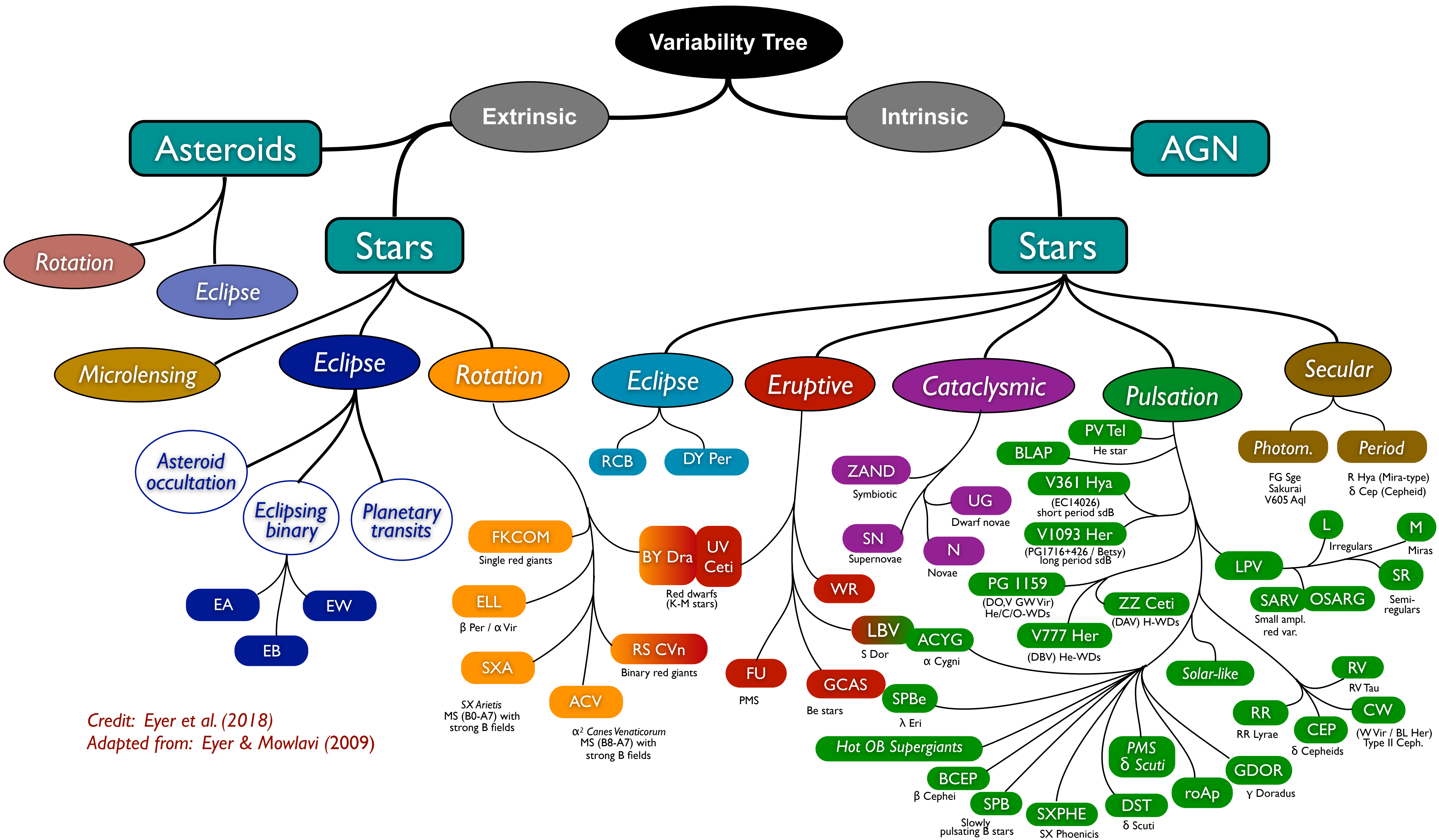
Variable stars with LSST

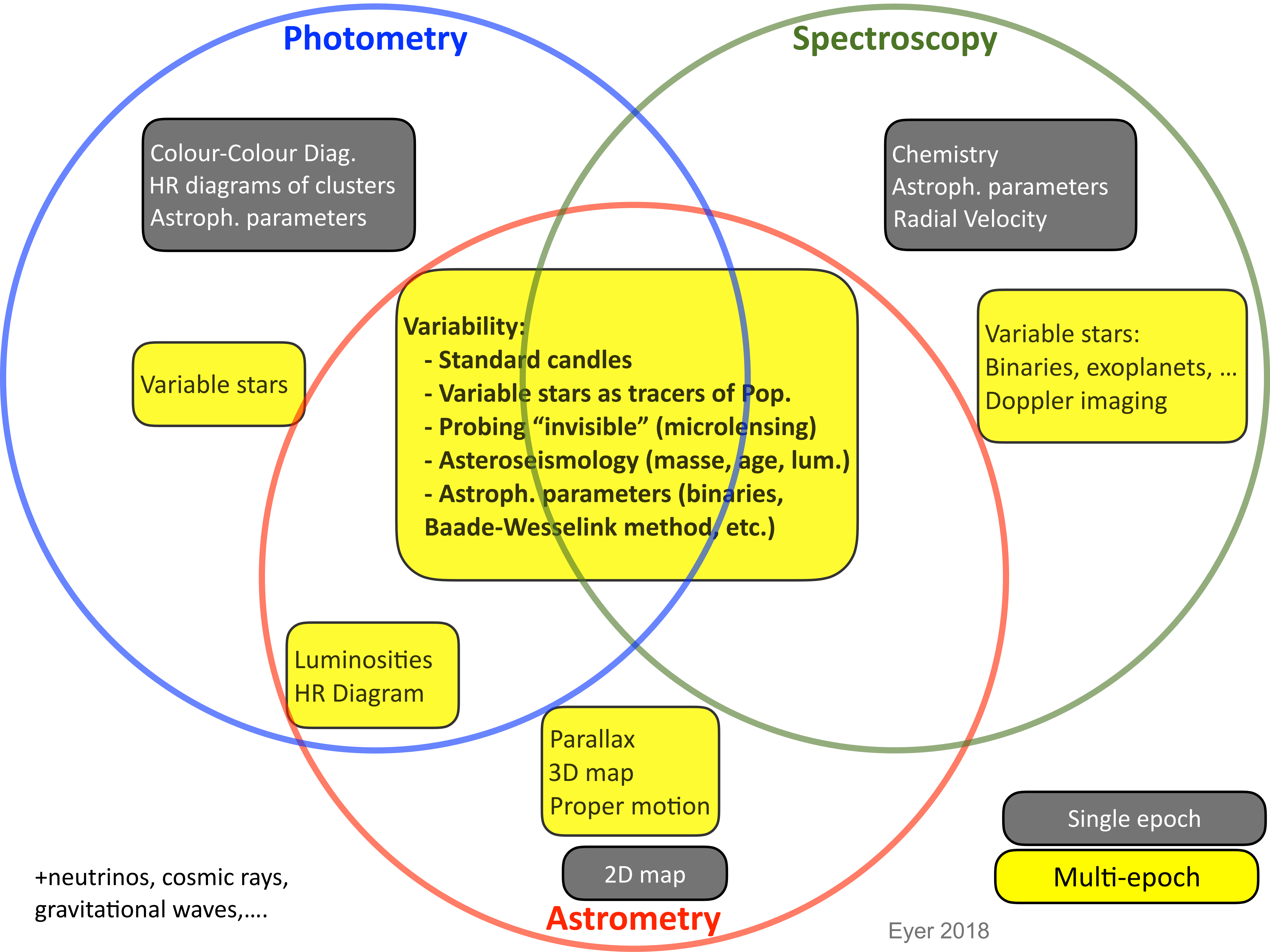
Laurent Eyer
University of Geneva, Switzerland

LSST@Europe3, Lyon, France
Wednesday, 13 June 2018

The variability tree: A temptative to organise variable phenomena in the Universe



Credit: Eyer et al. (2018)
Adapted from: Eyer & Mowlavi (2009)

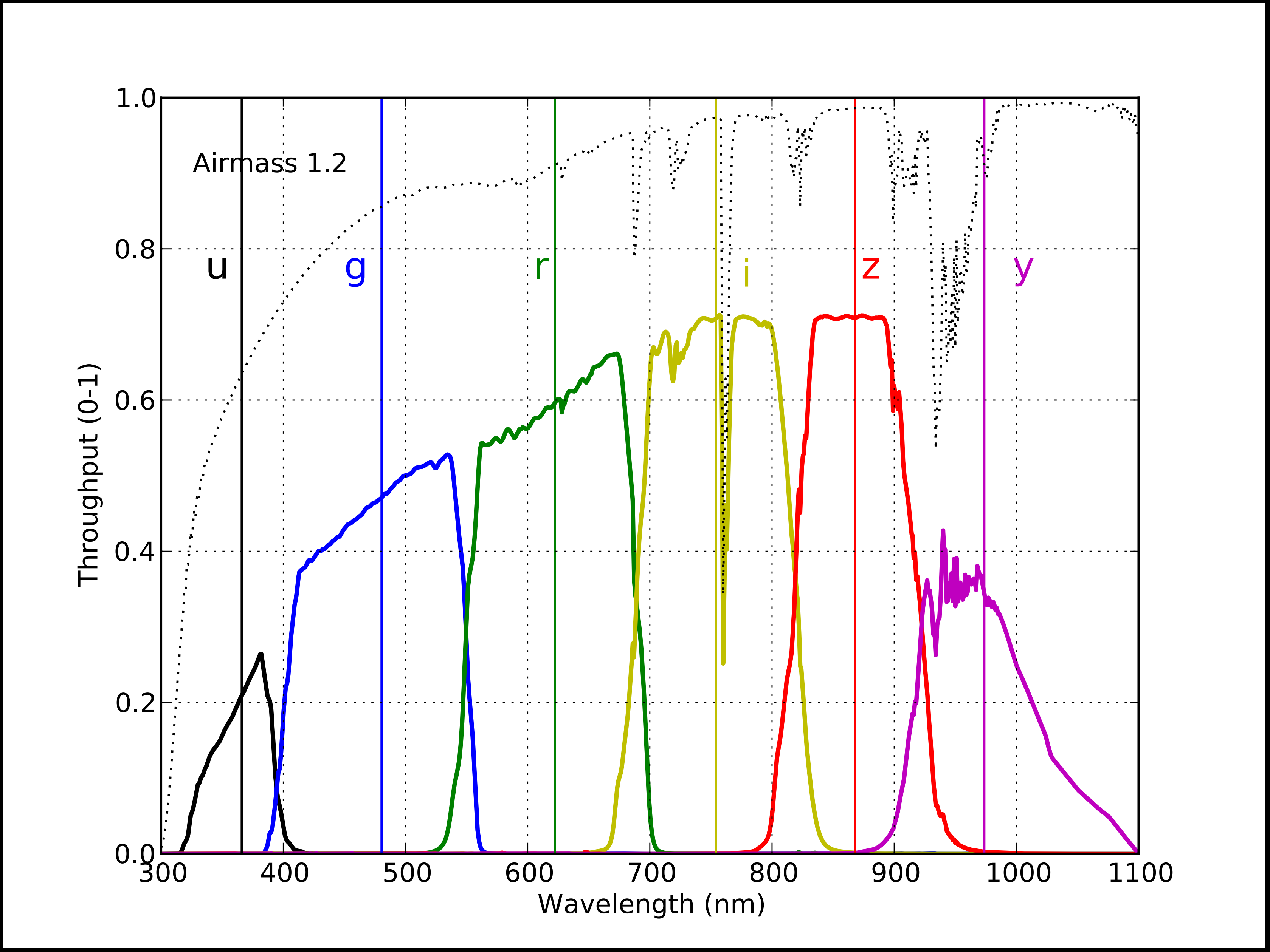

Photometry
Spectroscopy
Colour-Colour Diag.
HR diagrams of clusters
Astroph. parameters
Chemistry
Astroph. parameters
Radial Velocity
Variable stars
Variability:
- Standard candles
- Variable stars as tracers of Pop.
- Probing “invisible” (microlensing)
- Asteroseismology (masse, age, lum.)
- Astroph. parameters (binaries, Baade-Wesselink method, etc.)
Variable stars:
Binaries, exoplanets, …
Doppler imaging
Luminosities
HR Diagram
Parallax
3D map
Proper motion
2D map
Astrometry
Single epoch
Multi-epoch
+neutrinos, cosmic rays, gravitational waves,….
Eyer 2018

The multi-epoch LSST photometry

>800 visits over 10 years

One visit corresponds to one photometric band observation

(non-simultaneous, filter are non-sequential for a given field)



Time allocation:

u: 8%; g: 10%

r: 22%; i: 22%

z: 19%; y: 19%

This for 20 billion stars!

