

The background image shows a star-forming region, likely the Taurus Molecular Cloud. It features a central protostar surrounded by a protoplanetary disk and a bipolar outflow. The surrounding space is filled with numerous stars of various colors and sizes, set against a dark, dusty background. The text is overlaid on this image.

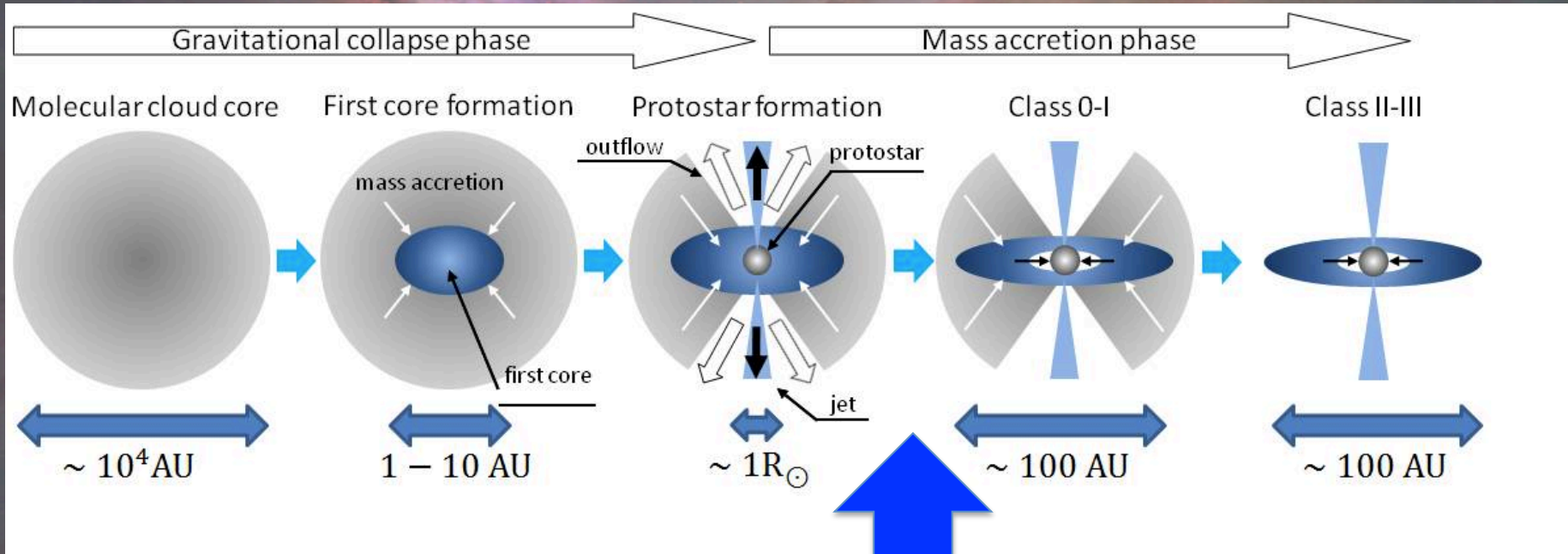
Diagnosing Mass Flows Around T Tauri Stars

