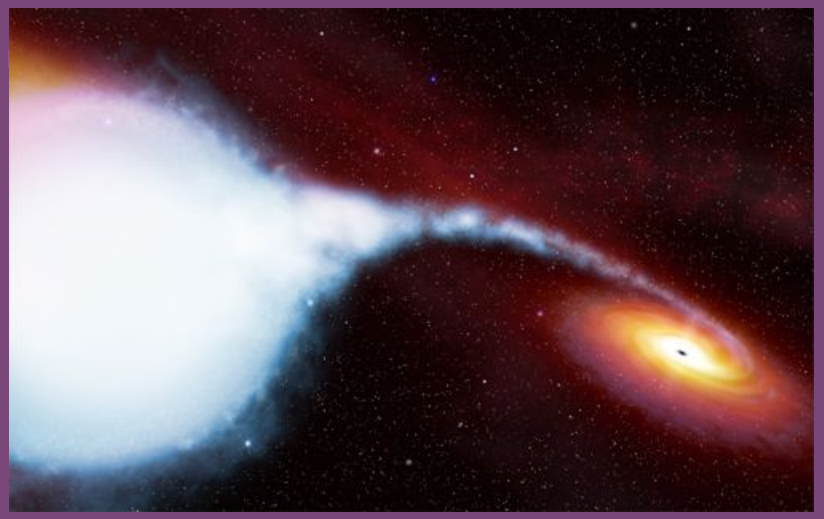
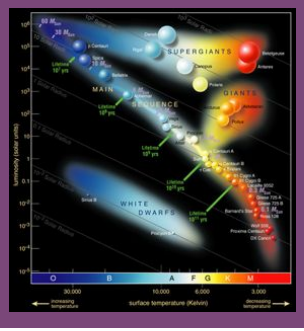
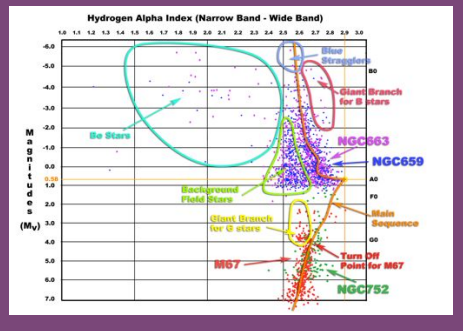
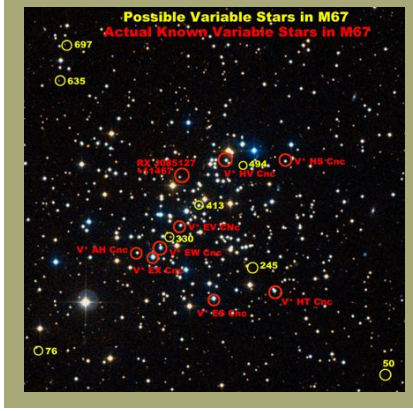
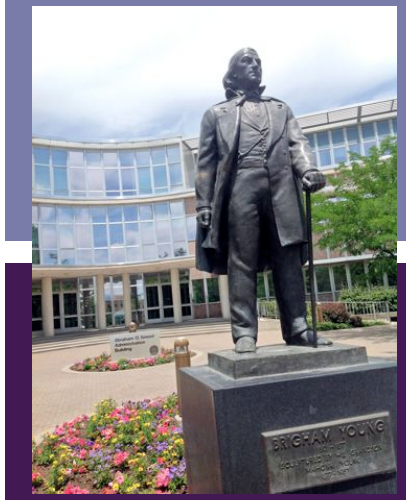
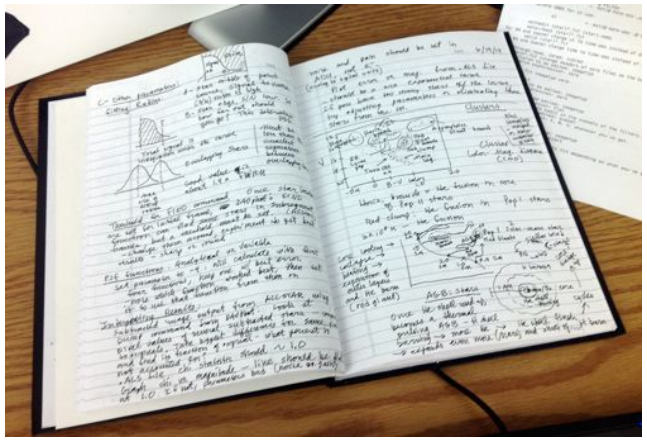












