THE HUNGARIAN IN-KIND CONTRIBUTION

CSFK KONKOLY OBSERVATORY

RÓBERT SZABÓ, TAMÁS SZKLENÁR, ATTILA BÓDI

2ND PLITVICE LSST REGIONAL WORKSHOP, CROATIA
2022 OCTOBER

HISTORY

- Zsolt Frei (Institute of Physics, ELTE Uni) paid 10 instalments
- Z. Ivezic Distinguished Guest Professor at the HAS (2013)
- Konkoly Observatory paid 2 instalments (2014, 2018), MoA in 2014
- R. Szabó 5-yr Lendület grant for Near-field cosmology, pulsating variable stars, and LSST contribution
- 2 PI involvement

HUN-KON 1 & 2

- 5 PIs
- TVS, SMWLV (Szabó R.)
- Galaxies (Frei Zs.)
- Solar System (Szabó M. Gy)
- Solar System (Kiss Cs)
- Transients - TVS (Vinkó J.)

Proposal Title: Hungarian LSST Consortium In-kind Contributions to the Vera C. Rubin Observatory Legacy Survey of Space and Time

Participating Institution: Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungary (contribution lead), together with the Gothard Astrophysical Observatory of Eötvös Loránd University, and the Institute of Physics at Eötvös Loránd University (Hungarian LSST Consortium).

Program Code: HUN-KON

Key Personnel:

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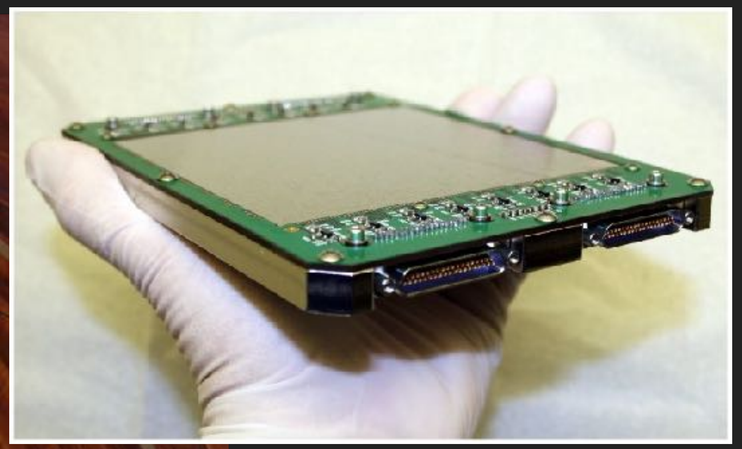
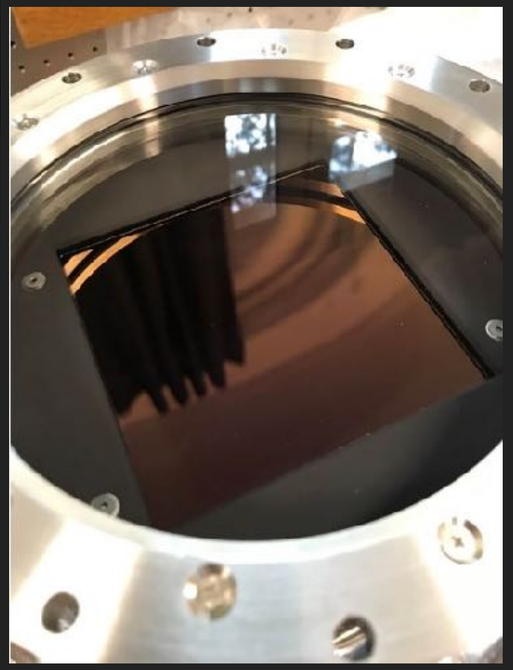
HUN-KON 1 & 2

- Solar System
- 10560x10560 STA 1600L CCD
- 3 x 3 degrees FOV
- ~100 NEO discoveries
- 11 March 2022





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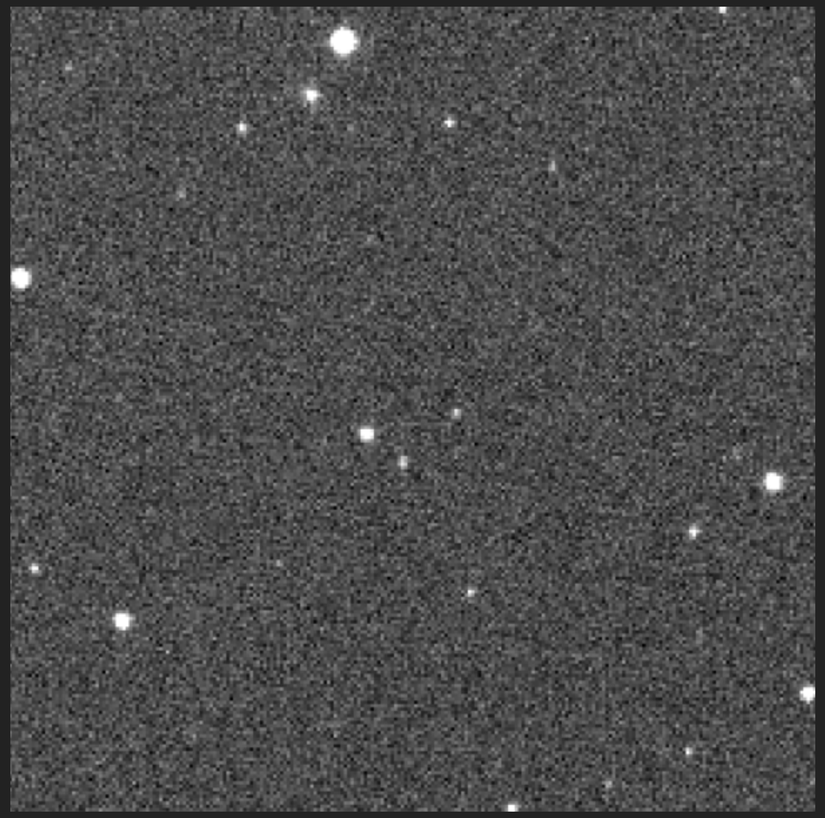

