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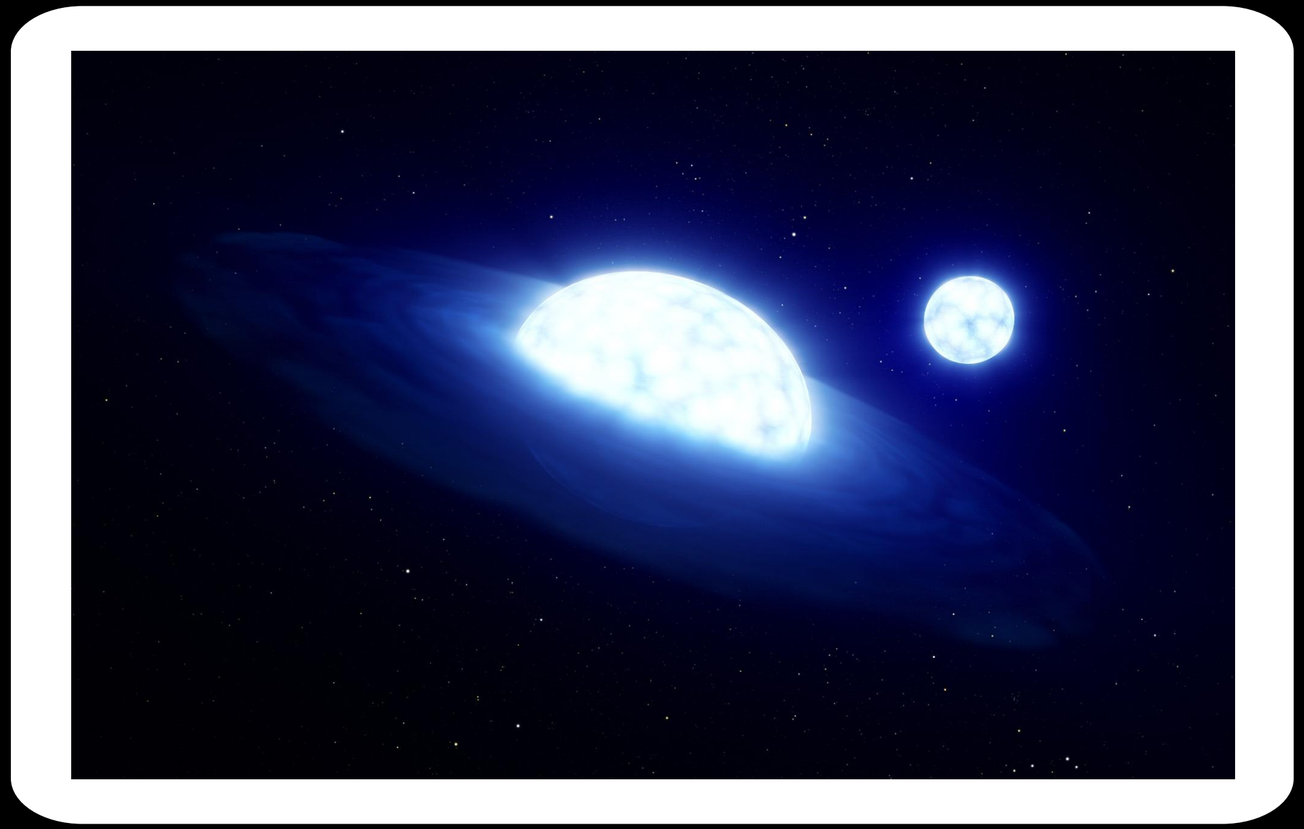
Nagaraj Vernekar

