WHITE DWARFS IN THE BLUE: EXPLORING THE UV SIDE OF A DOUBLE DEGENERATE SYSTEM

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OUTLINE

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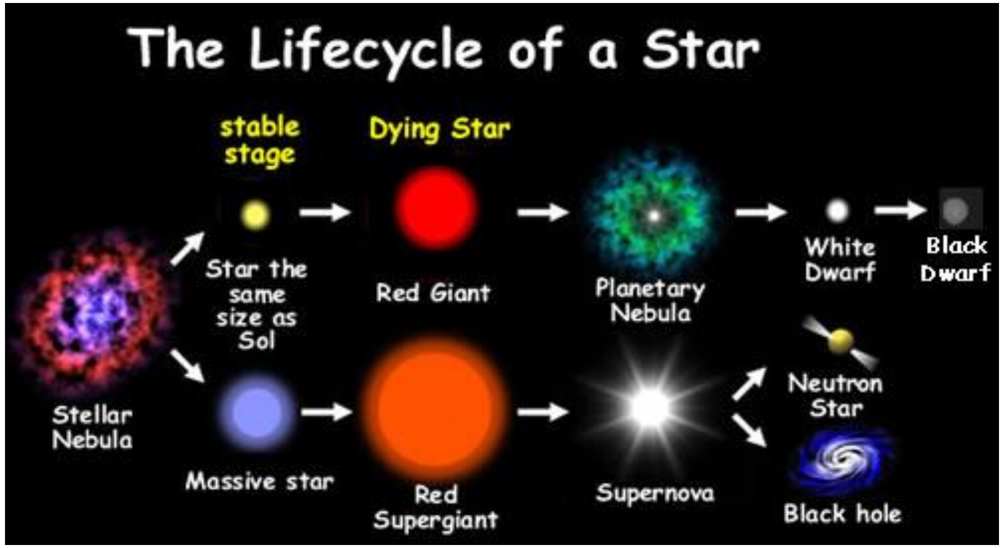
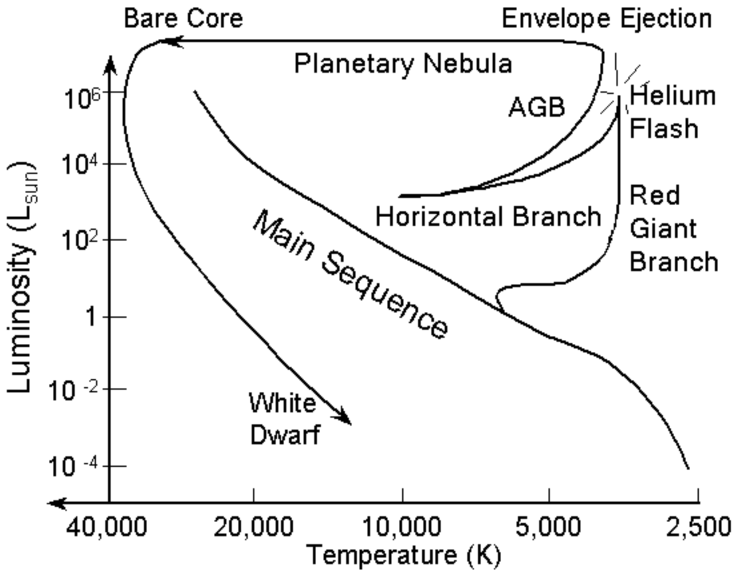
WHAT IS A WHITE DWARF?

- A white dwarf (WD) is the final known phase in the life cycle of low-mass stars
- The vast majority of stars will become white dwarfs at the end of their life
- A typical WD is extremely dense with masses around 0.6 $M_\odot$ and 0.013 $R_\odot$



