Development of a T Tauri Star Spectral Analysis Infrastructure

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Motivation

- Significant research progress in recent times
  - Star-forming regions
  - Young stars
  - Exoplanet research
- Understanding how planetary systems form
  - Necessary to study development of young stars and interactions with surrounding disk material

https://www.spacetelescope.org/news/heic1007/

https://www.nasa.gov/feature/jpl/20-intriguing-exoplanets

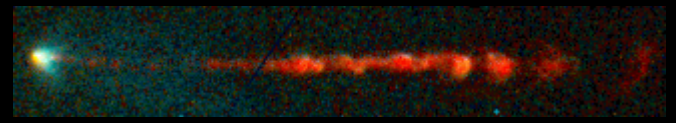
https://www.eso.org/public/images/eso1436a/

Background: T Tauri stars

- Young stars
  - Millions of years old (versus stellar lifetimes of billions of years old)
- Beginning of nuclear fusion in core
  - Pre-main sequence
- Highly active
  - Polar jets eject stellar material from accreting material
- Often accompanied by circumstellar disks

https://www.cfa.harvard.edu/news/su201623

http://homepages.uc.edu/~hansonmm/ASTRO/LECTURENOTES/W02/Lec6/Page9.html



http://homepages.uc.edu/~hansonmm/ASTRO/LECTURENOTES/W02/Lec6/Page9.html

Background: Circumstellar disks

- Collection of material collapsed into a disk surrounding the star
  - Leftover material from collapse of original stellar gas cloud
  - Planets form here
- Interaction with central star
  - Accretion of disk material onto star
    - Outflow as well
  - Radiative excitation of disk material during accretion
  - Visible in stellar spectrum

http://www.spitzer.caltech.edu/images/2027-ssc2009-11b1-The-Disk-of-an-Erupting-Star

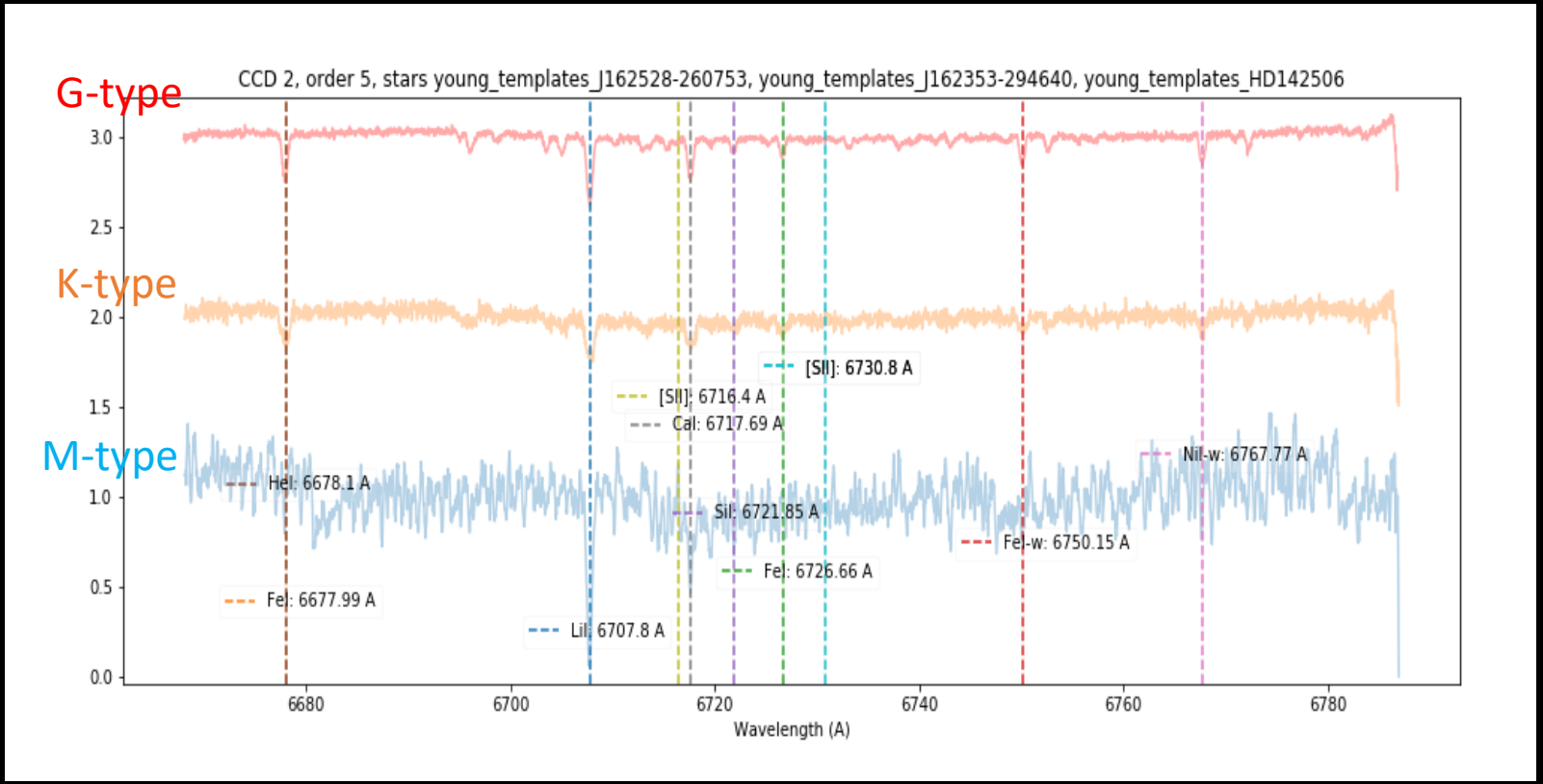
Project Outline

- Software Infrastructure
  - IPython Notebook
  - Python 2.7
  - Numpy, astropy, matplotlib, and more
  - Separate directories for distinct types of data
    - Young template stars, standard stars, object stars
    - Spectral lines and atmospheric absorption bands
- Analysis of Keck Observatory HIRES (high resolution) stellar spectroscopy data
  - ~ 4000–9000 A (optical spectrum)
  - Resolution of ~40000
- Two major goals
  - Stellar properties of T Tauri stars
  - Accretion properties of circumstellar disk and T Tauri star

