The variable Universe through Gaia's eyes

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Pierre Dubath, Paul Bartholdi
Geneva Observatory, Switzerland

ELSA conference, June 8 2010, Sèvres-Paris

Introduction

Repeated observations is one of the royal road of astrophysics

- astrometry: parallax, proper motion
- photometry and spectroscopy (radial velocity, line profile variations)

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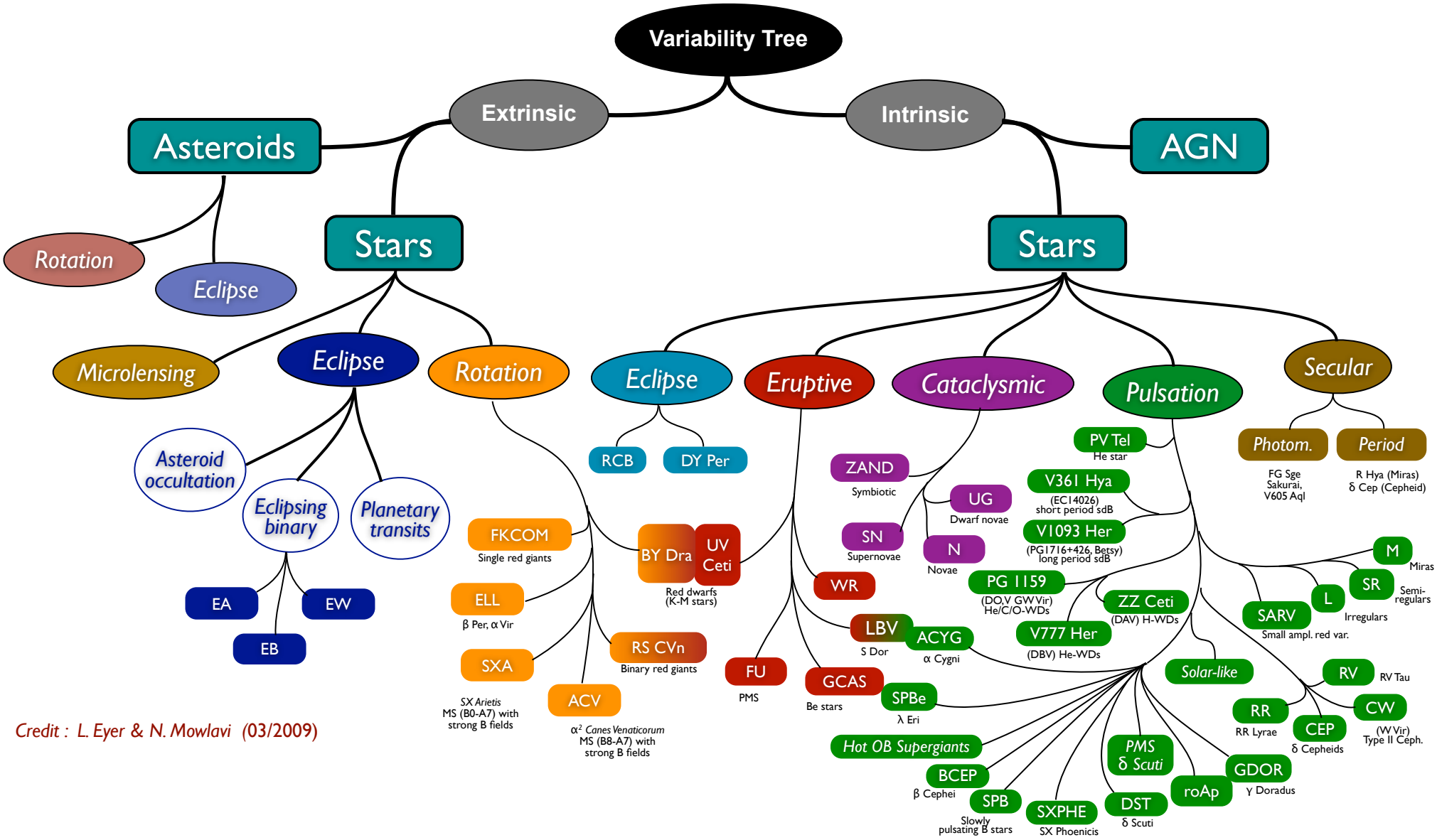
and soon Gaia

Introduction: Variability tree



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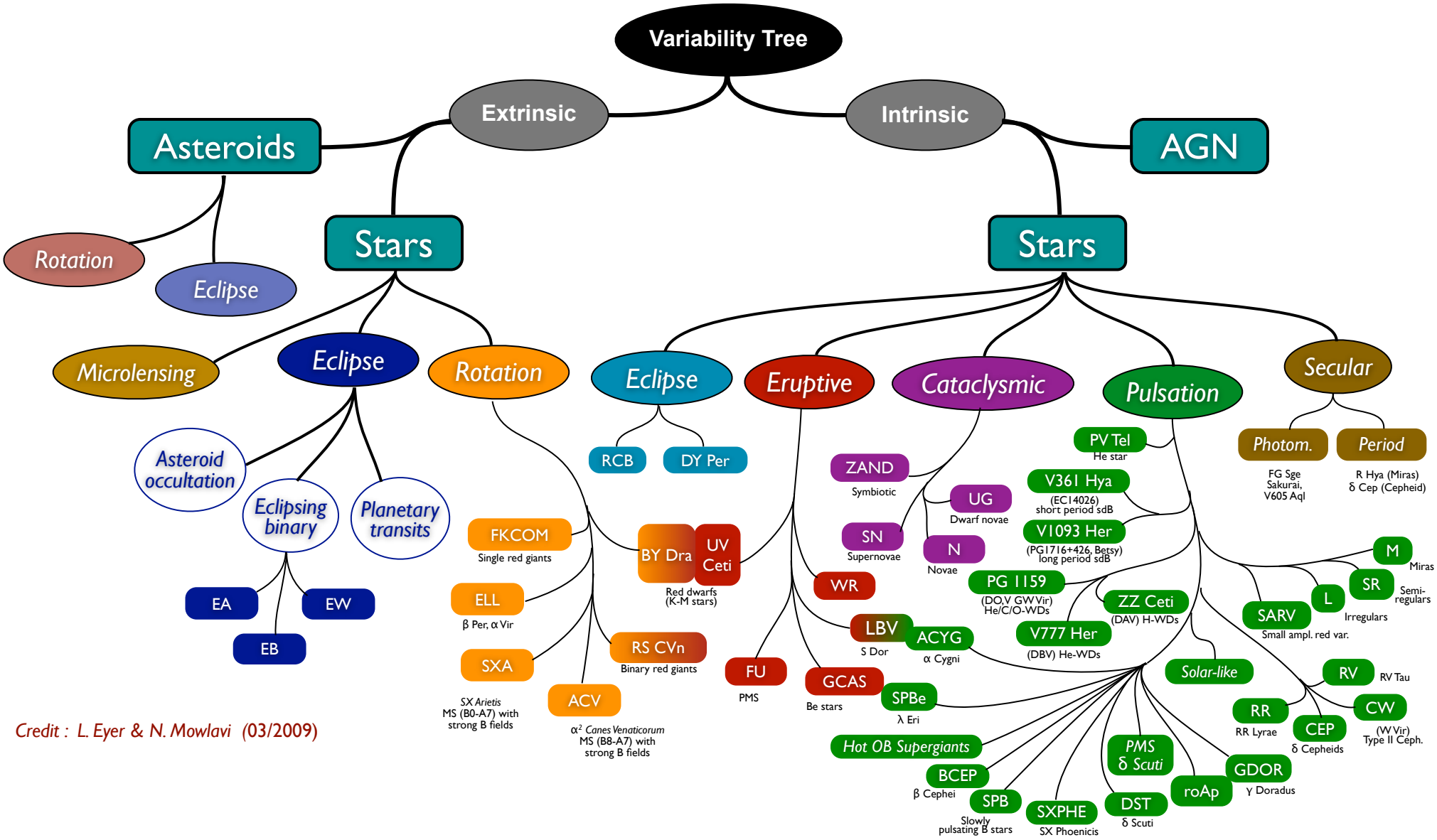

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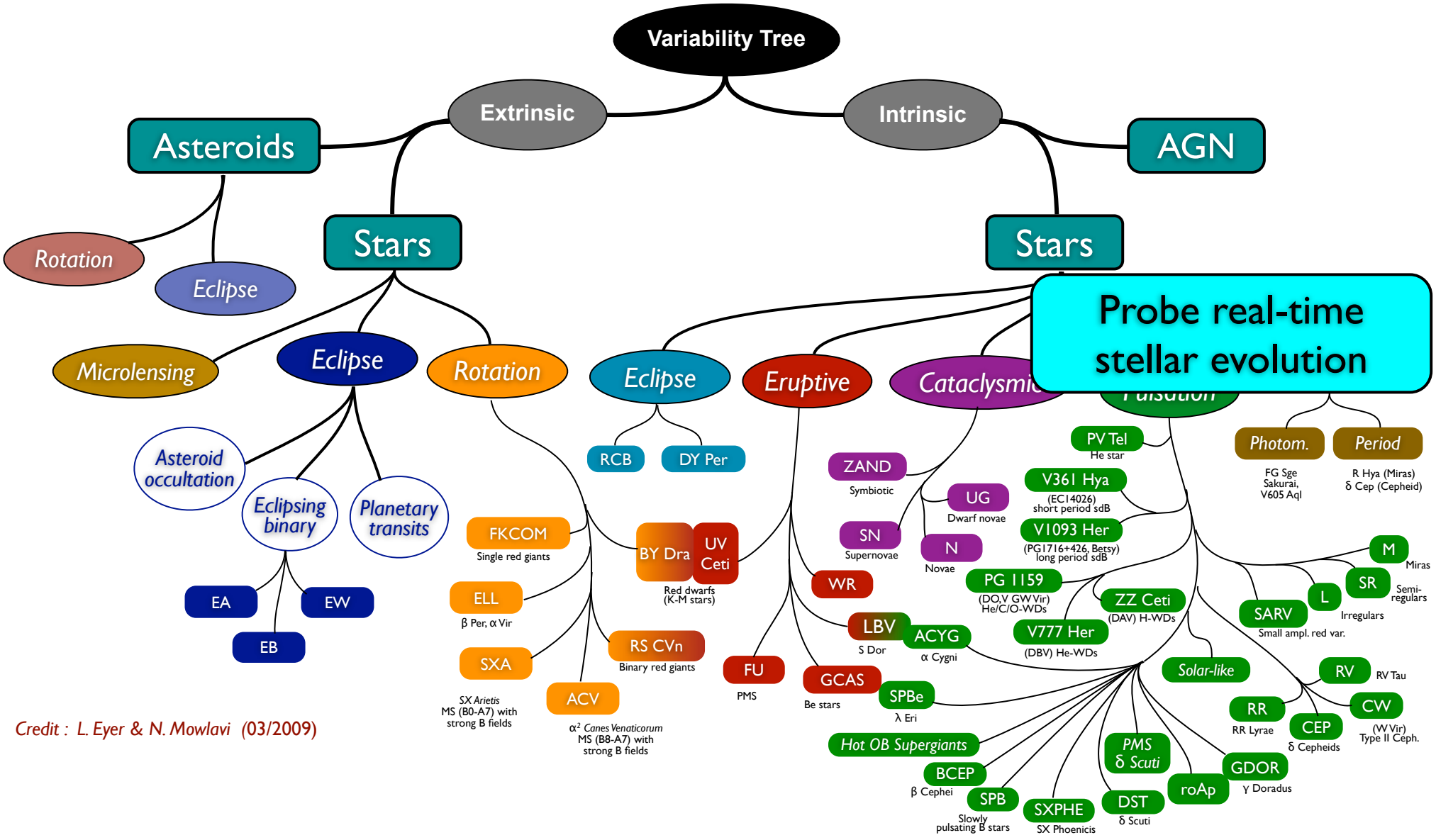

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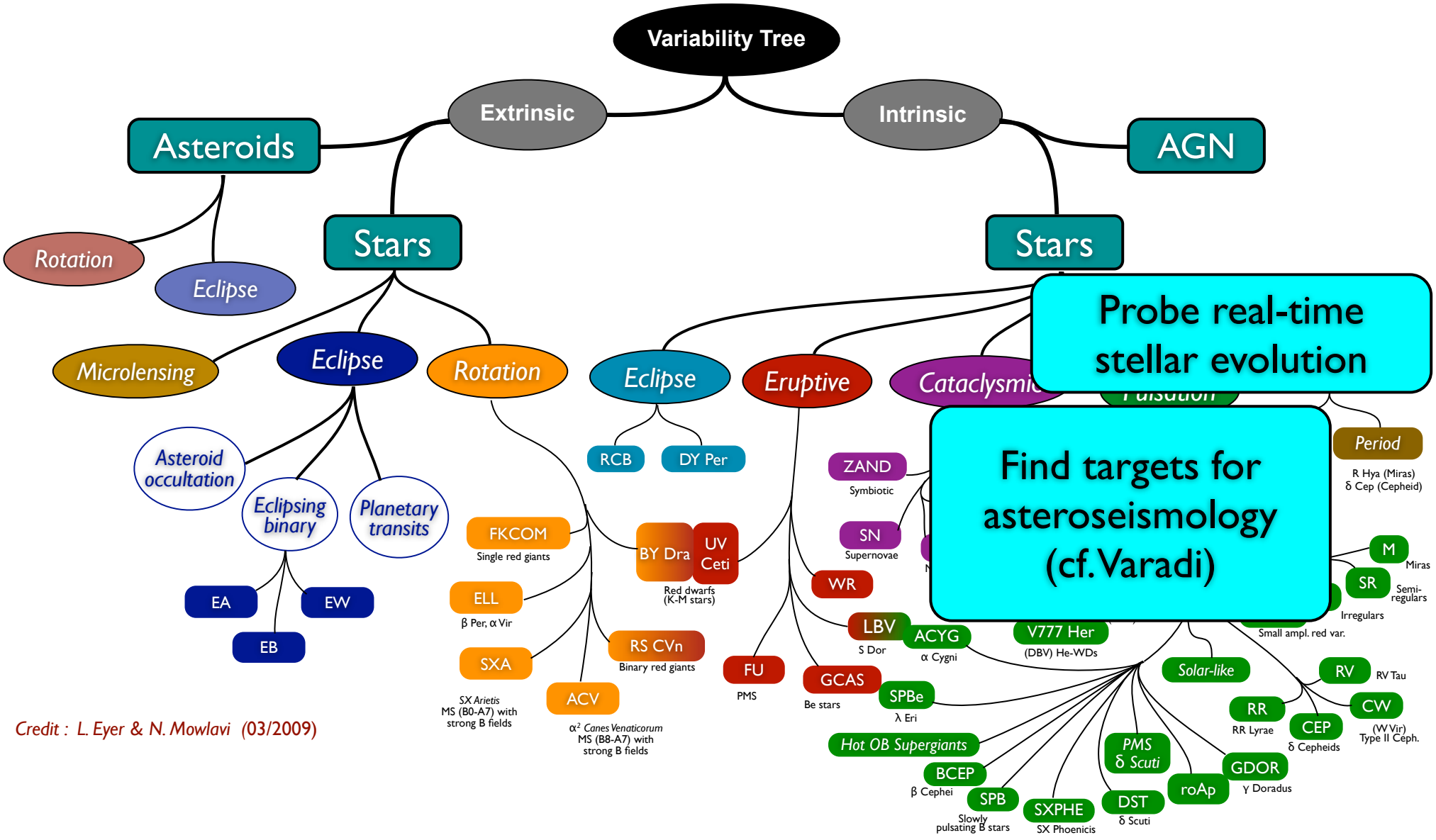

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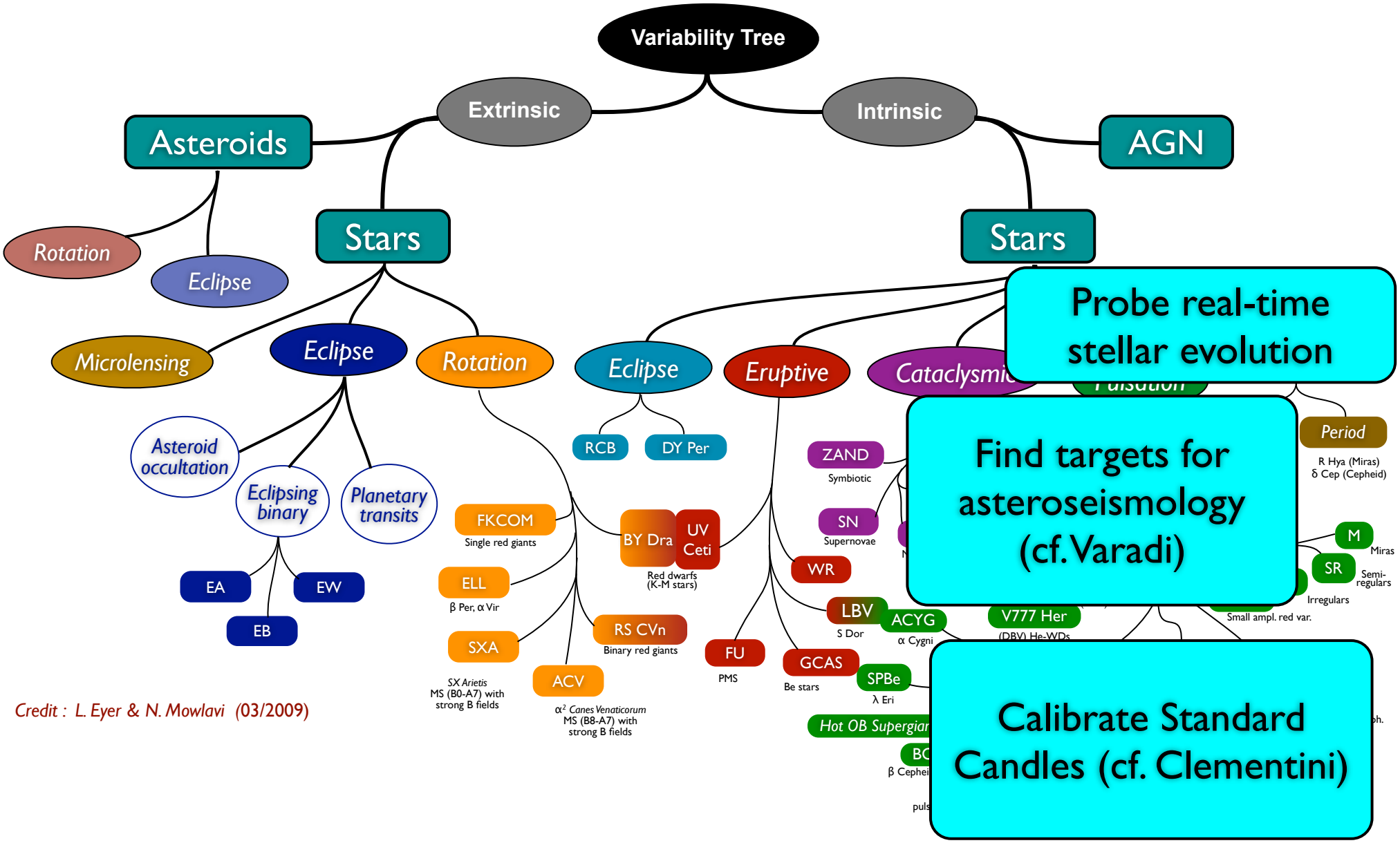

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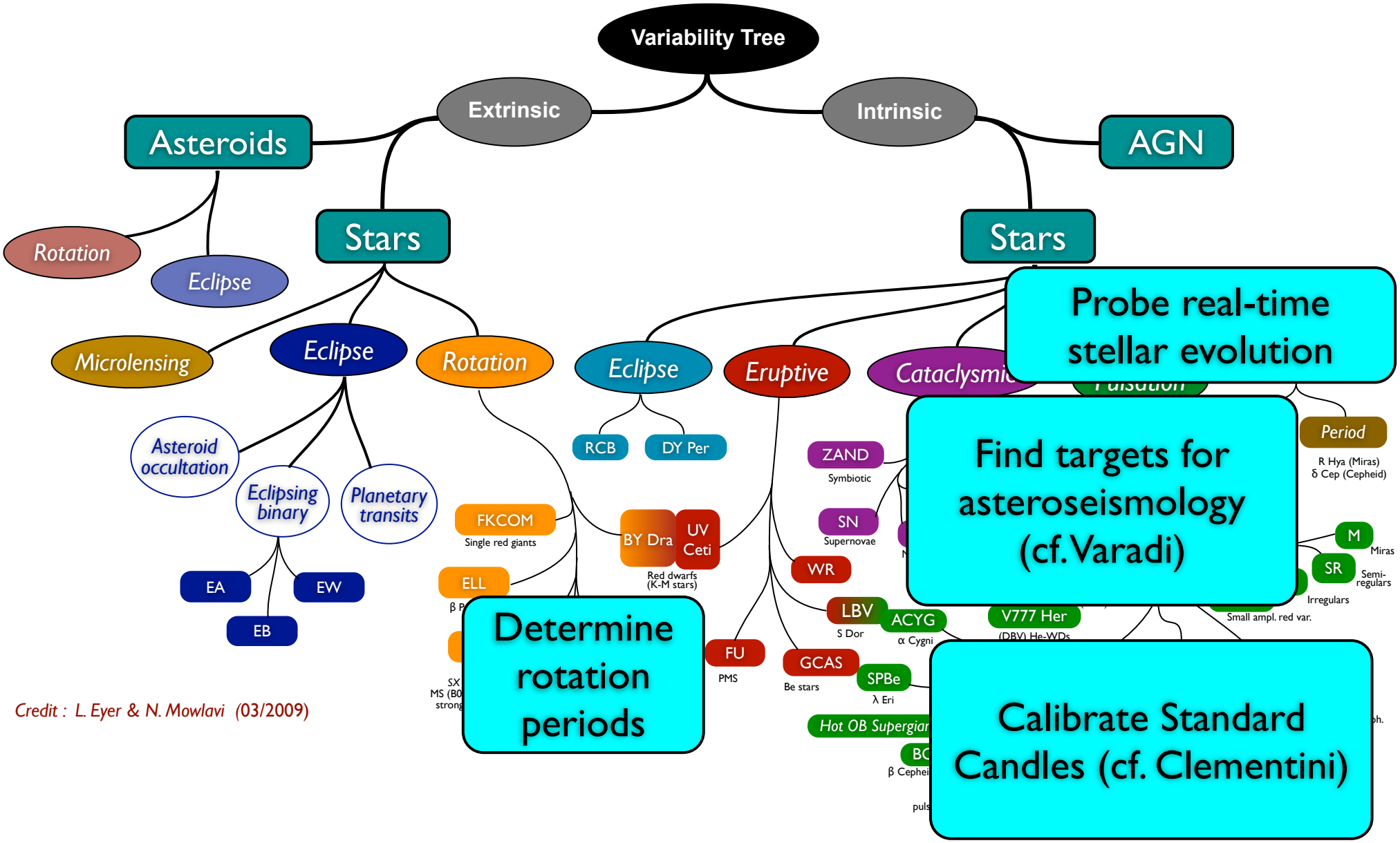

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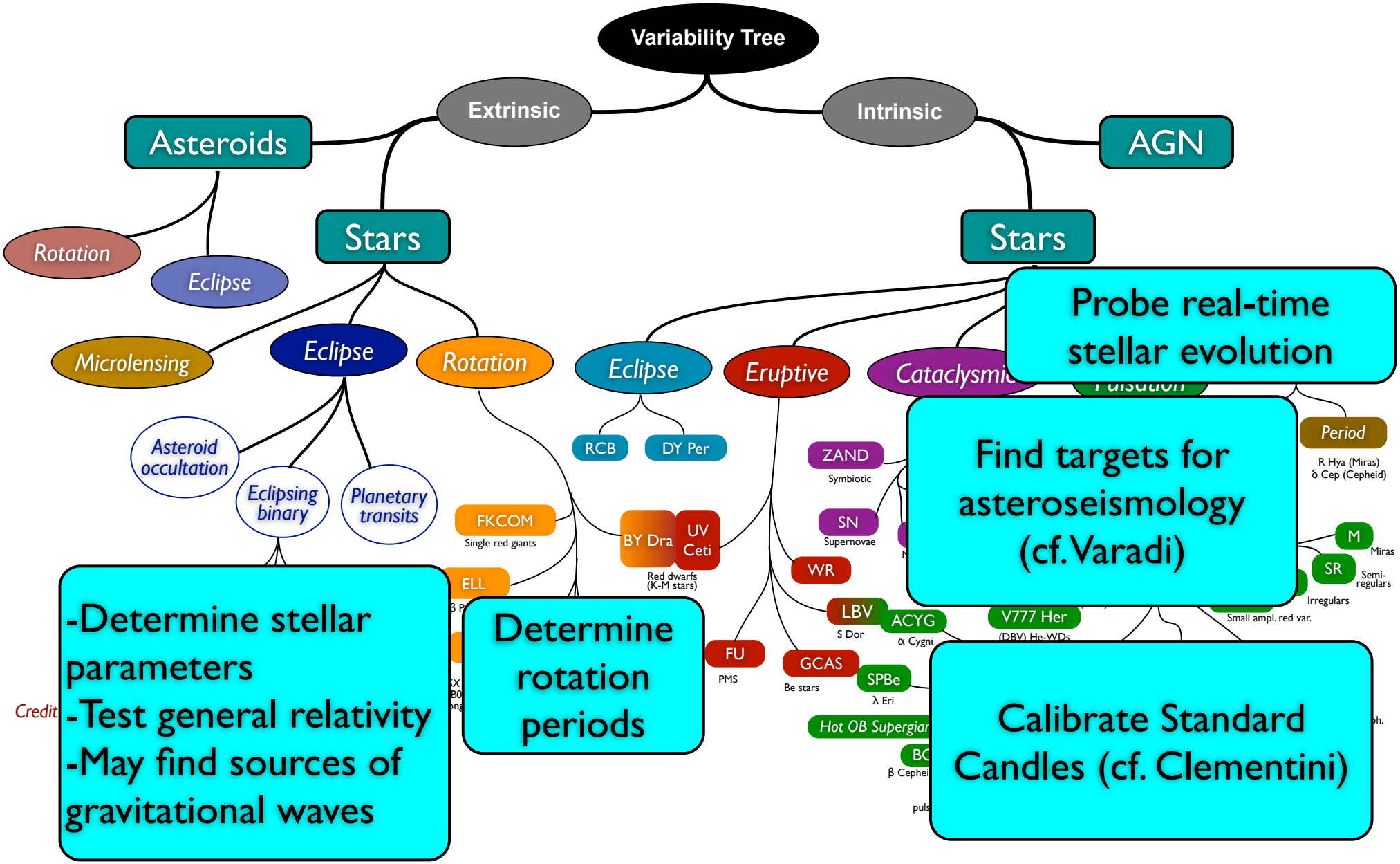

