International Workshop
«Accretion Processes in Cosmic Sources — II»

Machine Learning analysis of supernova light curves

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Saint Petersburg, 2018

Motivation

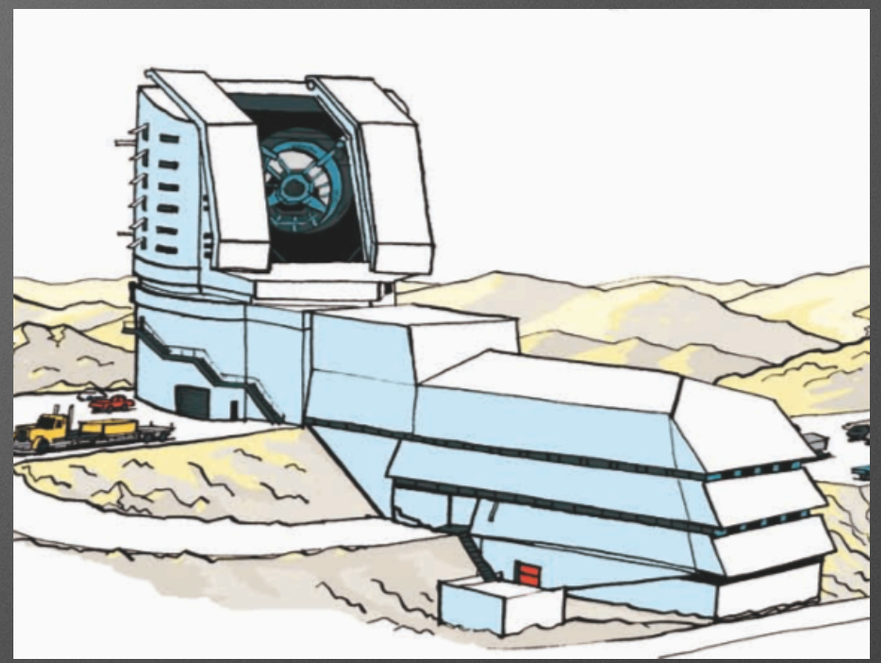
- Discovery of Uranus by William Herschel in 1781 while observing the parallax of the fixed stars near ζ Tauri

- Discovery of the cosmic microwave background radiation in 1965 by Arno Penzias and Robert Wilson, while testing Bell Labs horn antenna (Penzias & Wilson 1965)

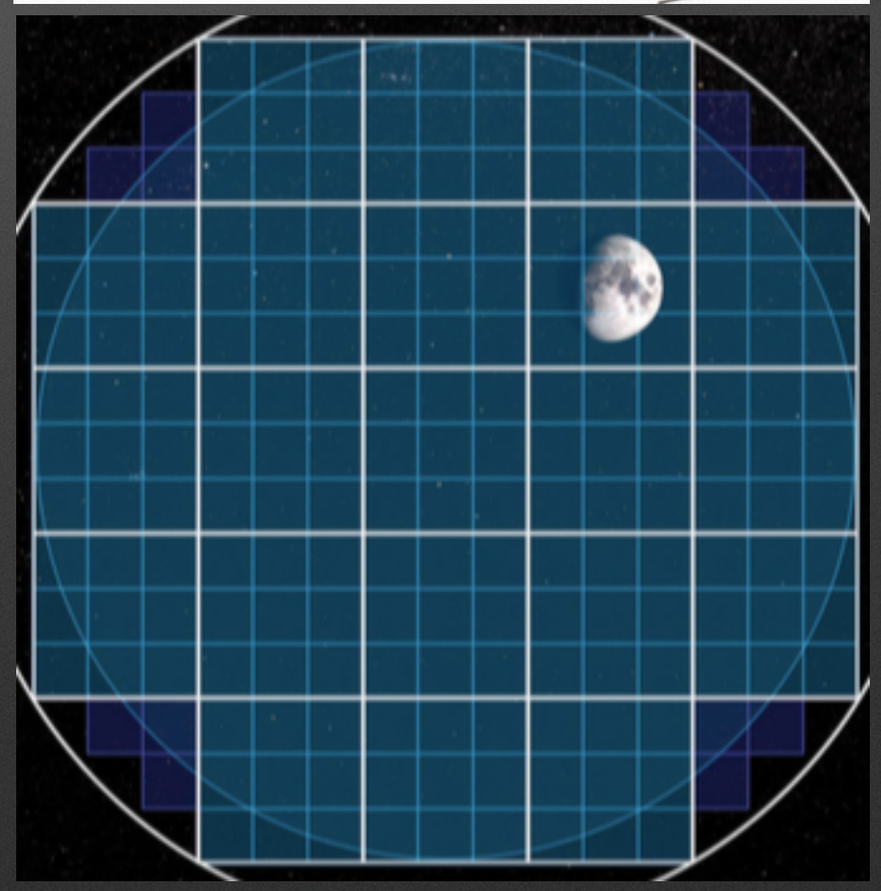
- Discovery of GRBs by Vela satellites in 1967 developed to detect gamma radiation pulses emitted by nuclear weapon tests

Motivation

LSST
10^7 SNe during its
10 years survey!