Identification and Classification of eclipsing Be Stars

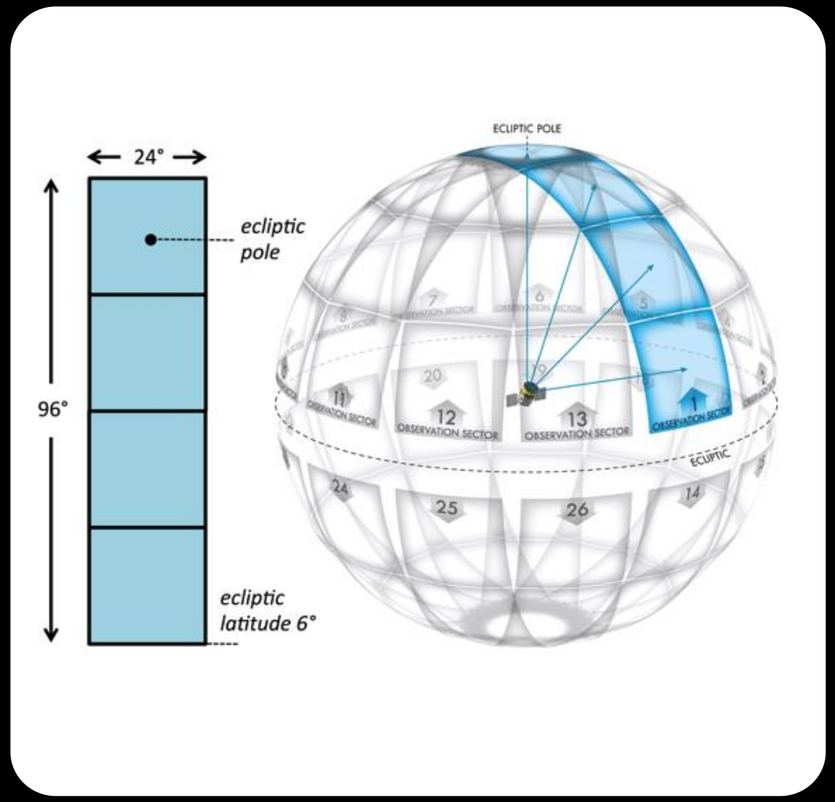


What is a Be star?

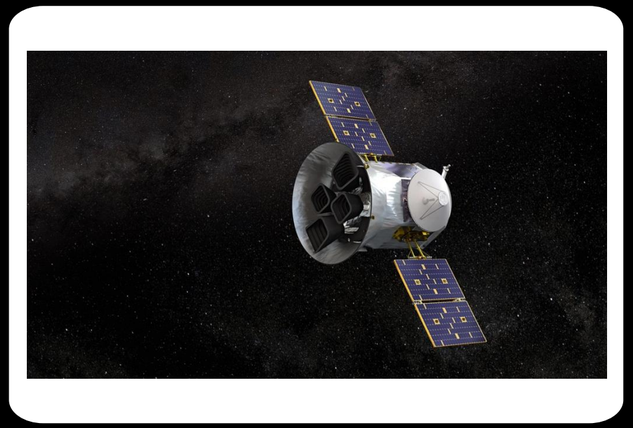
- 2-10 times hotter than the Sun
- Thousands of times brighter
- Possess gaseous equatorial disk

TESS (Transiting Exoplanet Survey Satellite):

- Records photometry. NOT spectra
- 26 sectors, 27 days each
- 2 years to cover both hemispheres