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Gaia Observables

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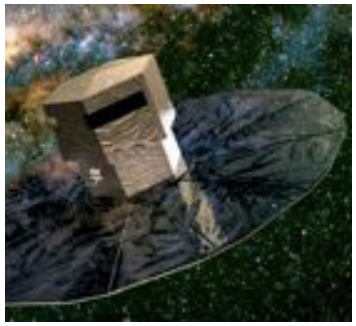

One billion objects

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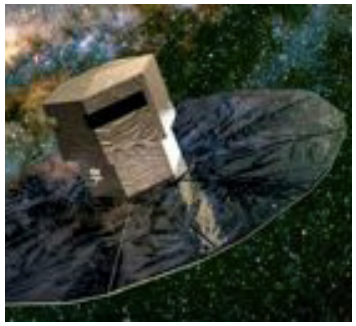
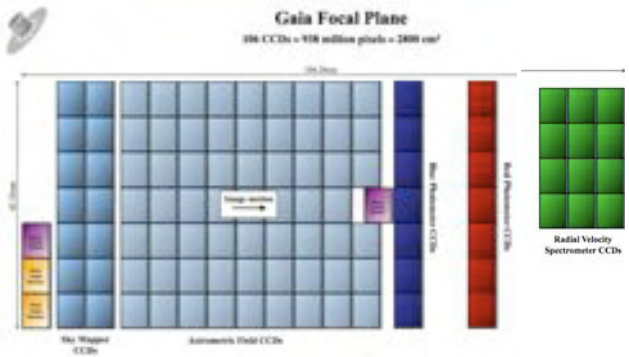


One billion objects

mean of 70 transits
over 5 years



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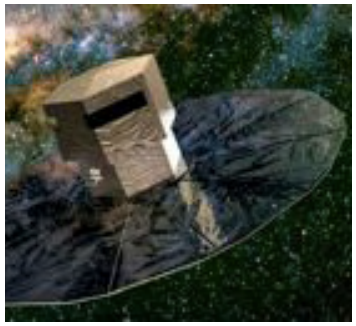

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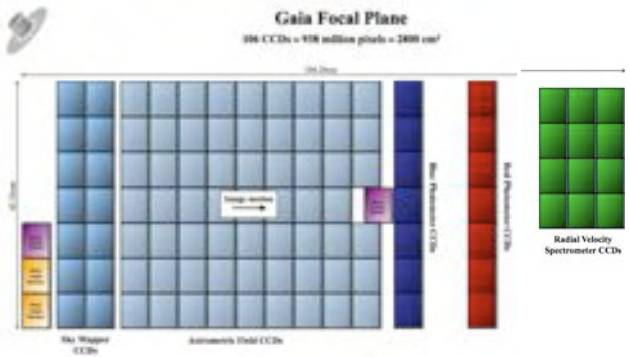

Gaia DPAC

Astrometry

G-band photometry

BP and RP spectrophotometry

Spectra Radial velocities

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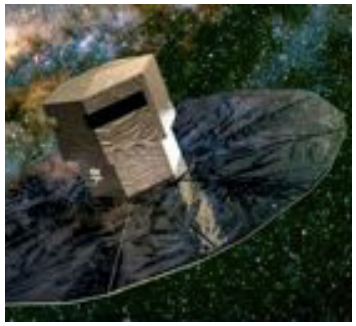

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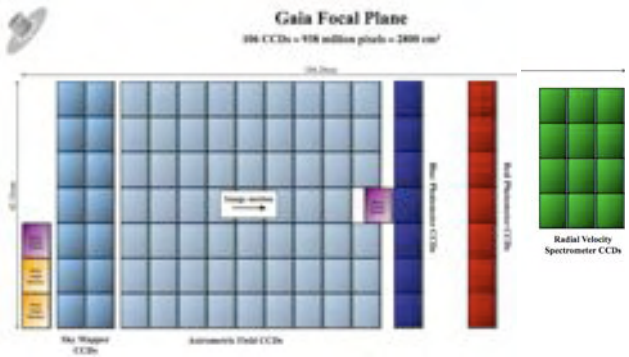

Gaia DPAC

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Spectra Radial velocities

Gaia DPAC

Luminosity

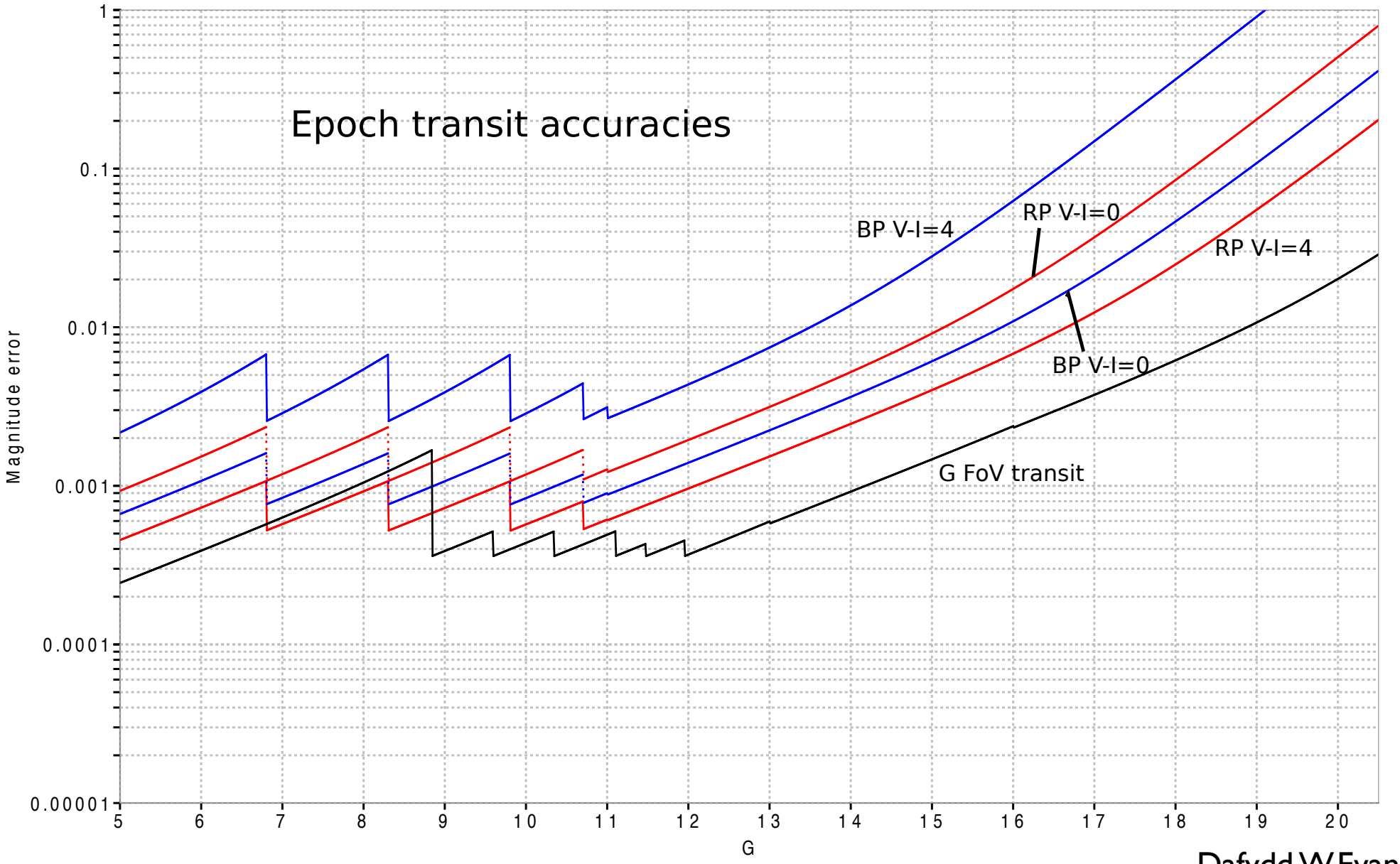
dereddened Colour

...

Time scales

Amplitudes

Epoch photometric accuracies



Dafydd W. Evans

Numbers of variable objects for Gaia

Estimations of ~ 50-150 million variable objects

Conservative: 18 million Classical Variable stars

- 0.5 or 2-3 or 7 million Eclipsing Binaries (Söderhjelm 2004, Eyer & Cuypers 2000, Zwitter 2002)
- 5,000-30,000 Planetary transit systems (Robichon 2002)
- 70,000 RR Lyrae stars (Eyer&Cuypers 2000)
- 2,000-8,000 Cepheids (Eyer&Cuypers 2000)
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Big difference between the signal presence and its detection

Examples of light curves

100 million variable objects?

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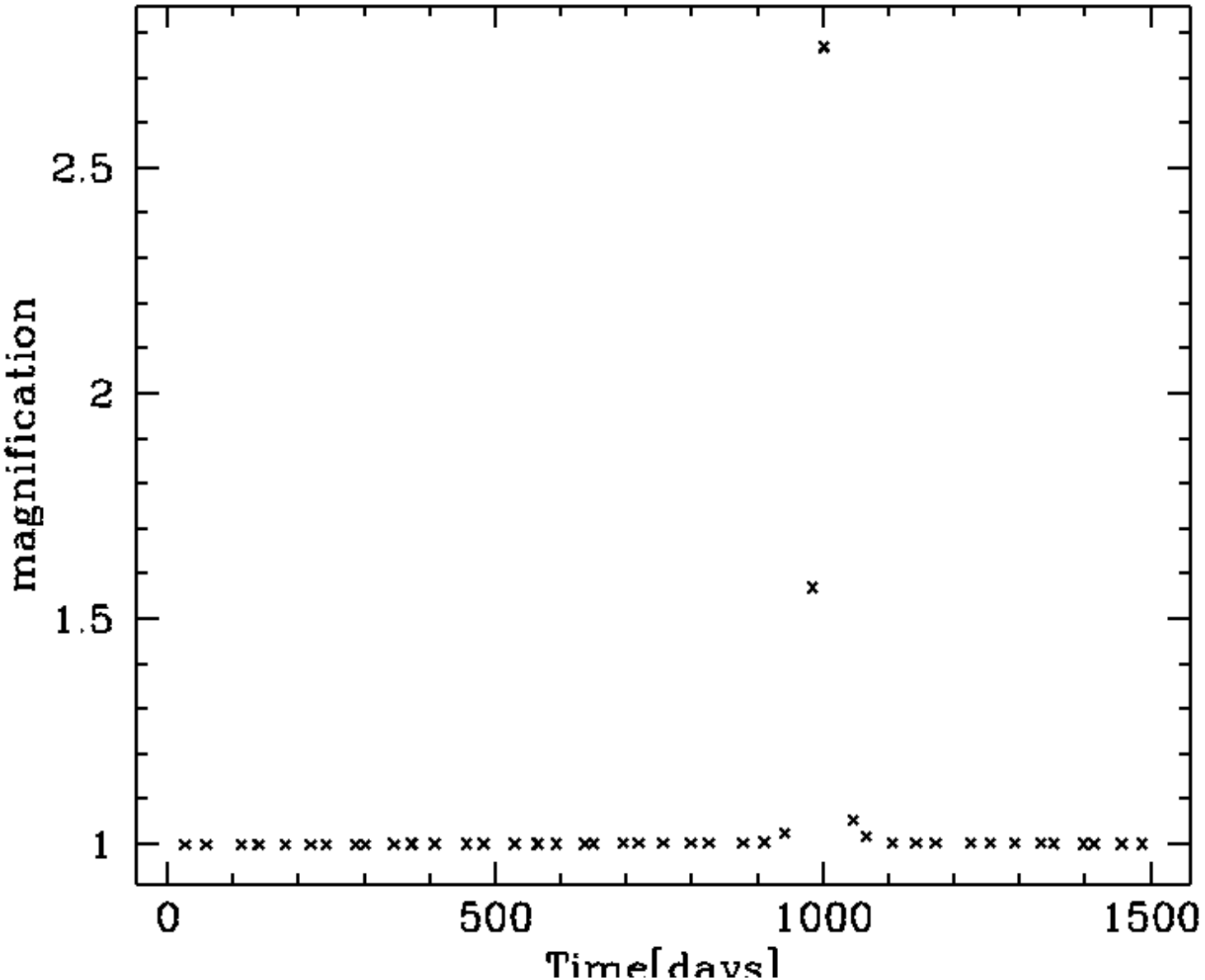

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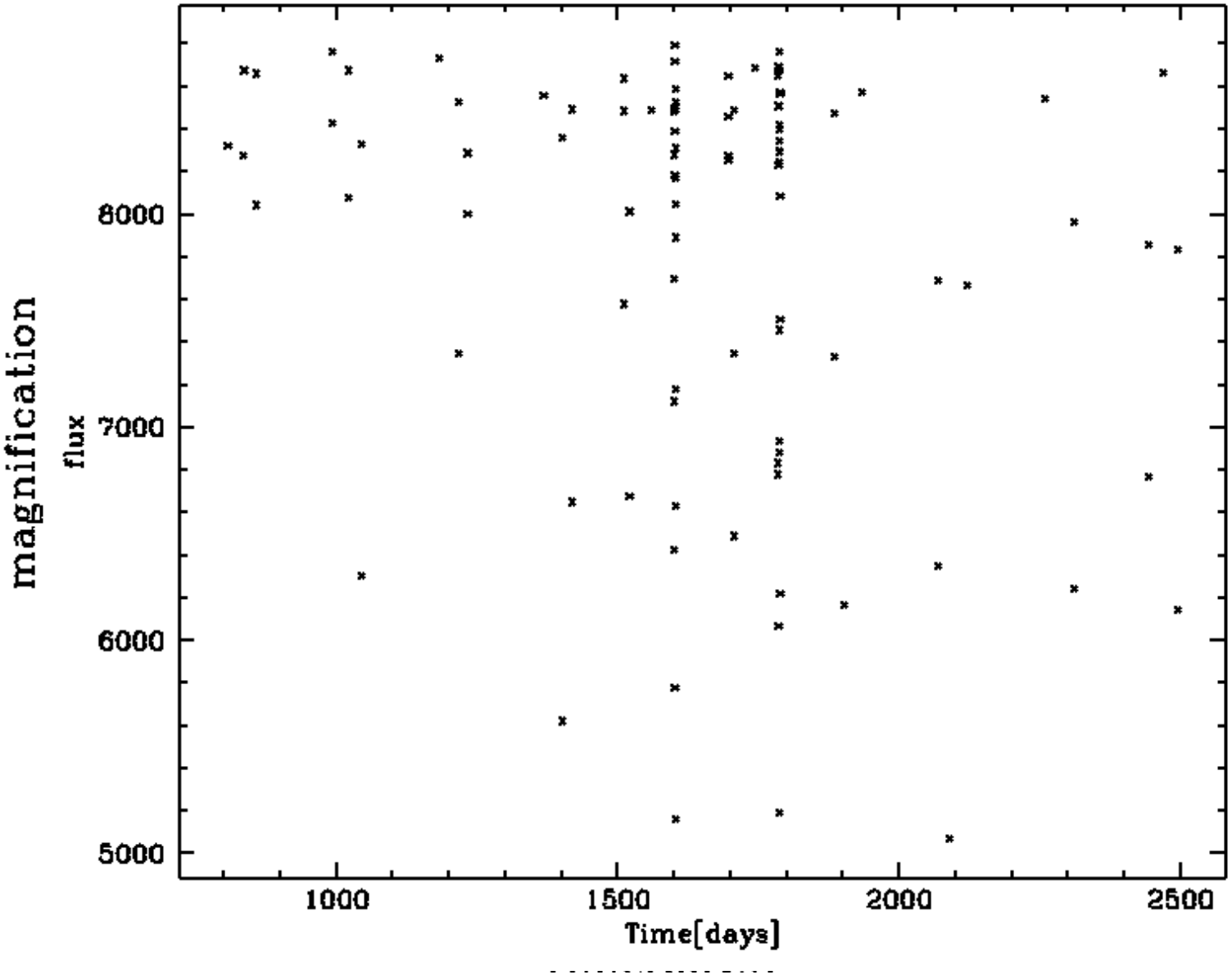

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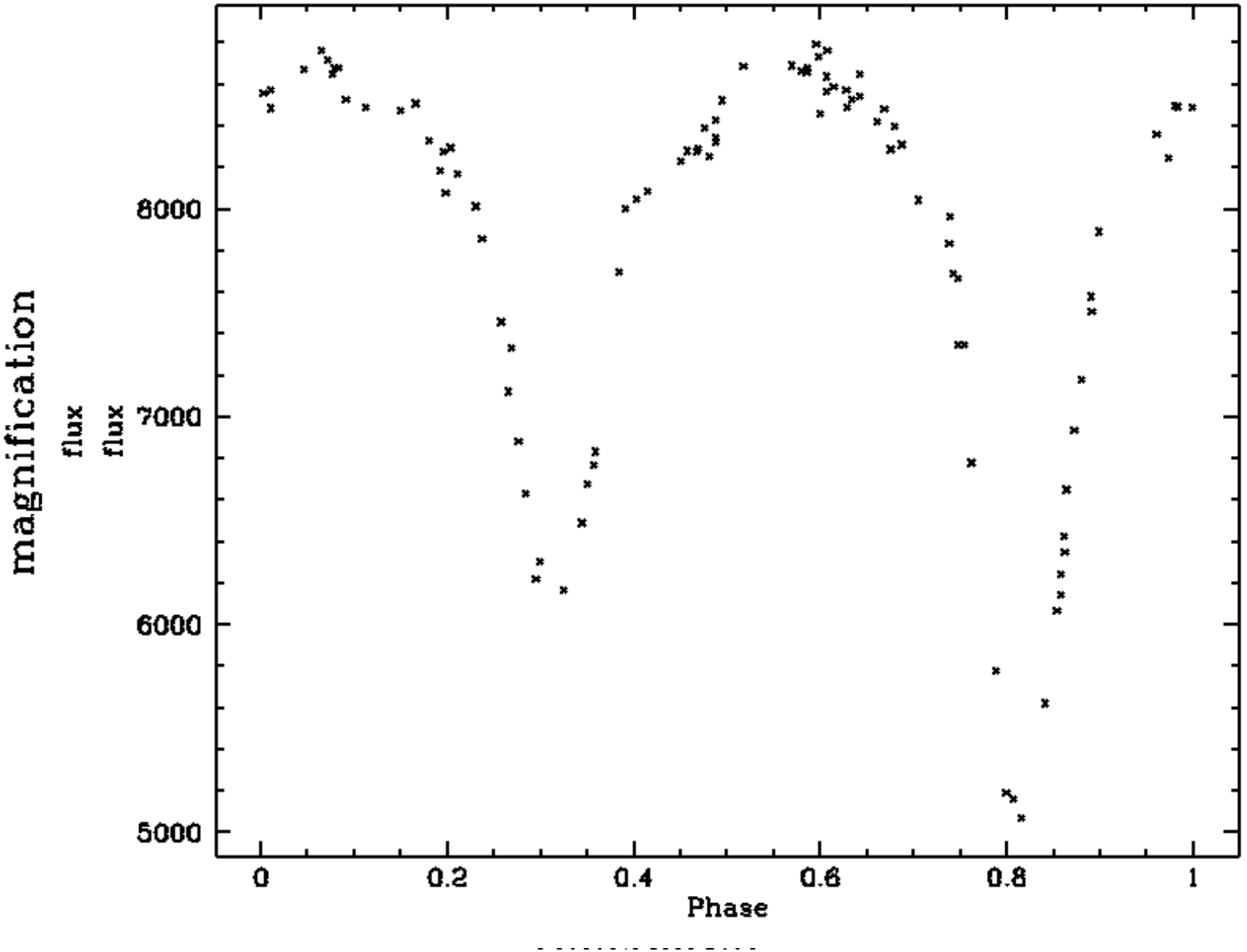

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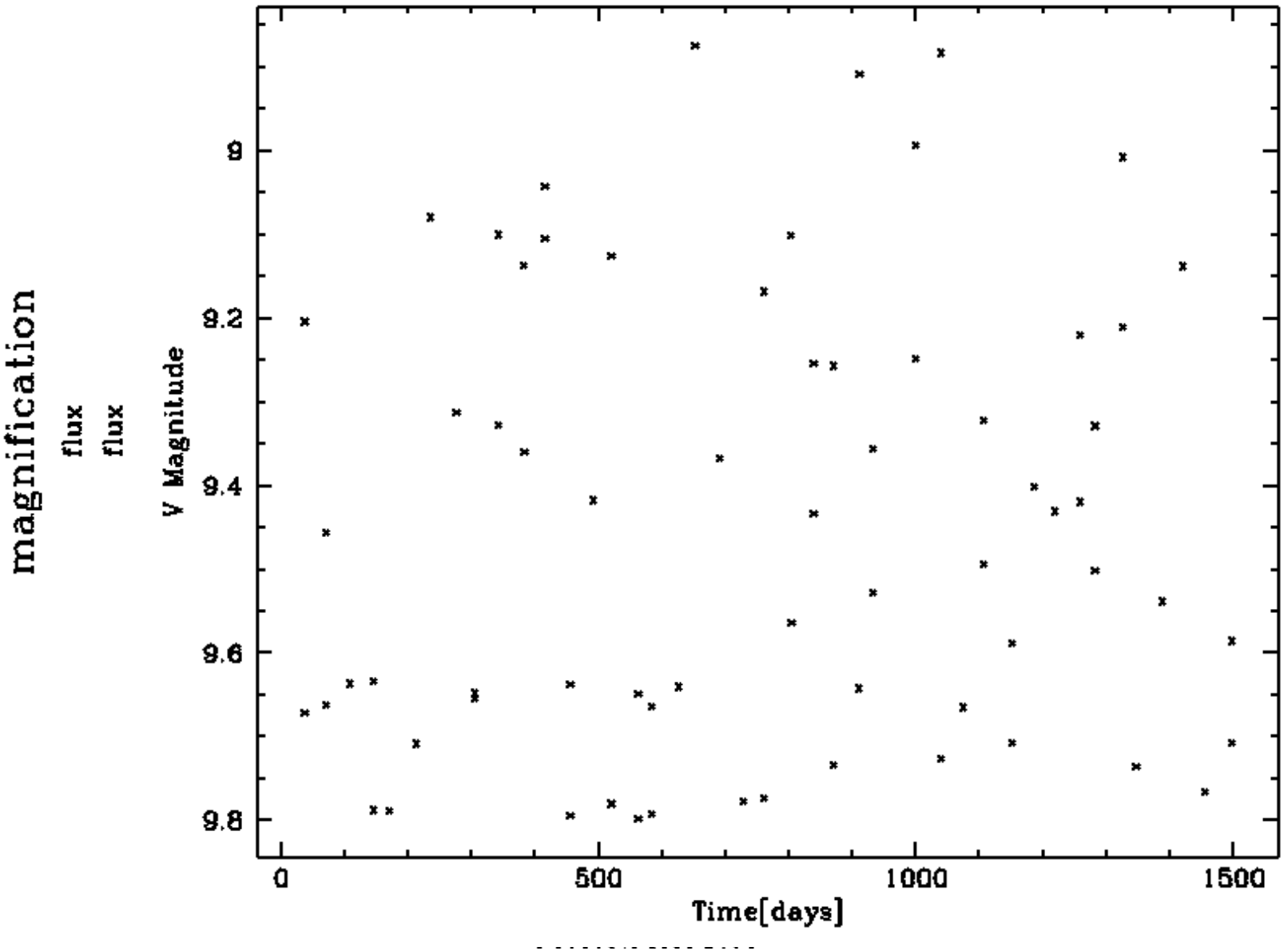

