Variability Analysis of the Gaia data

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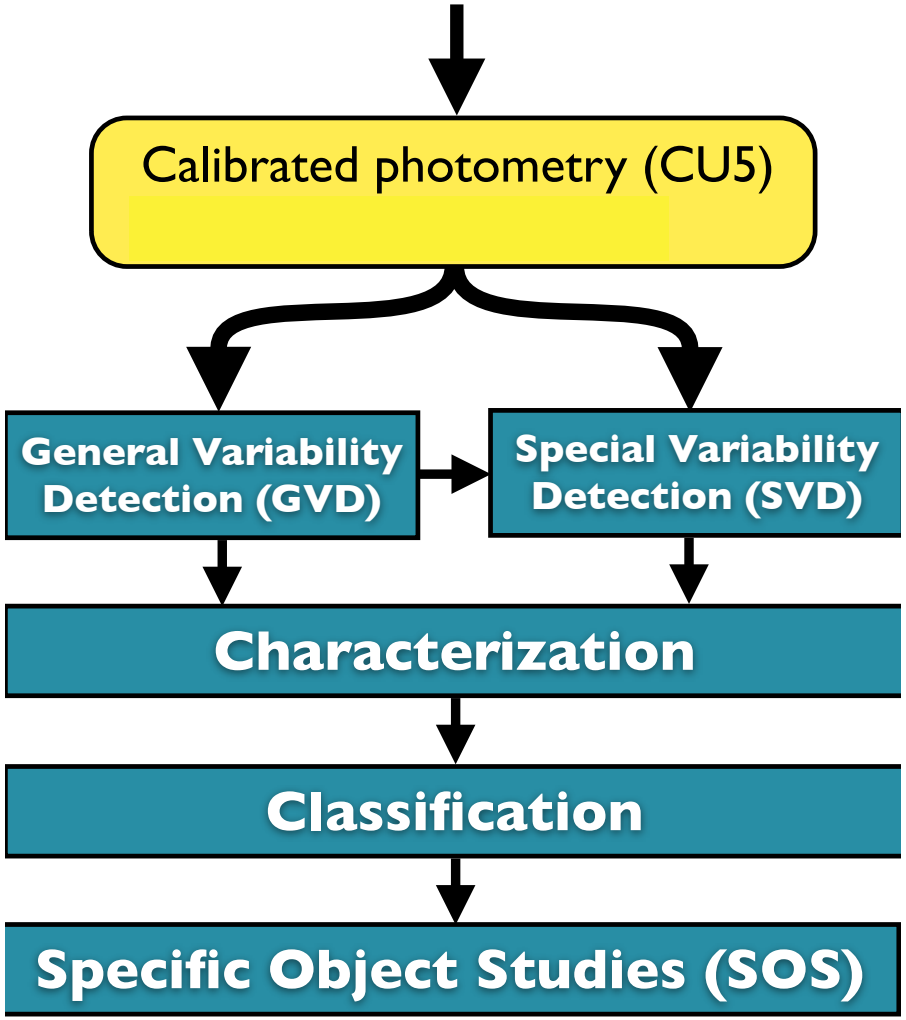
Gaia Mission Status and First Data Processing
Division A, IAU
Hawaii, USA
Friday August 7, 2015

Gaia Variability Processing and Analysis

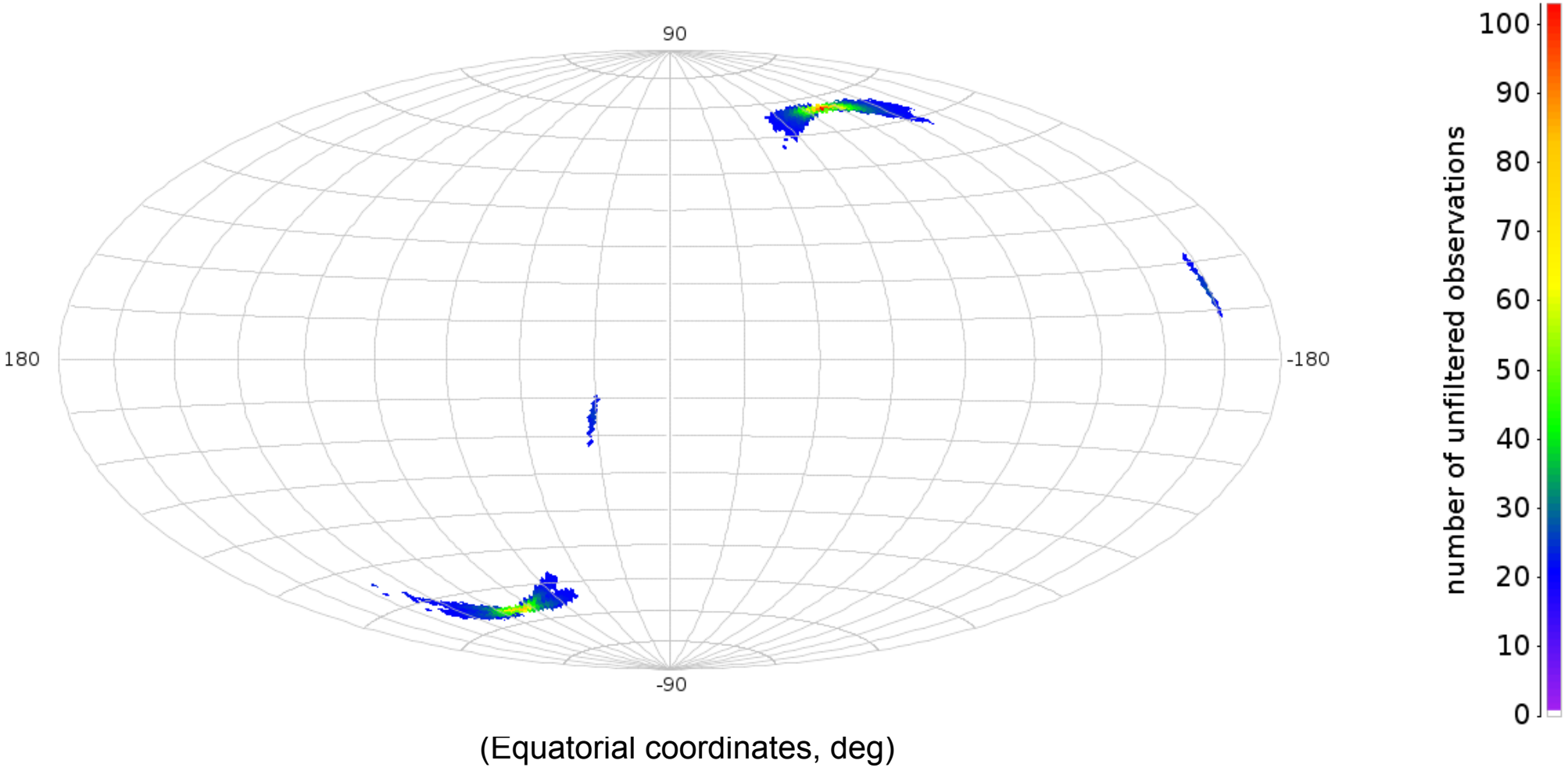
1 billion sources observed by Gaia
790,000 REAL Gaia data from Ecliptic Poles

Time series of 70 (40-250) measurements over 5 years
Time series up to 170 measurements over 28 days