- 8.4-m mirror
- 3200 megapixel camera
- Each image the size of 40 full moons
- 15 Terabytes of data every night!
- 40 nights of LSST — entire Google database



«If you have a synoptic telescope with an aperture D you have to construct a spectral telescope with an aperture 10D»

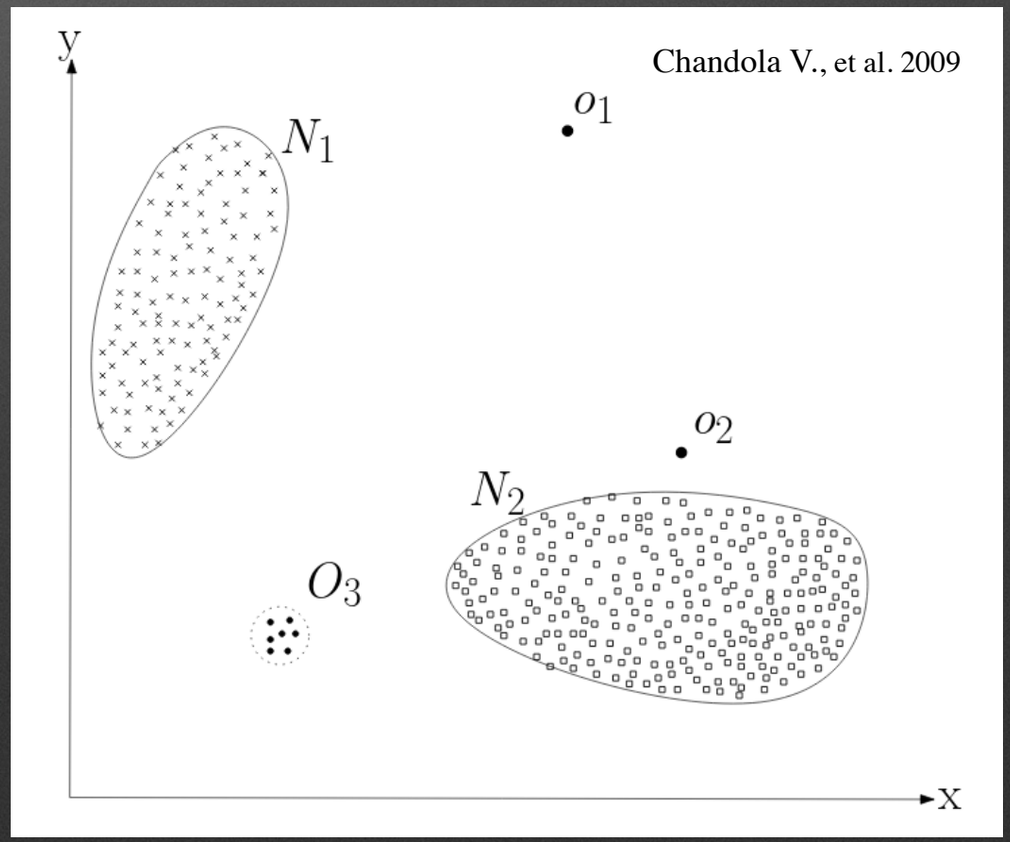
— V. Lipunov (PI of MASTER project)

Big data in astronomy means more photometry

Machine Learning

Anomaly detection

- to detect (a lot of ML algorithms; Chandola et al. 2009, Kou et al. 2004)
- to study (matching with available catalogs, theoretical modelling, spectra?)



