Backyard Spectroscopy: High Resolution Characterization of Stellar, Planetary and Nebula Spectroscopy

Michael Caligiuri

Be Star Basics

A Be star is a young hot star characterized by spectra that has one or more Balmer (hydrogen) lines in emission. These stars are presumed to be fast rotators spinning at 200 km/s or more (i.e. between 50%-90% of their critical velocity). They have large stellar winds and high mass loss rate. In any given stellar field, approximately 20 % of the B-type stars are in fact Be stars. This percentage can be much higher in some young clusters where up to 60-70 % of the B stars are showing the Be phenomenon. These stars are very bright and over luminous compared to "normal'' B-type stars due to the presence of their circumstellar envelope.

Why Image Spectra from Be Stars?

Providing reliable systematic data on variability of the stellar properties of hot young emission stars can enhance the understanding of stellar physics. The standard catalog or atlas of Be stars lists 166 well-characterized stars. If 20% of B-type stars are emission stars, our understanding of emission star dynamics is based on a very small sample. Setting out to characterize the short (days) and long (years) term variability of more Be stars appears to be a worthwhile exercise.

There are many challenges to obtaining reliable accurate data on Be star dynamics and meeting these challenges can be satisfying. Unlike color or narrowband CCD imaging of deep sky objects, which can take hours of work under steady skies, useful data from stellar spectroscopy can be acquired in a matter of minutes under average skies.

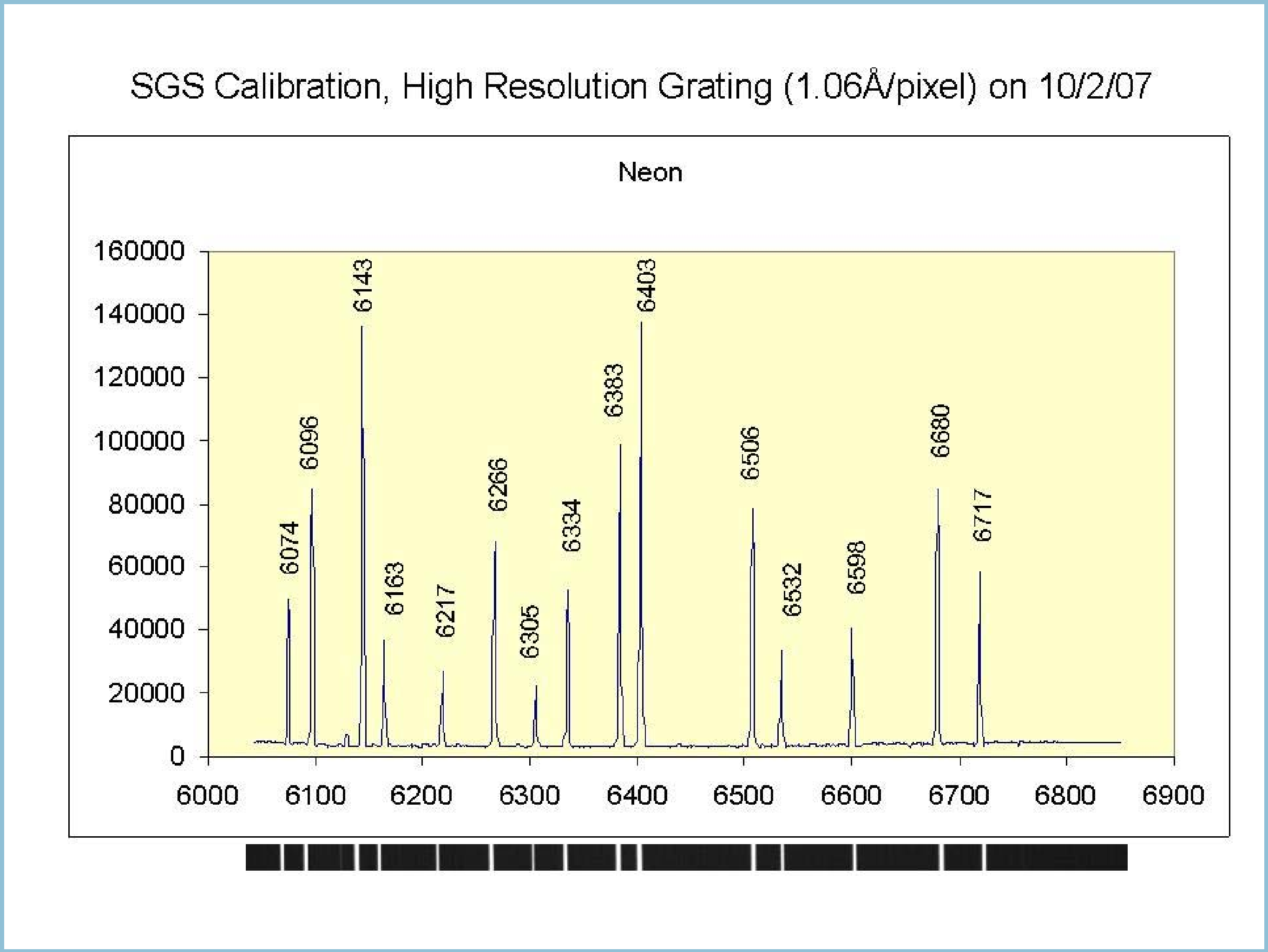
These pages showcase effort over a two year period (2006-2007) in characterizing stellar, planetary, and nebula spectra using amateur-grade instruments and telescopes. Most of this work was done in a suburban backyard.

Instrumentation

SBIG spectrographs attached to Meade 8” (left) or Celestron 9.25” telescopes. The left photo shows a lower resolution (6A/pixel) DSS spectrograph; while the right photo shows the self-guided high-resolution (1A/pixel) SGS spectrograph. Light from a star is diffracted by a tunable grating and passed through a narrow slit which is then projected to a CCD camera (SBIG ST-7) for recording.