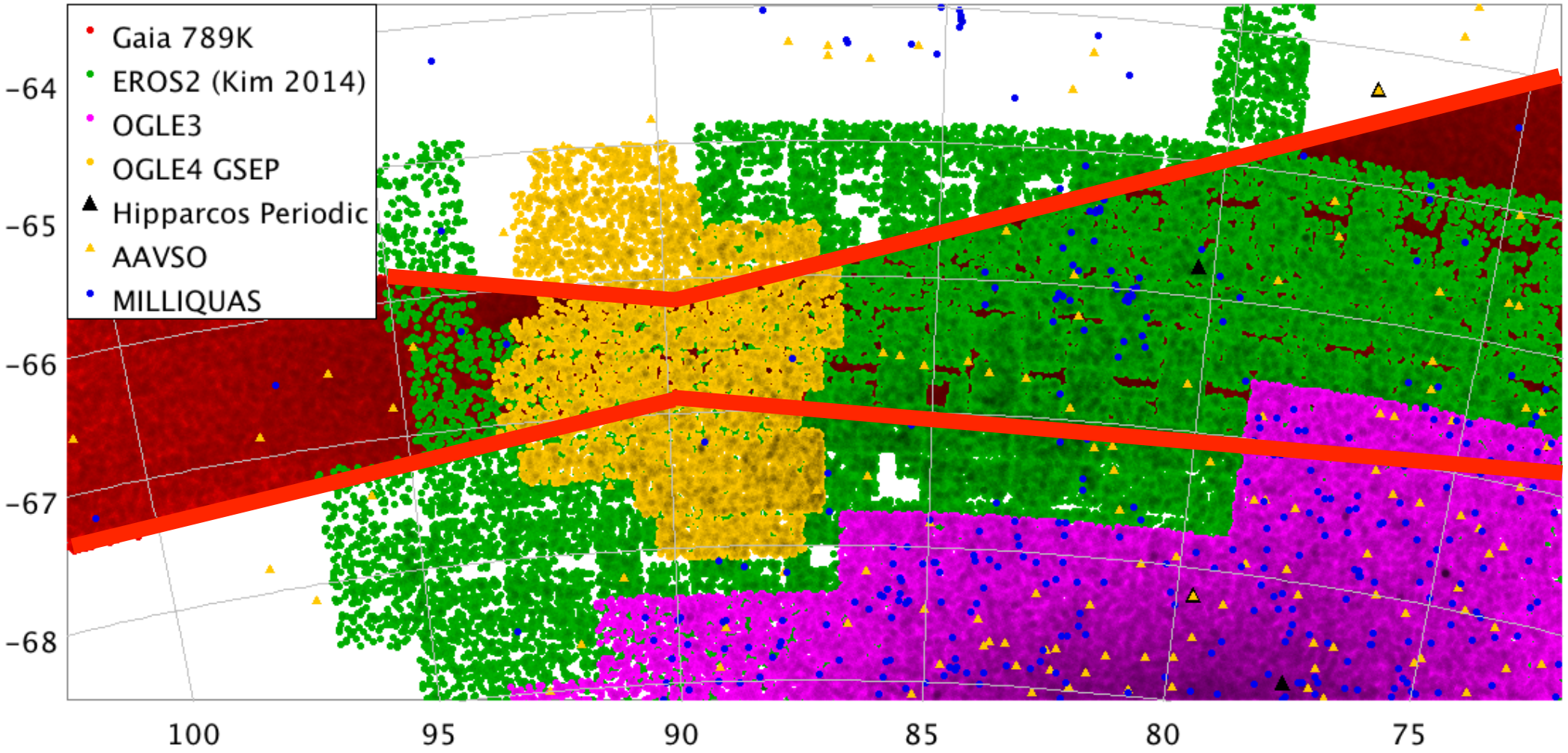
Selection of sources observed by Gaia from Ecliptic Pole Scanning Law (790,000 sources)

~28 days



Warning: Sampling regular, different from Nominal Scanning law

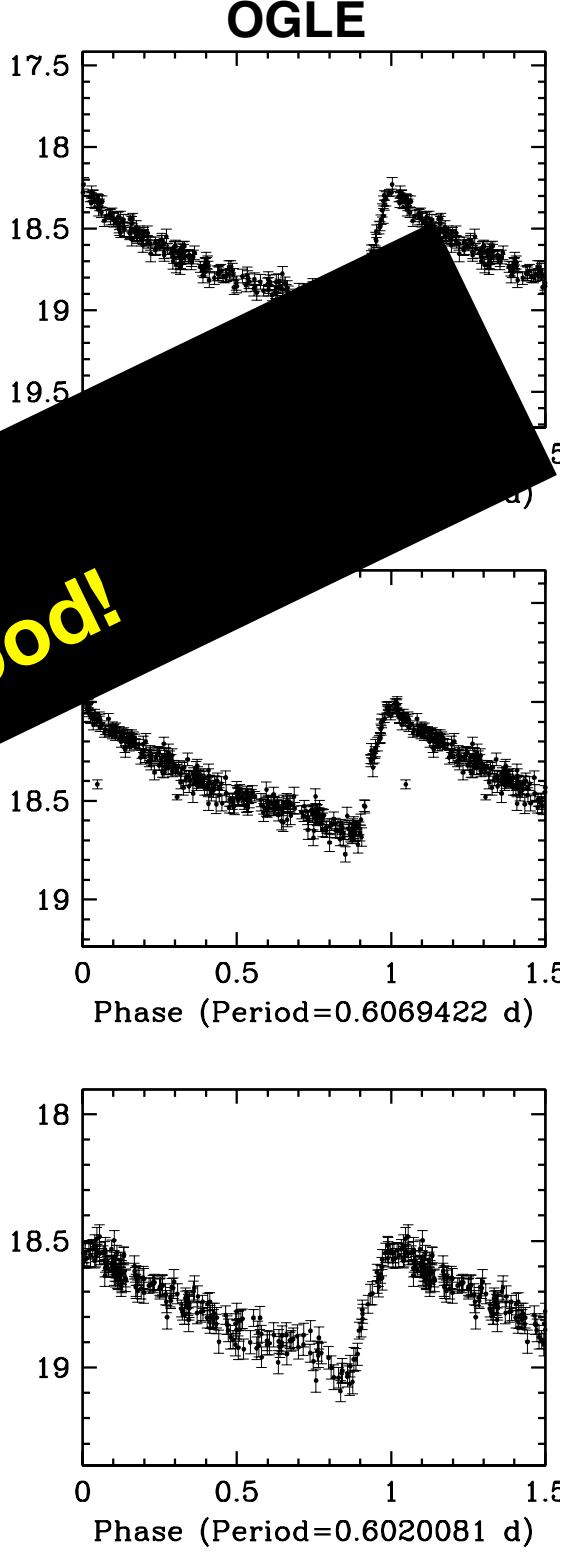
South Ecliptic Pole region (part of Large Magellanic Cloud): Gaia and other surveys



To get the data flavour
Comparison with OGLE

Image of the Week (March 05, 2015):
RR Lyrae stars

Take-home message:
Gaia G band photometry is good!



Cr… C/CU5/CU7/INAF-OABo, Gisella Clementini, Dafydd E… Eyer, Krzysztof Nienartowicz, Lorenzo Rimoldini and the Geneva CU7/DPCG and CU7/INAF-OACN teams.

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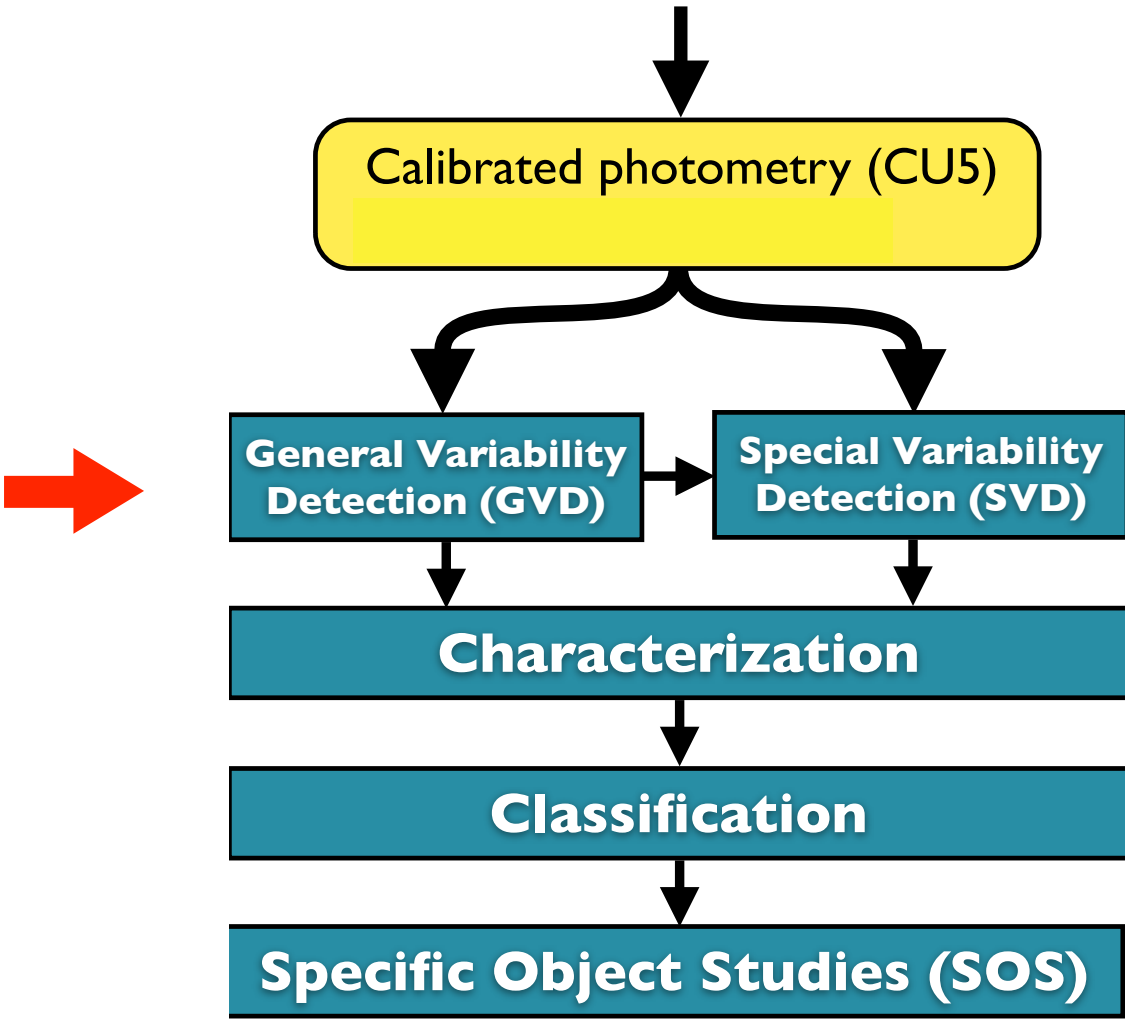


