

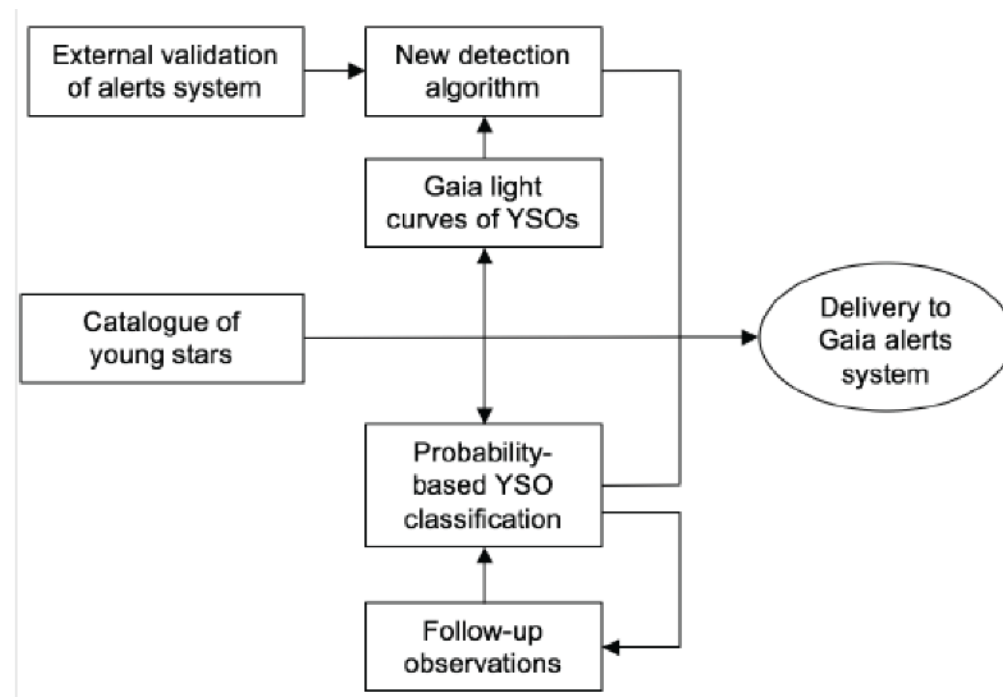
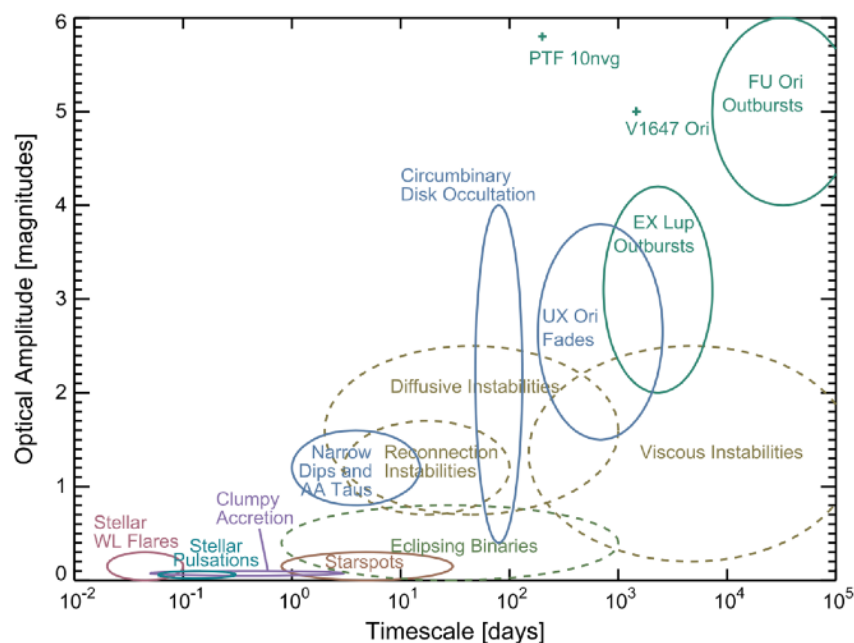
PyTorch classification of astronomical light curves

G. Marton on behalf of the Konkoly ESA Gaia & the Machine Learning Groups



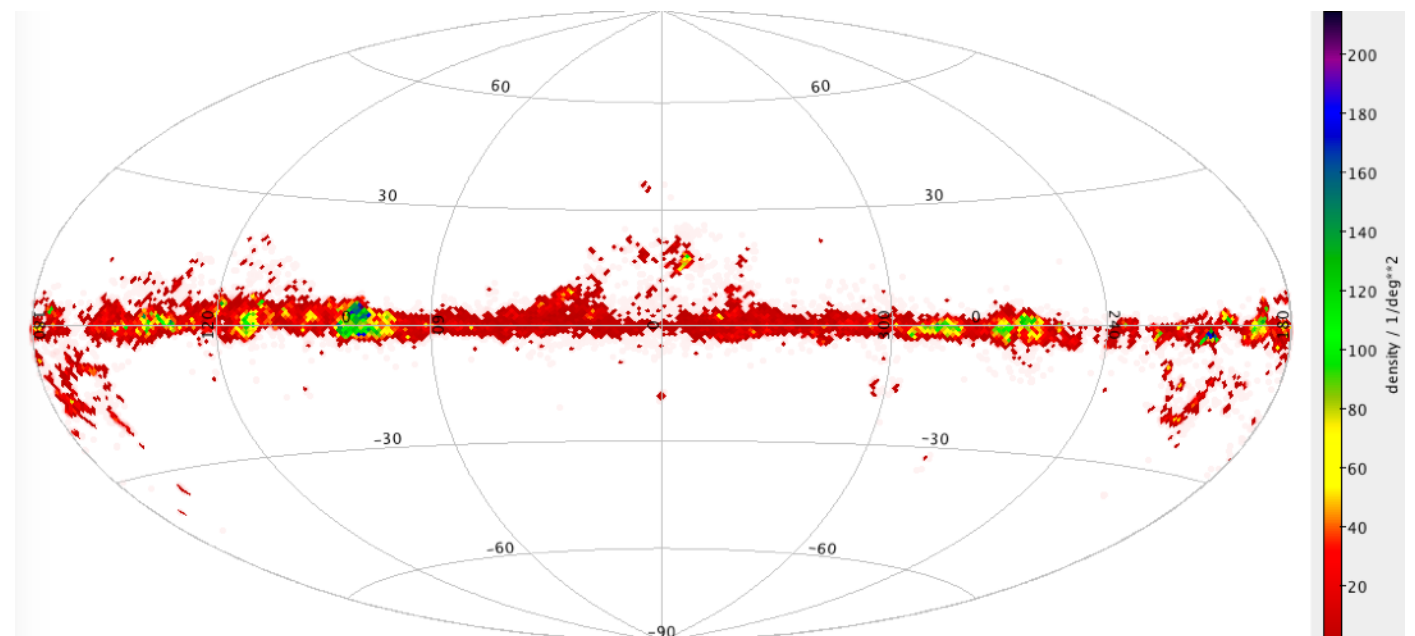
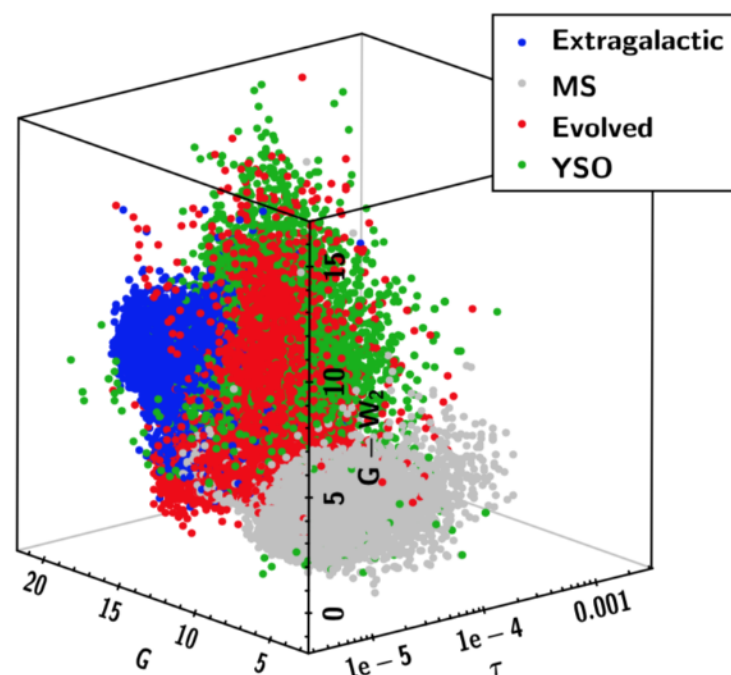
The Konkoly ESA Gaia project