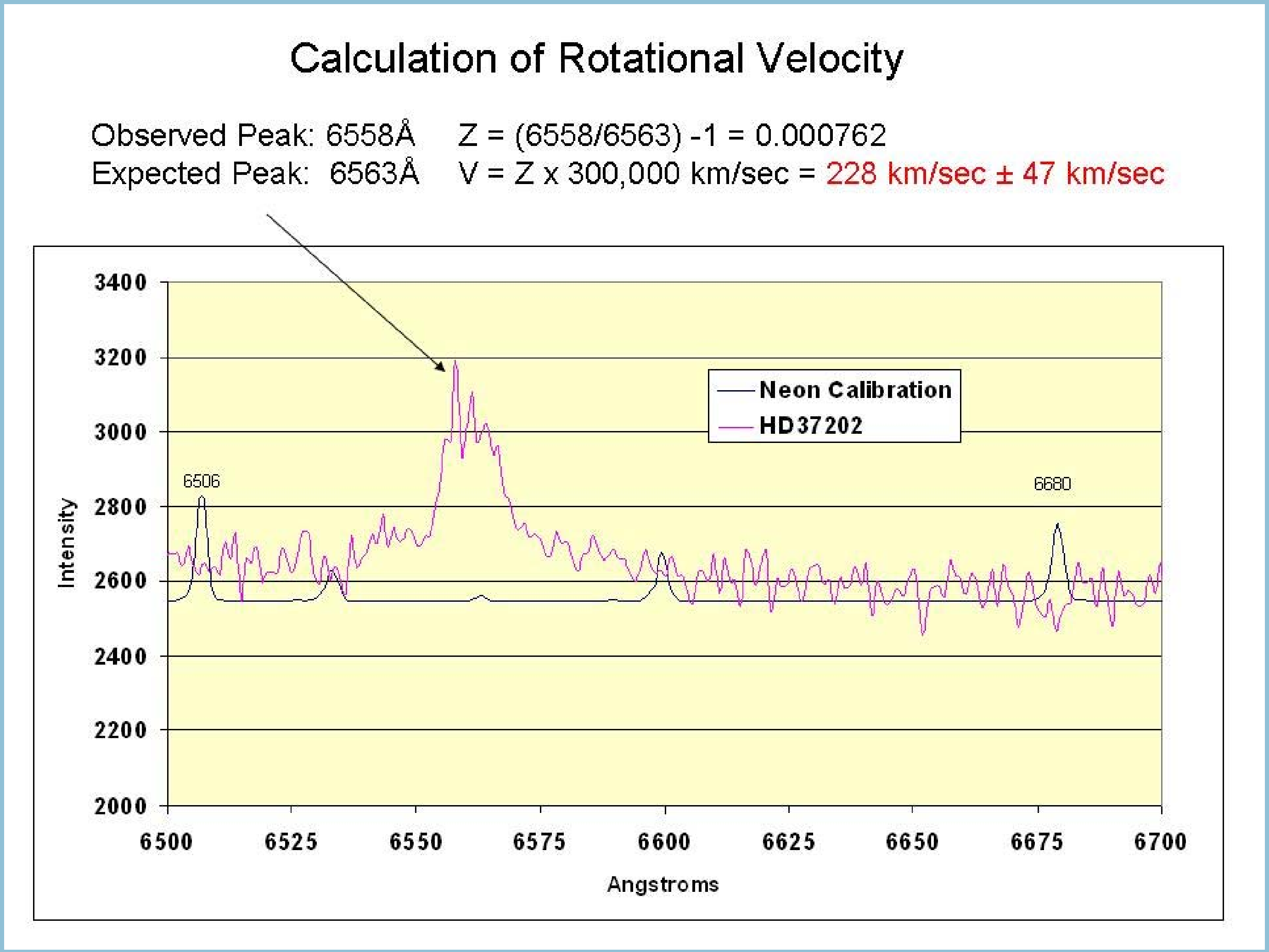
Calibration

Stellar spectroscopy requires careful calibration to ensure that the emission or absorption peaks correspond to the correct wavelength. Here, a neon lamp was used as the light source. Neon emits spectral peaks at known wavelengths and can be used to align the spectral lines from natural light sources.   Calibration files are collected with each run.

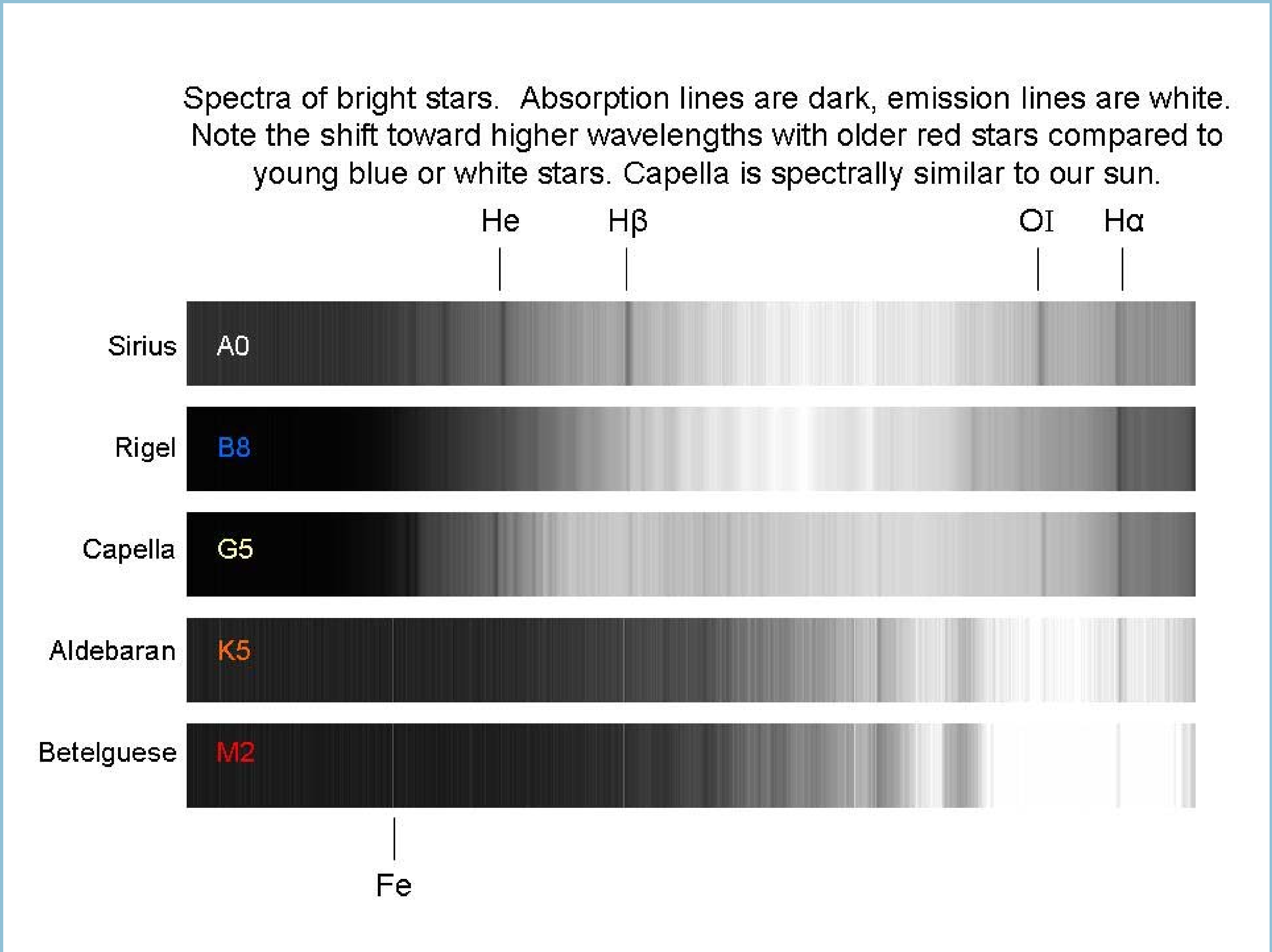


Calibration

If one is interested in calculating the radial velocity of a star, or redshift from a distant galaxy, a different calibration must be done. This is an example of how to estimate radial velocity from a star using its hydrogen peak as a reference. Note the neon calibration line is used to align the wavelength axis.