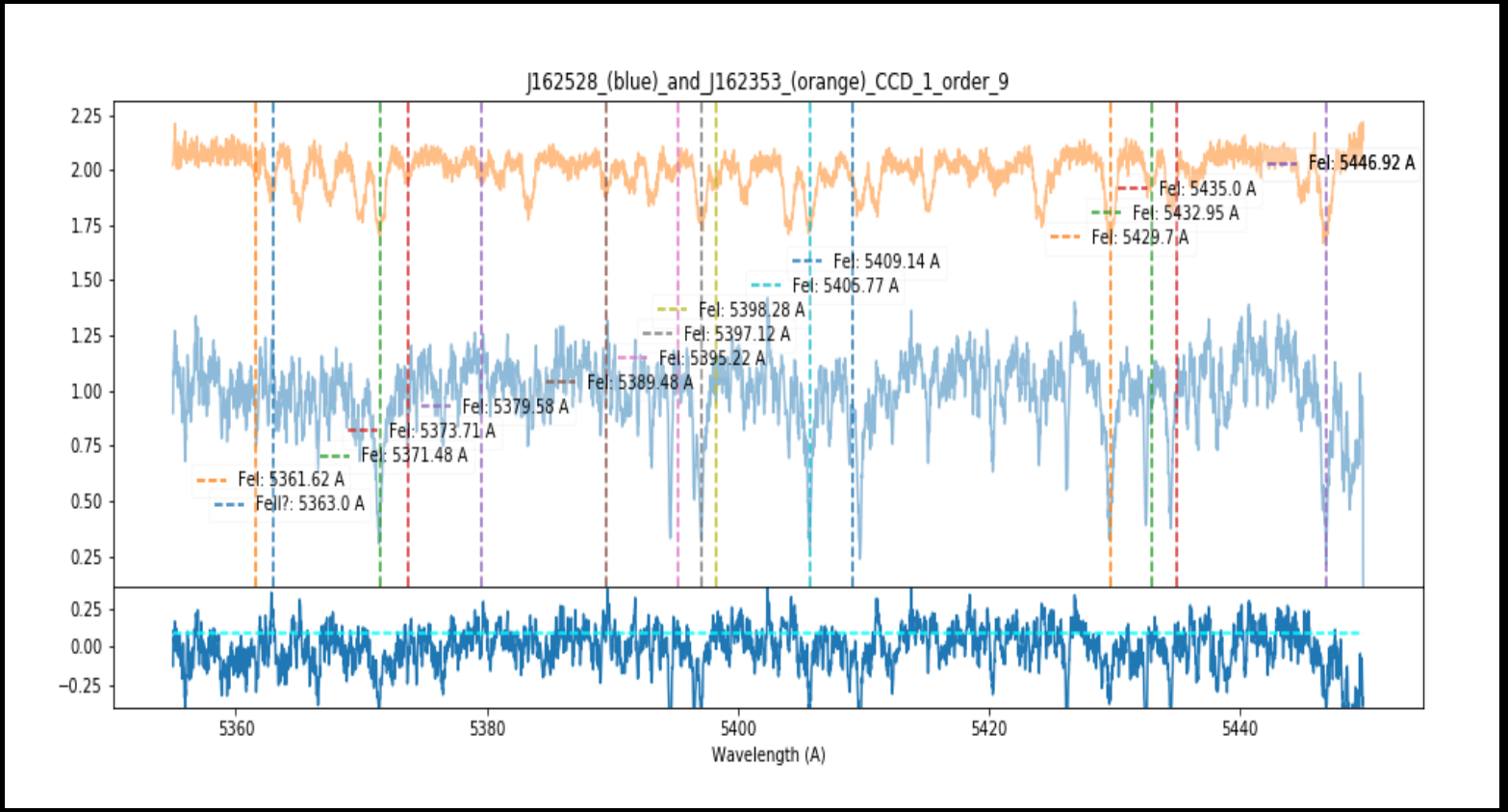
Analysis Tools: Examining Stellar Properties

- Data visualization
- Comparison of spectra
- Determining key stellar properties directly from spectrum data
  - Signal-to-noise
  - Radial velocity
  - Line identification
  - Equivalent width
  - Emission line detection
  - Plots of stellar properties against each other
    - Application for spectral type classification
  - Projected rotation velocity (vsini)

