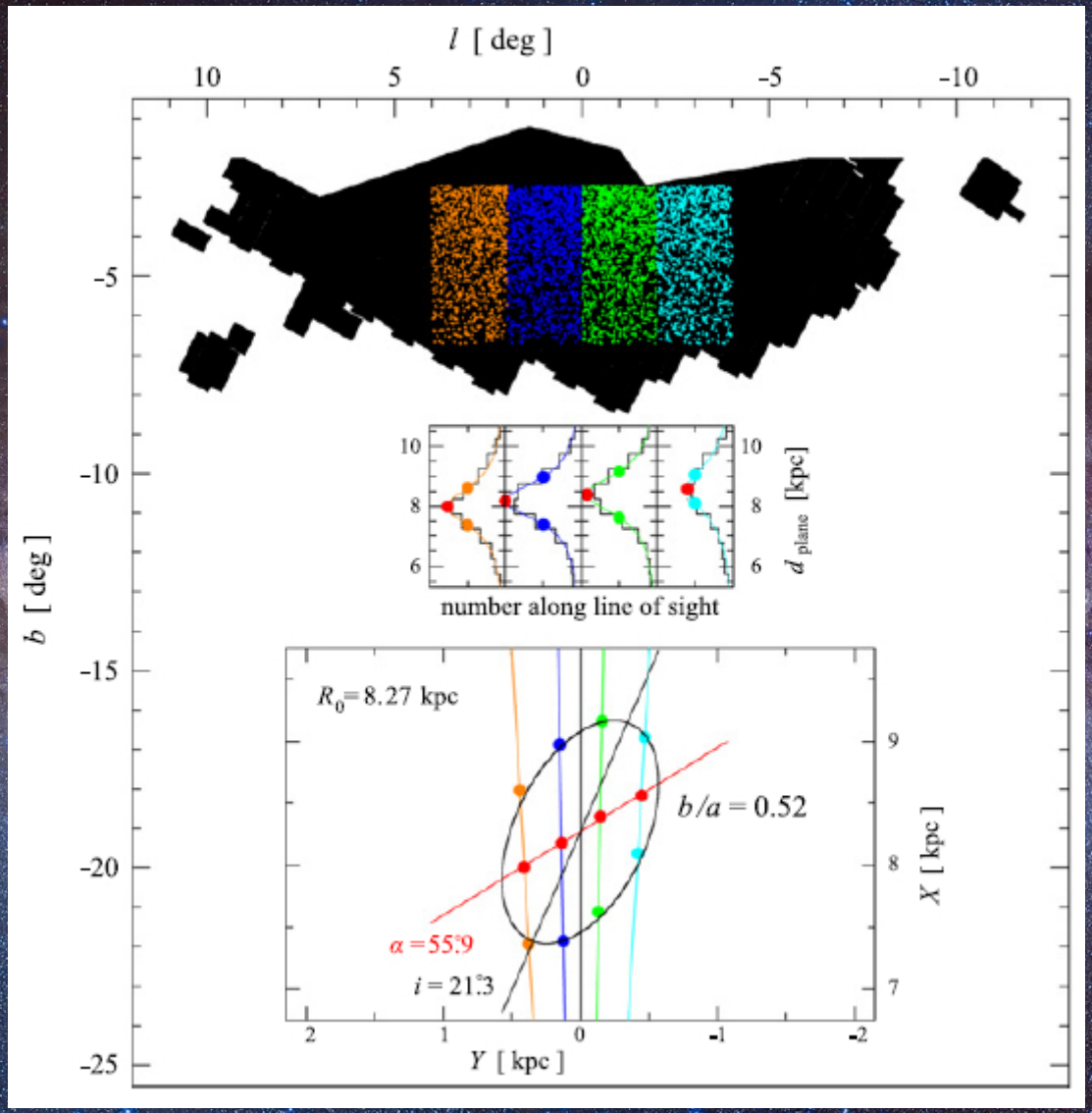
RR LYRAE STARS IN THE GALACTIC BULGE

OGLE-IV RR Lyrae stars



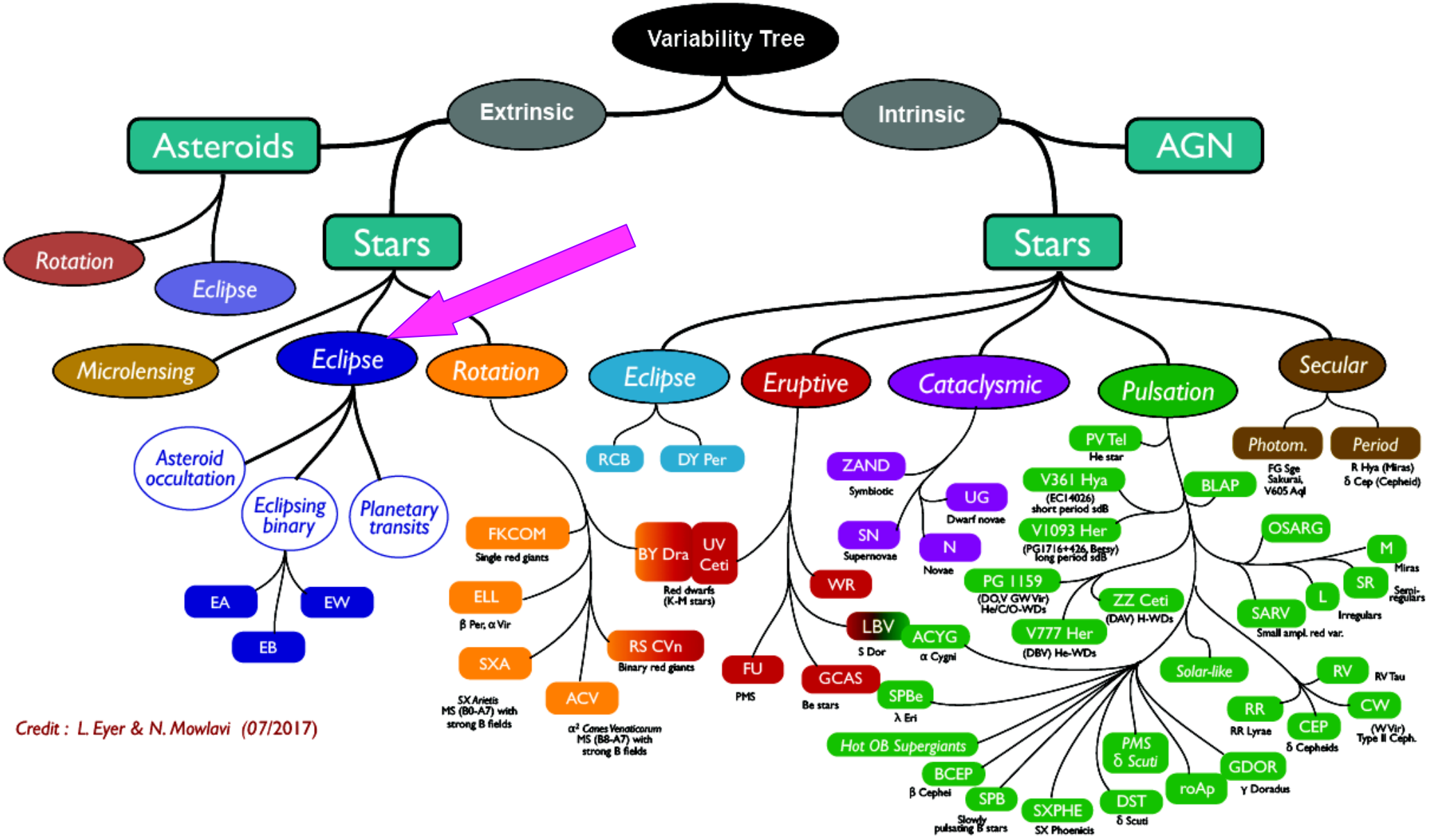
Soszynski et al. (2011)