- Duration: 2017 Sep - 2019 May (ESA tender)
- Likely extension for 2020-2021
- Goal: increase the number of young stellar object (YSO) alerts
- Special interest: young outbursting stars (FUors, EXors)
- Optical follow-ups at Piszkestető Observatory

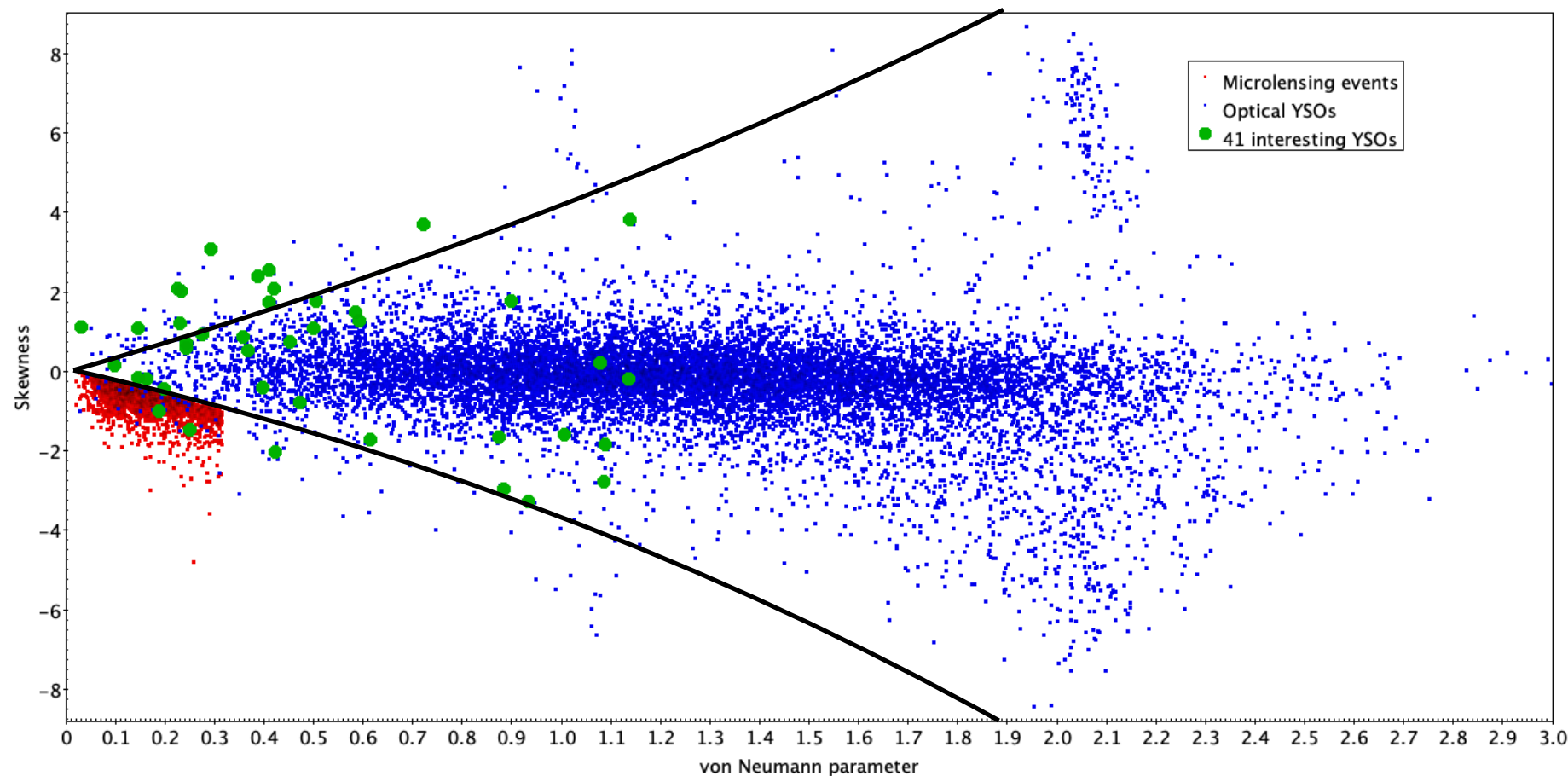
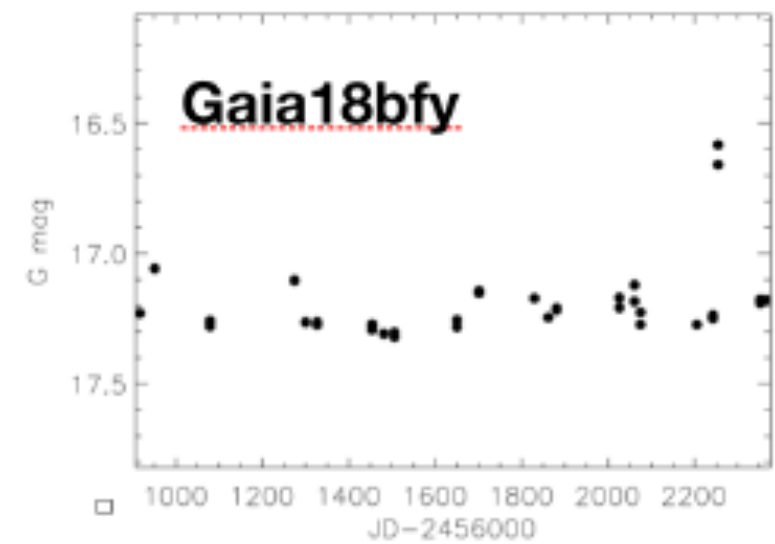
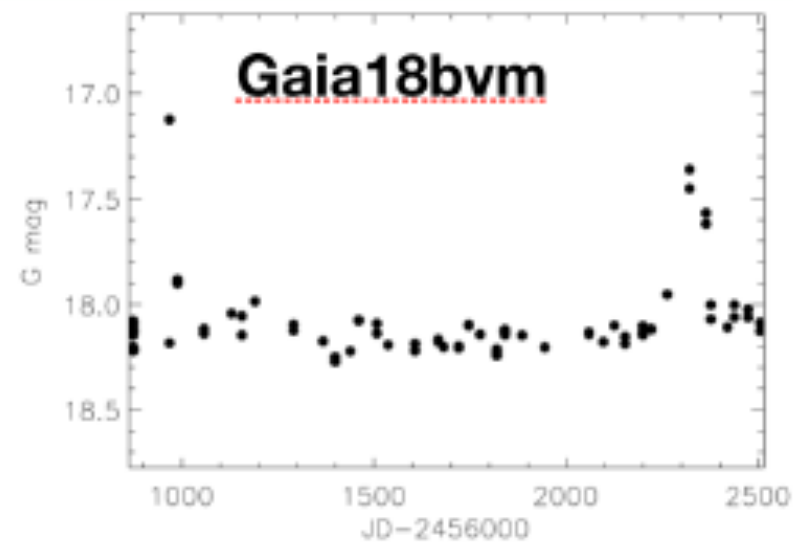
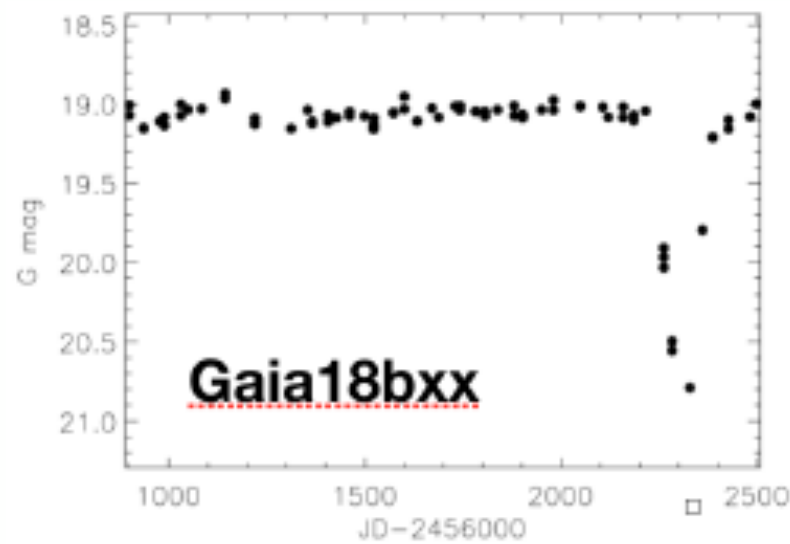


