A Convolutional Autoencoder-Based Pipeline for Anomaly Detection and Classification of Periodic Variables

Ho-Sang Chan[1,2], Siu-Hei Cheung[1,2], Victoria Ashley Villar[3], Shirley Ho[2]

Machine Learning and the Physical Sciences workshop

Workshop at the 35th Conference on Neural Information Processing Systems
December 13, 2021

1. The Chinese University of Hong Kong
2. Center for Computational Astrophysics, Flatiron institute
3. The Pennsylvania State University

FLATIRON INSTITUTE


Introduction And Motivation
Image credit: Nasa.gov

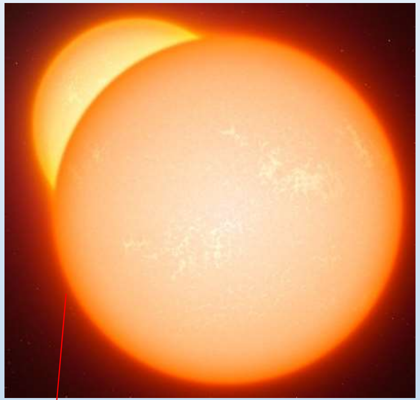
Searching For Anomalous Periodic Variable Stars

Image credit: astro.wisc.edu

Intrinsic

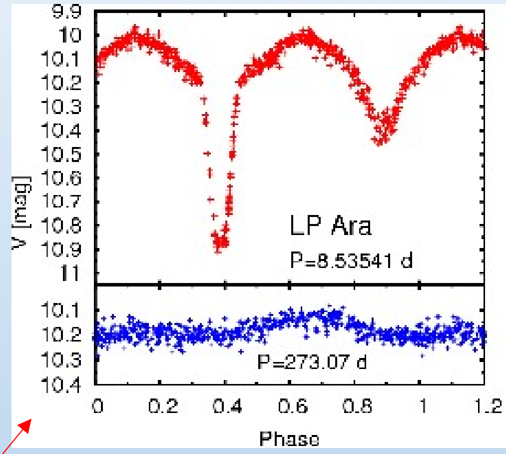
Or

Image credit: newatlas.com



Extrinsic

Image credit: Michalska et al. (2009)



- Periodic variable stars → brightness changes periodically
- Source: Pulsations, eclipsing, and more …
- Physics of sources encoded in their light curves
- Search for wild cats → New discoveries