RR LYRAE STARS IN THE GALACTIC BULGE



Pietrukowicz et al. (2015)

VARIABLE STAR TYPES

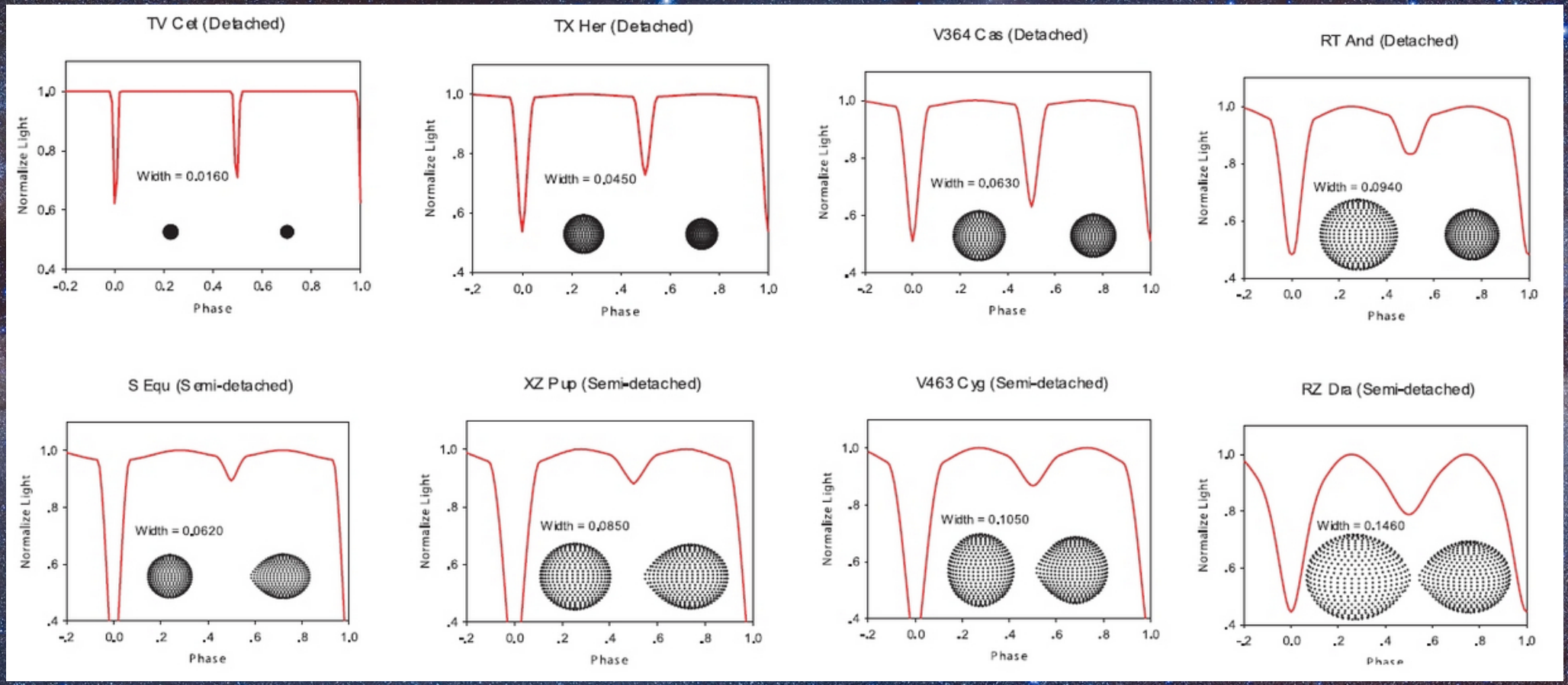


Credit : L. Eyer & N. Mowlavi (07/2017)

ECLIPSING BINARIES

- accurate distance indicators in the MW and other galaxies
- direct measurement of fundamental stellar parameters (mass, size, temperature)
- allow for testing stellar evolution theories (both components have the same age and composition)
- Studies of dynamical interactions between stars, mass exchange and loss, stellar magnetic activity, limb darkening, and tidal circularization theories

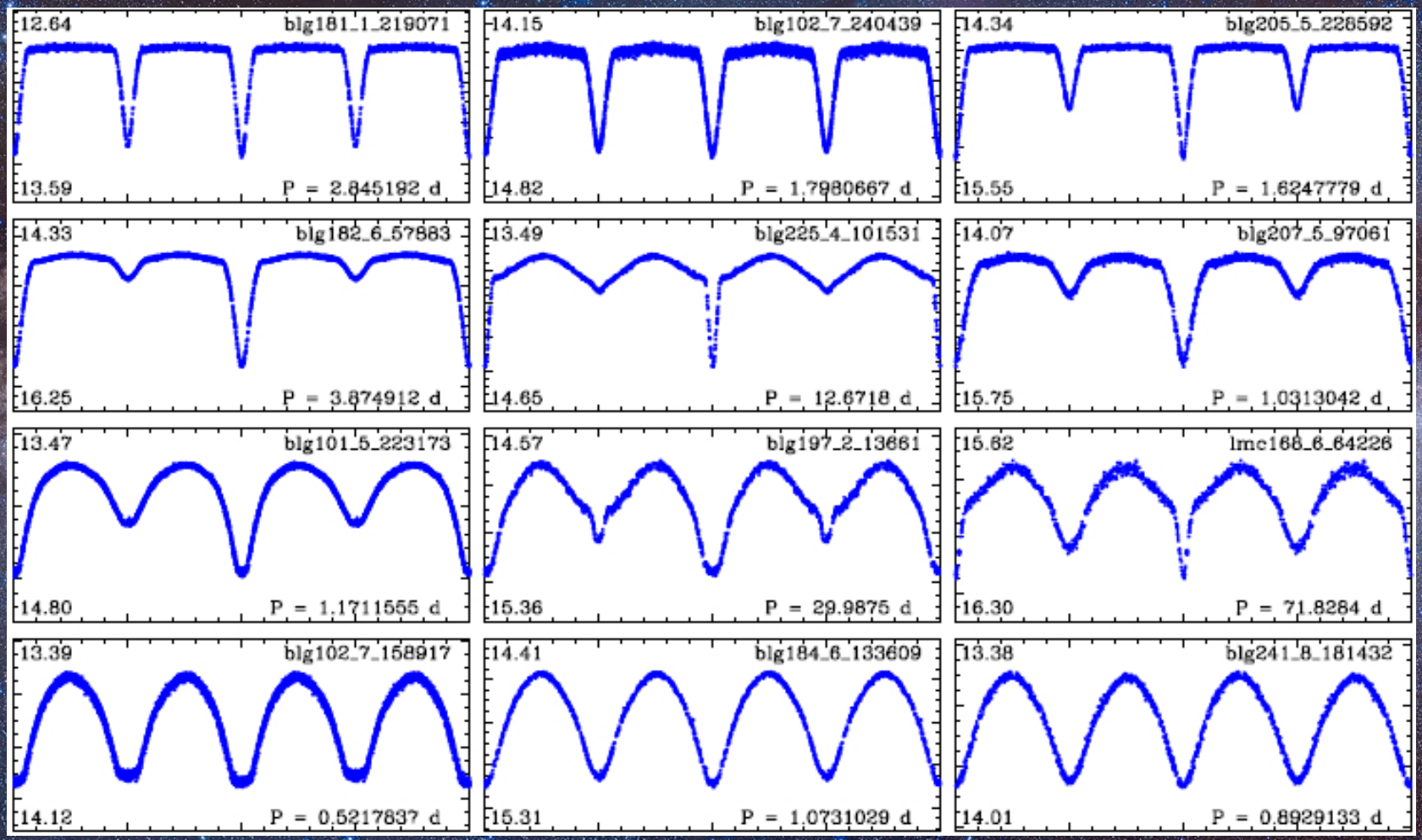
ECLIPSING BINARIES



Kang Young-Woon (2010)