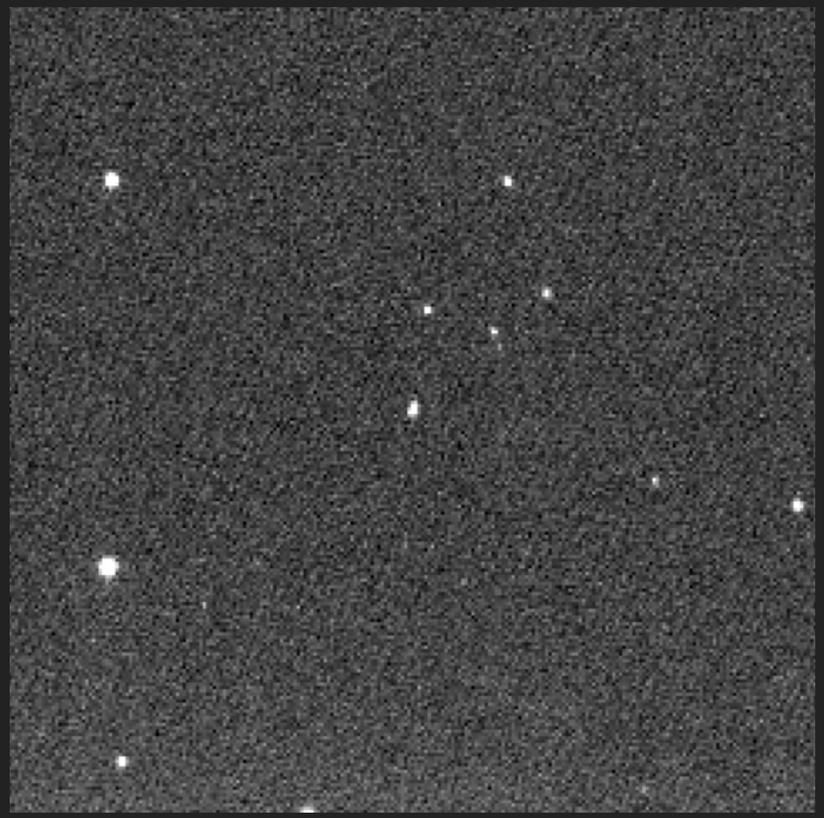

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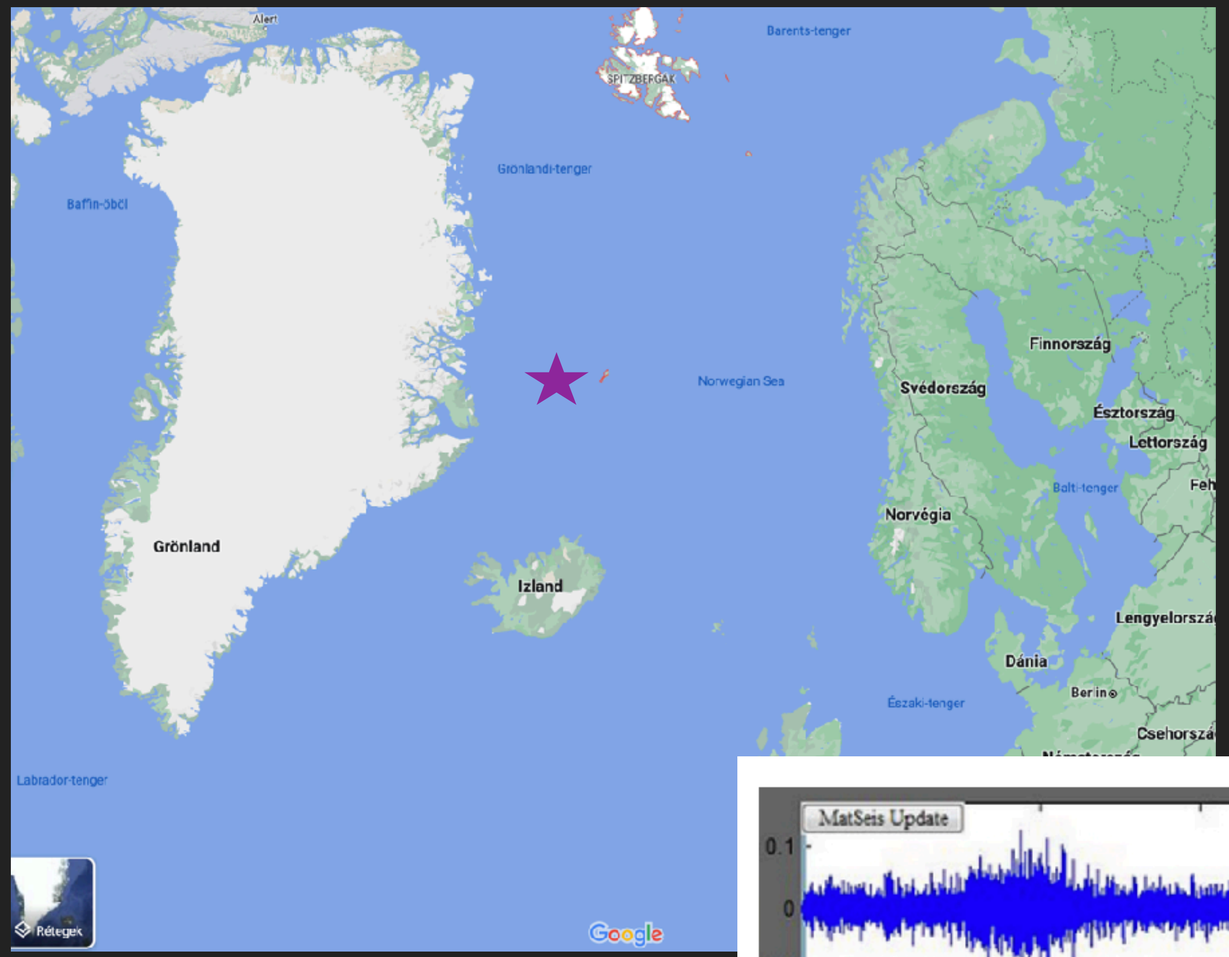
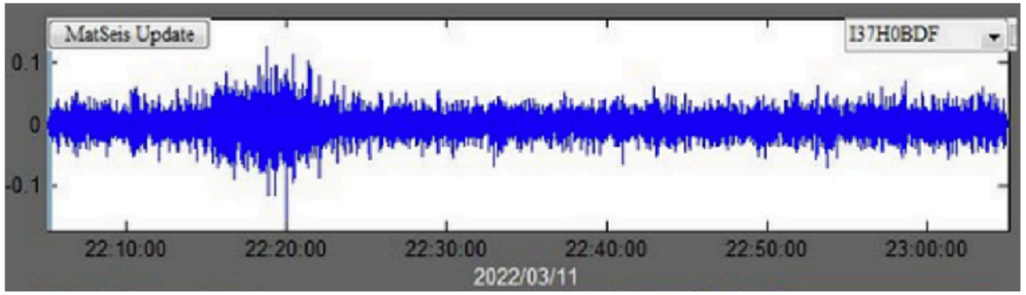
Krisztián Sárneczky

HUN-KON 1 & 2

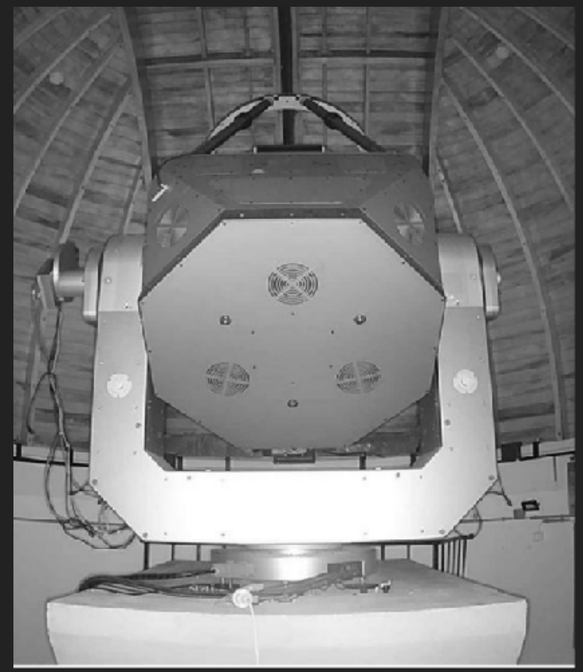
- 2022 EB5
- Impact: 2022. March 11
- 21:22 UT
- 2-3m diameter
- 18 km/s velocity
- 2 kT TNT
- Hiroshima: 15 kT
- Celjabinsk: 5-600 kT





HUN-KON 1 & 2

- Transients
- Dedicated 80 cm robotic telescope in Piszkéstető Mountain Station
- SNe, novae, recurrent novae, TDEs, GRB follow-up, GW events, ...