Methodology

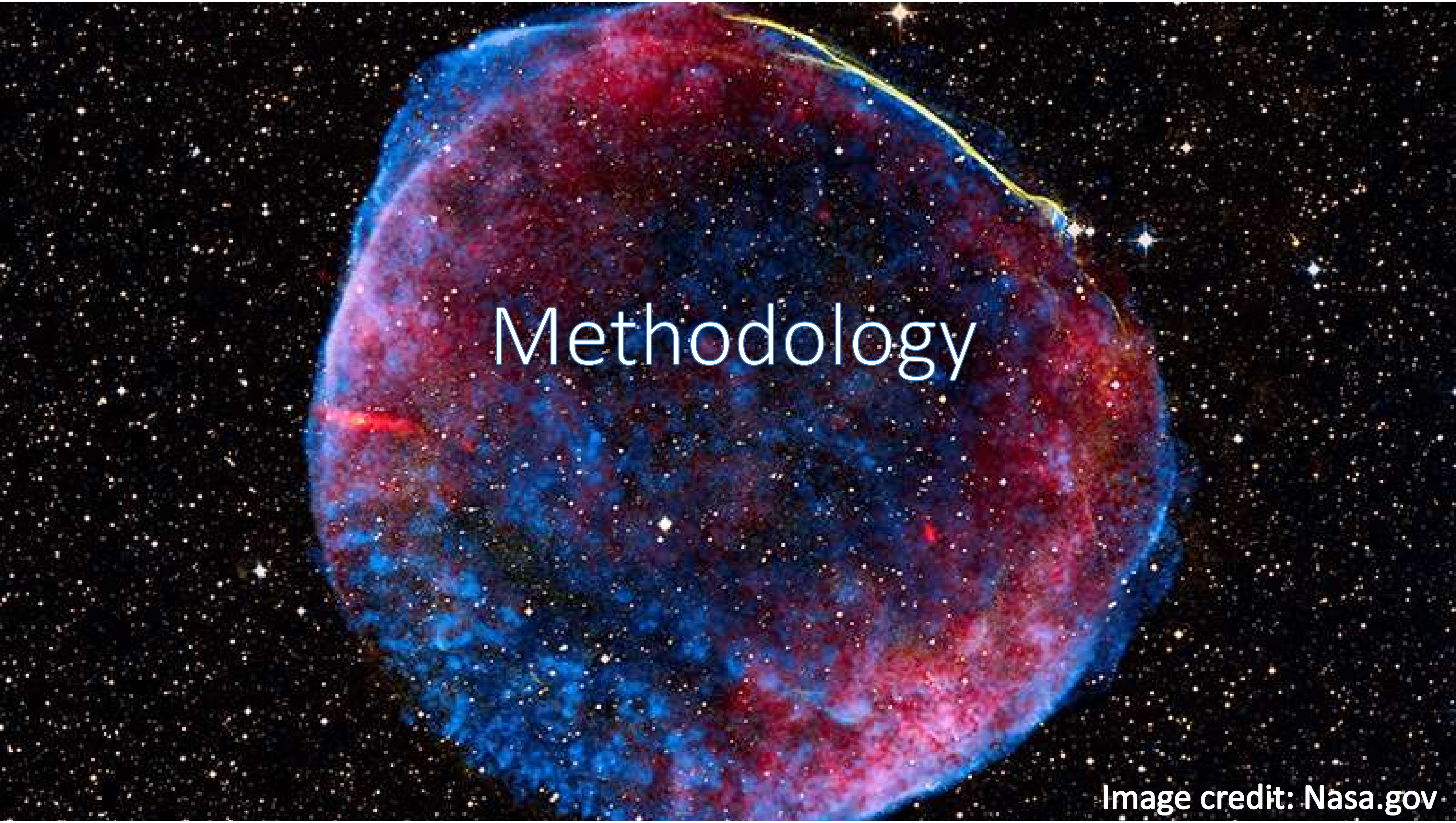
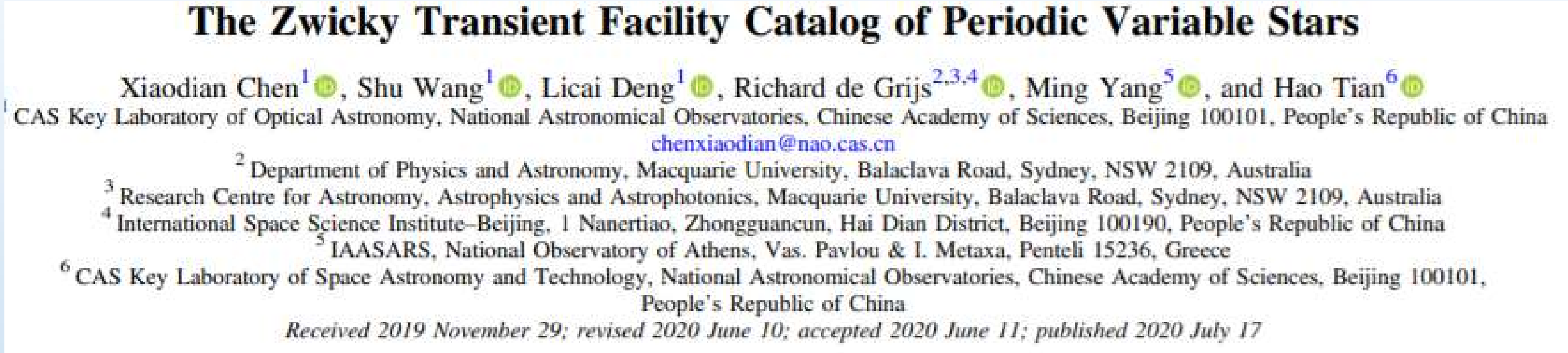