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Stellar Evolution



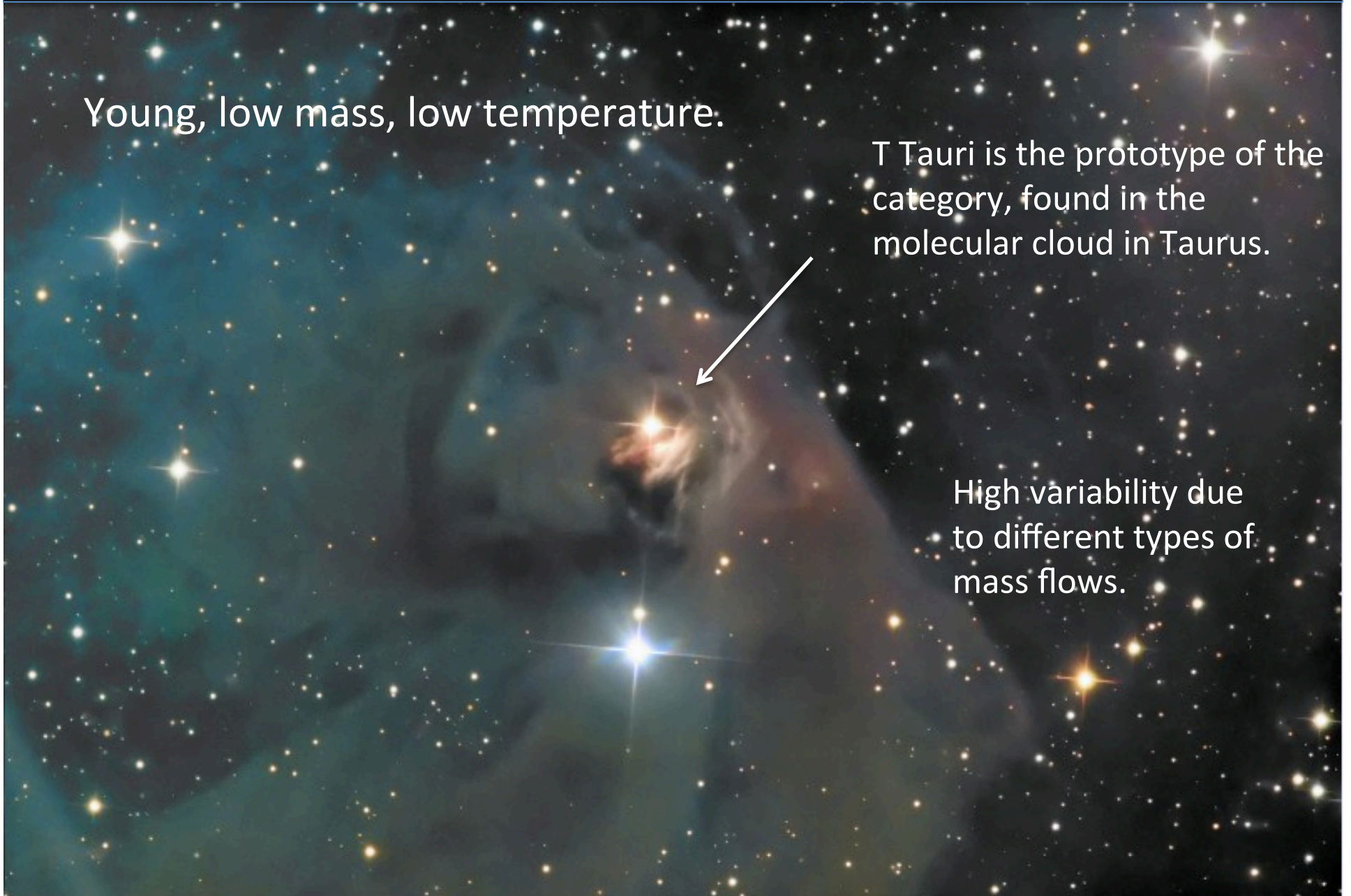
T Tauri phase

T Tauri Stars – connecting protostars to the Sun

Young, low mass, low temperature.

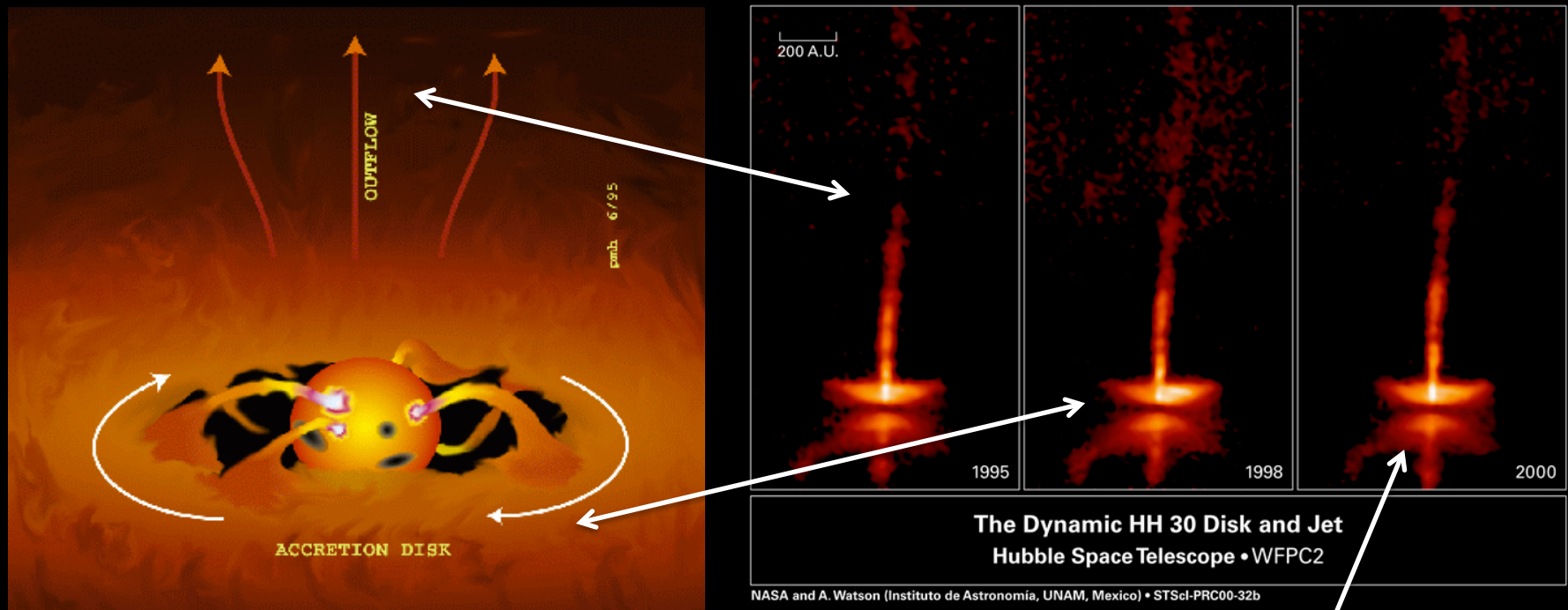
T Tauri is the prototype of the category, found in the molecular cloud in Taurus.

High variability due to different types of mass flows.



Types of mass flows

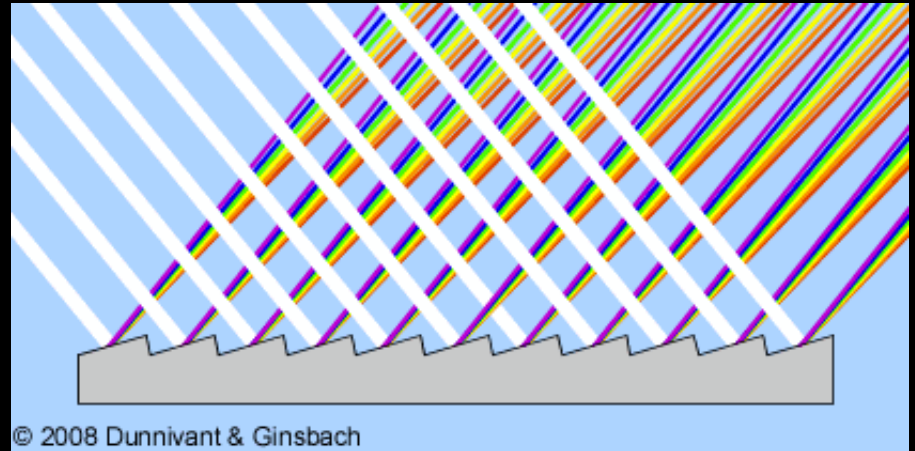
Bipolar outflows, rotating disk, accretion from disk



Spectroscopy allows a deeper look at what's happening.