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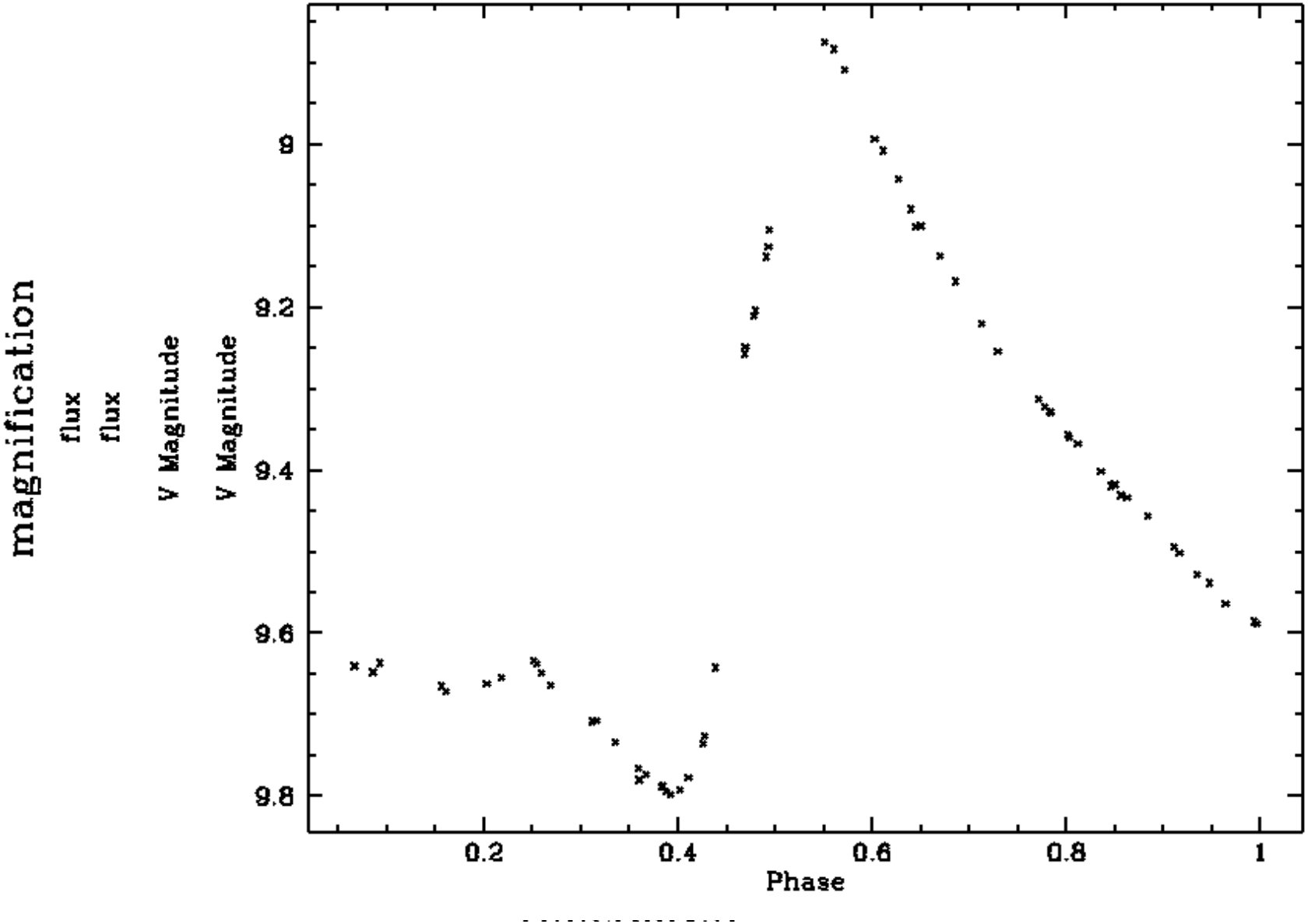

Introduction: two approaches

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1. Find particular objects

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2. Global

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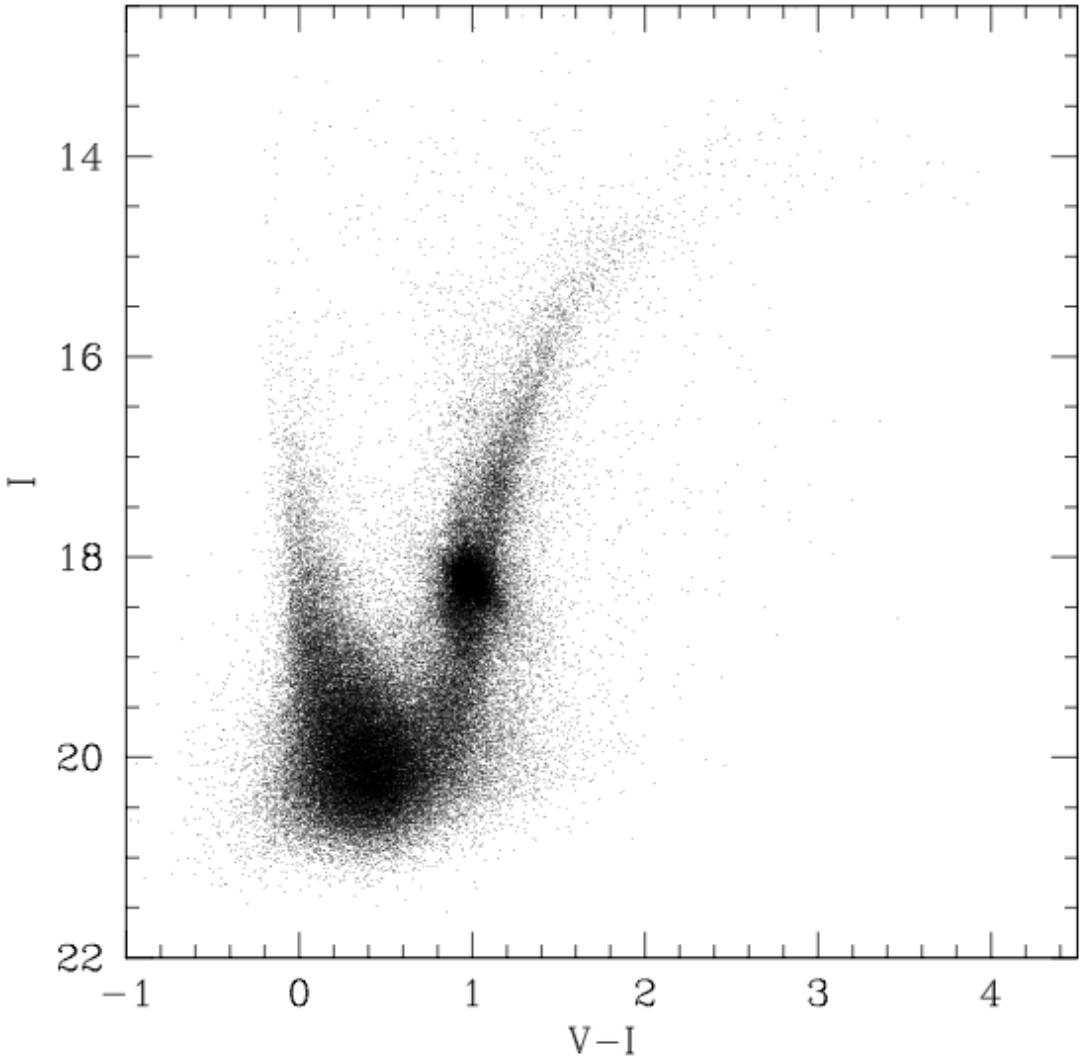
Need of good parameters characterizing the phenomenon and efficient methods

Colour Magnitude diagram: OGLE-II LMC

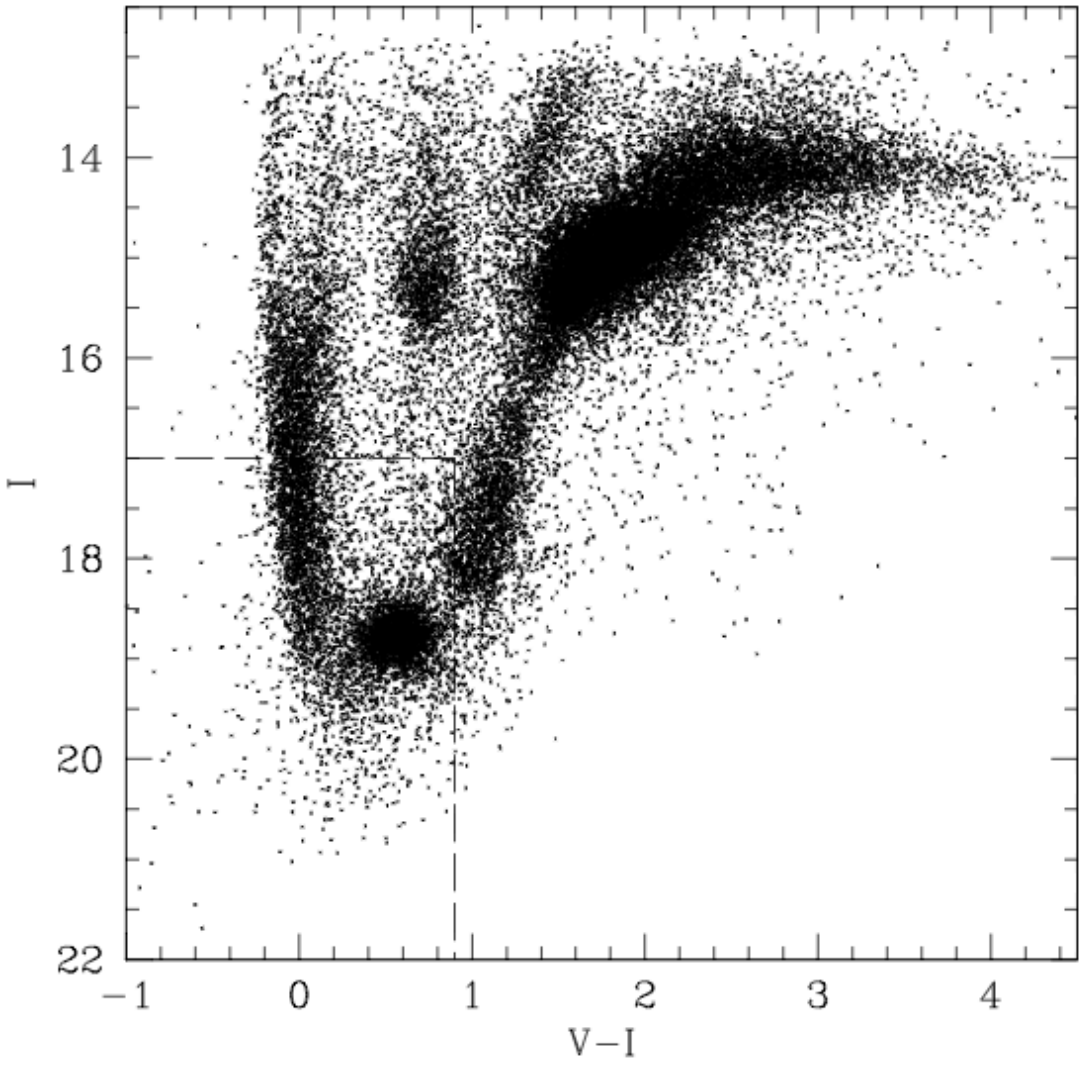
6 million stars



Eyer 2002

Colour Magnitude diagram: OGLE-II LMC

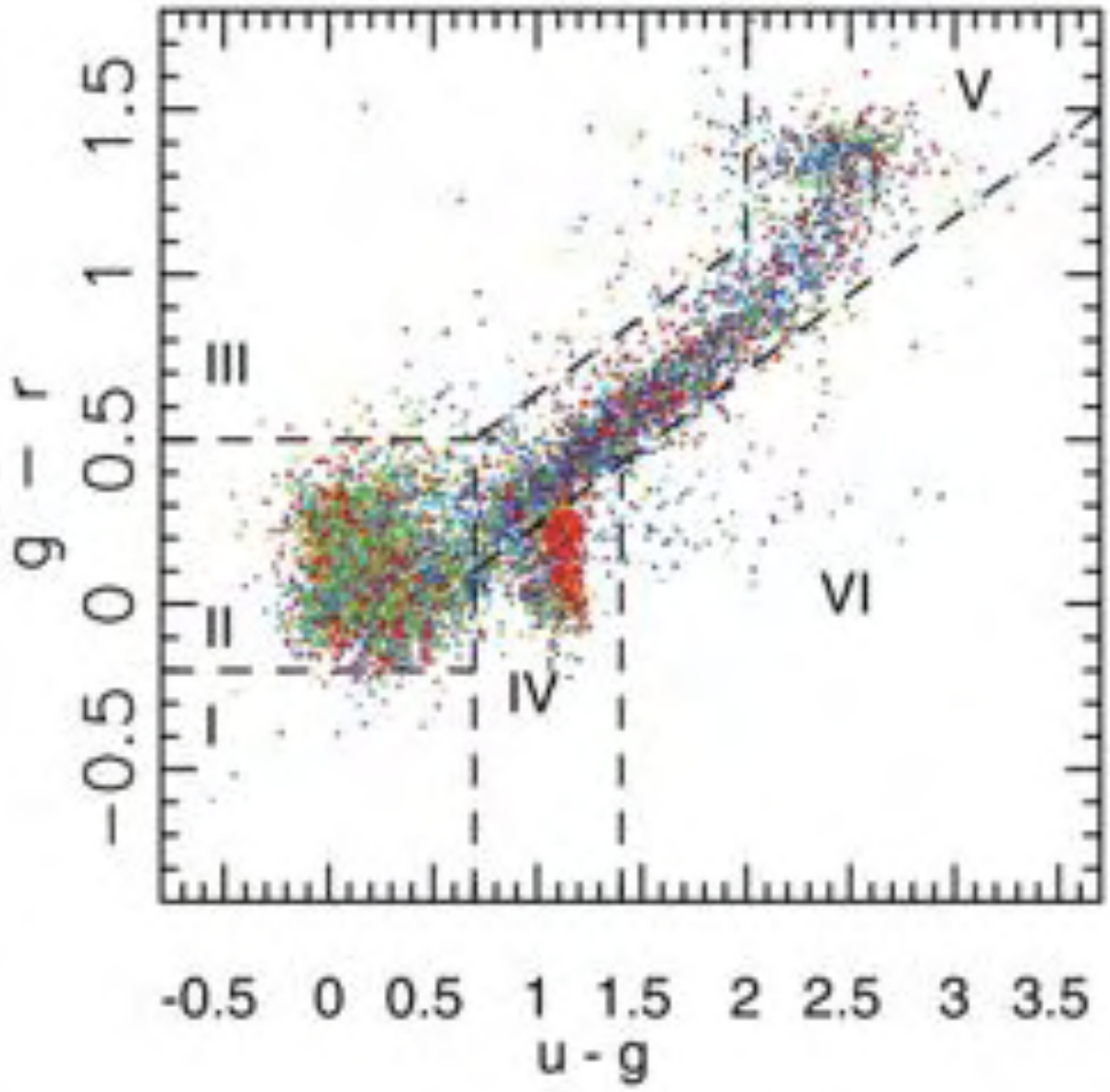
53’000 variable stars



Eyer 2002

SDSS Stripe 82

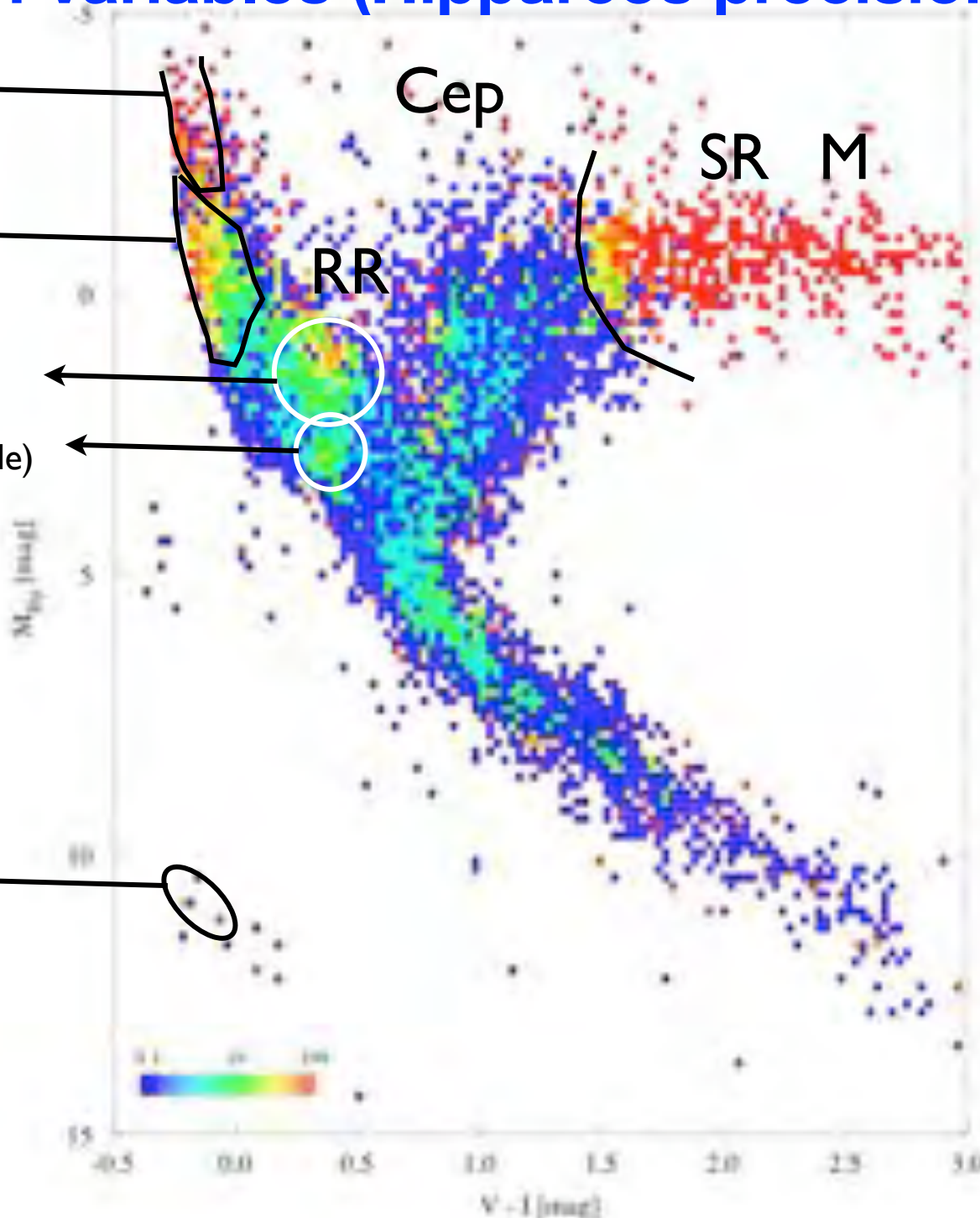
18,000 variables/750,000 objects



mean of
10 measurements
over 6 years

Sesar et al. 2007

Fraction of variables (Hipparcos precision)



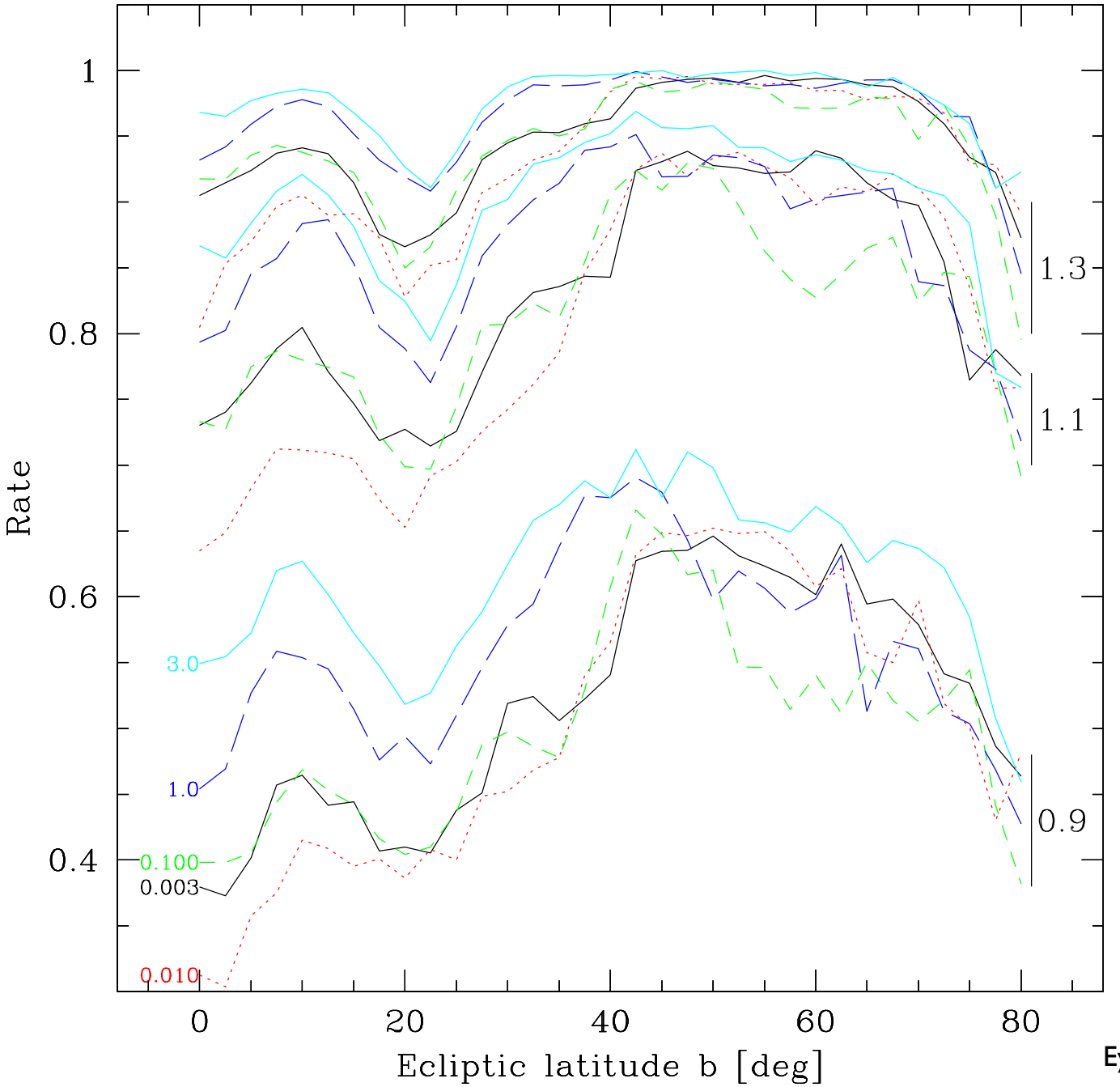
β Cep (p mode)
Be stars
SPB (g mode)
δSct (p mode)
γDor (g mode)
ZZ Ceti
DAV (g mode)

ESA SP-1200 1997

11,587 variables
118,204

But limited to "good" parallaxes

Period recovery rate: exploring the parameter space



Eyer & Mignard 2005

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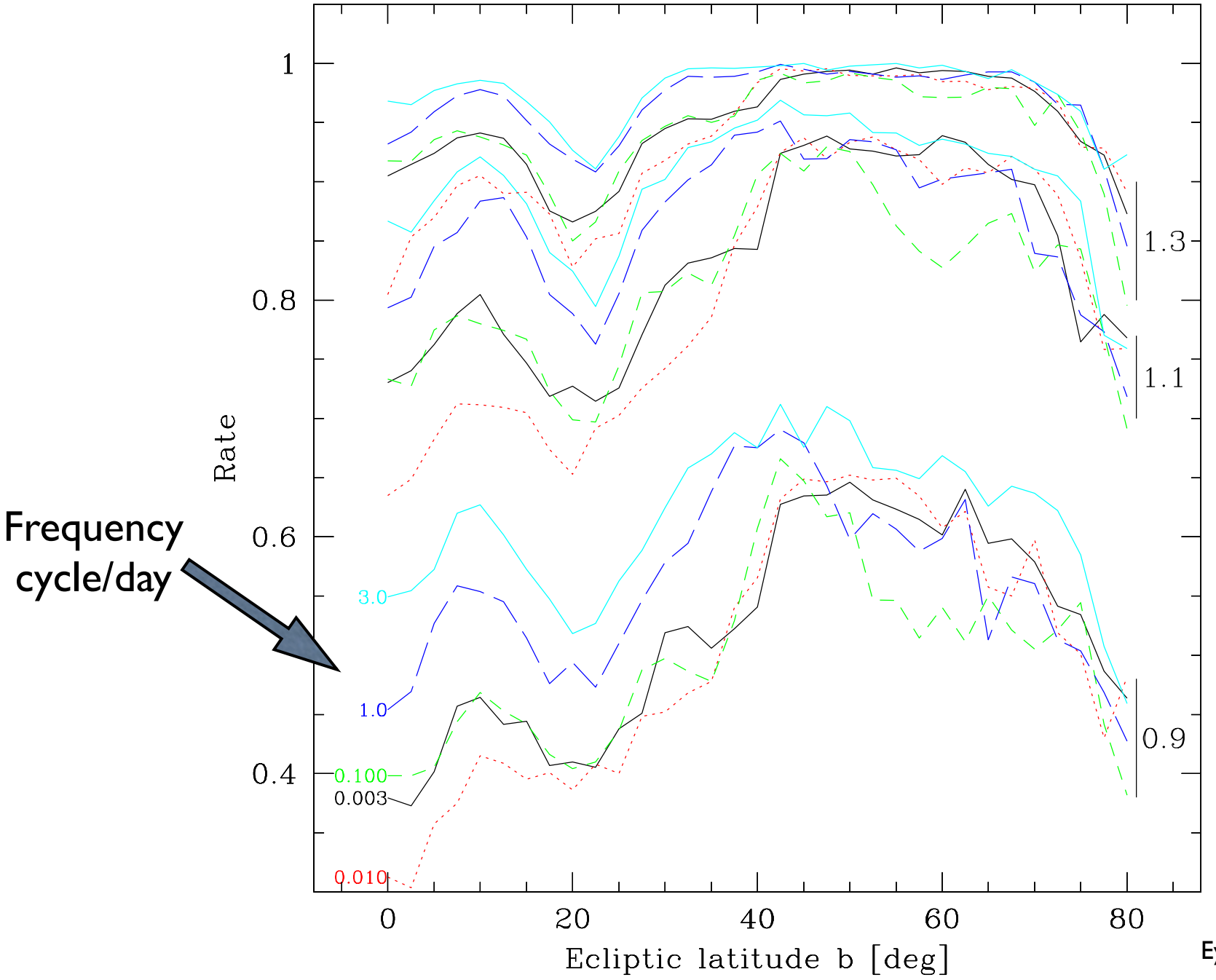