József Vinkó

HUN-KON 1 & 2

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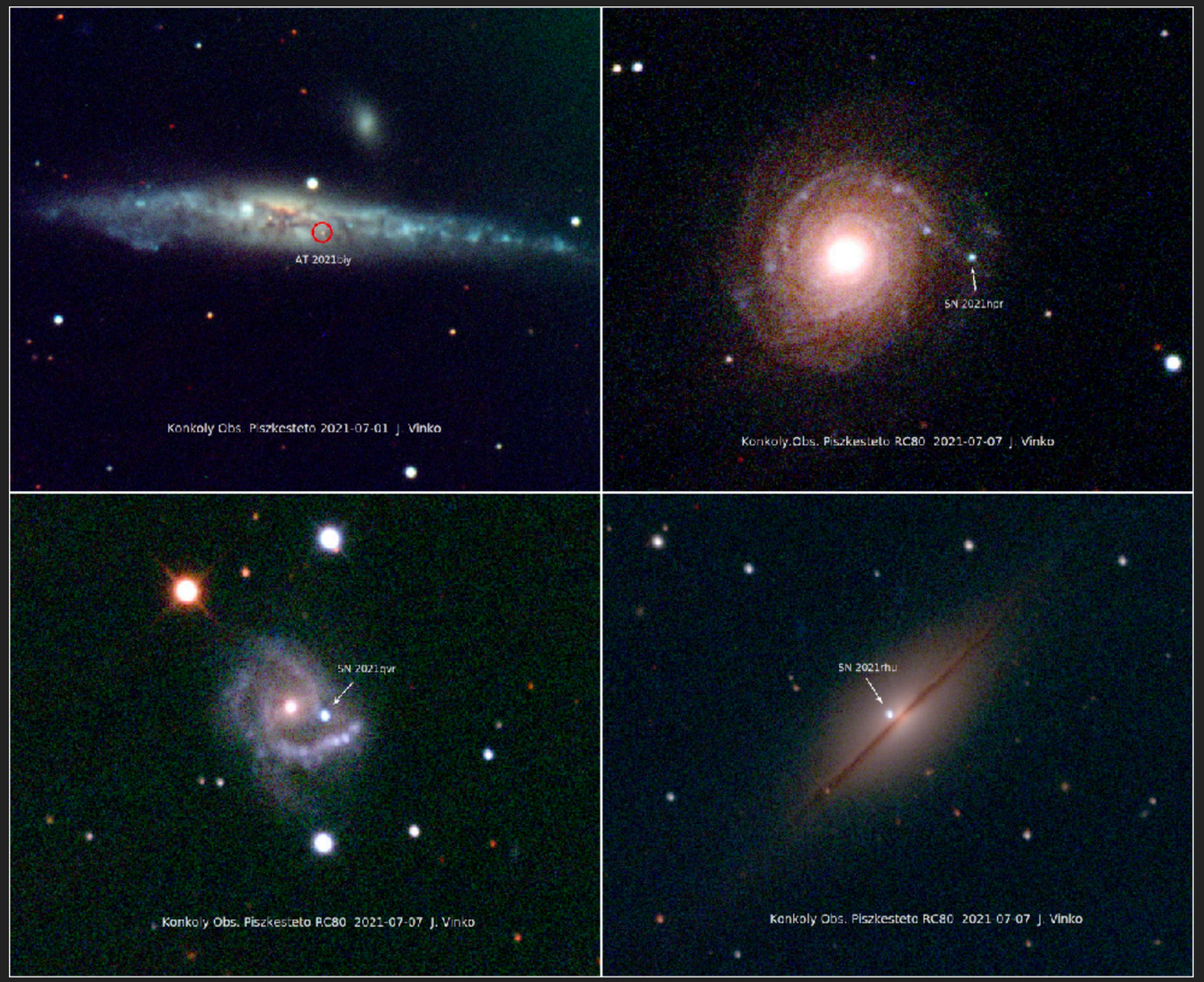


HUN-KON 1

- Leaders: Zs. Frei (Galaxies)
- Gy. M. Szabó (Solar System)

Proposal 4. Targeted Identification of Low Signal-to-Noise Detections of Solar System Objects

Proposal 5. sbpy Enhancements Requested

S1. Statement of Work and Detailed Plan for Proposed Contribution 1

S1.1 TITLE: General Pooled Software Development Effort

S1.3.2 Activity: One Sentence Summary

The Hungarian LSST Consortium will provide a fully directable software development effort towards the general pool to be used by Rubin Observatory, preferably, but not exclusively geared towards TVS, Galaxies or Solar System Science Collaboration activities.

S1.4.3 Deliverables: Timeline

FY22: László Szigeti (ELTE Gothard Astrophysical Observatory): 0.5 FTE

FY22: new hire postdoc (ELTE Institute of Physics) 1.0 FTE

HUN-KON 1

Proposal 5. Summary: **Enhance the sbpy Python module by completing the following:**

1. Create a module for sbpy that, given an arbitrary filter transmission curve (e.g., a custom VR filter, PanSTARRS w' band, ATLAS c' or o' band) and an assumed object spectrum, can compute equivalent magnitudes in LSST bands from magnitudes measured in the arbitrary filter, or vice versa, with reasonable performance at large scales, with the goal of providing a means for linking LSST data with other photometric data from other surveys.

2. Improve sbpy installation infrastructure to better align with the Rubin Science Platform, e.g., make it conda-installable.

3. Convert key sbpy code (e.g., for fitting disk-integrated phase functions) from Python to Cython to improve performance when applied to LSST-scale datasets, and potentially identify and address other primary performance bottlenecks in sbpy code as time allows.

HUN-KON 2

- Leader: R: Szabó (TVS)
- Participants:
- Attila Bódi
- Tamás Szklenár

S2. Statement of Work and Detailed Plan for Proposed Contribution 2

S2.1 TITLE: Directable Effort in the General Aarea of Machine Learning Classification and Associated Infrastructure Software

S2.3.2 Activity: One Sentence Summary

The Hungarian LSST Consortium will provide directable software development effort to the LSST TVS Science Collaboration in the general area of LSST TVS science analysis, possibly including classification of variable sources using machine learning algorithms.

S2.4.3 Deliverables: Timeline

FY21-FY22: Attila Bódi (Konkoly) 0.5 FTE/yr postdoc, astronomer

FY21-FY22: Tamás Szklenár (Konkoly) 0.5 FTE/yr programmer

FY23-FY35: potential new hire (0.2 FTE/yr) continued contribution to the development and maintenance effort.