Stellar spectra

- Echelle spectrograph on 2.7m Harlan J. Smith telescope at McDonald Observatory
 - Broader wavelength coverage
 - High resolution
 - 5 km/s velocity resolution



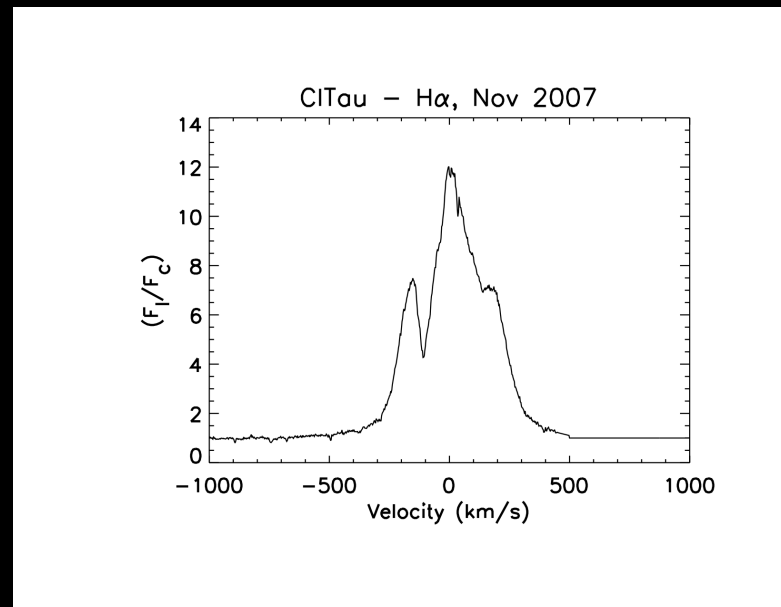
- Spectra taken from 2004-2012
 - ~75 T Tauri stars
 - Images of consecutive years
 - » Some strings of consecutive nights

Relating Spectra to Mass Flows

- Extract $H\alpha$ and $H\beta$ lines
 - Plot them on a velocity scale
 - Look for features as they change over time
- Have to be able to compare each observation
 - Depends on reduction and calibration of spectra

Isolating lines

- Plot spectrum against Th-Ar to locate H α and H β
 - Cut out that order
- Normalize flux to the continuum
- Correct velocity for barycentric motion
 - Now we have a spectral line in velocity space



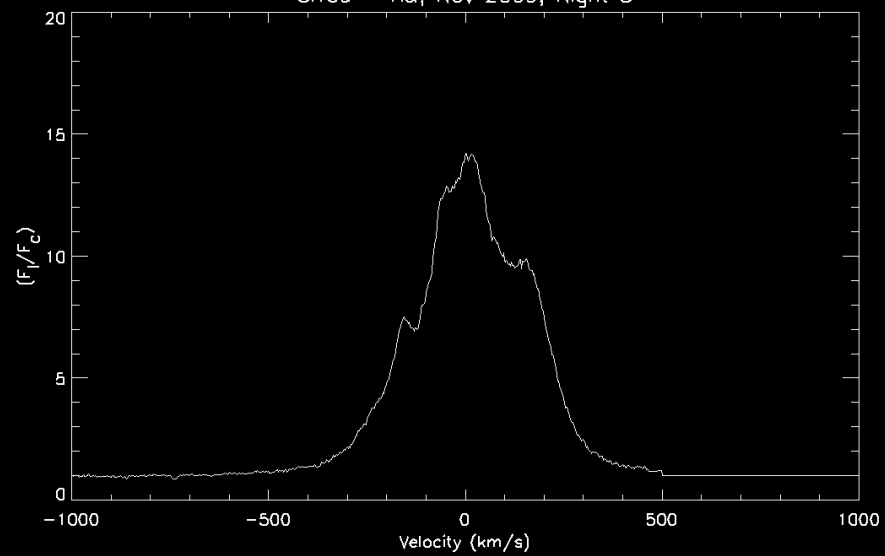
Comparing lines to each other

- Looking for absorption patterns, shape-shifting
 - Velocity placement of absorption features can indicate accretion

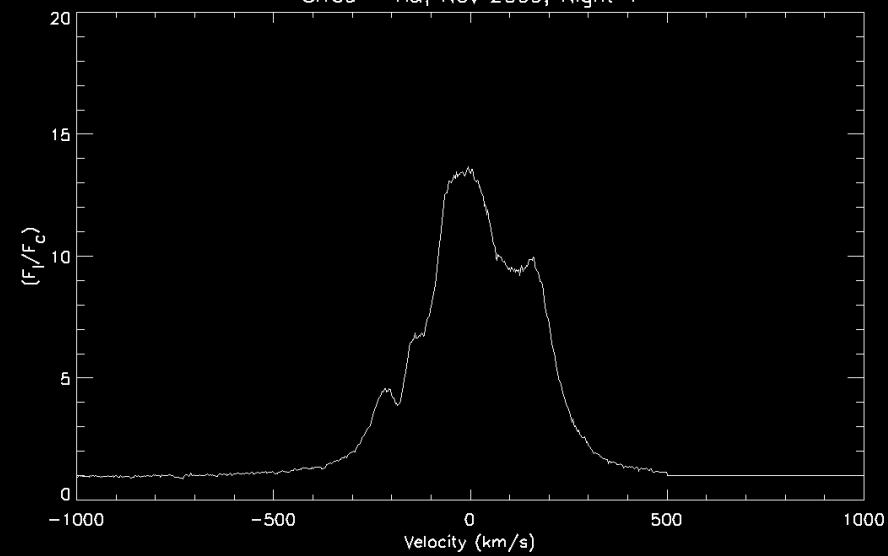
CI Tau

- Crockett et al. (2012)
 - Preliminary observations of star spots and suspected planet
 - Observations of 9 very young stars
- Two suspected rotation periods
 - ~ 6 day stellar rotation
 - ~ 10 day period of orbiting companion
 - Jupiter-like planet or brown dwarf star