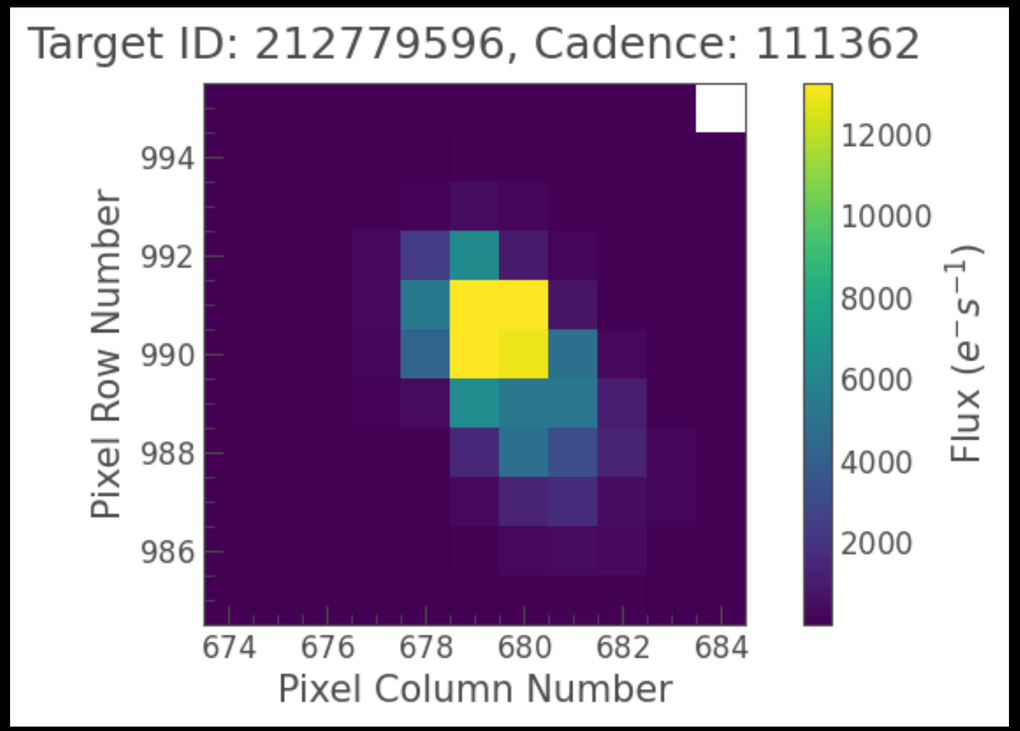


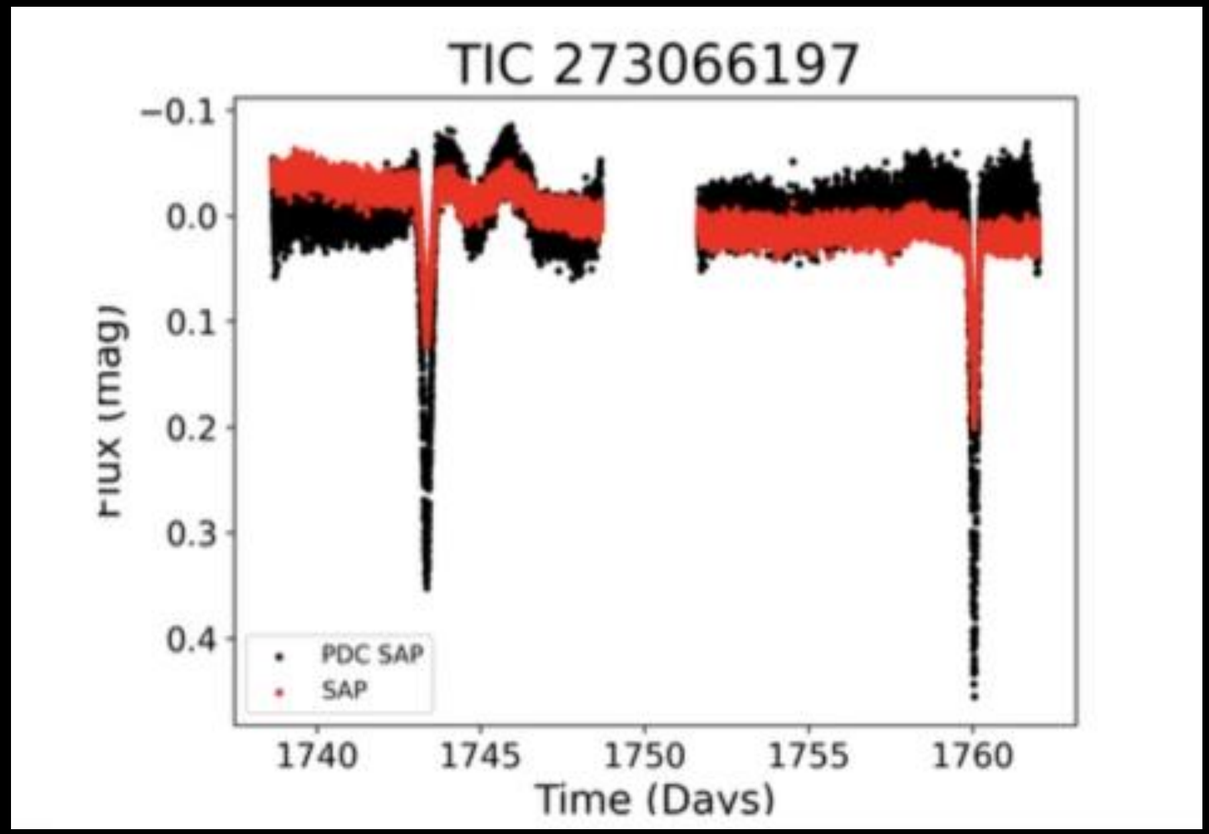
Sectors and hemispheres



Satellite picture

SPOC and SAP/PDCSAP





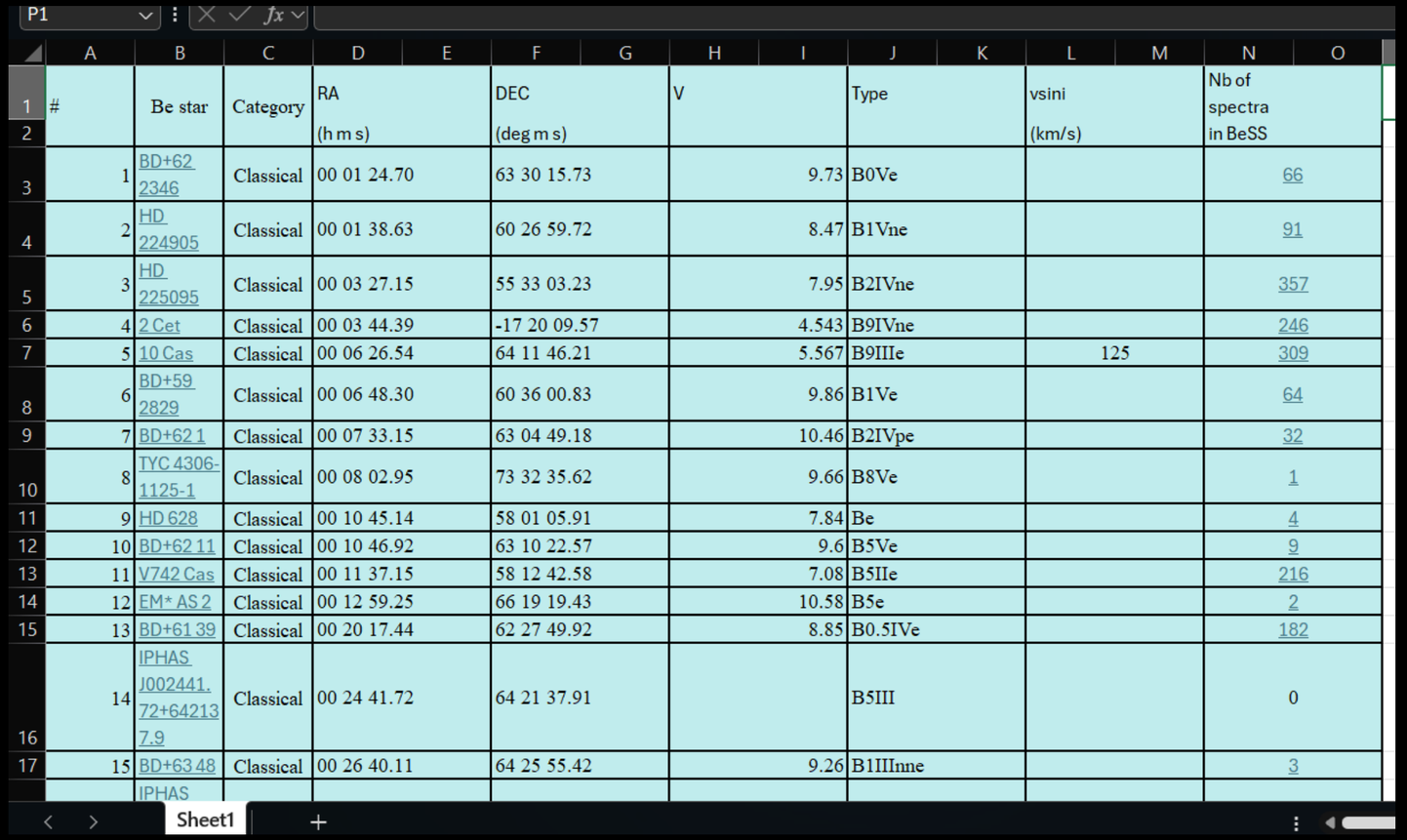
Nagaraj Vernekar, *"On the photometric and spectroscopic variability of Be stars: the case of HD 93683,"* Master's Thesis, KU Leuven (2021), p. 15, Figure 2.3

Initial Methodology

Obtain information about classical Be stars from BeSS.

Use SIMBAD to get the TIC ids.

Write two codes that download and plot light curves



#	Be star	Category	RA (h m s)	DEC (deg m s)	V	Type	vsini (km/s)	Nb of spectra in BeSS
1	BD+62 2346	Classical	00 01 24.70	63 30 15.73	9.73	B0Ve		66
2	HD 224905	Classical	00 01 38.63	60 26 59.72	8.47	B1Vne		91
3	HD 225095	Classical	00 03 27.15	55 33 03.23	7.95	B2IVne		357