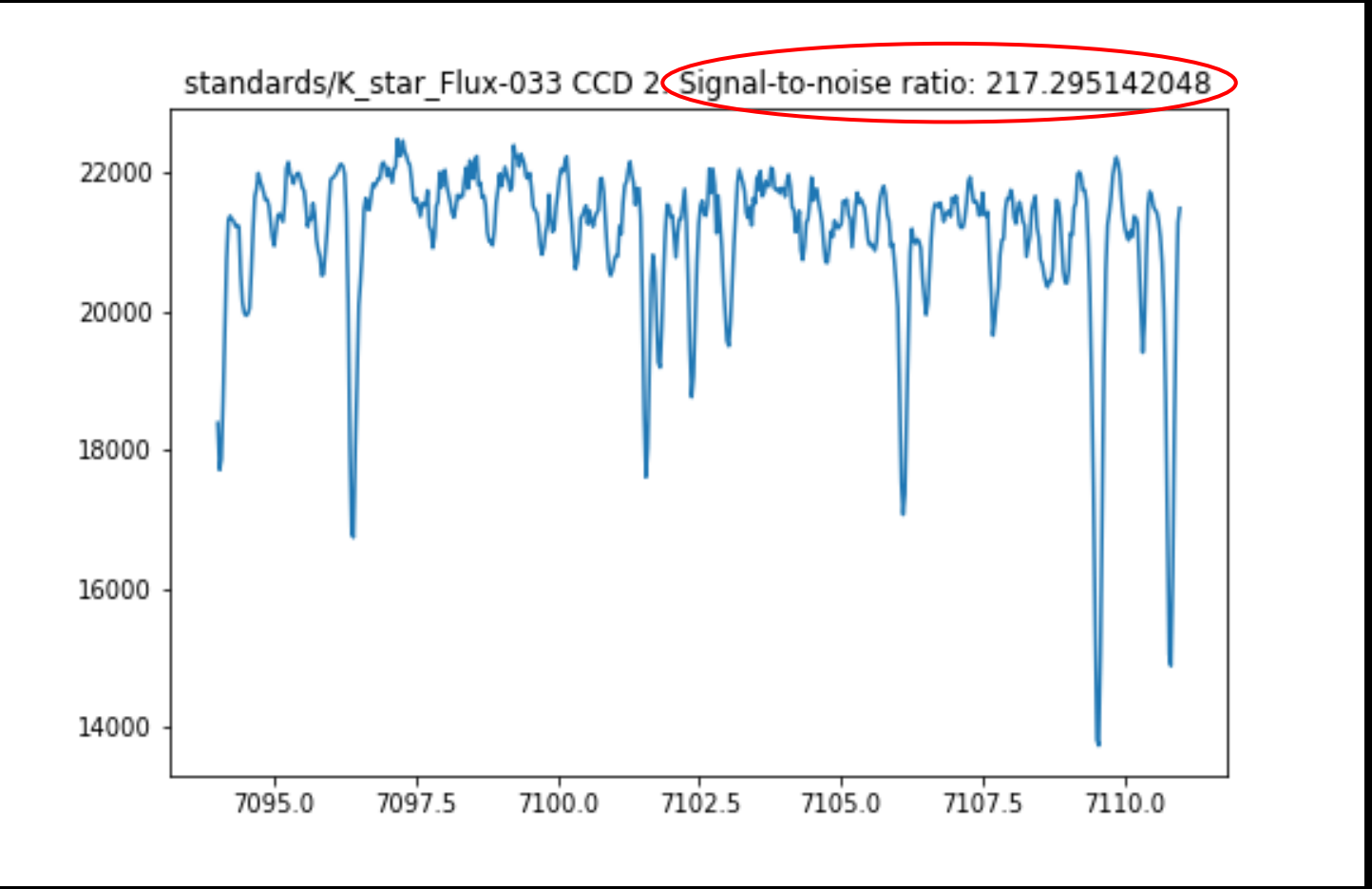
Spectrum Plotting



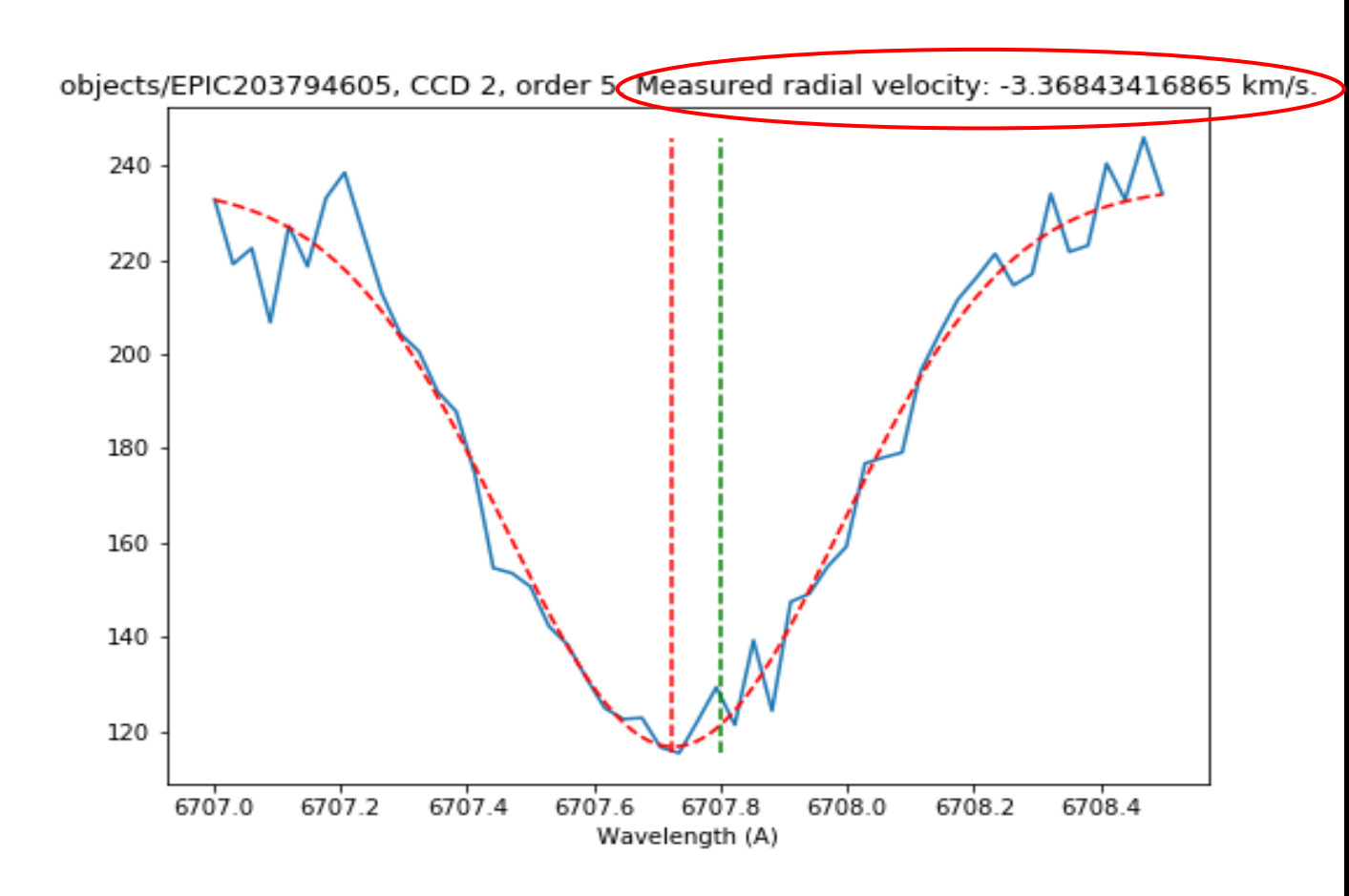
Spectra Comparison



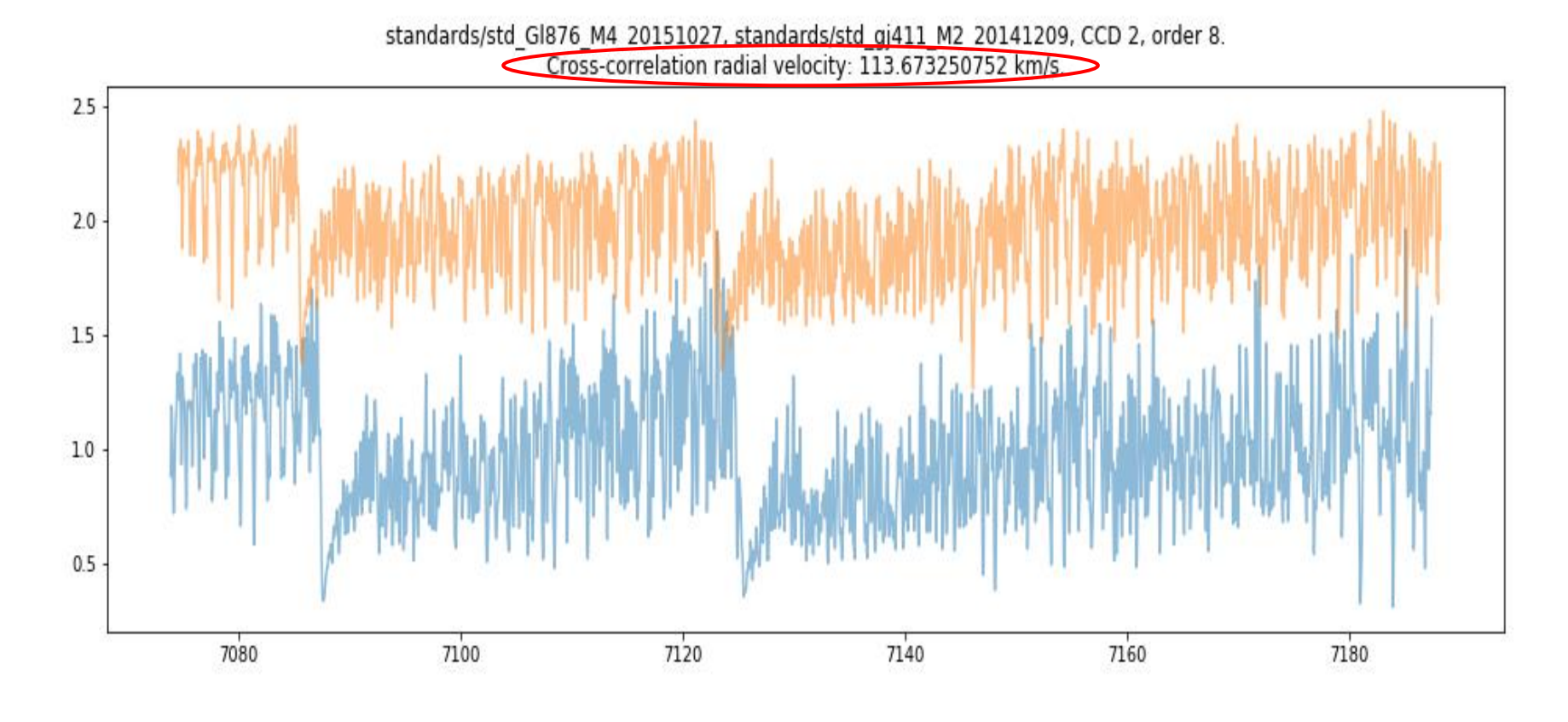
Signal-to-noise ratio