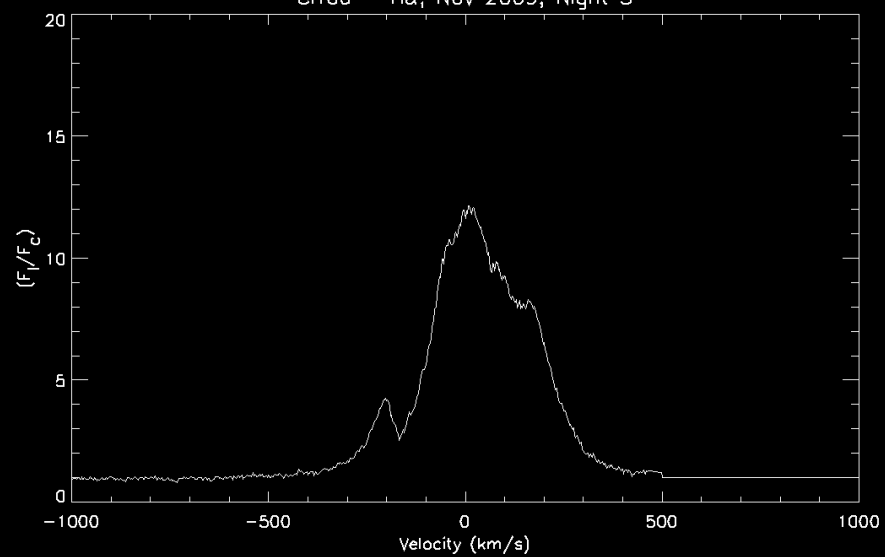
CI Tau - H α , Nov 2009, Night 3



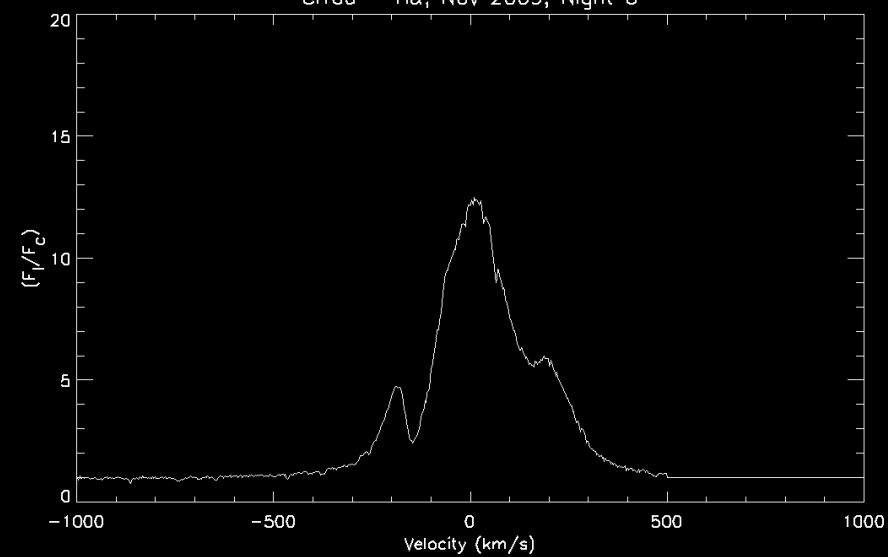
CI Tau - H α , Nov 2009, Night 4

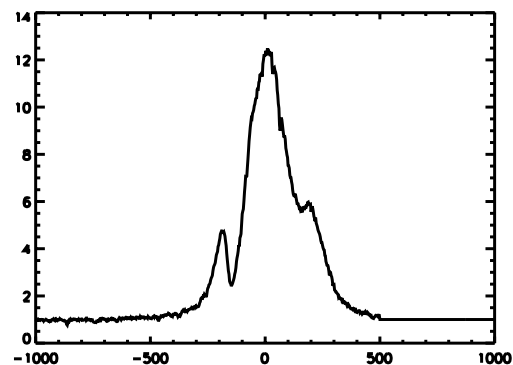
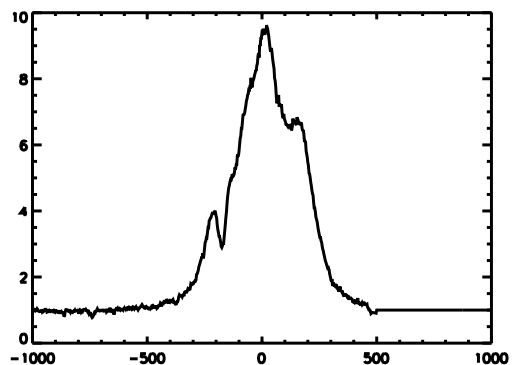
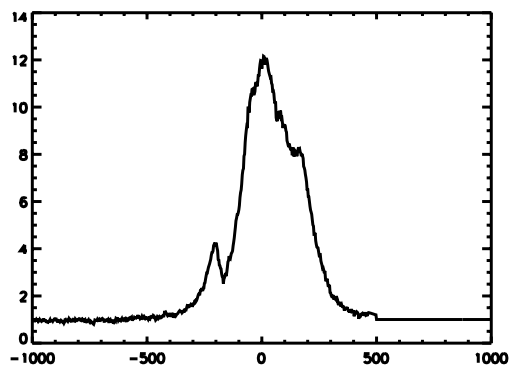
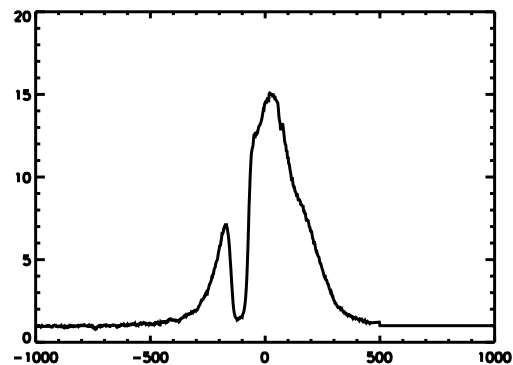
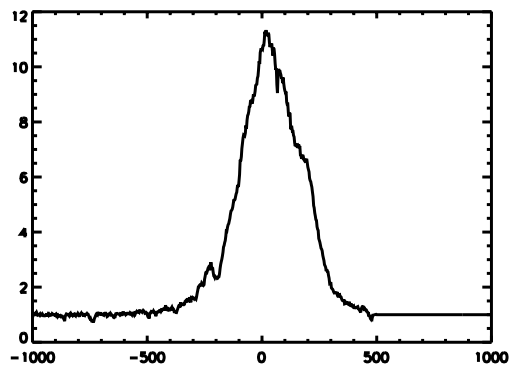
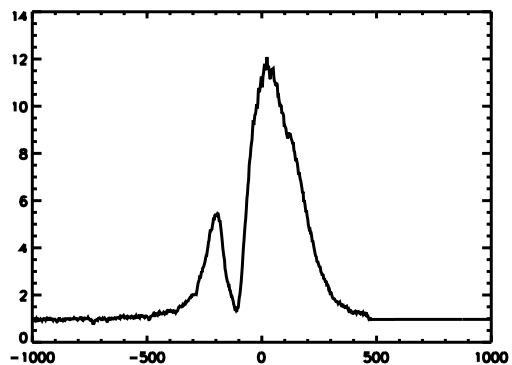
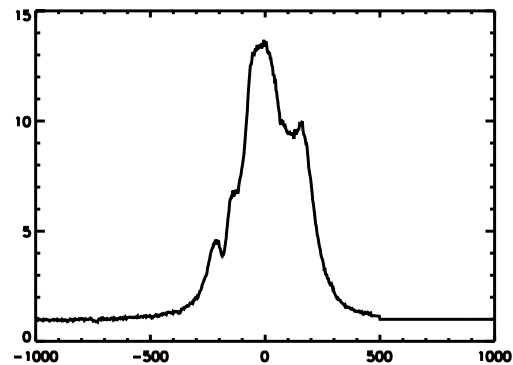
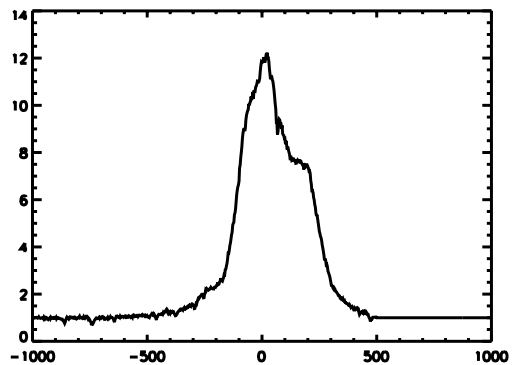
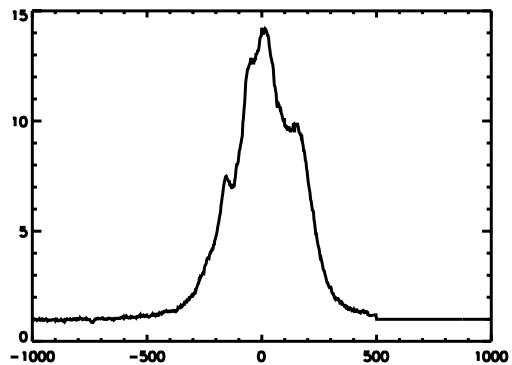