MACHINE LEARNING IMAGE-BASED CLASSIFICATION METHODS

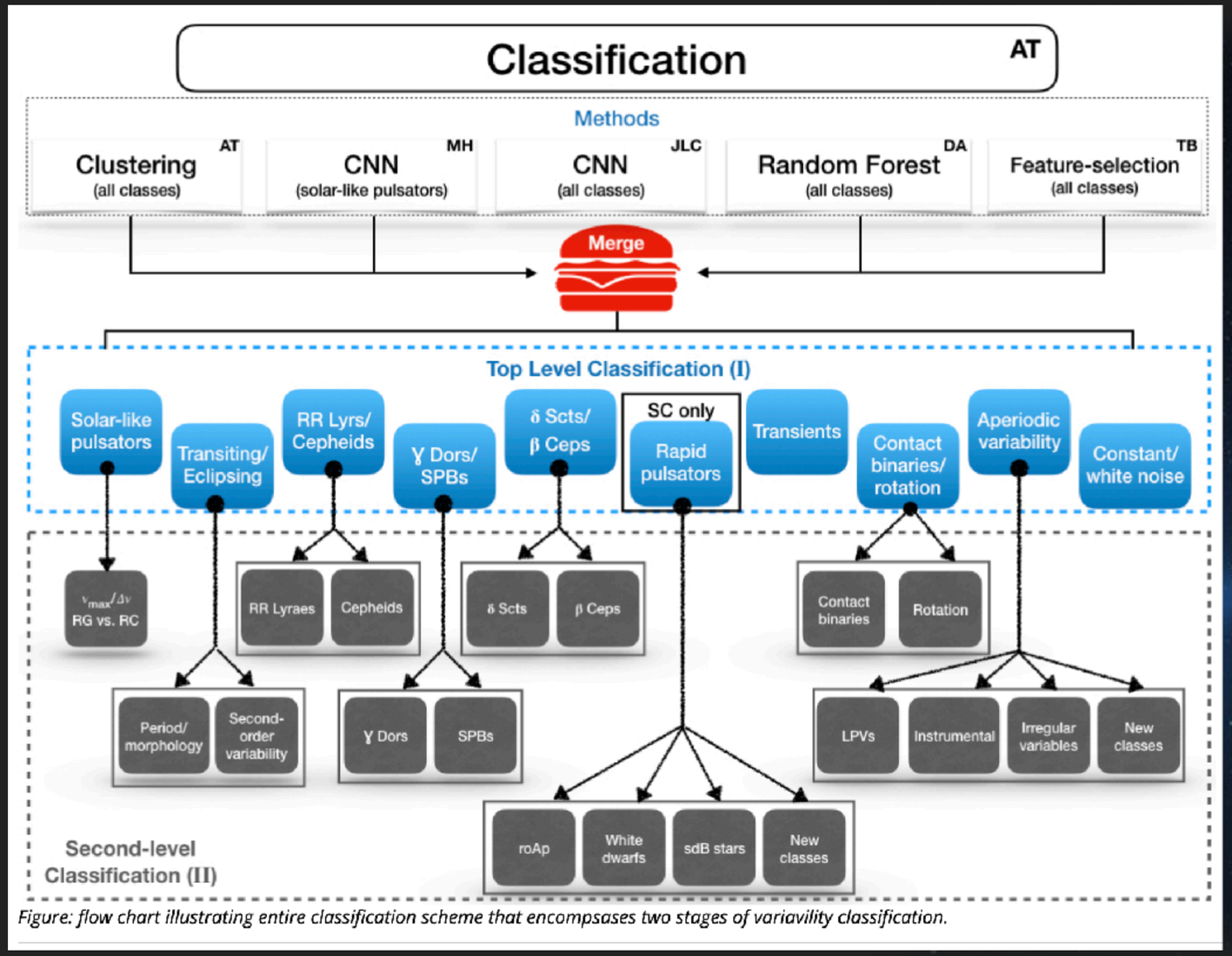
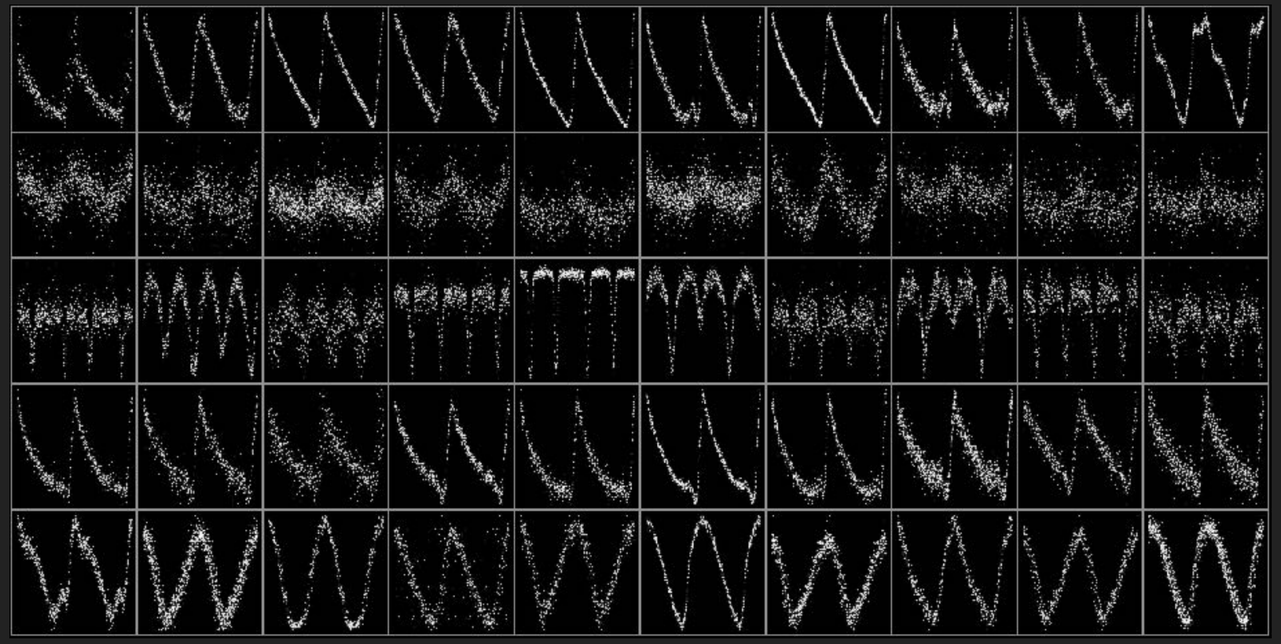
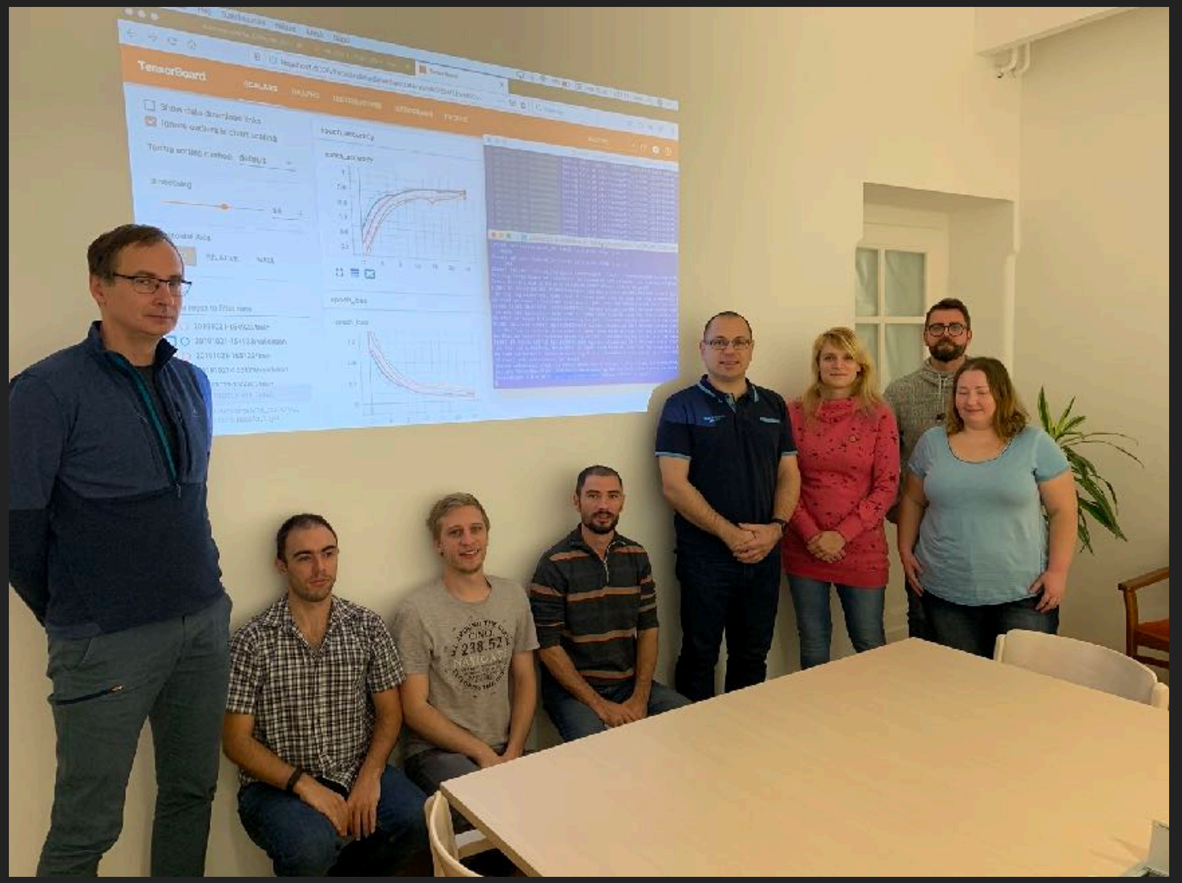


Figure: flow chart illustrating entire classification scheme that encompsases two stages of variavility classification.

MACHINE LEARNING IMAGE-BASED CLASSIFICATION METHODS

Image (light curve) based
classification of variable stars





Szklenár et al. ApJL, 897, L12, 2020

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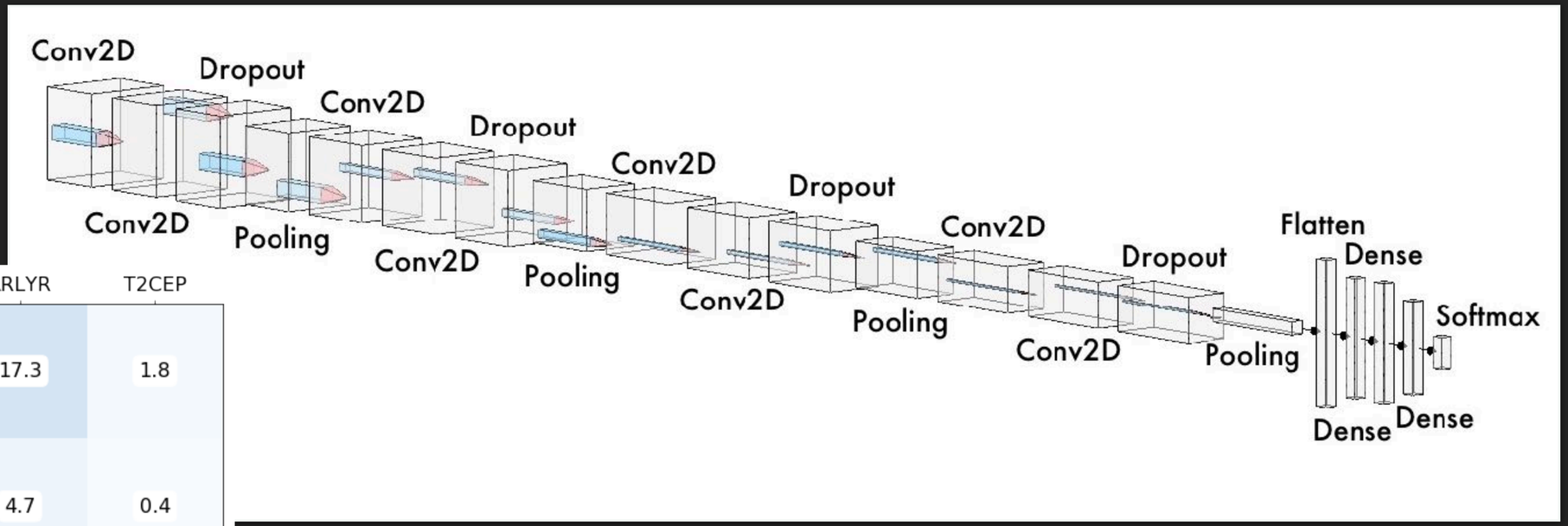