Anomaly detection

ML methods

supervised

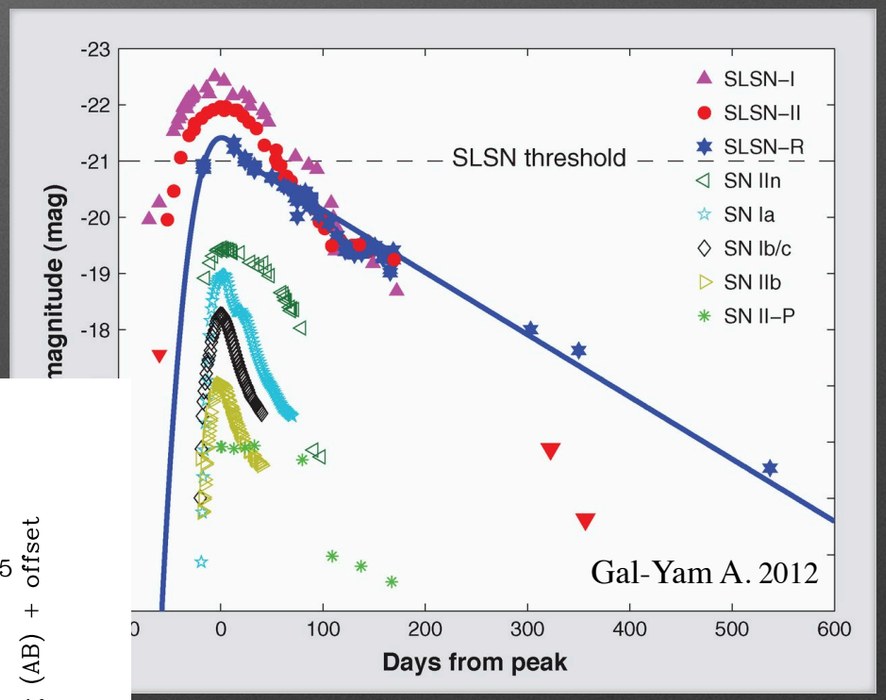
- classification problem

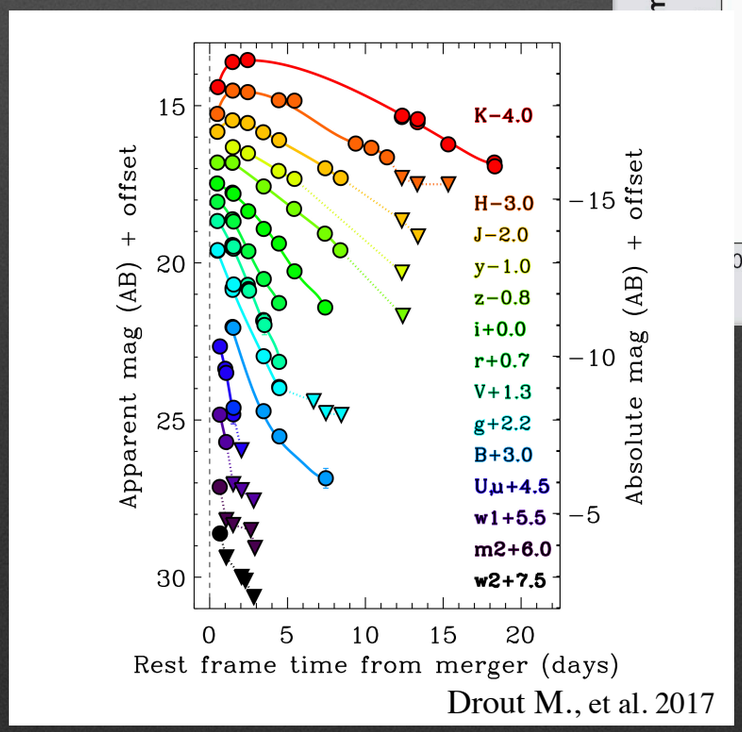
unsupervised

- statistical methods
- proximity based methods
- clustering methods

Anomaly detection

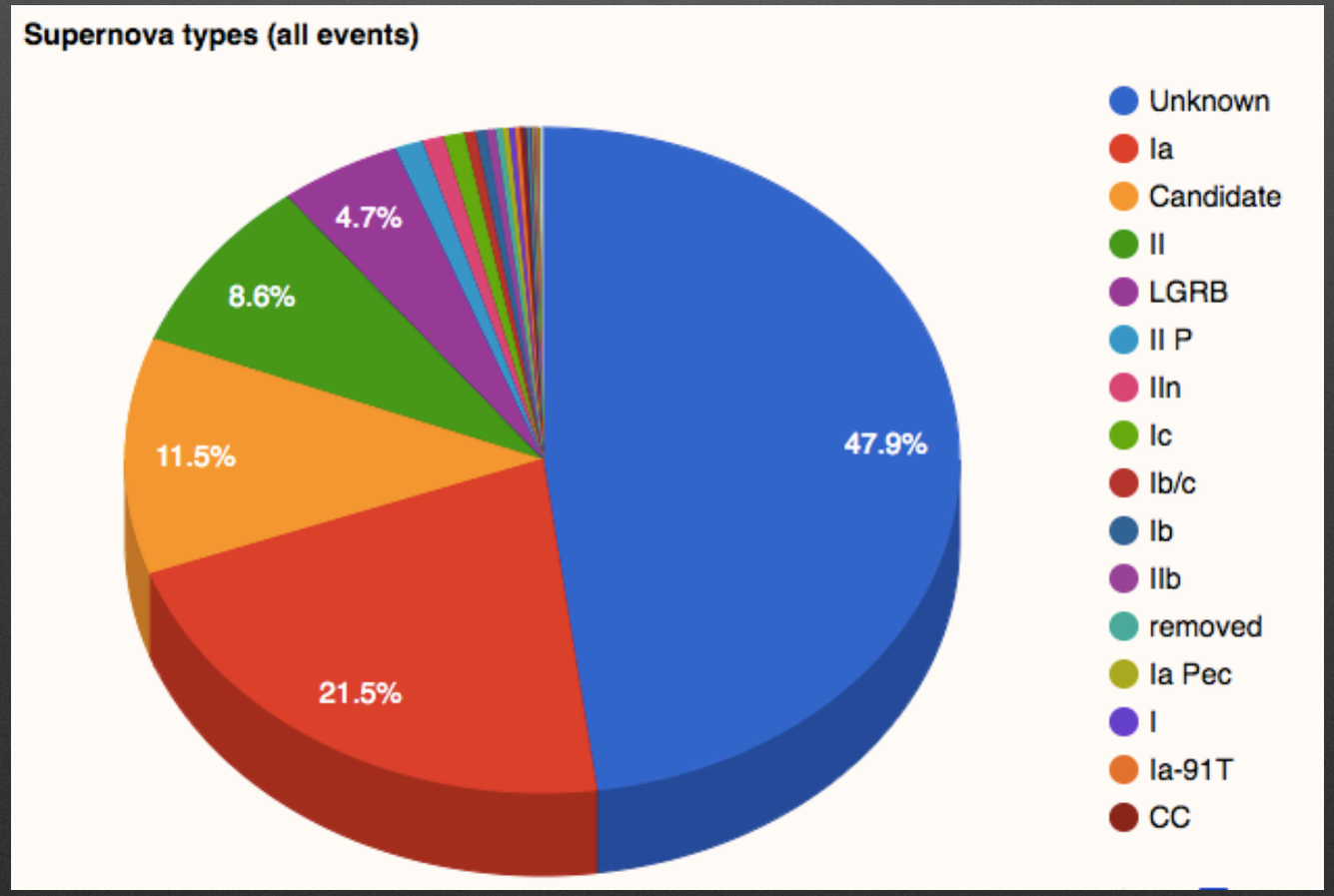
- rare class of objects (super-luminous supernovae, SN-GRBs)
- misclassified objects
- kilonovae
- new physics