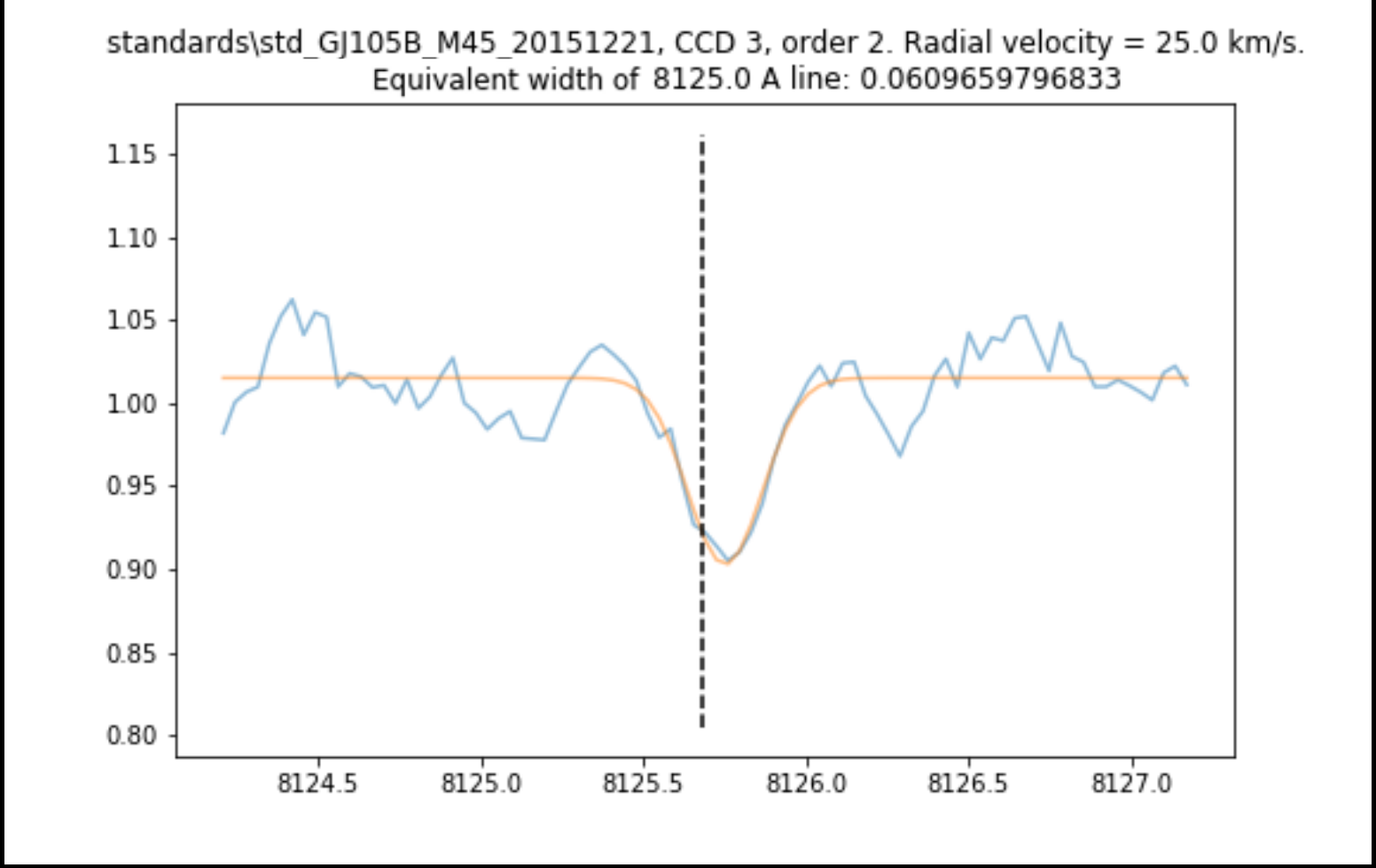
Radial velocity (via spectral line shift)



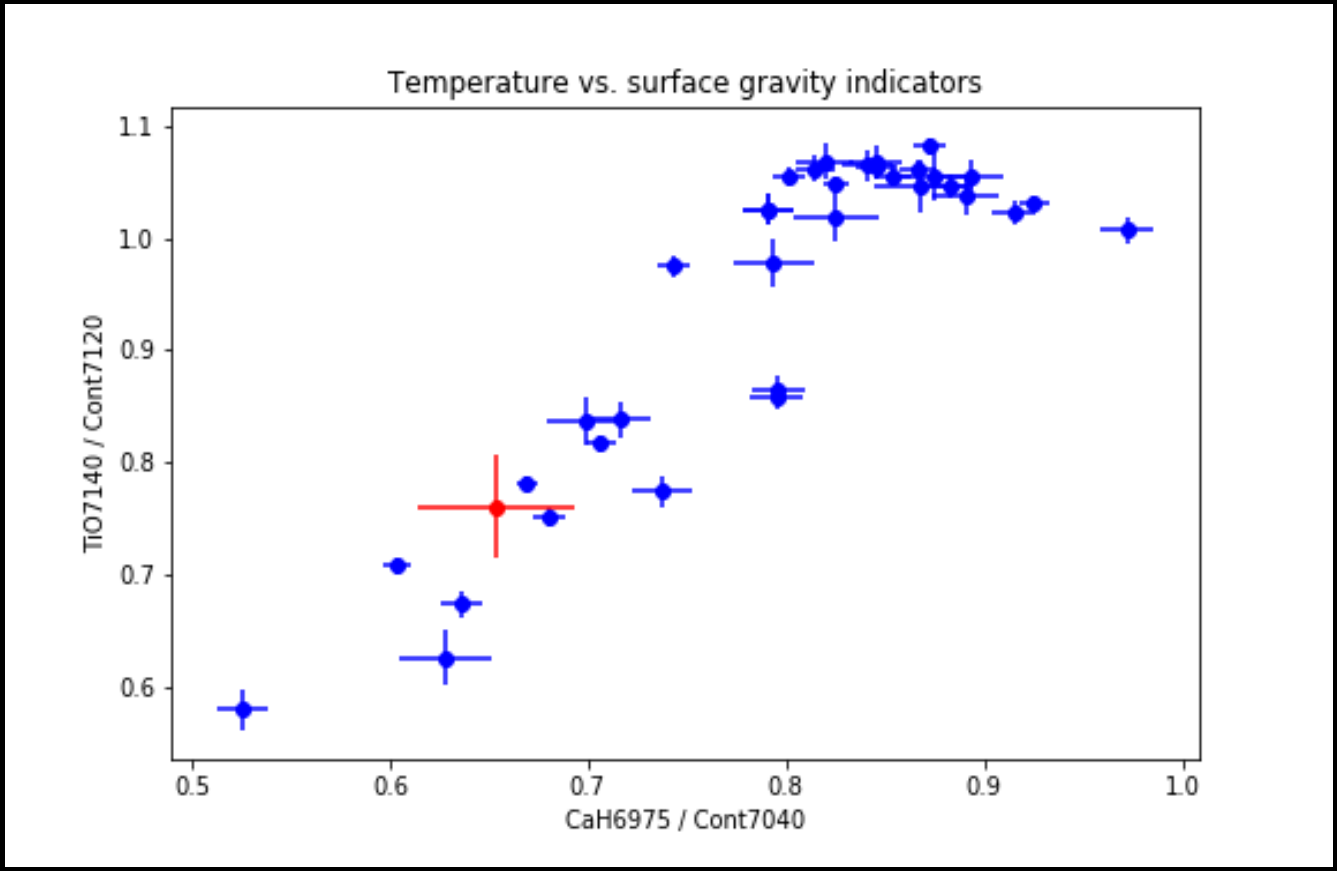
Radial velocity (via cross correlation)