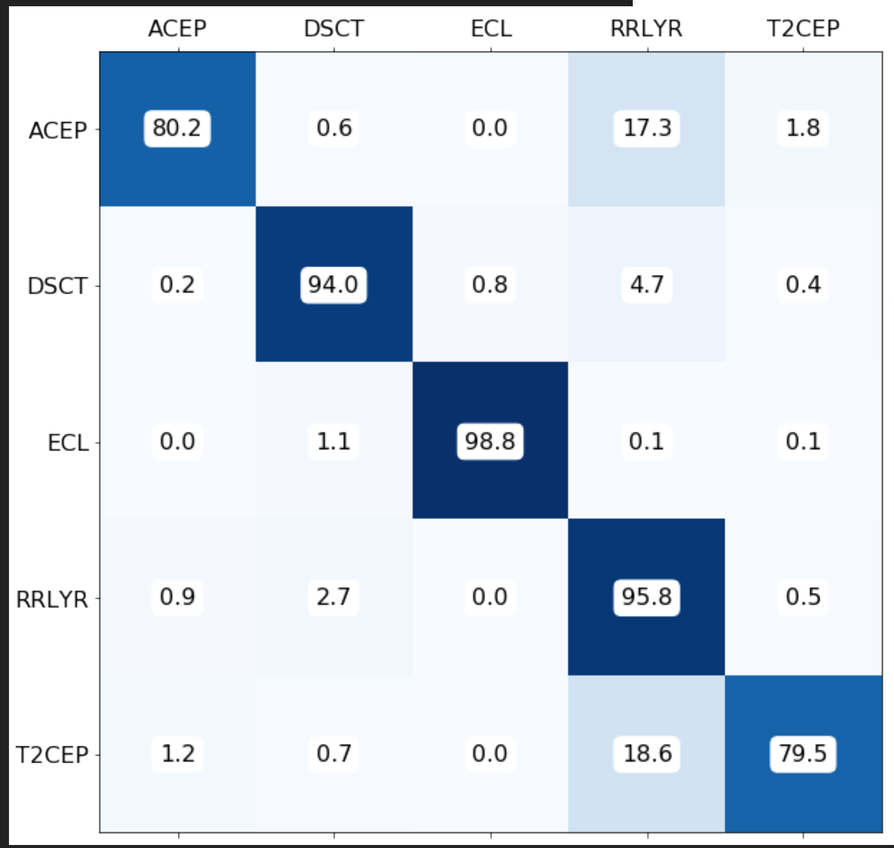

Convolutional Neural Network
applied to OGLE data

An attempt to mimic
how humans classify.

Szklenár et al. ApJL, 897, L12, 2020

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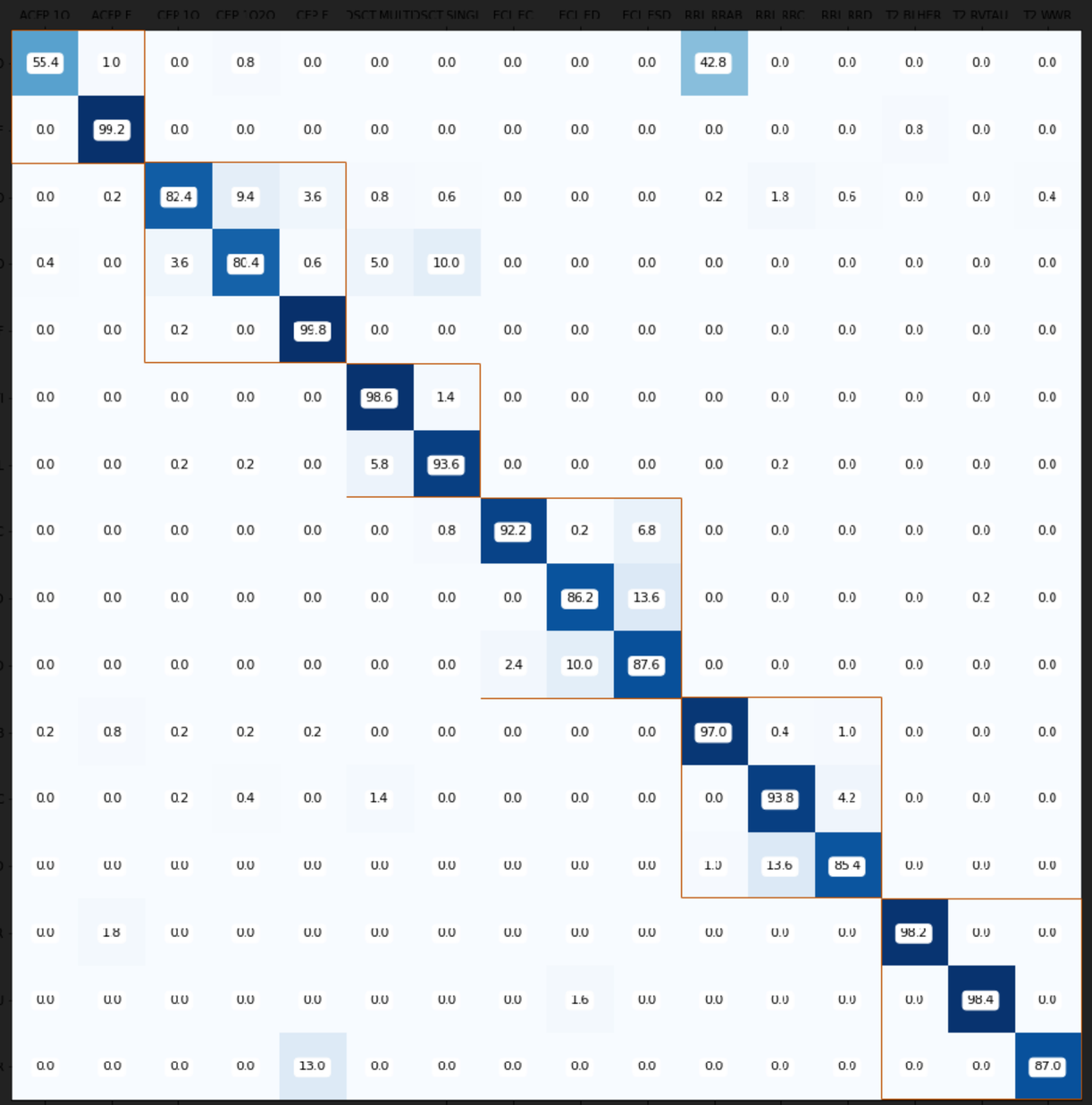