Image credit: Nasa.gov

Data Pre-Processing

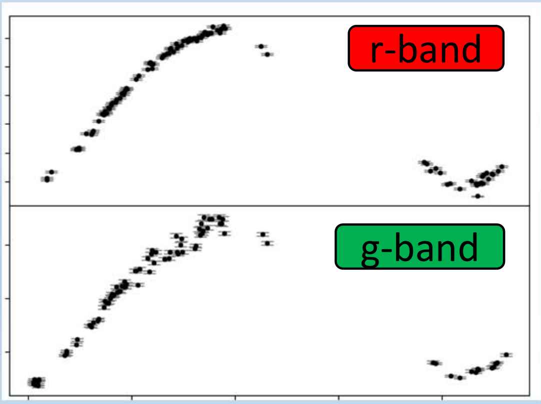


The Zwicky Transient Facility Catalog of Periodic Variable Stars

Xiaodian Chen[1], Shu Wang[1], Licai Deng[1], Richard de Grijs[2,3,4], Ming Yang[5], and Hao Tian[6]
[1] CAS Key Laboratory of Optical Astronomy, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, People's Republic of China
chenxiaodian@nao.cas.cn
[2] Department of Physics and Astronomy, Macquarie University, Balaclava Road, Sydney, NSW 2109, Australia
[3] Research Centre for Astronomy, Astrophysics and Astrophotonics, Macquarie University, Balaclava Road, Sydney, NSW 2109, Australia
[4] International Space Science Institute–Beijing, 1 Nanertiao, Zhongguancun, Hai Dian District, Beijing 100190, People's Republic of China
[5] IAASARS, National Observatory of Athens, Vas. Pavlou & I. Metaxa, Penteli 15236, Greece
[6] CAS Key Laboratory of Space Astronomy and Technology, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, People's Republic of China

Received 2019 November 29; revised 2020 June 10; accepted 2020 June 11; published 2020 July 17

Raw Detections



Phase-Folding

Multivariate-GPR

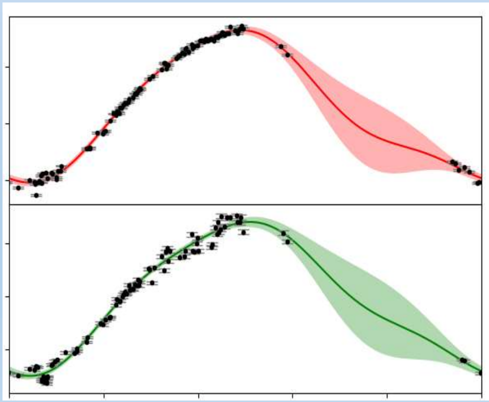
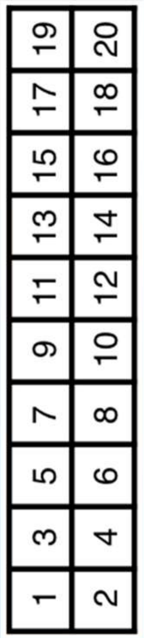


Image credit: wordpress.com

1	3	5	7	9	11	13	15	17	19
2	4	6	8	10	12	14	16	18	20

Stacked “Images”

Latent Features Extractions



Stacked “Images”