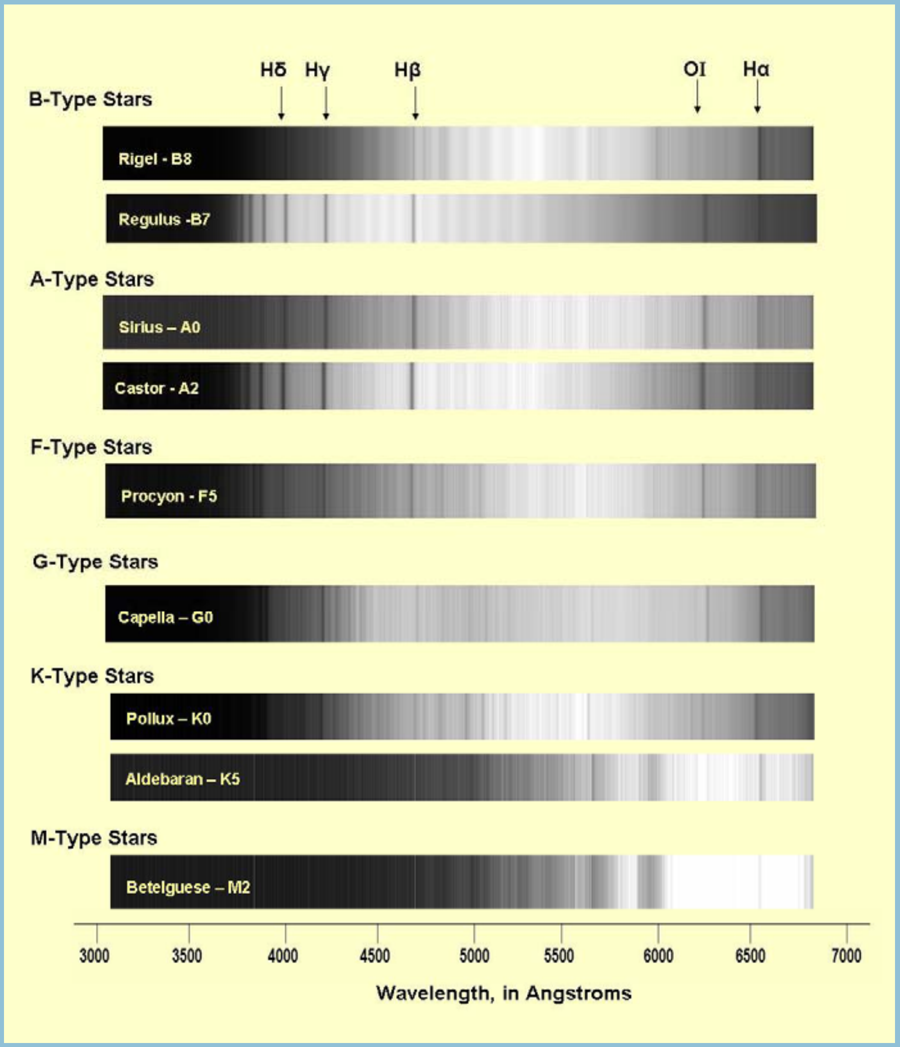


Stellar Spectroscopy Basics



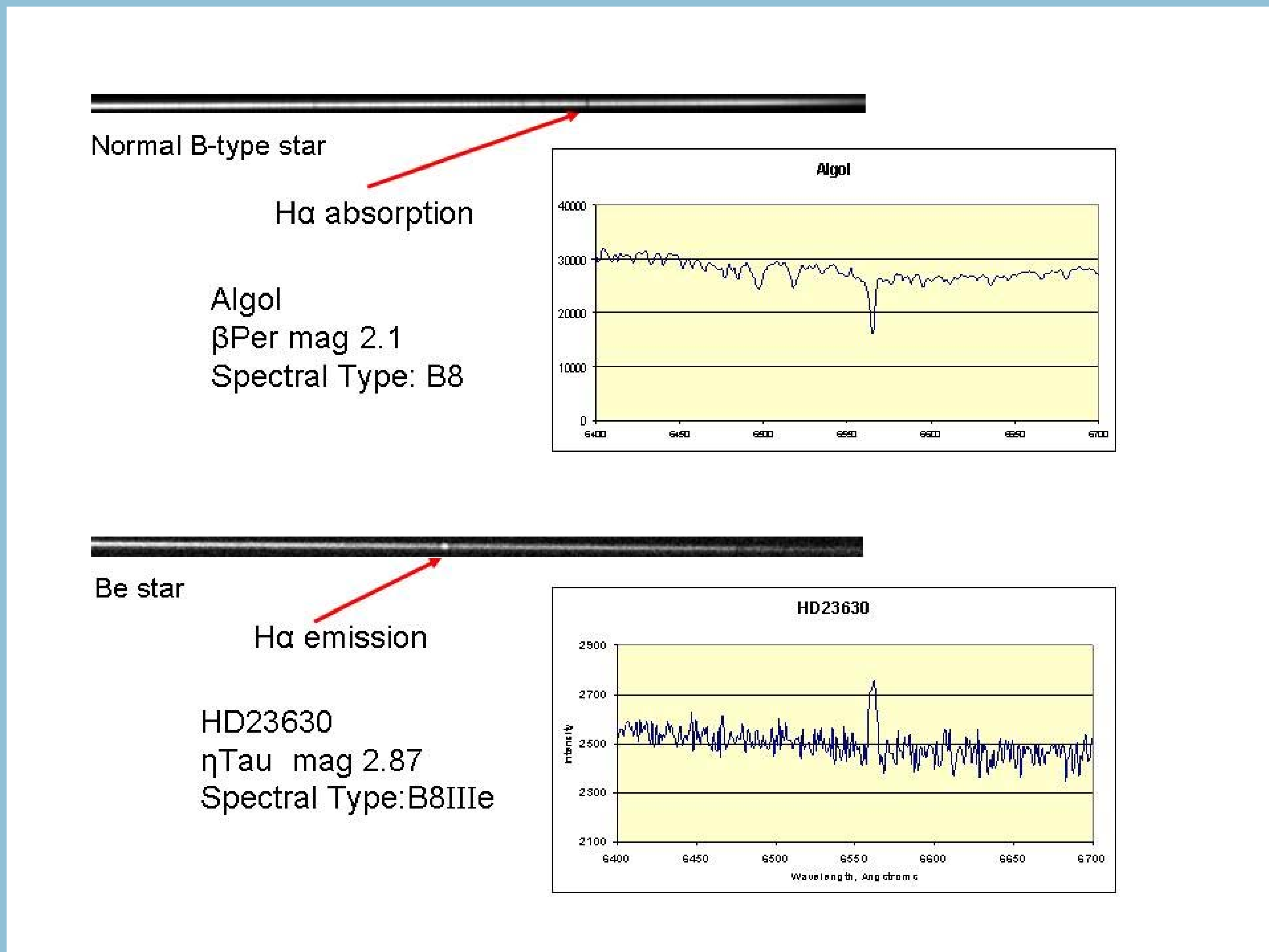
Stellar Spectra

Raw spectra of several bright stars arranged by spectral temperature (from hot to cool). Arrows point to dark absorption lines for common elements. Note how the bright spectral regions correspond to the classic Hertzsprung-Russell diagram from hot B-type stars to the cool M-type stars.