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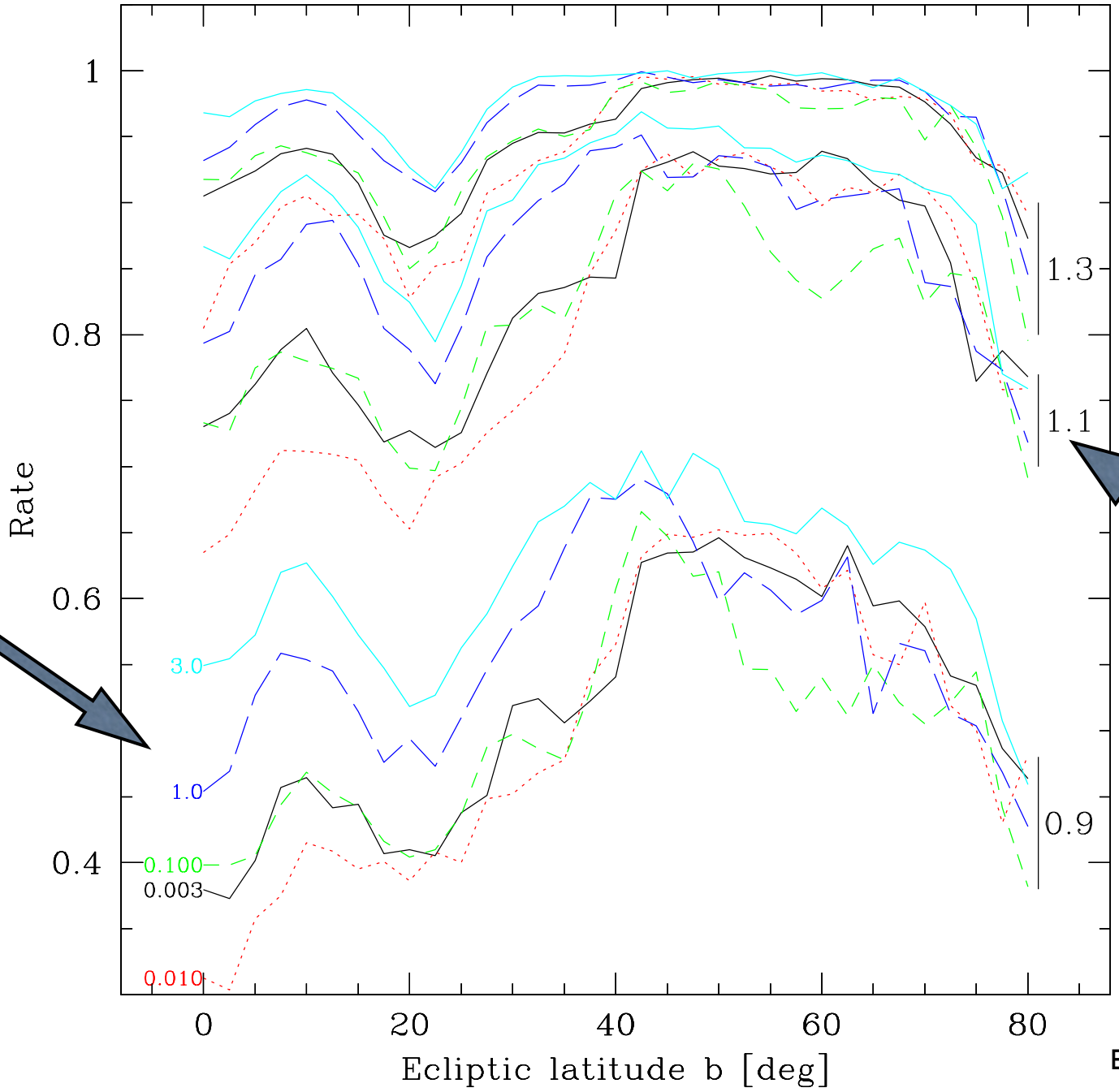
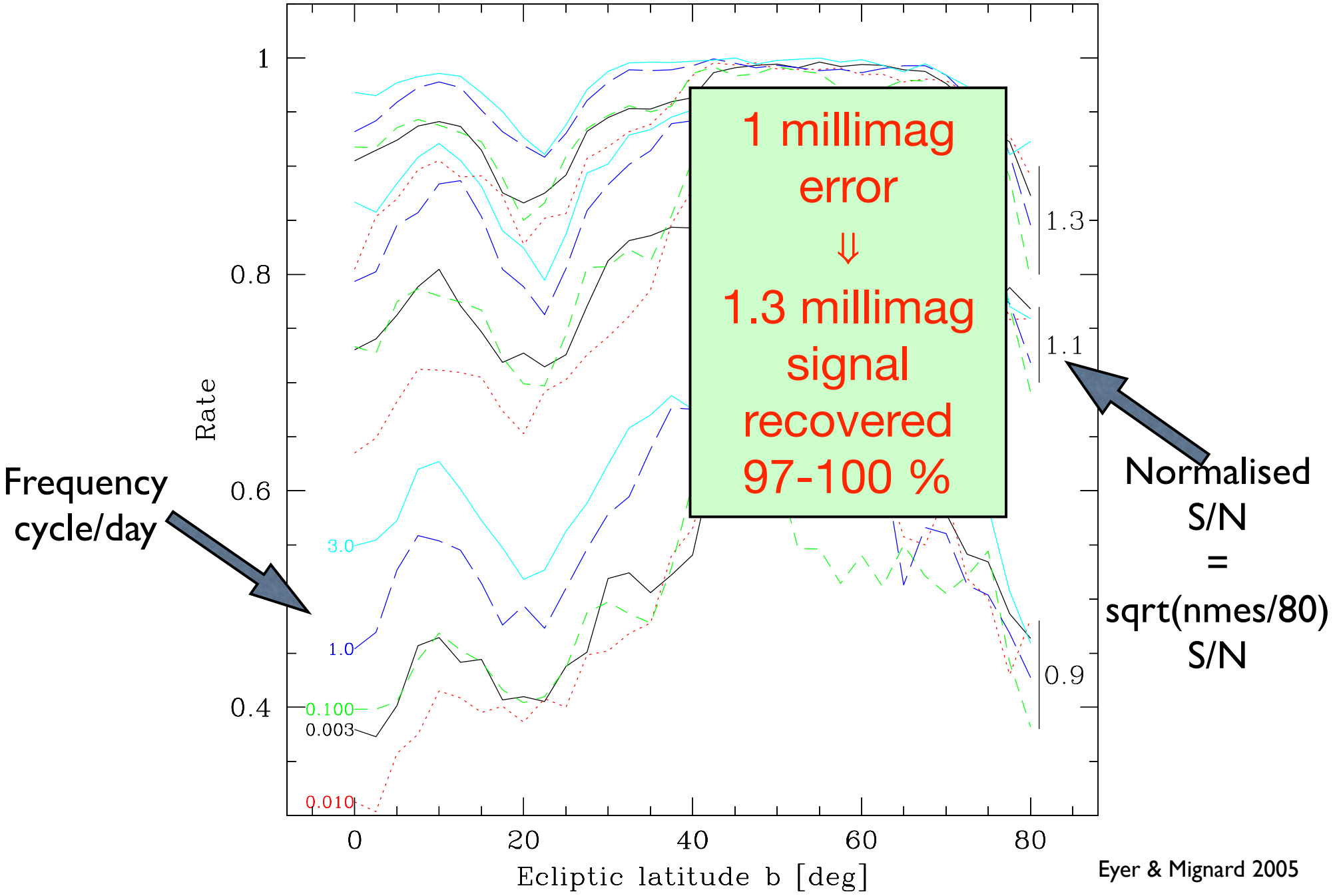


Frequency
cycle/day

Normalised
S/N
=
sqrt(nmes/80)
S/N

Eyer & Mignard 2005

Period recovery rate: exploring the parameter space



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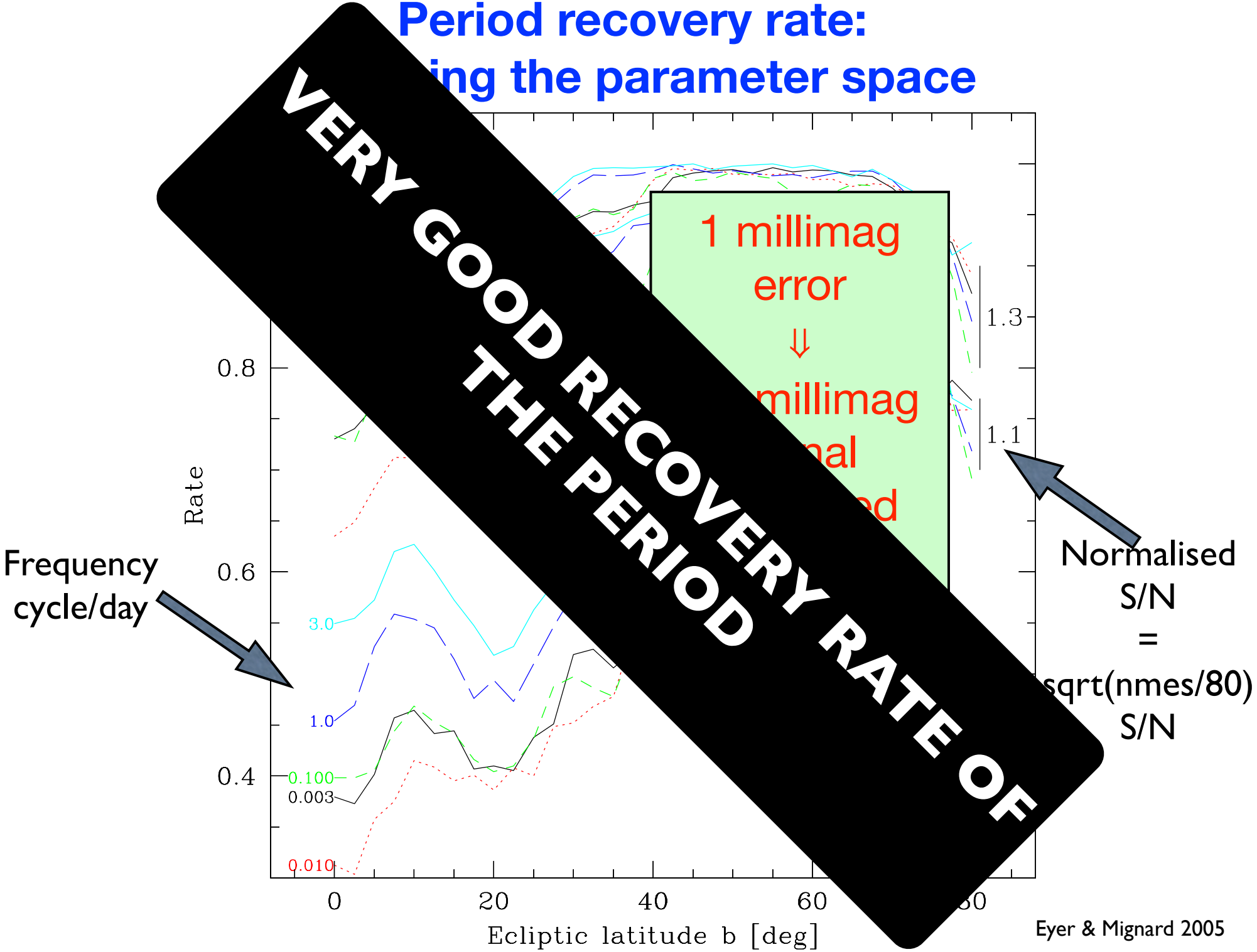
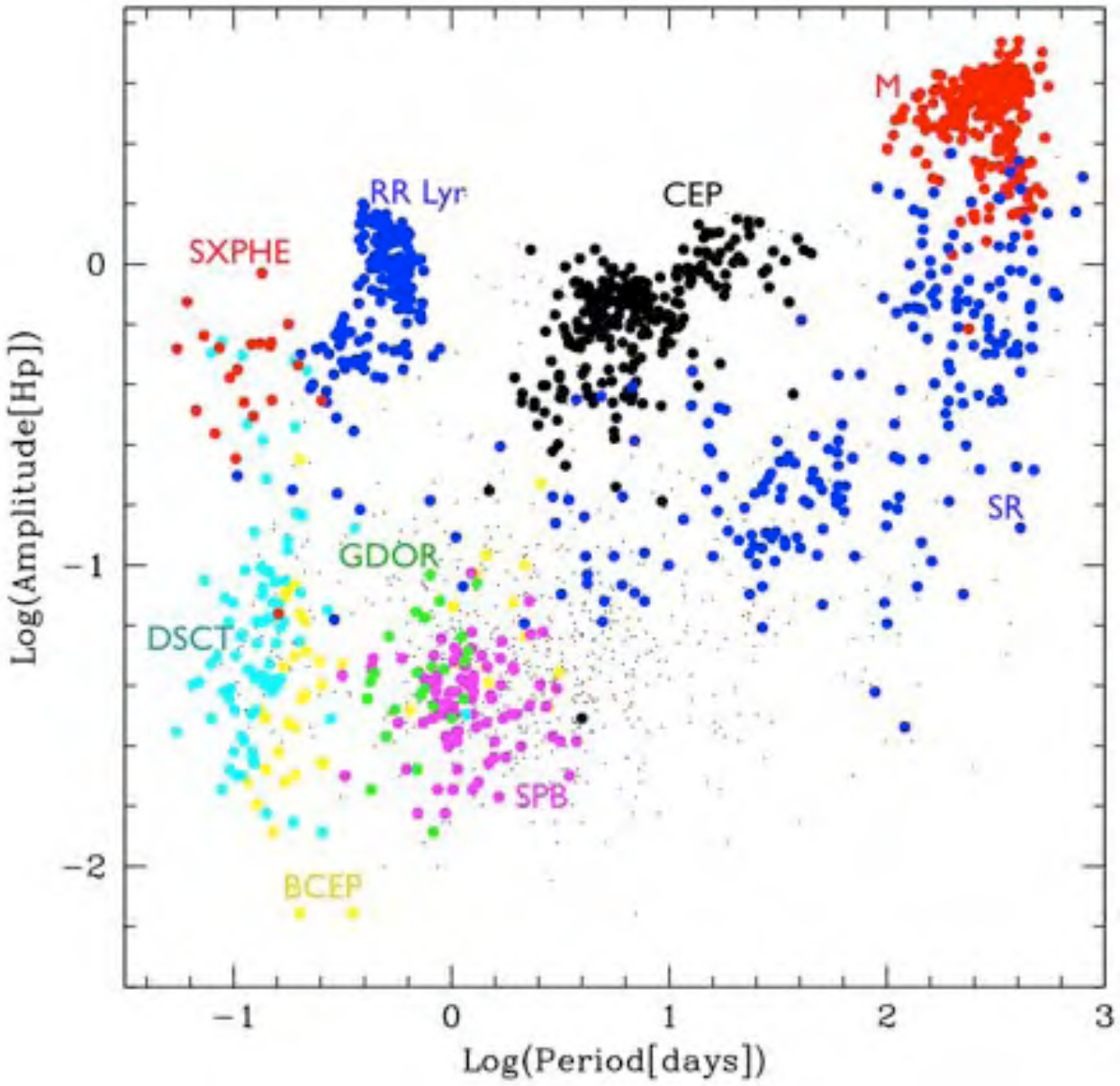


Eyer & Mignard 2005

Hipparcos Period-Amplitude Diagram for pulsating stars



Amplitude période couleur (V-I)
3-D

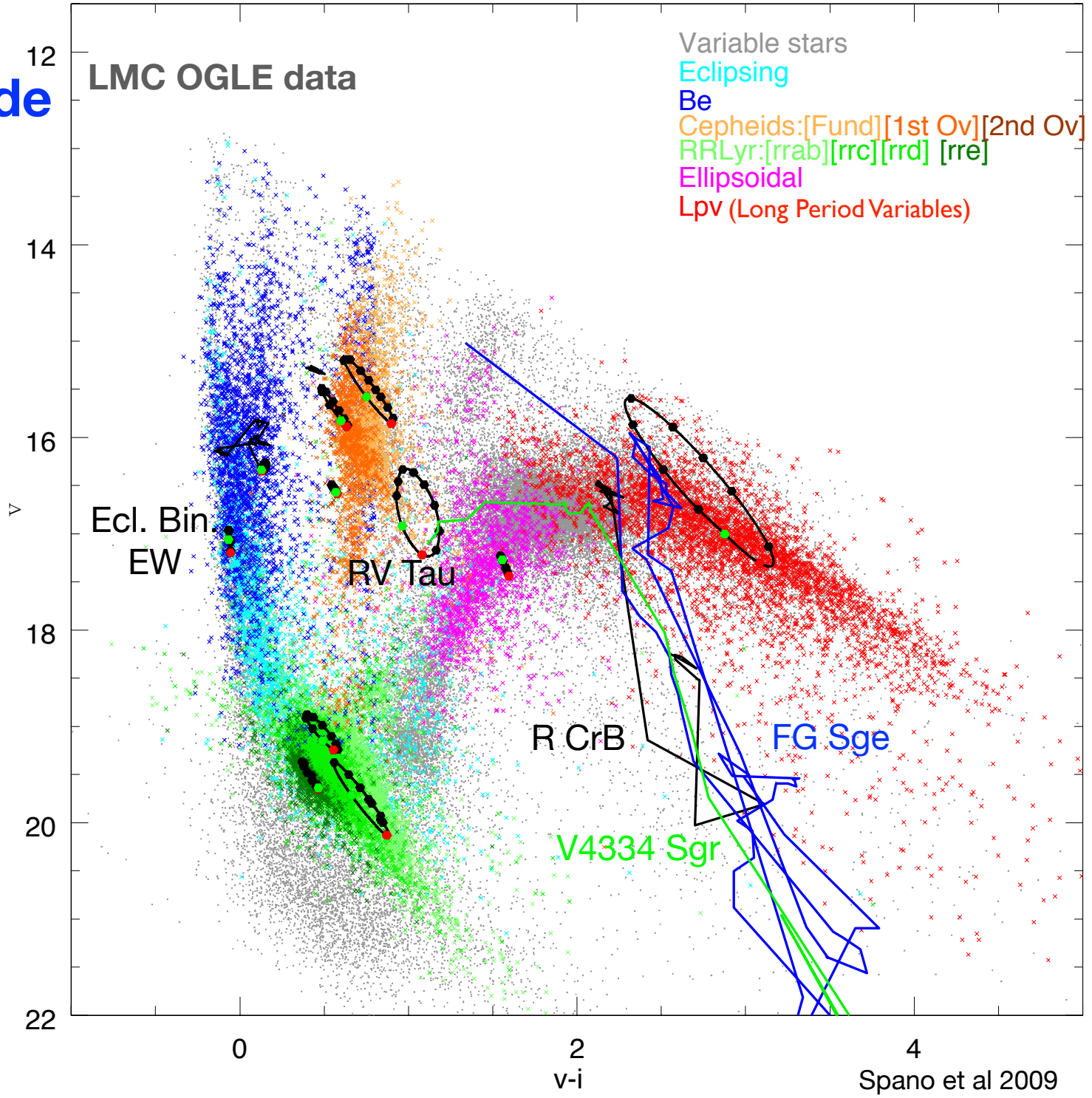
Classification of Hipparcos sources (CU7)

CU7 work:
Characterize
+
Classify
+
Additional
charact.
on specific
objects

	ECL	LPV	DCEP	RRAB	RRC	DSCT	SXPHE	GDOR	BCEP	GCAS	ACYG	SPB	ACV	RS	
601	582	3		1	1	1		3				5	3	2	ECL
421		410	5											6	LPV
258		5	247	1	1			1		1	1			1	DCEP
72				68	2		1	1							RRAB
26					23	1	2								RRC
83				1	4	70	5	1	1			1			DSCT
20				2	3	1	14								SXPHE
38	2					3		32				1			GDOR
28						2			26						BCEP
15			3			1	1			1	2	4	3		GCAS
18	1	2	1							1	8	2	3		ACYG
87	1									1	2	74	9		SPB
72	3					1				2	1	9	56		ACV
27		3	6								1			17	RS

EROS, SDSS,
CU2 simulations

Variable stars in Colour-Magnitude Diagram



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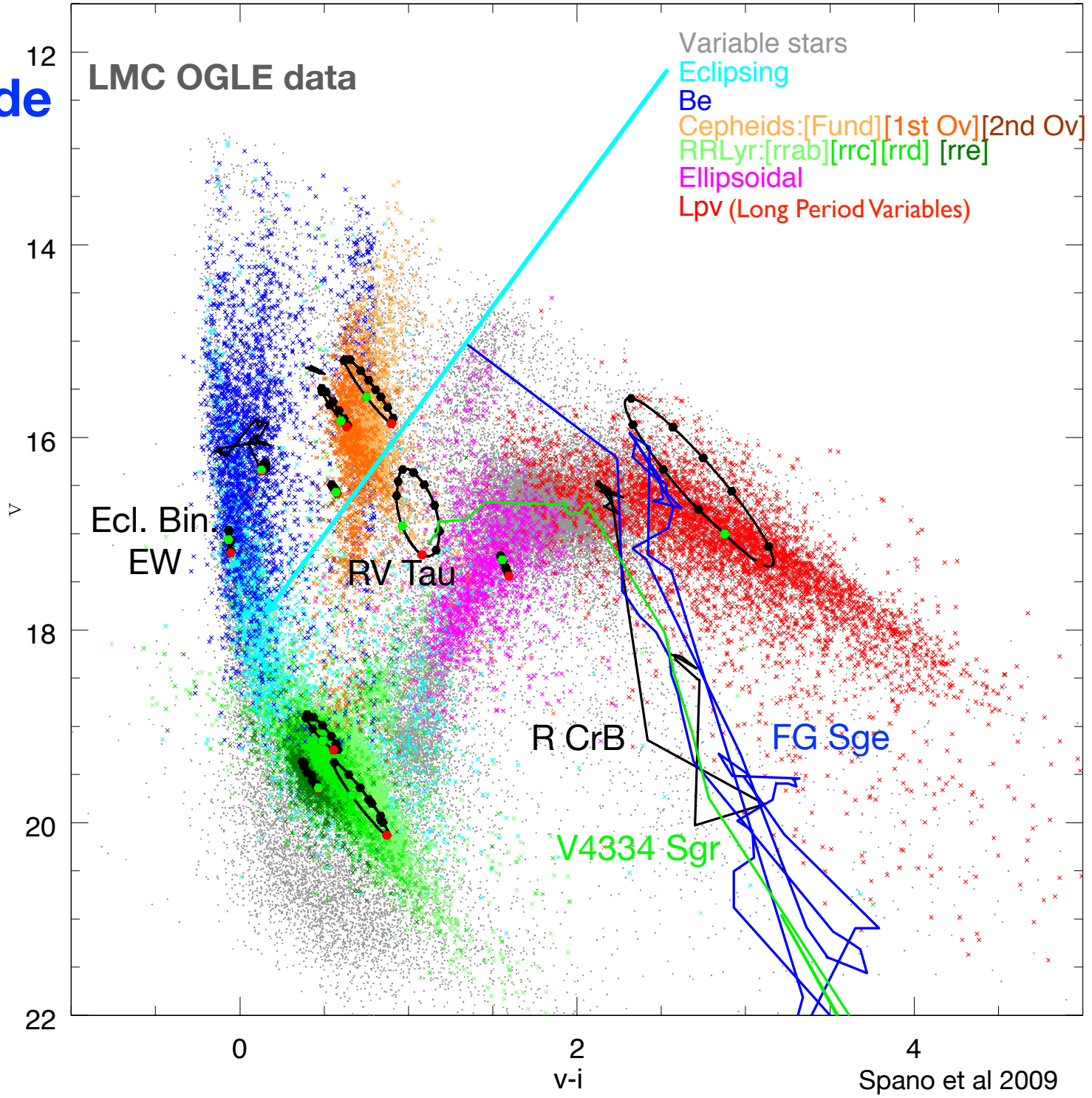