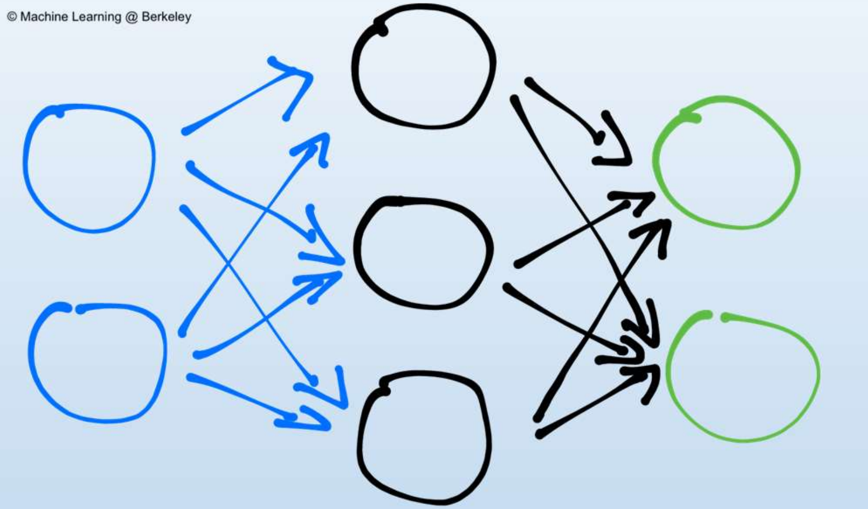
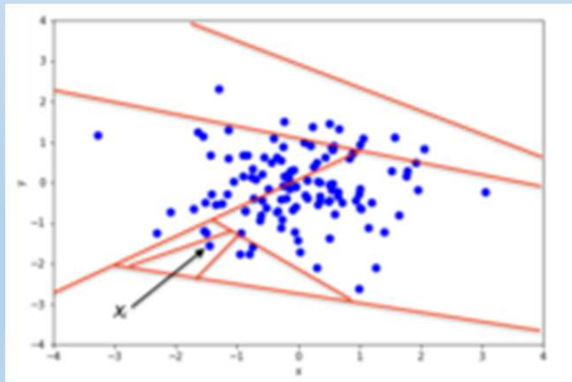