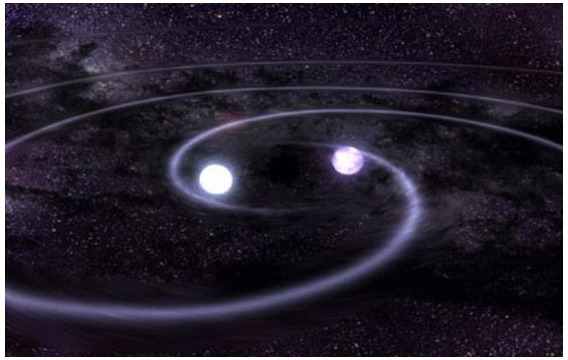


SOME REASONS WHY WHITE DWARFS ARE INTERESTING

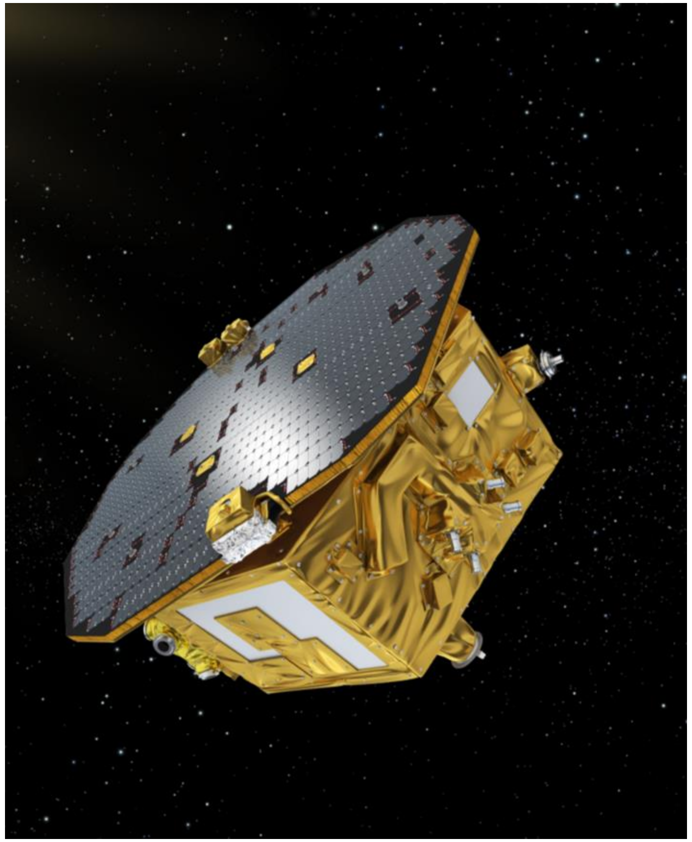
- Because of their continuous cooling, the observable properties of white dwarfs change drastically as they age, making them uniquely precise cosmic clocks. They have been used to measure the age of a variety of stellar populations
- Because ~98% of the stars in our Galaxy will become WDs at the end of their lives, all the elements ejected to the interstellar medium during the planetary nebula explosion will create a change in the chemistry of the Galaxy. Therefore, they give us important information about the chemical evolution of the Milky Way.

WHAT IS THE PROJECT?

- J2322+0509 is a detached binary composed of two He-core white dwarfs with an orbital period of 1201s at ~27 degree inclination
- The low inclination makes this system a strong source of gravitational waves
- We have gotten UV HST STIS data to characterize the parameters of the system such as mass, period, inclination, and temperature



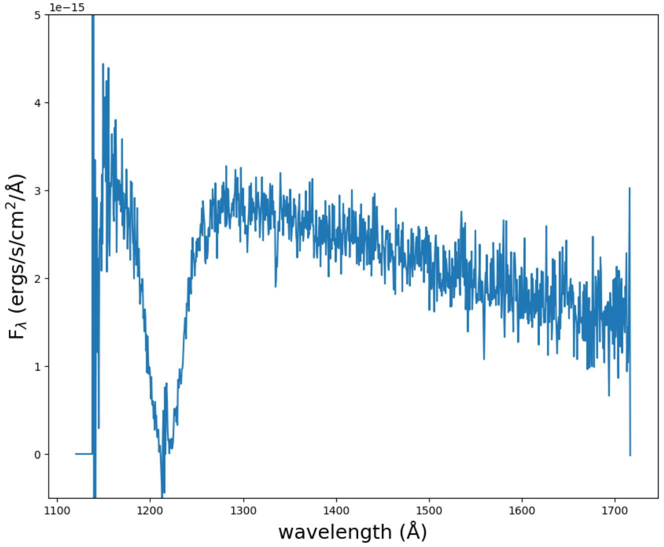
WHY IS THE PROJECT IMPORTANT?