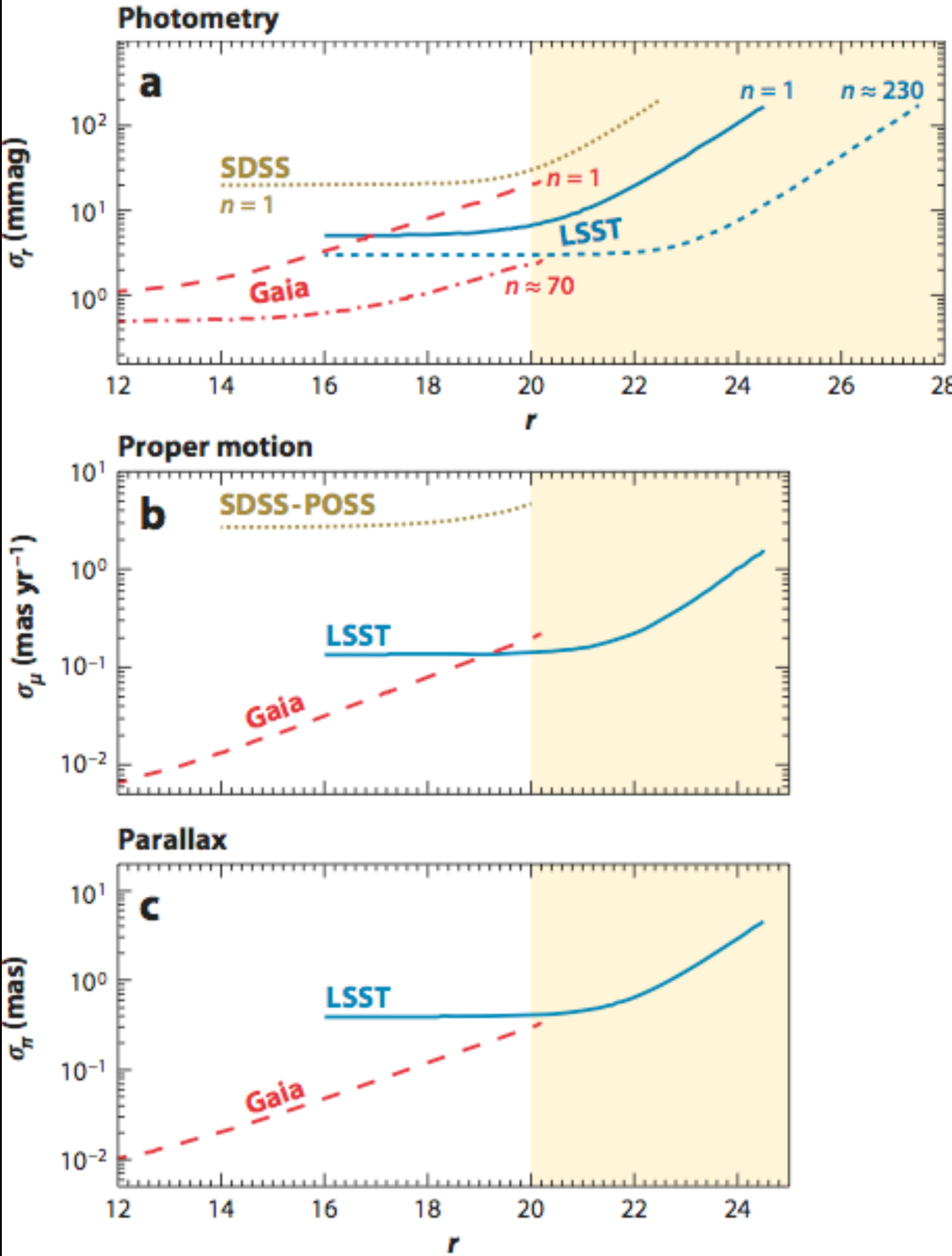
Courtesy of Z.Ivezic

LSST/Gaia photometry and astrometry

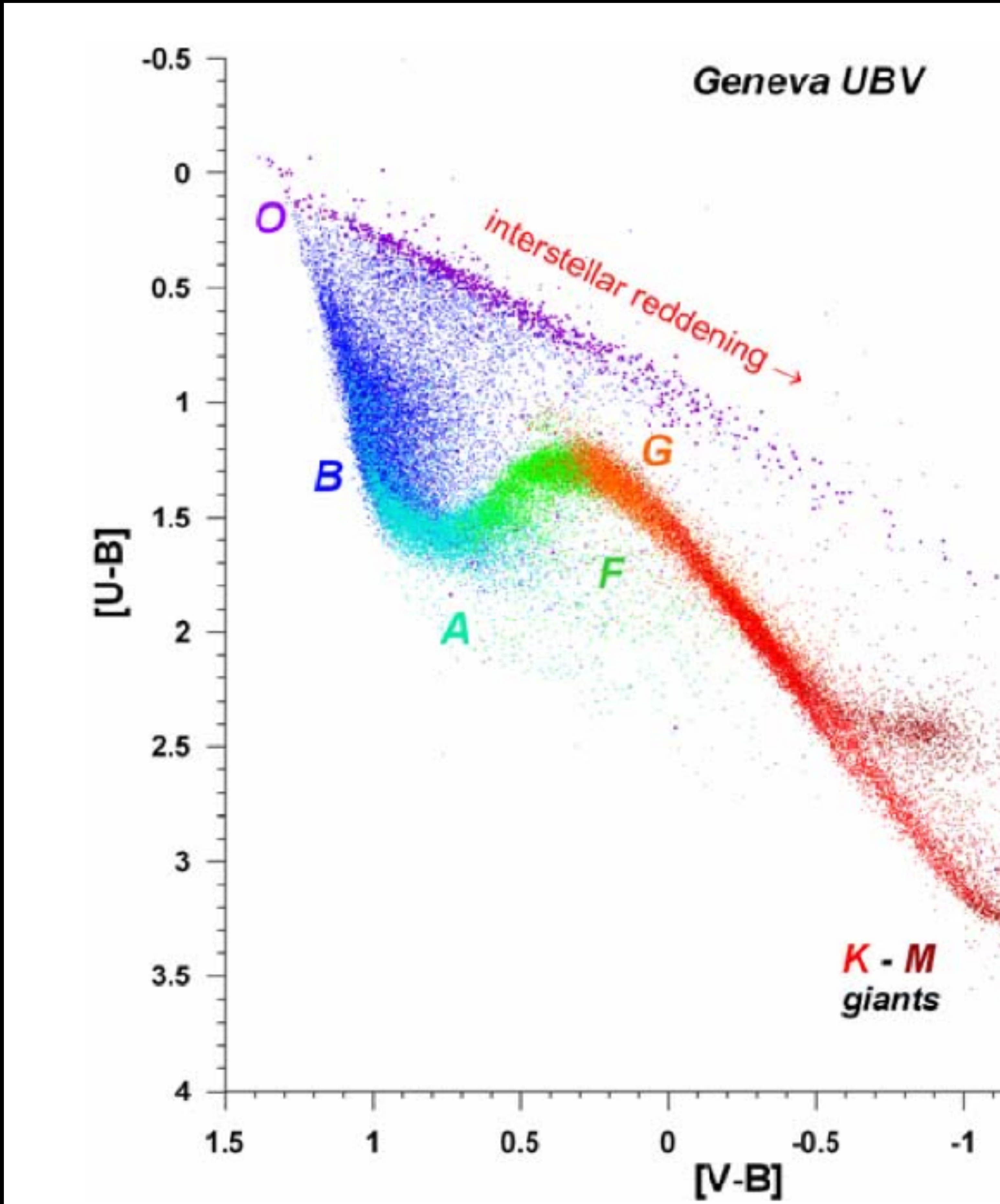
Complementarity of the Gaia and LSST surveys: photometric, proper motion and trigonometric parallax errors are similar around r=20

LSST: Two exposures of 15 seconds (or maybe one of 30 seconds) 3-5 days back on the same field