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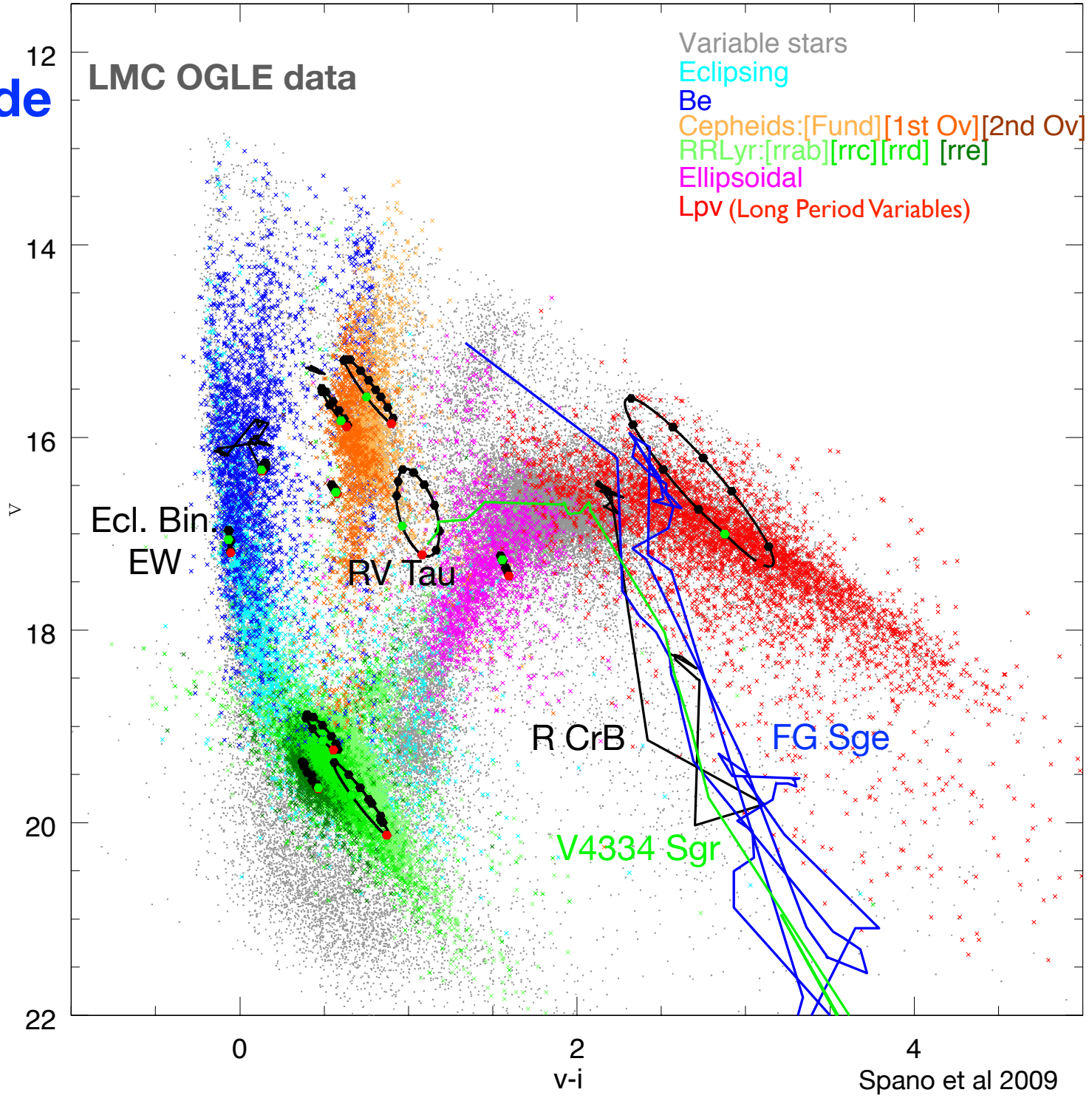

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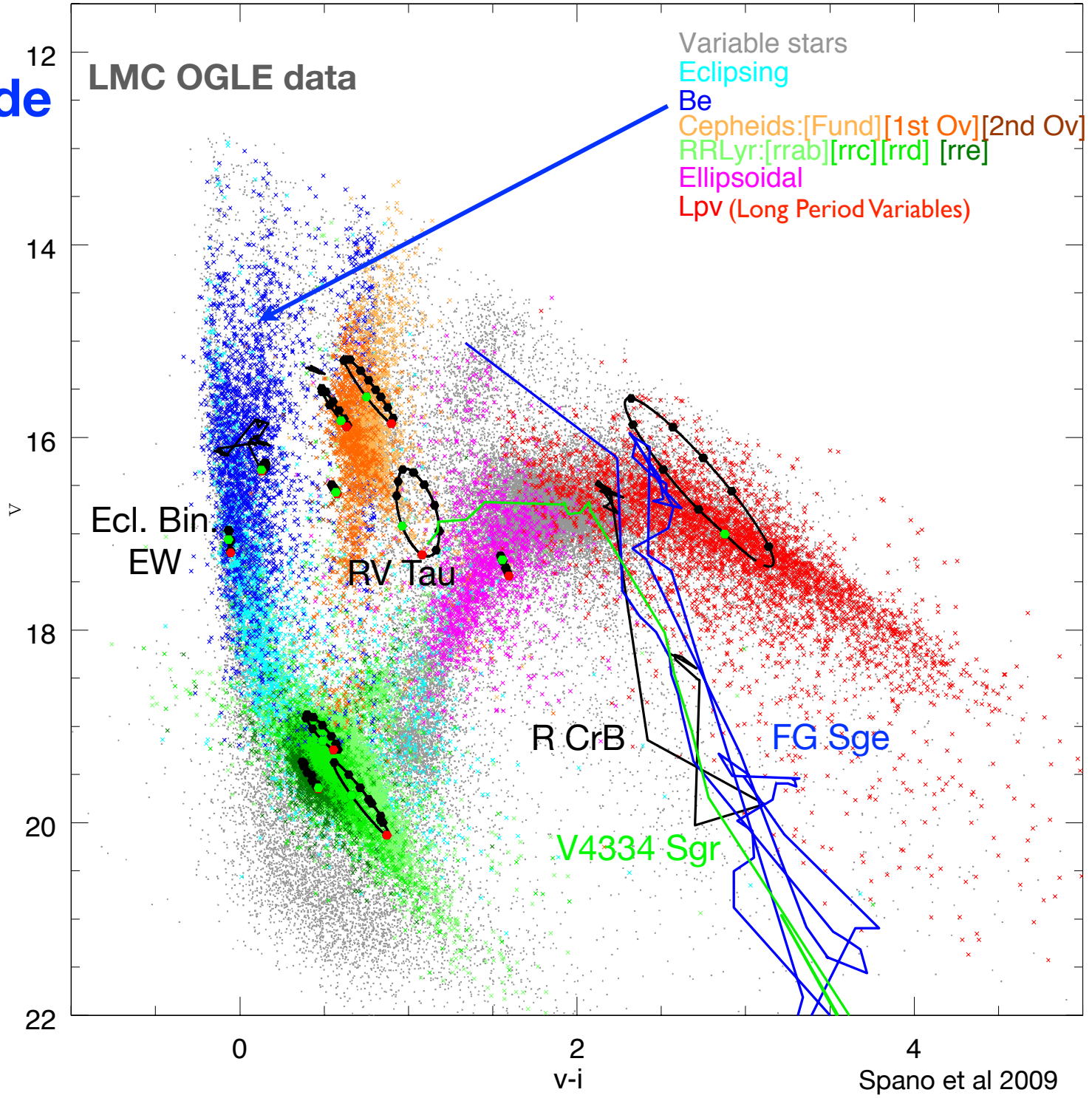

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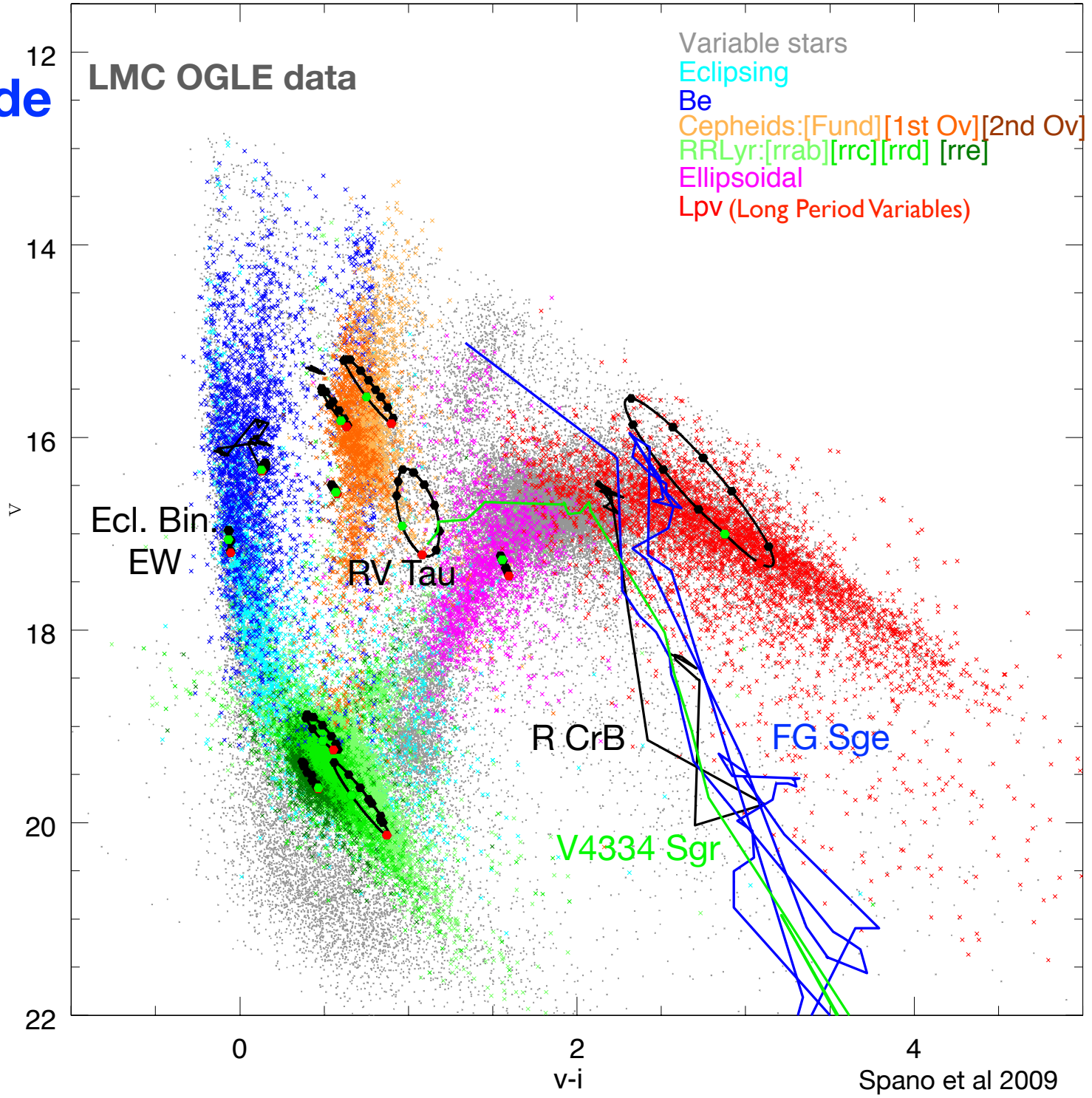

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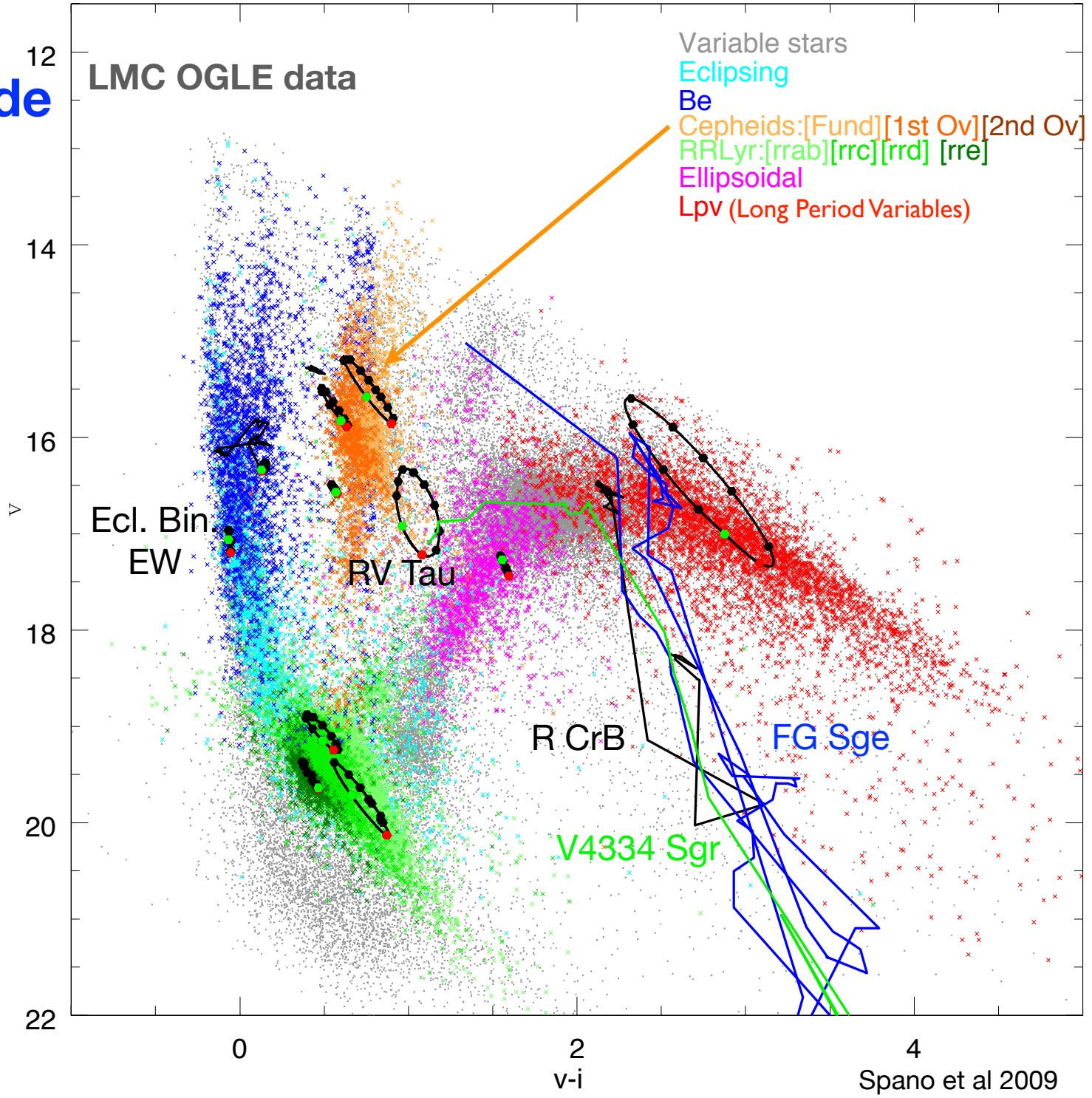

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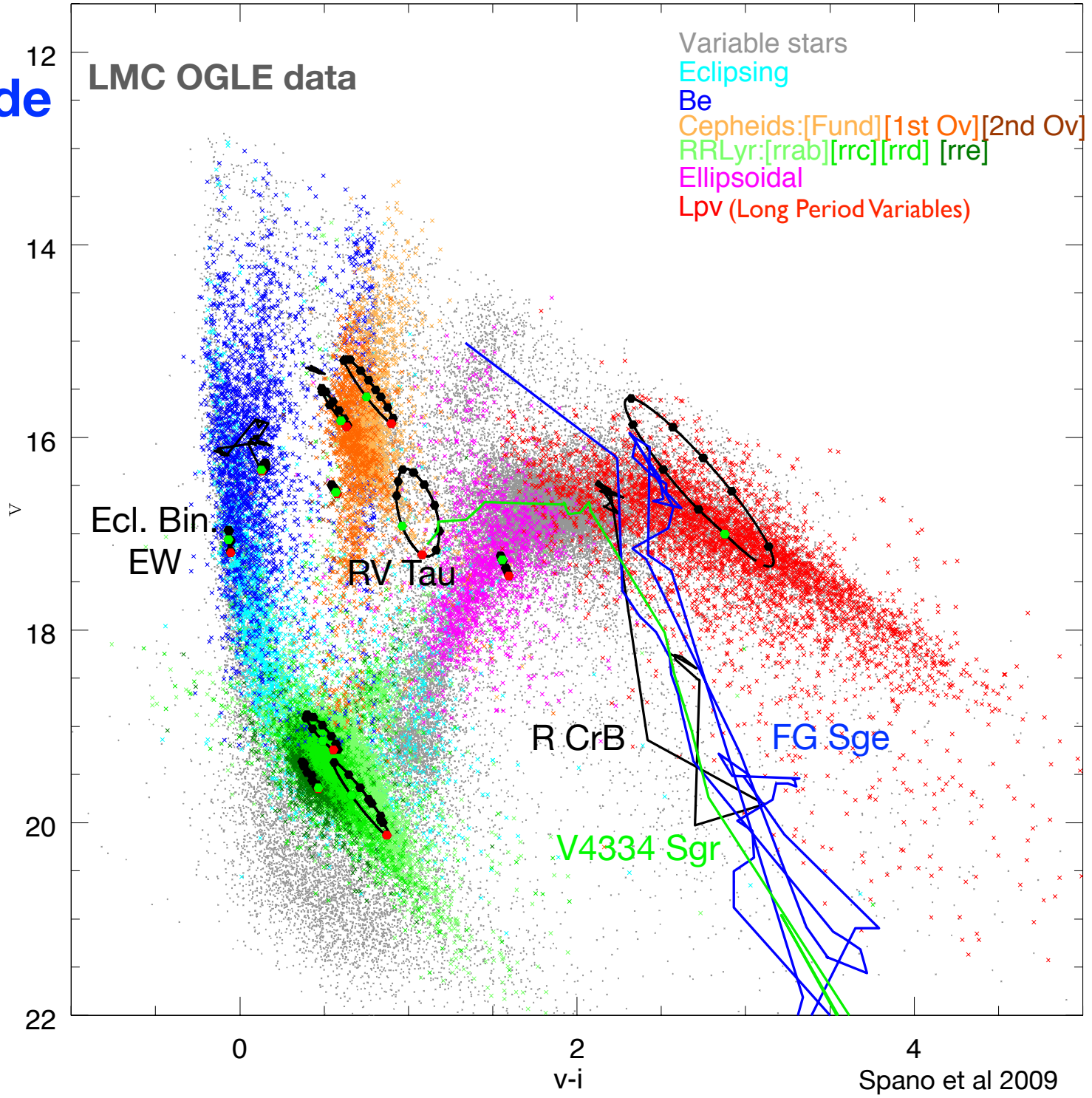

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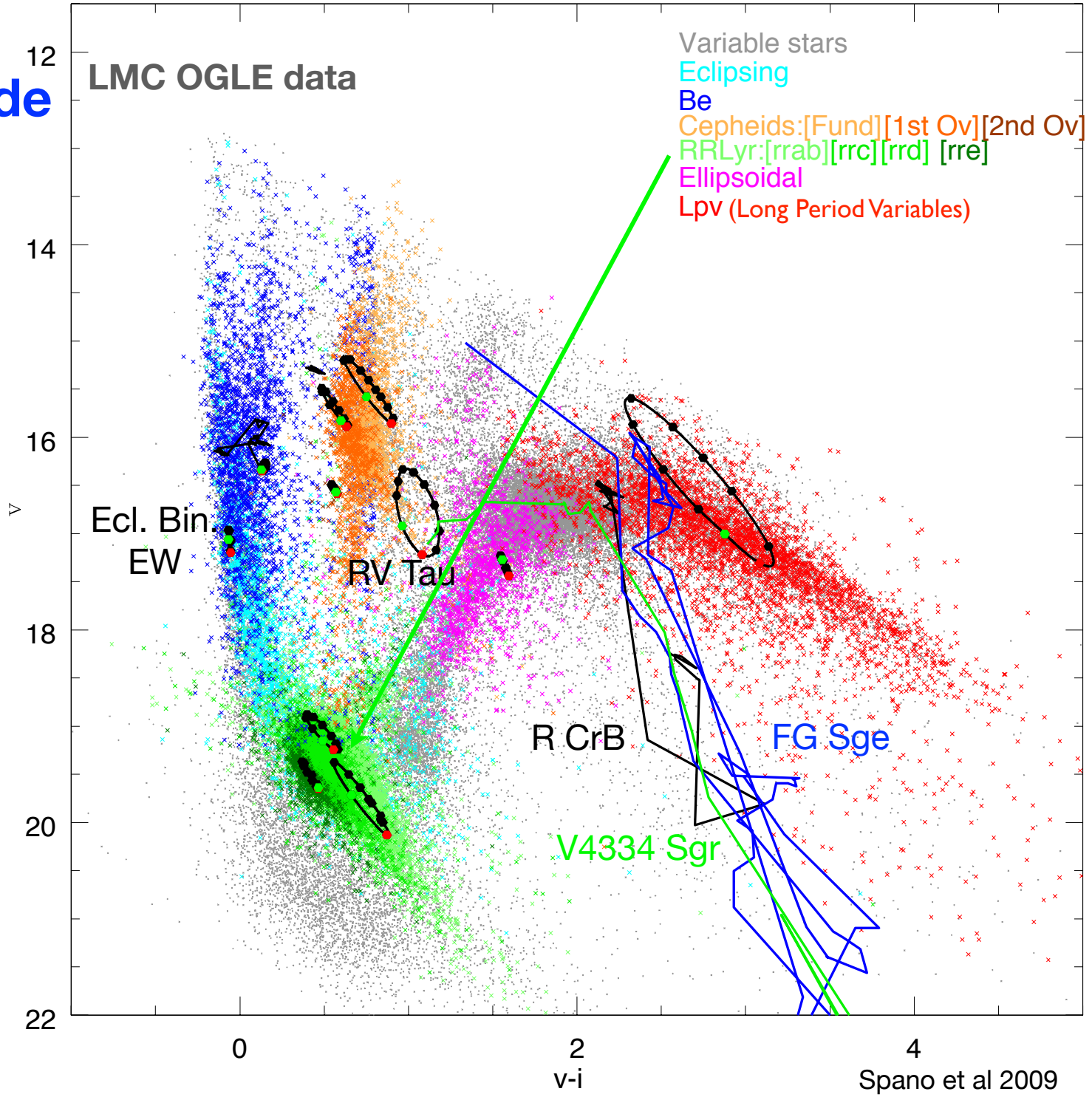

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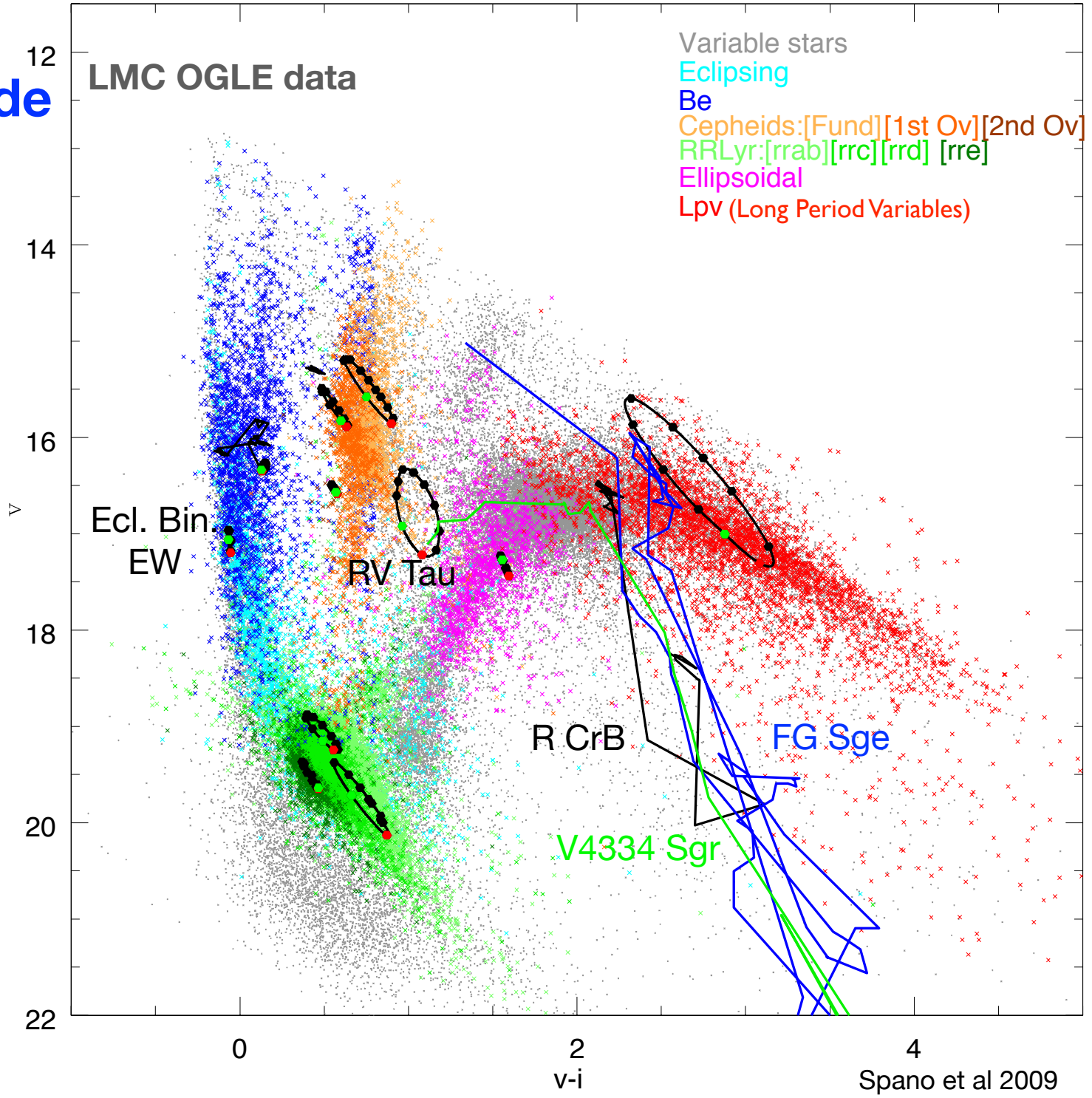