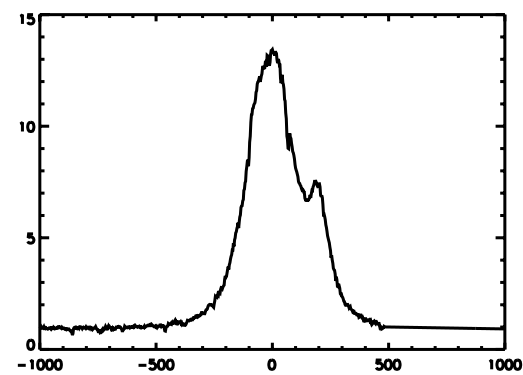
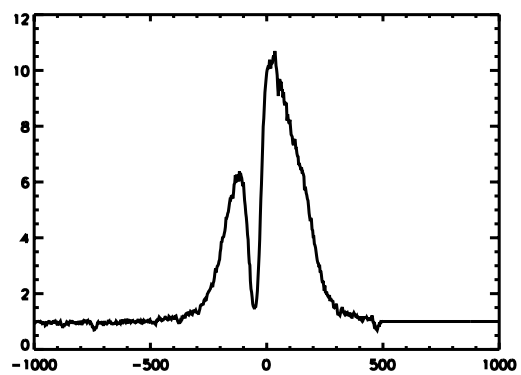
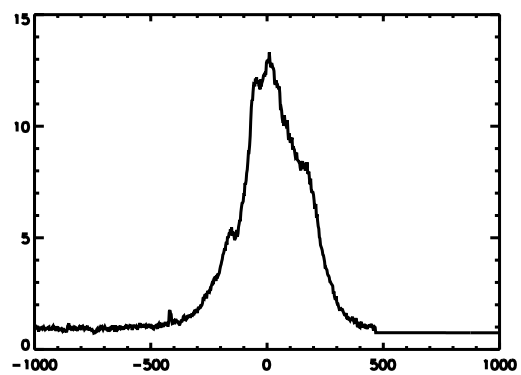
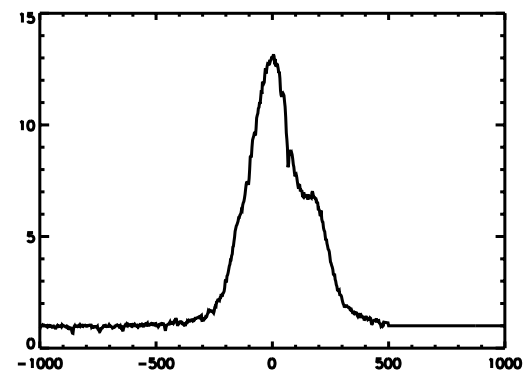
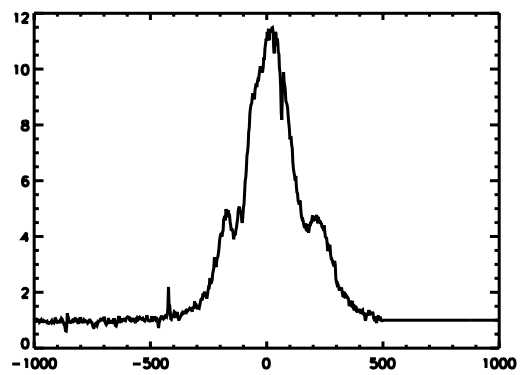
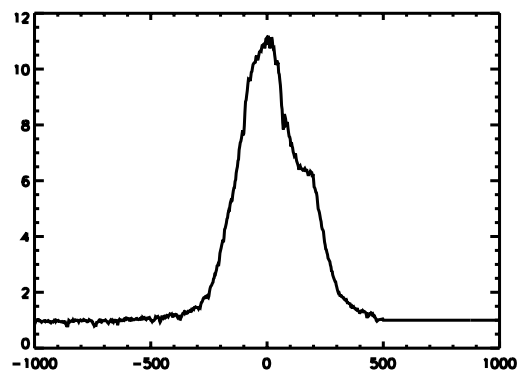
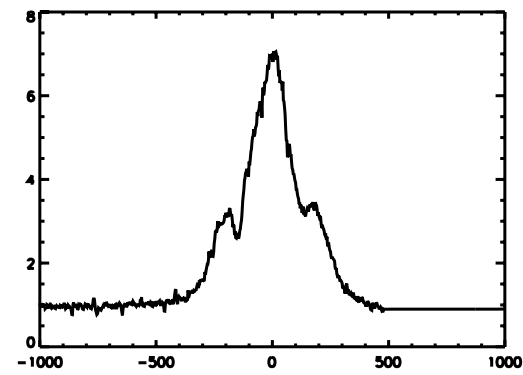
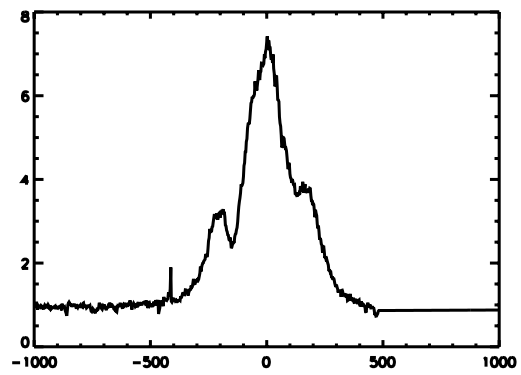
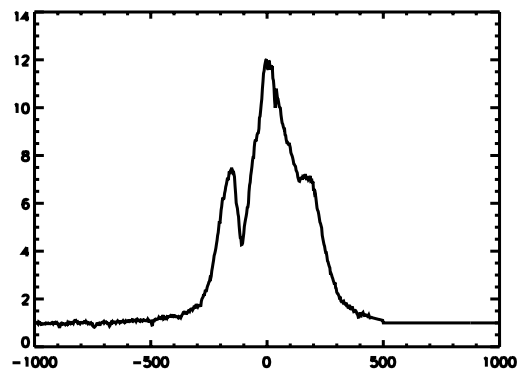
CI Tau - H α , Nov 2009, Night 5