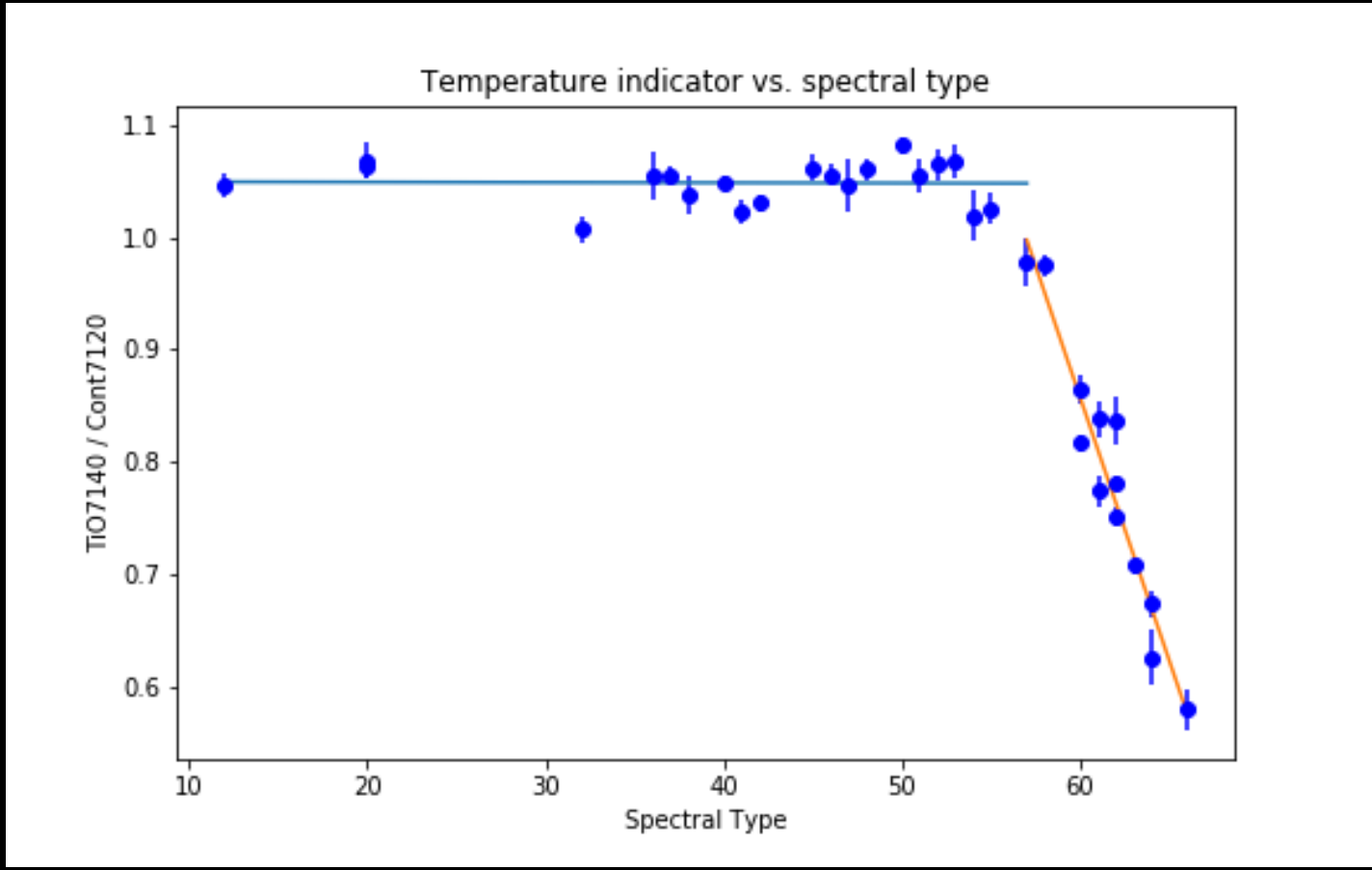
Equivalent width measurement



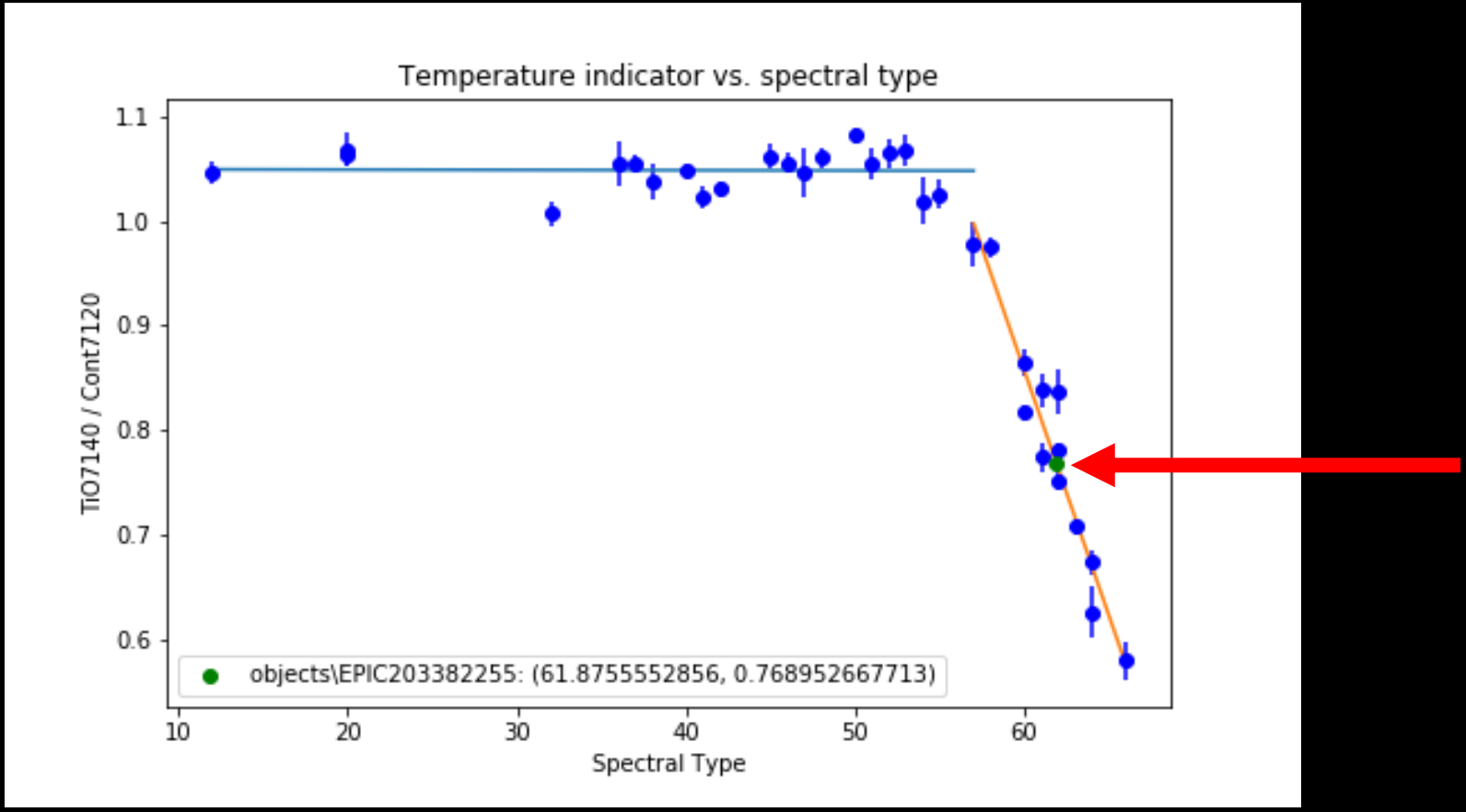
Temperature vs. surface gravity indicators