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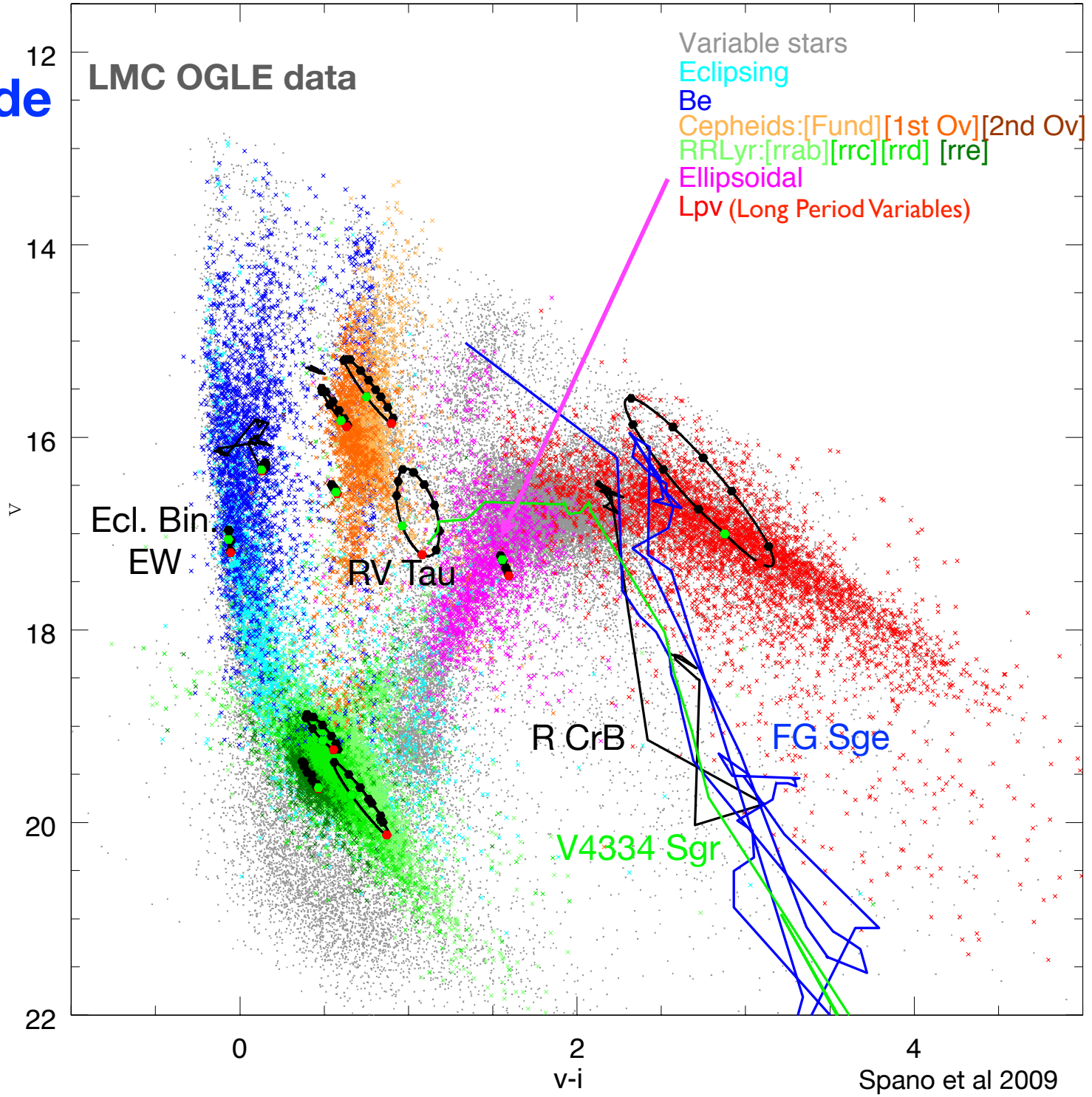

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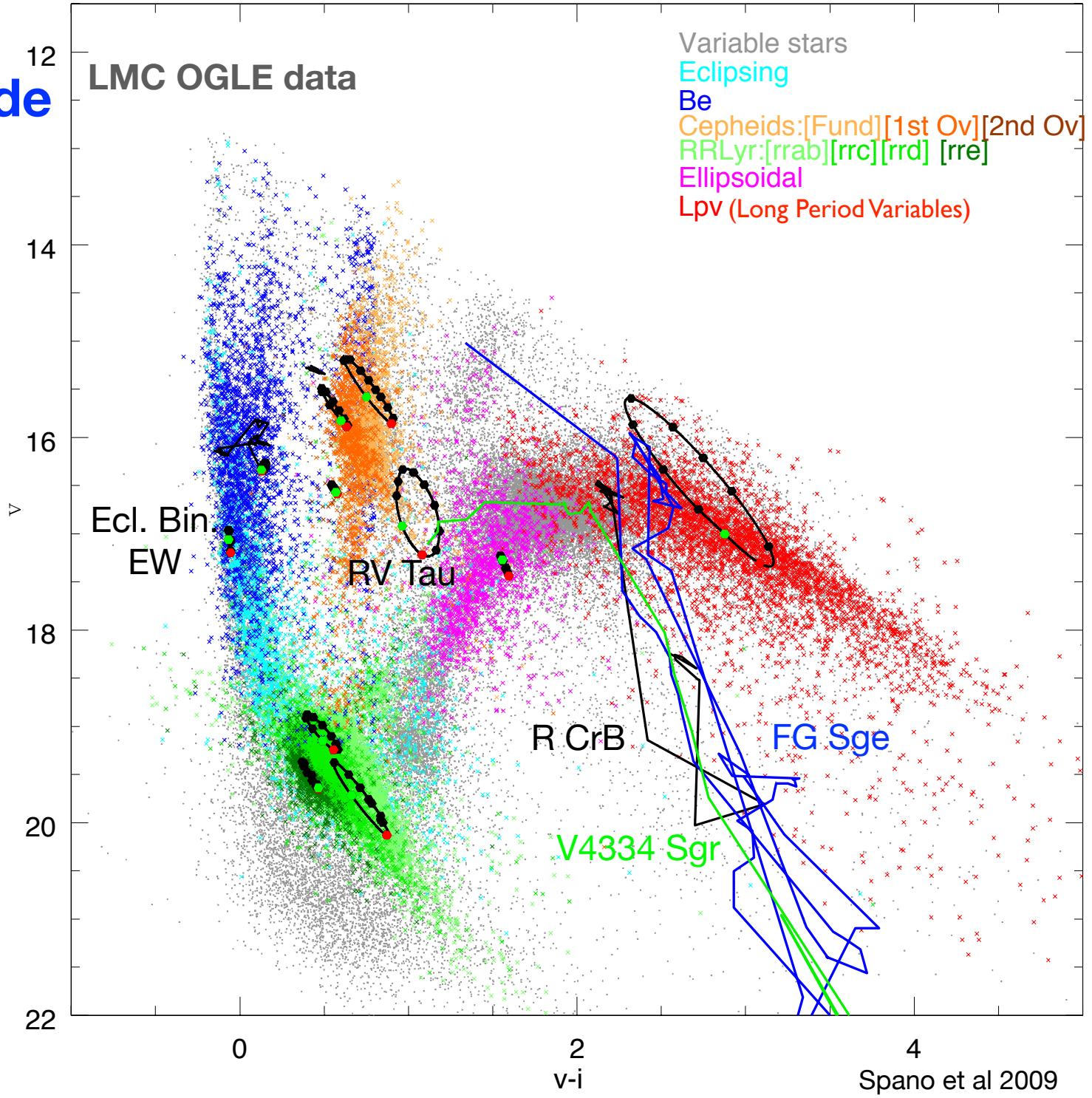

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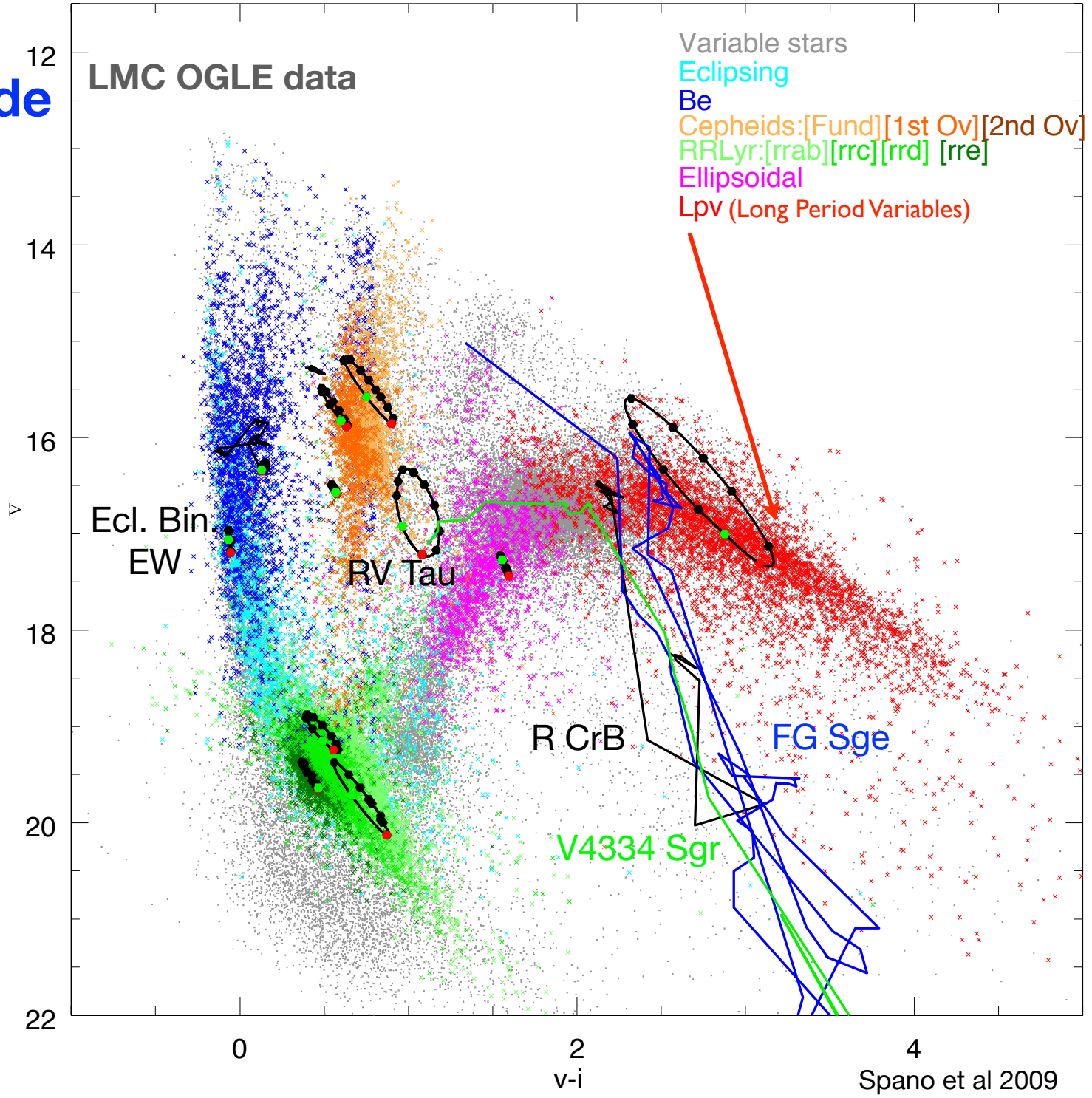

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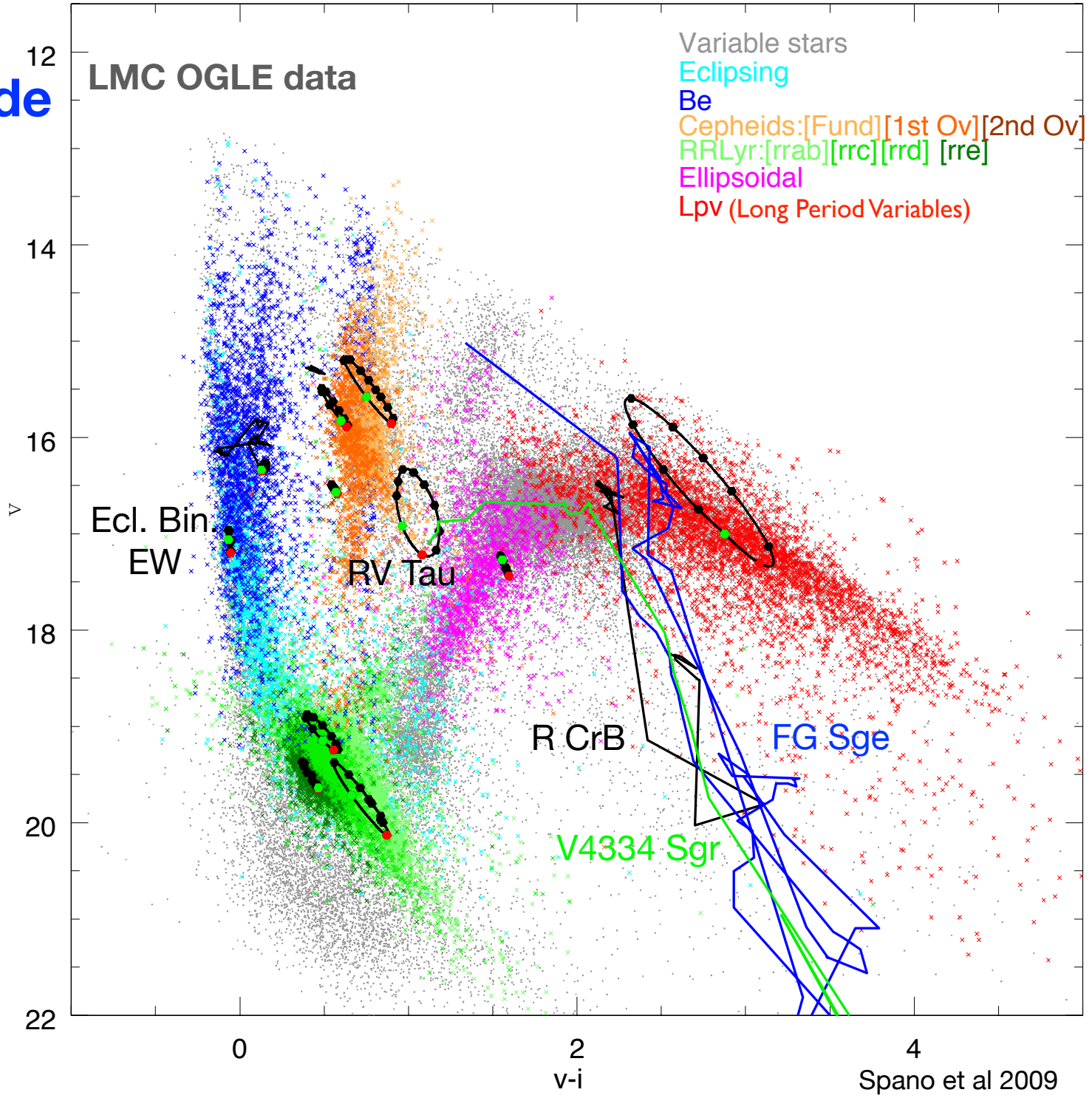

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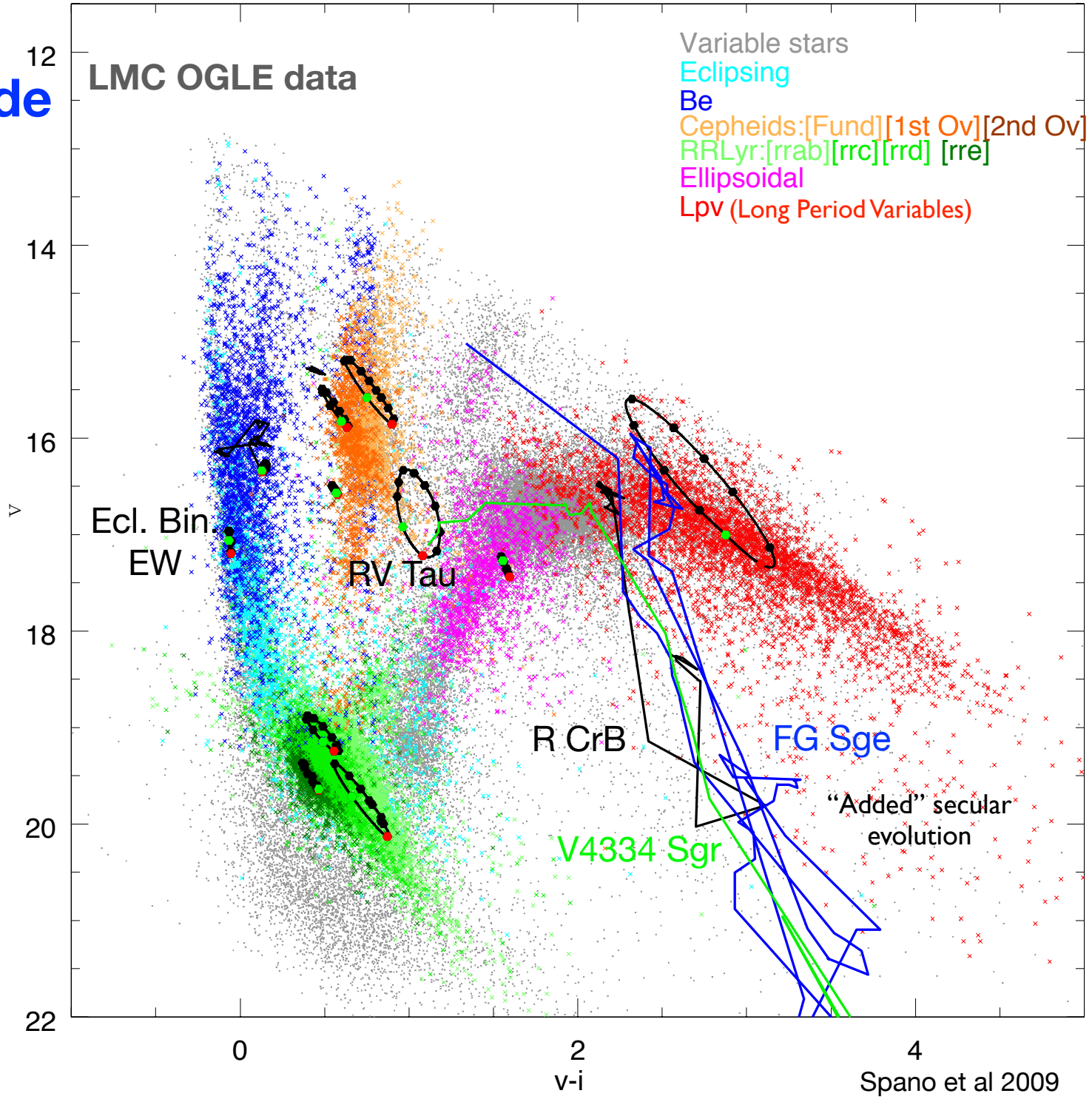


Variable stars in Colour-Magnitude Diagram

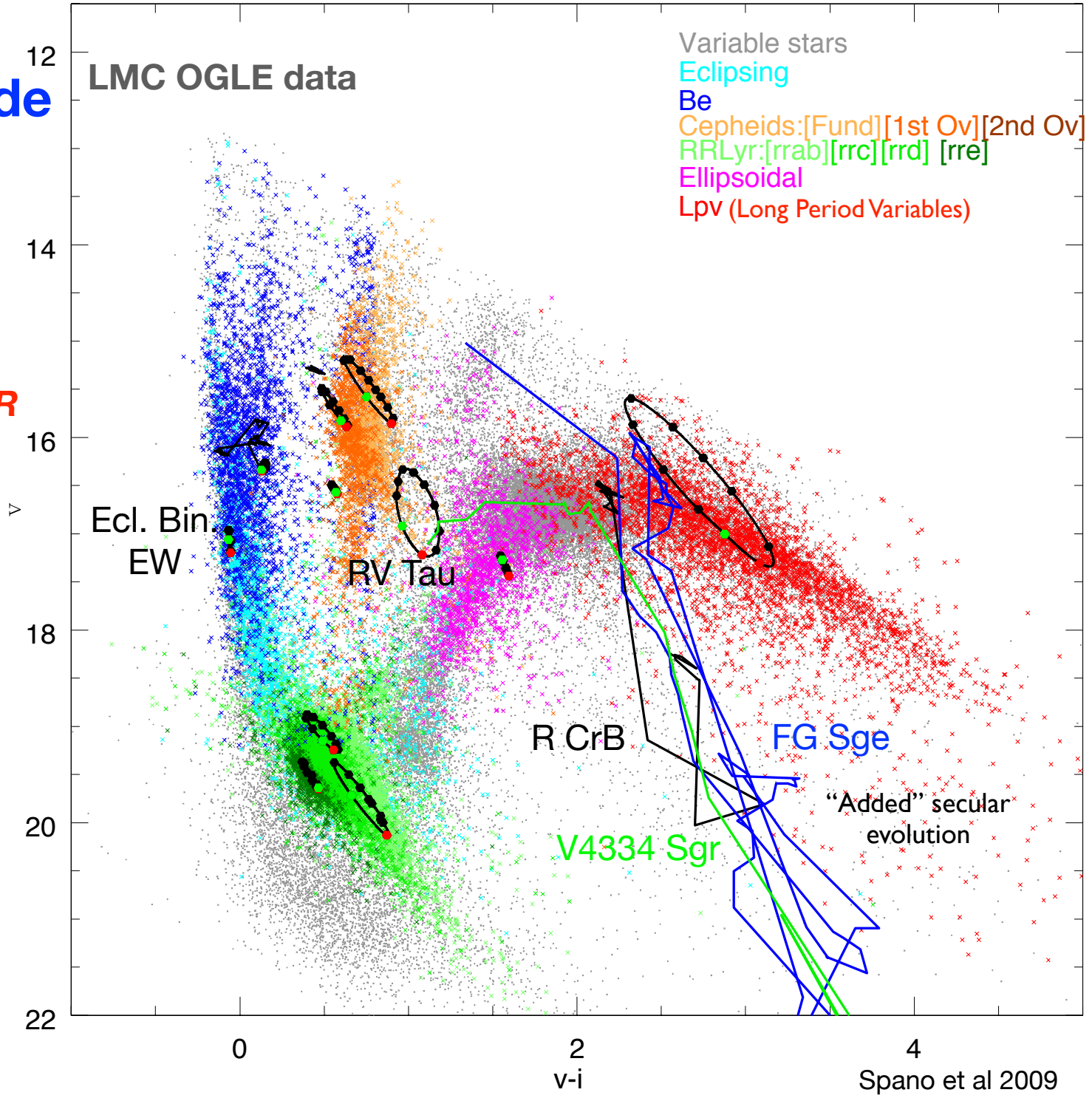
Gaia:

1) Full description of HR diagram (parallax)

2) better precision (detection of many additional types)

3) simultaneous data in G, BP, RP (motion!)