YSOs in the Gaia DR2

- Classification with machine learning
- Gaia DR2 + 2MASS + AllWISE + Planck data: ~100 million sources
- 4 main types: extragalactic, MS, evolved, YSO
- Several methods: RF, kNN, NN, SVM, nB
- >1 million YSO candidates



Gaia LCs of interesting YSOs

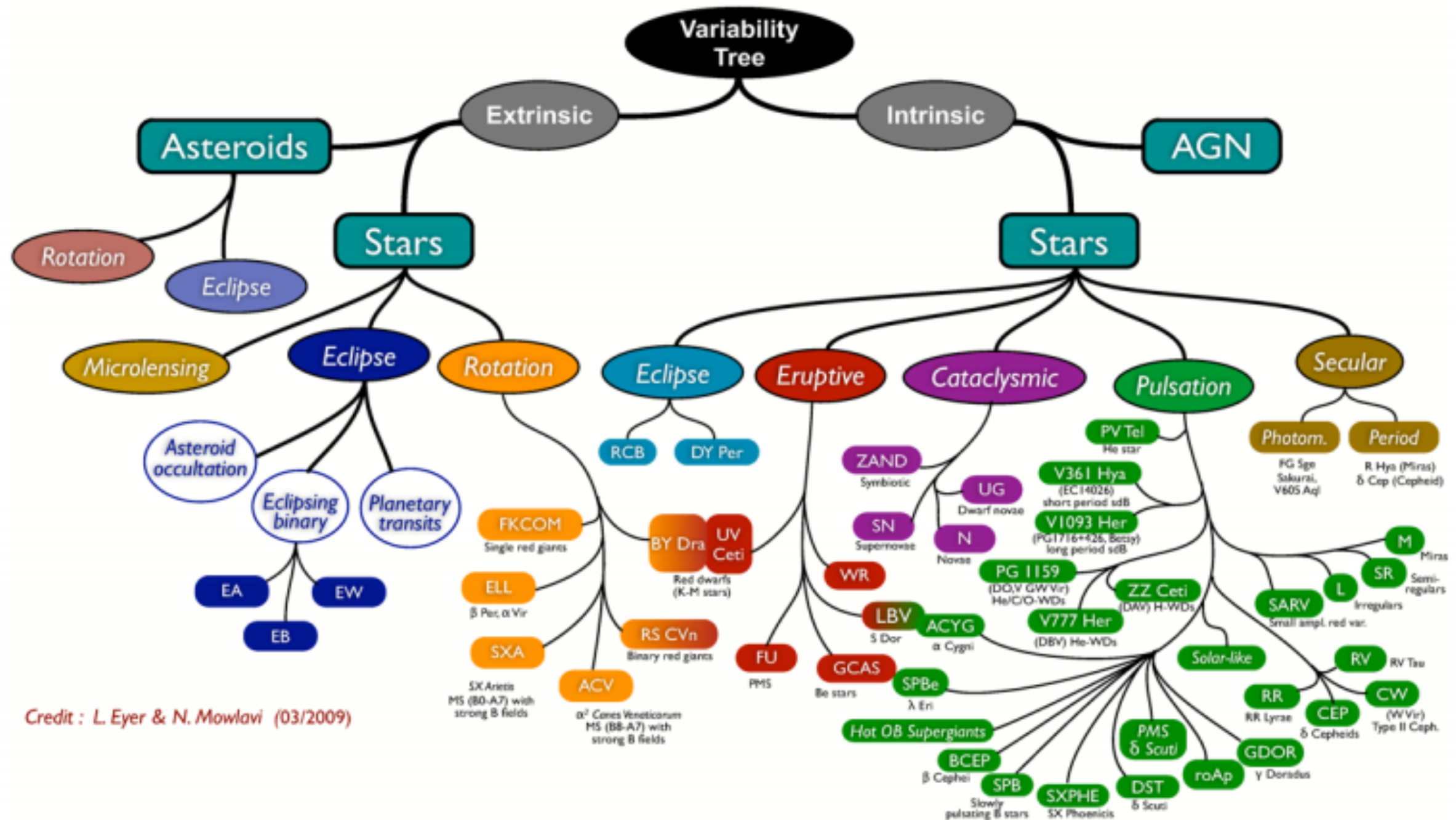


Year	All	YSO	YSO [%]
2014	104	0	0.00
2015	169	1	0.59
2016	1523	17	1.12
2017	2323	17	0.73
2018	2730	57	2.09
2019	3553	95	2.67

Time series analysis & light curve classification

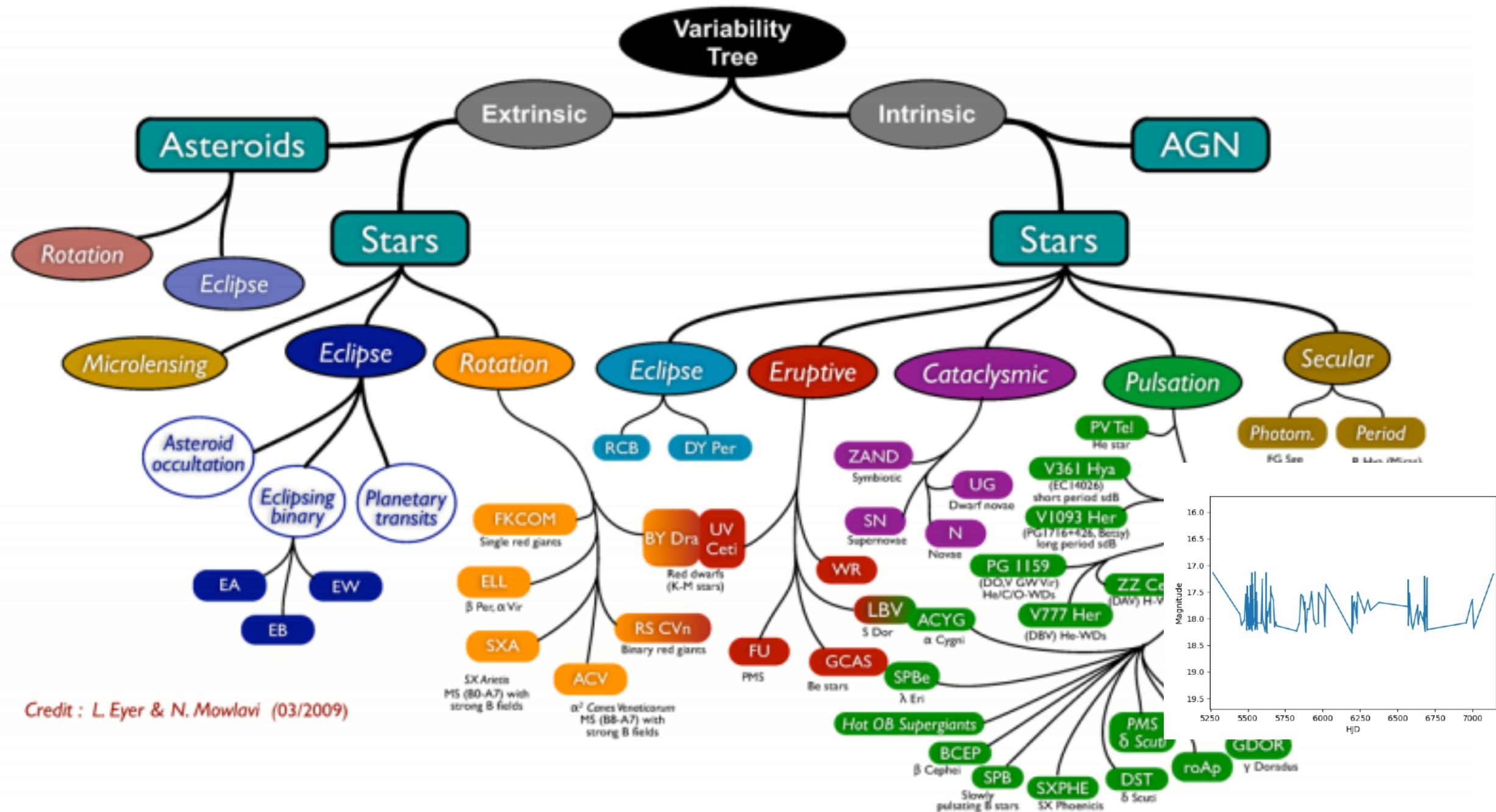
- Billions of light curves
 - Gaia
 - Zwicky Transient Factory
 - Palomar Transient Factory
 - Catalina Real-time Transient Survey
 - ATLAS
 - Kepler
 - TESS
 - ASAS-SN
 - WISE
 - ...
- Period finding
 - Lomb-Scargle
- Variability
 - Von Neumann
 - Stetson K index
- Morphology
 - Skewness
 - Kurtosis
 - Ratio of magnitudes brighter/fainter than mean
 - ...
- Trends
- Model fitting (Fourier)