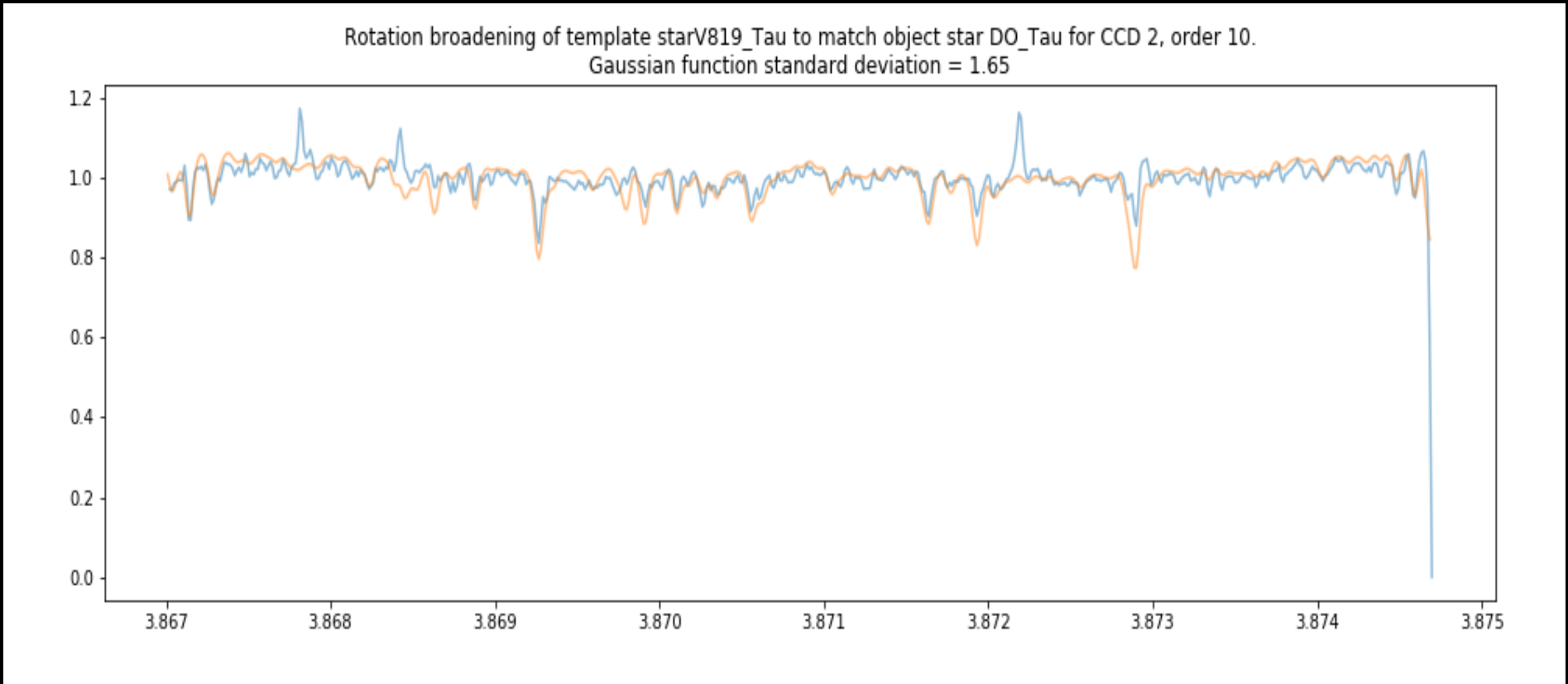
Temperature indicator vs. spectral type



Spectral classification of M-type star



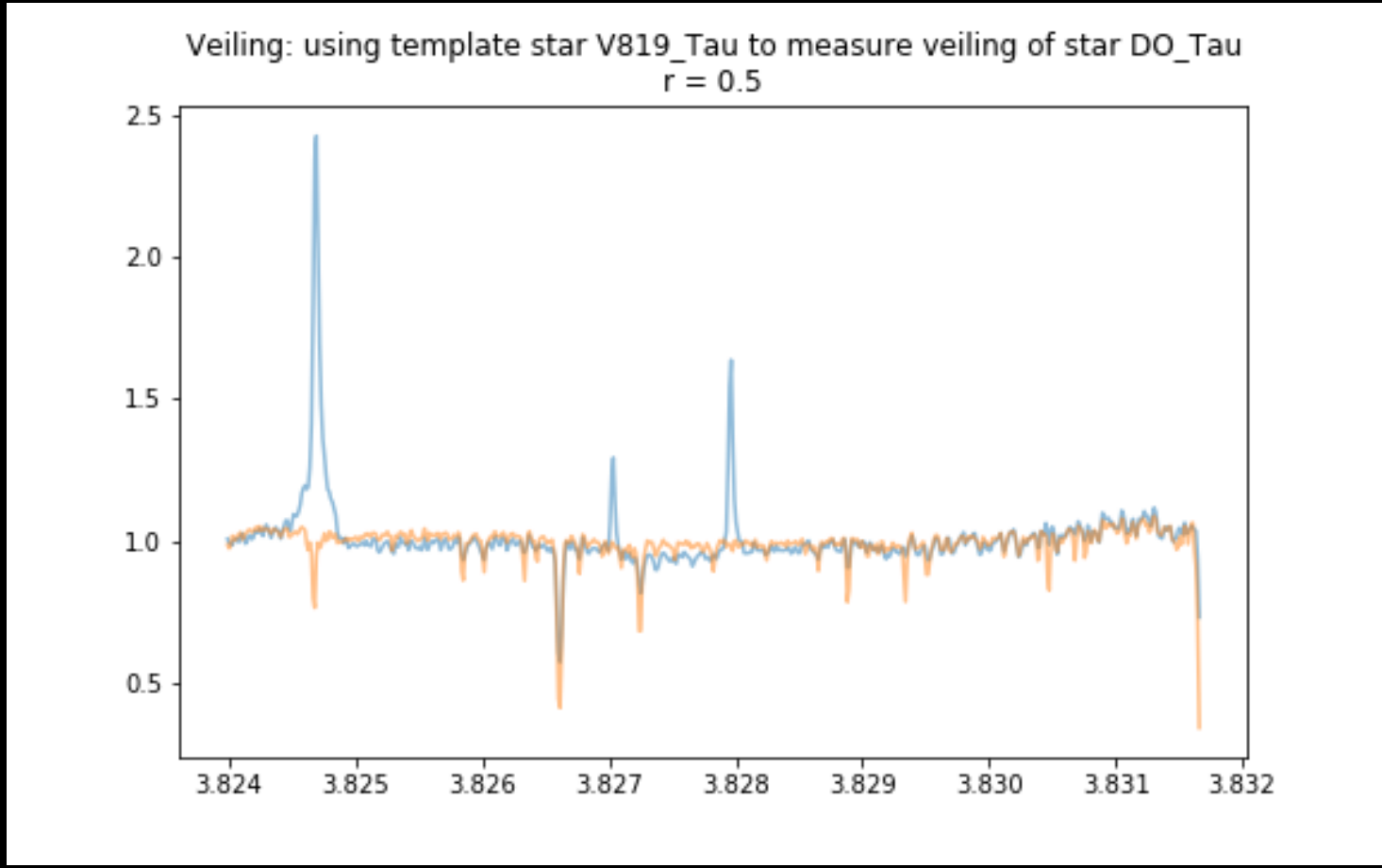
Rotation broadening



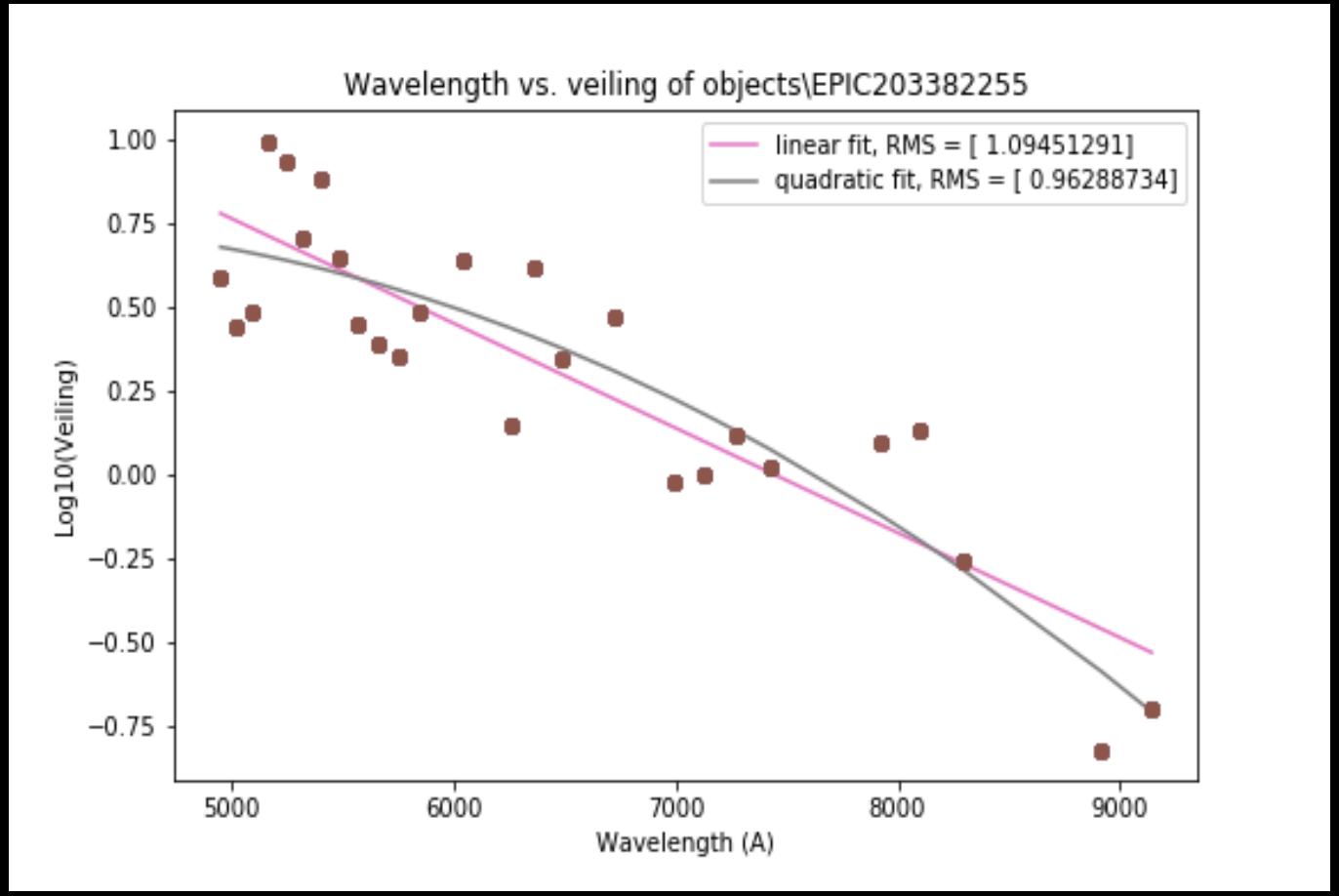
Analysis Tools: Circumstellar Properties

- Determining the dynamics of circumstellar disk accretion