4) Radial Velocities



Geneva photometry

50,000
stars

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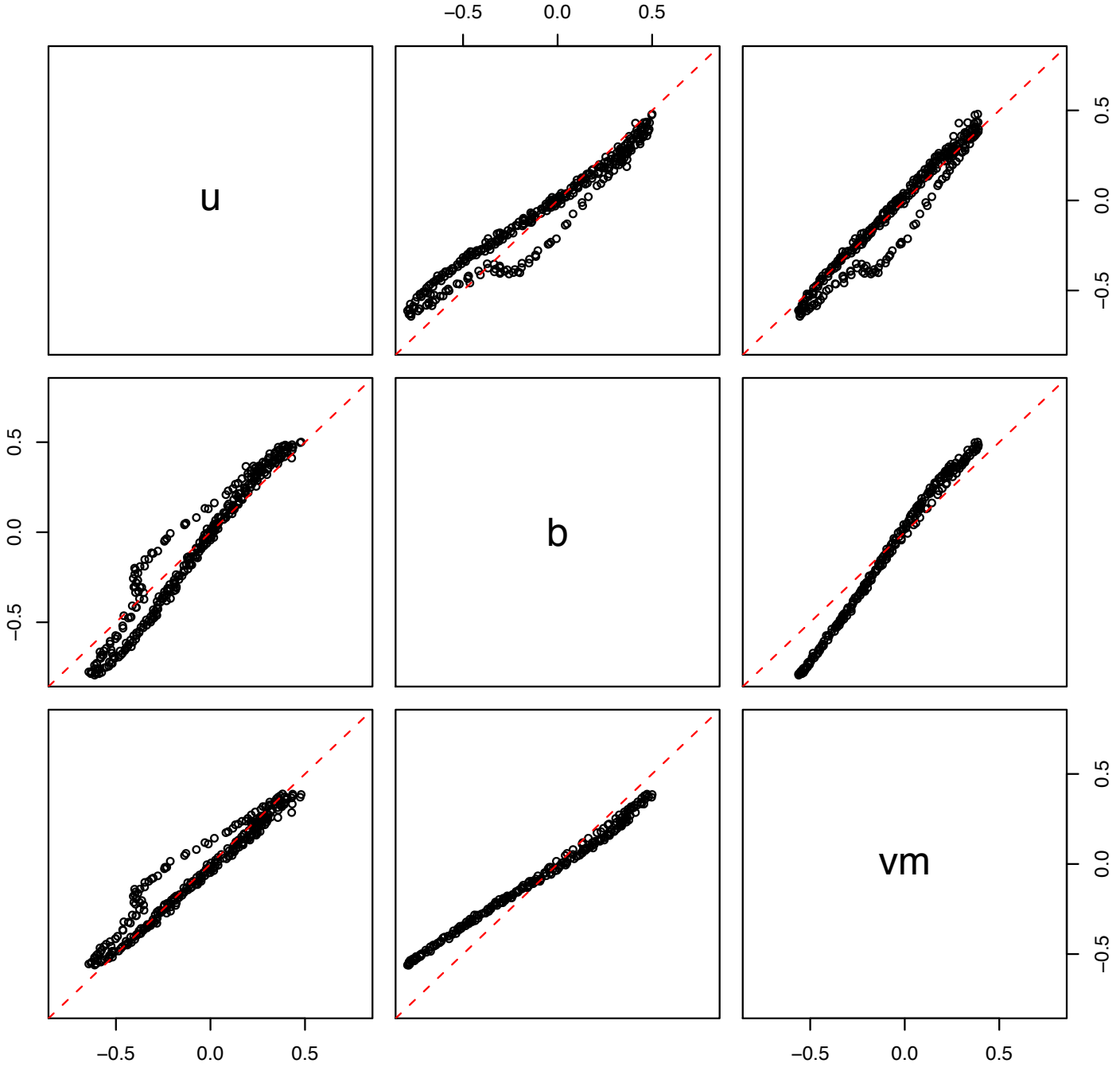
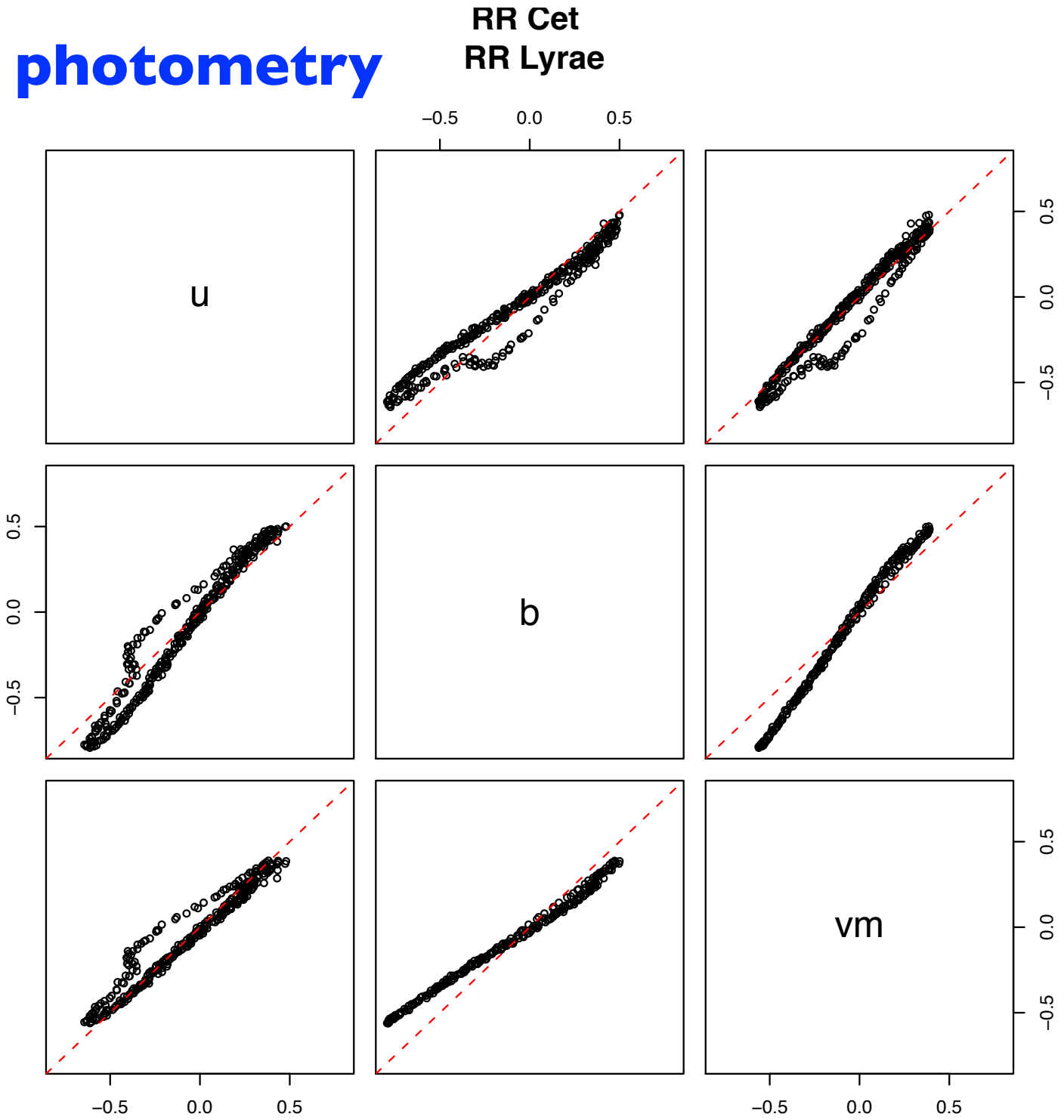
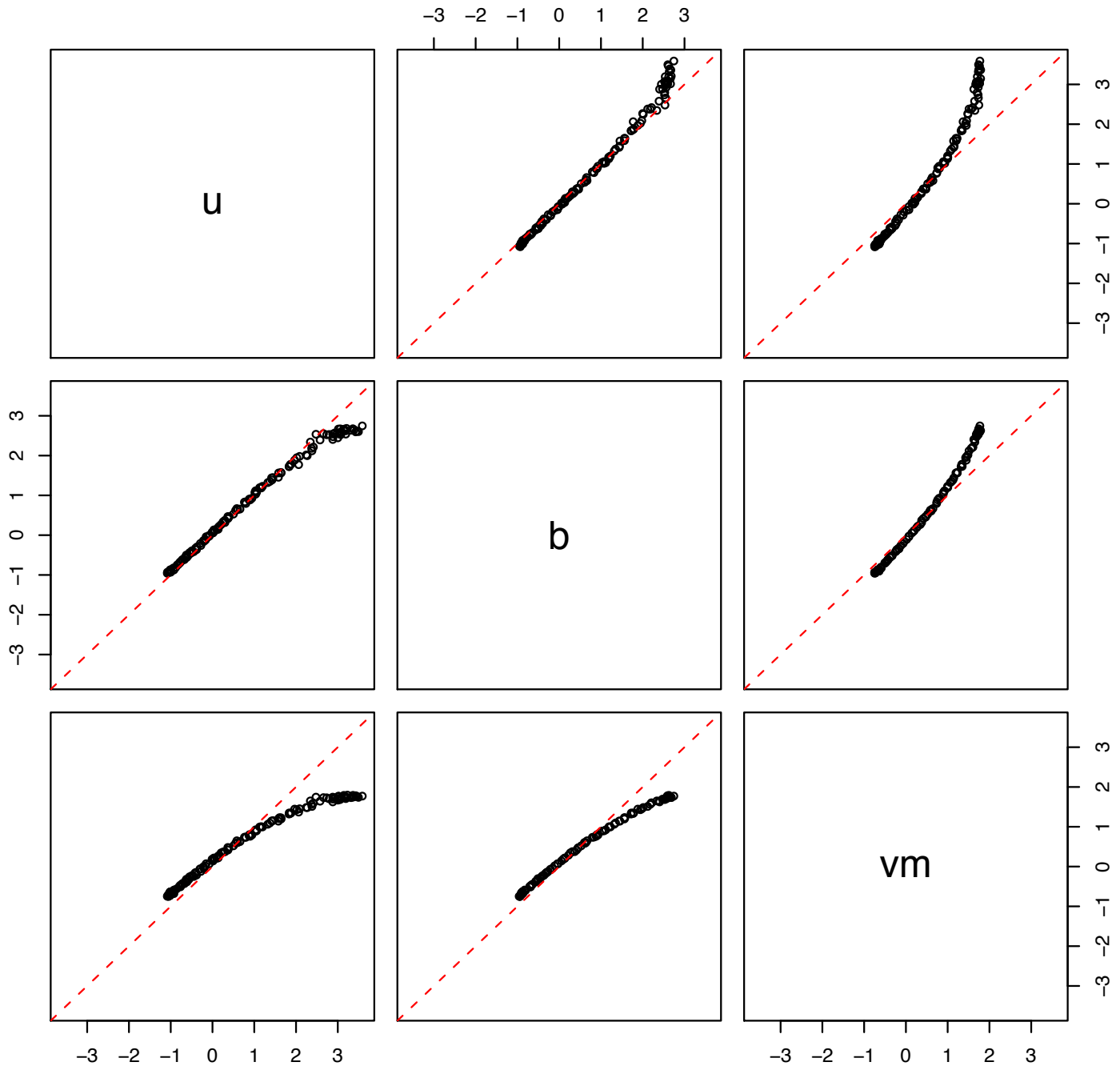


Geneva photometry

50,000 stars

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b
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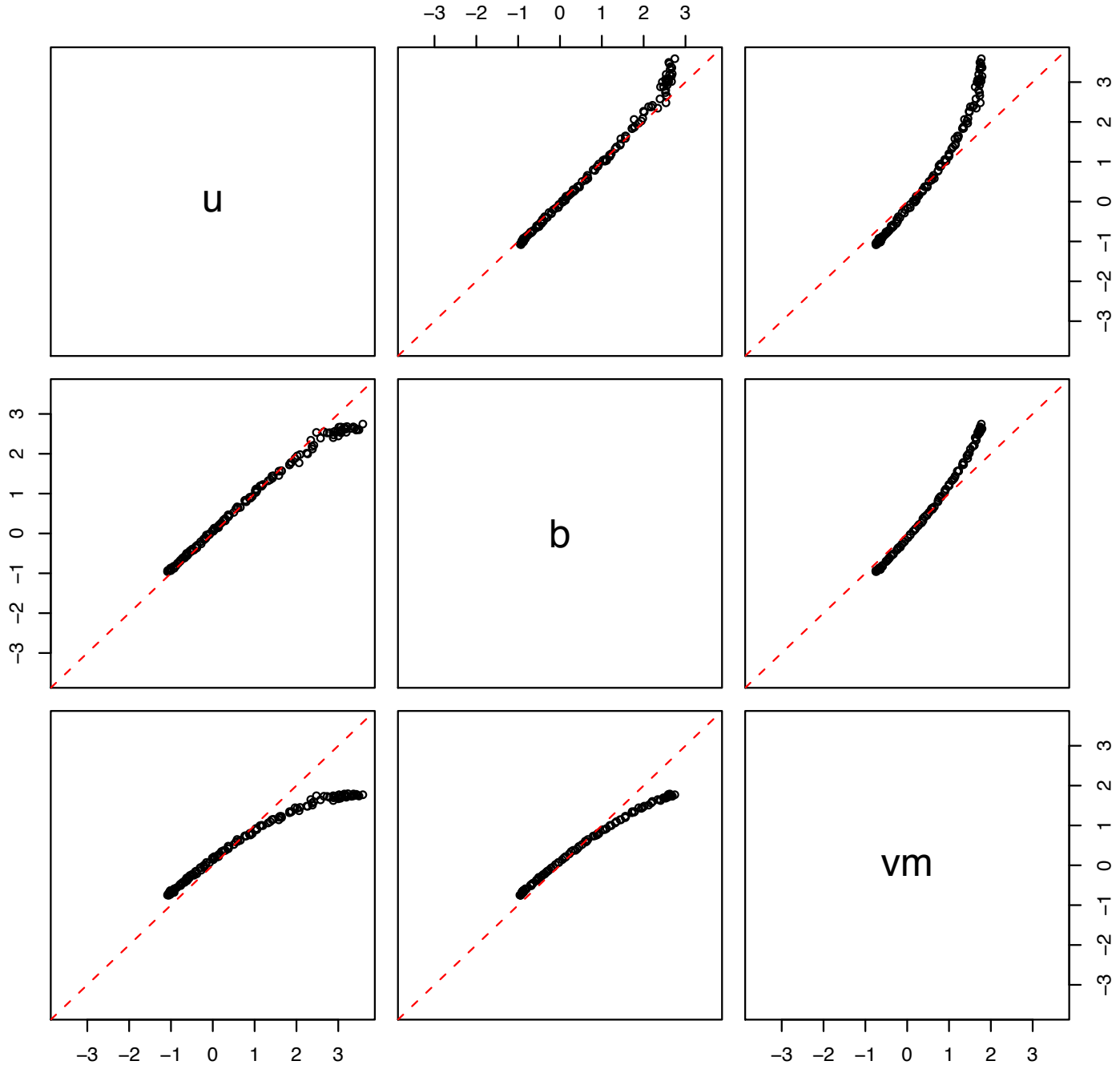
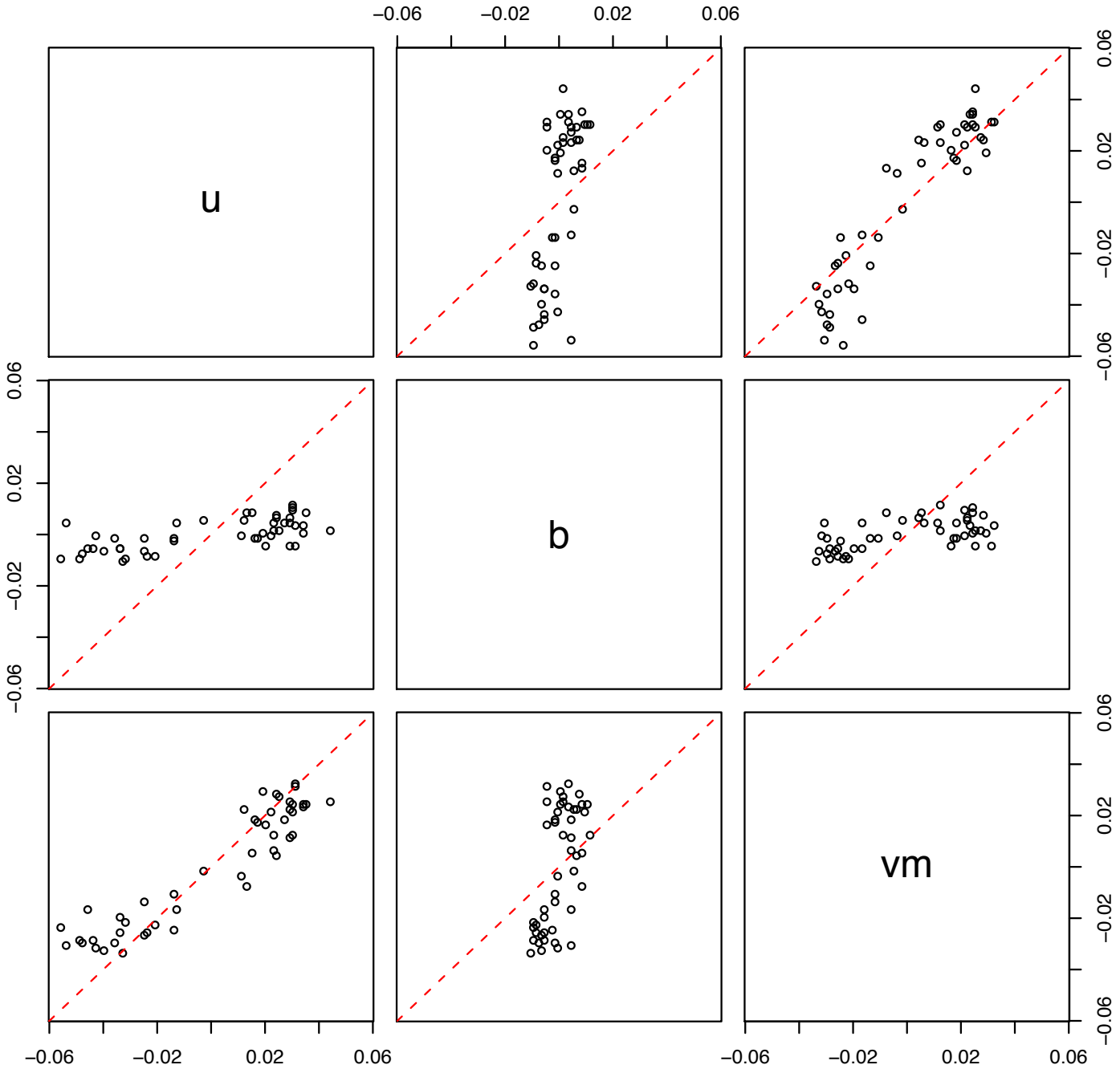
−3 −2 −1 0 1 2 3

TZ Eri
Eclipsing binary

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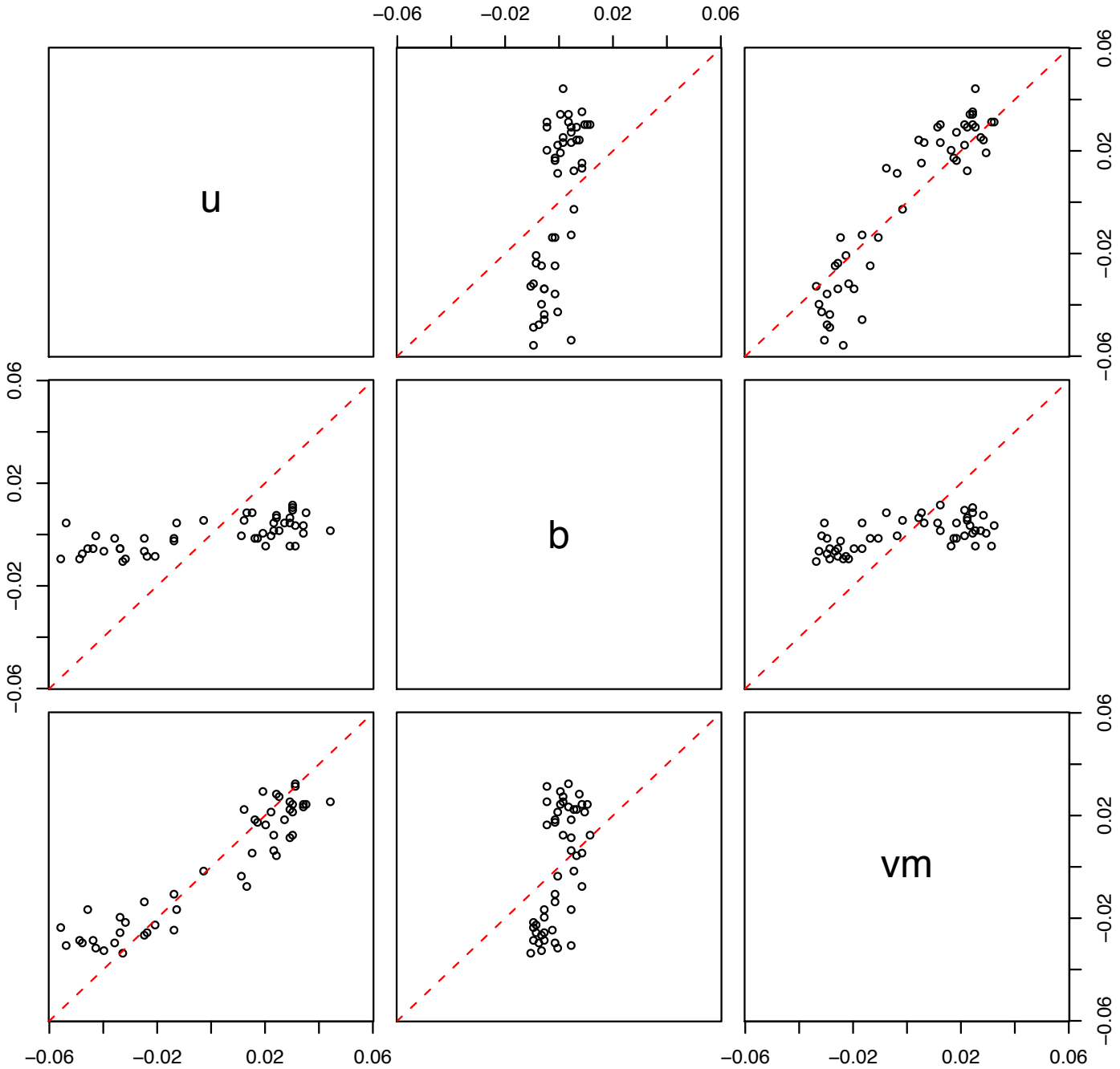
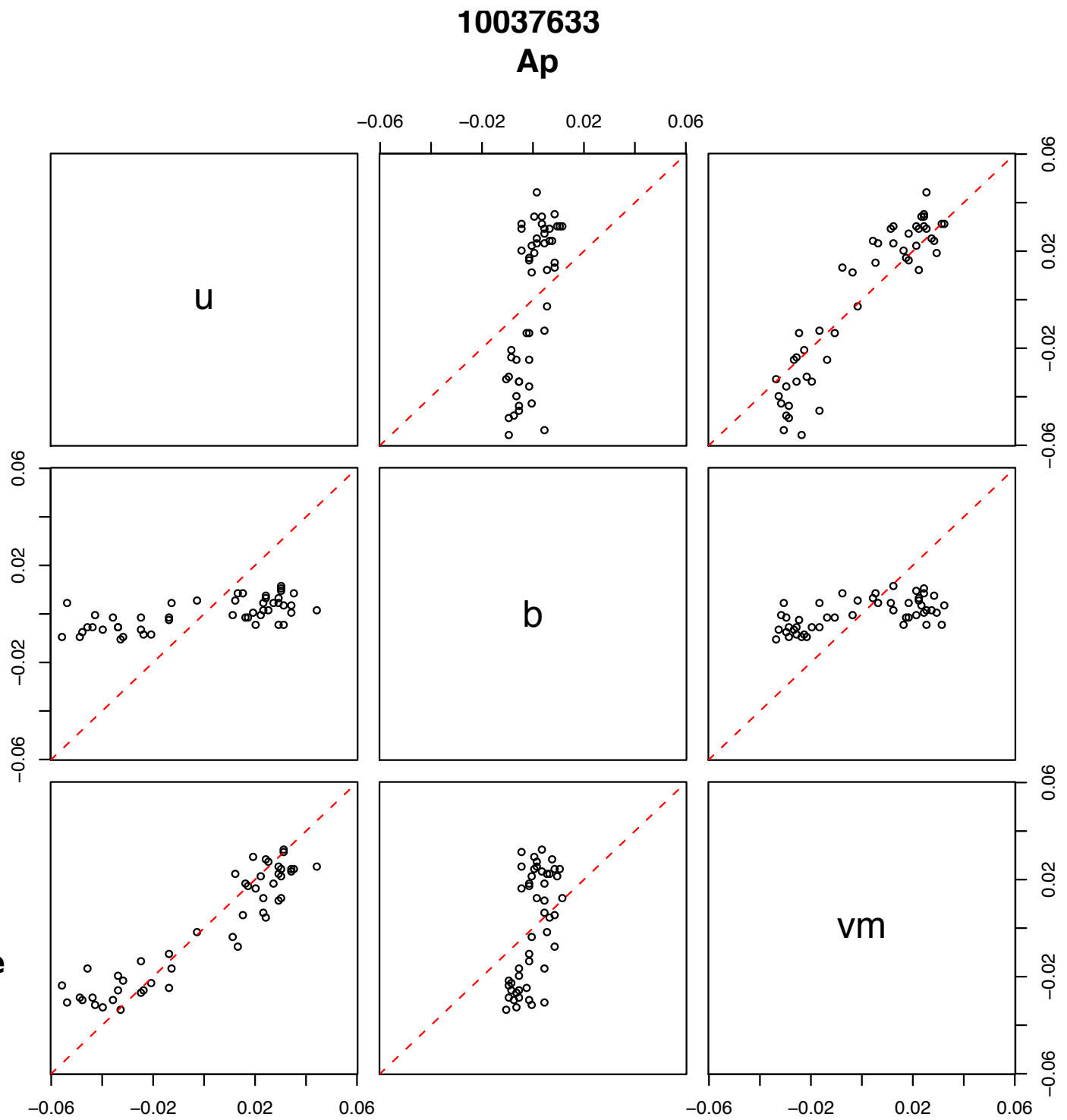
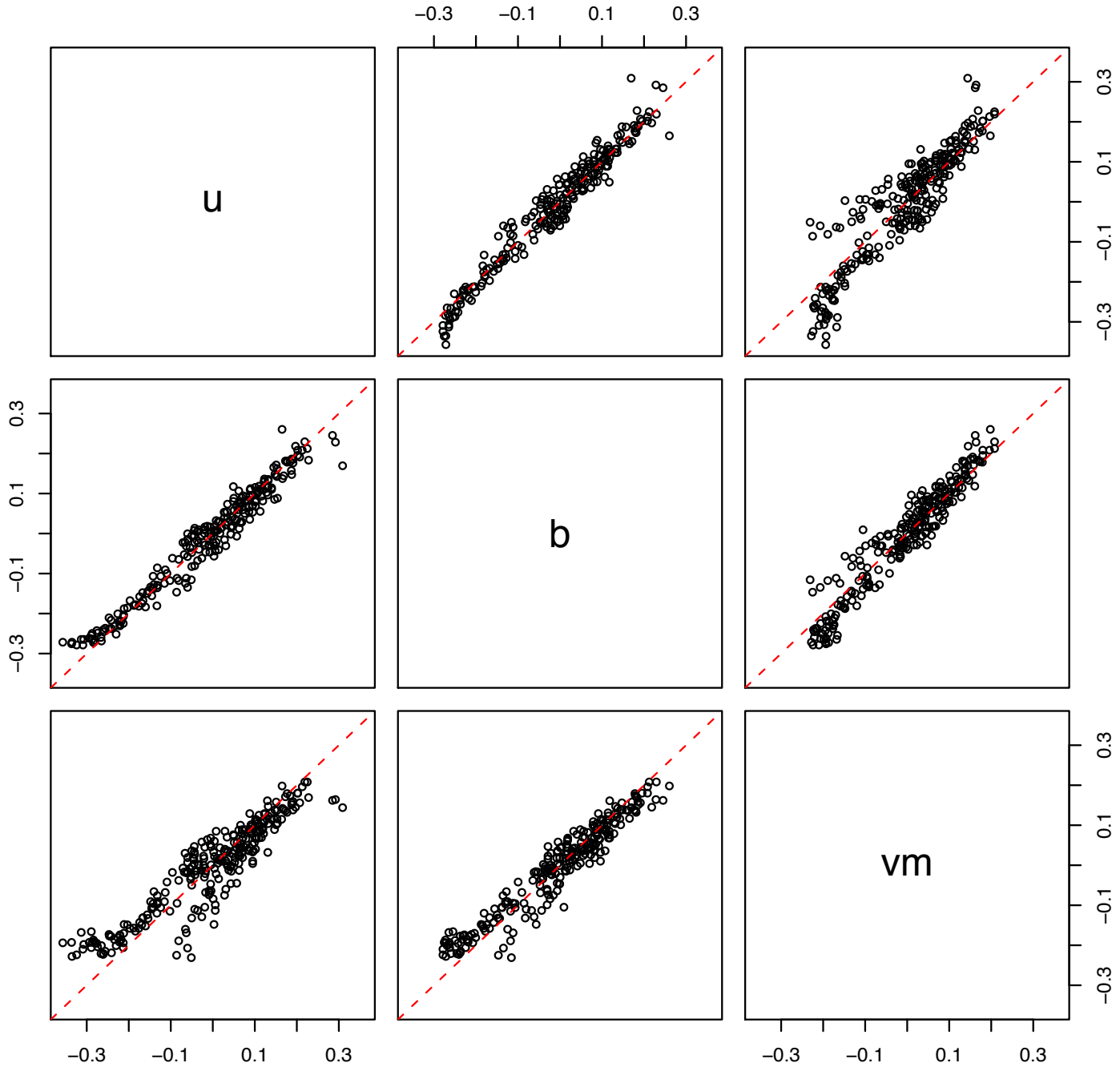
10037633
Ap