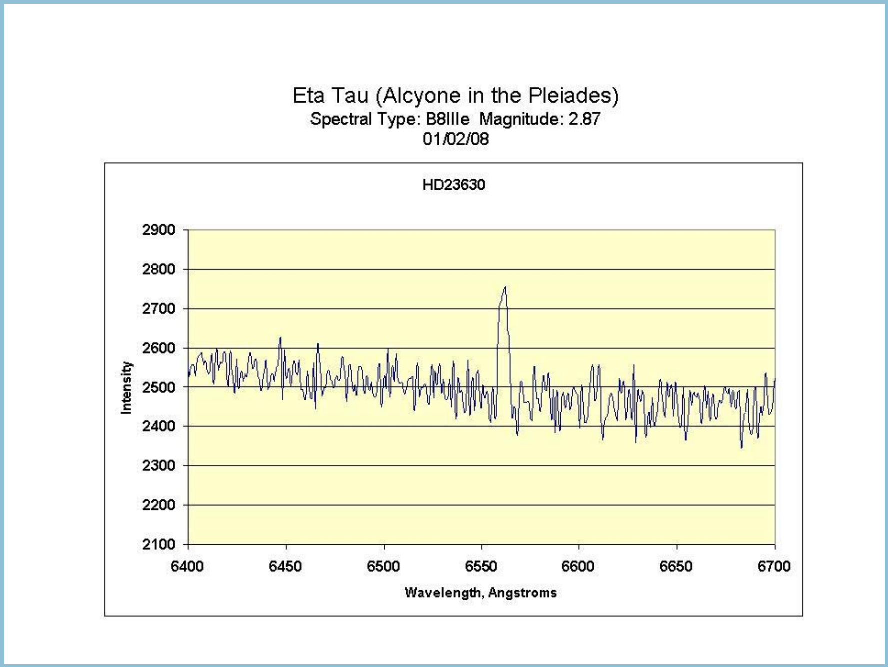
Stellar Spectra

Clear differences in the spectra of a normal B-type star and Be star

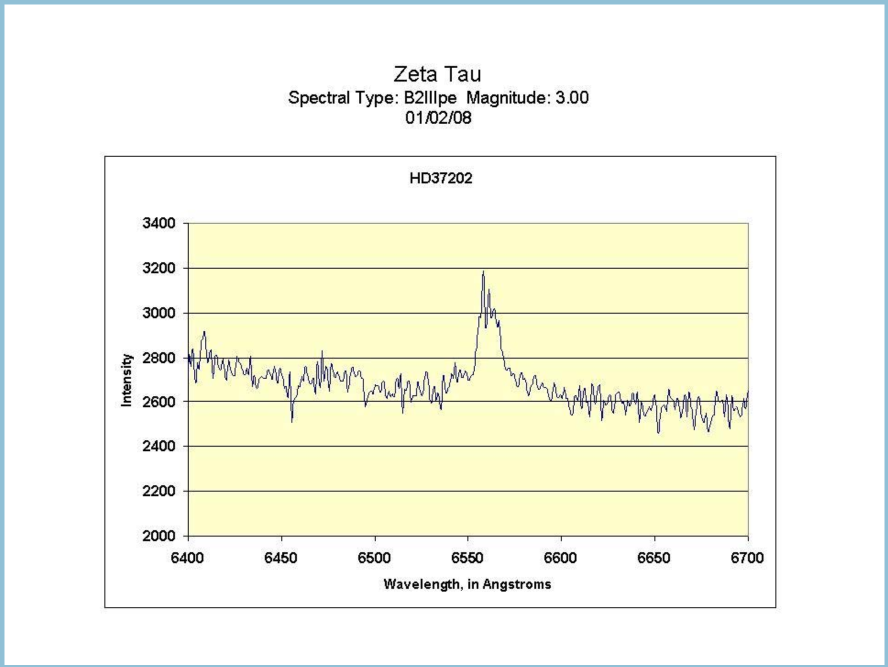


Examples of Be Spectra

Alcyone in the Pleiades

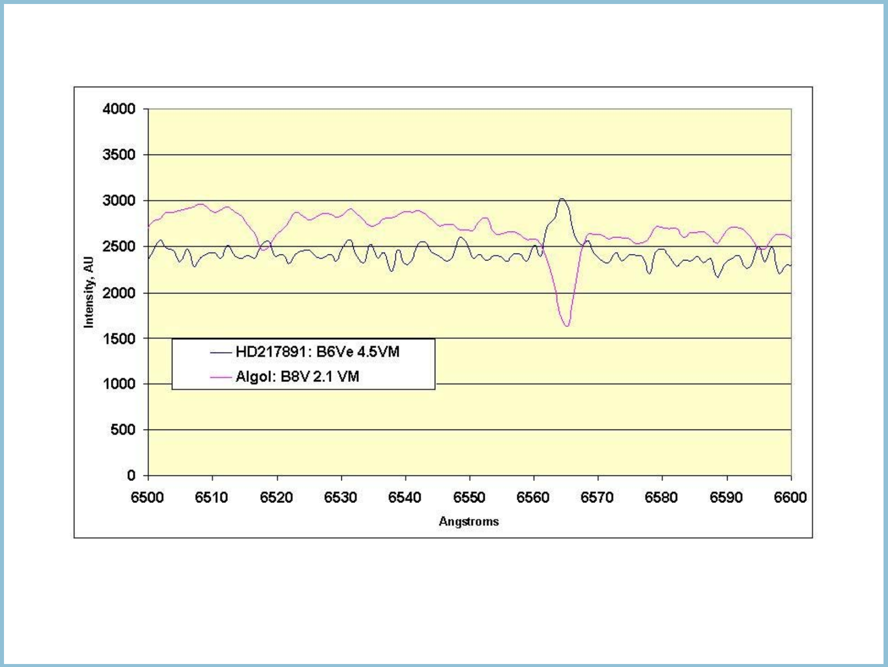


Zeta Tau (near M1)