4	2 Cet	Classical	00 03 44.39	-17 20 09.57	4.543	B9IVne		246
5	10 Cas	Classical	00 06 26.54	64 11 46.21	5.567	B9IIIe	125	309
6	BD+59 2829	Classical	00 06 48.30	60 36 00.83	9.86	B1Ve		64
7	BD+62 1	Classical	00 07 33.15	63 04 49.18	10.46	B2IVpe		32
8	TYC 4306-1125-1	Classical	00 08 02.95	73 32 35.62	9.66	B8Ve		1
9	HD 628	Classical	00 10 45.14	58 01 05.91	7.84	Be		4
10	BD+62 11	Classical	00 10 46.92	63 10 22.57	9.6	B5Ve		9
11	V742 Cas	Classical	00 11 37.15	58 12 42.58	7.08	B5IIe		216
12	EM* AS 2	Classical	00 12 59.25	66 19 19.43	10.58	B5e		2
13	BD+61 39	Classical	00 20 17.44	62 27 49.92	8.85	B0.5IVe		182
14	IPHAS J002441.72+642137.9	Classical	00 24 41.72	64 21 37.91		B5III		0
15	BD+63 48	Classical	00 26 40.11	64 25 55.42	9.26	B1IIInne		3
	IPHAS							

Research code- Python

The LightKurve Python package was used to facilitate the process.