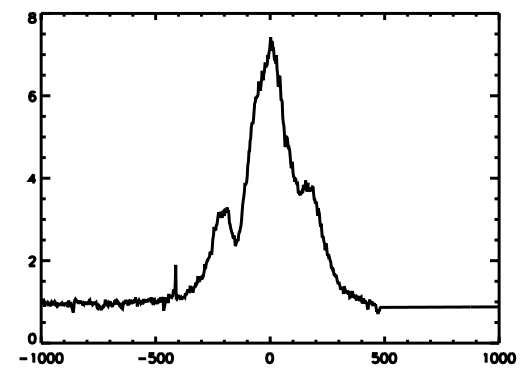
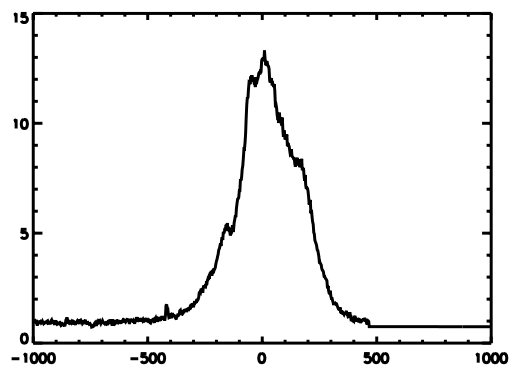
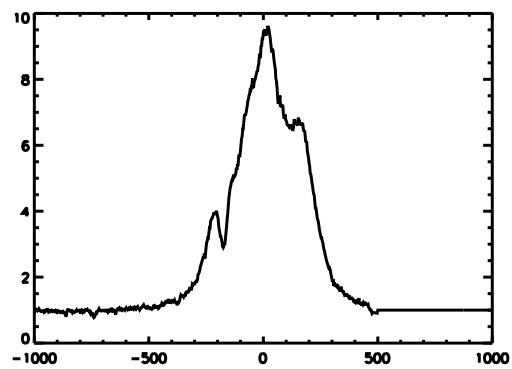
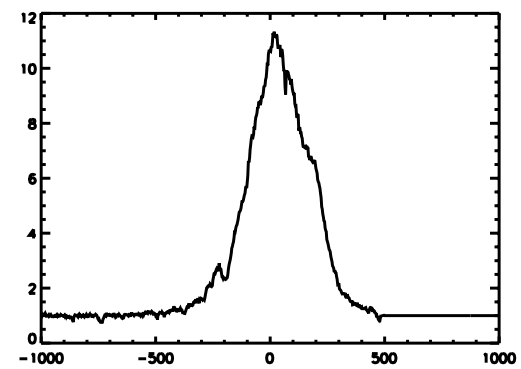
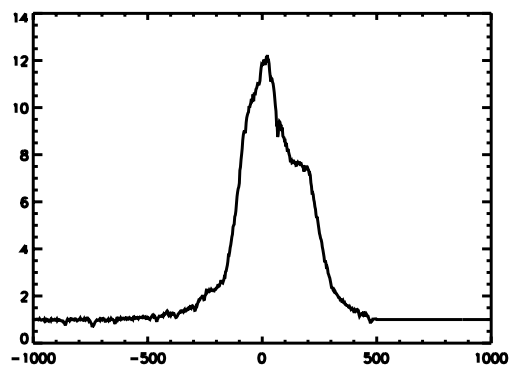
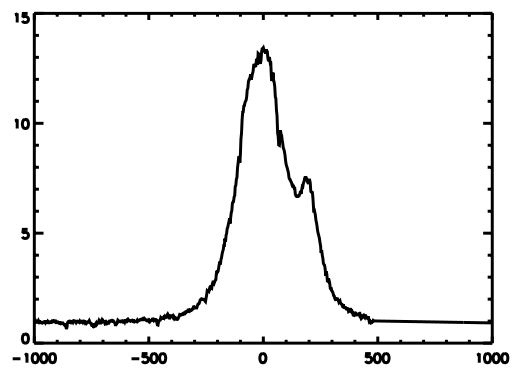
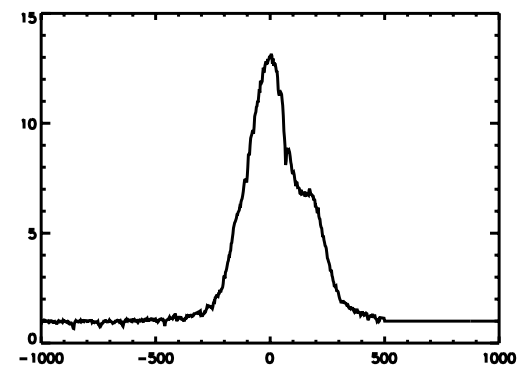
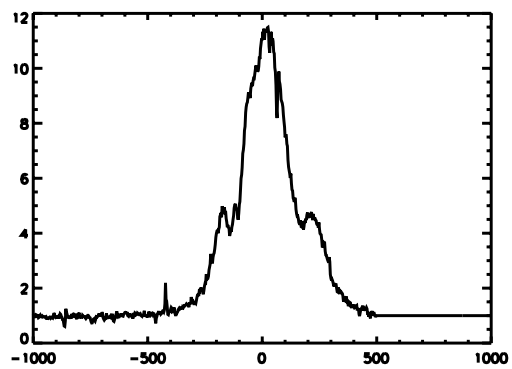
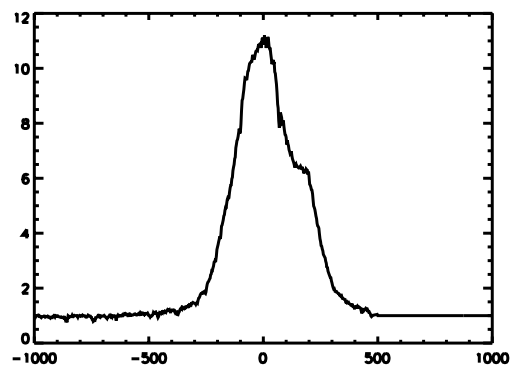