Time series analysis & light curve classification

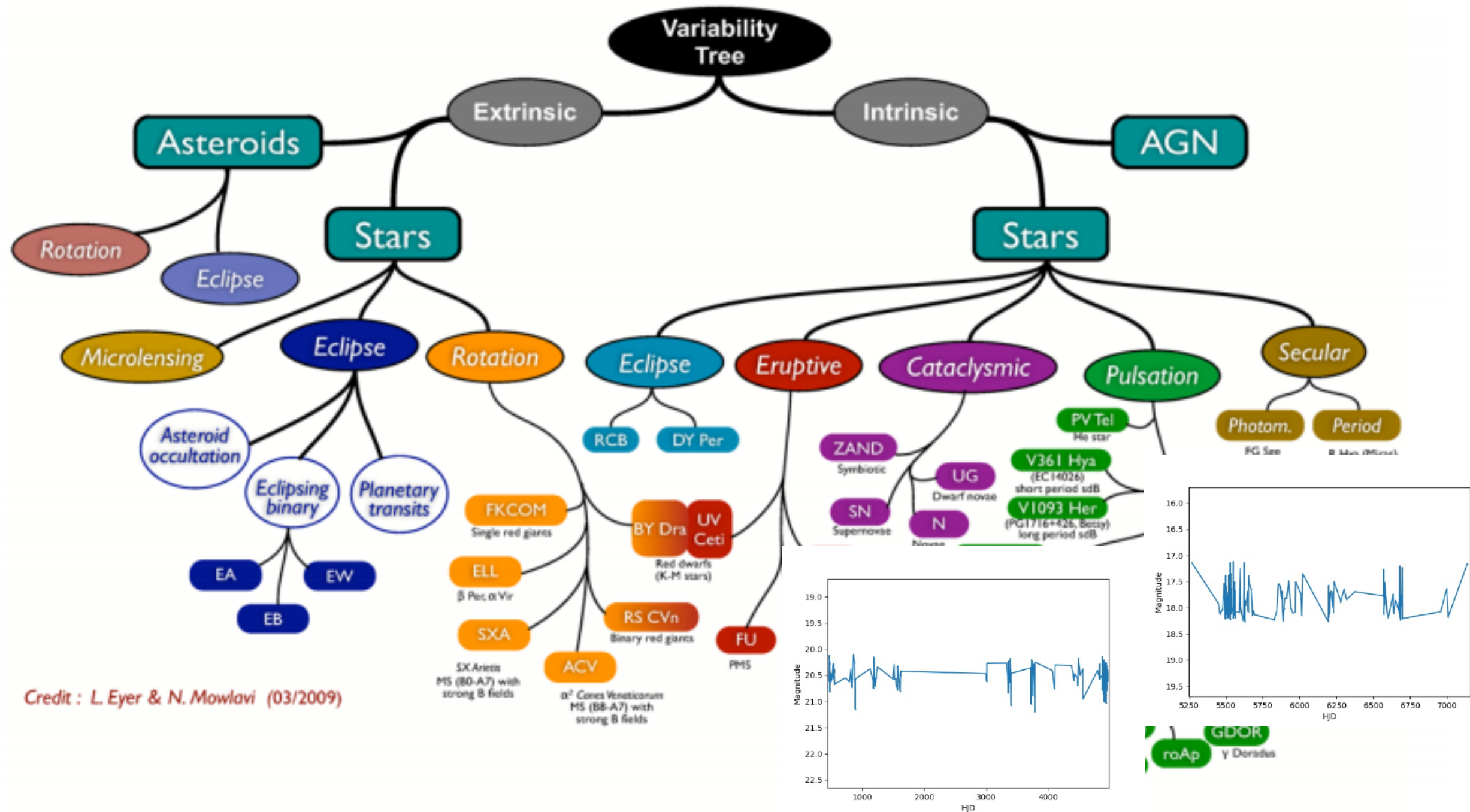


Credit : L. Eyer & N. Mowlavi (03/2009)

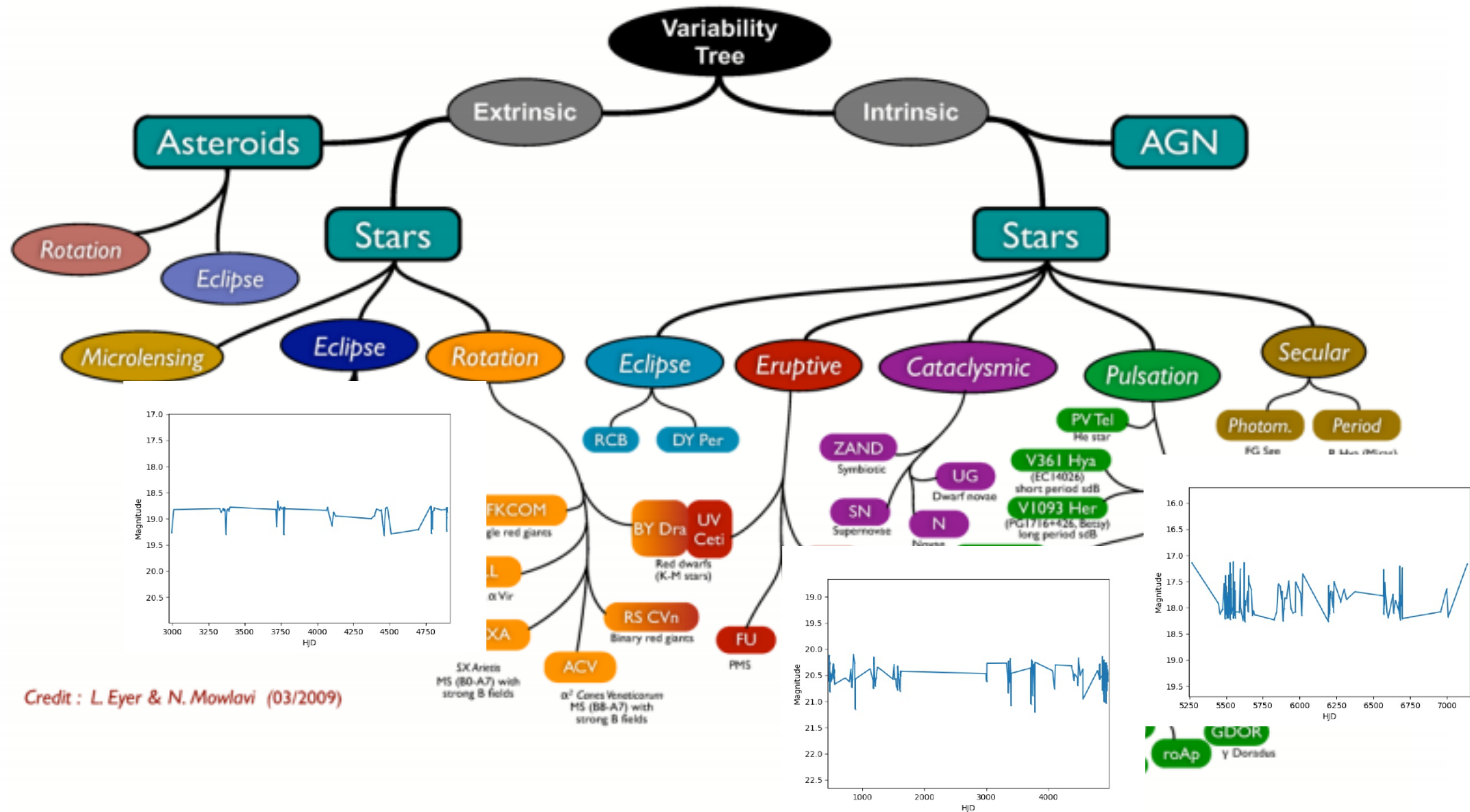
Time series analysis & light curve classification