Downloading data code

```
[22]: import warnings
      import pandas as pd
      import lightkurve as lk

      warnings.filterwarnings("ignore")

      EXCEL_FILE = "Just_TIC.xlsx"
      COLUMN_NAME = "TIC"


      df = pd.read_excel(EXCEL_FILE)

      tic_list = (
          df[COLUMN_NAME]
          .dropna()
          .astype(str)
          .tolist()
      )

      print(f"{len(tic_list)} TIC IDs loaded.")


      all_lightcurves = {}

      log = []


      for tic in tic_list:

          print("="*70)
          print(f"TIC {tic}")
```

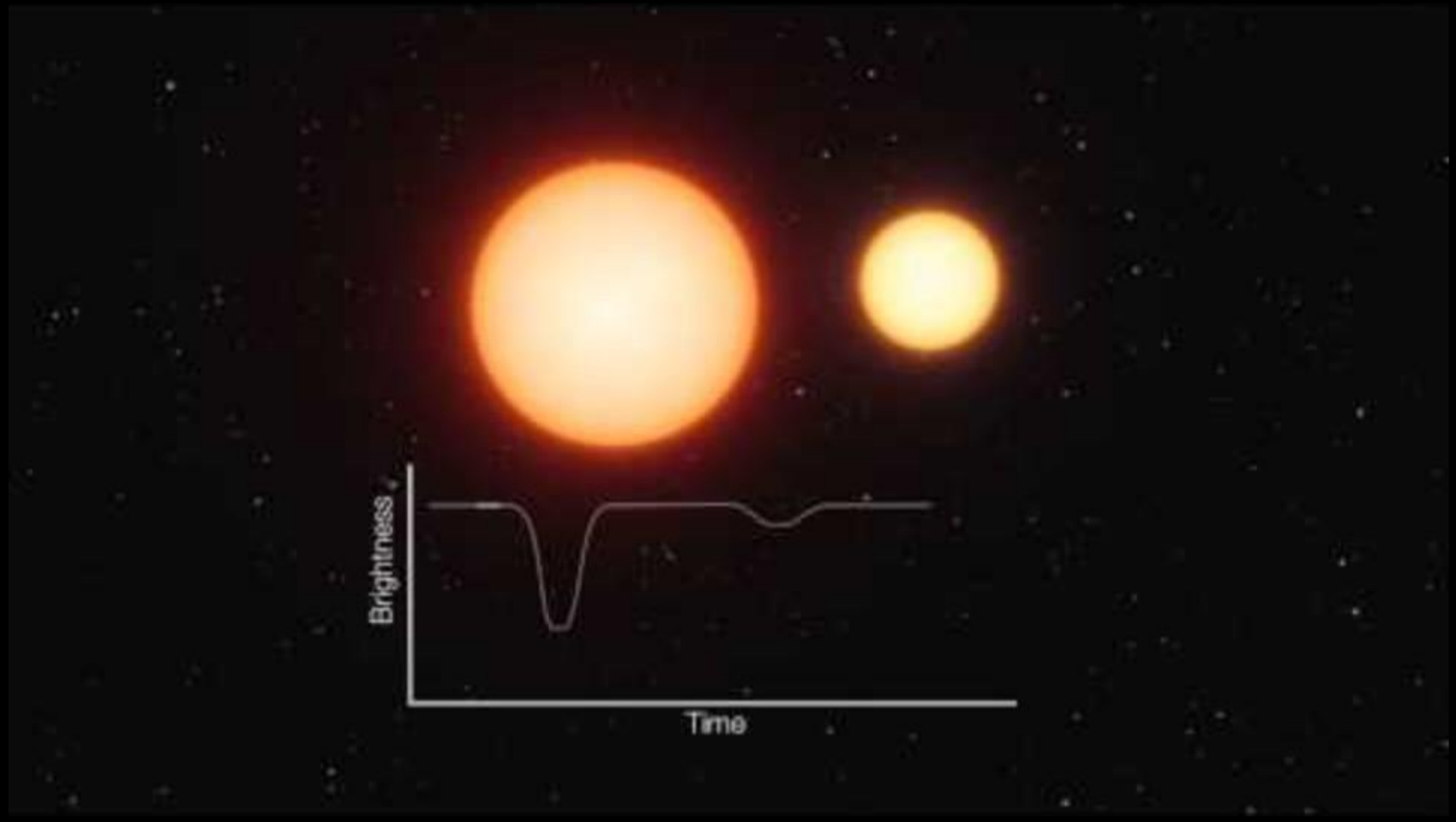
First Program:
Downloads all the data

Plotting Code

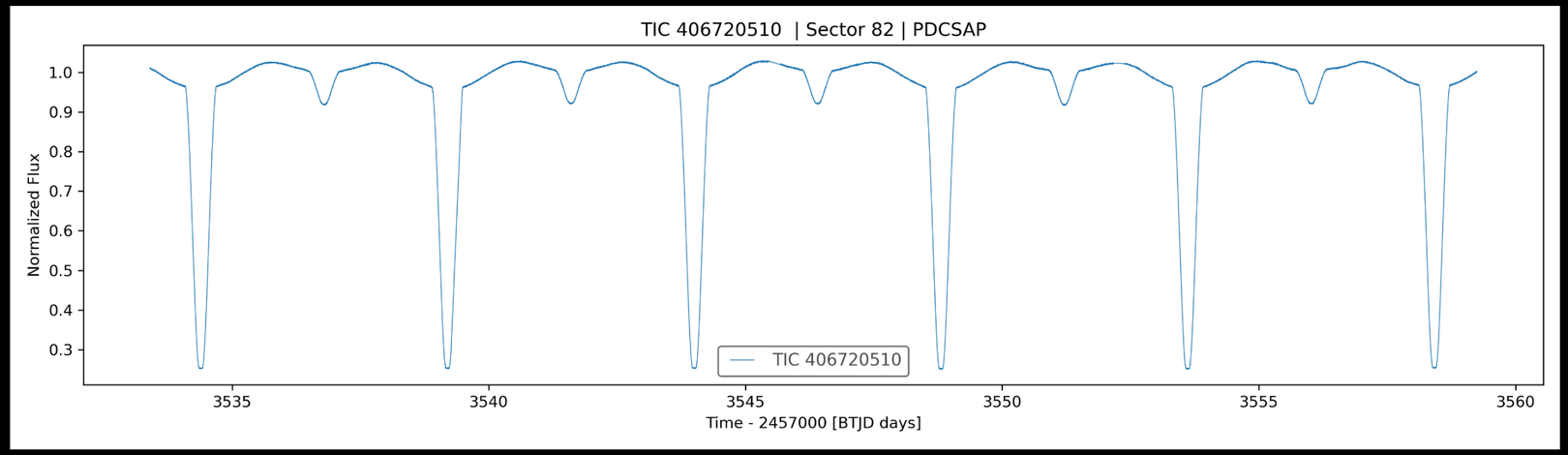
```
[1]: import os
     import pickle
     import matplotlib.pyplot as plt