Ivezić, Beers, Jurić 2012, ARA&A, 50, 251

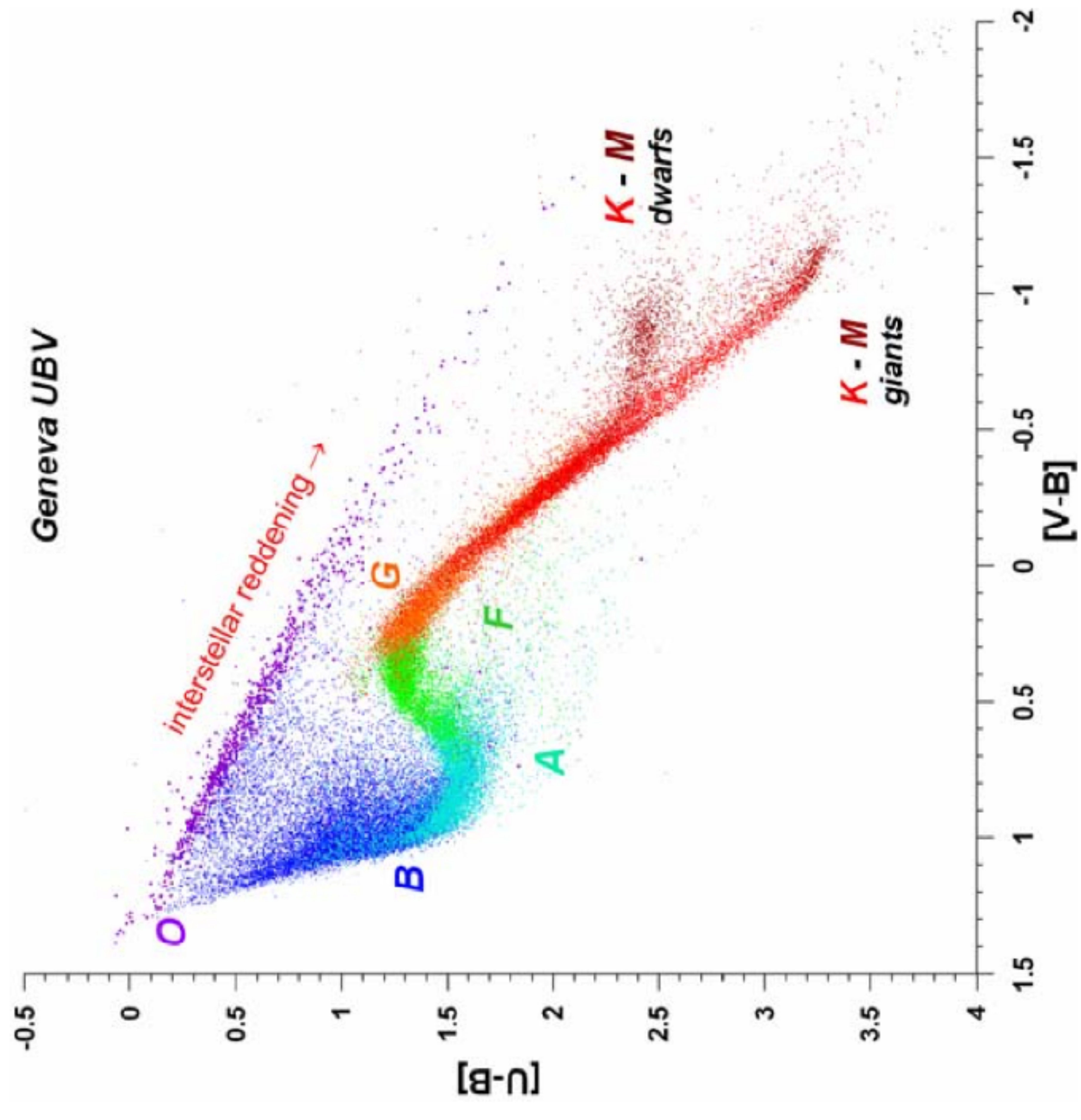


Geneva photometry: colour-colour diagramme

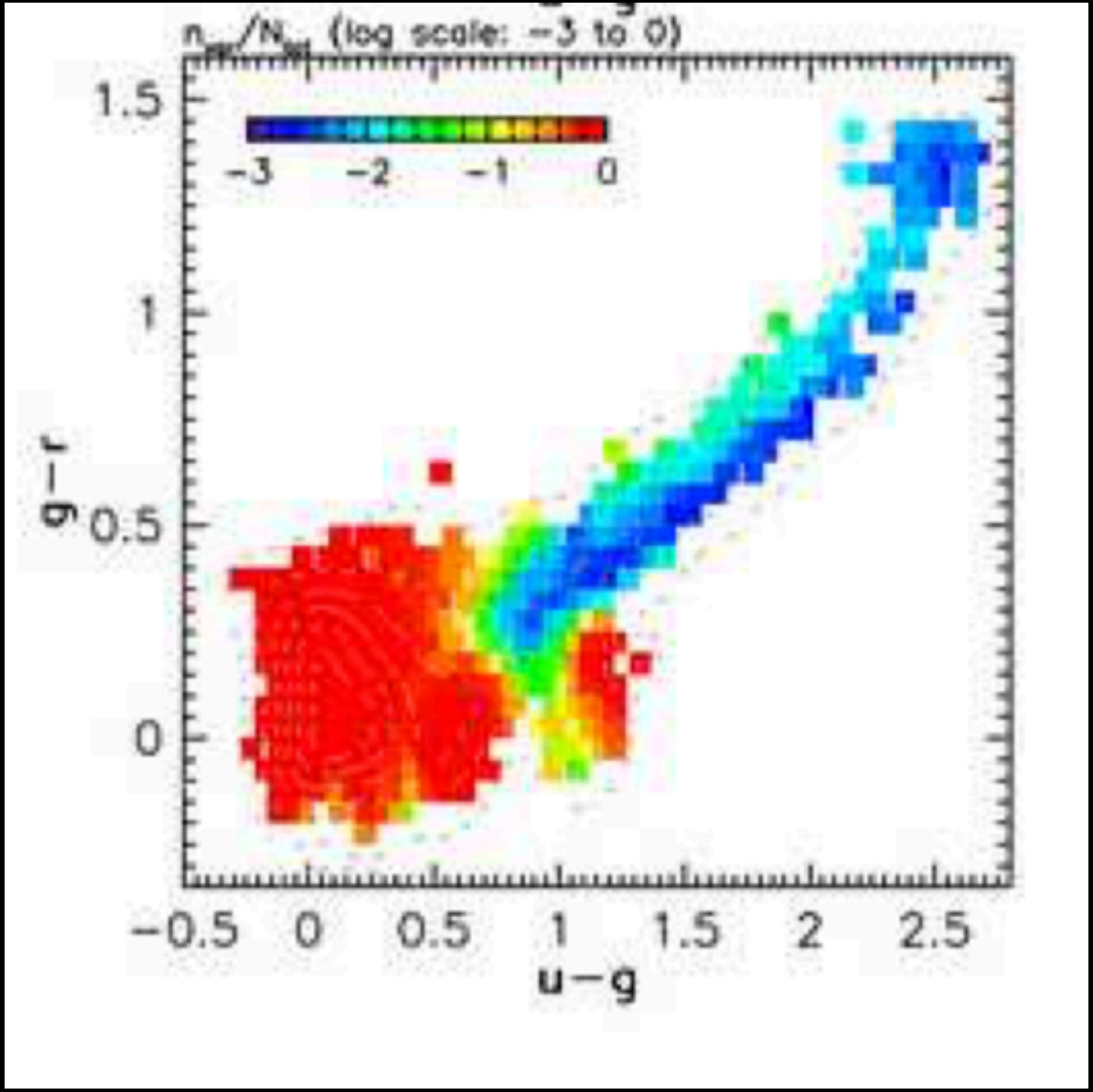


50,000 stars

396,000 measurements

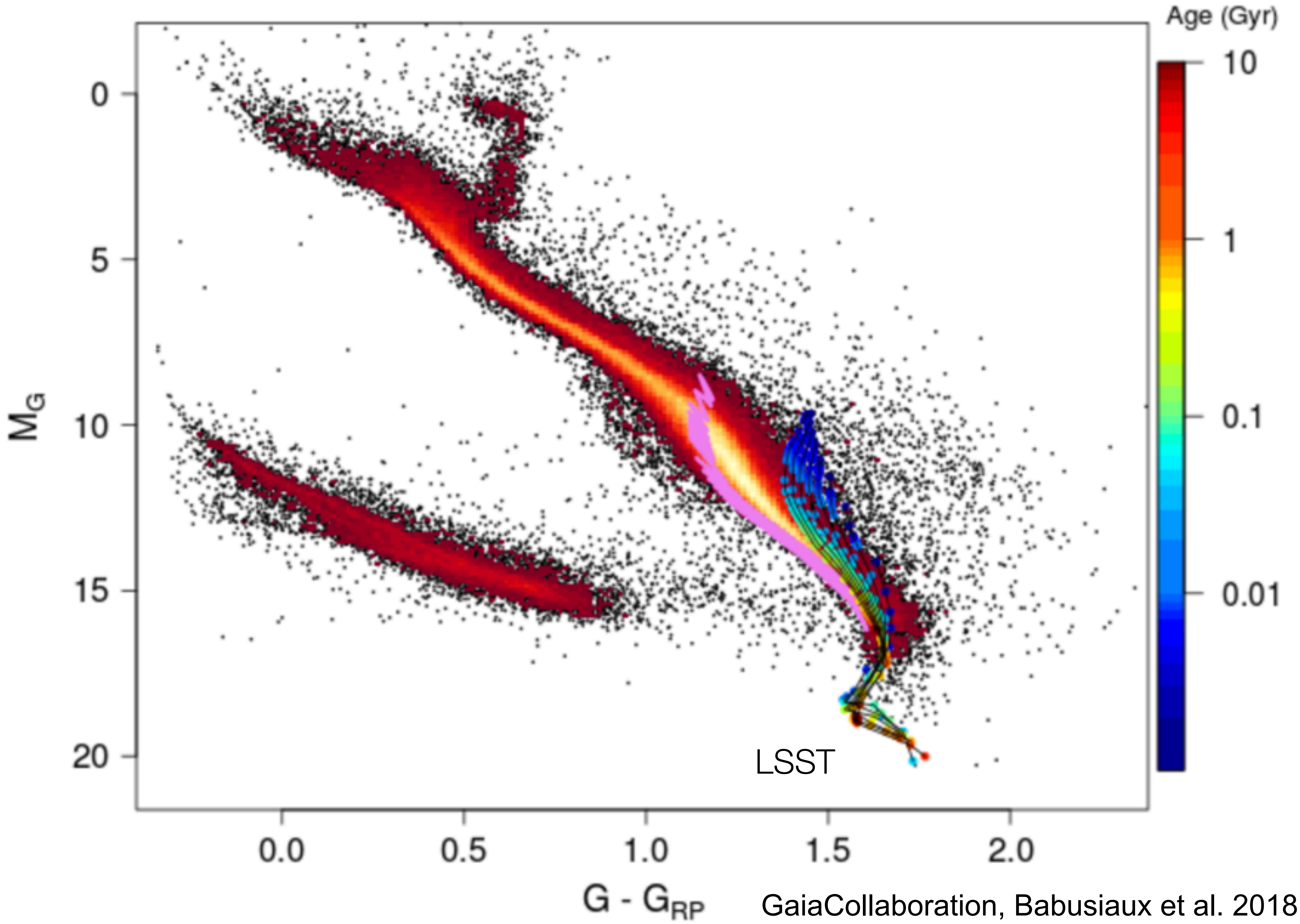

Geneva UBV
interstellar reddening →
O
B
A
F
G
K - M
dwarfs
K - M
giants
[V-B]
[U-B]
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
1.5
1
0.5
0
-0.5
-1
-1.5
-2