General Variability Detection

Two fundamental quantities to estimate:

- **Completeness**
- **Contamination**

Detection was done with a classifier (Random Forest)

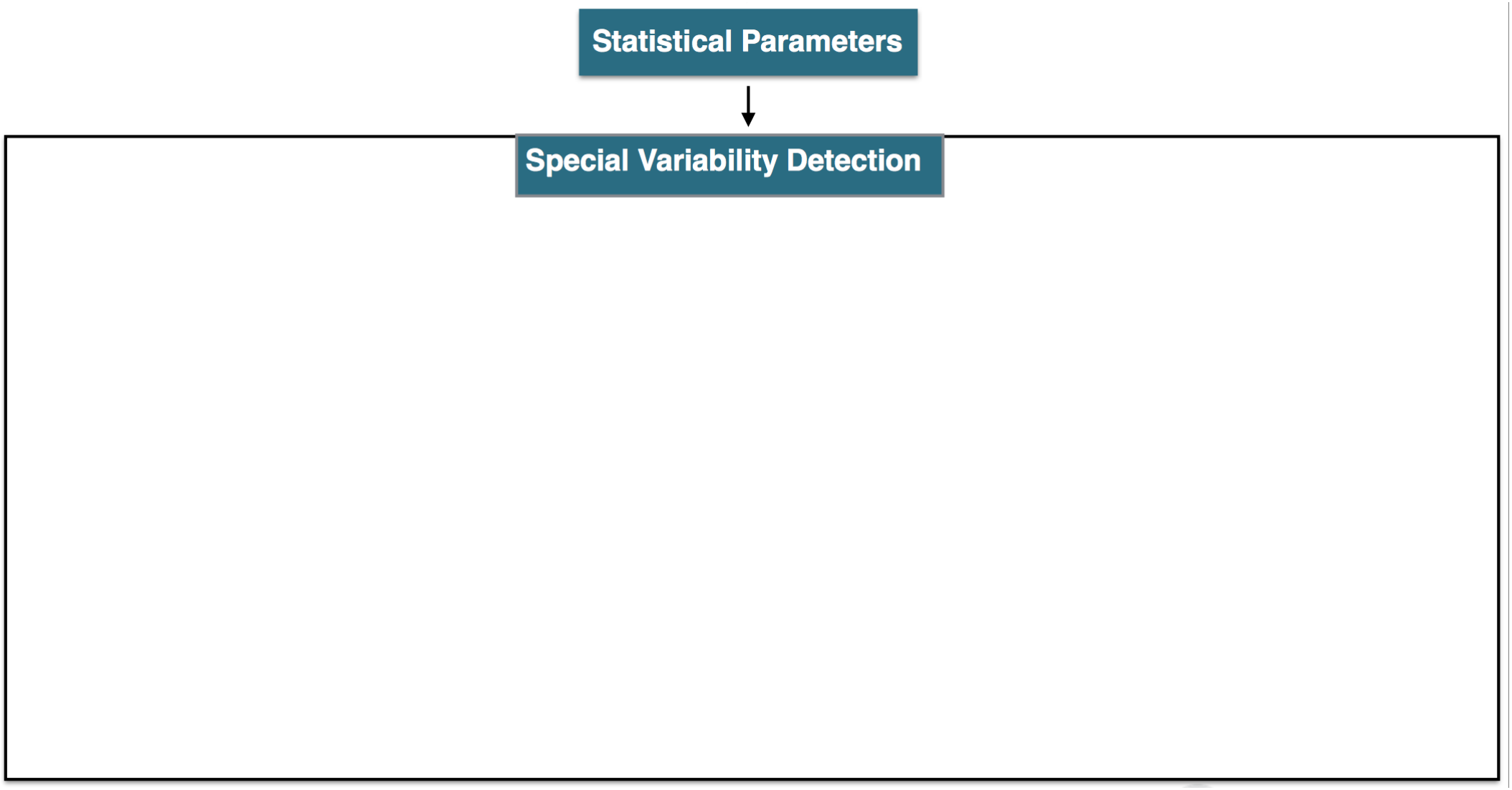
attributes were computed

a training set was defined (based on OGLE)

Classifier result: The confusion matrix

		VARIABLE	CONSTANT
376	VARIABLE	80	20
546	CONSTANT	5	95
	Contamination	8	13

Special Variability Detection:



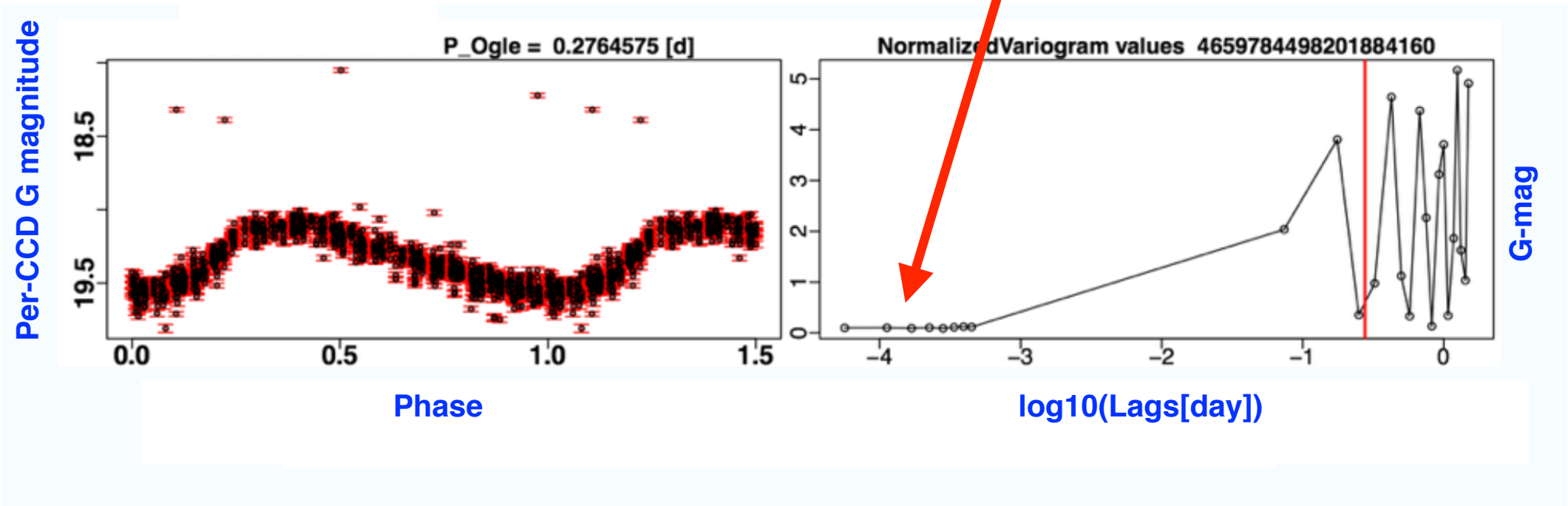
Courtesy of L.Guy

Special Variability Detection: short time scale

Implementation of variogram: “variance” for all the paired magnitude difference separated by a certain time lag

Probed Time-scales: ~10 seconds

One example of per-ccd data:



Courtesy of M.Roelens/I.Lecoeur

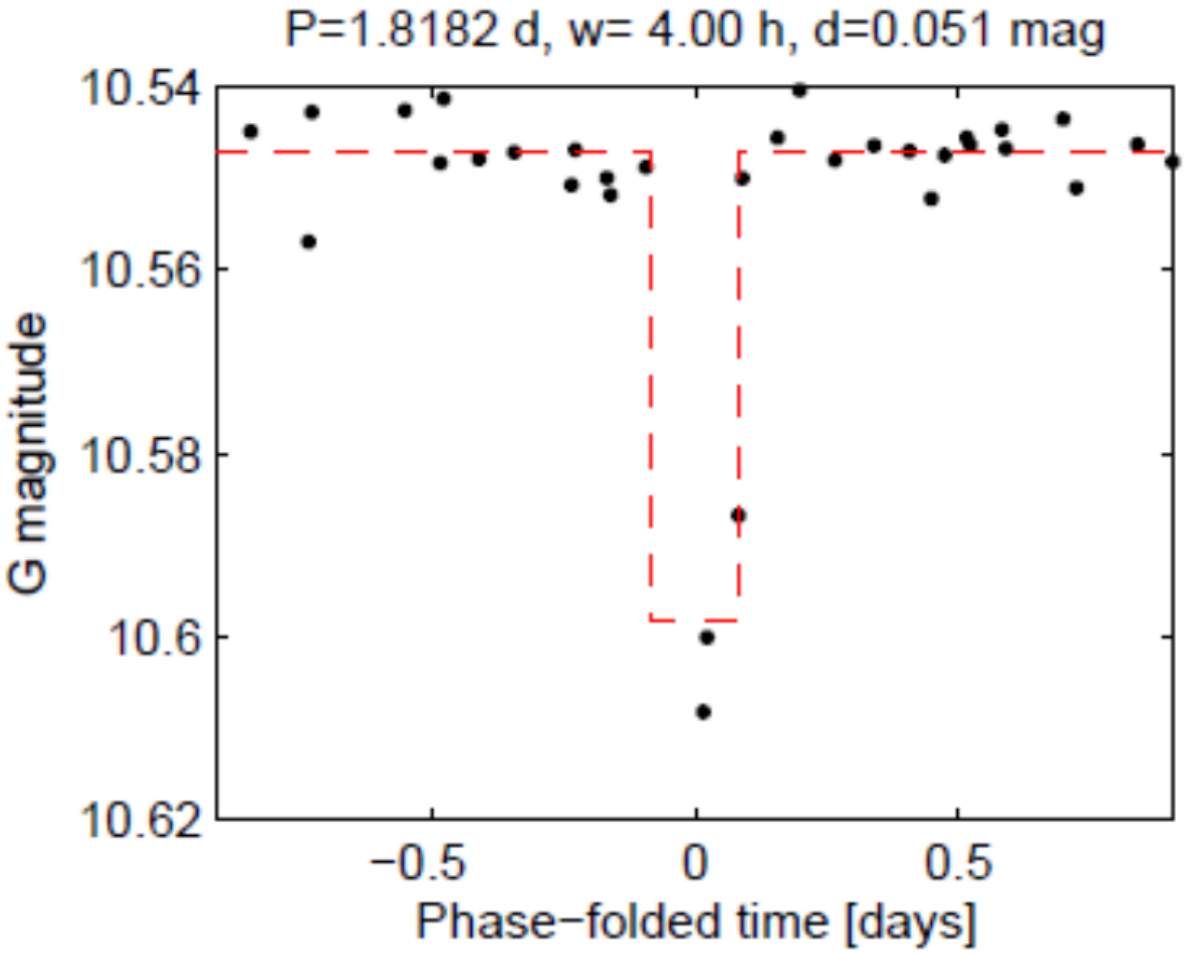
Special Variability Detection: exo-planet transits

Two algorithms:

1) Box-Least Square

2) Outlier Probability, Tingley (A&A 2011)

Box Least Square algorithm gives about 200 candidates



Courtesy of S. Zucker

We do not claim any detection! yet !

Conclusion Box-Least Square is functioning well

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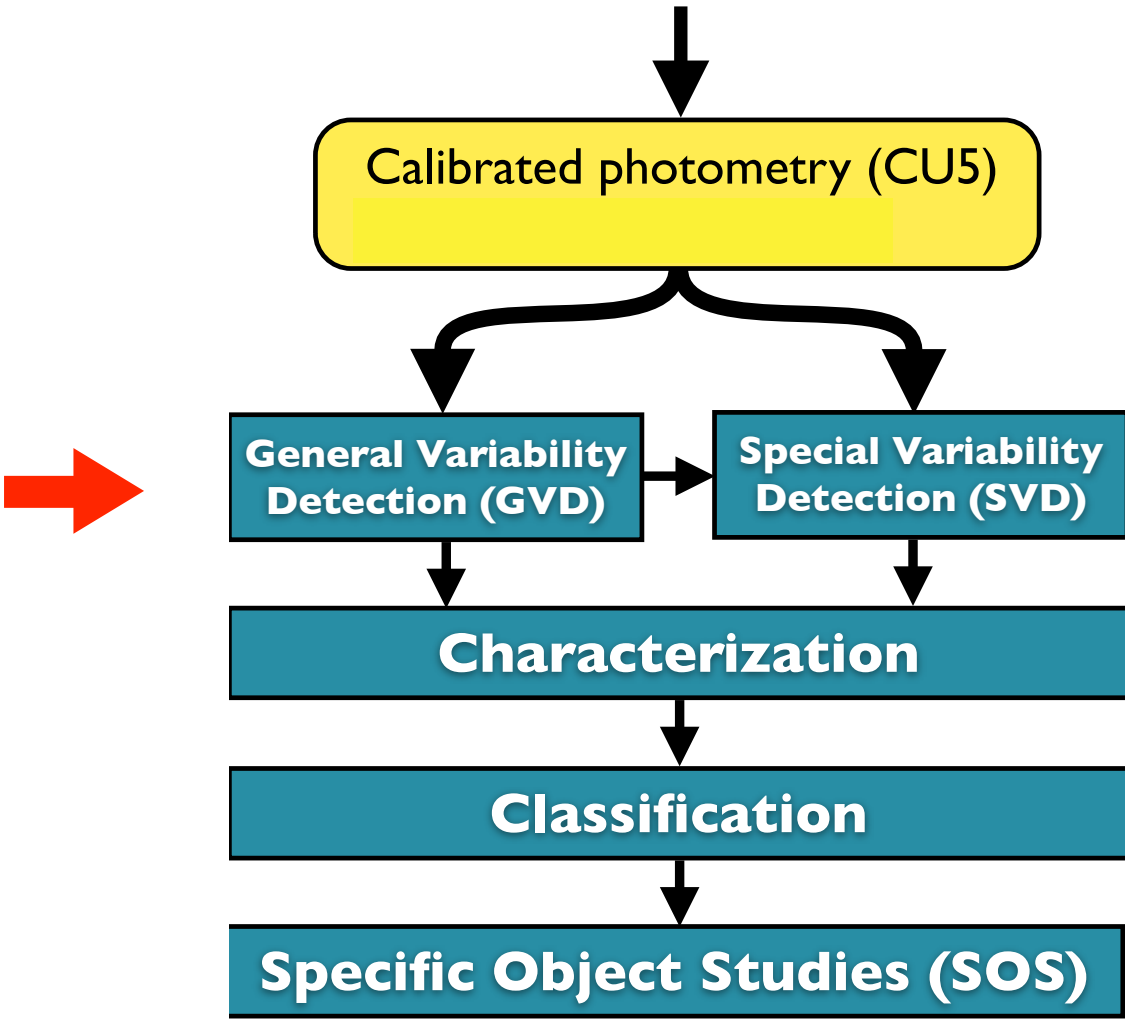


Characterisation

Time series per object:

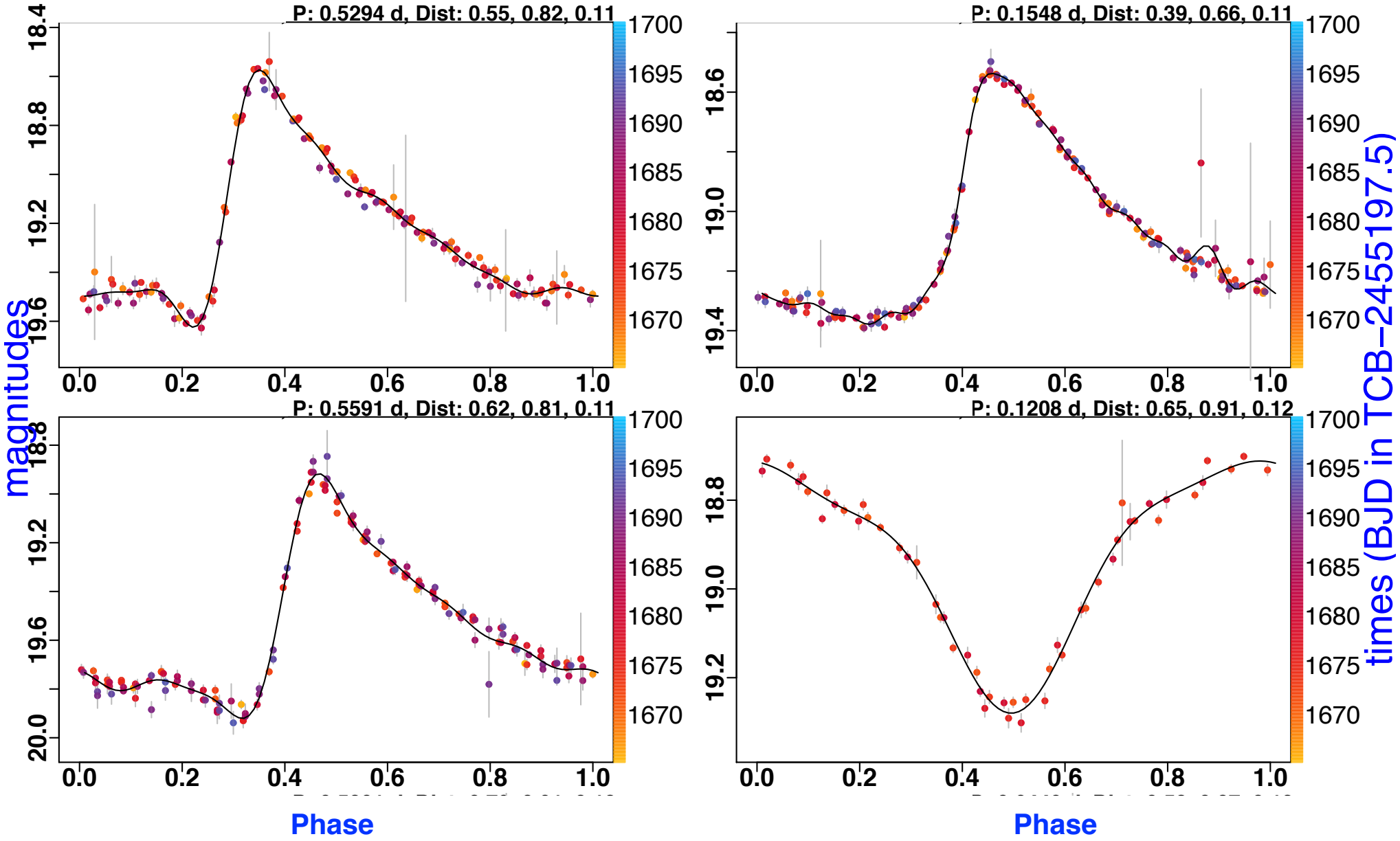
$\text{Time}_{(i)}$, G-, BP-, RP- $\text{mag}_{(i)}$ [or radial $\text{velocity}_{(i)}$]