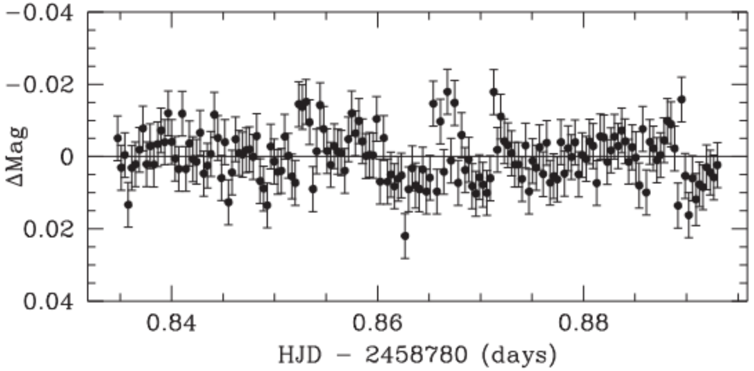


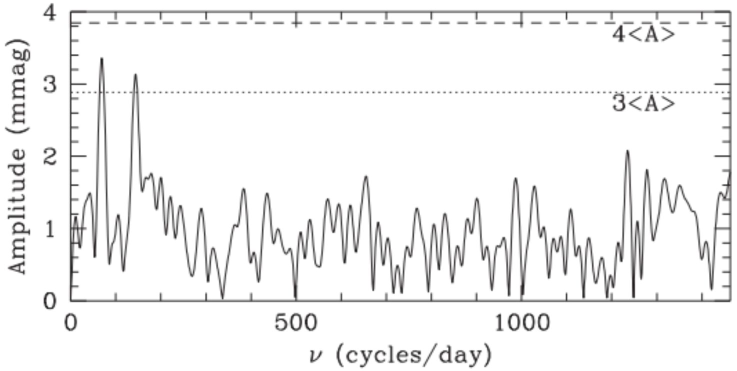
- J2322+0509 is the first He core WD verification binary for the Laser Interferometer Space Antenna (LISA) which is planned to launch in 2037
    - WDs can be observed with both light and gravitational waves (GWs)
    - WD + WD binaries are expected to be the most prolific LISA source
- LISA will continuously monitor the entire sky. It has been estimated that knowing a binary's sky position and having an inclination constraint can improve its GW parameter uncertainties.

PROJECT GOALS

- Characterize the parameters of the first He+He WD LISA verification binary, a source class that is predicted to account for one-third of all resolved LISA ultra-compact binary detections.
- Constrain the temperature and mass of the primary WD with high precision. Considering this and the previous ground-based optical and near-infrared photometry/spectroscopy data, it will allow us to constrain the parameters of the secondary WD precisely.
- Constrain the inclination angle of the binary precisely, which is essential for the gravitational wave strain estimates.