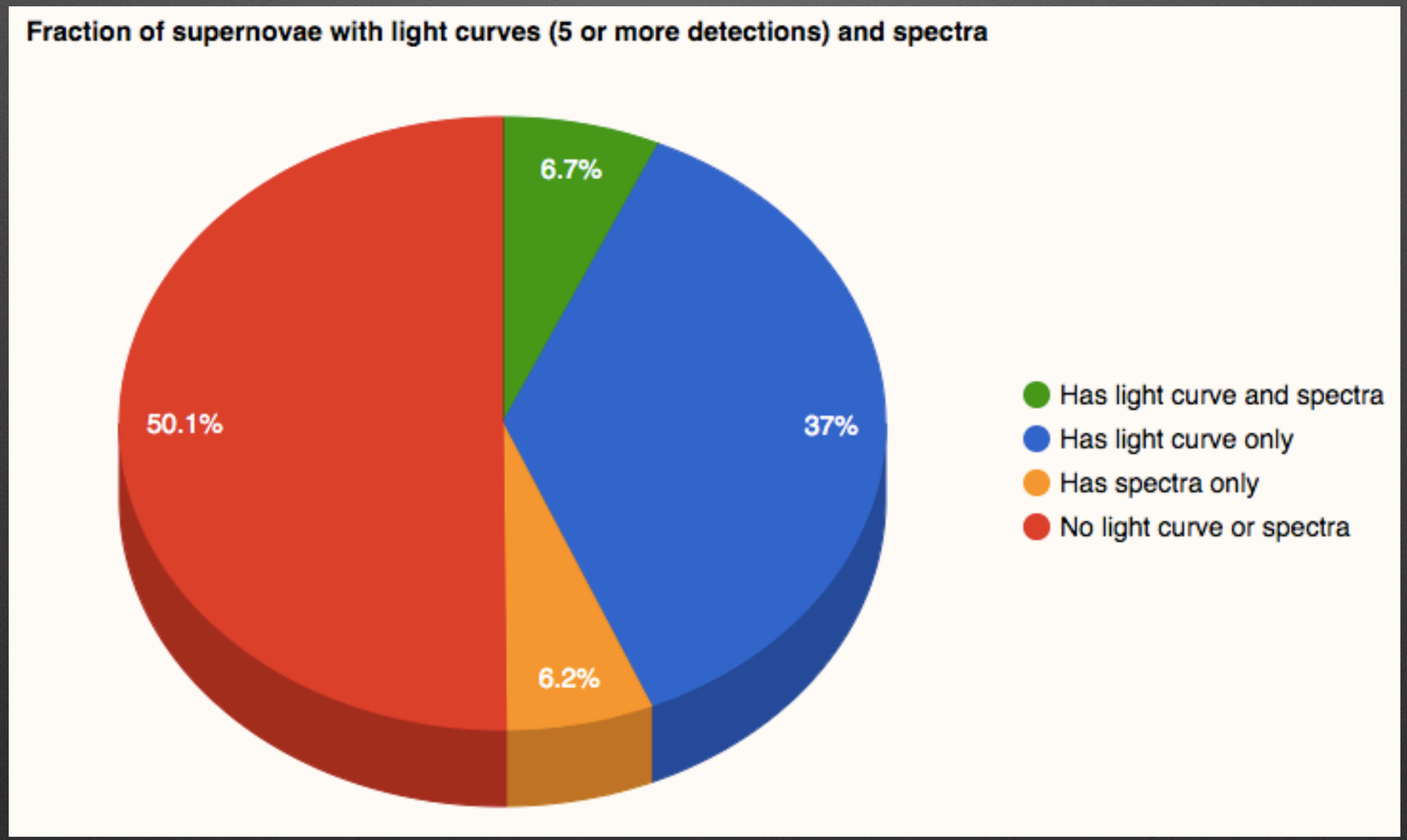
Data

- The Open Supernova Catalog (sne.space, Guillochon, J. et al. 2017)
- 50,884 supernovae
- 591,090 individual photometric detections
- 20,097 individual spectra