i=1,…, number of measurements

Goal: To define attributes

- statistical parameters
- Modelling
  - —Period search
  - —Fourier Series and polynomial fit

Characterisation: few examples of modelling



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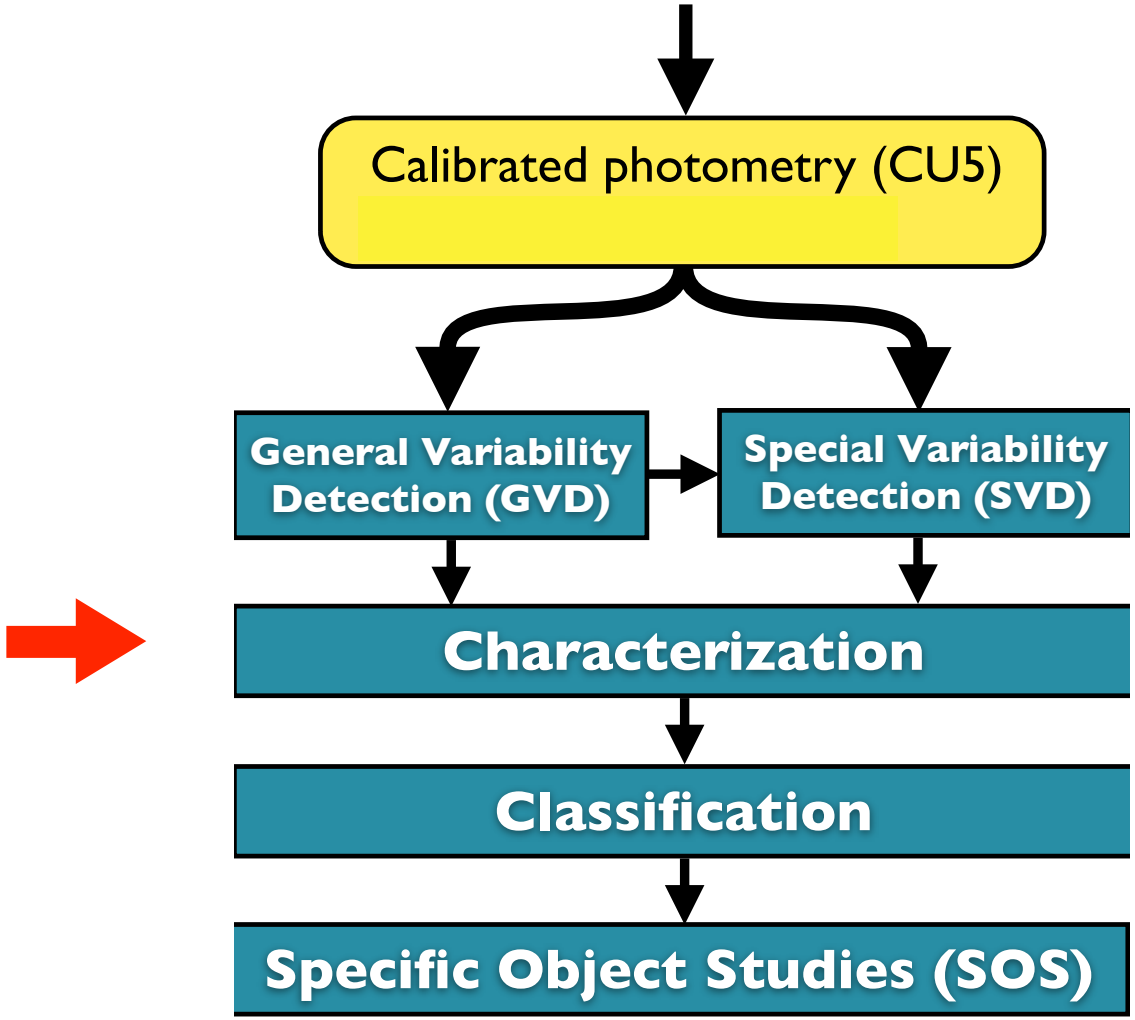


Classification

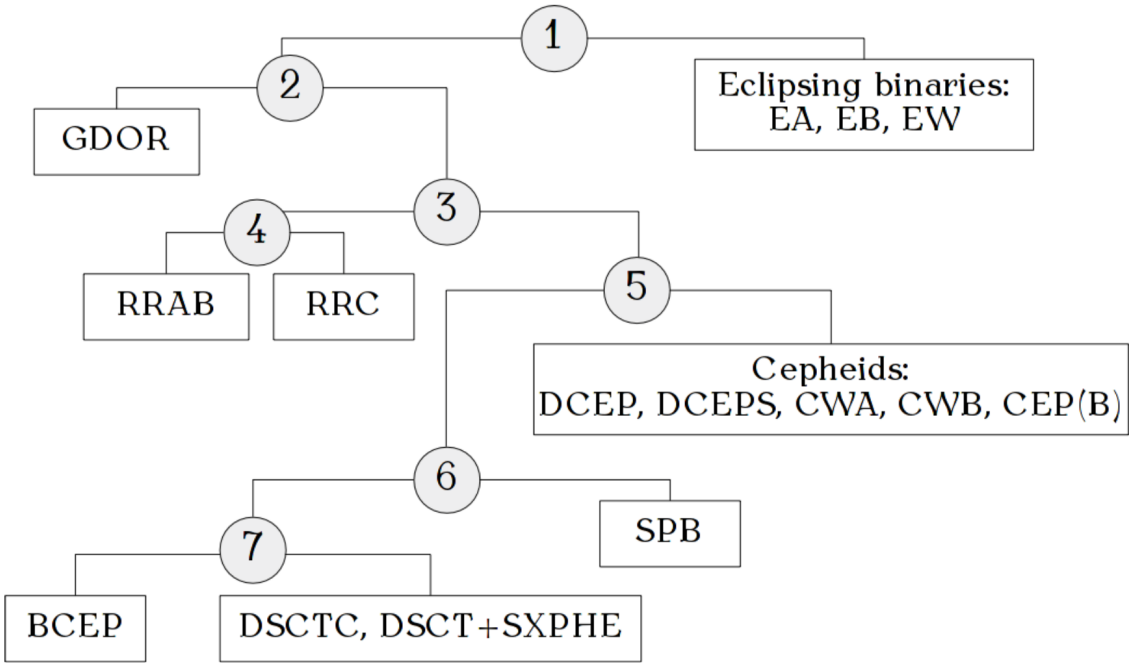
Supervised classification (several methods):