General description of variability
Fraction of Variables with SDSS



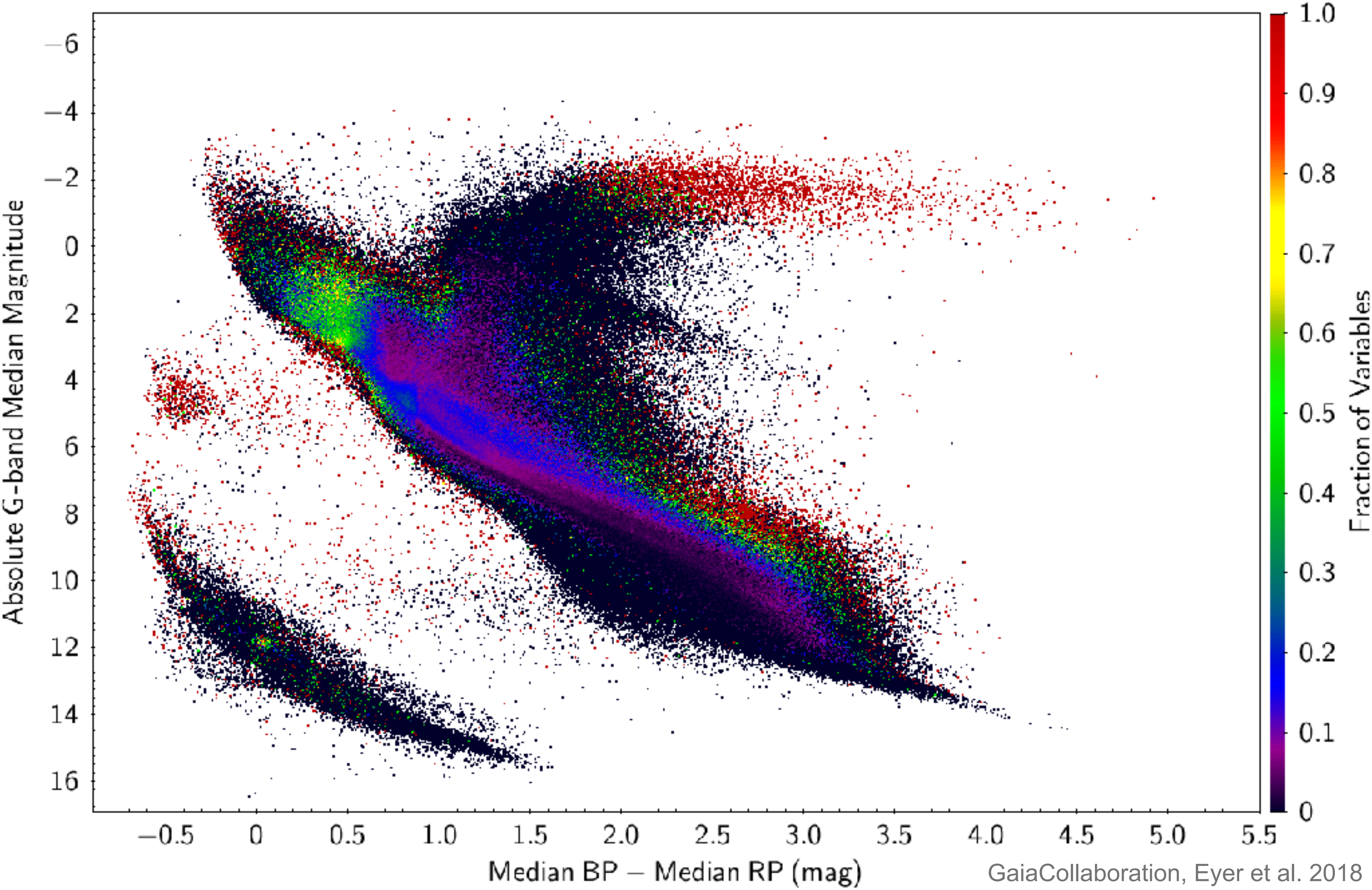
Sesar et al. 2007

Hertzsprung-Russell diagramme



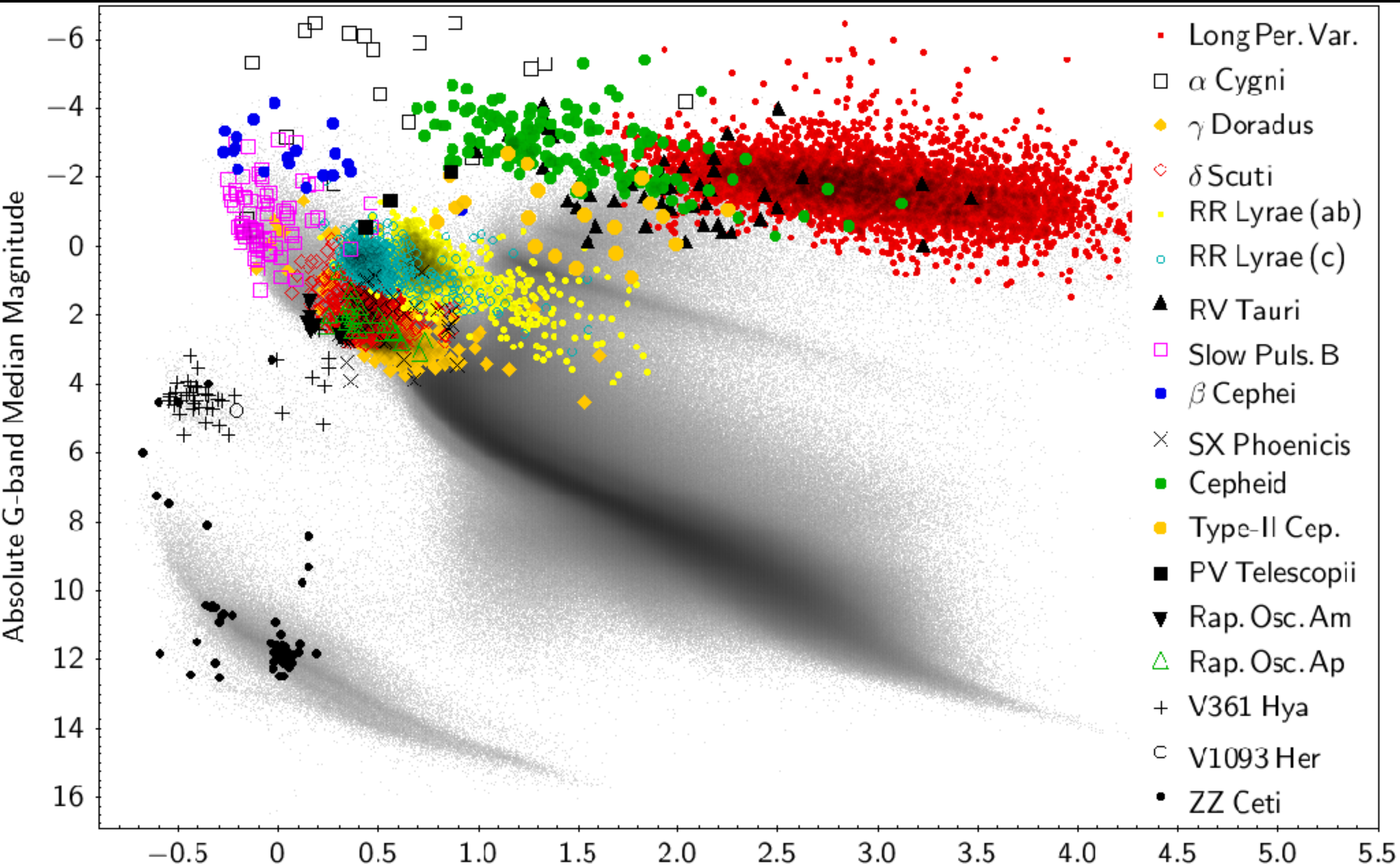
GaiaCollaboration, Babusiaux et al. 2018