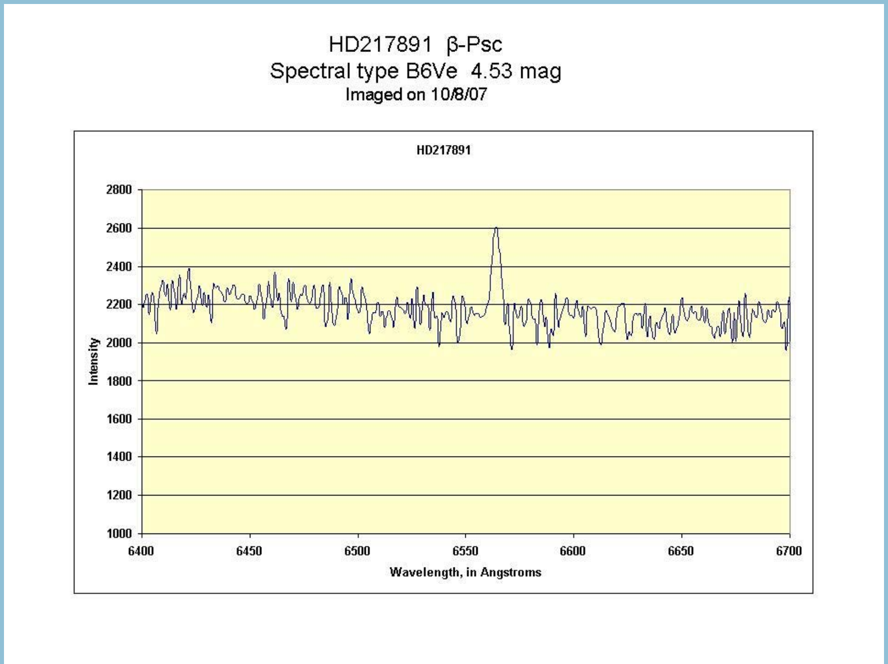


Examples of Be Spectra

A comparison of hydrogen emission and absorption spectra from 2 different stars



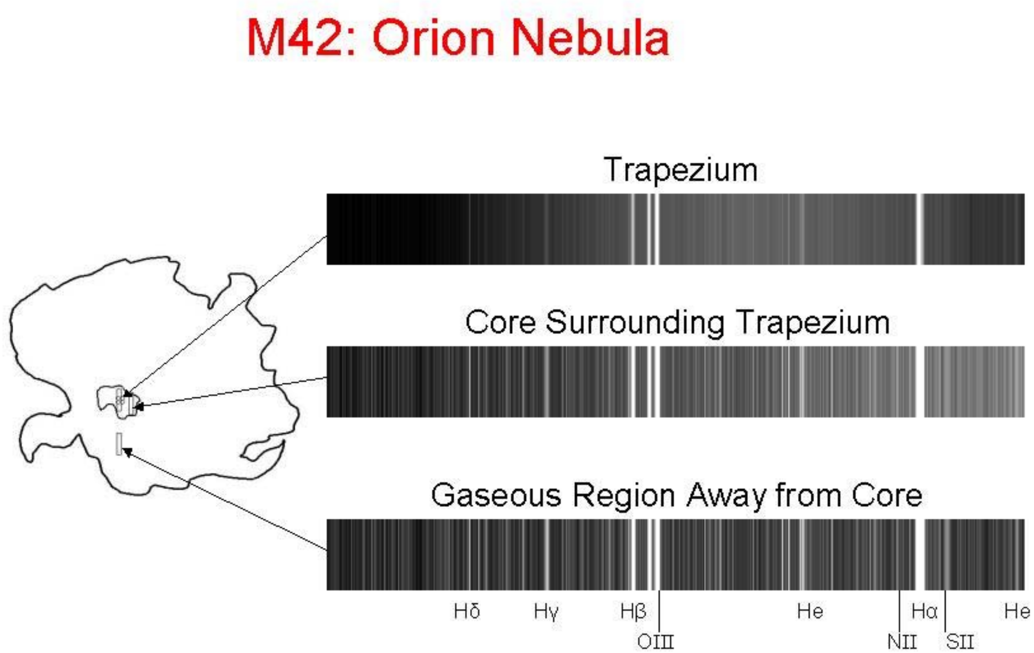
HD217891



My Orion Project

Spectra from the Orion Nebula

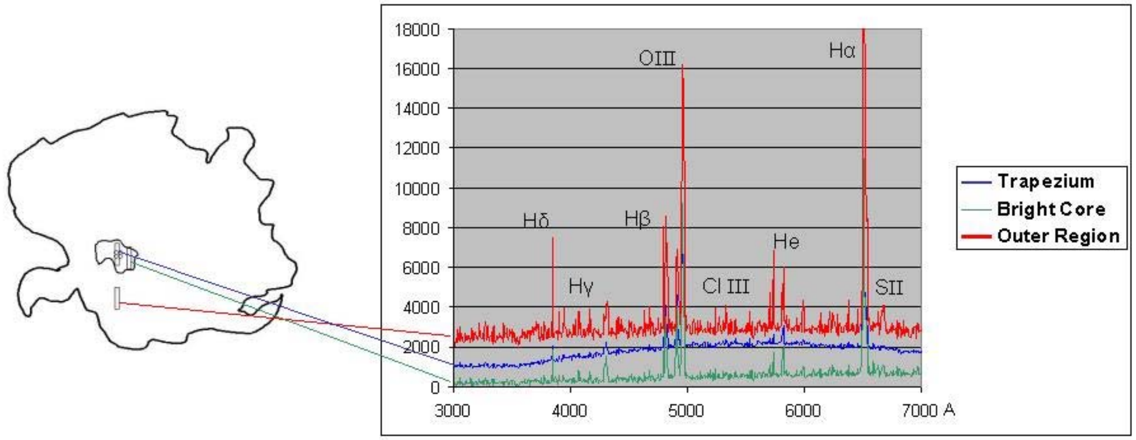
Three regions were imaged: trapezium (5”), the hot core surrounding the trapezium (5”), and the gaseous outer region (60”). CCDOPS was used for acquiring and initial processing of data; Spectral graphs were created using vspec. Imaged from the Anza Borrego Desert, east of San Diego on 11/18/06



Spectral bands showing bright emission lines from the three target regions. Note weak or absent hydrogen (Hδ, Hγ) lines, ionized nitrogen (NII) and ionized sulfur (SII) in the trapezium. Outer gaseous region shows similar Hα, stronger sulfer line, and weaker nitrogen emissions compared to core. Emission lines for core indicate that this region is much more complex chemically than the young hot stars of the trapezium.