Multistage tree: Bayesian networds

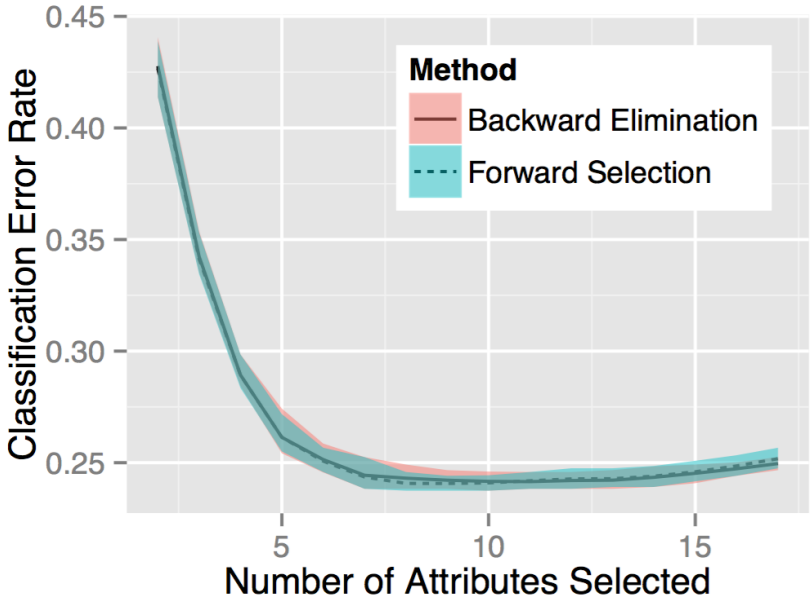
Multistage tree: Gaussian mixture

Random Forest

Tree for Gaussian Mixture:



Furnish training set
built from Crossmatched data



Classification

Confusion matrix of Random Forest
using cross-matched data (OGLE, Hipparcos, AAVSO, Milliquas)

		CONSTANT	QSO	ECL	OTHER	RRLYR	LPV	ELL	DSCT	DCEP	UG
103	CONSTANT	79	8	5	9						
100	QSO	7	88	2	3						
135	ECL	4	3	84	7	1	1	1			
108	OTHER	13	4	12	69		2	1			
106	RRLYR	3		1	2	94					
27	LPV	30	19	7	30		15				
8	ELL	25	12		62						
7	DSCT	14		29	29	29					
2	DCEP	50		50							
2	UG					100					
	Contamination	34	20	19	34	5	43	100	_	_	_

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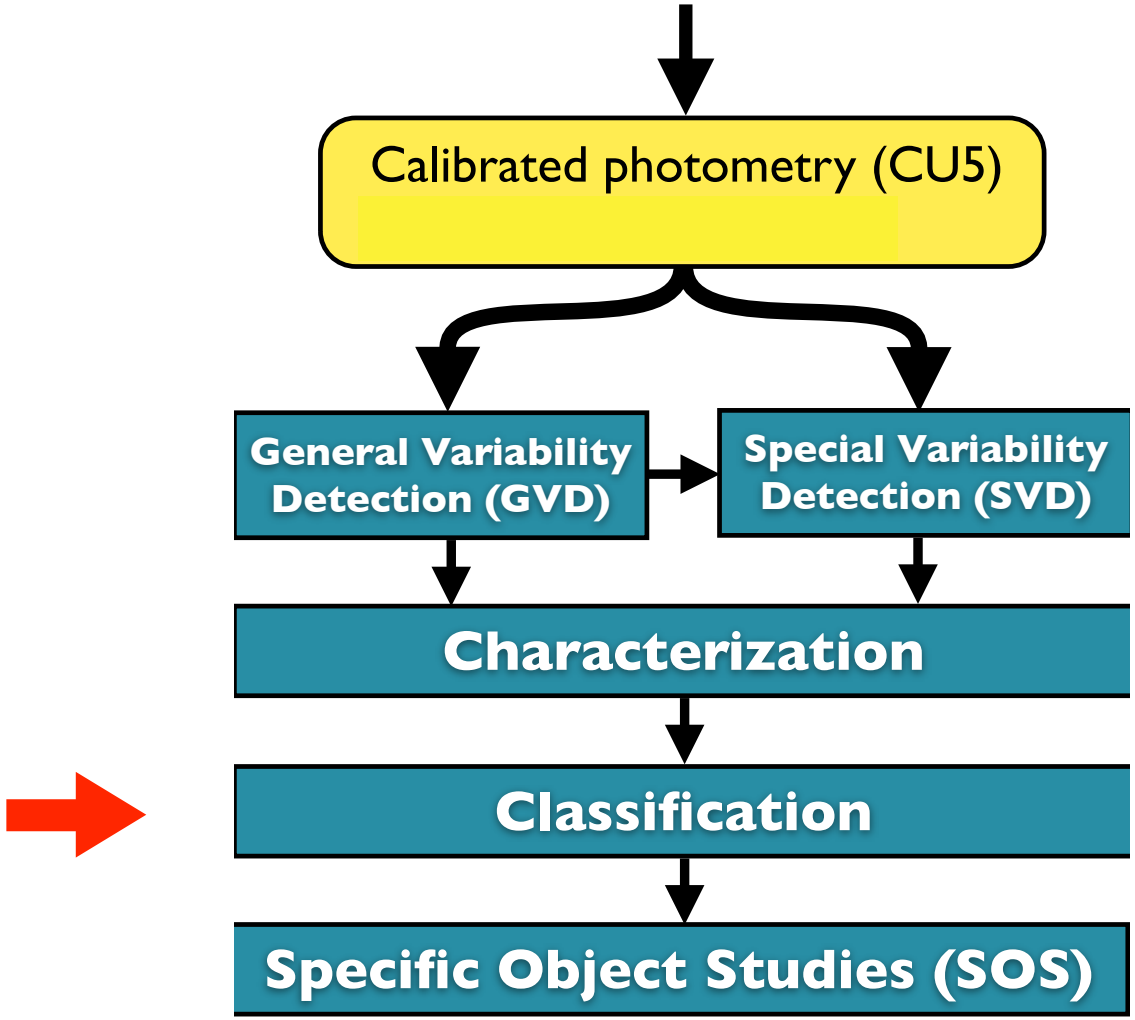


Specific Object studies: a list of variability types

Eclipsing Binaries

Cepeids & RRLyrae stars

Long Period Variables

Exoplanet transits

Be stars

Short time scales

Pre-main sequence

Flaring Stars

Rotational Modulation

μ-lensing events

Cataclysmic Variables

AGN

Rapid-phases

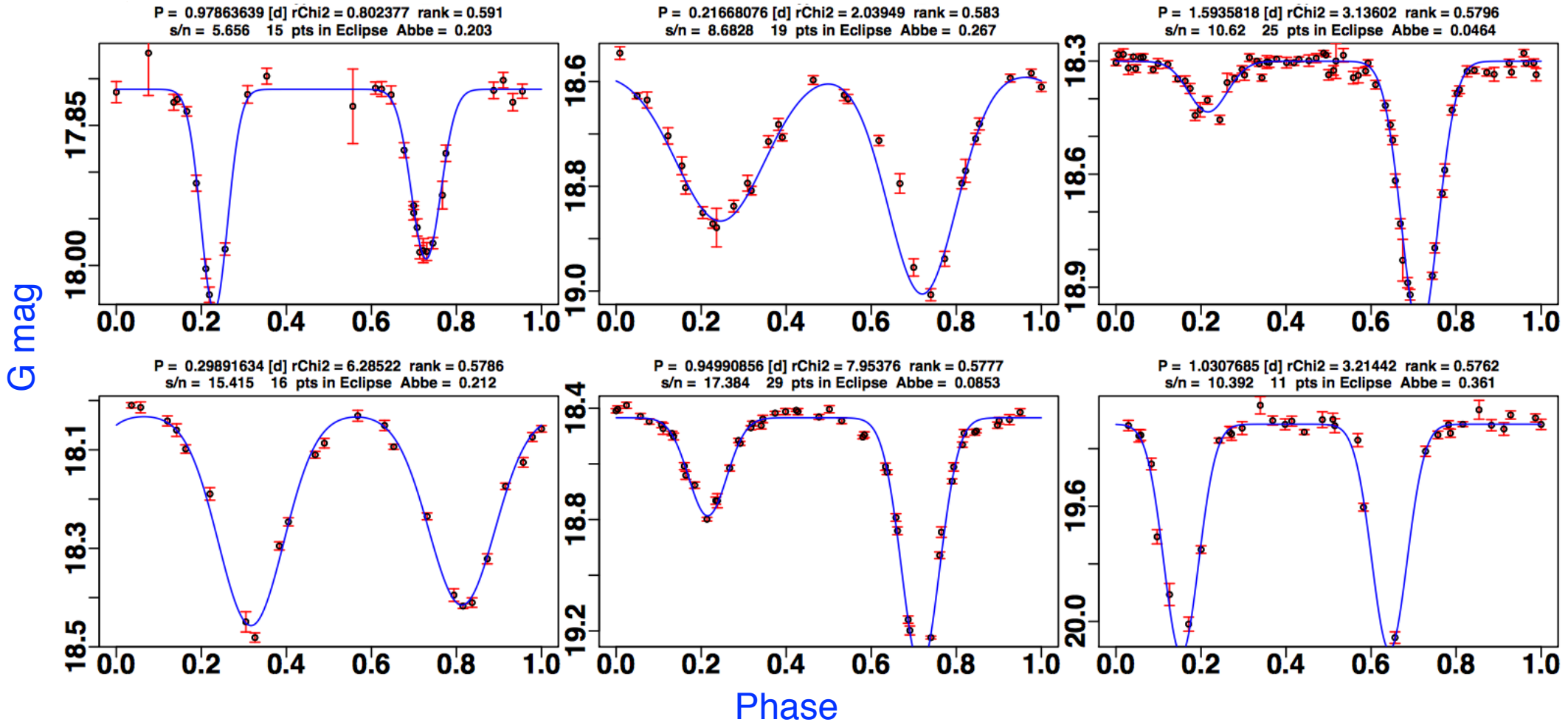
Specific Object Studies: Eclipsing binaries