Fraction of variable stars with Gaia in HR diagramme



GaiaCollaboration, Eyer et al. 2018

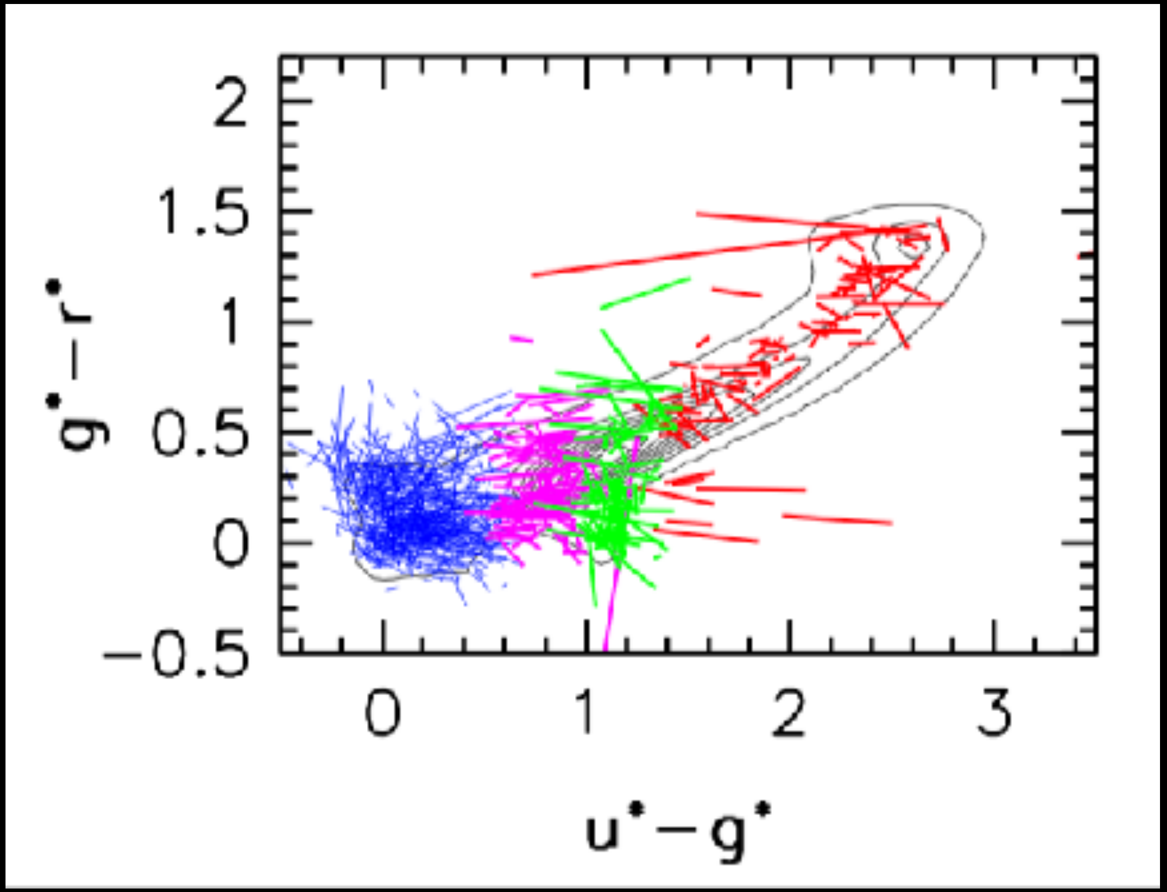
Variability types in the HR diagram



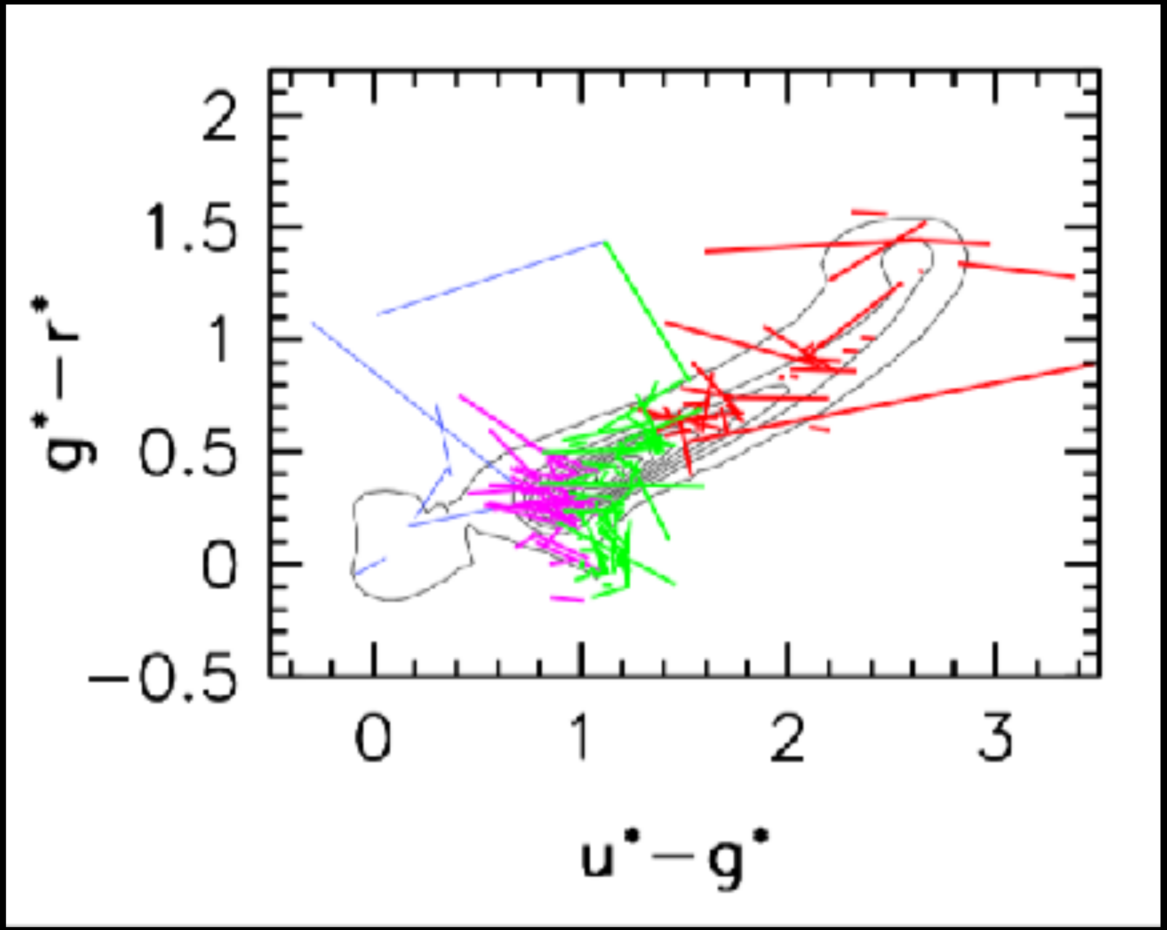
GaiaCollaboration, Eyer et al. 2018

Motion in colour-colour diagramme with SDSS data

2 years appart



3 hours appart



Ivezic et al. 2007

Motion of variable stars
in the HR diagram
based on a Gaia DR2 sample

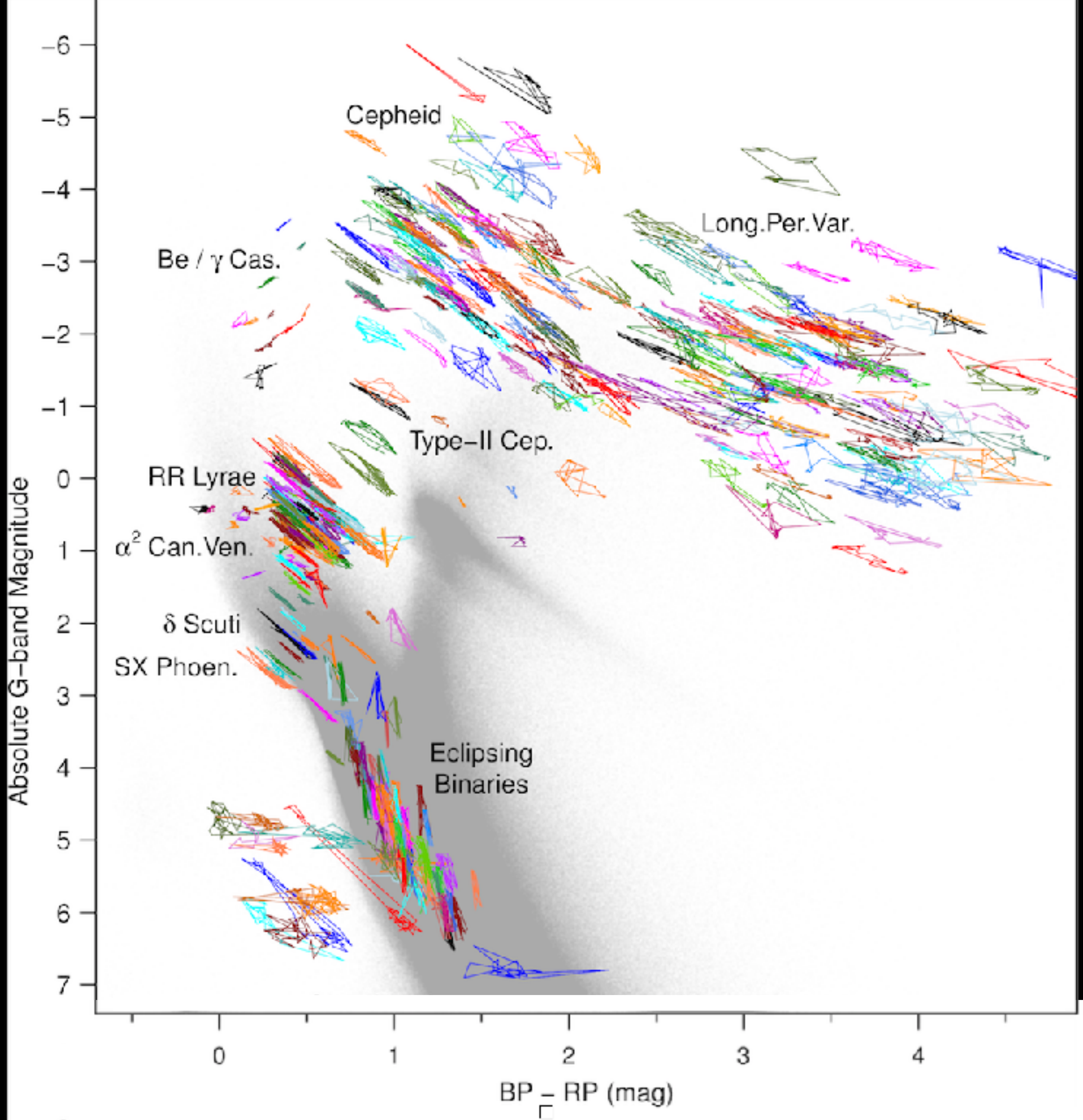
https://www.youtube.com/watch?v=Pcy4U5uvL8I

Motions in the Colour-Absolute Magnitude Diagram

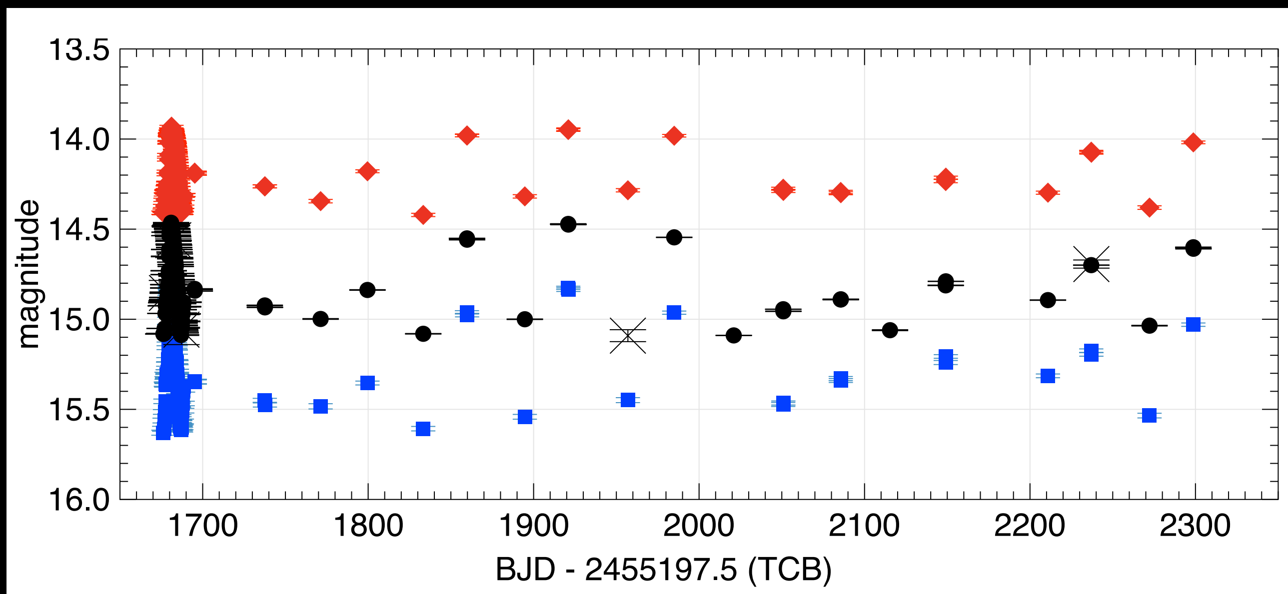
"Pollock" diagram

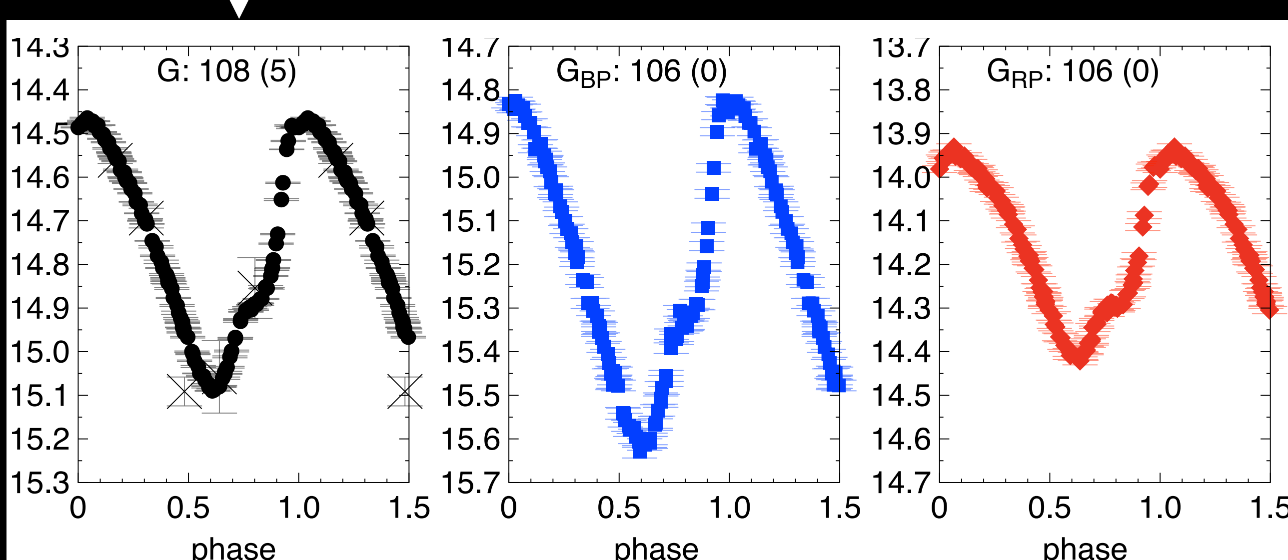
With LSST filters system will be remarkable

GaiaCollaboration, Eyer et al. 2018



Variability Processing and Analysis





Time series of 3 colour bands for Gaia:

- **G**(aia) = most visible light
- **R**(ed)
- **B**(blue)
- + position, parallax (distance), motion

LSST: 6 bands!

Variability Processing and Analysis

Extracted scientific information:

- Variability type: **Classical Cepheid**
- Period: **10.44 days**
- Amplitude, absolute brightness, effective temperature, etc…

Courtesy of B.Holl

LSST will have a very important impact on period objects

In the phase space observations overlaps

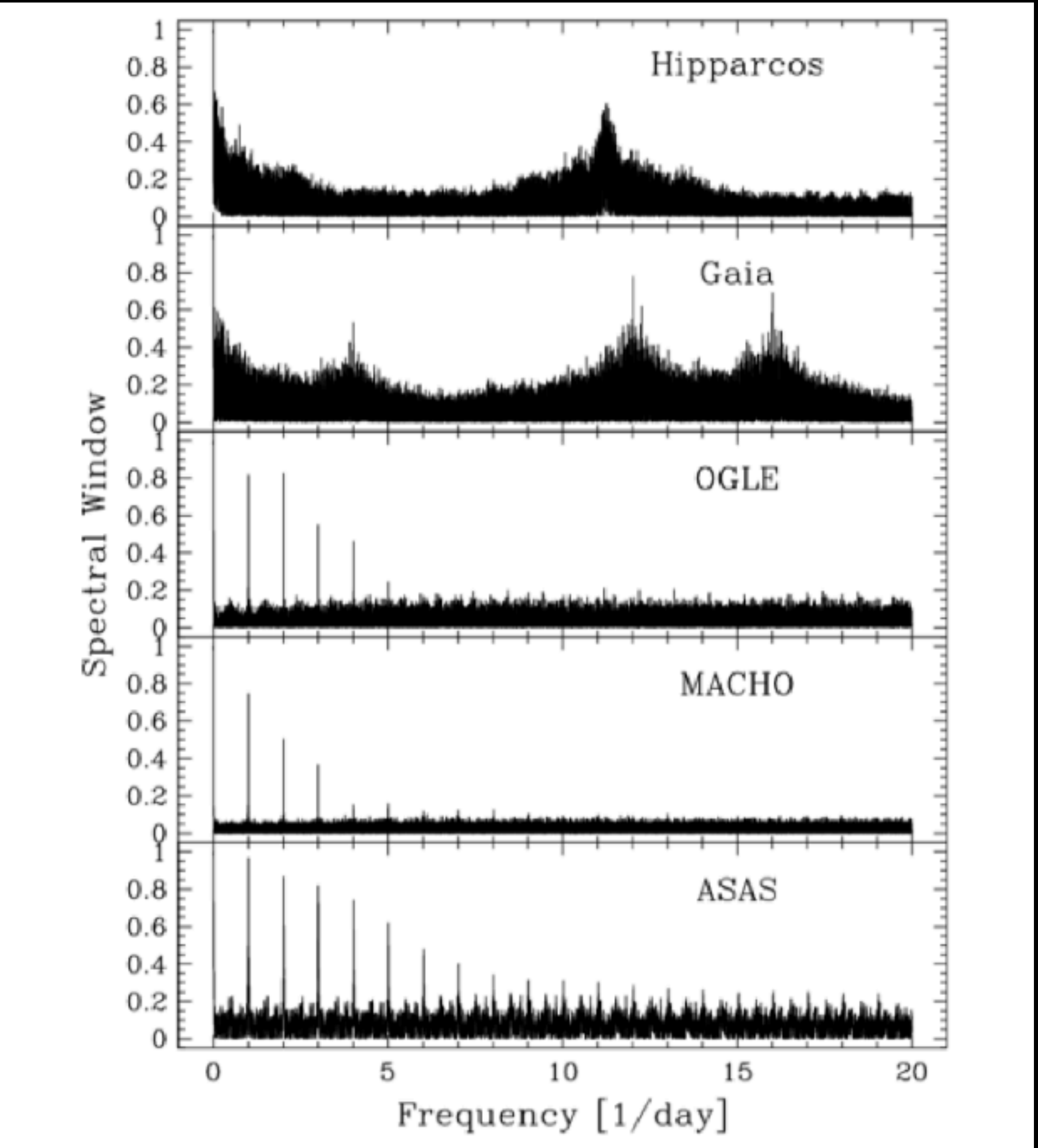
Vanderplas and Ivezic 2015 developed a period search that uses all bands