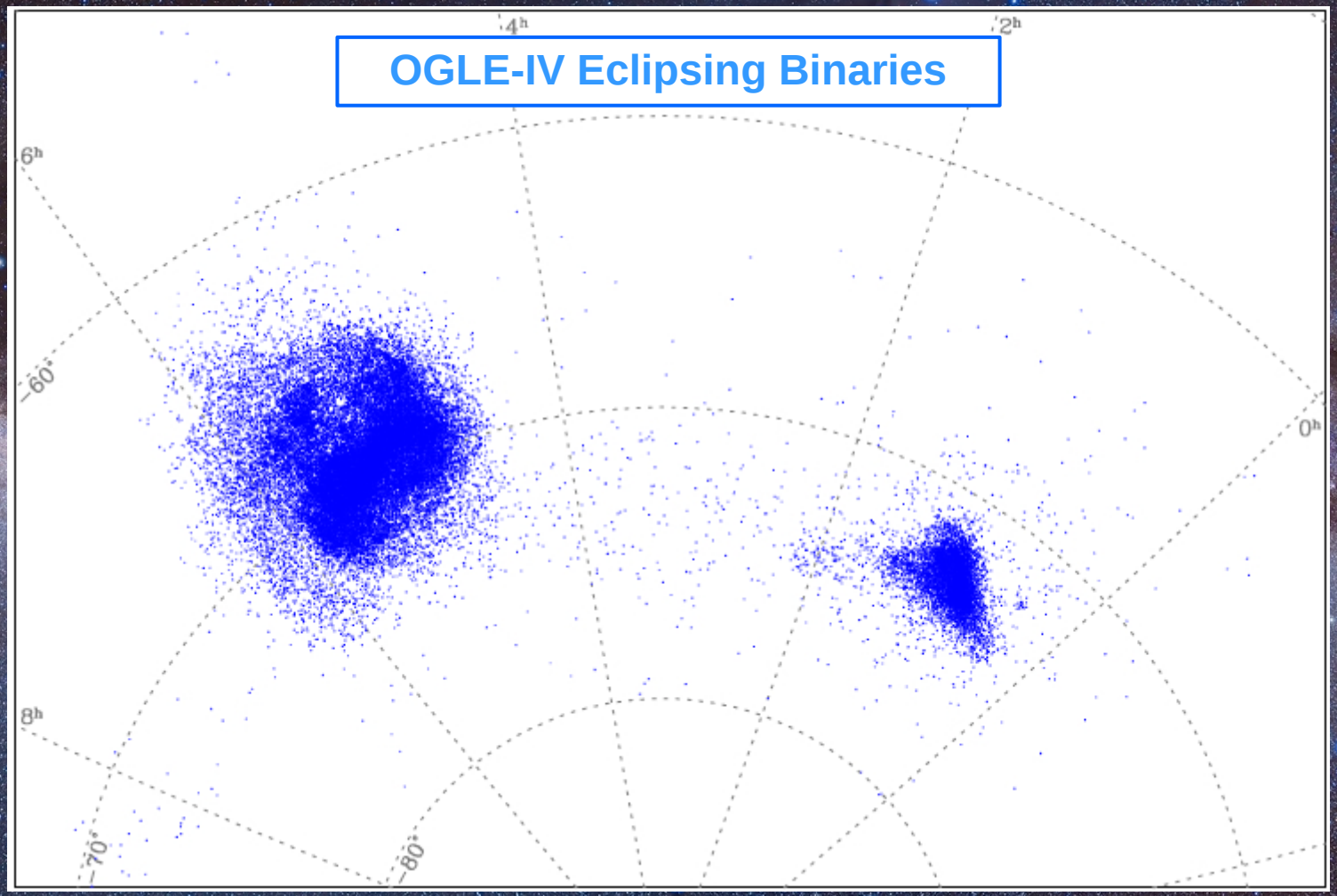
ECLIPSING BINARIES

OGLE-IV Eclipsing Binaries



Credit: I.Soszynski

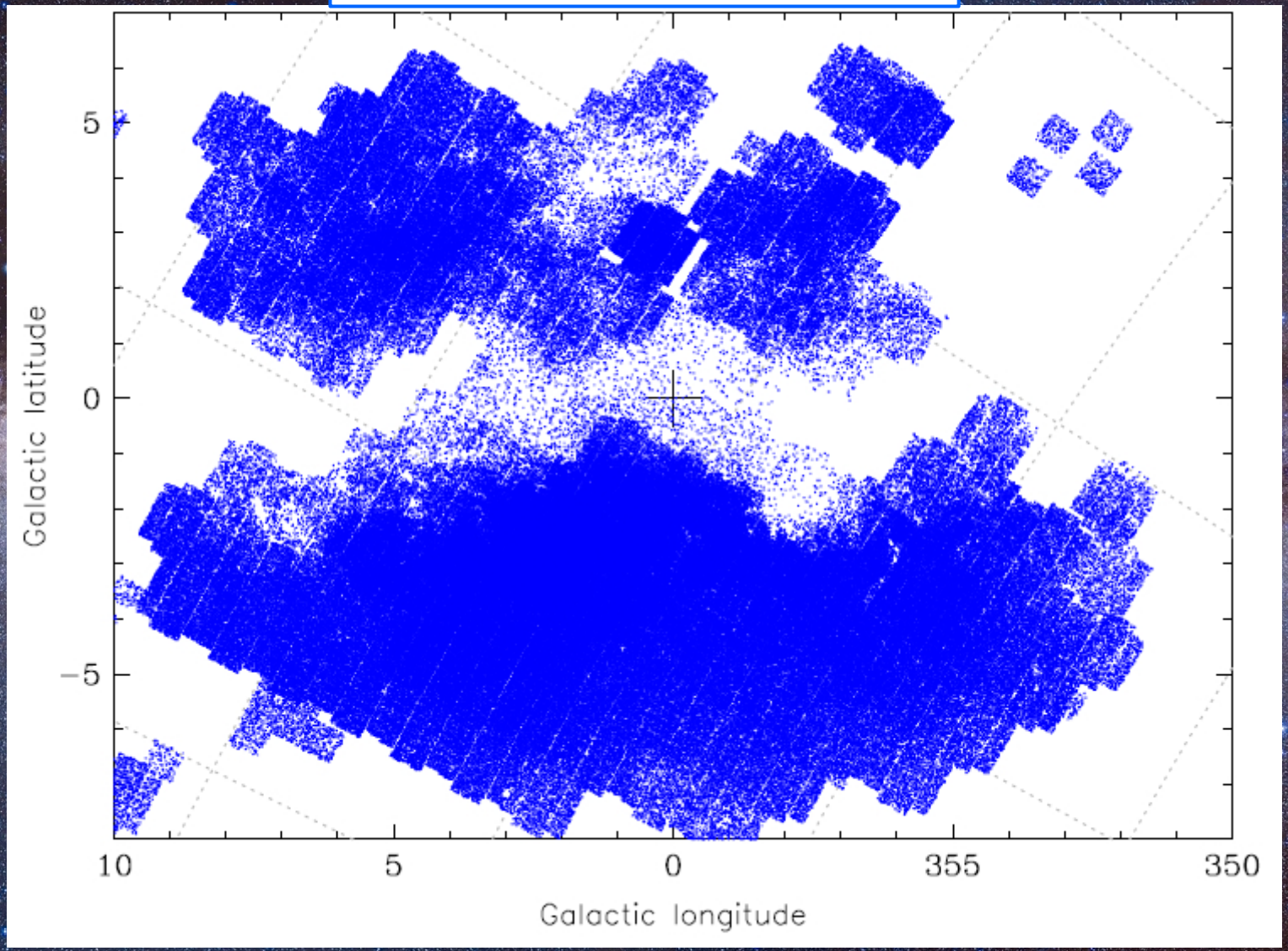
ECLIPSING BINARIES IN THE MAGELLANIC SYSTEM