- Involves comparison of spectrum data with artificially modified "template" spectra
  - Veiling
- Emission line identification
- Velocity profile
  - Gas kinematics

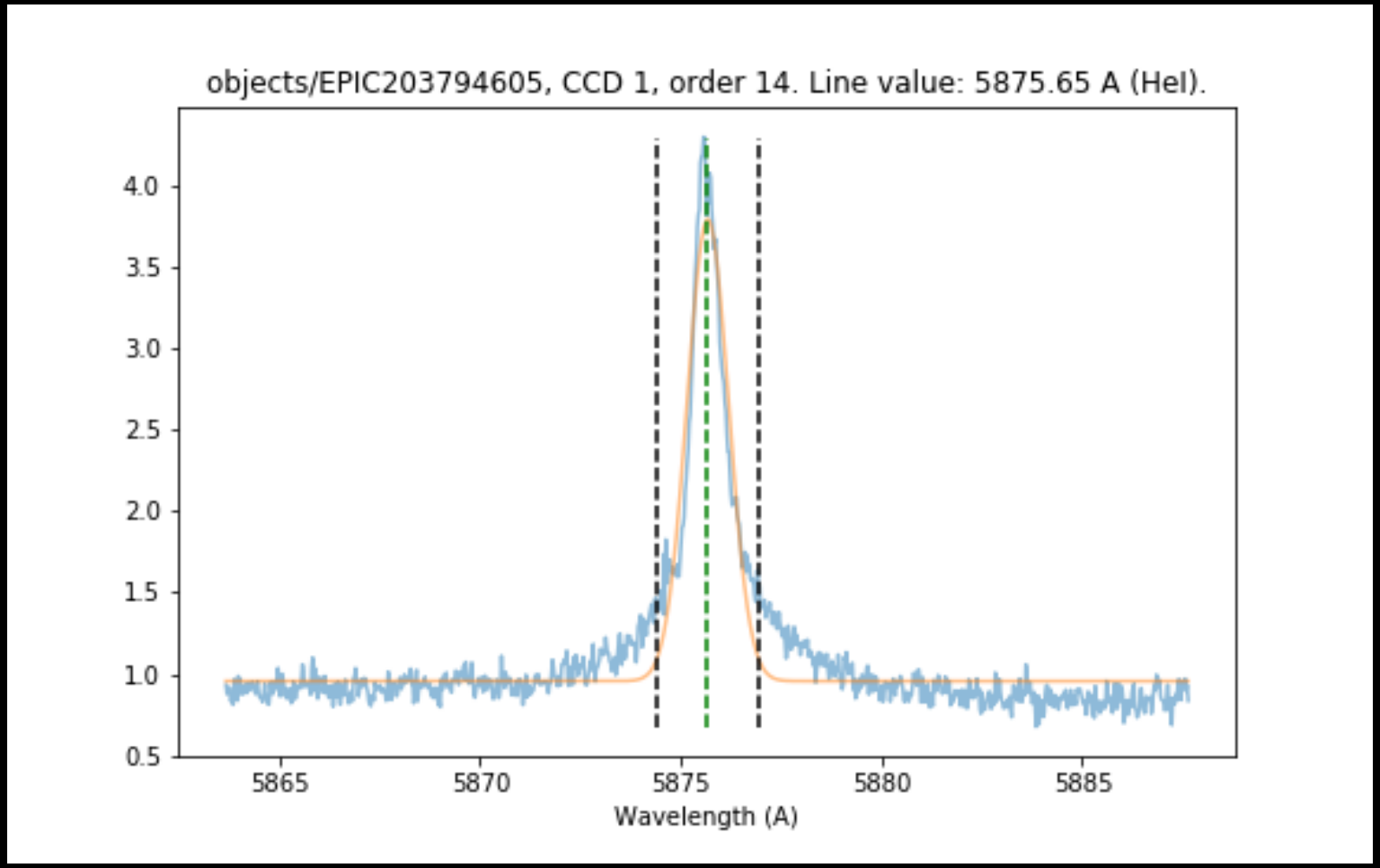
Veiling


Veiling: using template star V819_Tau to measure veiling of star DO_Tau
r = 0.5
2.5
2.0
1.5
1.0
0.5
3.824
3.825
3.826
3.827
3.828
3.829
3.830
3.831
3.832