Time series analysis & light curve classification



Time series analysis & light curve classification



The big Facebook shut down

 Image may contain: night, sky and outdoor



 Image may contain: flower



 Image may contain: tree, sky, outdoor and nature



 Image may contain: sky, cloud and outdoor



 Image may contain: one or more people, people sitting, shoes and indoor

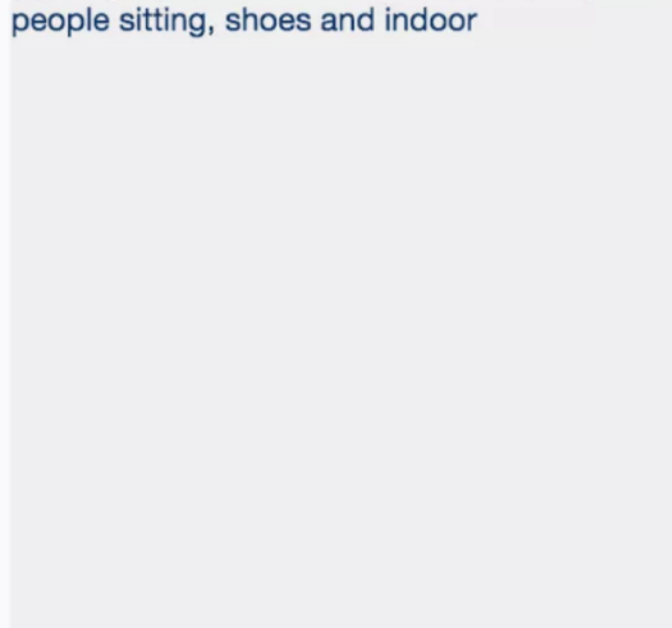


 Image may contain: people standing



 Image may contain: 1 person, outdoor



 Image may contain: 1 person, sky, outdoor



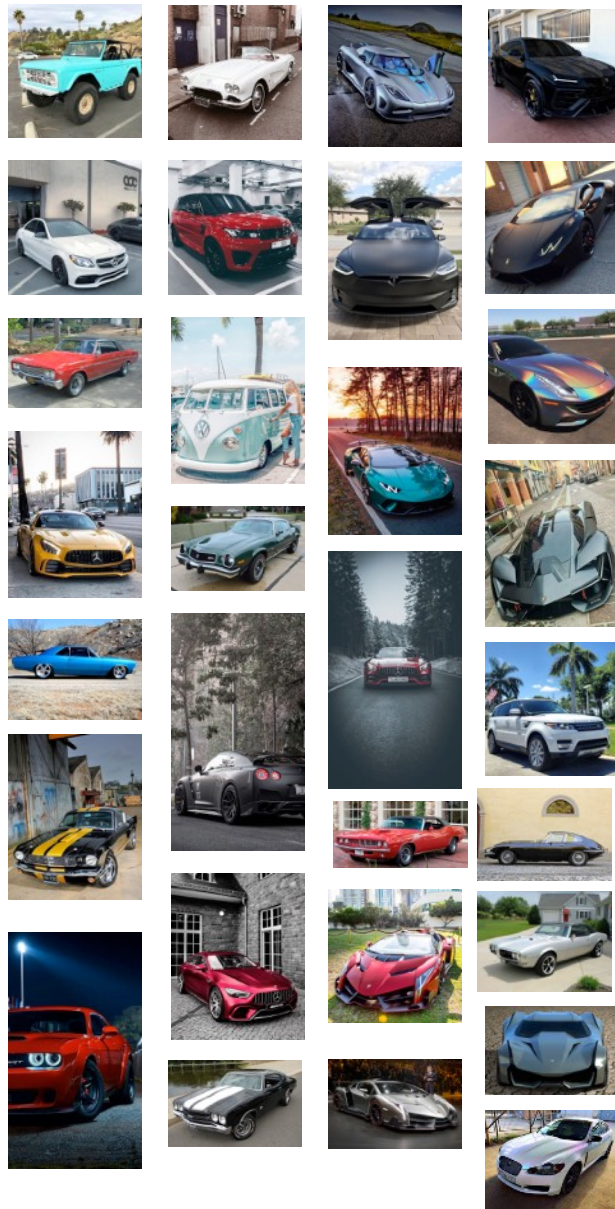
 Image may contain: 2 people, people



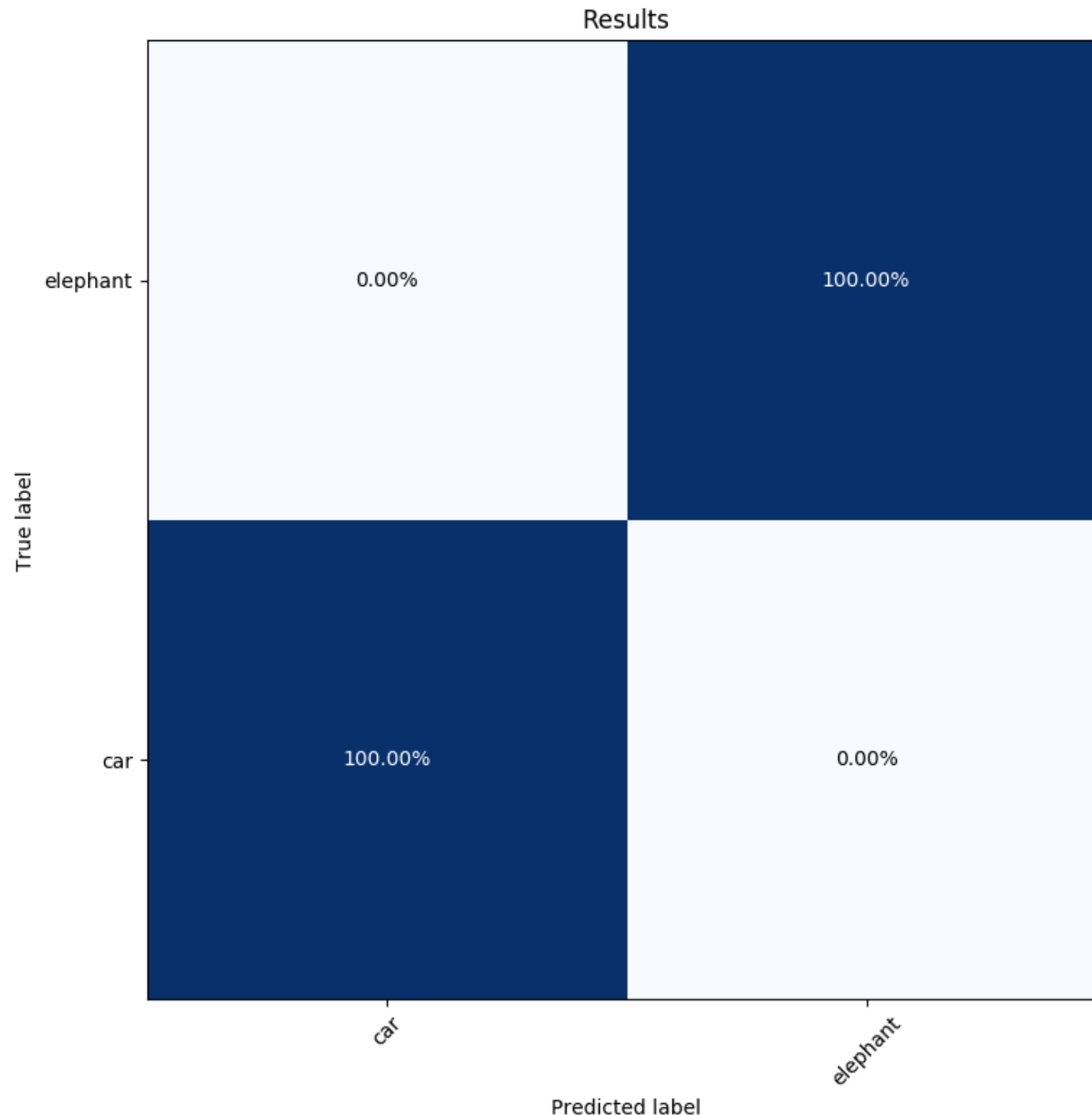
PyTorch

- Open source machine learning library
- developed by Facebook's AI Research lab
- Python and C++ interface
- Tensor computing with strong GPU acceleration (CUDA)
- Linux, macOS, Windows
- Several pre-trained CNN models (ResNet, VGG, DenseNet, Inception, AlexNet, SqueezeNet)
- Can be used on Google Colab with GPU acceleration