Pawlak et al. (2016)

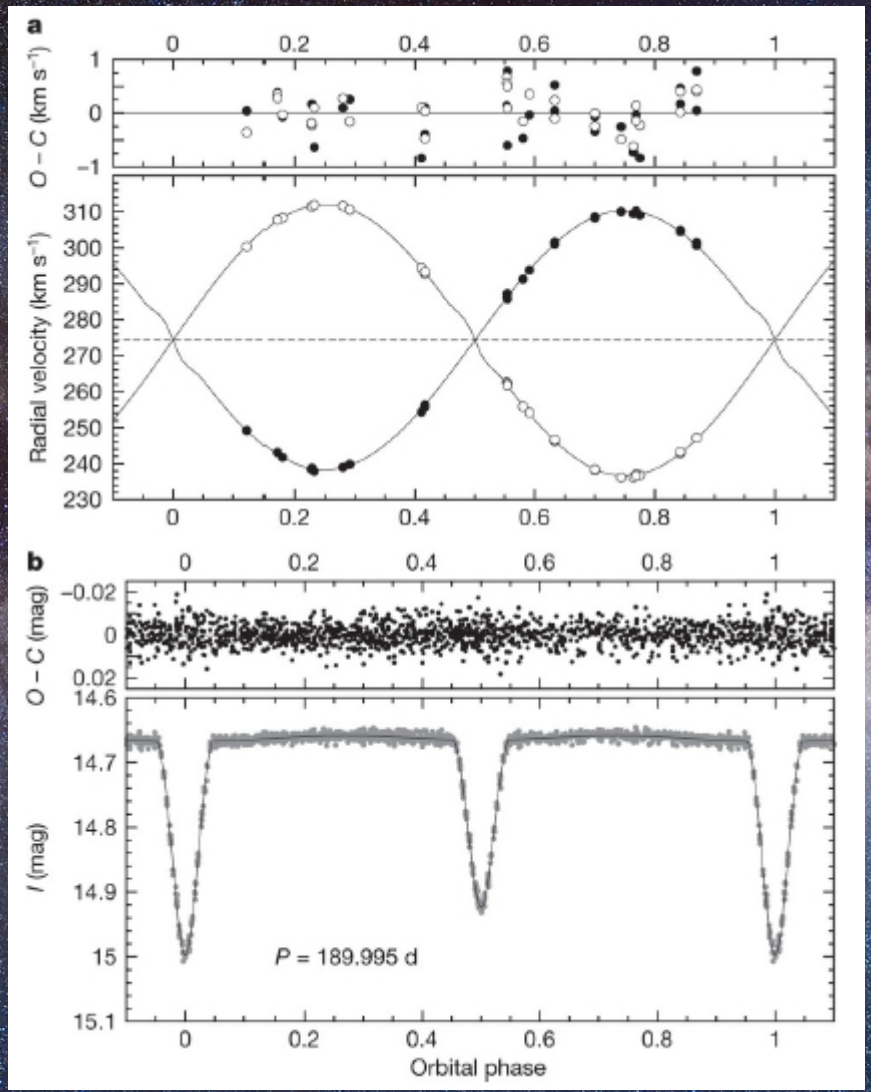
ECLIPSING BINARIES IN THE GALACTIC BULGE

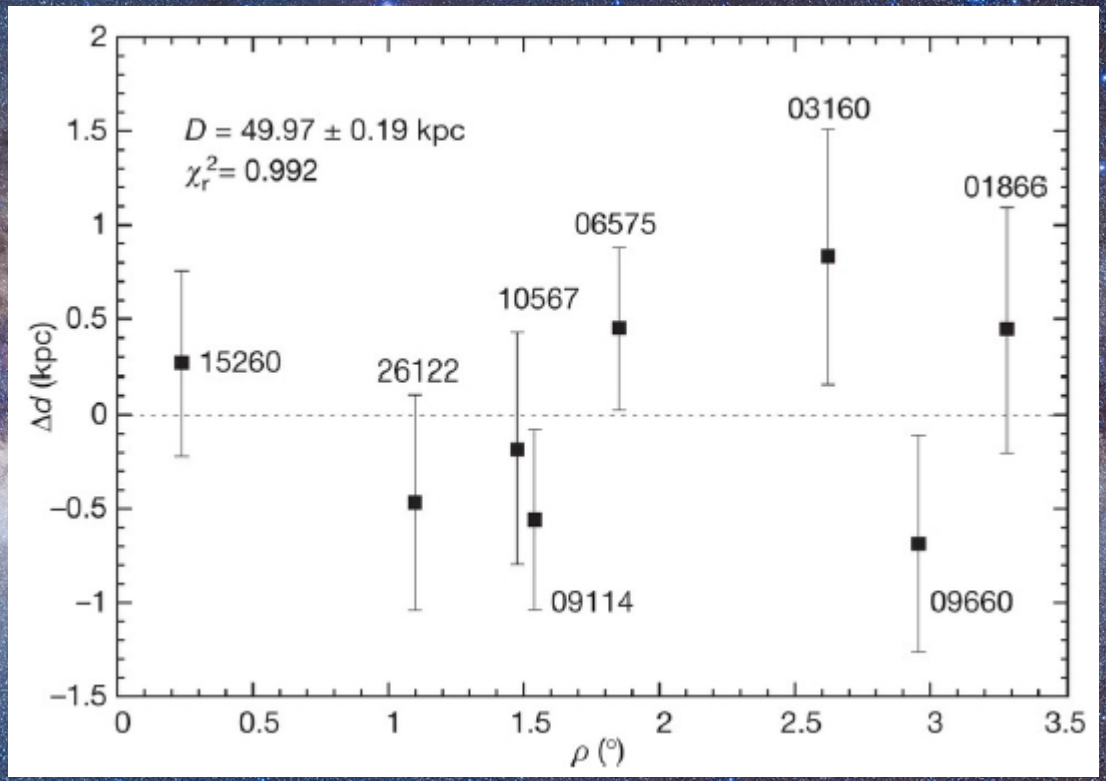
OGLE-IV Eclipsing Binaries



Soszynski et al. (2016)