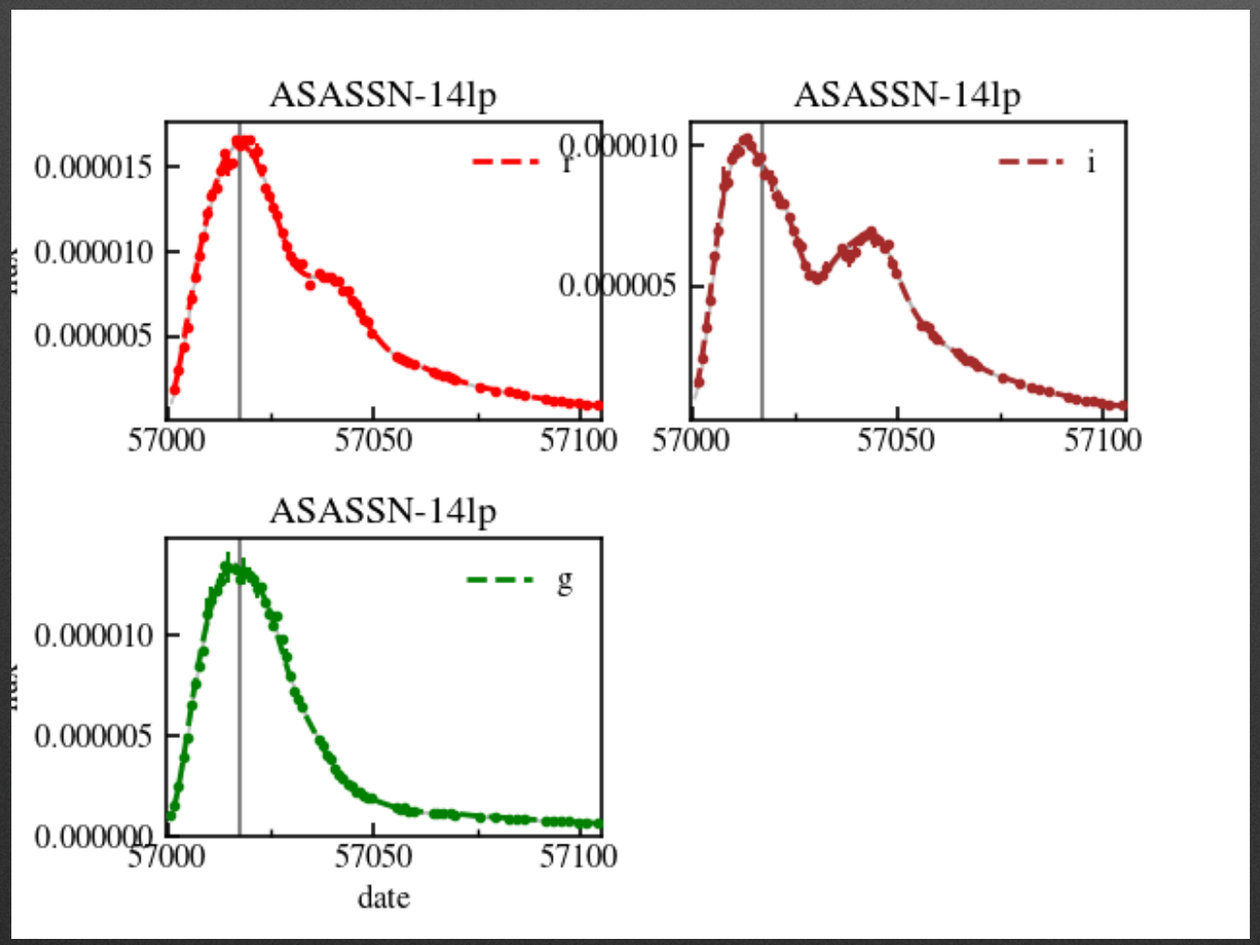
Data

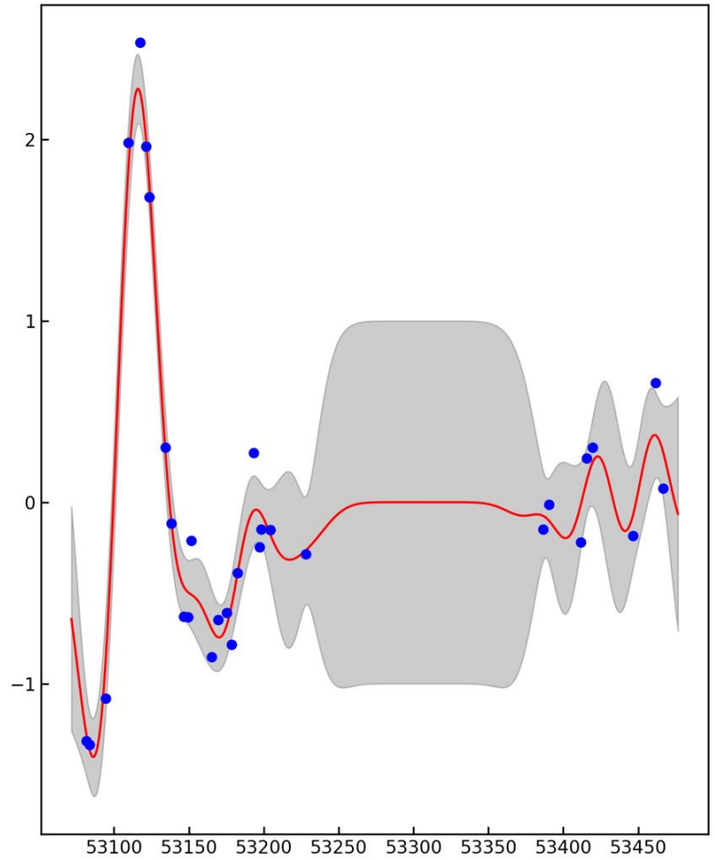
- 3 filters (g r i)
- at least 3 photometrical points per filter



Light curve interpolation

- Gaussian processes
- at least 3 photometrical points per filter
- no errors, wrong points, upper limits from small telescopes, big gaps