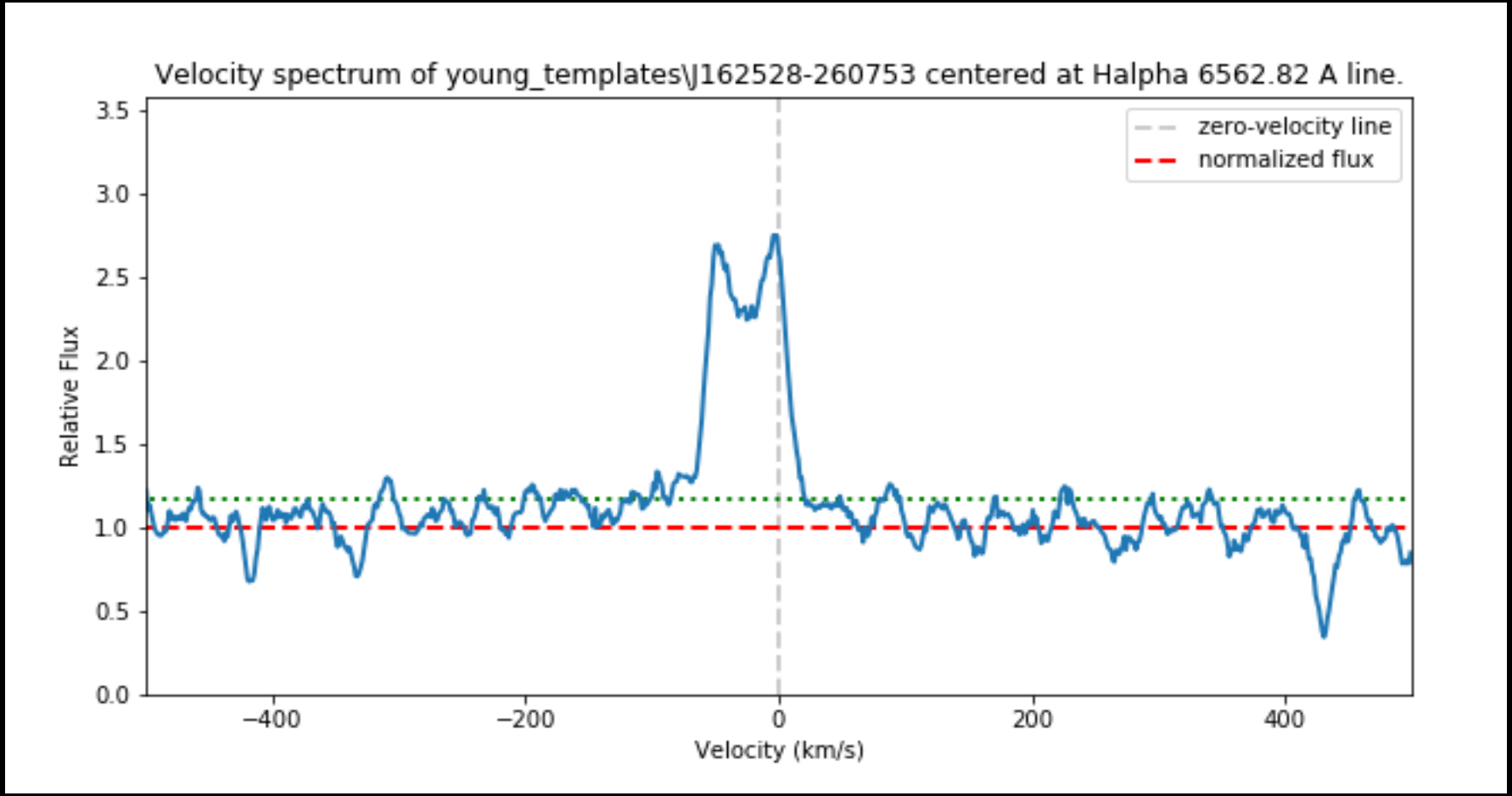
Wavelength vs. veiling



Emission Line Detection

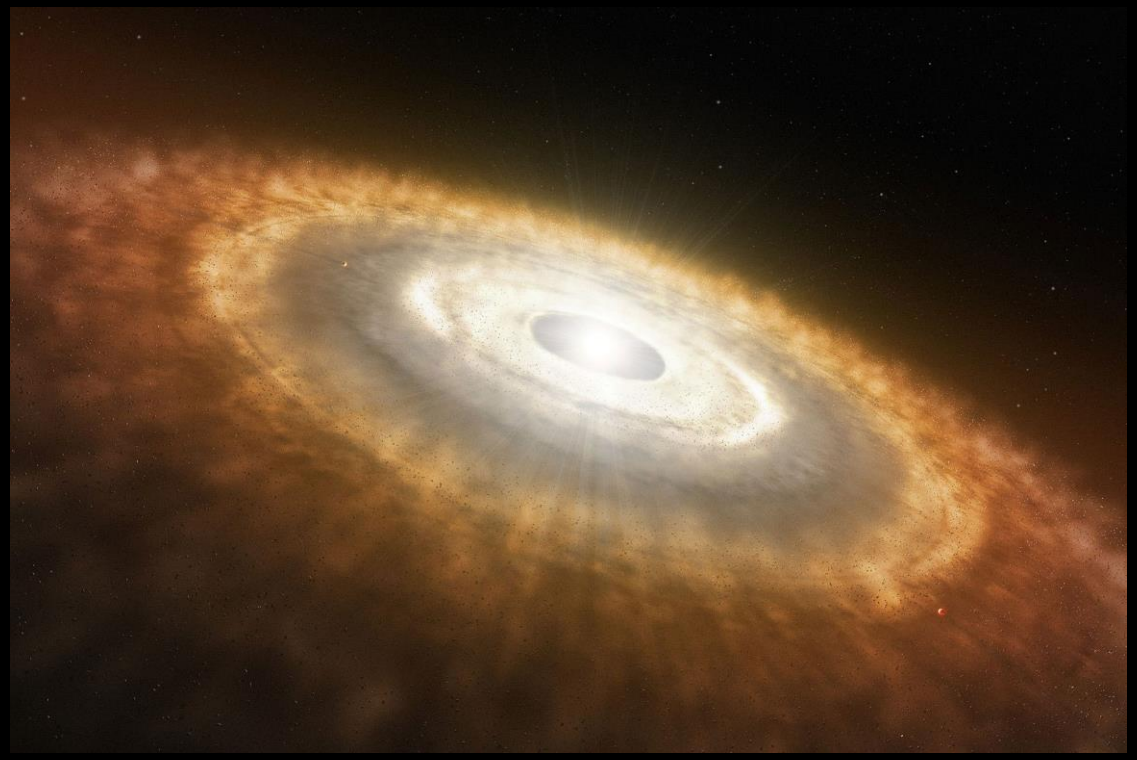


Velocity spectrum plot



Conclusions

- Significant progress made with development of data analysis tools
- Ready to use for analysis HIRES data for thousands of stars
- Plan to make further improvements in modules



https://scitechdaily.com/astronomers-examine-the-circumstellar-dust-around-kic-8462852/

Future work

- Incorporate general convolution of vsini measurements
  - Limb darkening for rotation broadening
- Generic spectral line ratio plotting
- Improvements for spectral line list data
  - Creating a comprehensive list of most important lines for relevant study

References

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