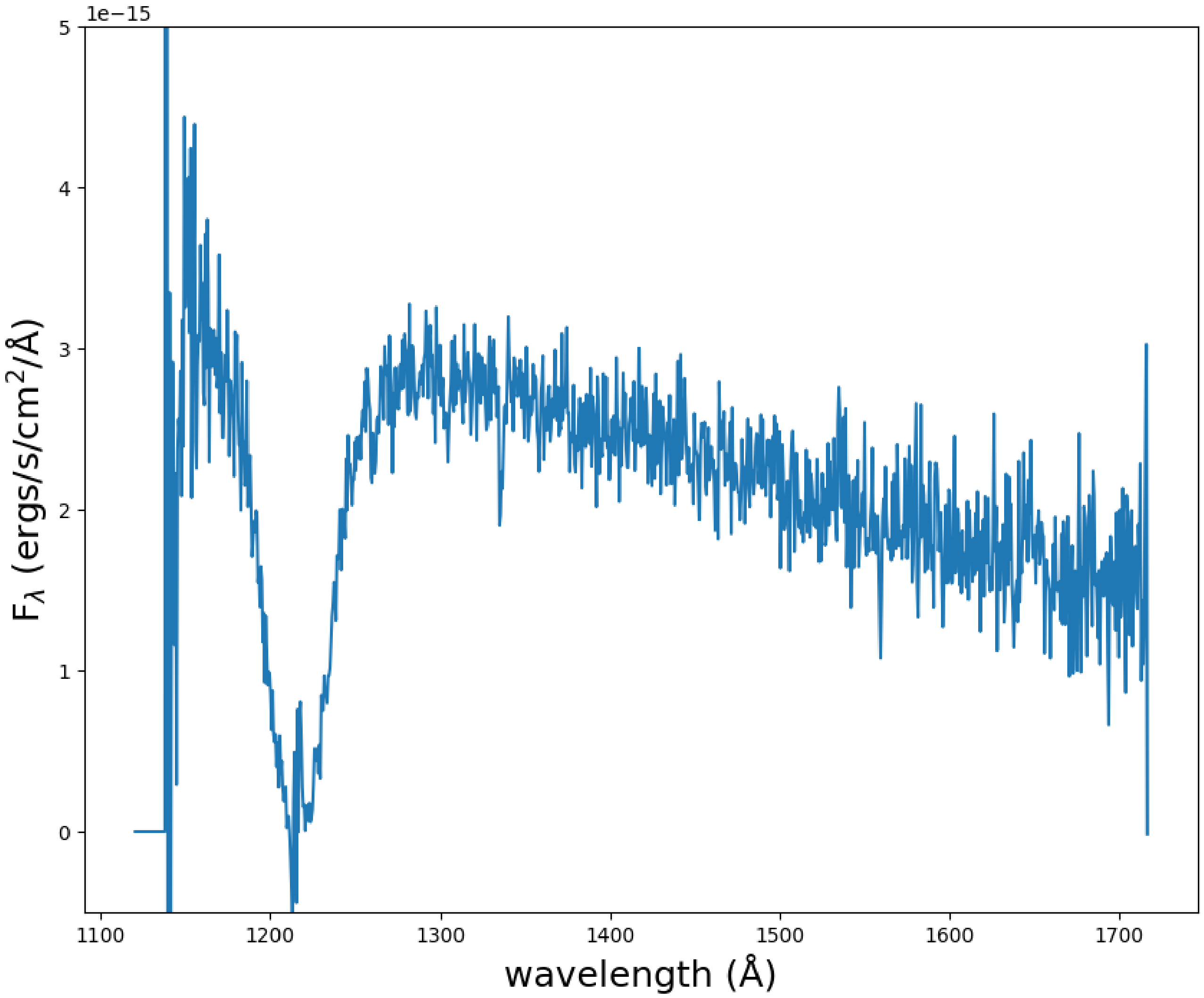
WHAT I HAVE DONE

- I have:
  1. Manipulated spectra for the three HST data sets that we have using python
  2. Used the Image Reduction and Analysis Facility (iraf) program to combine the three spectra for a higher S/N
  3. Worked with time-tag method on HST STIS data
  4. Created light curves
  5. Used Period O4 program to constrain the period of the system
  6. GAINED RESEARCH EXPERIENCE AND BECOME FAMILIARIZED WITH THE DIFFERENT TELESCOPES AND DATA AVALIABLE

STEP 1

Manipulate spectra for the three HST data sets that we have using python

OEA101010 SPECTRA



Spectra:

- This is one exposure of ~2200s
- This shows the Lyman-alpha line

STEPS 2 & 3

Use the Image Reduction
and Analysis Facility (iraf) program

&

Work with time-tag method
on HST STIS data

TIME TAG METHOD

Odelay

- Applies the light delay correction
- Inttag only uses the values in a column called TIME, so it is convenient to overwrite the existing TIME column. The odelay command is used to correct the time for heliocentric and barycentric light delay.

Inttag

- Converts Time-Tag events into an Accum image
- For multiple sub exposures you will want to set the time interval of each sub exposure and the number of sub exposures. You can accomplish this by setting the parameters of the inttag command.