ECLIPSING BINARIES IN THE LMC



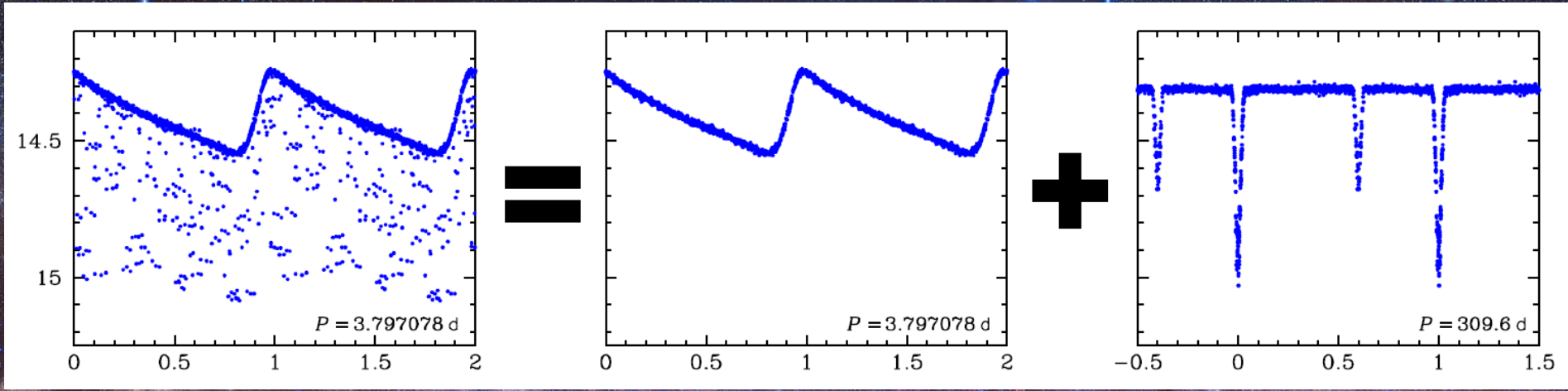


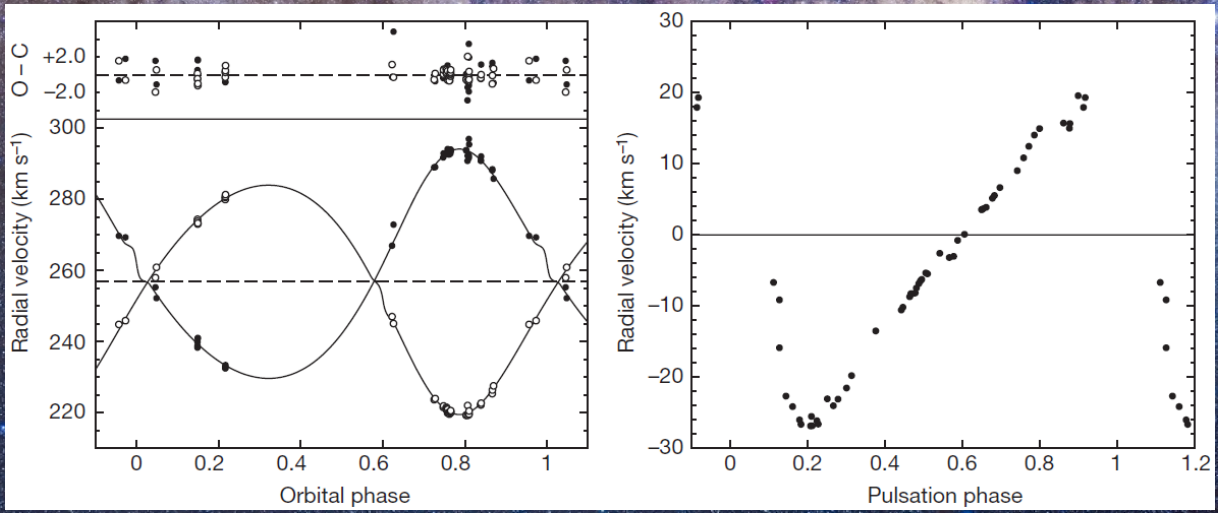
Pietrzynski et al. (2013)

VARIABLE STARS

NEW DISCOVERIES AND PHENOMENA

CLASSICAL CEPHEIDS IN BINARY SYSTEMS





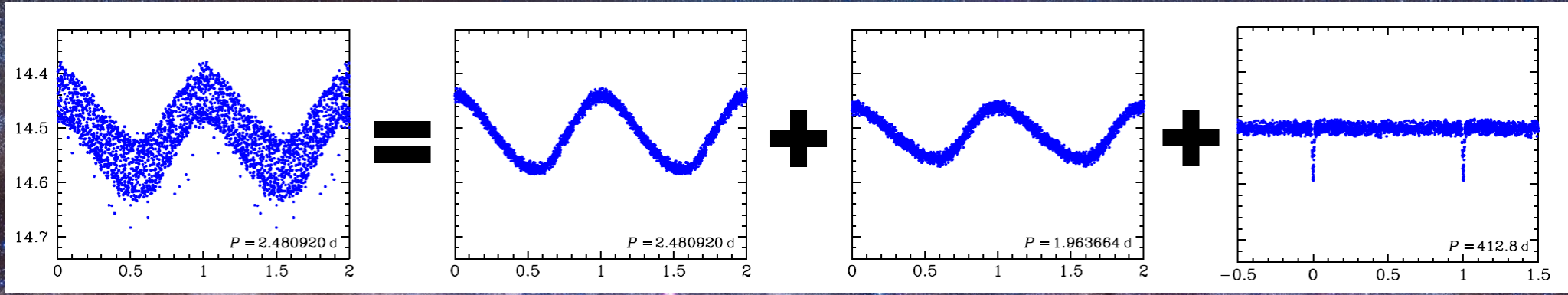
DYNAMICAL CEPHEID MASS

4.14 ± 0.05 $M_\odot$

MASS DISCREPANCY SOLVED!