Spectra from the Orion Nebula

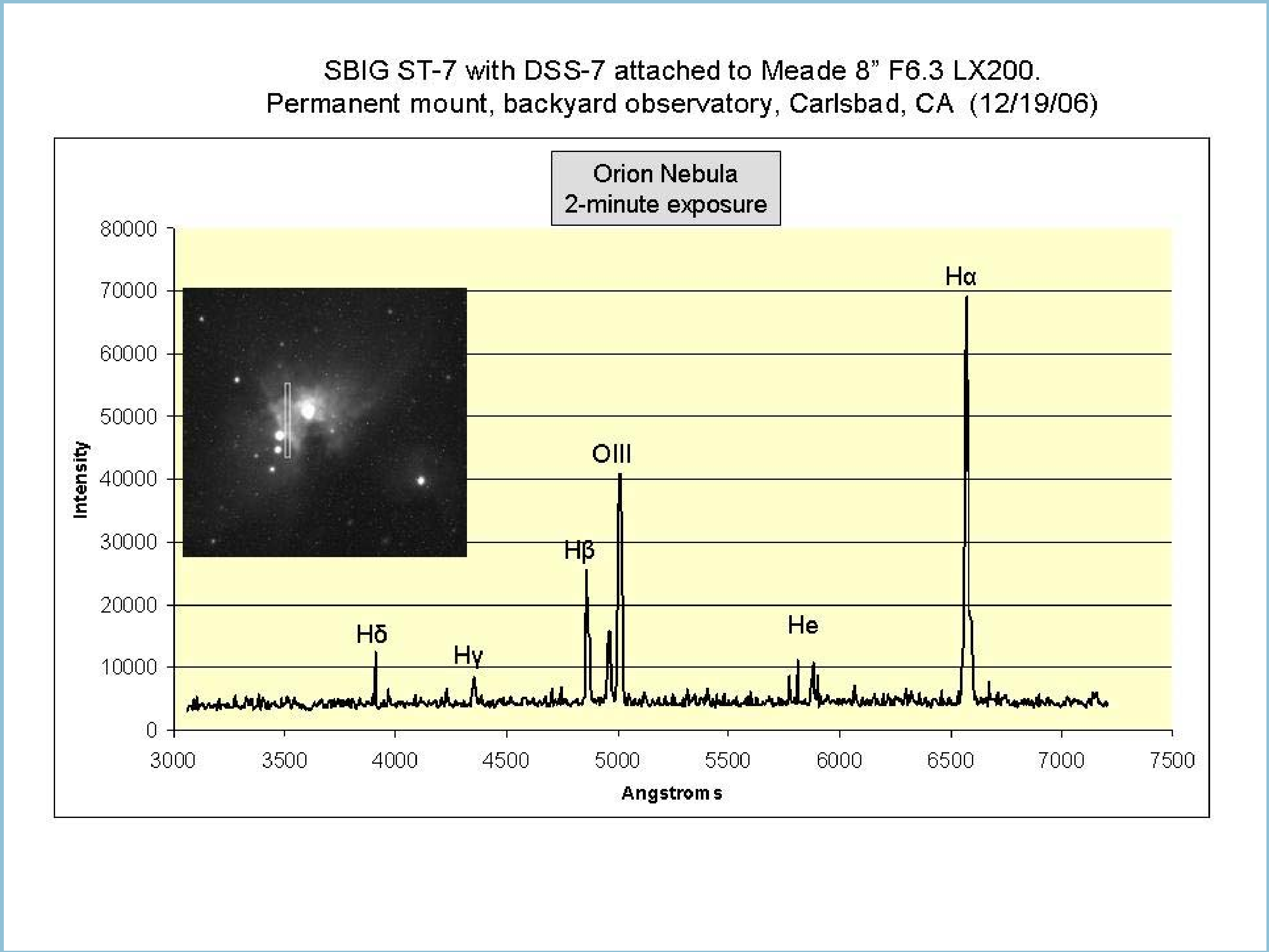
This graph shows differences in spectral characteristics of three regions within the Orion Nebula. Note low levels of helium (He) in the trapezium, higher levels of atomic carbon (CI) in the outer region, and weaker Balmer hydrogen lines in the trapezium.



Spectral graphs showing peak emission lines from the three target regions. Graph highlights subtle differences in chemical properties between the three regions of M42.