Michael Jonhson showed it works remarkably well

However, the spectral window of the cadence is currently not optimal

Many discussions on the cadence…

Spectral windows from various surveys

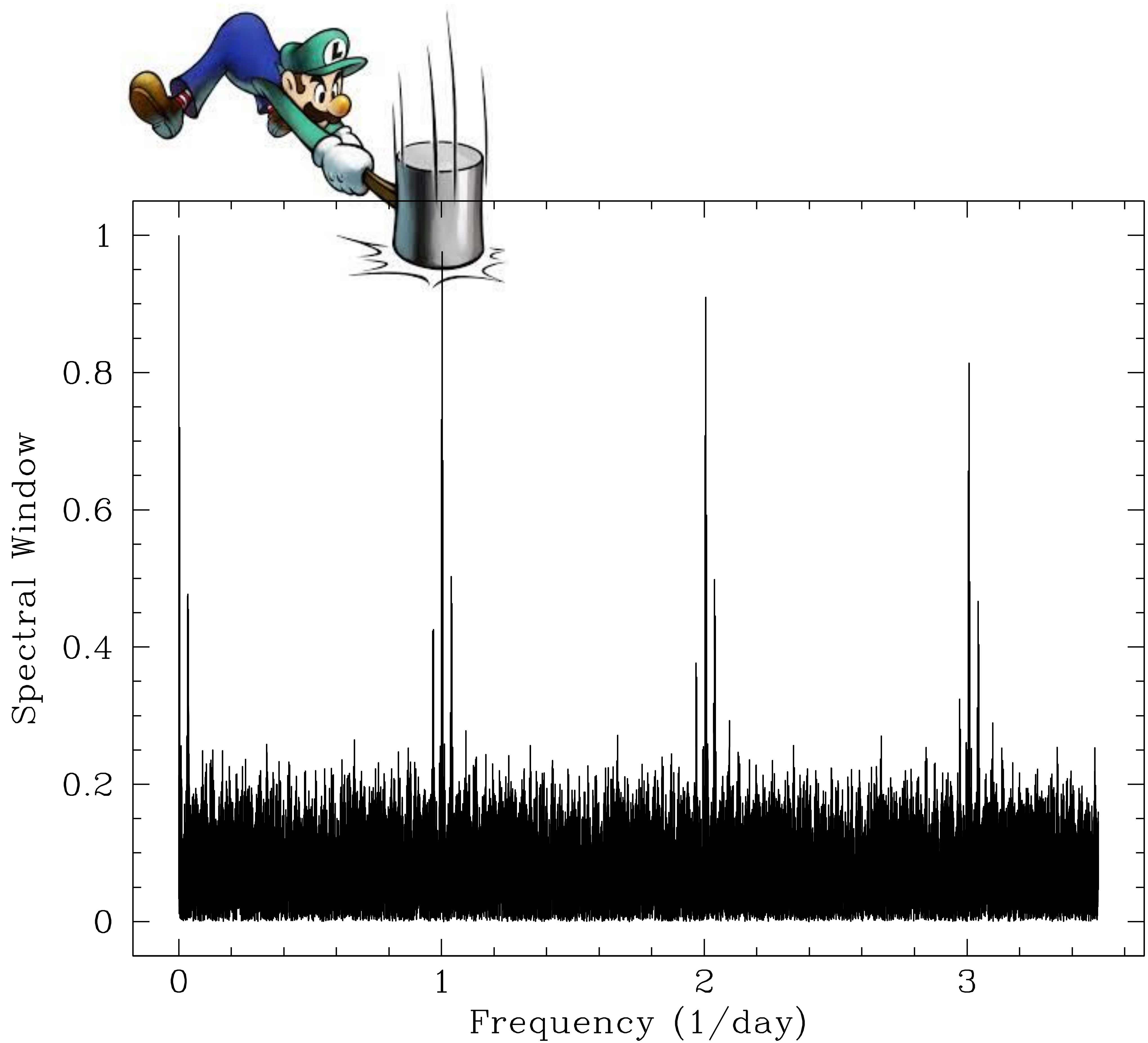


Eyer et al. 2009

Spectral windows from LSST

I contacted Zeljko

Lynne Jones efficiently transmitted me few files



Principal component analysis

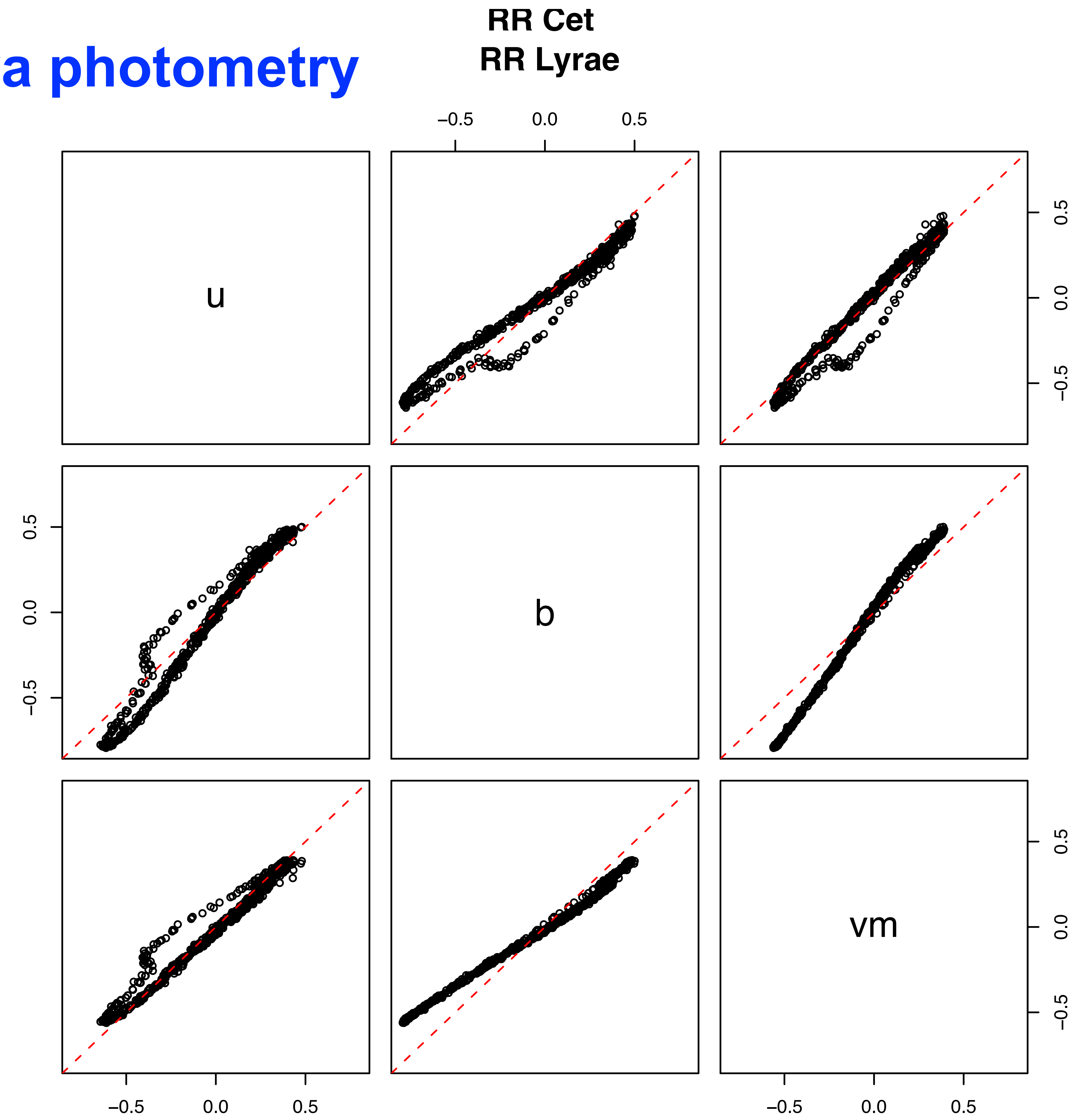
- Idea: $\overline{s}_j = \frac{1}{N}\sum_i s_{ij}$ $\quad d_{ij} = s_{ij} - \overline{s}_j$

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

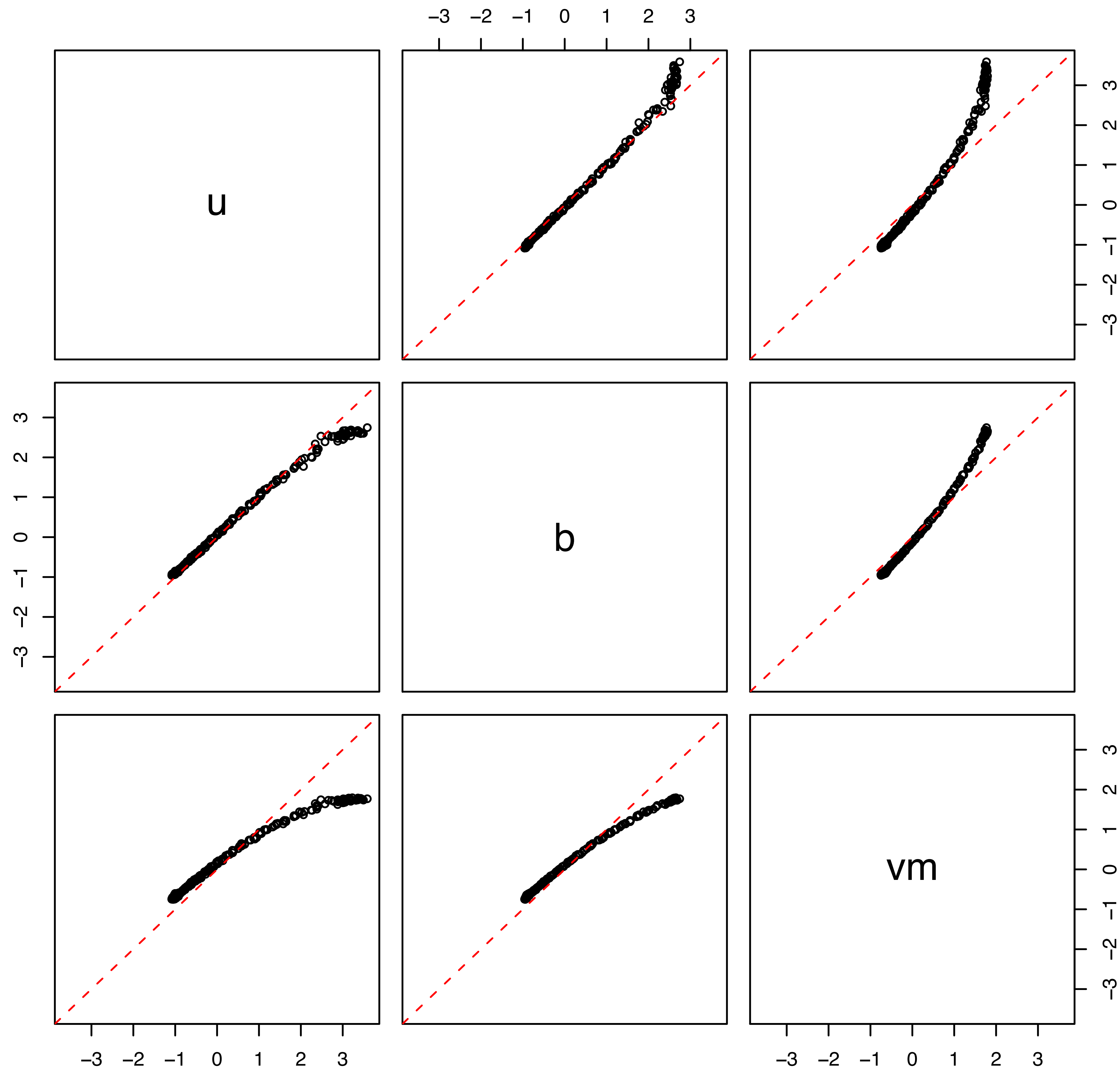
- Proposed by Paul Bartholdi 2005
- Applied to the Geneva constant stars (results: some are variable!)
- Perform the period search on the “new magnitude” (first component)
- Characterize the physical properties of stars
- Tests on Geneva Photometry, and on SDSS stripe 82