Open Clusters & HMXBs

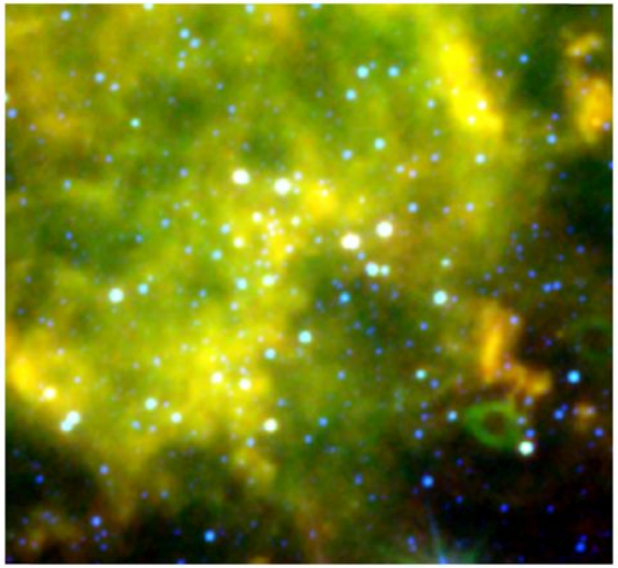
Final Report by
David V. Black
For the BYU-RET Program, 2014

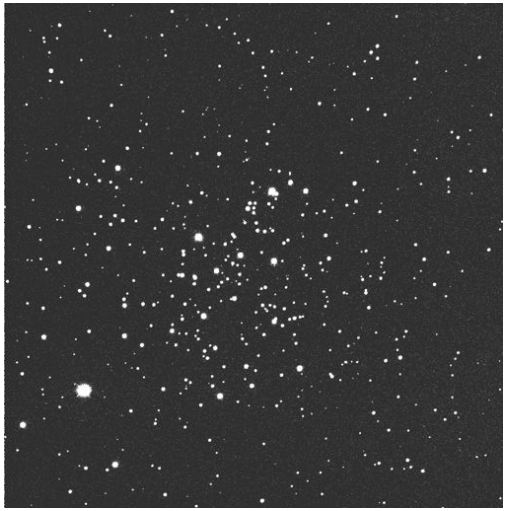
Acknowledgements

- This project was made possible through a grant from the National Science Foundation, Grant # PHY1157078.
- Thanks also to Dr. Eric Hintz, my mentor professor for this project, for suggestions regarding my results and presentation.