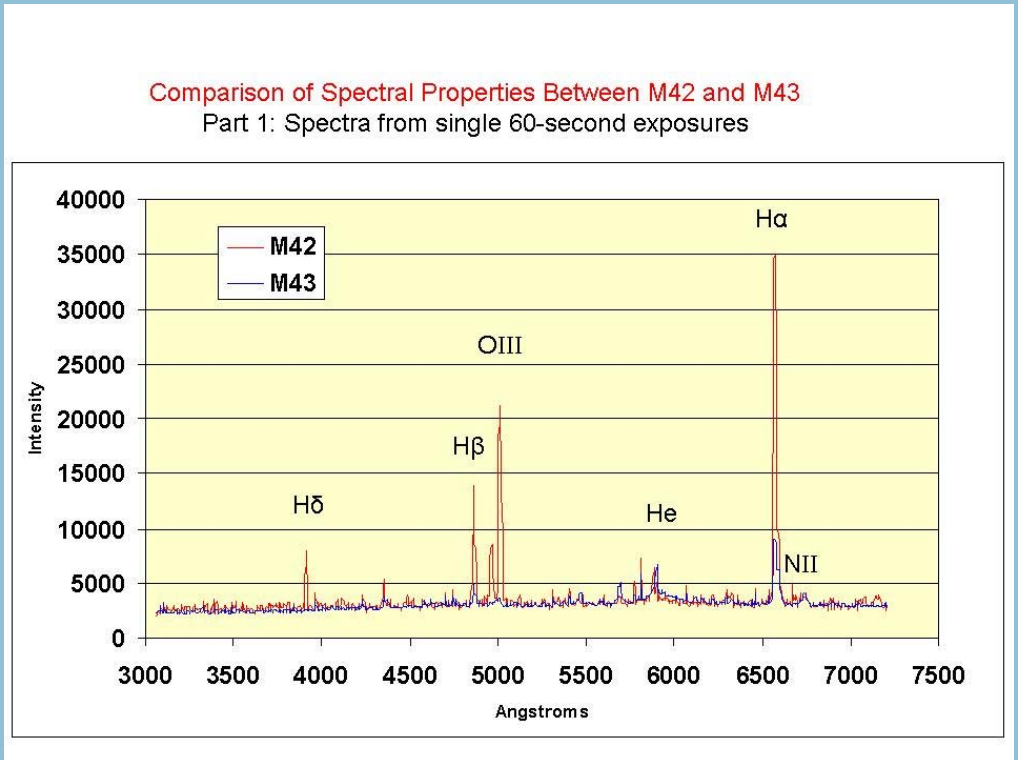
Spectra from the Orion Nebula

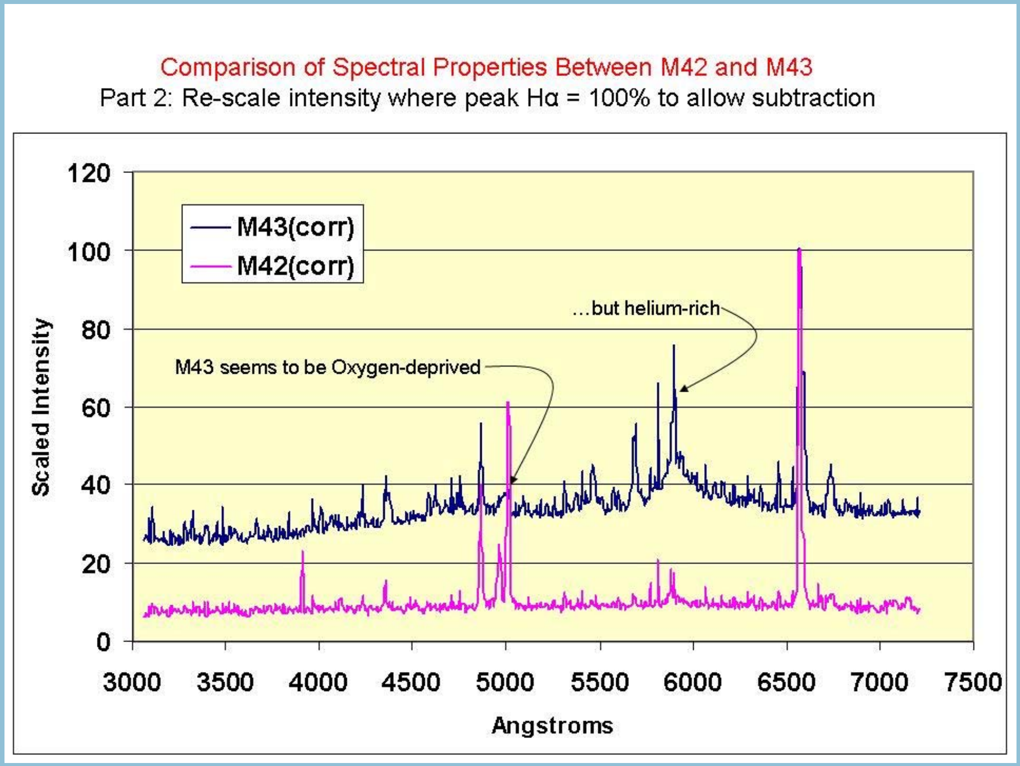
This graph shows results from a 2-minute exposure of M42



Spectra from the Orion Nebula

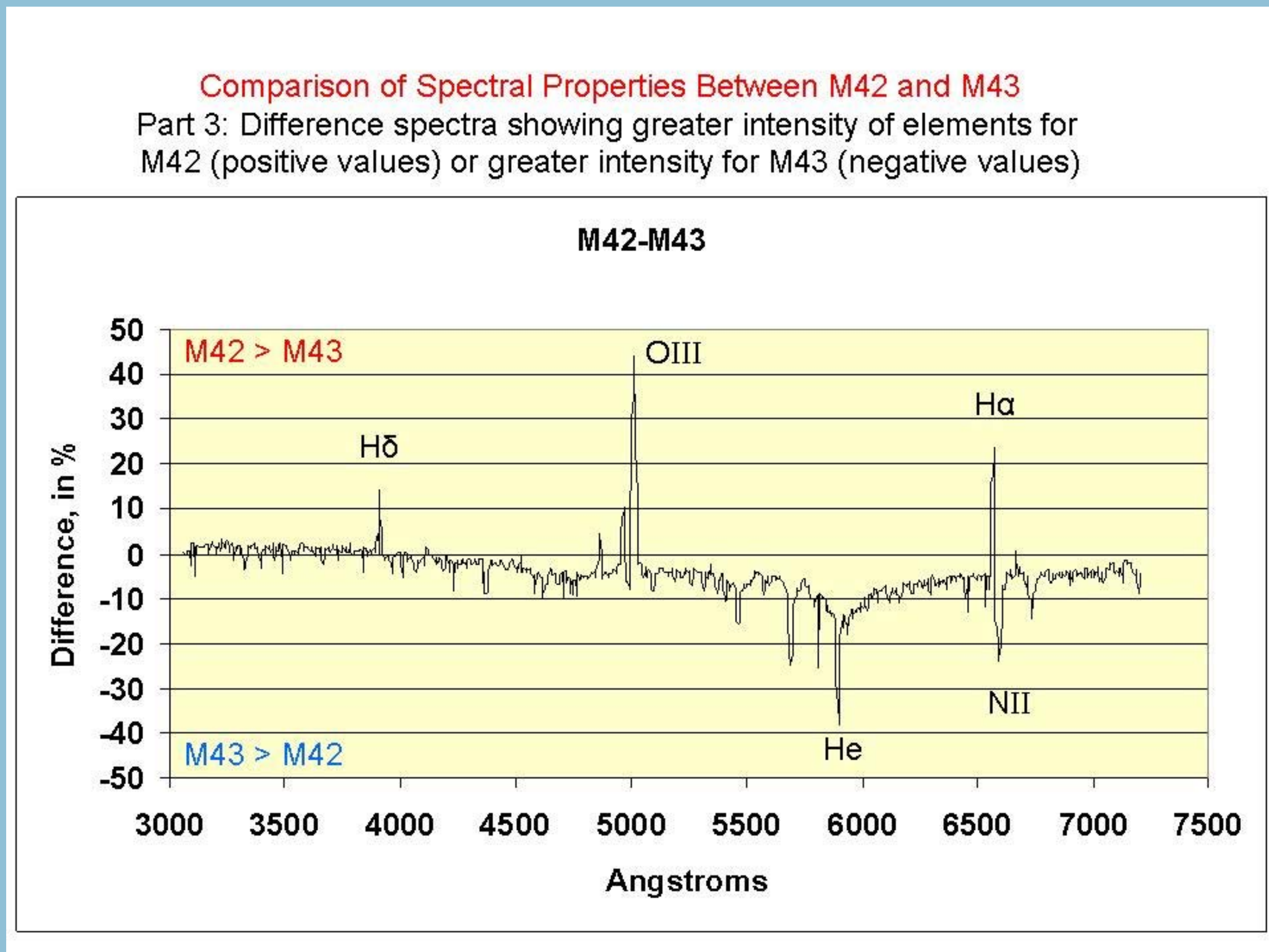
M42 and M43 are spectrally different and may have taken different evolutionary paths.