PyTorch classification of cars and elephants



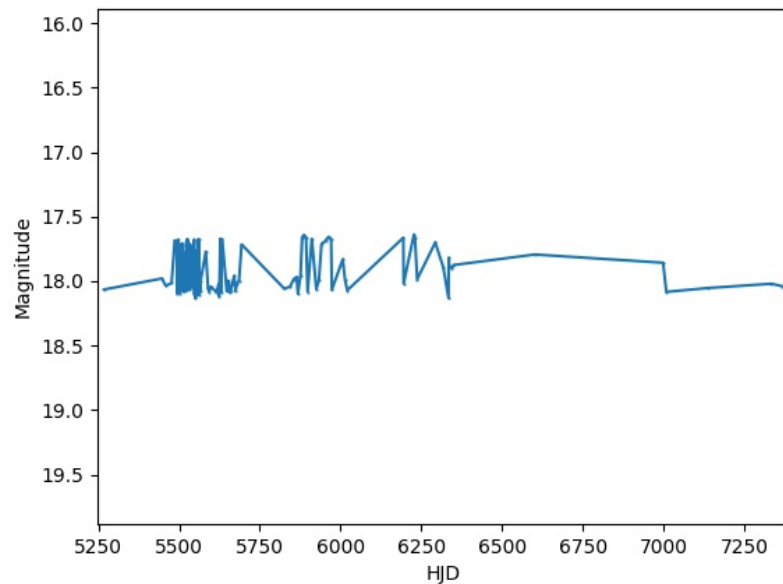
PyTorch classification of cars and elephants



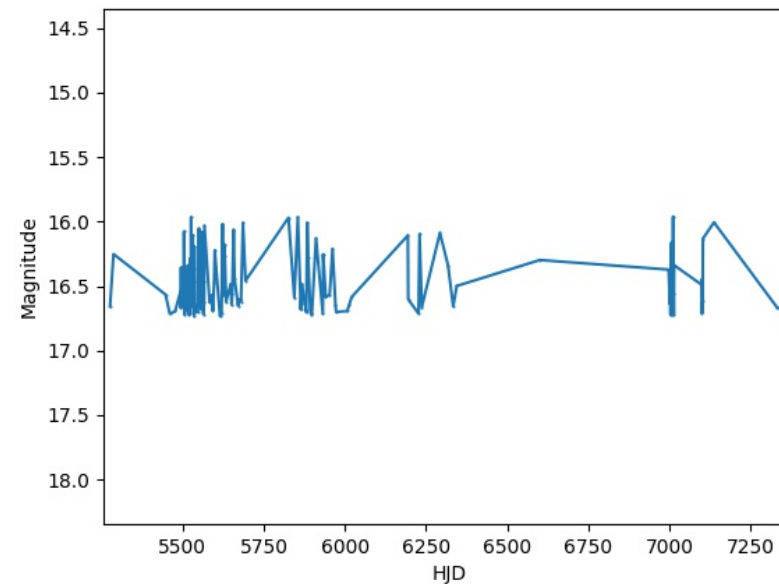
Light curves as images

(from OGLE)