Goals for My Project

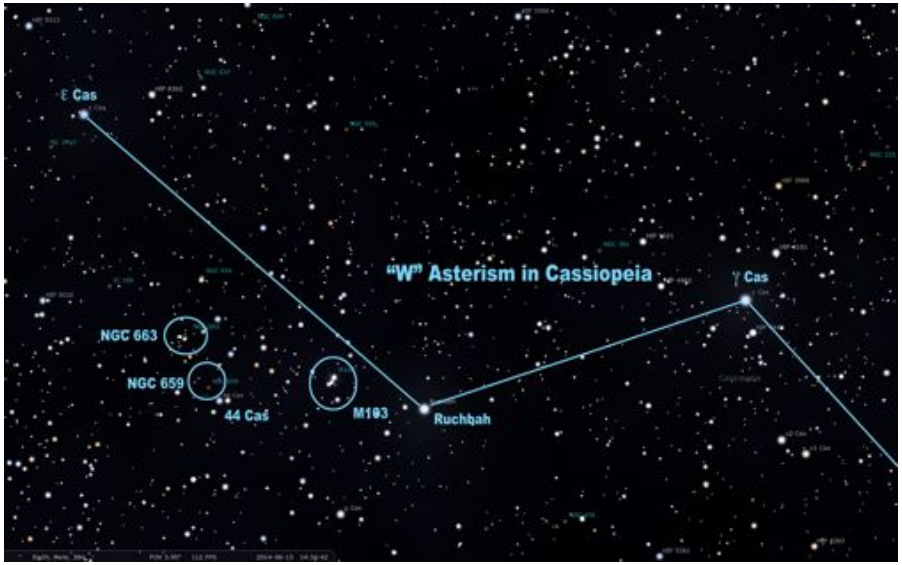
- Study open clusters (NGC 663, NGC 659, M67, etc.) looking for the periodicity of variable stars, especially high-mass x-ray binaries (HMXBs).
- Learn how to use photometry software: IRAF, DAOphot, AstroImageJ, PyRAF, DS9, etc.
- Learn how to make my own observations using various filters and telescopes and reduce data.
- Create tutorials for my high school students so that they can successfully do astrophysics for their own science projects.
- Communicate the process of doing astronomy as a science to a larger audience through my blog site: http://spacedoutclass.com.