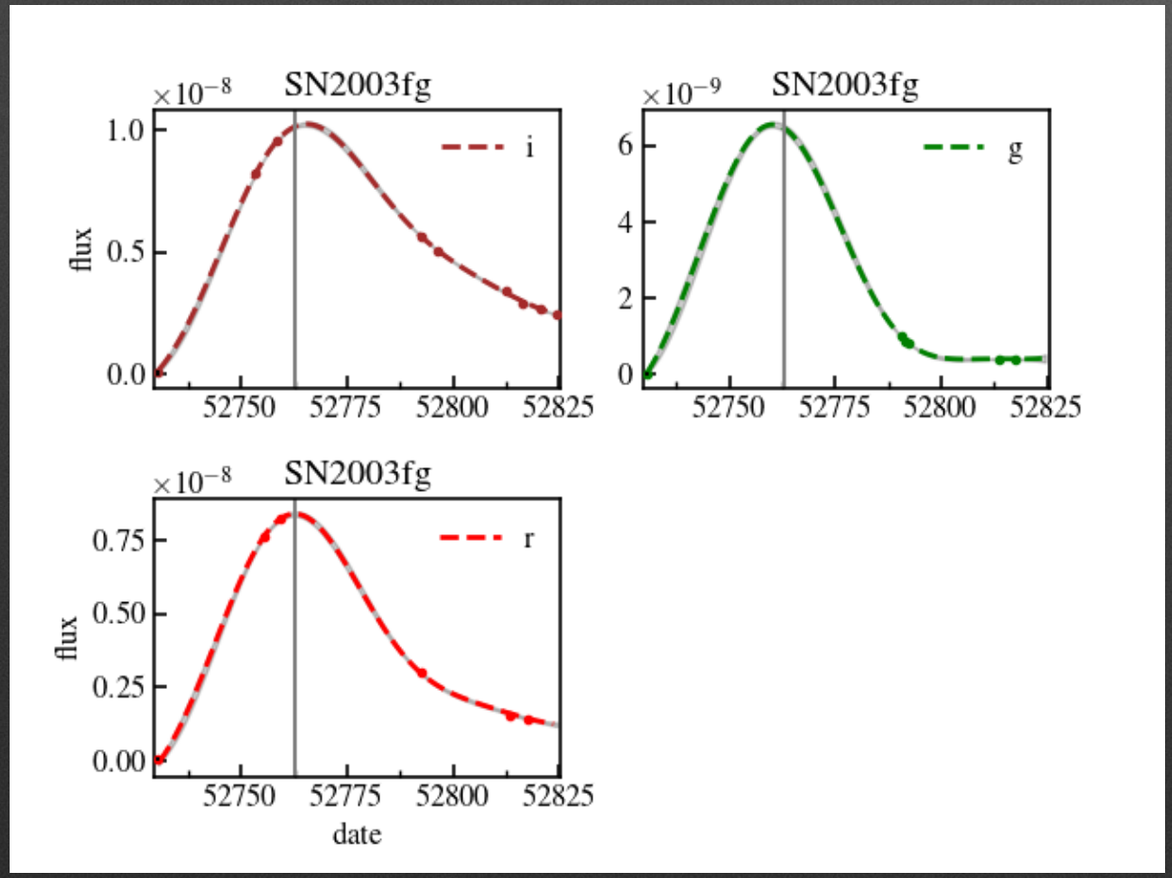


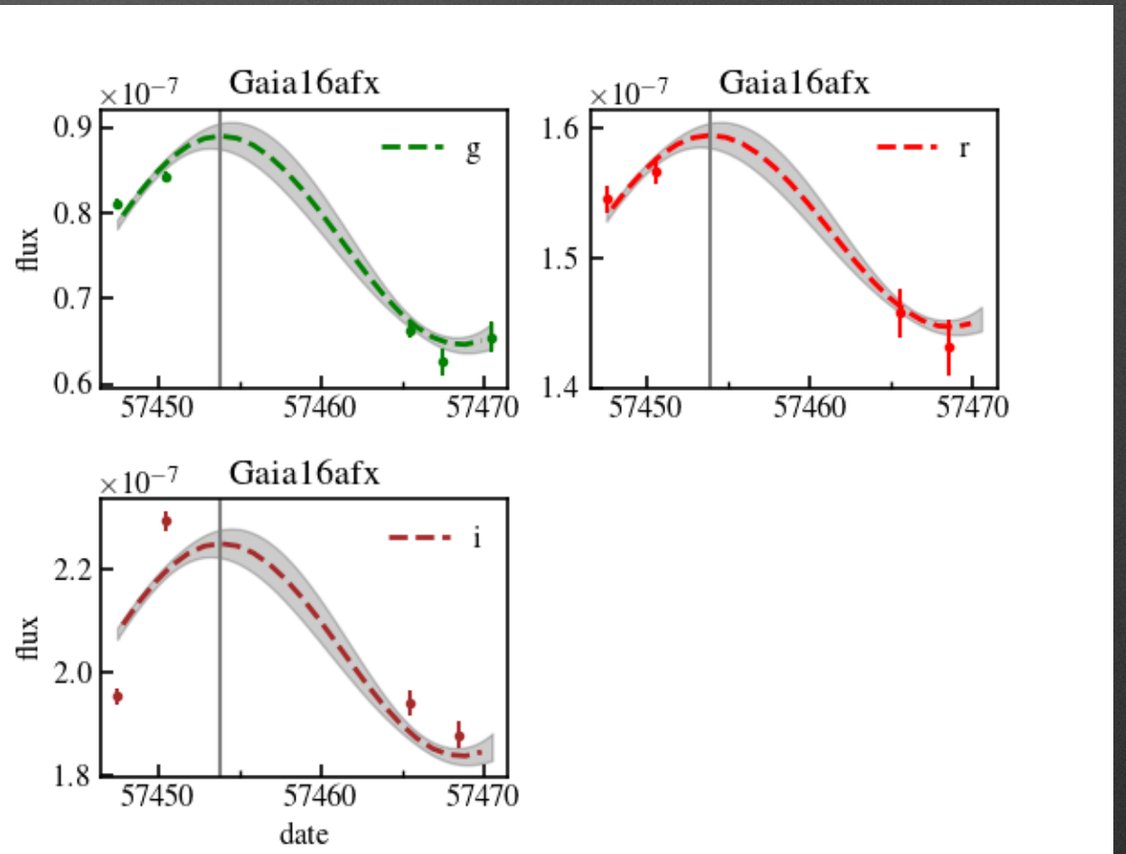


Light curve interpolation

gp-multistate-kernel

https://gp-multistate-kernel.readthedocs.io





Results

Final sample (2016 objects)