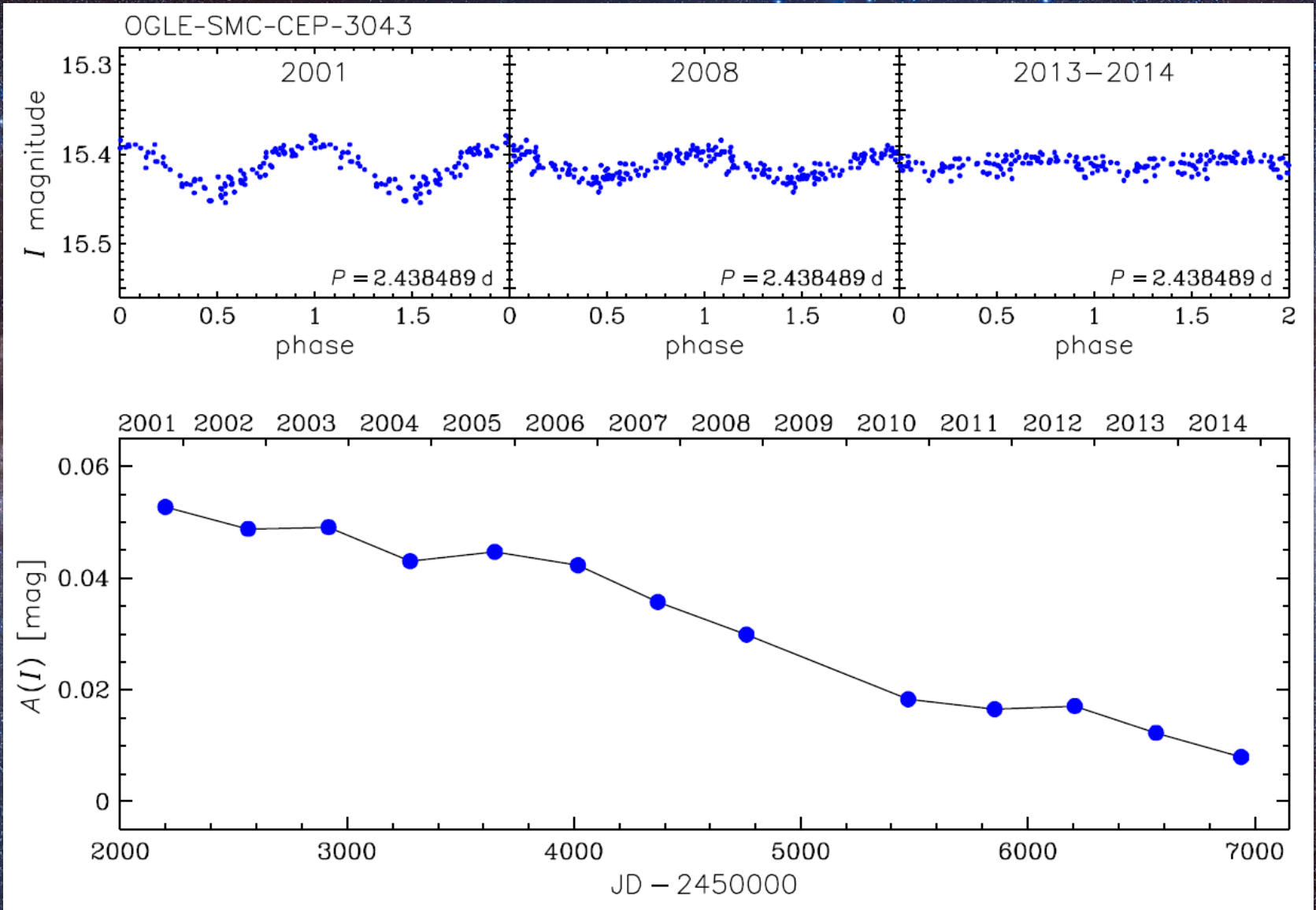
Pietrzynski et al. (2010)