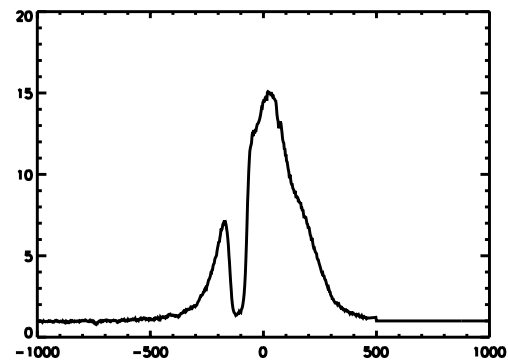
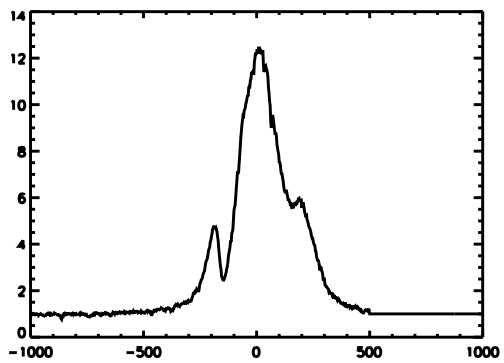
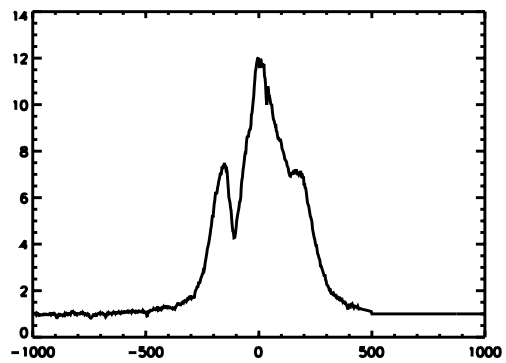
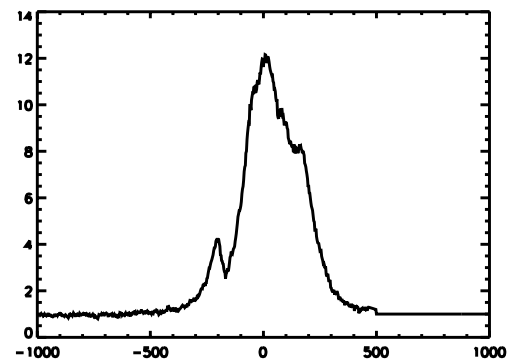
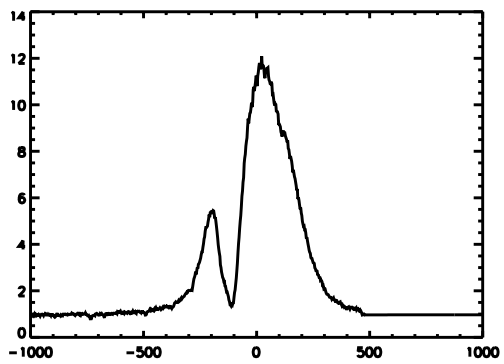
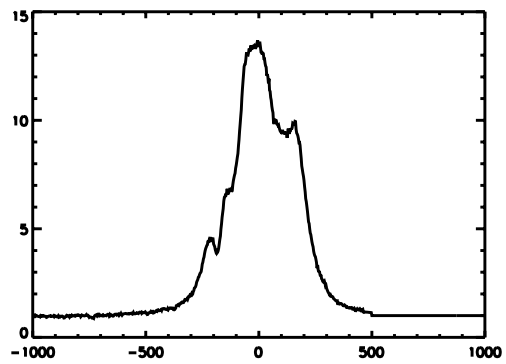
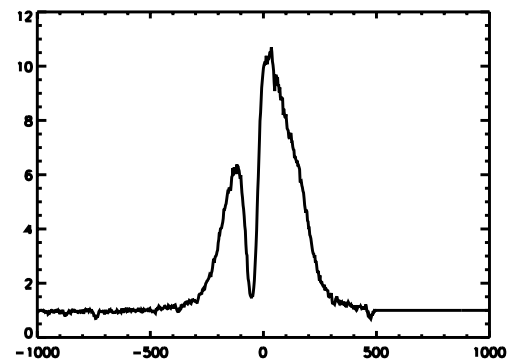
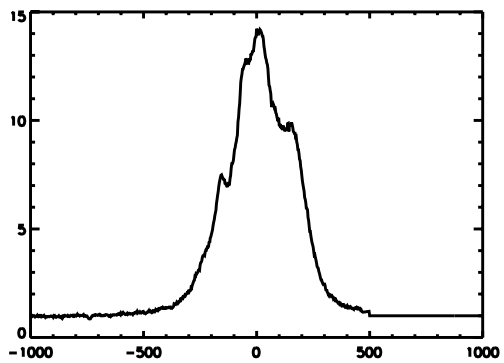
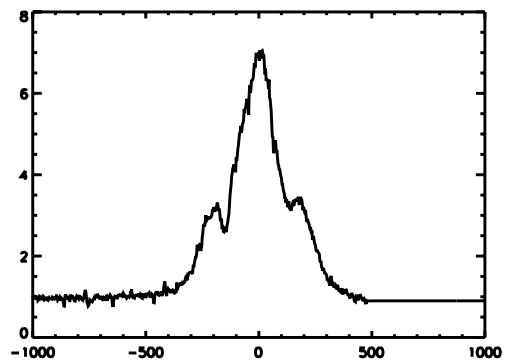
CI Tau - H α , Nov 2009, Night 6