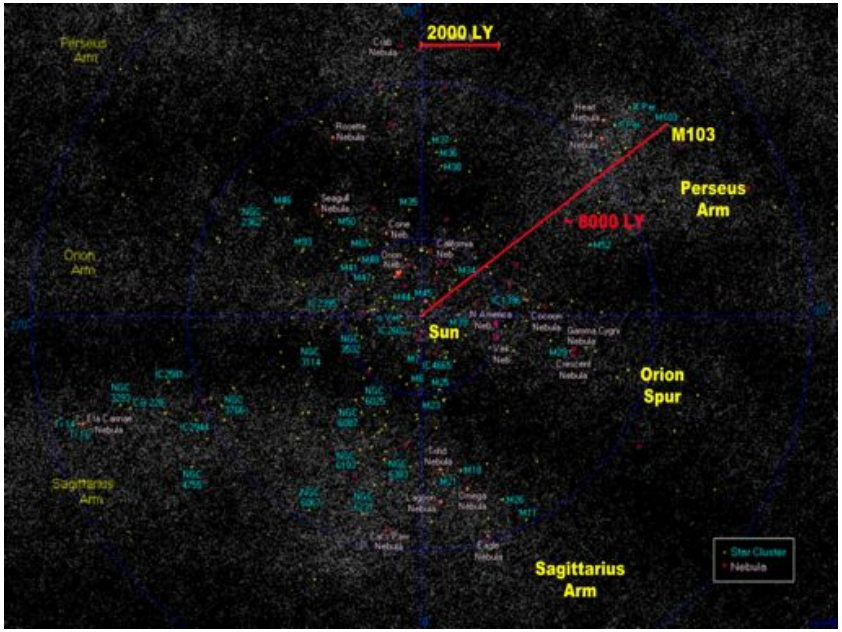




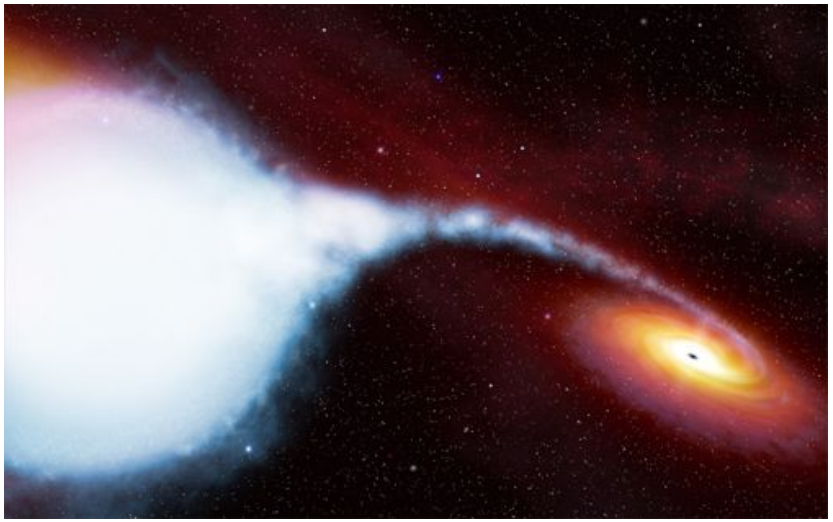
My Targets

- Target clusters NGC 663 and NGC 659 are in Cassiopeia to the west of Ruchbah and northwest of 44 Cas.
- Part of Cassiopeia Association about 8000 light years away in the Perseus Arm of the galaxy.
- Estimated age of only 20-25 million years (MY).
- Comparison clusters: NGC 752 in Andromeda (2 BY old) and M67 in Cancer (4 BY old).