Geneva photometry

50,000
stars

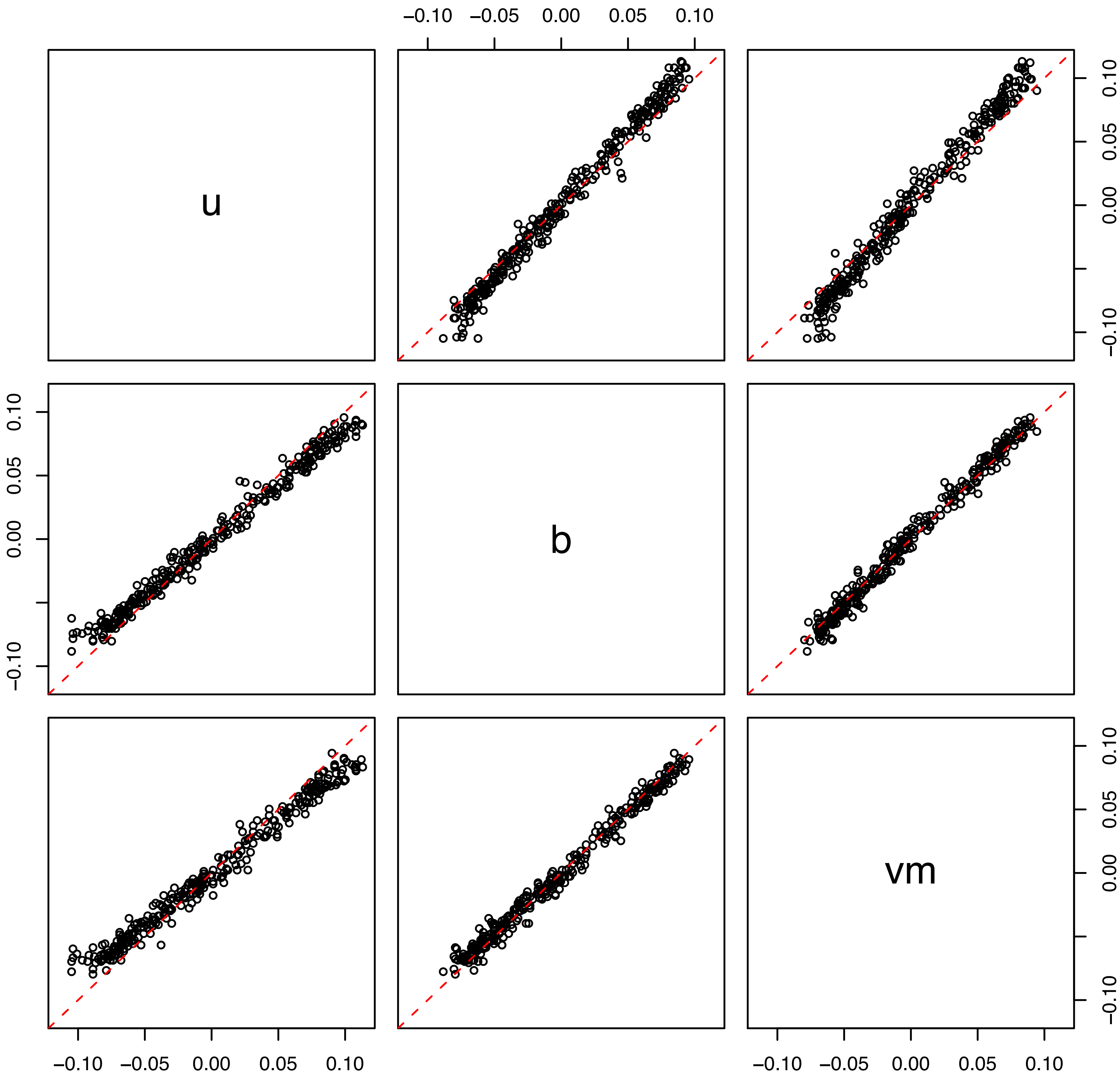


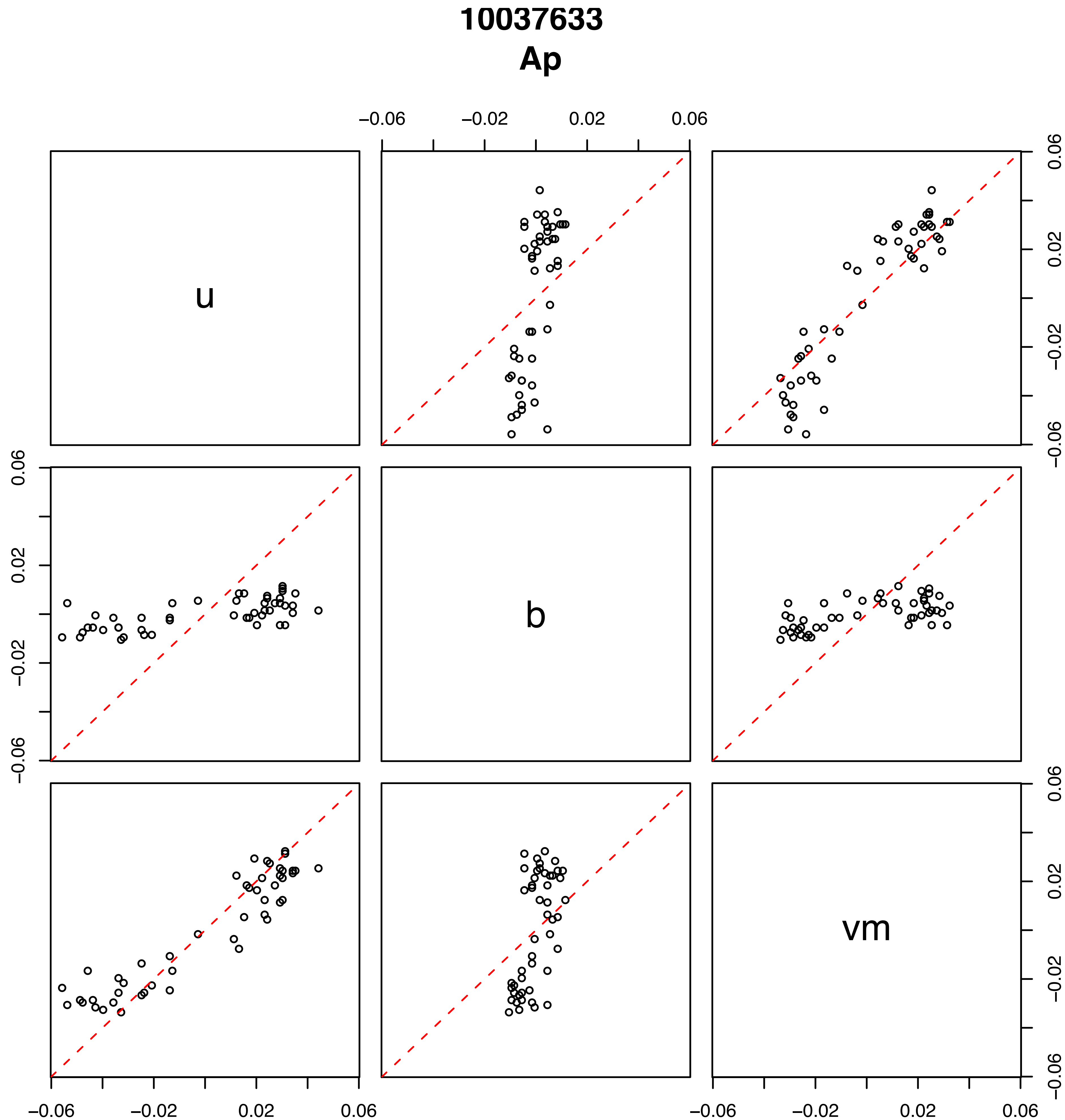
TZ Eri
Eclipsing binary



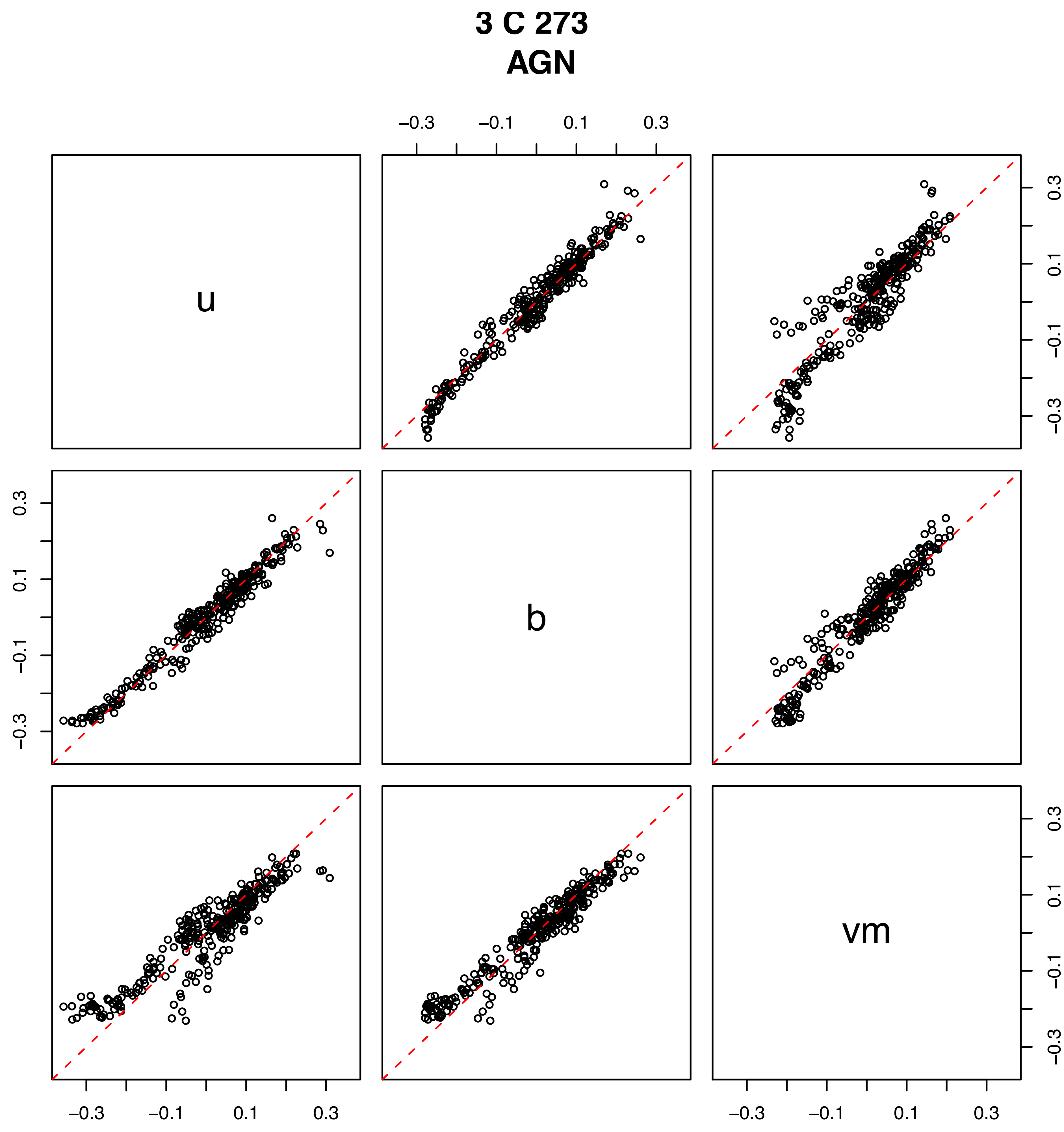
V 831 Cen

EW eclipsing

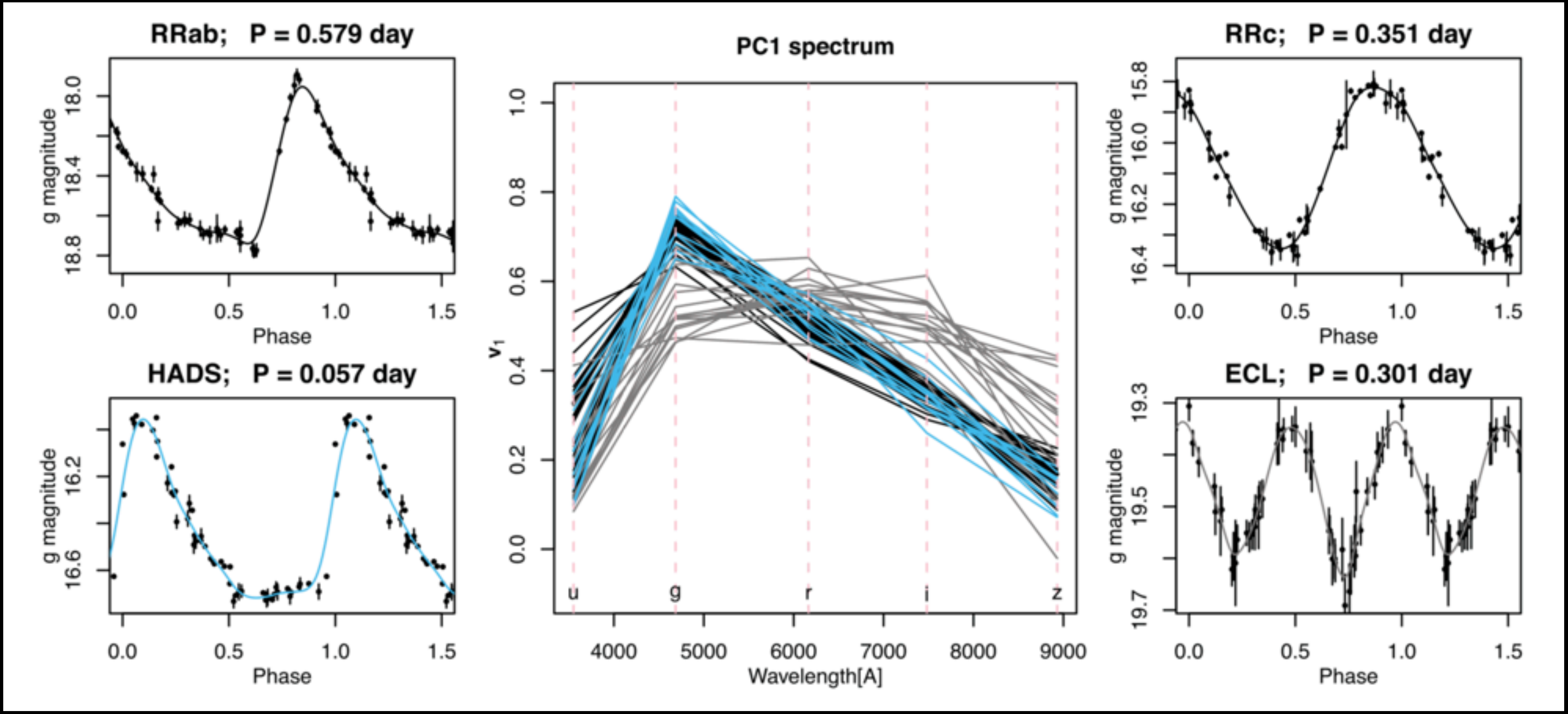




Struggle to find a dozen case with Gaia: 40,000 ? !!


3 C 273
AGN
u
b
vm
−0.3
−0.1
0.1
0.3

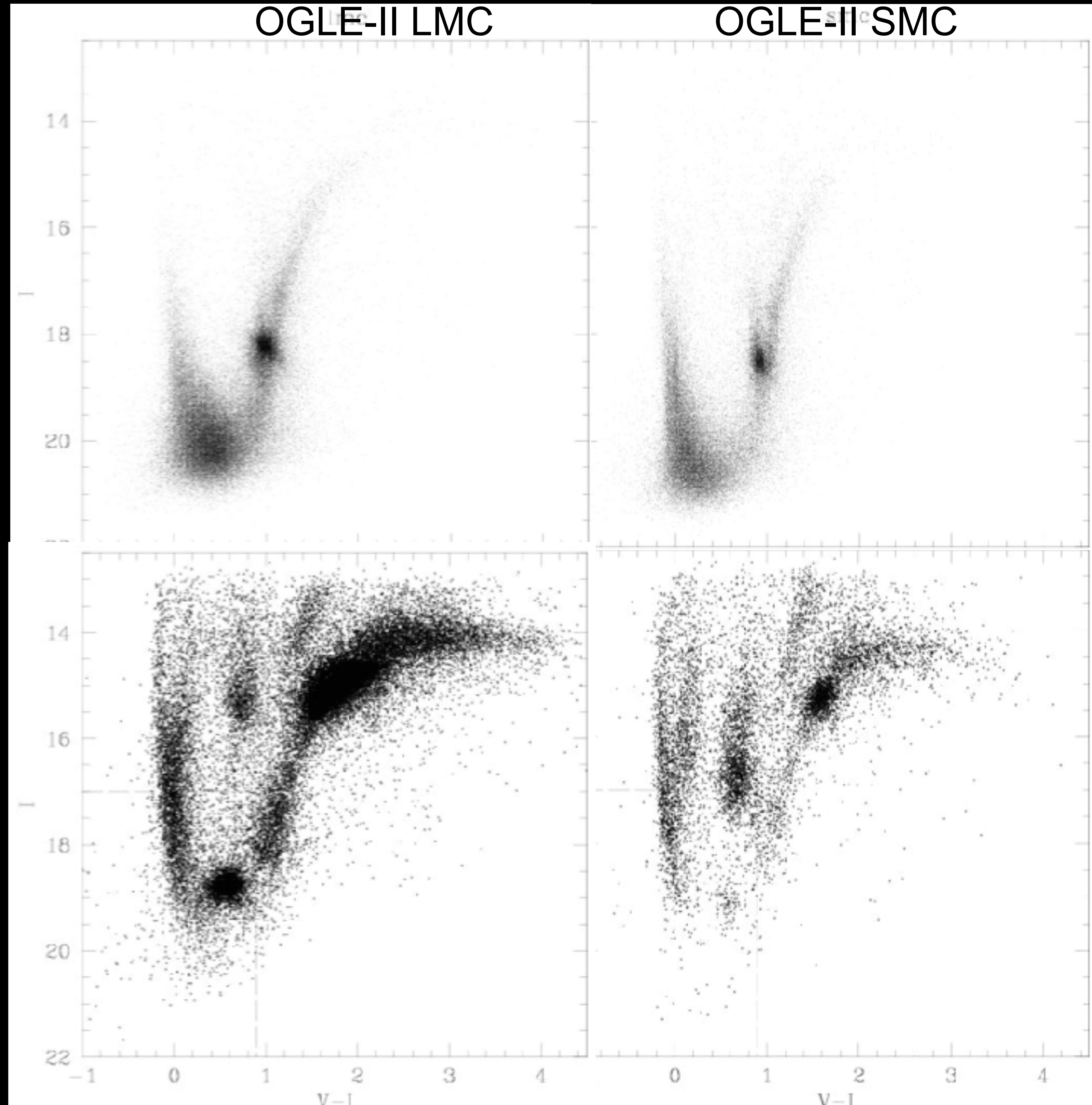
Principal component analysis on SDSS stripe 82 data



Süveges et al. 2012

LSST should not have difficulties to determine the physical origin of variability

LSST will be able to compare population of variables in different systems



Eyer 2002

Focus on Eclipsing binaries thanks to Kepler

Kepler is ``game-changer",
unprecedented sampling/photometric precision

For eclipsing binaries:

Kepler is complete to 10 days for the selected sample of F, G, K stars (Kirk et al 2016)

One surprise: 18 % are not regular (with eclipses changing/disappearing)