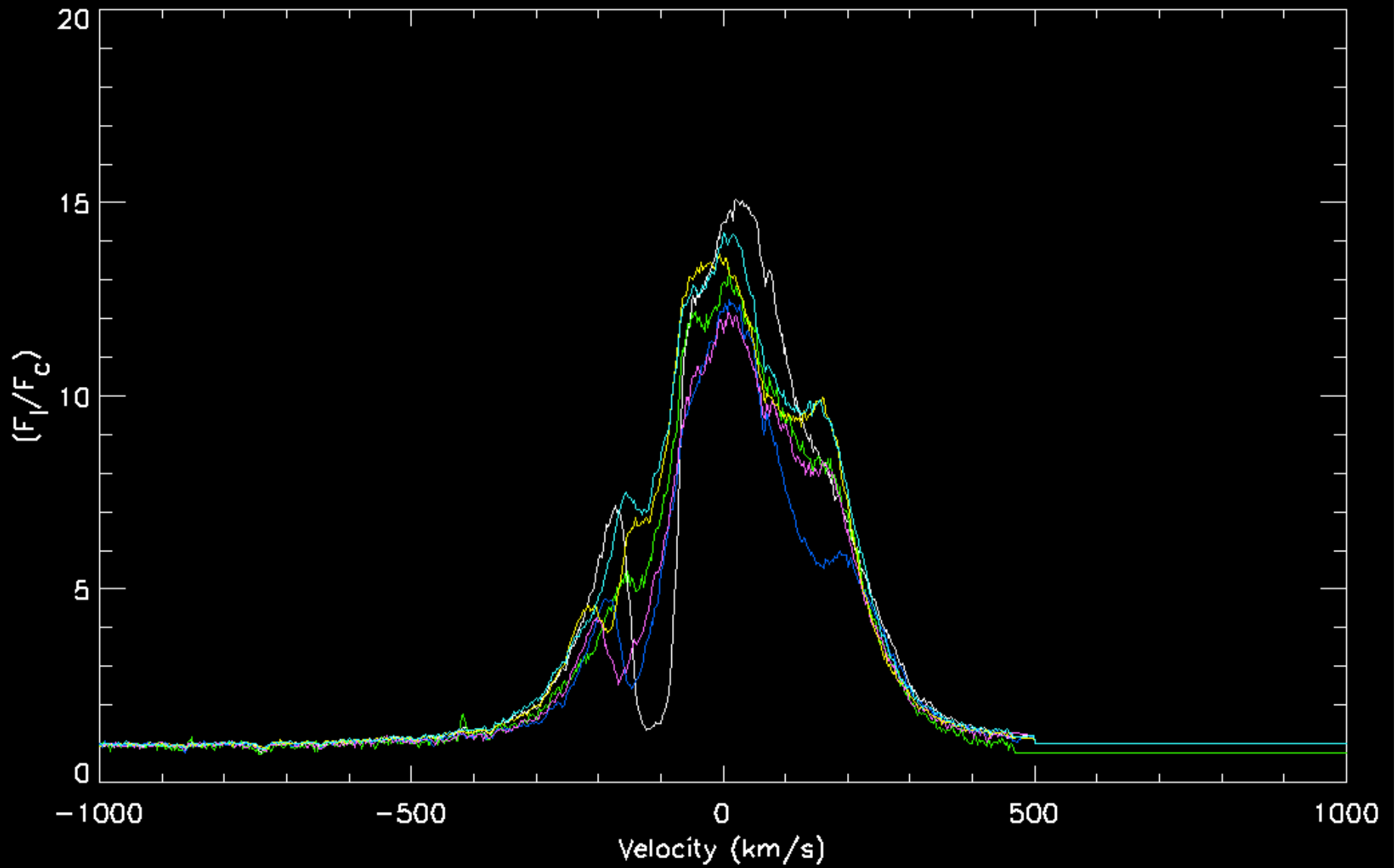








CI Tau - H α , Nov 2009



Statistical Analysis

Principal Component Analysis

Pick out the features that indicate planetary companions

Time Series Analysis

Look at line evolution over rotation period

Kernel Smoothing

Fill in gaps where we don't have spectra

Future Work

- Continue looking at CI Tau to determine if this data lines up with previous observations and confirms a companion
 - More data for CI Tau coming later this month
- Move on to other stars and see how spectral lines translate into physical processes
 - Broader pool of data for more statistical analysis