     with open("all_lightcurves.pkl", "rb") as f:
         all_lightcurves = pickle.load(f)

     print(f"{len(all_lightcurves)} TICs loaded.")


     output_folder = "Results"
     os.makedirs(output_folder, exist_ok=True)


     for tic, sectors in all_lightcurves.items():

         if len(sectors) == 0:
             continue

         tic_folder = os.path.join(output_folder, f"TIC_{tic}")
         os.makedirs(tic_folder, exist_ok=True)

         fig, ax = plt.subplots(figsize=(18, 5))

         for sector in sorted(sectors):
             lc = sectors[sector]

             lc.plot(
                 ax=ax,
                 label=f"Sector {sector}"
             )
```

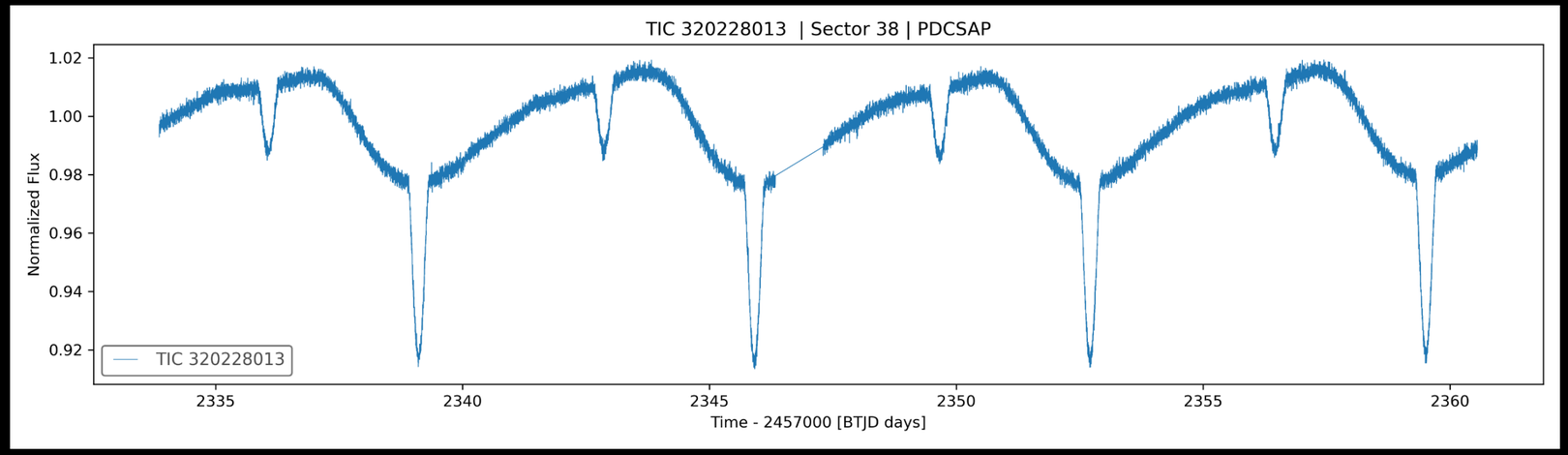
Second Program:
Generates two different types of figures for all stars