Calstis

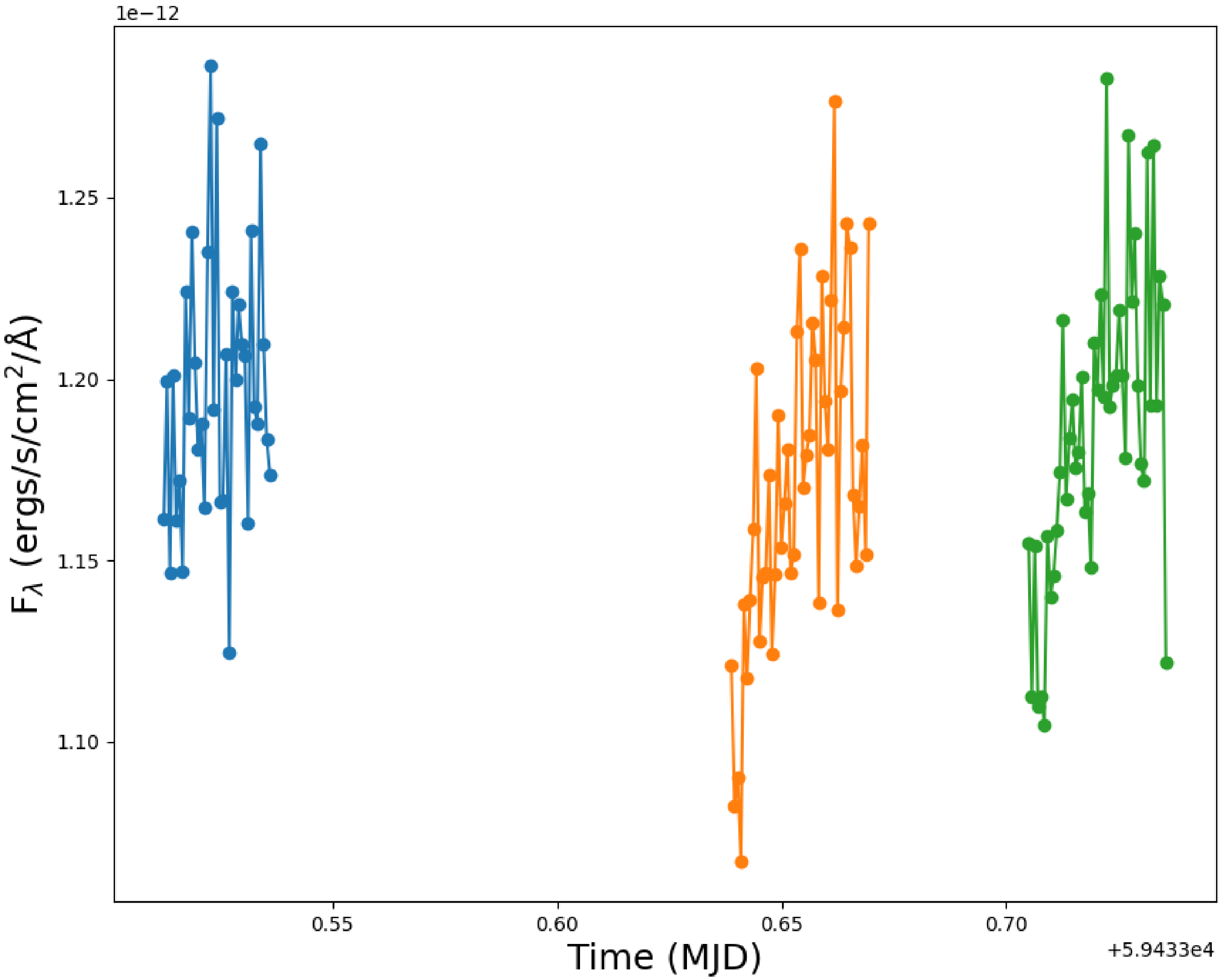
- Calibrates the Accum image and extract a 1-D spectrum