Eclipsing binaries go to a dedicate treatment (Université Libre de Bruxelles) for a full modelling

Here, simple modelling are made

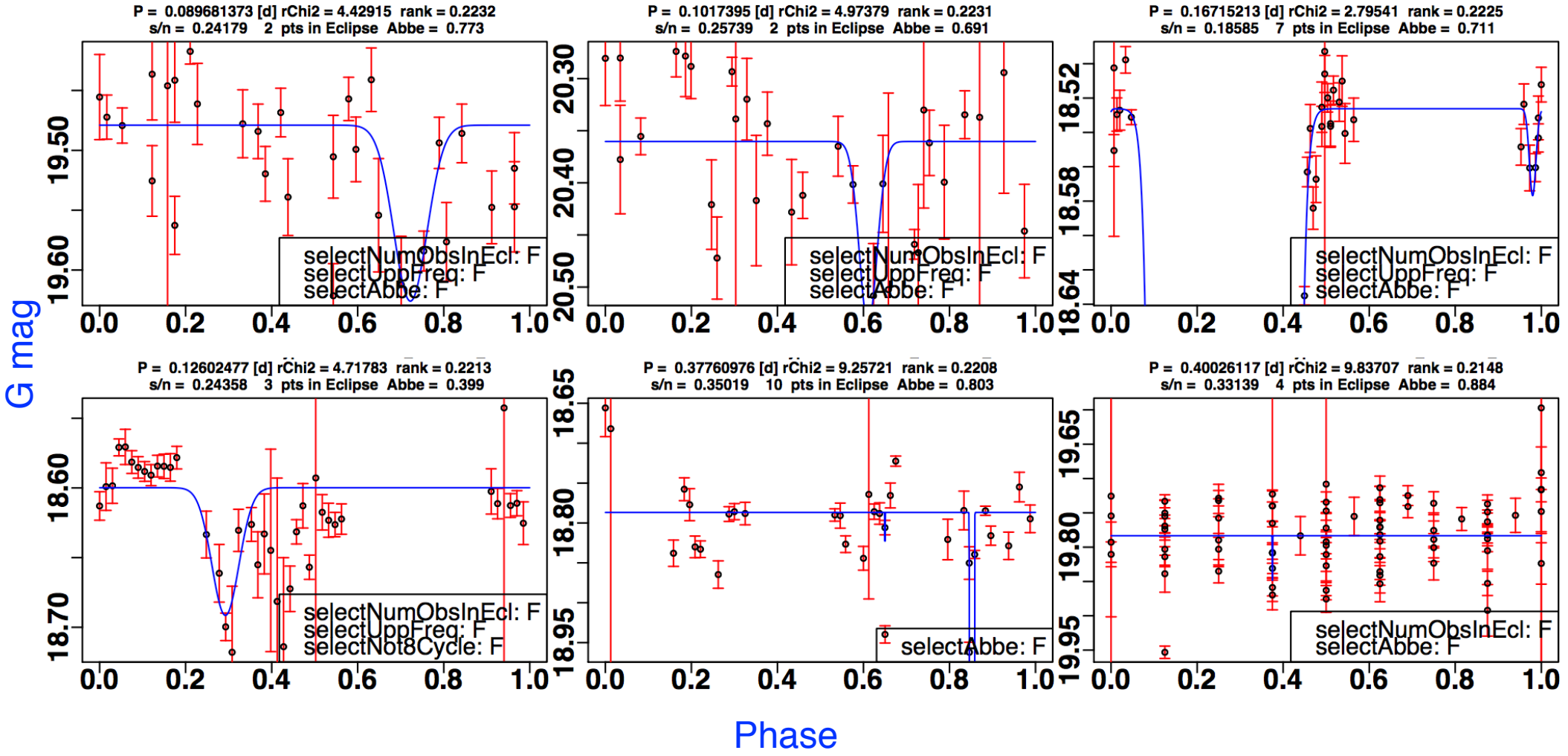
The solutions enable a ranking

Highest rank



Specific Object Studies: Eclipsing binaries

Lowest rank



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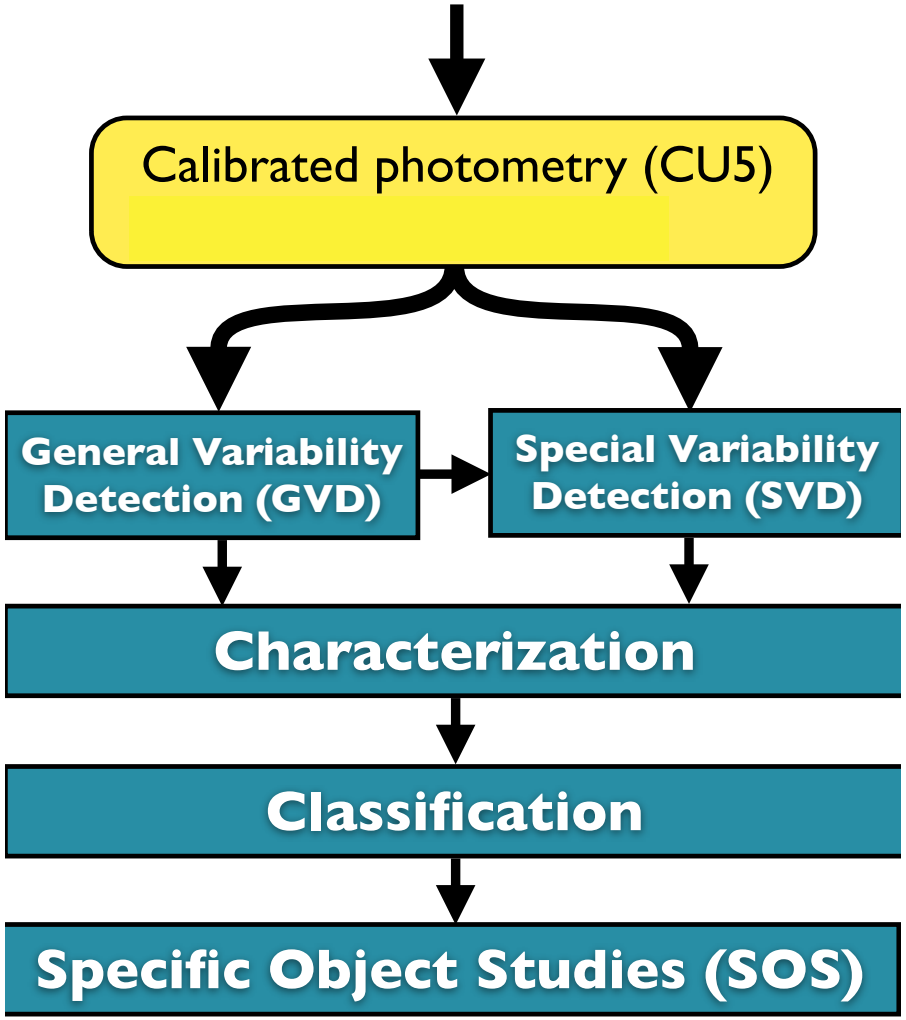
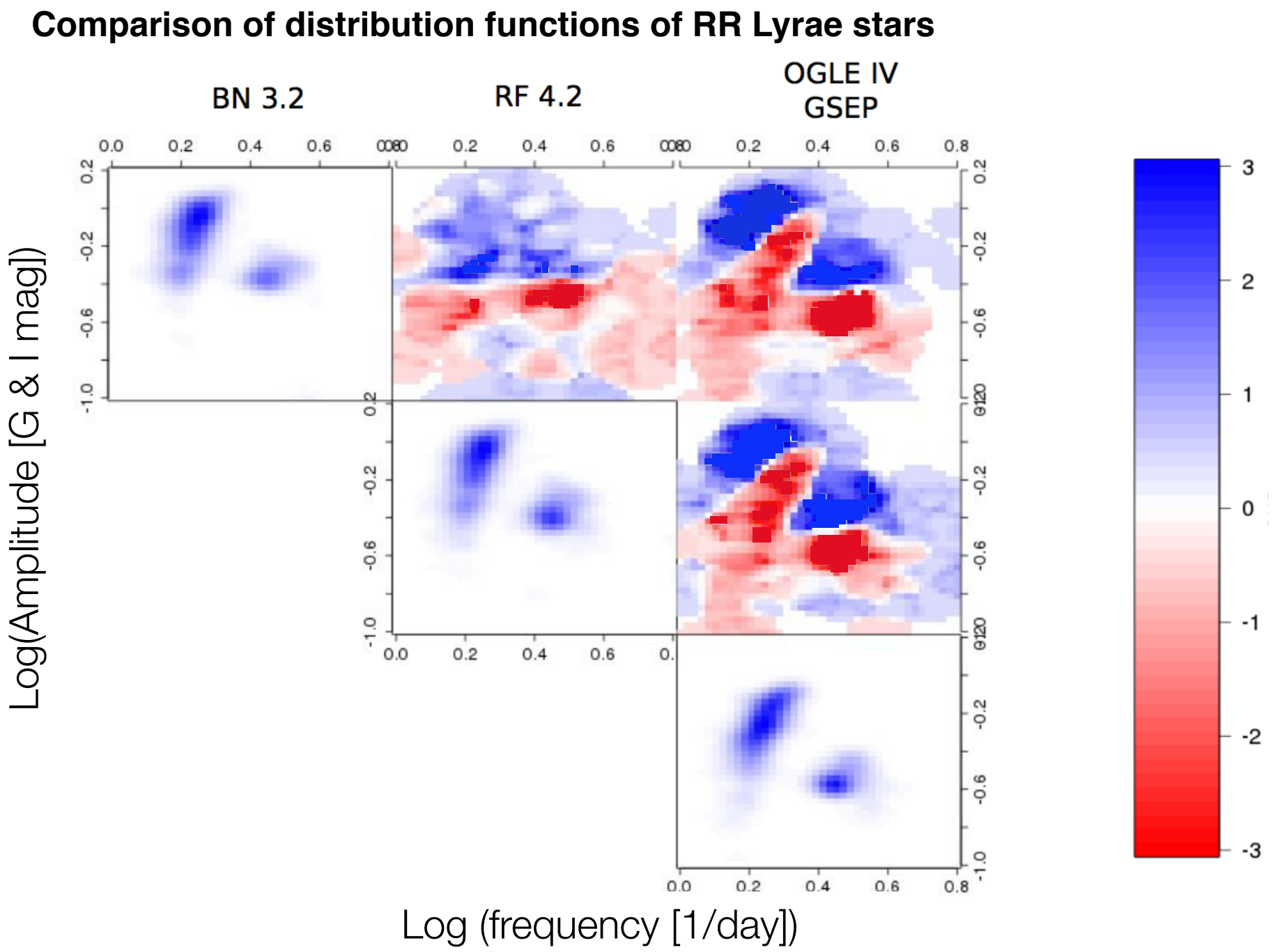