Dimensionality Reduction

Yes

No

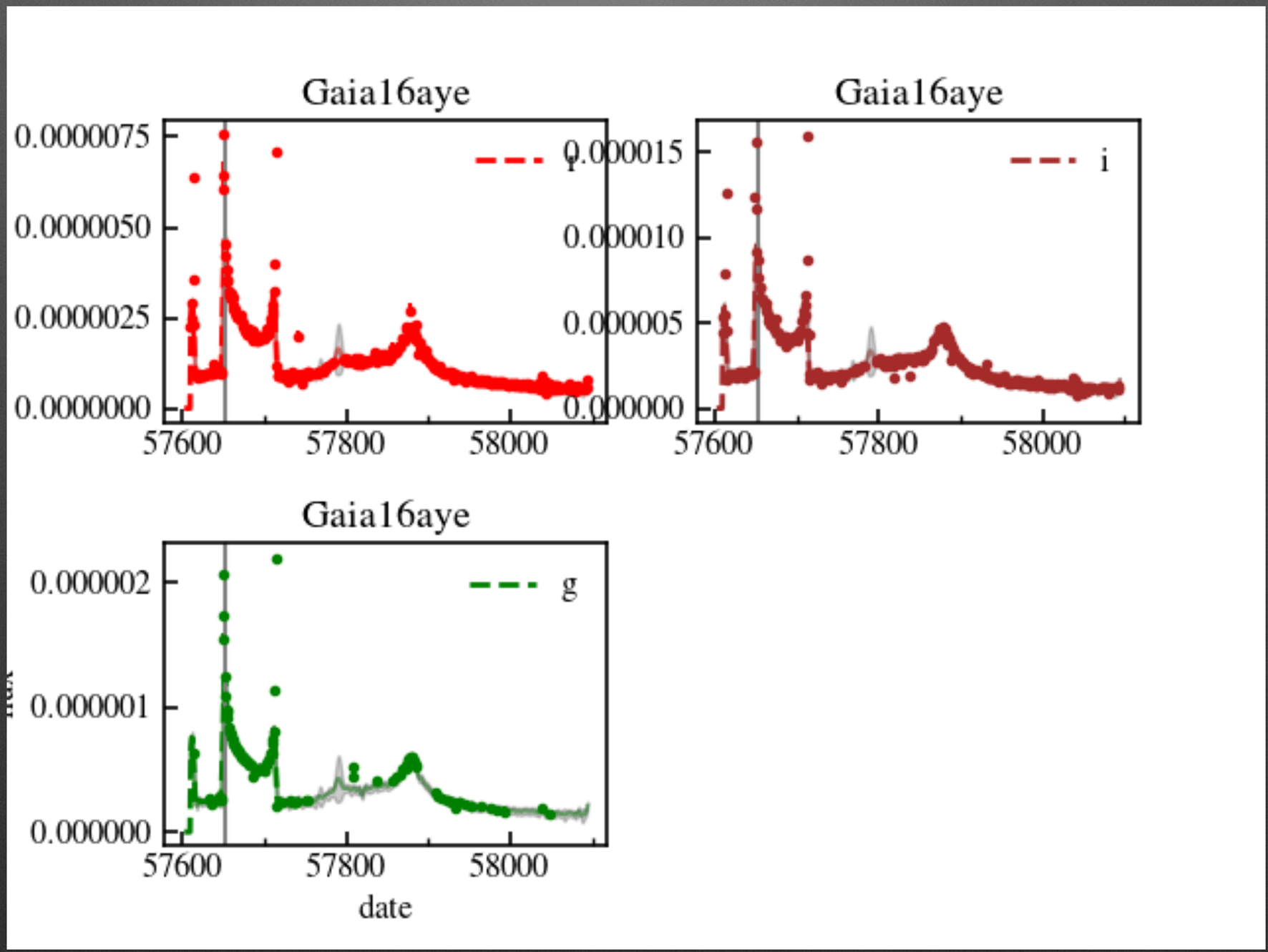
2D … 9D ISOFOREST LC LC+ker

Results

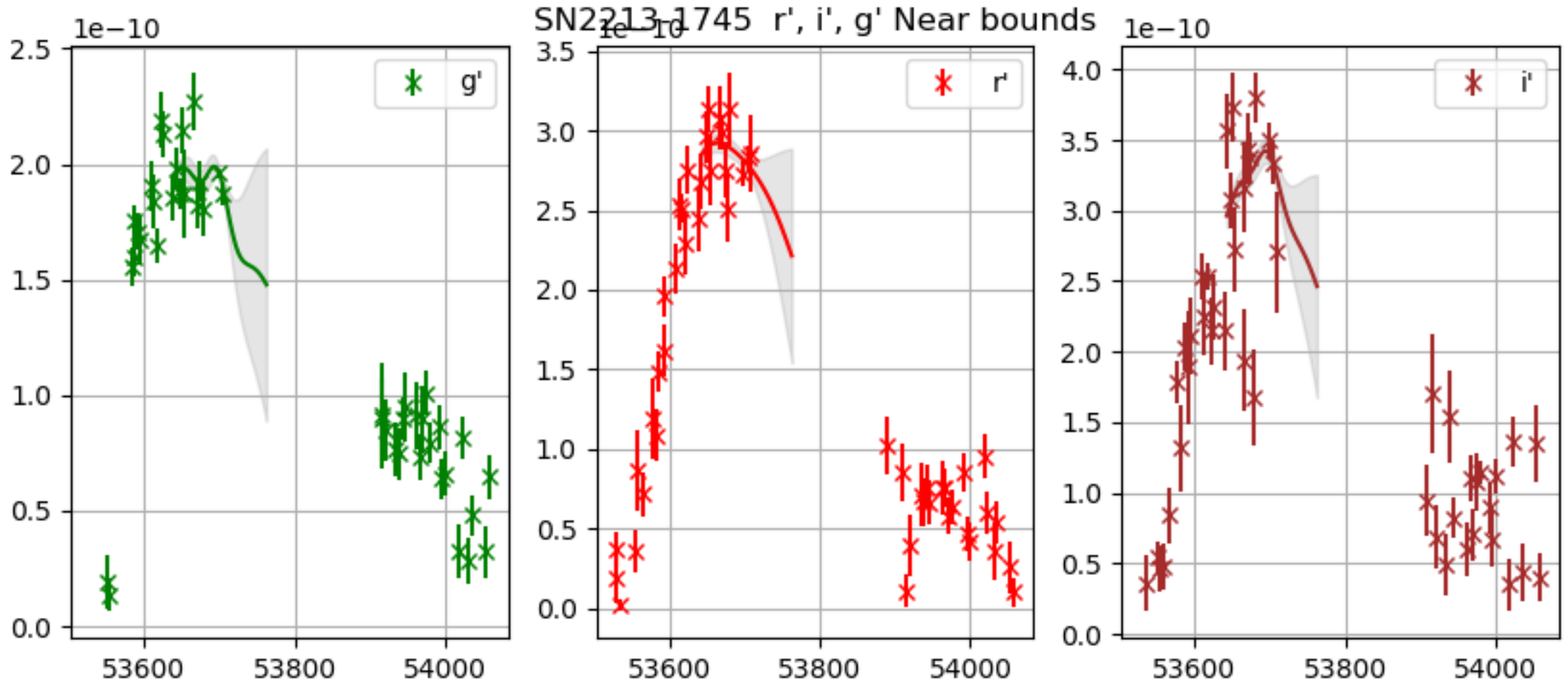
105 anomalies:

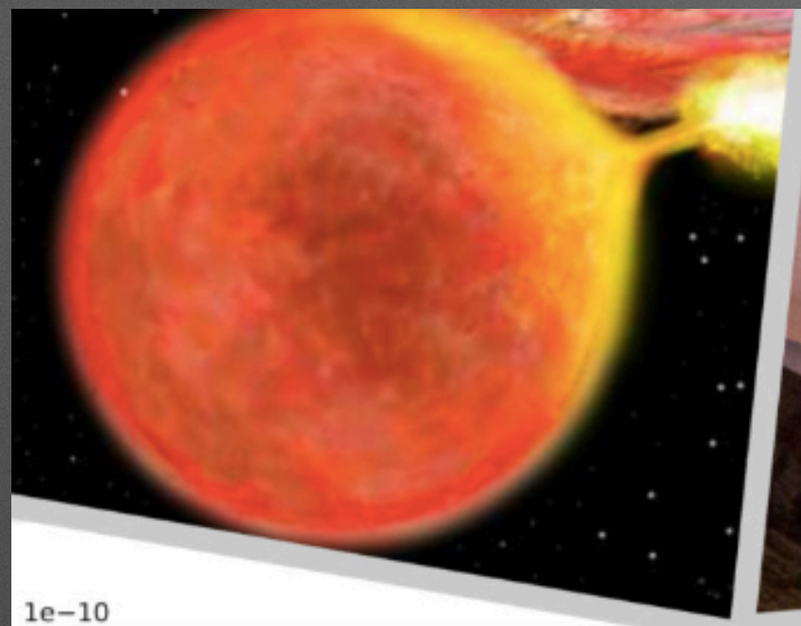
- still some data problems
- 2 supernovae of 91-T
- 1 microlensing event
- 1 super-luminous supernova
- AGN
- the rest are still being studied (mainly Type Ia)

Binary microlensing event

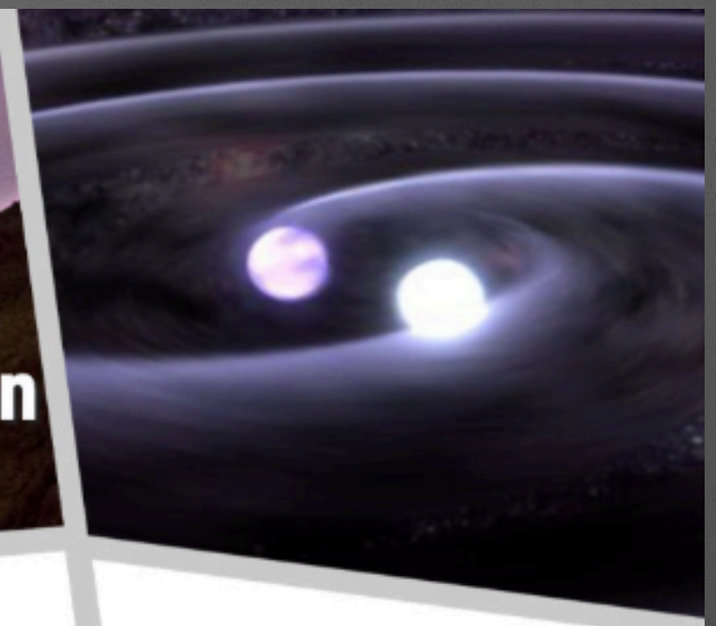


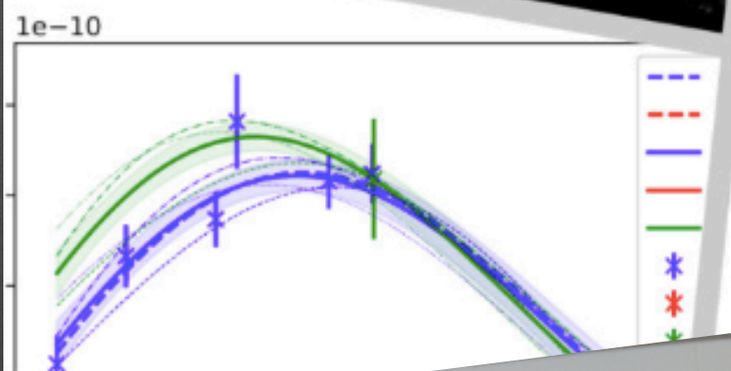
SLSN

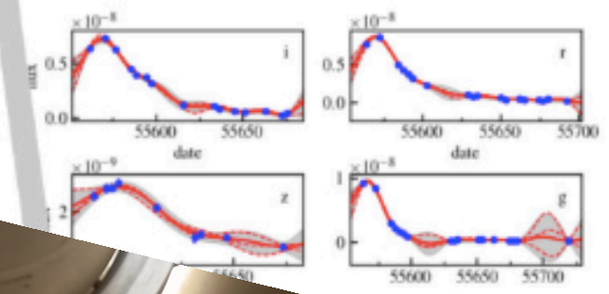




Workshop
Supernova Anomaly Detection
Moscow 4-8 June 2018







pruzhinskaya.com/snad/2018

Conclusions

- We produced a sample of interpolated LCs of objects from The Open Supernova Catalog (~4000 objects)
- gp-multistate-kernel was developed to introduce the correlations between processes in several filters
- Few methods of ML for novelty detection were examined (the code is available via GitHub)
- Around 100 anomalies are found and are being studied

Thanks!