Quick video example

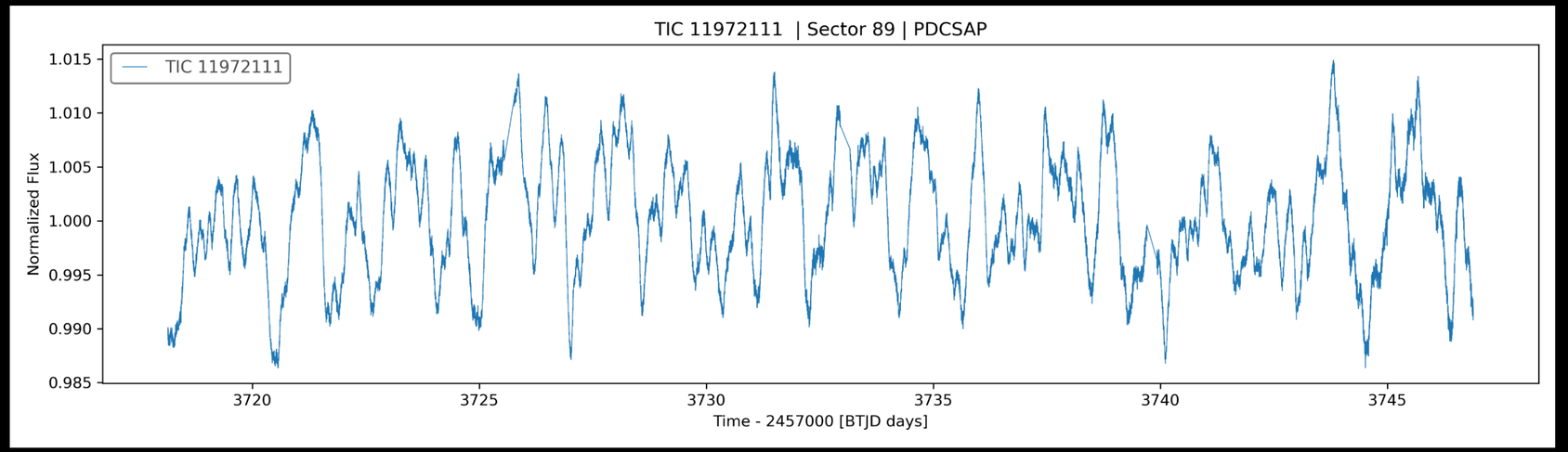


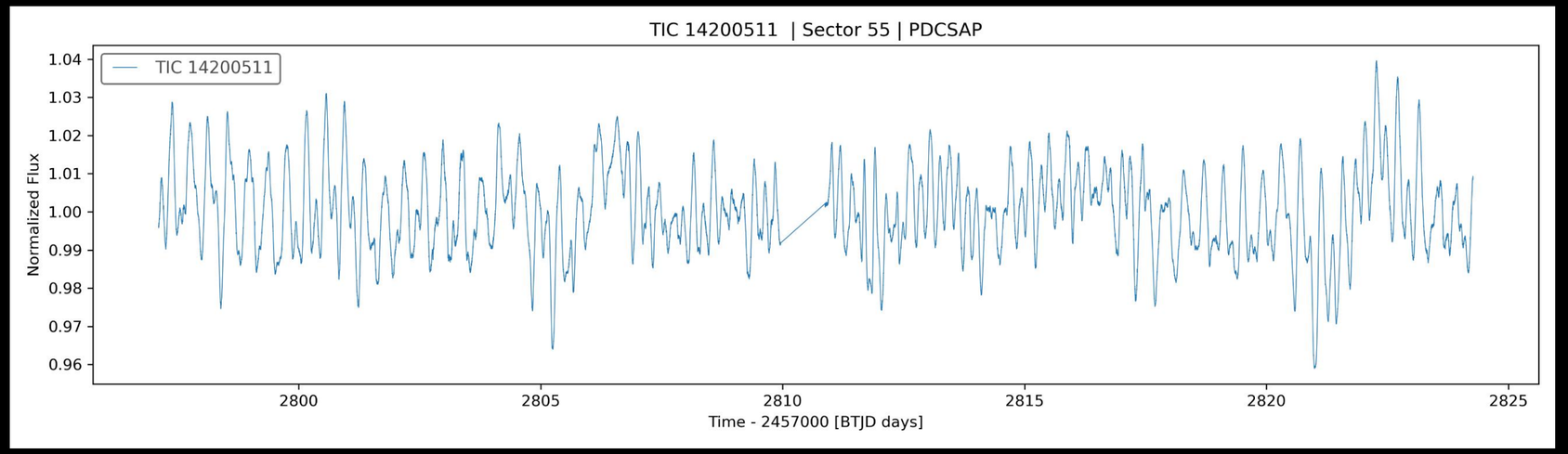
Manual Observation: Eclipsing Examples





Manual Observation: Non-Eclipsing Examples



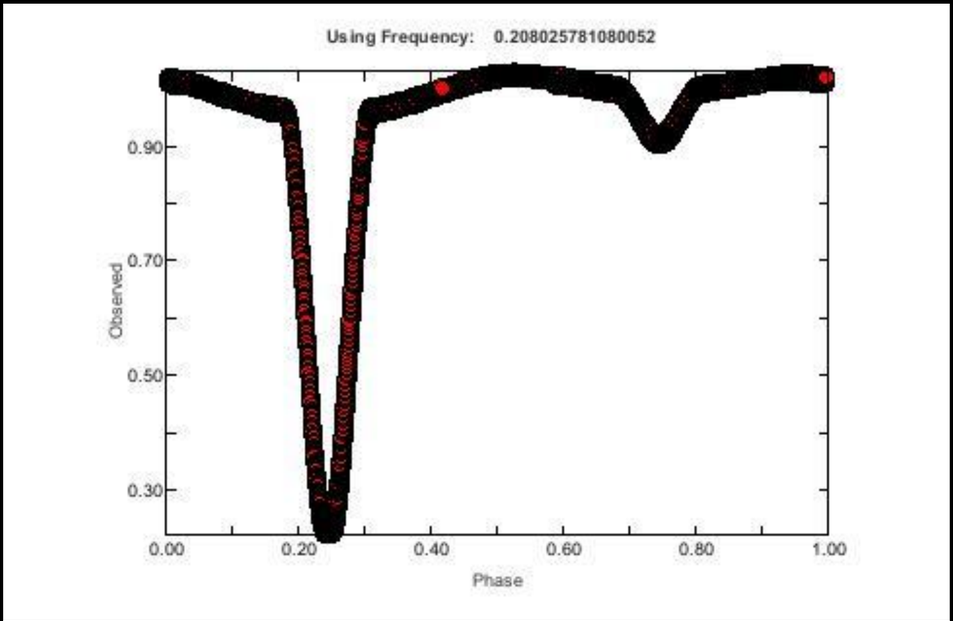