Global processing

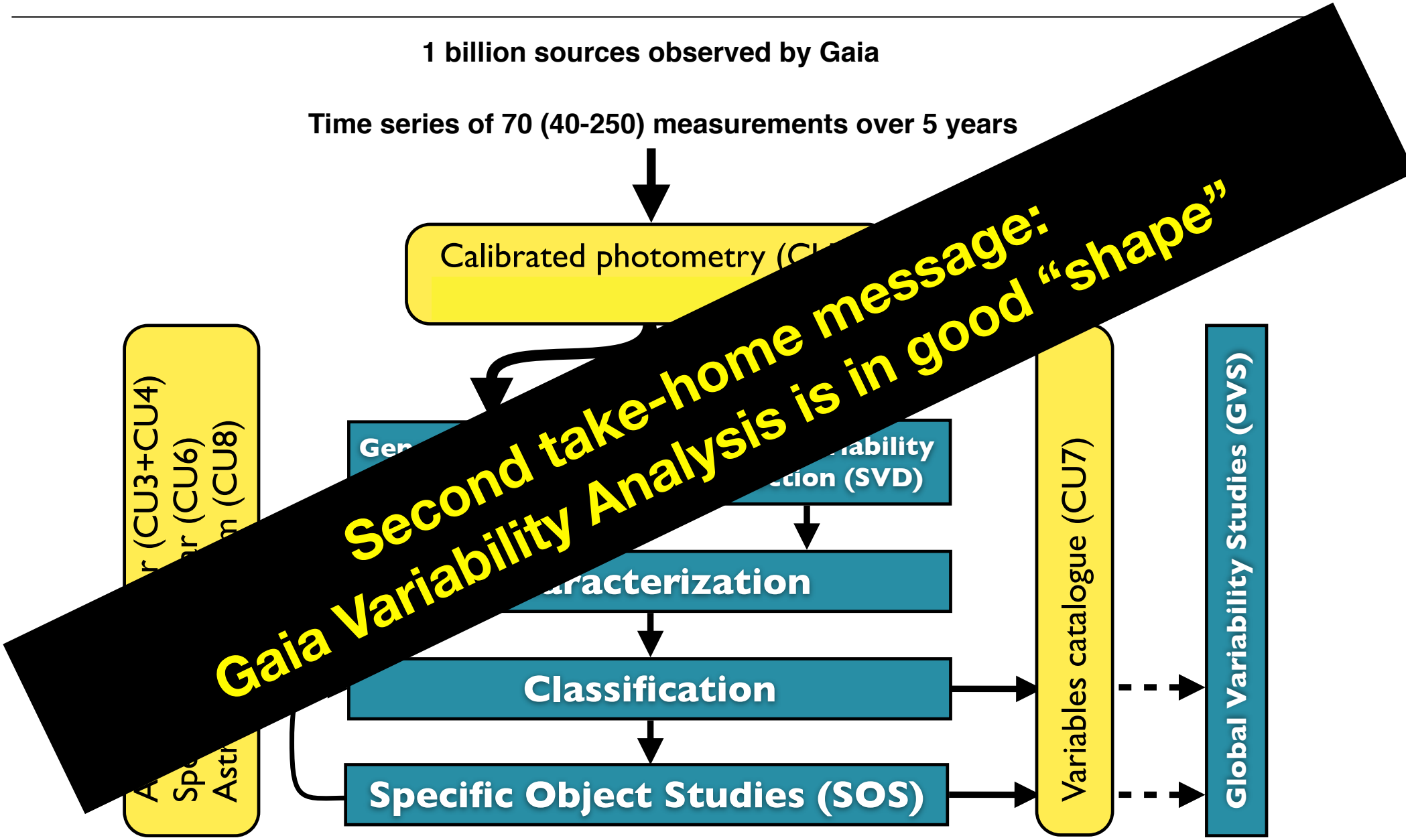
Per source processing

Global Variability studies:

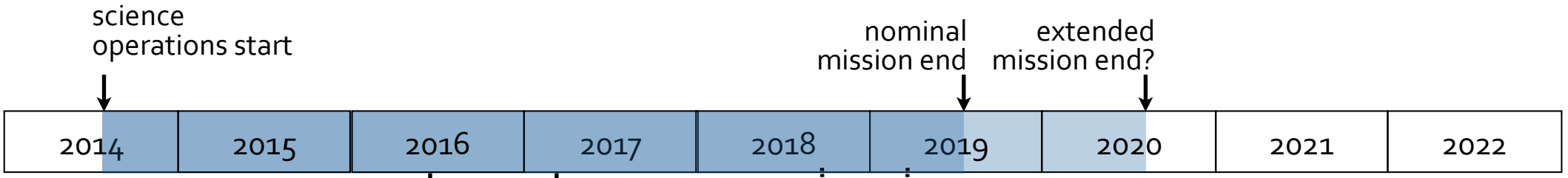


Courtesy of L. Sarro (modified by L.Eyer)

Gaia Variability Processing and Analysis



Release scenario



Release 1:

- **α and δ, mean G-magnitude**
- **Commissioning data**
- **100K proper motion stars (Hipparcos+Gaia)**

- **+ (?) Groups of variables: RR Lyrae stars + Cepheids + Short times scales**

Release 2:

- **5-parameter astrometric solutions for single star (parallax)**
- **Integrated BP/RP + Astrophysical parameters**
- **Mean V_{rad} (for non variable)**

Release 3:

- Mean V_{rad}
- 5-par astrometry
- Object classifications and Astrophysical Parameters
- **Orbital solution of binaries**
- **Mean RVS spectra**

Release 4:

- **Variable stars classification**
- **Non-single star catalogue**
- **Solar system objects**

Final release:

- everything !

Courtesy of B.Holl

Conclusions

Gaia is unique, also for variability analysis, be

- surveys the entire sky with on
- includes the "bright
- performs measurements with different inst
- ite parallaxes
- very distinctive sampling (complementary with respect to ground based surveys)

Final take-home message:
Gaia variable census will be exceptional!


Thank you for
your attention