STEP 4

Creating light curves

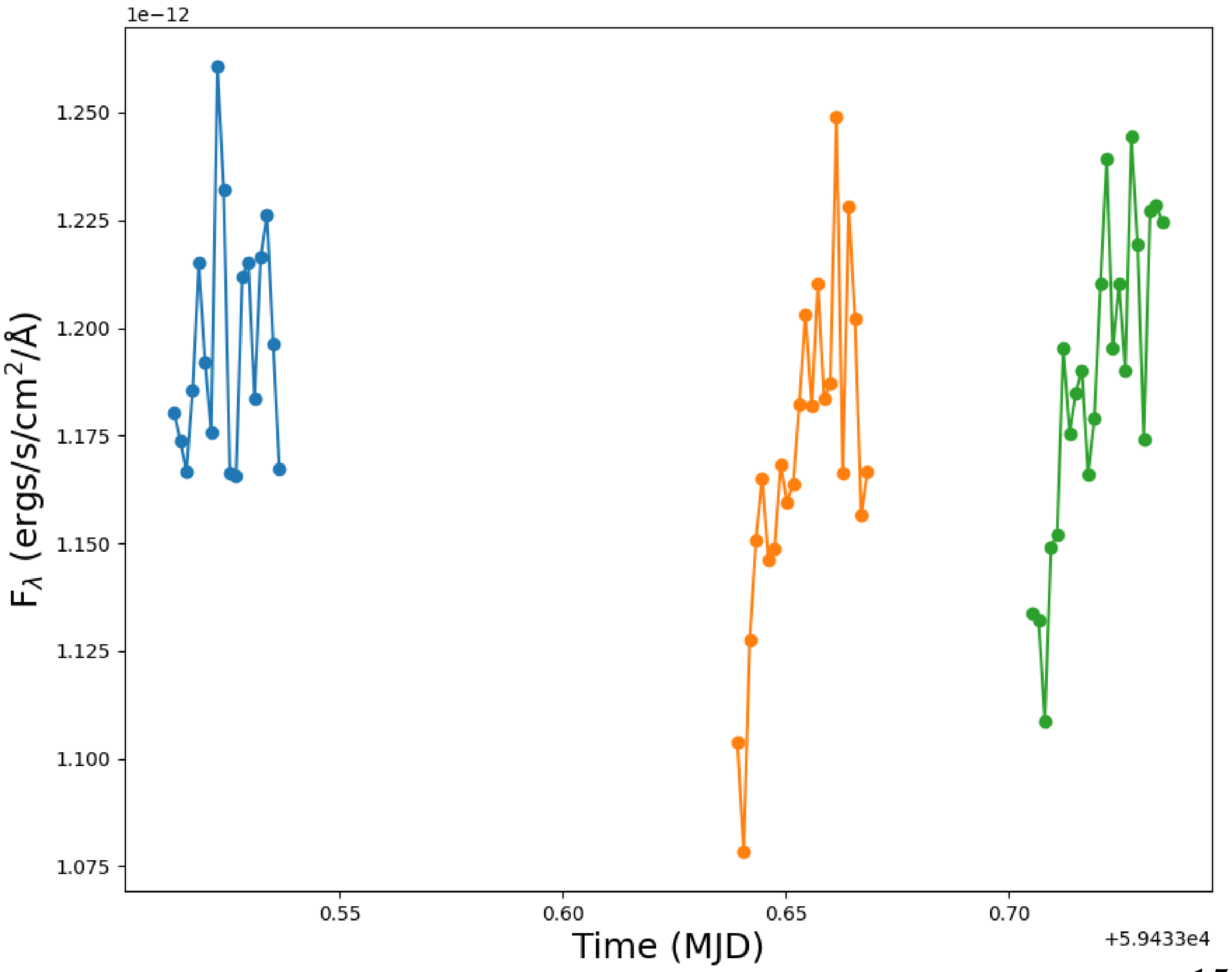
LIGHTCURVE

- 60 second exposures



LIGHTCURVE

- 120 second exposures