Image credit: UC Berkeley

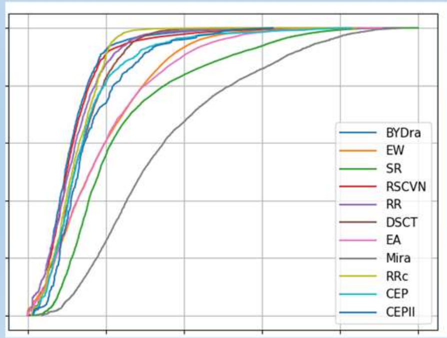
Convolutional AutoEncoder

Latent Features

Image credit: Wikipedia.com



Isolation Forest



List of Anomalies

Results

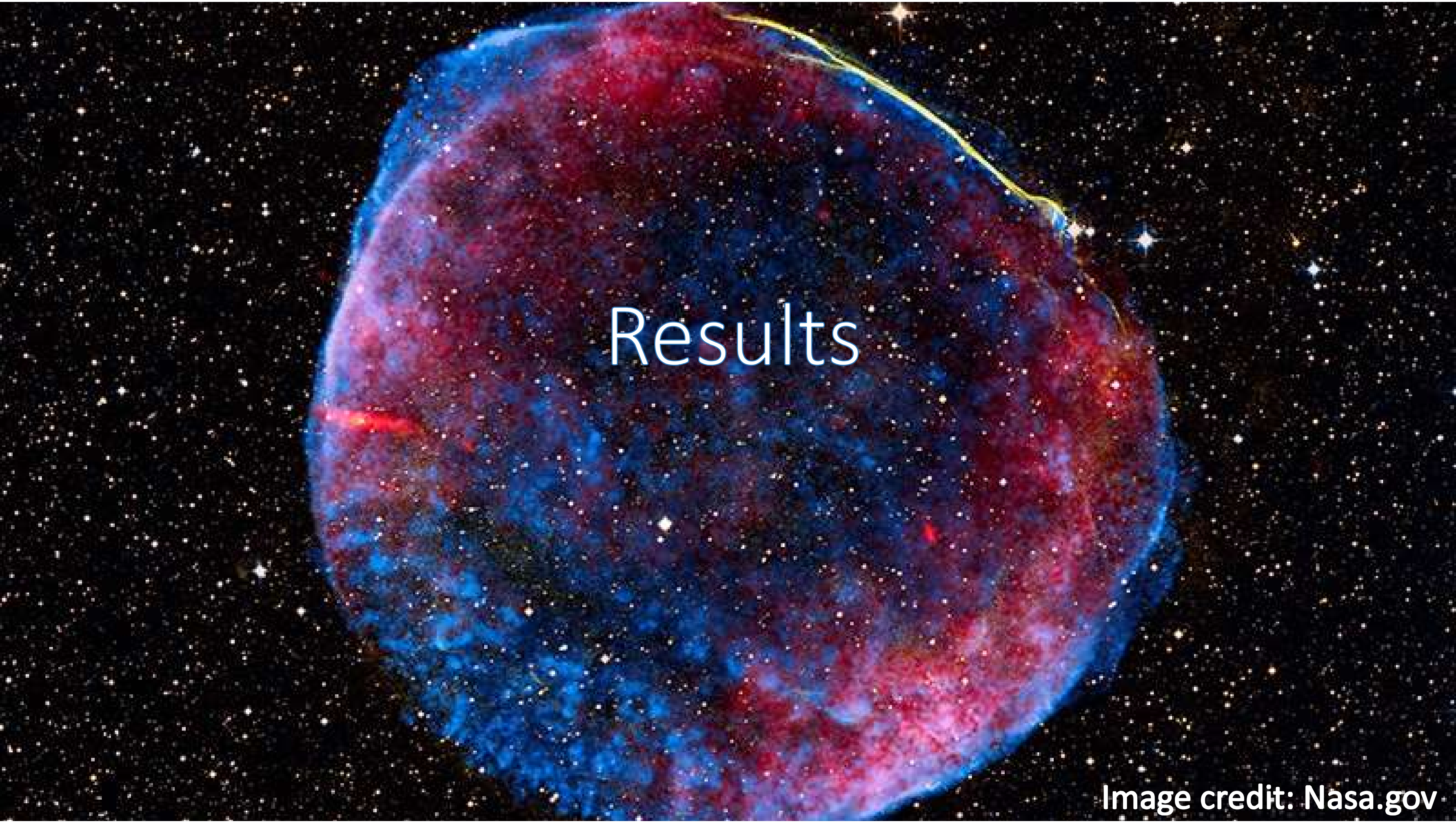


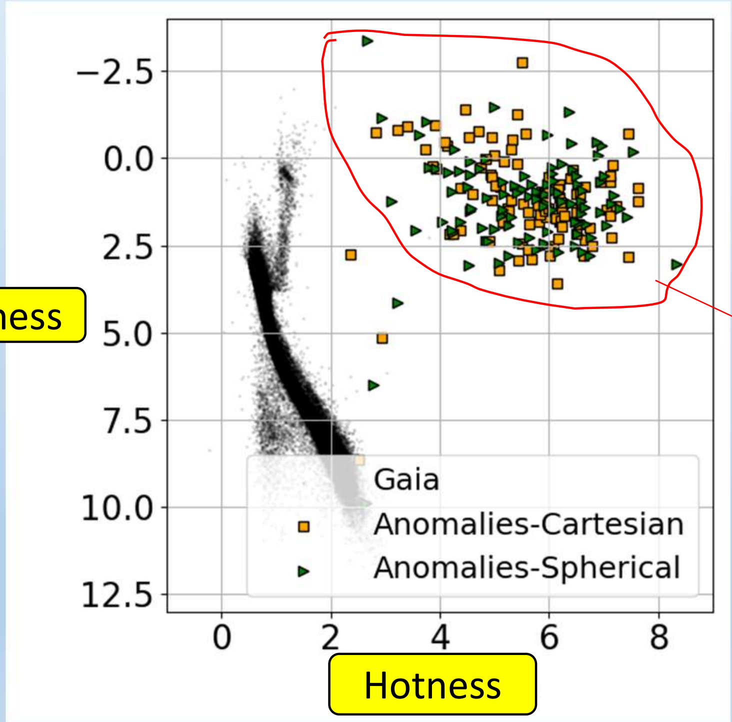
Image credit: Nasa.gov

The Anomalies

- Anomalous periodic variables are
  - Irregular oscillating
  - High variability