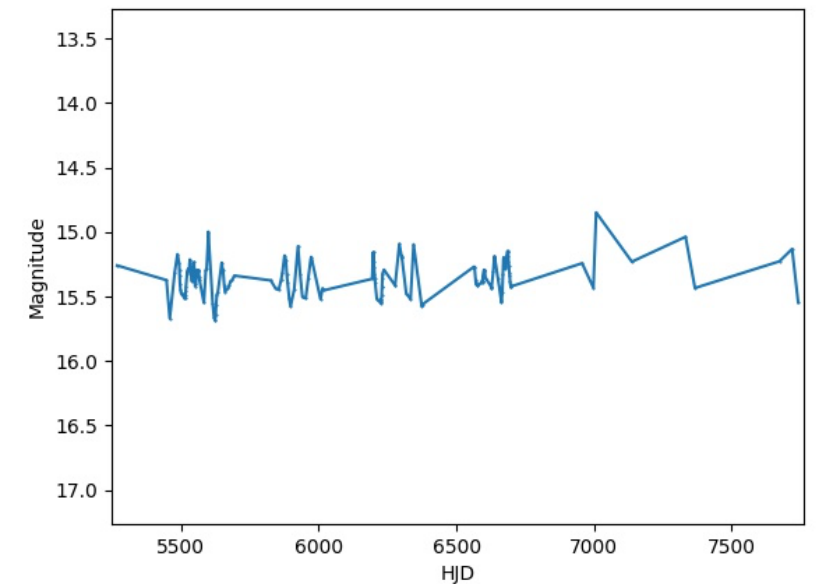
Anomalous Cepheid



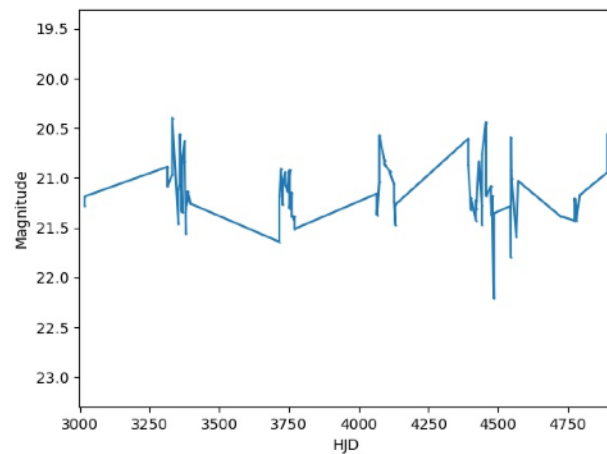
Classical Cepheid



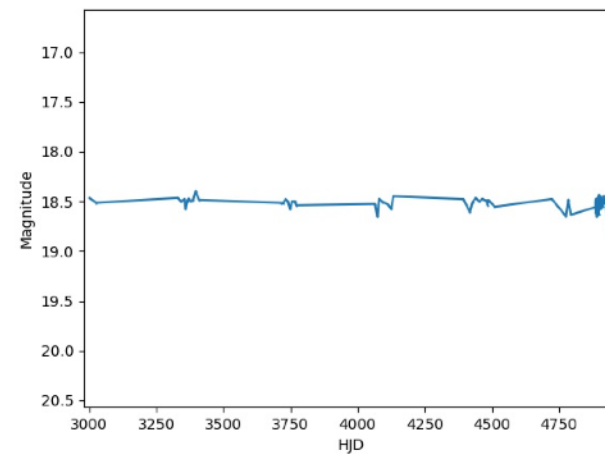
Type II Cepheid



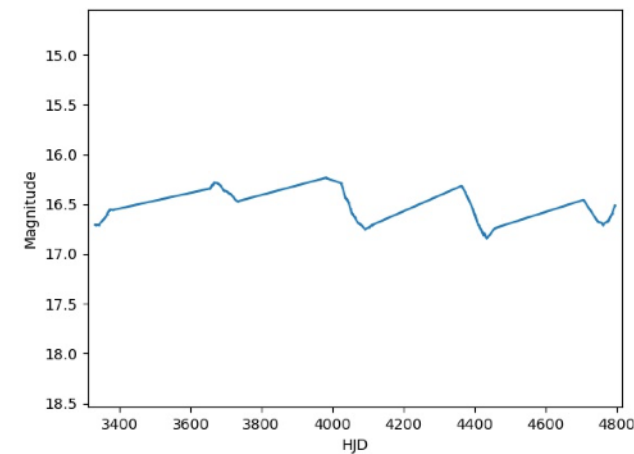
δ Scuti



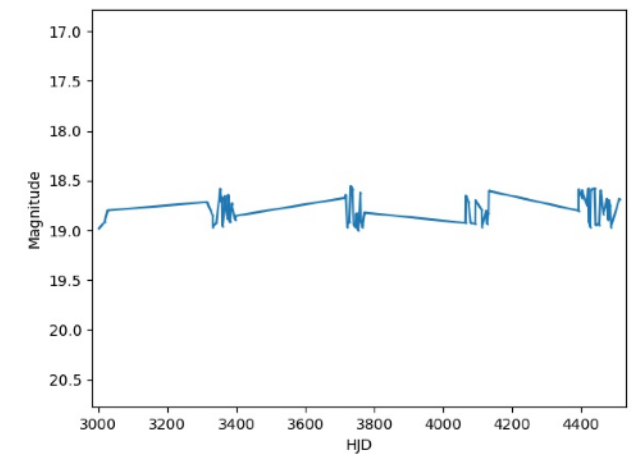
Eclipsing Binary



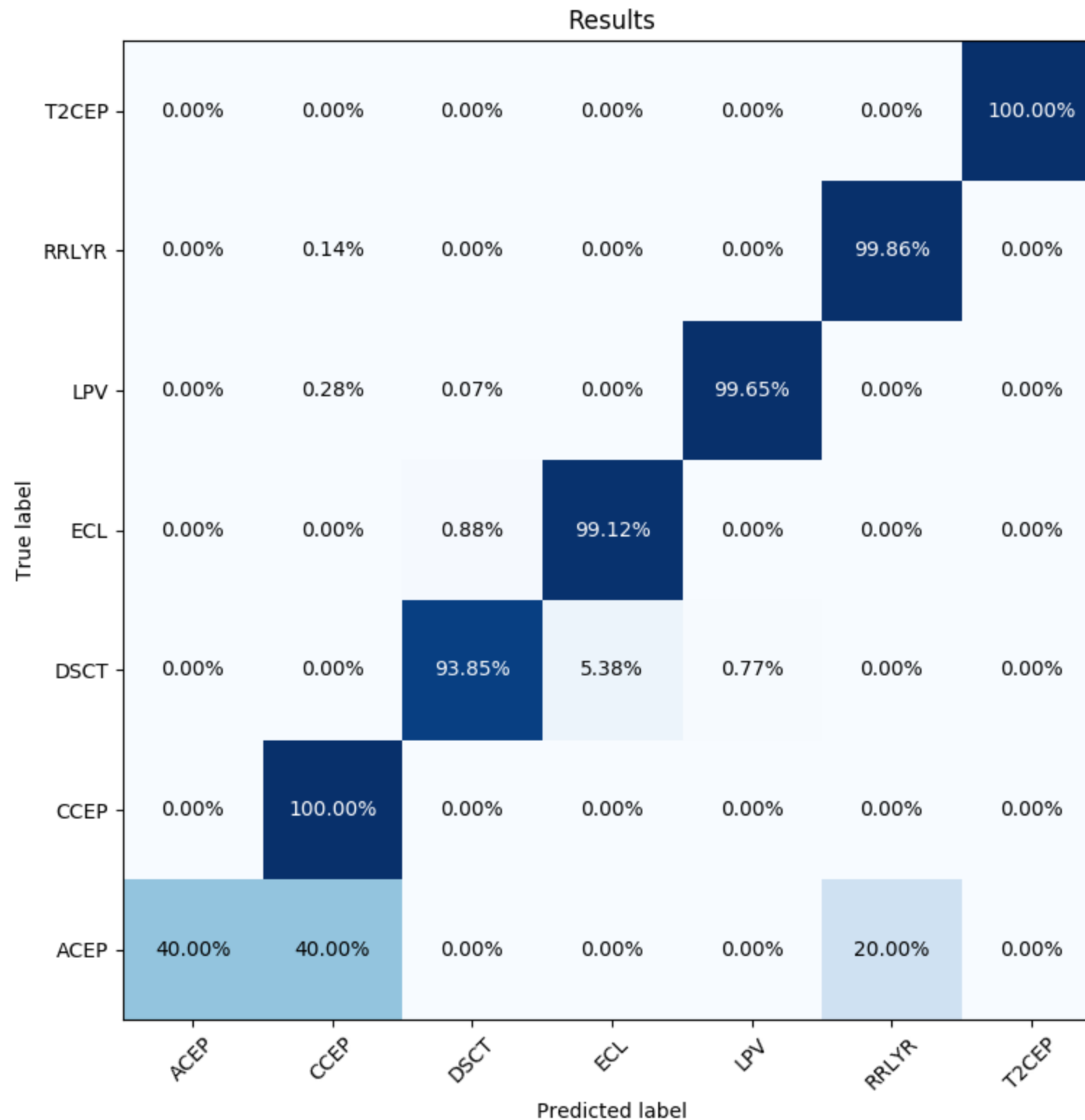
LPV



RR Lyrae

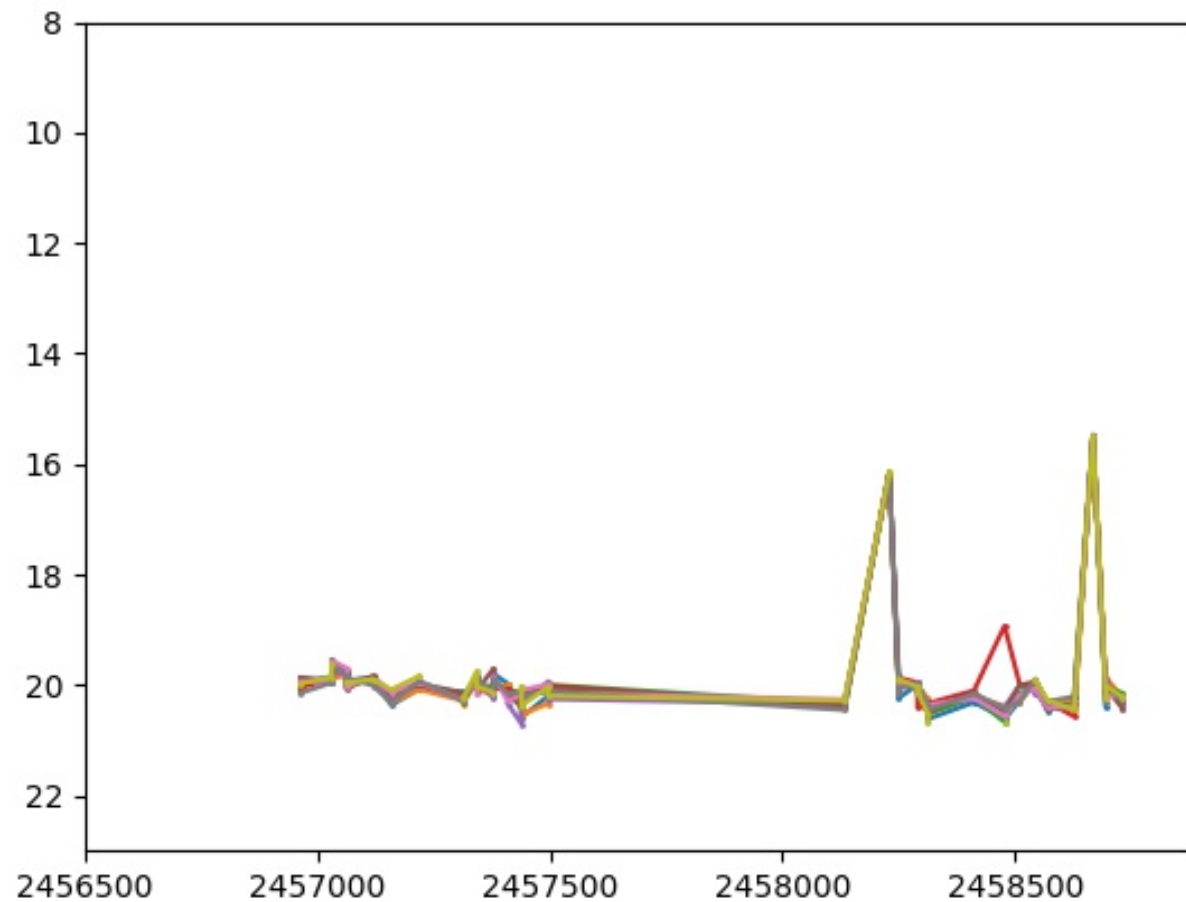


Light curves as images (from OGLE)