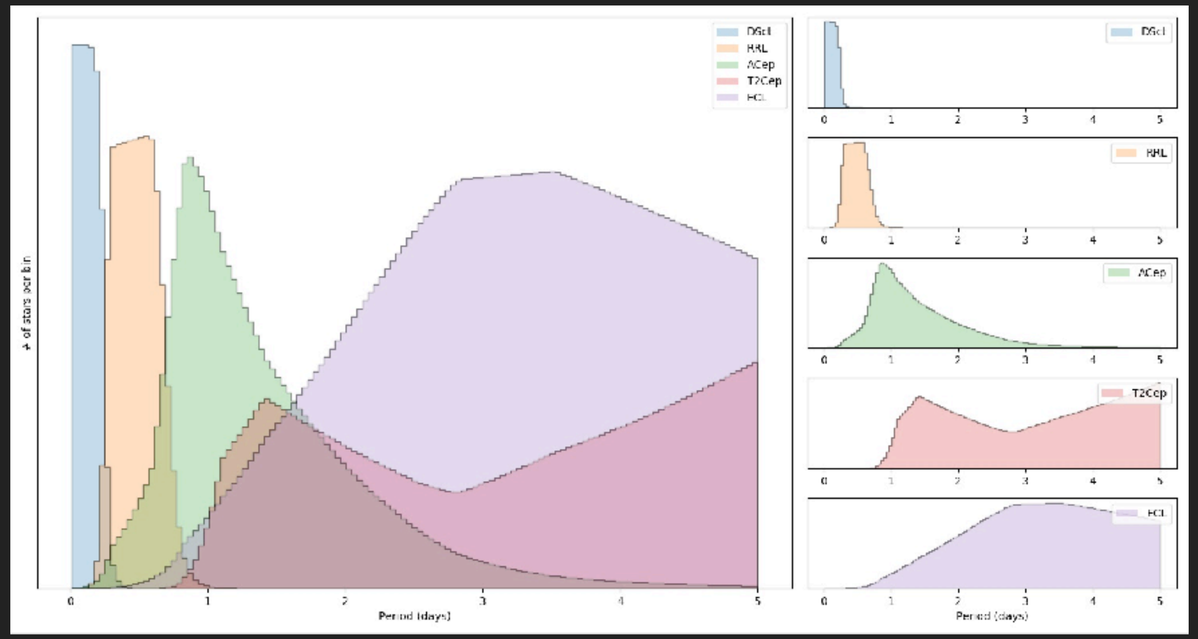

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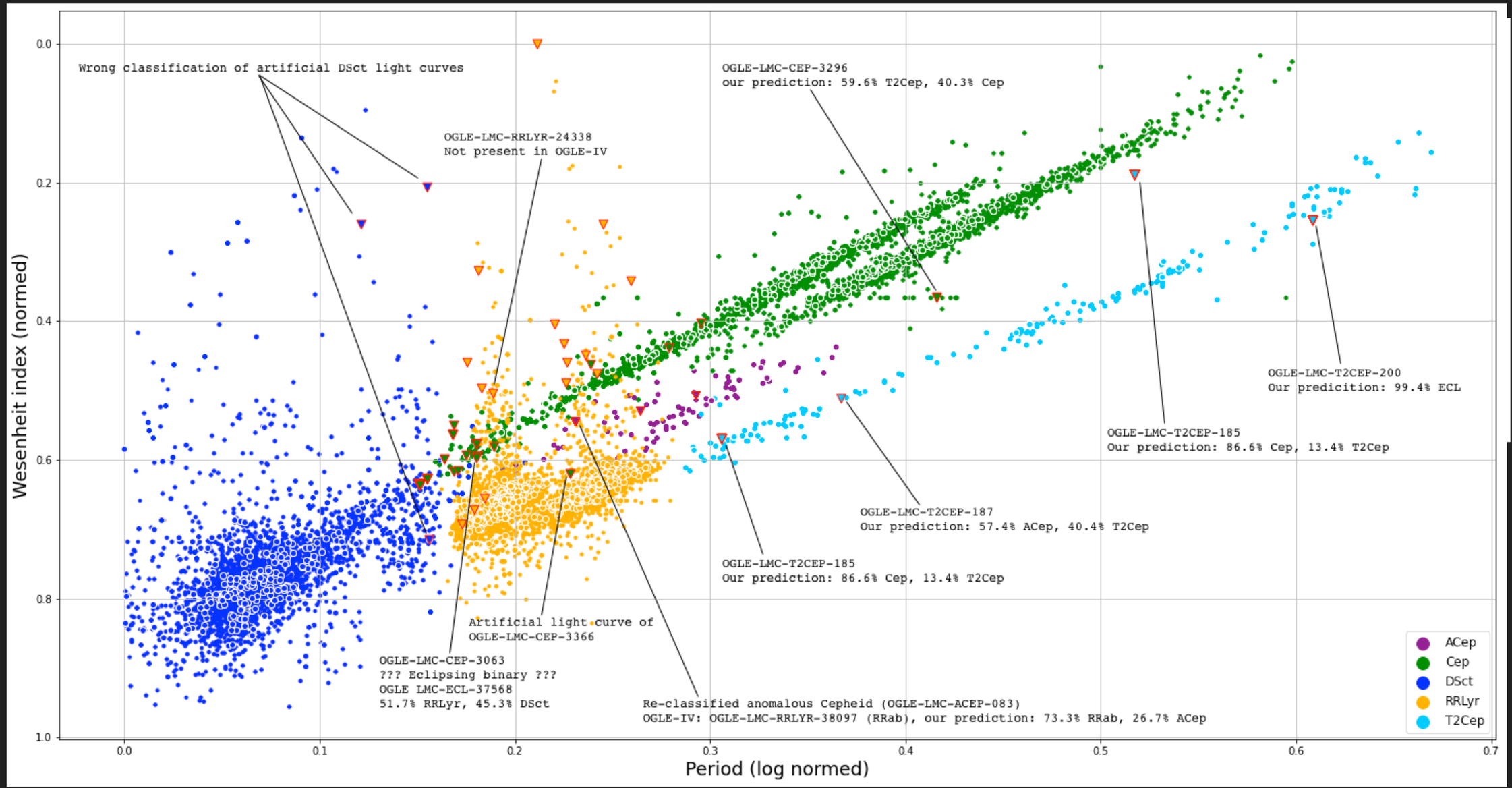
Szklenár et al. ApJ, accepted, 2022
arXiv:2209.02310

MACHINE LEARNING IMAGE-BASED CLASSIFICATION METHODS

P-L relation



MACHINE LEARNING IMAGE-BASED CLASSIFICATION METHODS

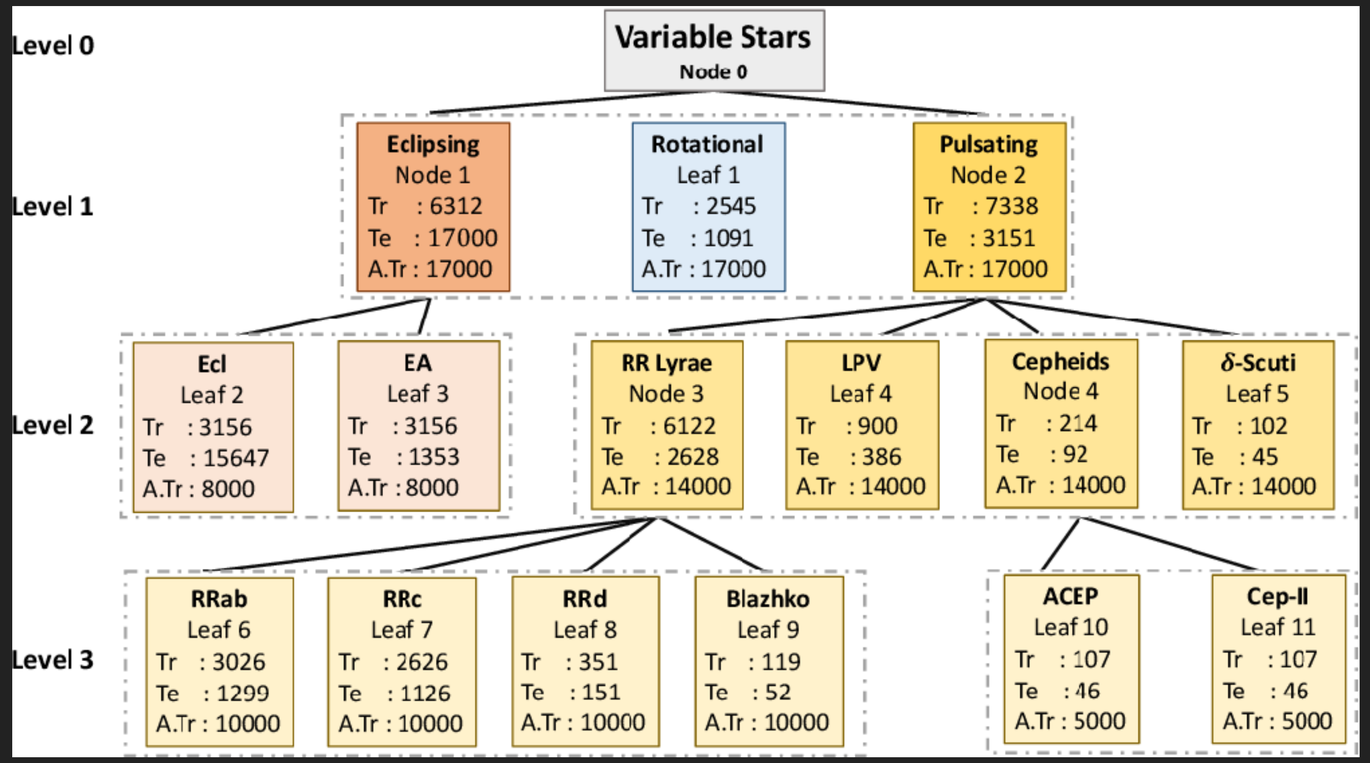
- **Malőr* server of machine learning computations**
  - 96 processor threads
  - 377 GB memory
  - 6x GeForce RTX 2080 (11GB) GPU