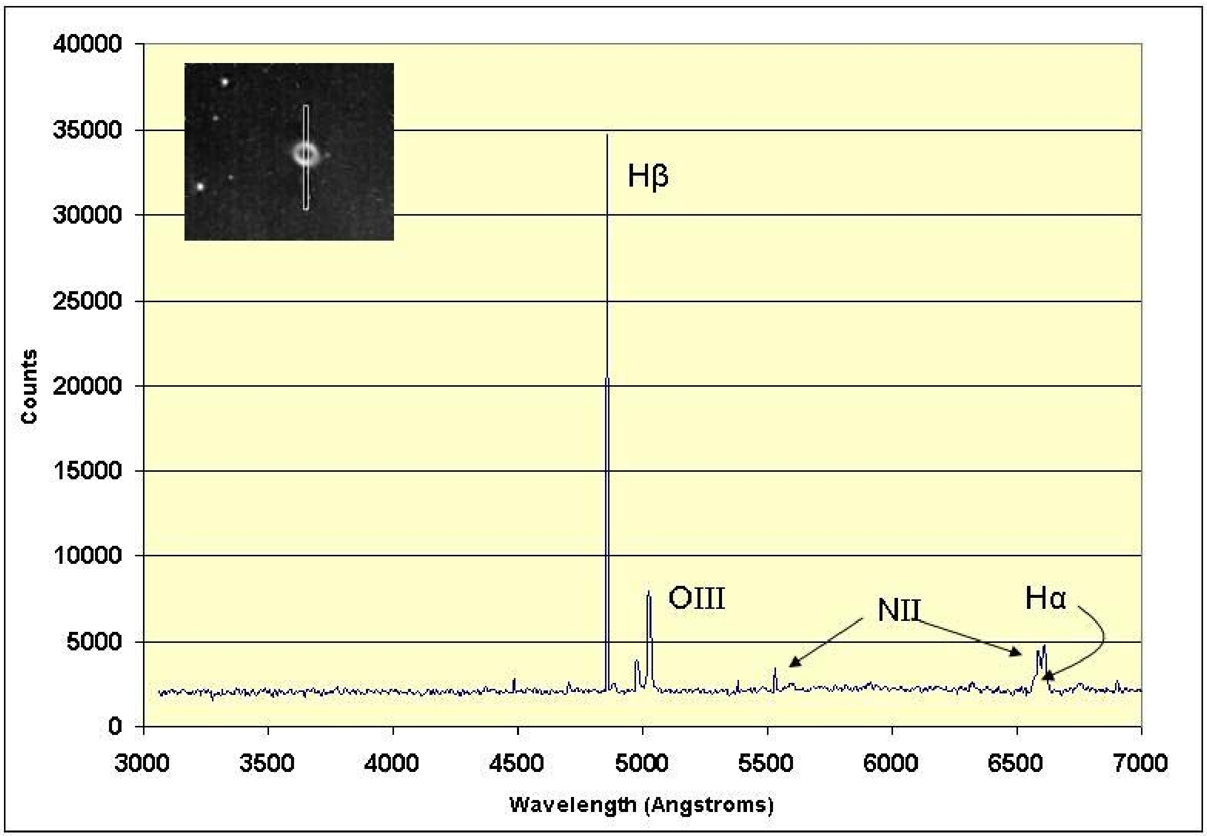
Spectra from the Orion Nebula

This is a "difference" graph highlighting the differences between M42 and M43



Planetary Nebula

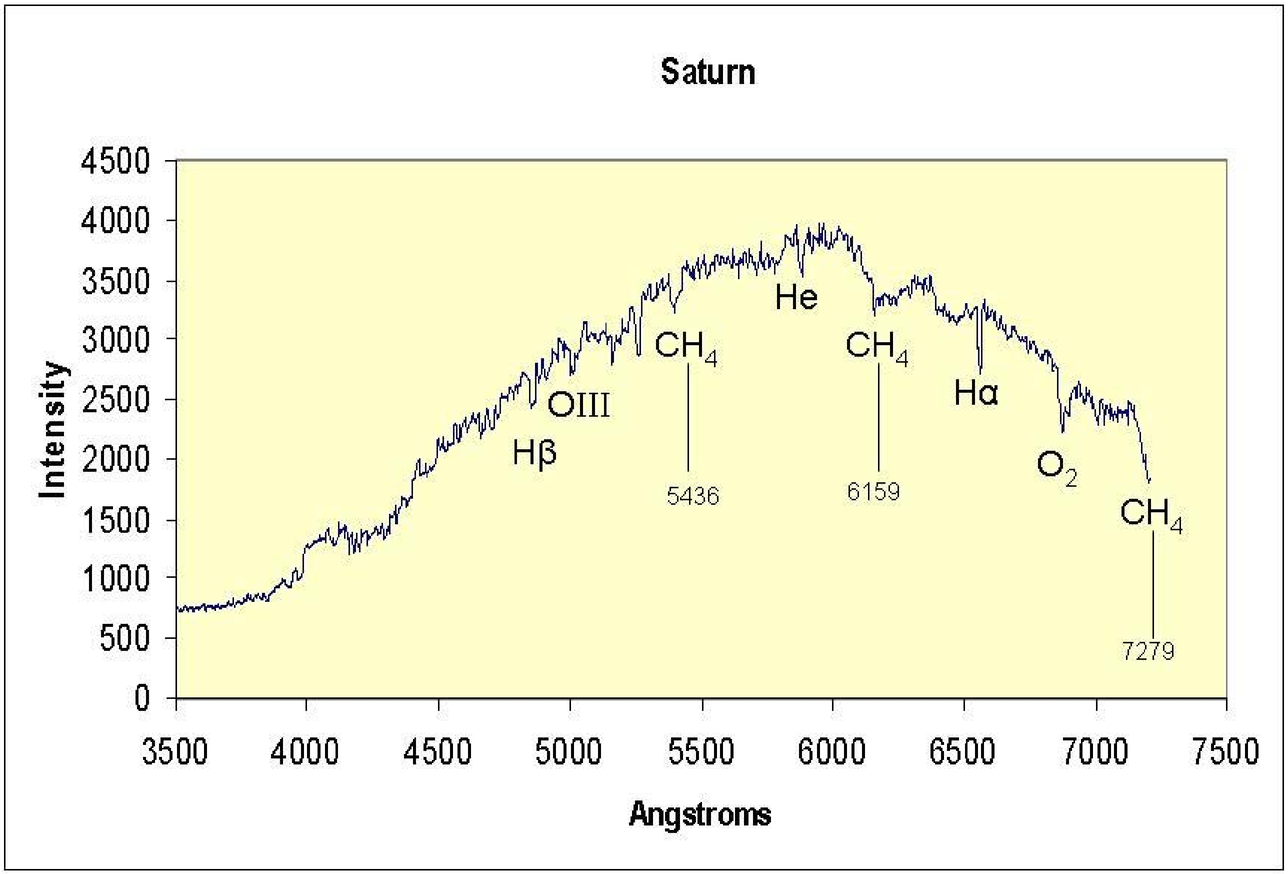
Spectral analysis of the Ring Nebula (M57) images from Little Blair Valley on 4/21/07.



M57 – Ring Nebula: 5 minute exposure through a C-5 (f10 1250mm fl).
04-21-07 from Little Blair Valley

Planetary Spectroscopy

Spectra of Saturn taken on 01/14/07 showing methane (CH4) absorption lines



Planetary Spectroscopy

Spectra of Jupiter and moons. Note Oxygen emission line from Europa (The Ice Moon) and absent carbon absorption line from Ganymede.