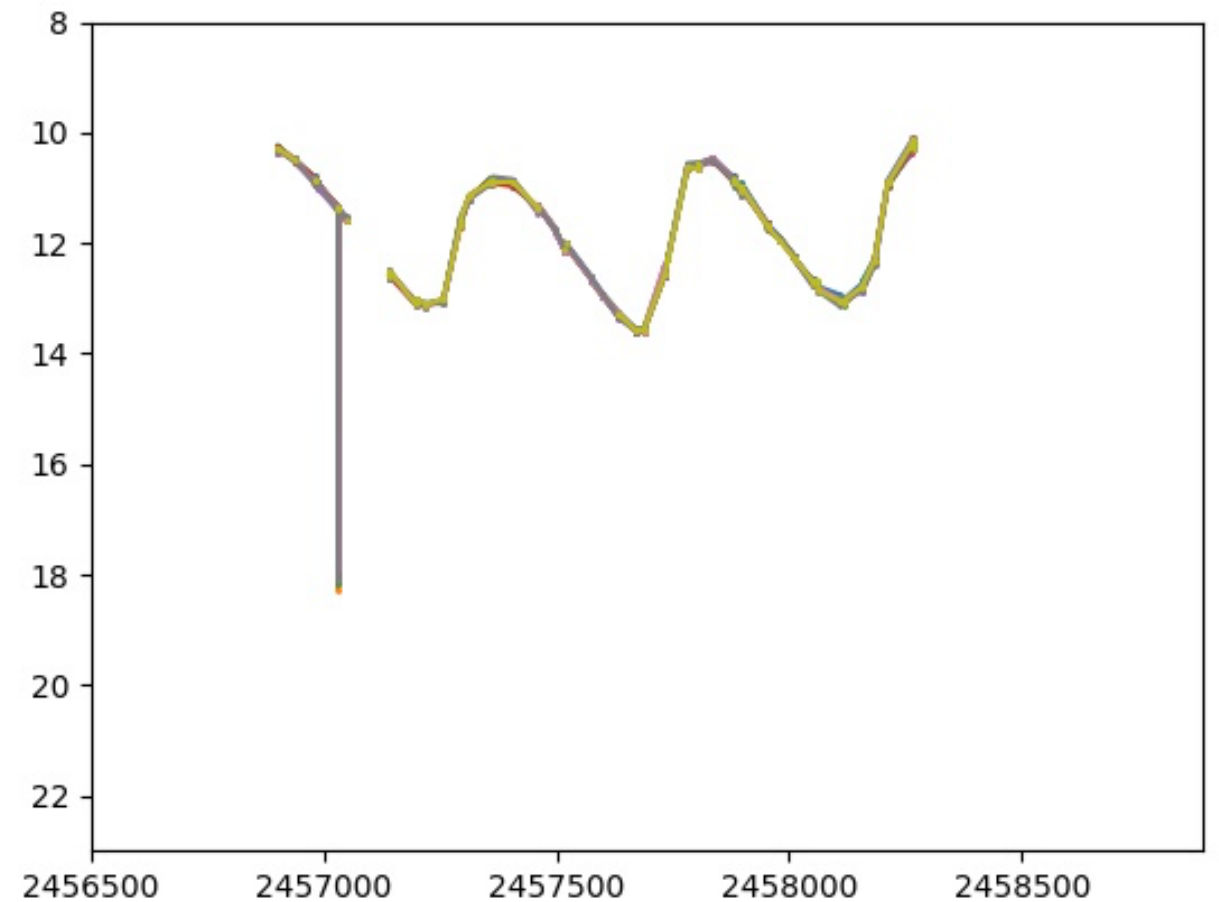


Published and unpublished Gaia Alerts

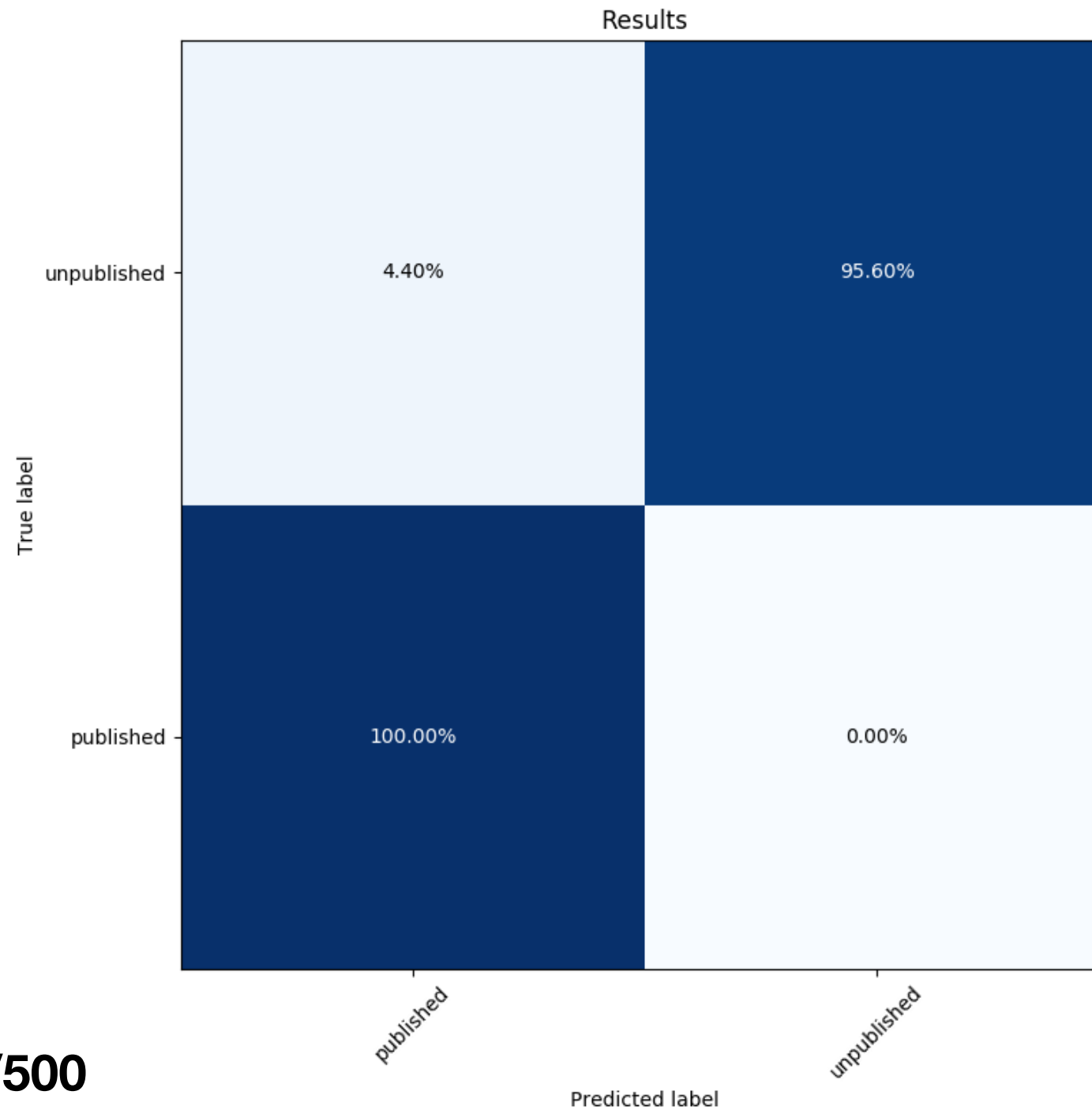
Published



Unpublished - don't look at it



Published and unpublished Gaia Alerts



Published: 500/500

Unpublished: 478/500