*blunder / bloomer / error / mischief

Malheur (French)

HUN-KON 2 GOAL

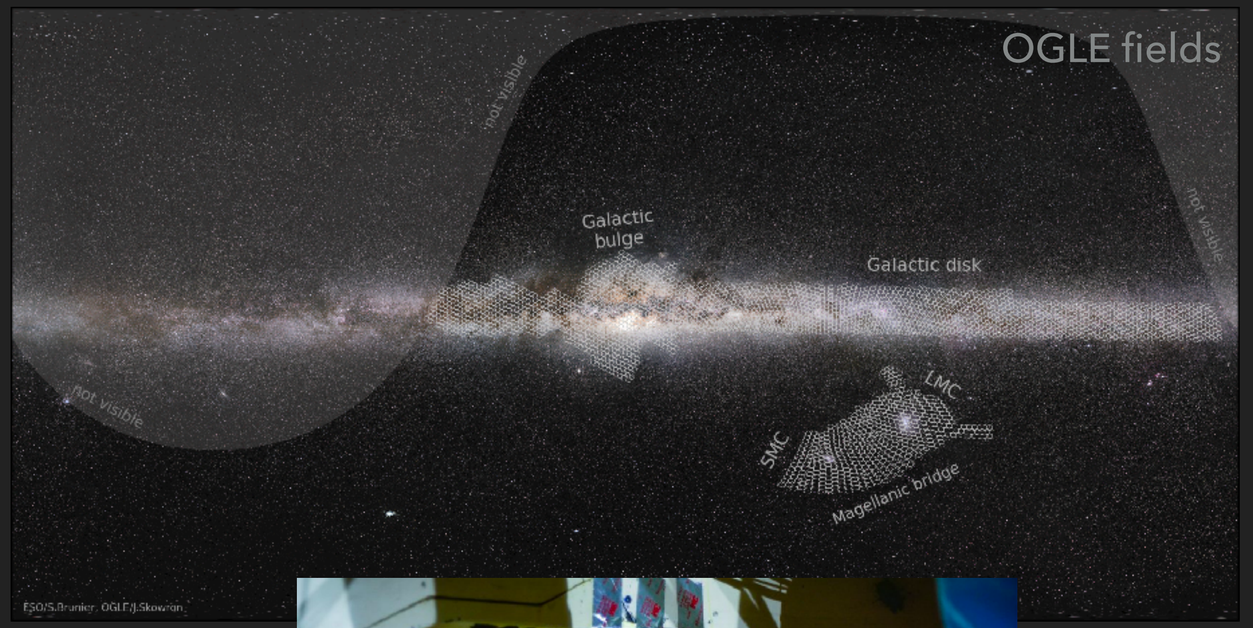
- Classify (quasi) periodic variable stars (no transients) in the LSST data with machine learning methods.
- Input: light curves, periods (from brokers?)
- Output: class probabilities
- Rubin Sscience Platform integration
- User interface
- Periodic update when new data available
- Documentation and technical help



Hosenie et al. MNRAS 493, 6050, 2020

MERGING OGLE AND ZTF DATA

- OGLE variable stars are well classified and labeled
- ZTF data contains no labels for known variable stars
  - many papers mention cross-validation of both databases
  - we used coordinates and V brightness to collect data from the ZTF database, based on the known OGLE variables



Technical lead Roger Smith, of Caltech Optical Observatories, inspects one of the three wide-field optical filters used for the Zwicky Transient Facility (ZTF) science survey. Credit: Caltech Optical Observatories