- Reduced noise



STEP 5

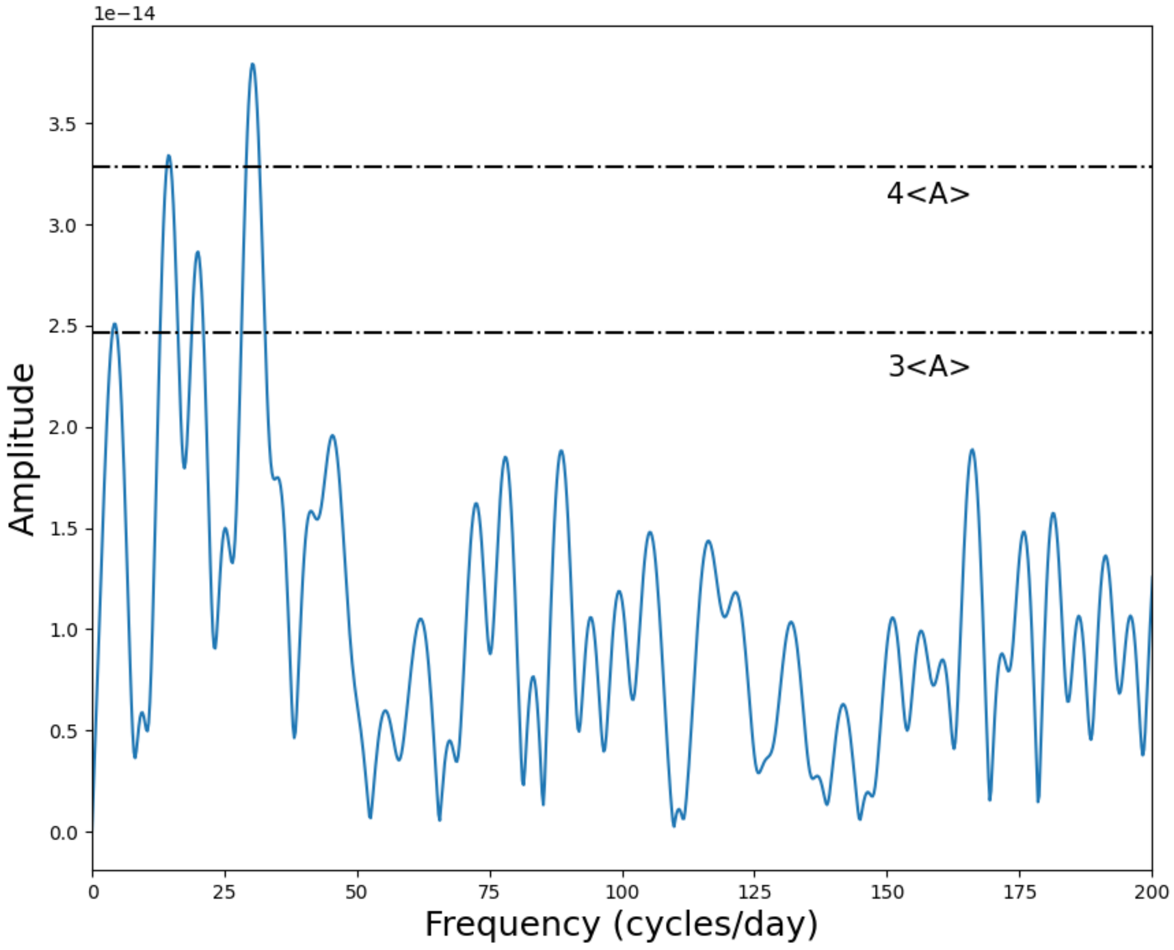
Using Period O4 program
to constrain the period
of the system