CLASSICAL CEPHEIDS IN BINARY SYSTEMS



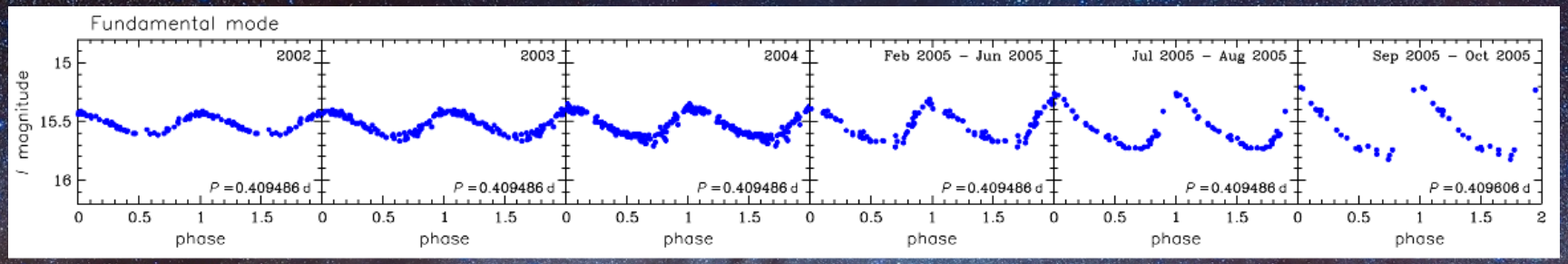
A BINARY STAR COMPOSED OF TWO CEPHEIDS

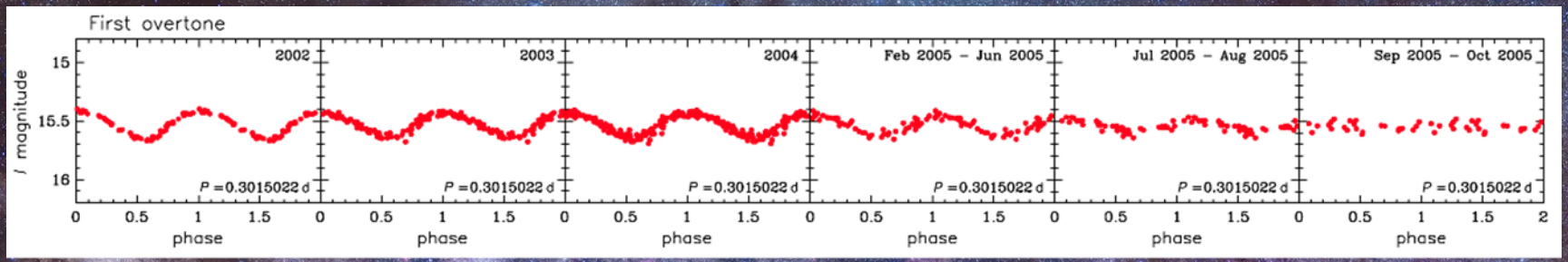
A CEPHEID THAT STOPPED PULSATING

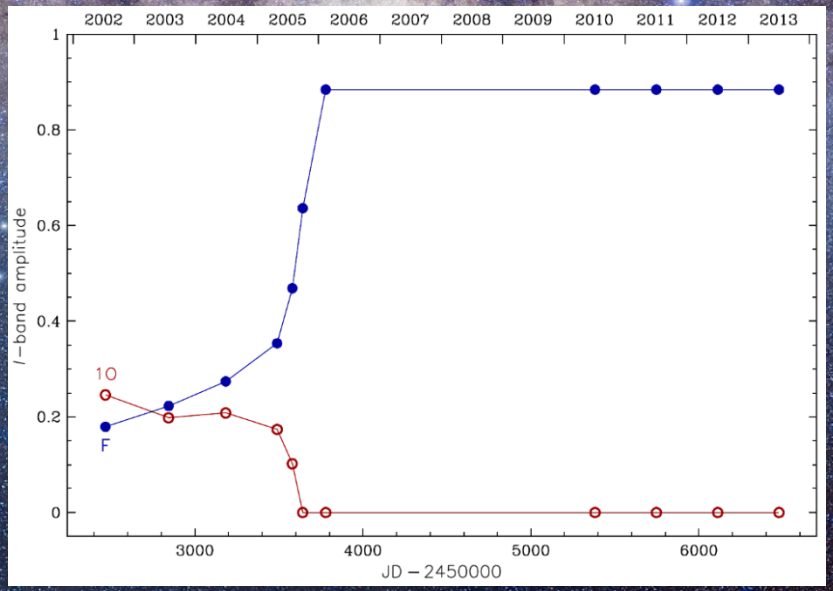


Credit: I.Soszynski

MODE SWITCHING IN RR LYRAE STARS

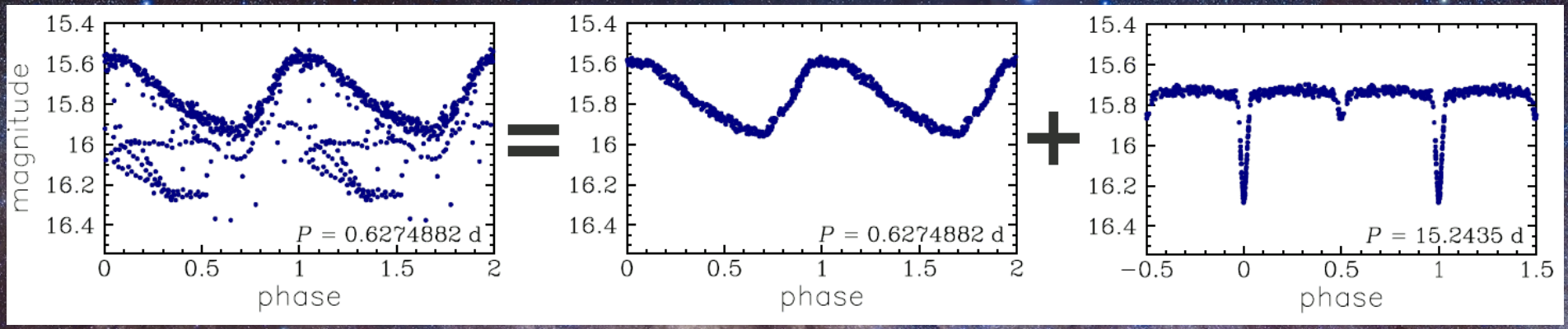


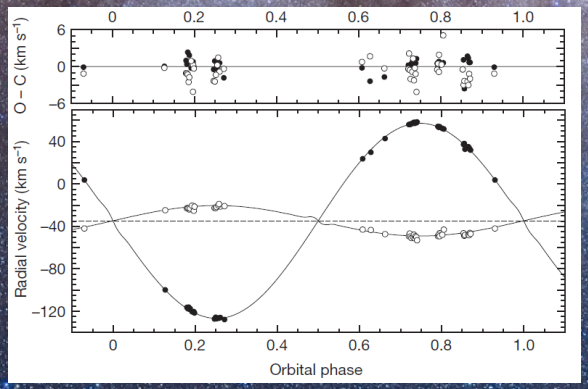


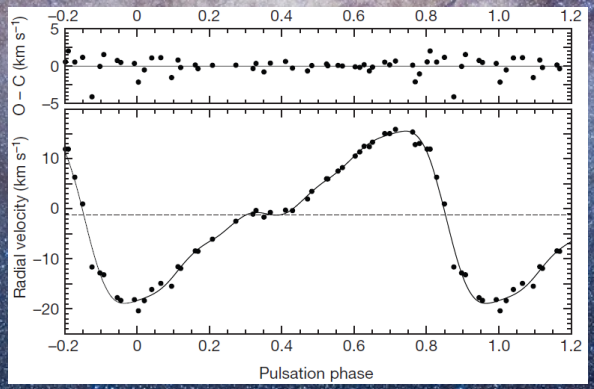


Credit: I.Soszynski

“RR LYRAE” IN BINARY SYSTEMS





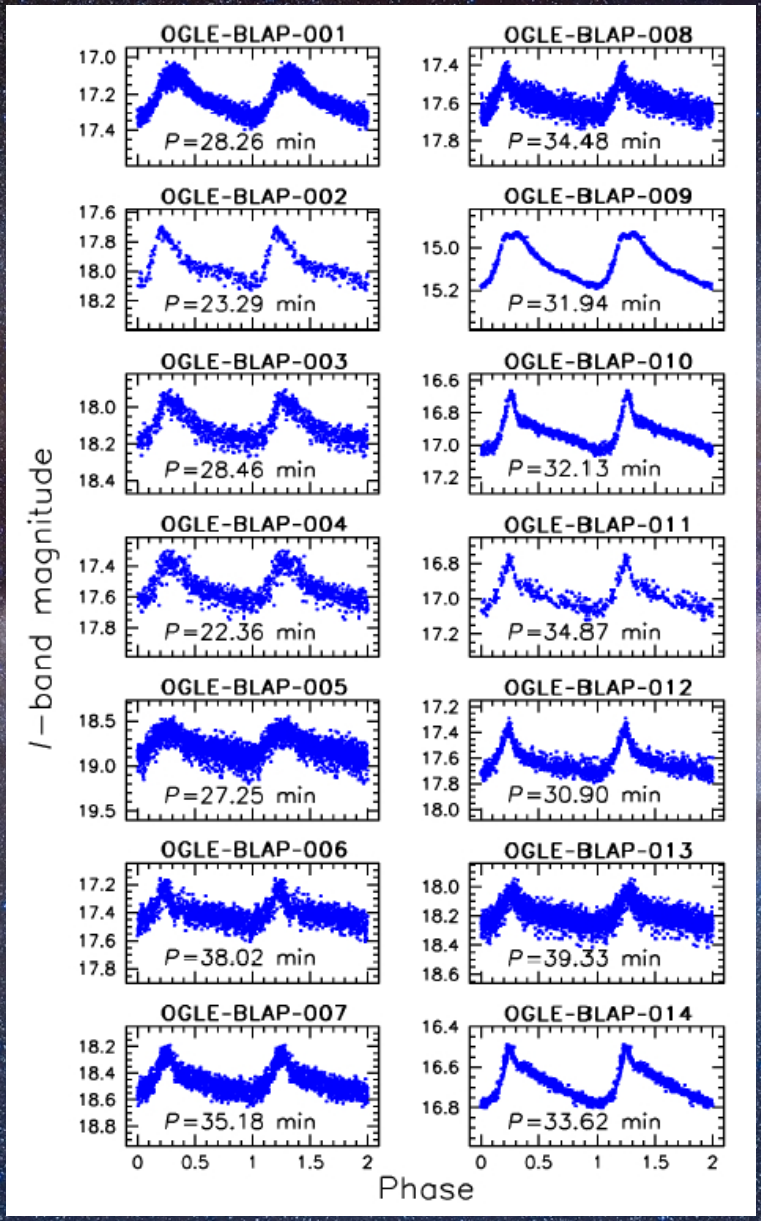


BINARY
EVOLUTION
PULSATOR

M = 0.26 $M_\odot$

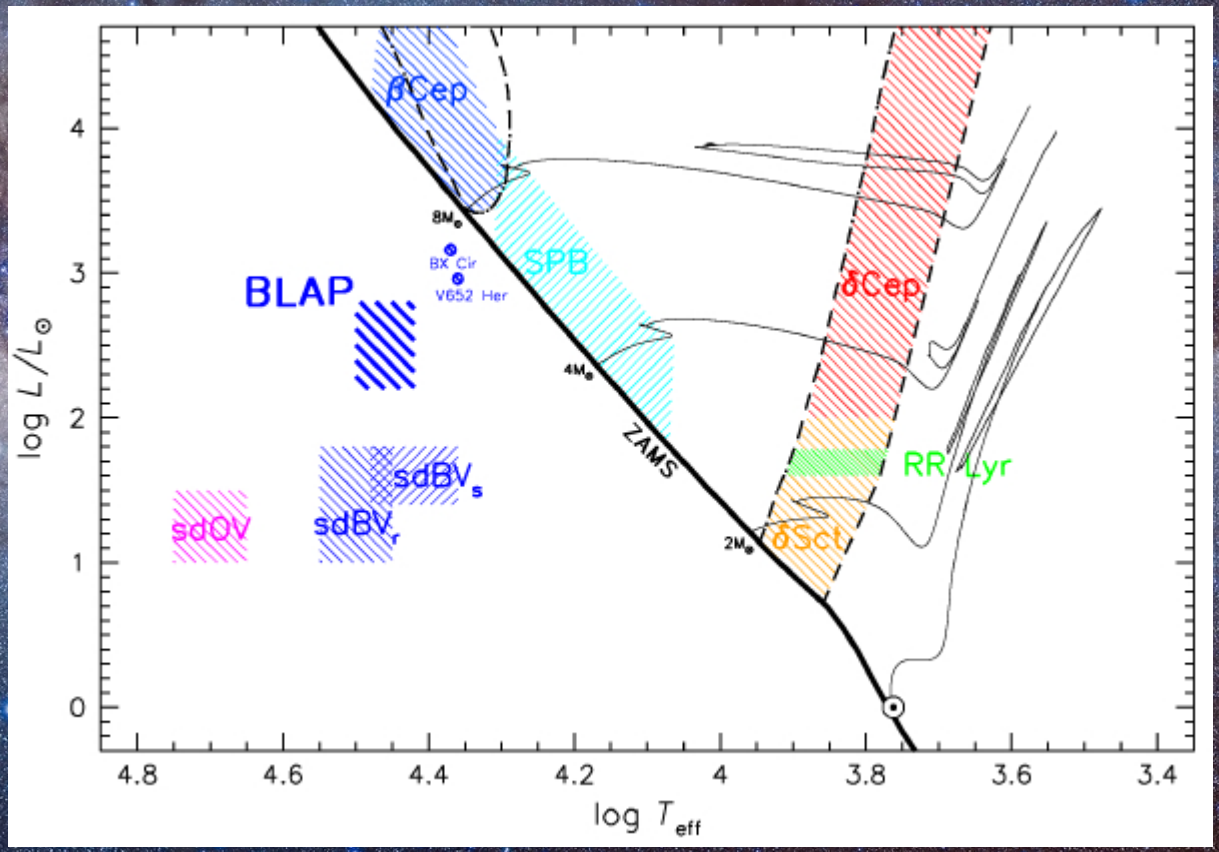
Pietrzynski et al. (2012)

A NEW CLASS OF PULSATING STARS