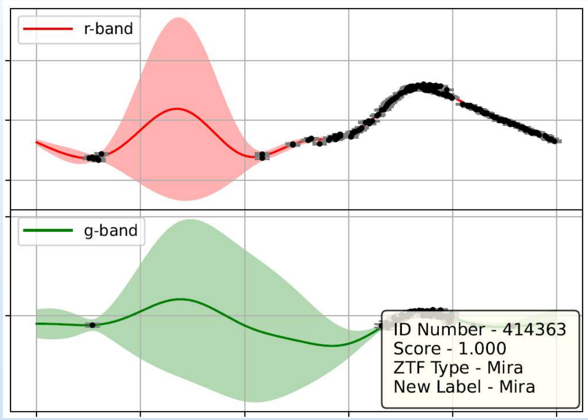
Brighter

Brightness



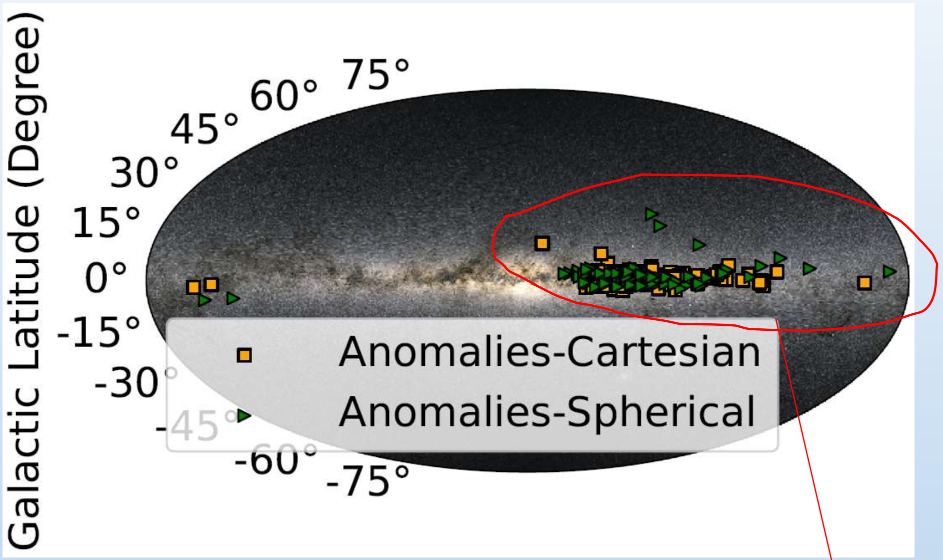
Cooler

Illustrations



- Plotted HR-Diagram
- Anomalies are
  - Brighter
  - Cooler
- Corresponds to evolved stars In their late phase of evolution

The Anomalies



- Located in the vicinity of the Galactic disk
- Younger (with respect to the Galactic age)