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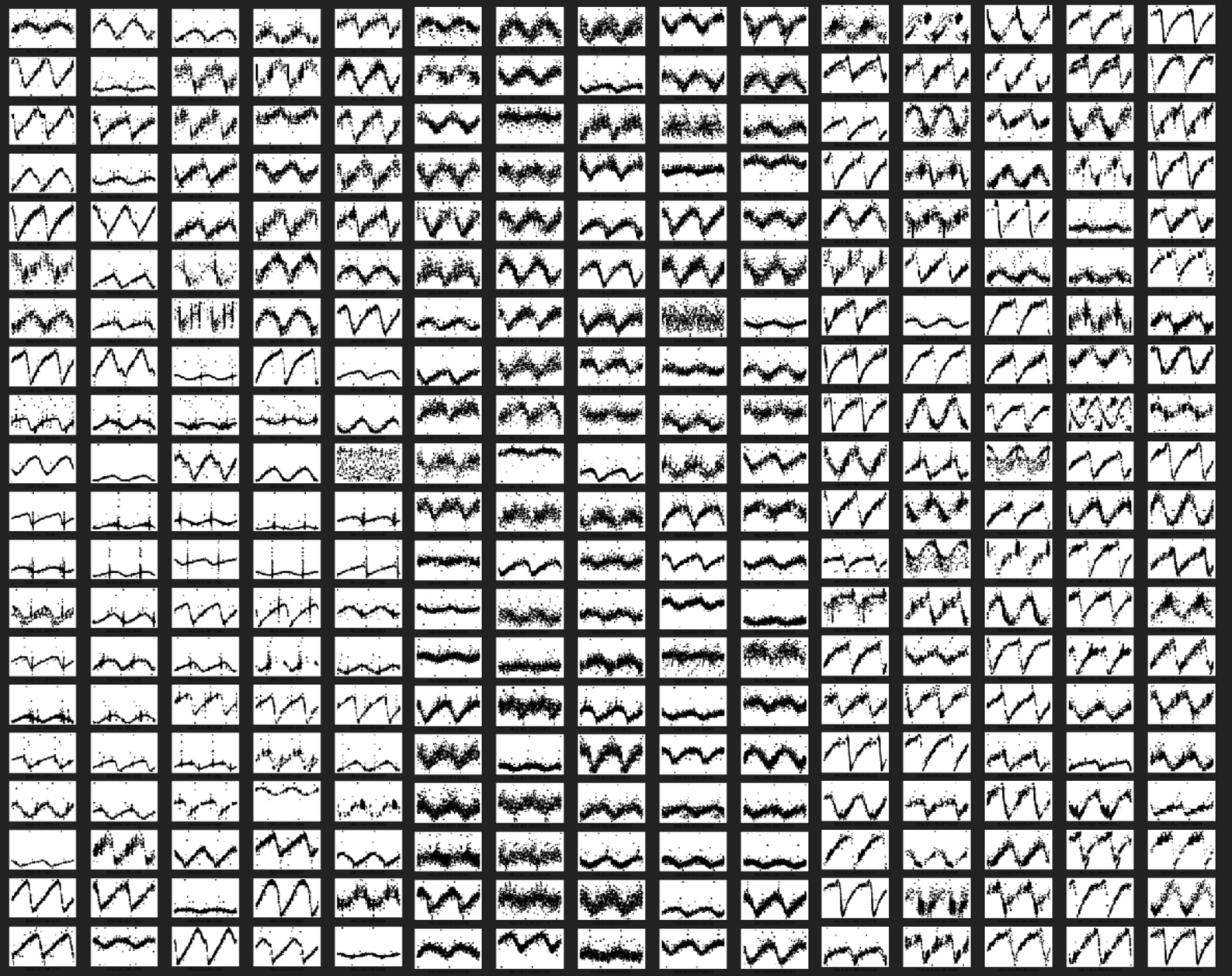
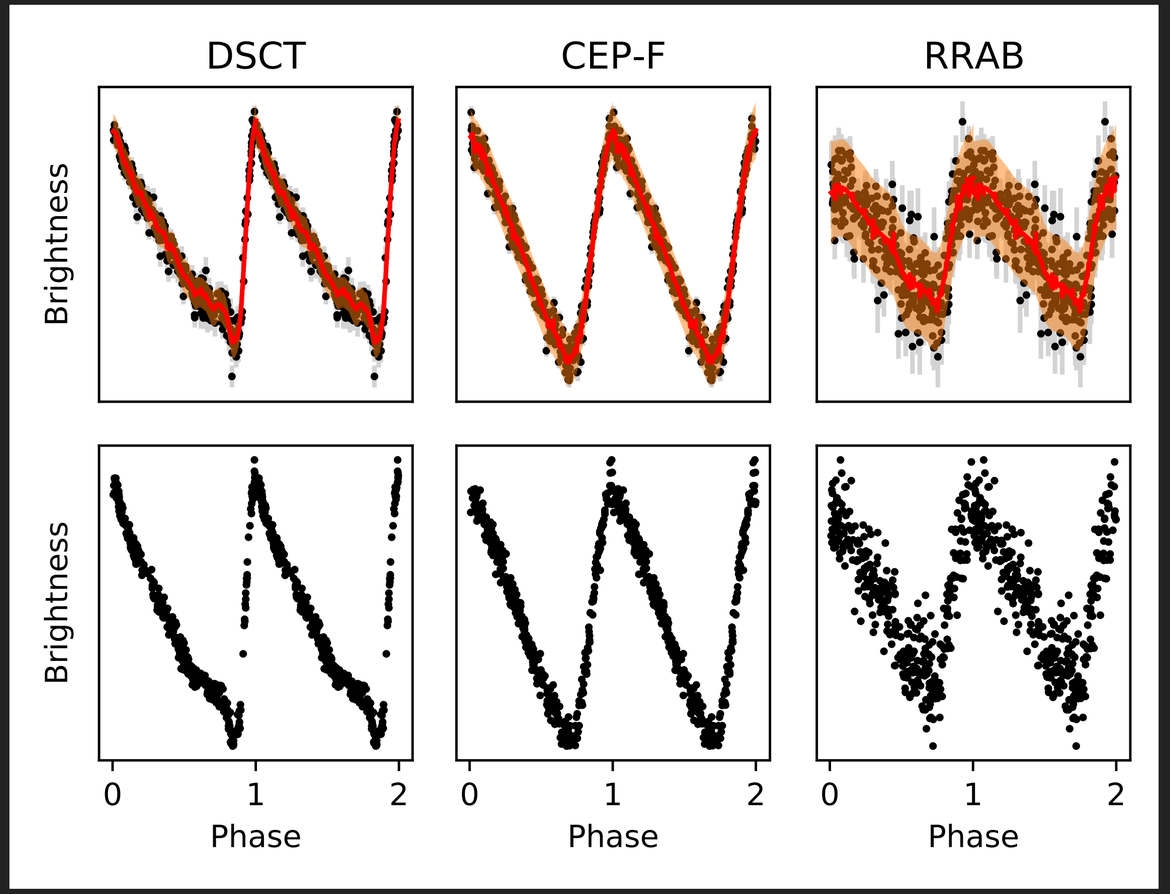


First batch of phase-folded light curves from the ZTF based on the known OGLE variables

DATA PREPROCESSING

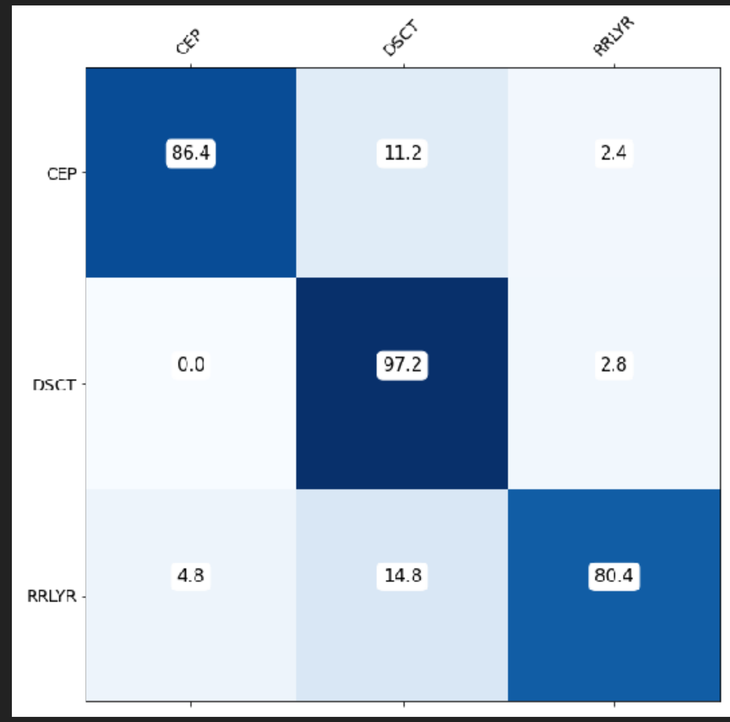
- We started our work with the following variable star classes:
  - classical Cepheid, delta Scuti, RR Lyrae stars
- Due to the small overlap of the two databases, we could not use the majority of the OGLE variables
  - possible solution: artificial light curve generation
- Collected and used data:
  - measurements in g and r filters (stars with at least 50 measurement points in each filter)
  - period, color-index



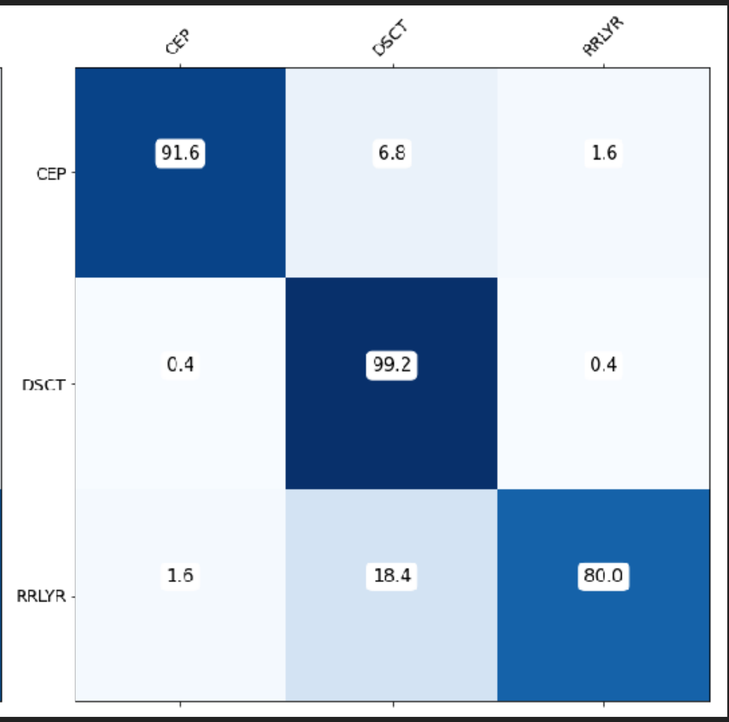
Synthetic data generation example using Gaussian Process regression

(CURRENT) NEURAL NETWORK

- The neural network has the following inputs:
  - phase-folded light curves in g and r filters
  - additional numerical data, e.g. period, color-index
- The base of the neural network is a Convolutional Neural Network (CNN) which is concatenated with additional MLP networks.
- Collected and used data:
  - measurements in g and r filters (stars with at least 50 measurement points in each filter)
  - period, color index



Phase-folded light curves without period information



Phase-folded light curves with period information