BLAP

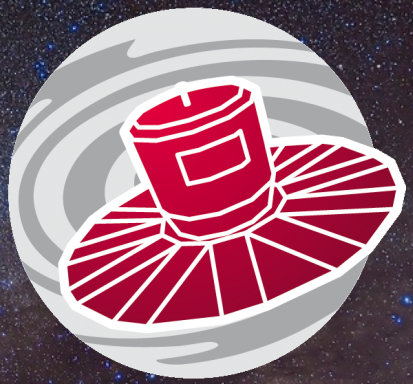
Blue Large Amplitude Pulsators



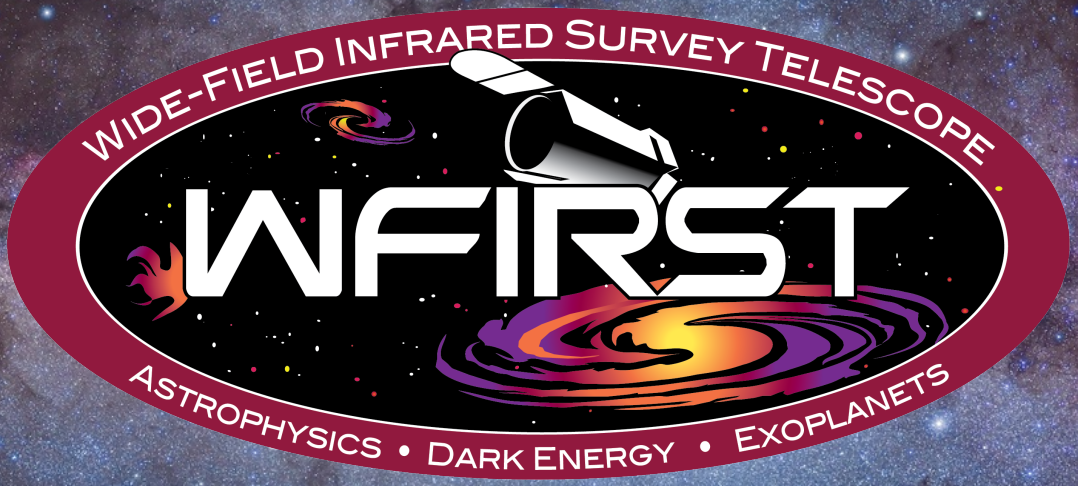
Pietrukowicz et al. (2017)

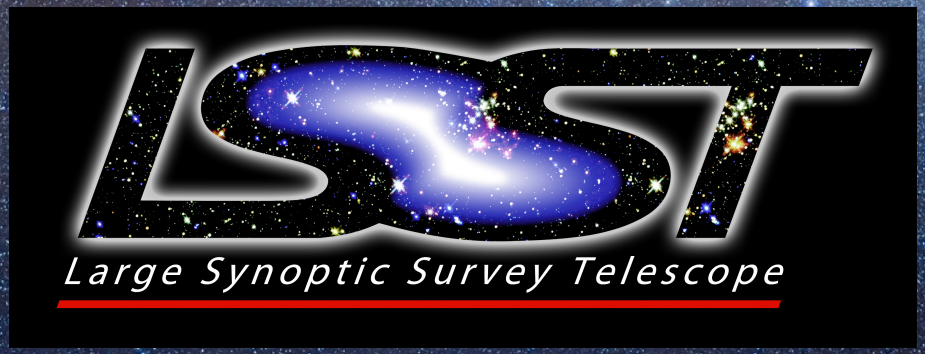
THE FUTURE

FUTURE MICROLENSING SURVEYS



gaia





Dorota Skowron, Warsaw University Observatory, dszczyg@astrouw.edu.pl 11 August 2017, Pasadena, CA

FUTURE MICROLENSING SURVEYS

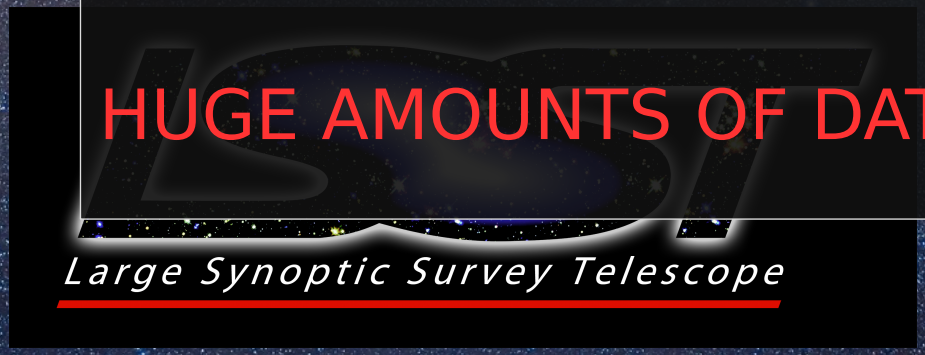
INFRARED BANDS:

- Can see the center of the Milky Way (extinction)
- Multi filter photometry for variable stars (e.g. VVV)

ALL SKY COVERAGE

TOTAL DURATION OF THE SURVEY

HUGE AMOUNTS OF DATA (technically challenging)




Thank you