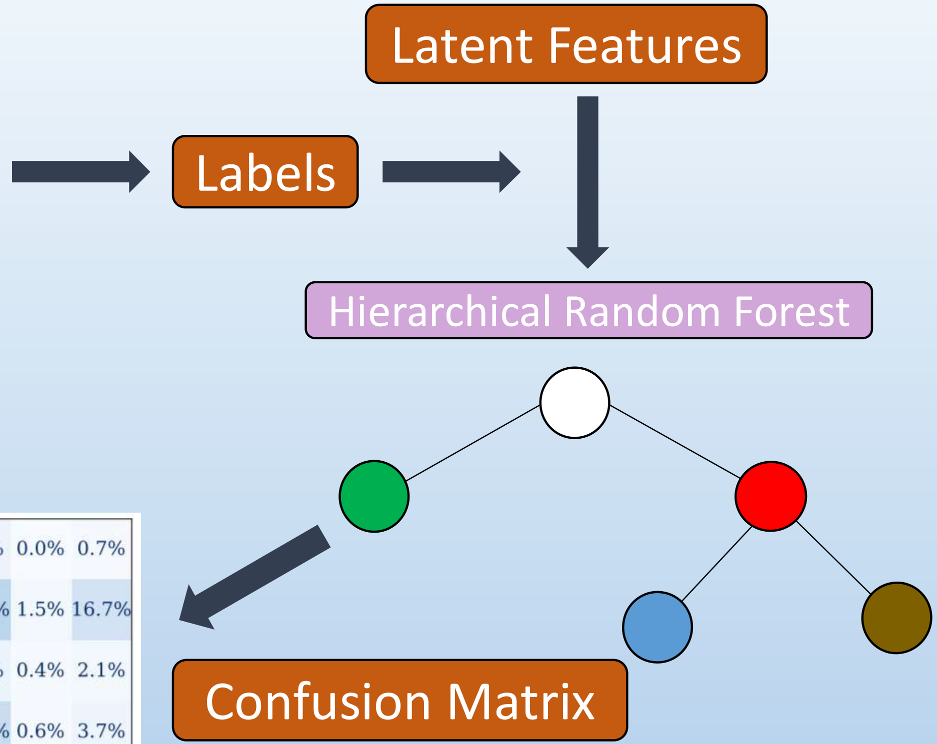
LSST

Image credit: symmetrymagazine.org

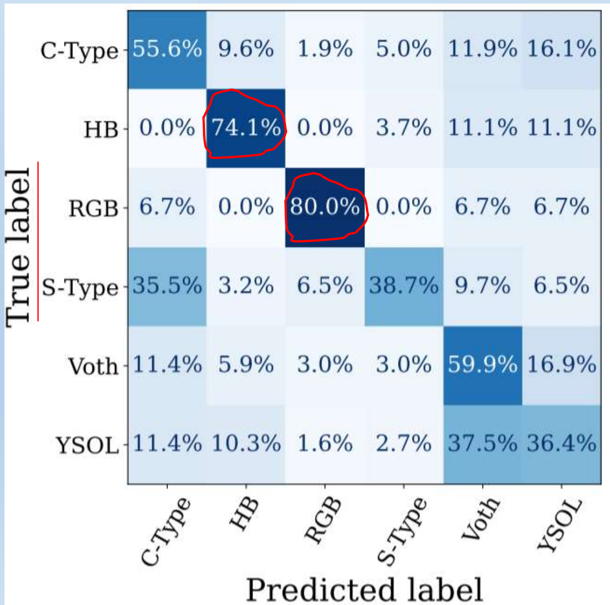
Detailed Spectroscopic Follow-Up Is Strongly Recommended!

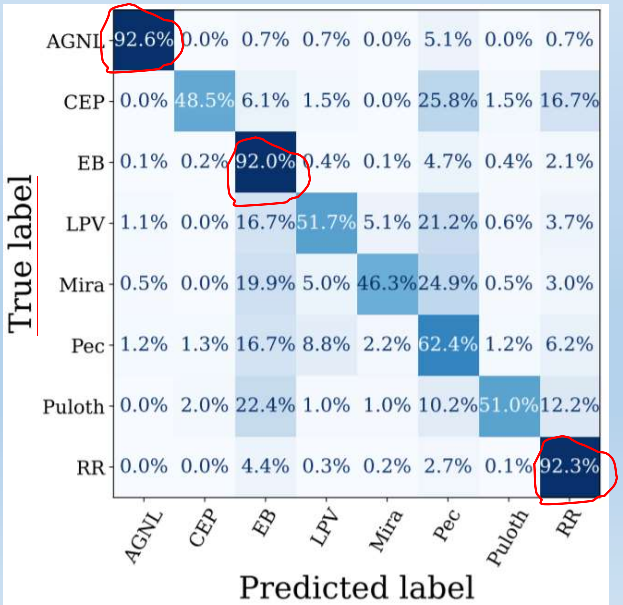
Classifications Using The SIMBAD Labels

Crossmatch



- Class labels from the SIMBAD catalogue
- Reliable but more expensive





- Good accuracy for SOME classes

Conclusion

I showed the application of machine learning in Astronomy for ...

1. Detecting anomalous periodic variable stars
2. Building classification model for periodic variable stars

Thank You