Period04 and Phase Folding

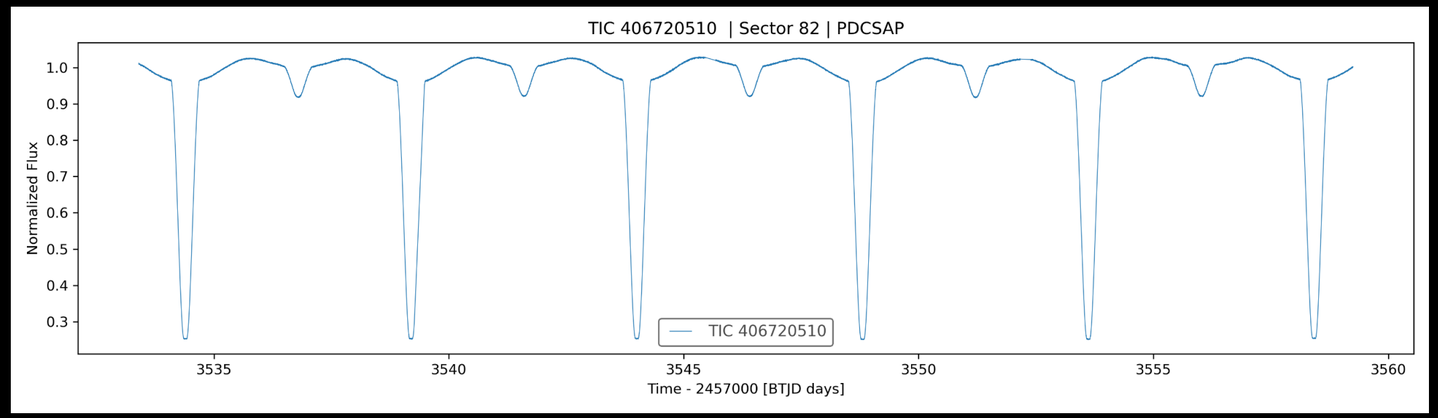
Period

$$T = \frac{1}{f}$$

Frequency



Phase folded light curve



Regular light curve

What’s next?

- Literature survey
- Spectroscopic observations
- Binary modeling


THANK YOU