Kepler allows to study performance for other projects

70% should be detected by LSST - r band detection - (Wells et al. 2017)

80% when other bands are taken into account (Prša private com.)

LSST will detect 24 million eclipsing binaries (Prša et al. 2011)

Detection of binaries: special eclipsing binaries
Double White Dwarf

Study by Korol et al. 2017

Ultra compact detached white dwarfs

	Gaia	LSST	LISA
Gaia	189	93	13
LSST	93	1100	50
LISA	13	50	24508

(a) $\alpha\alpha$ CE model

	Gaia	LSST	LISA
Gaia	246	155	24
LSST	155	1457	73
LISA	24	73	25735

(b) $\gamma\alpha$ CE model

LSST and standard candles stars

Discovery of distant RR Lyrae stars in the Milky Way using DECam

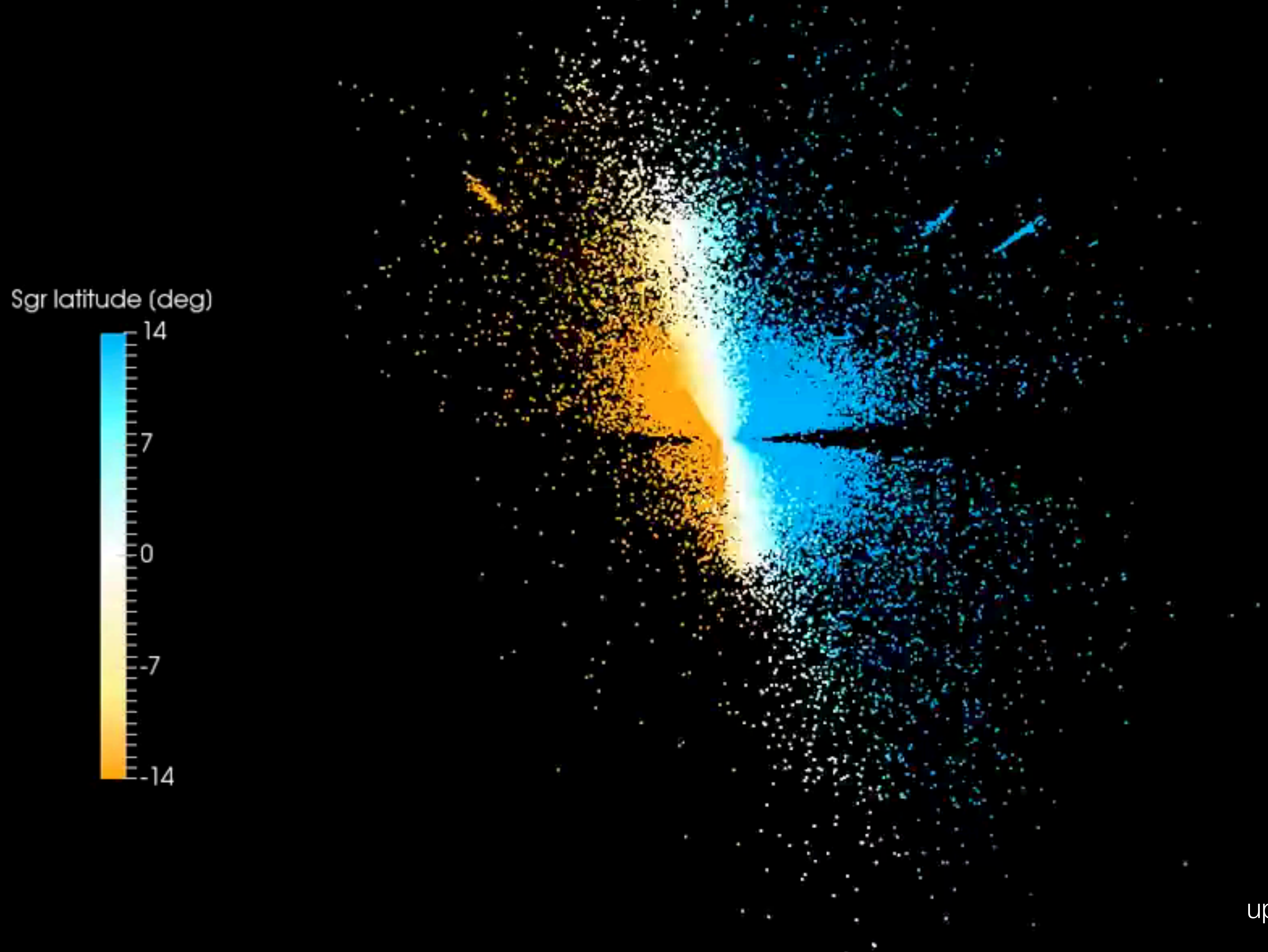
Medina et al. 2018

LSST will probe very large distances

complete to over 350 kpc!

LSST and standard candles stars

RR Lyrae stars in the halo with PS1 data from Sesar et al 2017



up to 130 kpc


Thank you for your attention