Struggle to find a dozen case with Gaia: 40,000 ? !!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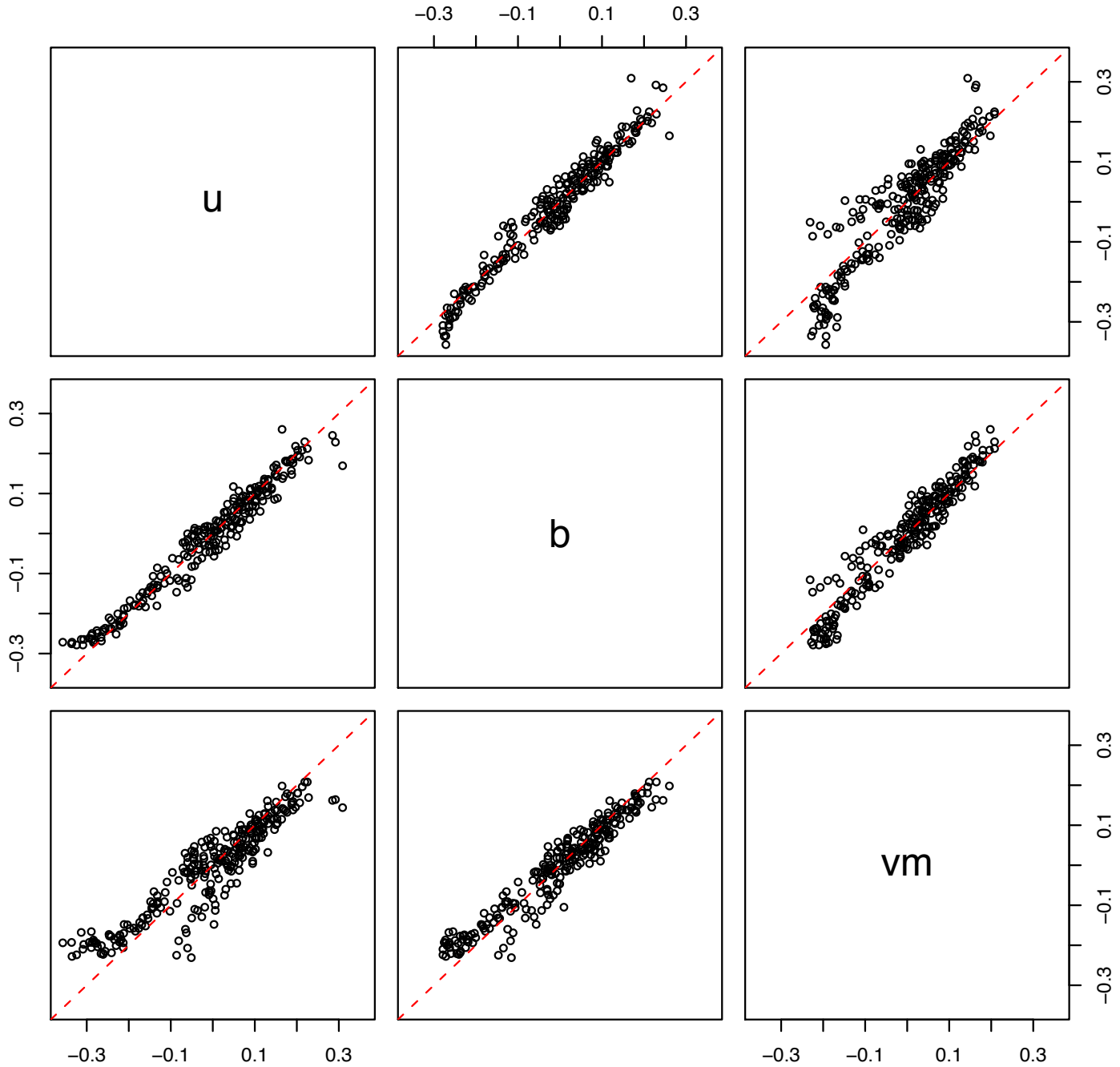
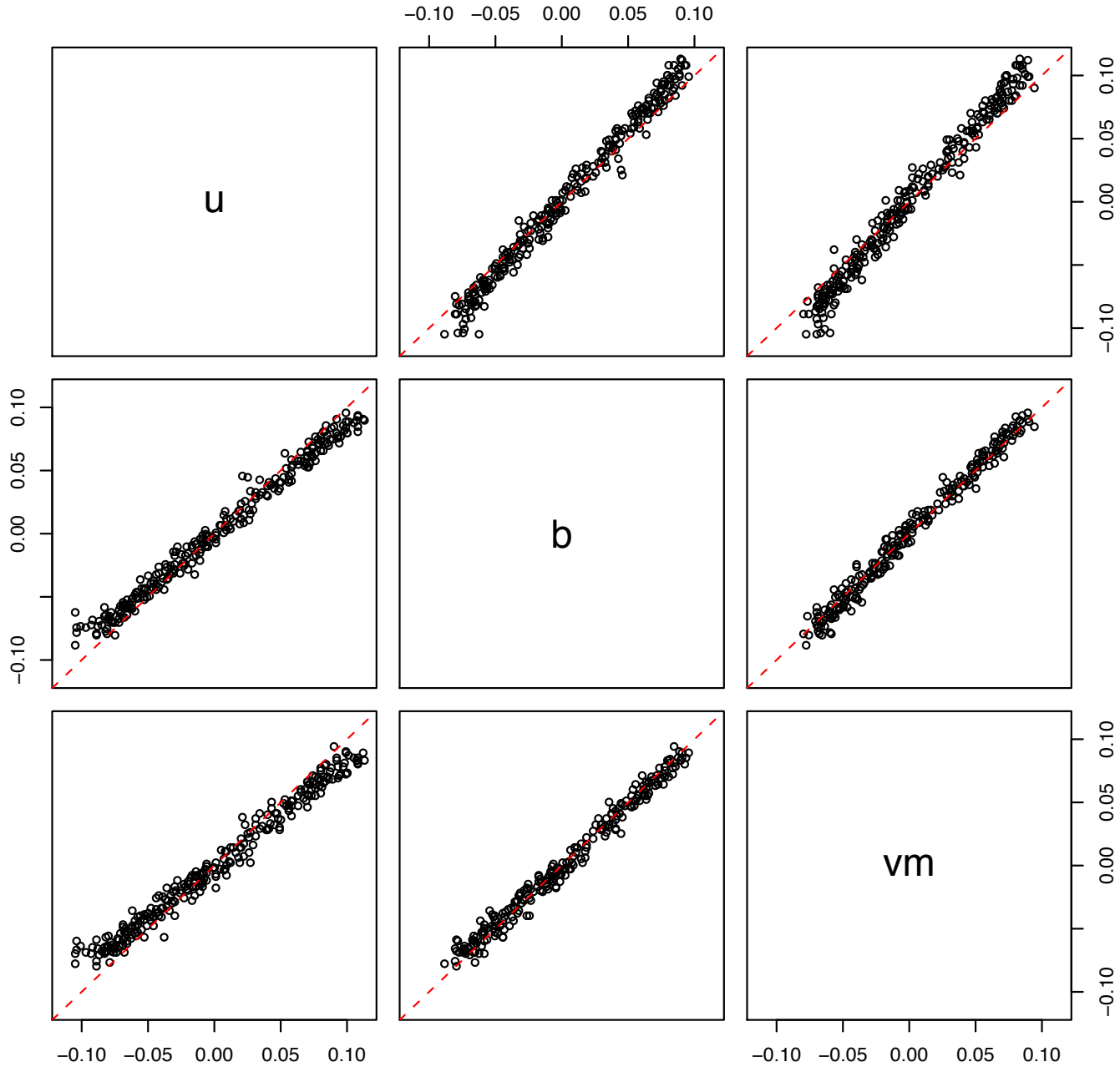
3 C 273
AGN

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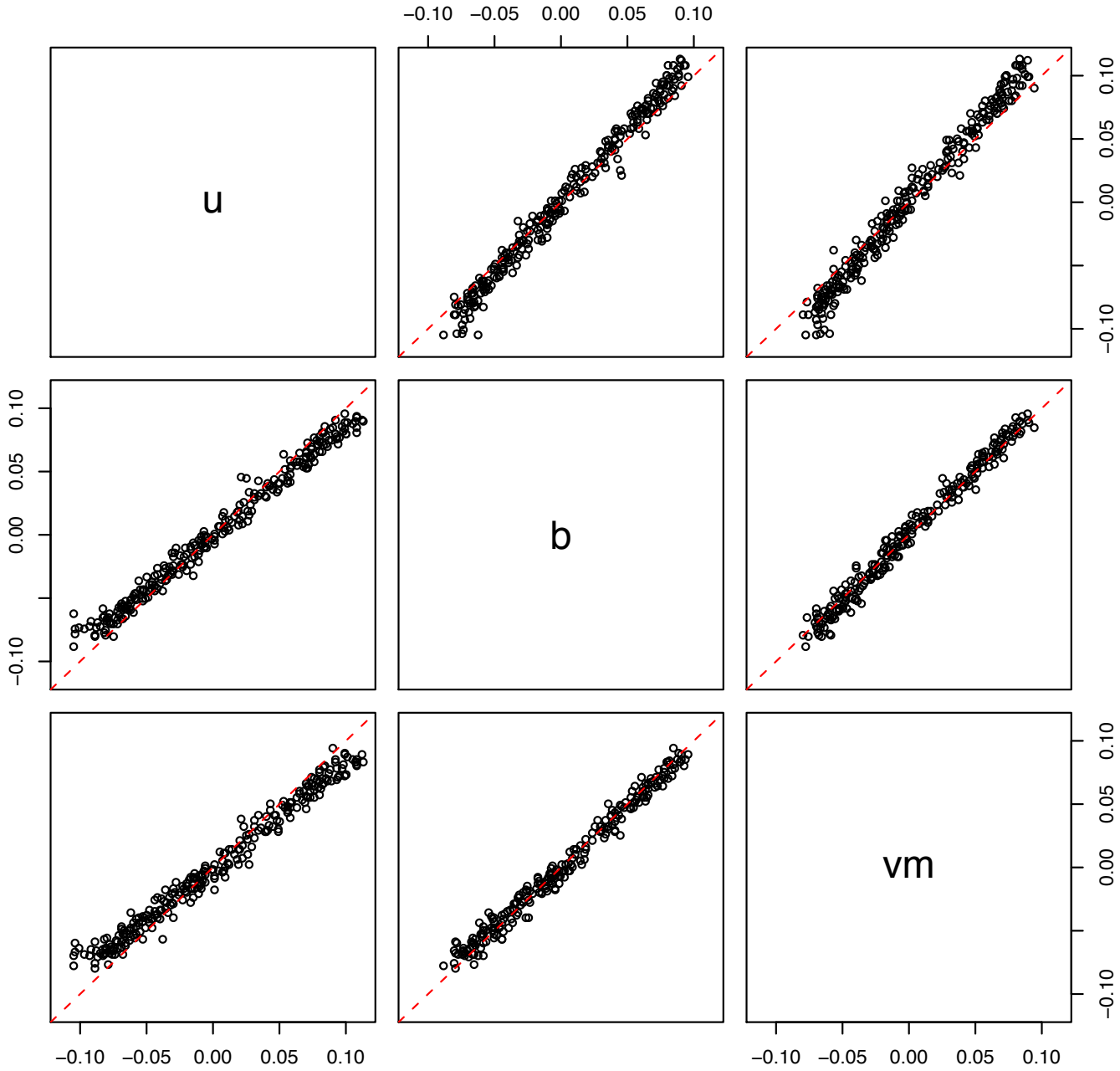
V 831 Cen

EW eclipsing



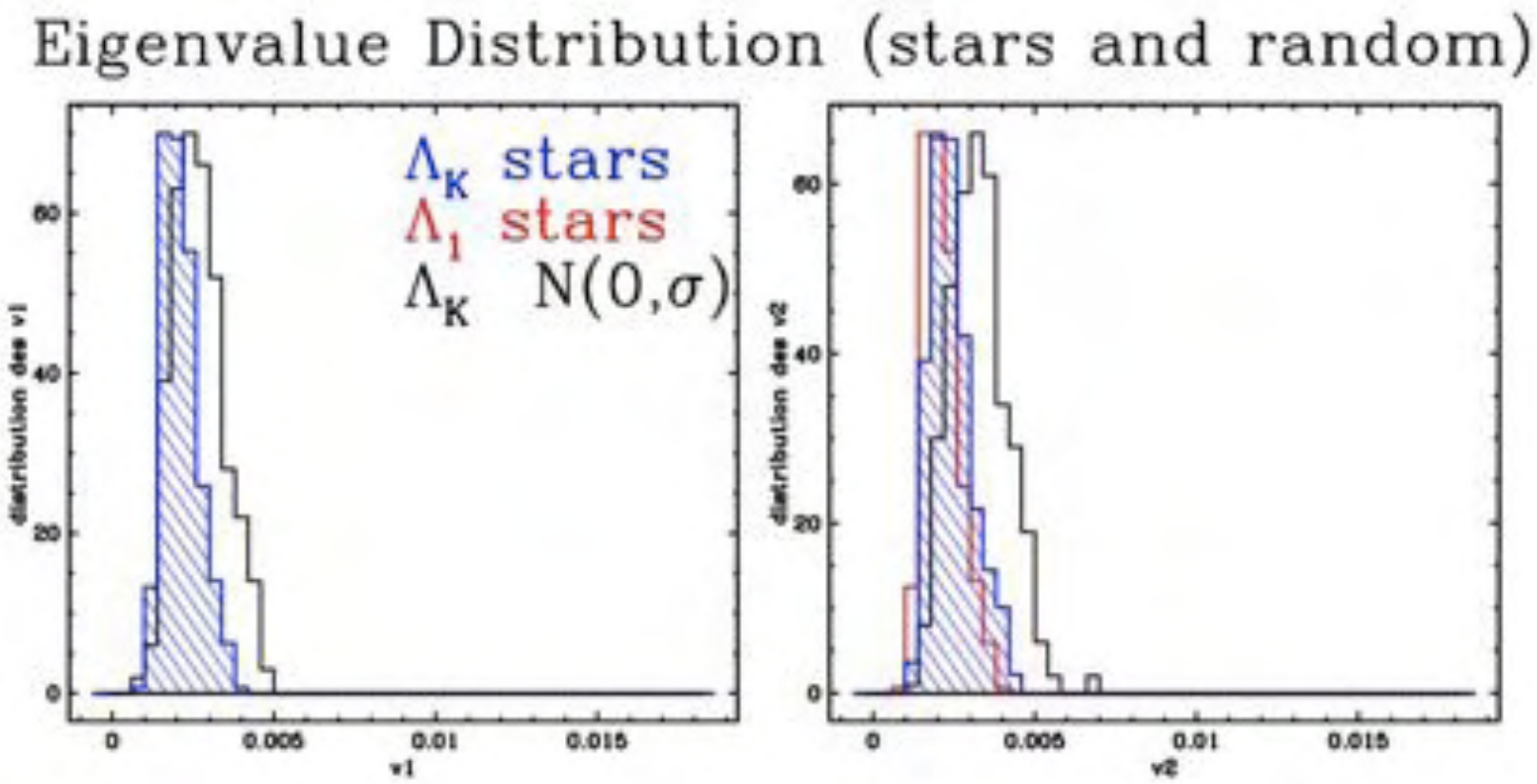
Principal component analysis

- Idea: $\overline{s}_j = \frac{1}{N}\sum_i s_{ij}$ $\qquad$ $d_{ij} = s_{ij} - \overline{s}_j$

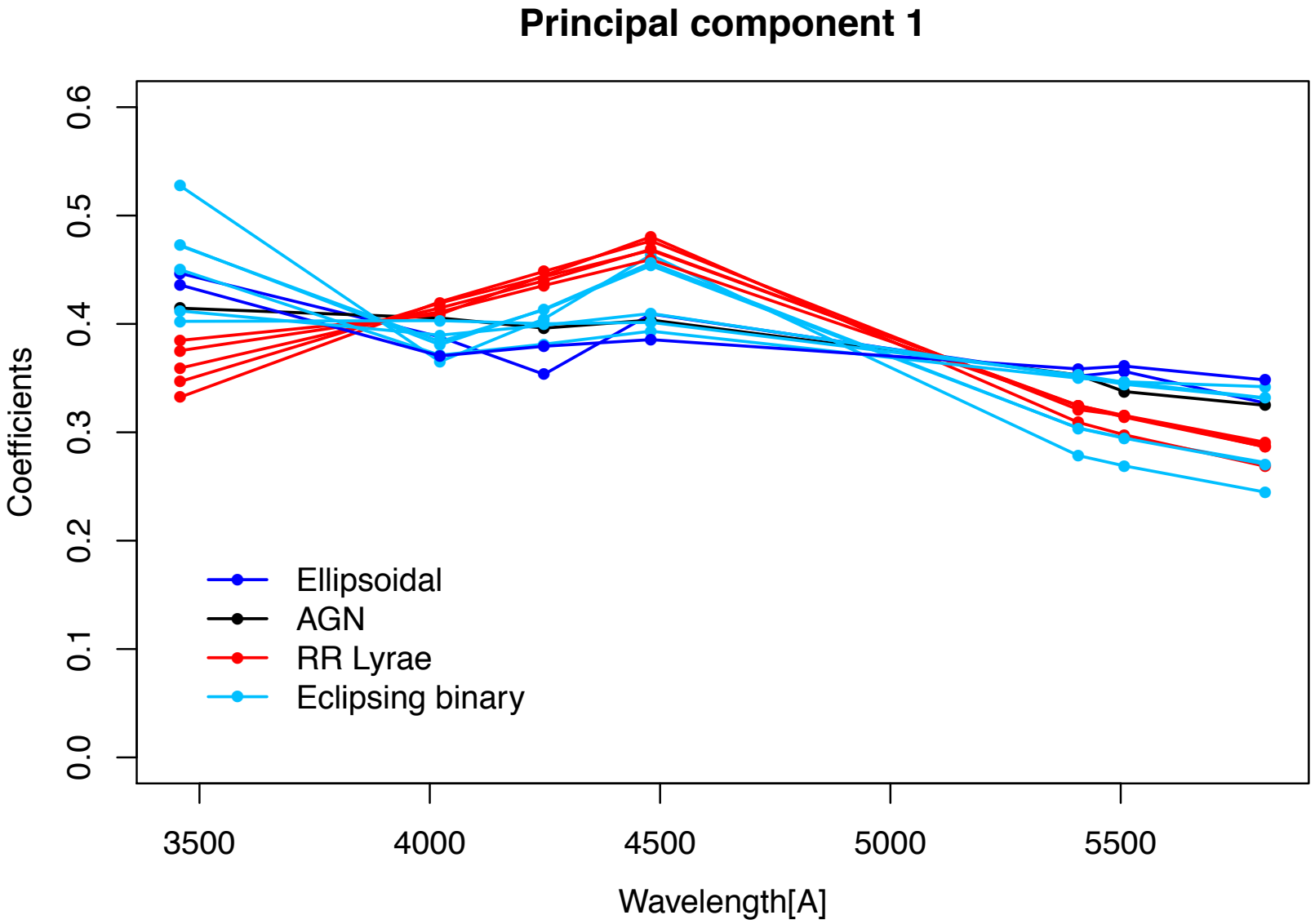
$$C_{lm} = \frac{1}{N}\sum_i d_{il} d_{im}$$

- Proposed by Paul Bartholdi 2005
- Applied to the Geneva constant stars (results: some are variable!)
- Perform the period search on the “new magnitude” (first component)
- Characterize the physical properties of stars
- Tests on Geneva Photometry, and on SDSS stripe 82

Distribution of eigenvalues



“spectral” variability



Apply this to SDSS stripe 82

Conclusions

Gaia will reveal the variable universe in an unprecedented way

- Gaia will provide fundamental properties of the objects and their variability
  - Describe properties of group of variable stars
  - Search for peculiar objects
  - Help other projects (CoRoT, Kepler, OGLE, LSST,...)

Conclusions

Gaia will reveal the variable universe in an unprecedented way

- Gaia will provide fundamental properties of the objects and their variability
  - Describe properties of group of variable stars
  - Search for peculiar objects
  - Help other projects (CoRoT, Kepler, OGLE, LSST,...)
- “New” efficient methods should be developed
- Work, work and work (mathematics, statistical methods, simulations, Gaia simulations, real data)
- Ground-based observations (“small telescopes”)

THANK YOU FOR YOUR ATTENTION