PERIOD04

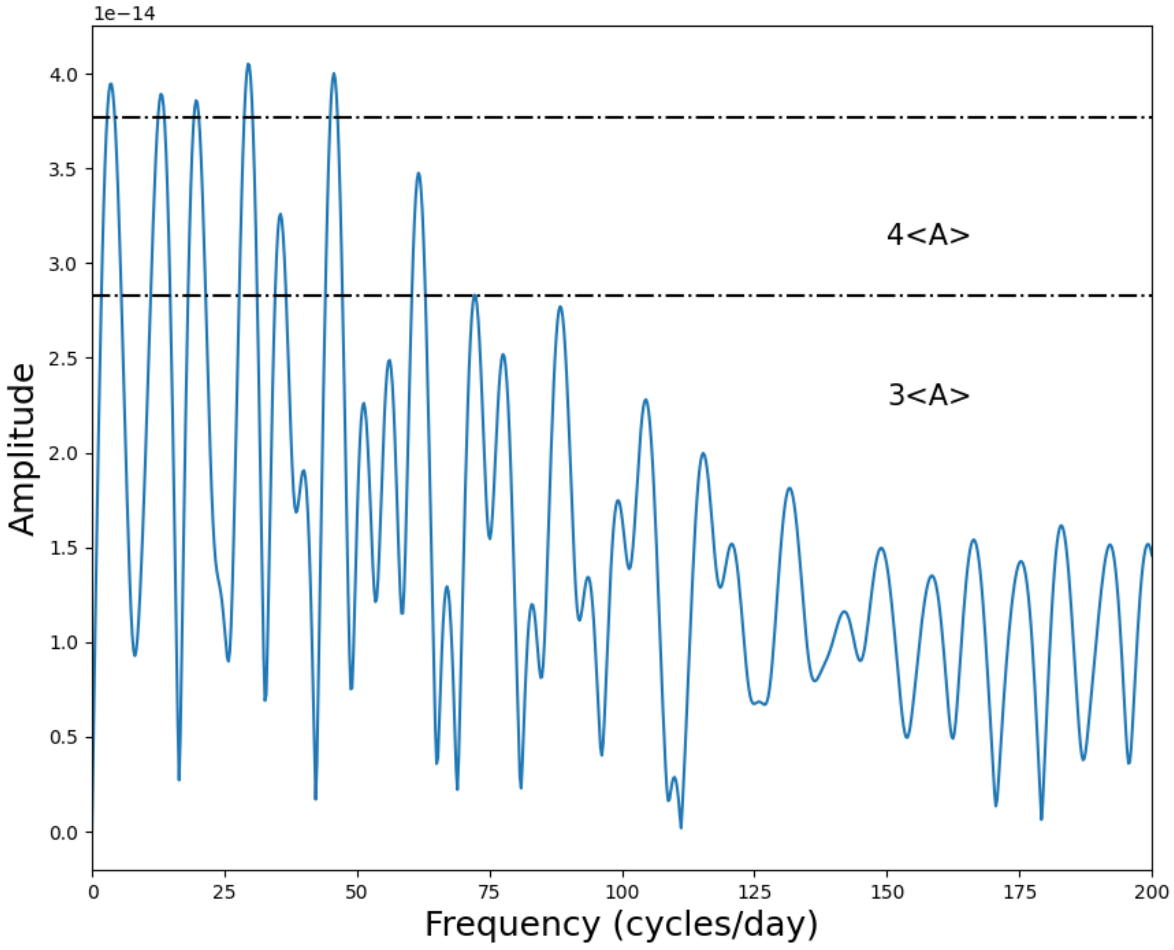
Period04 is a computer program especially dedicated to the statistical analysis of large astronomical time series containing gaps. The program offers tools to extract the individual frequencies from the multiperiodic content of time series and provides a flexible interface to perform multiple-frequency fits.

FOURIER TRANSFORM

- 120 s exposures
- 30 cycles/day
- T=1/f
- So, what conclusions can we make?



FOURIER TRANSFORM



QUESTIONS?

SOURCES

Text

- Brown, W. R., Kilic, M., Bedard, A., Kosakowski, A. & Bergeron, P. A 1201 s Orbital Period Detached Binary: the First Double Helium Core White Dwarf LISA Verification Binary. *arXiv.org* https://arxiv.org/abs/2004.00641v1 (2020) doi:10.3847/2041-8213/ab8228.
- Dashevsky, I., Sahu, K. & Smith, E. STIS Time-Tag Analysis Guide.
- Saumon, D., Blouin, S. & Tremblay, P.-E. Current challenges in the physics of white dwarf stars. *Physics Reports* **988**, 1–63 (2022).
- The First Double Helium White Dwarf LISA Verification Source.

Images

- Image 1 & 5: phys.org
- Image 2: picture credit cyberphysics.UK
- Image 3: uc.edu
- Image 4: universetoday.com
- Image 6: creativecommons.org
- Image 7: lisa.nasa.org