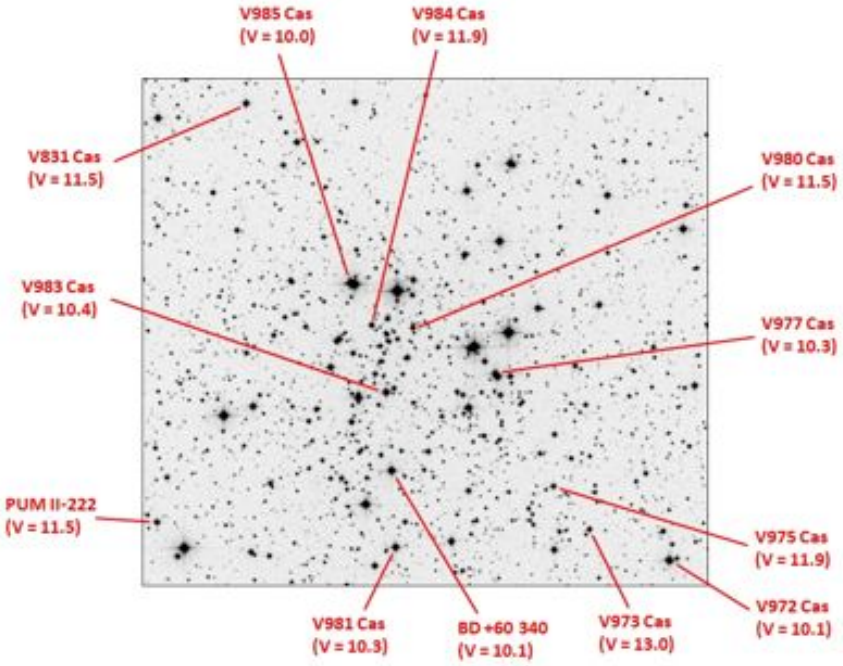


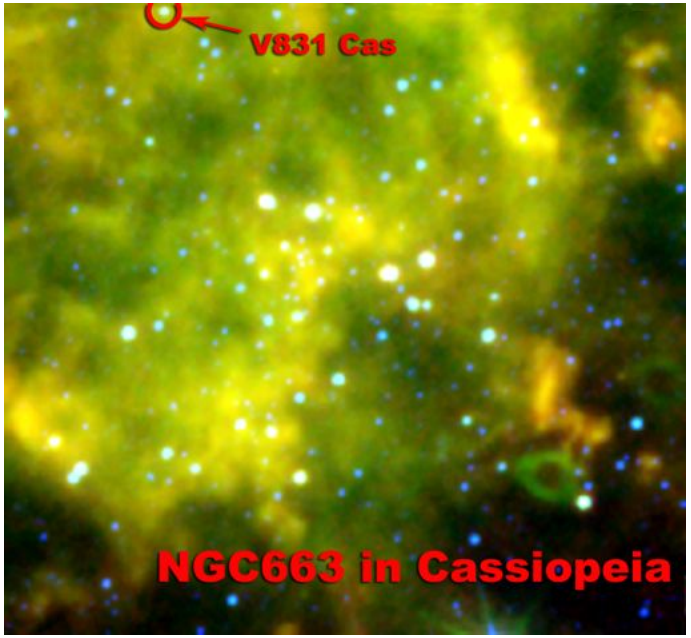


+ HMXB: V*V 831 Cas



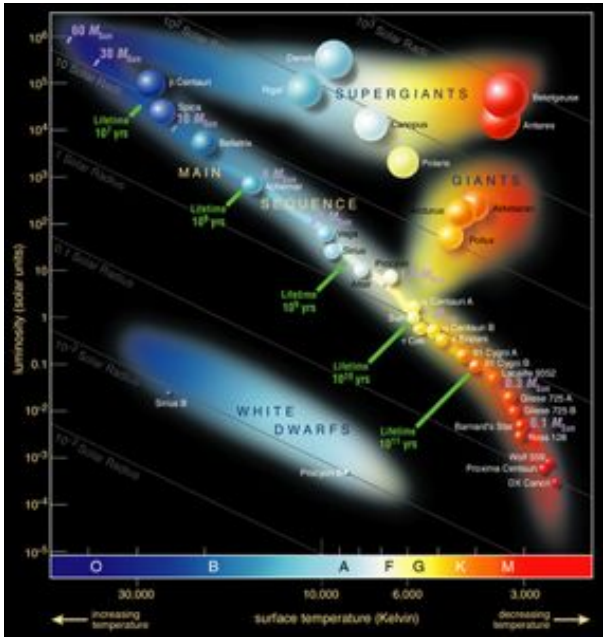
- Large Be star with compact x-ray source: black hole or neutron star.
- Emissions in radio through X-rays: very messy, dynamic system.
- Located in NGC 663.

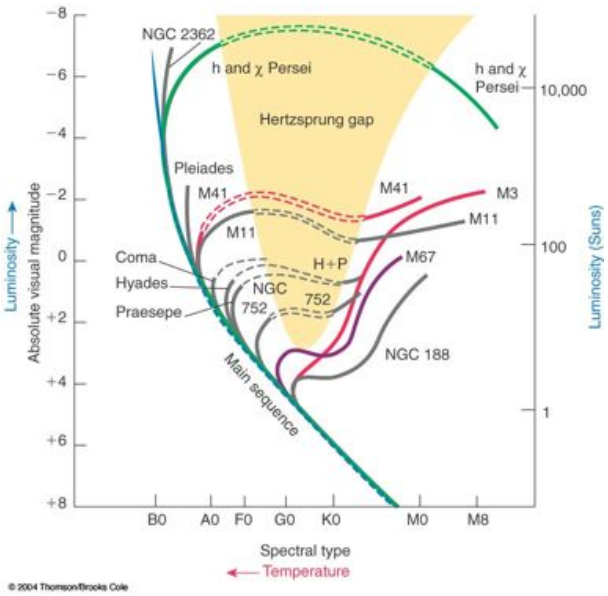




Open Cluster Ages

- H-R Diagrams for open clusters: Stars form at the same time and place, but with different sizes. Clusters therefore provide an excellent laboratory for stellar evolution.
- The Turn-Off Point (where a star leaves the Main Sequence): Determined by the mass of the star and the age of the cluster.





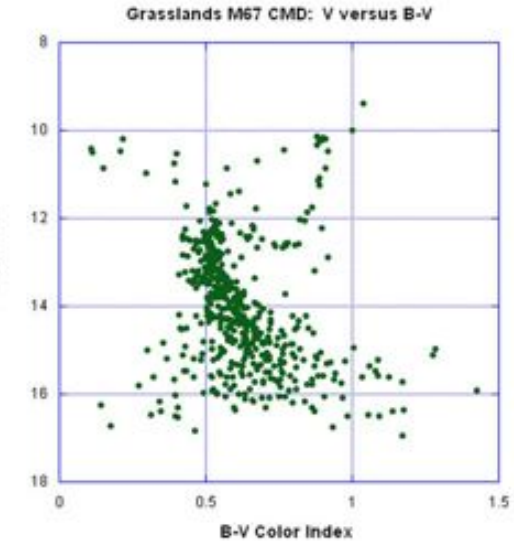
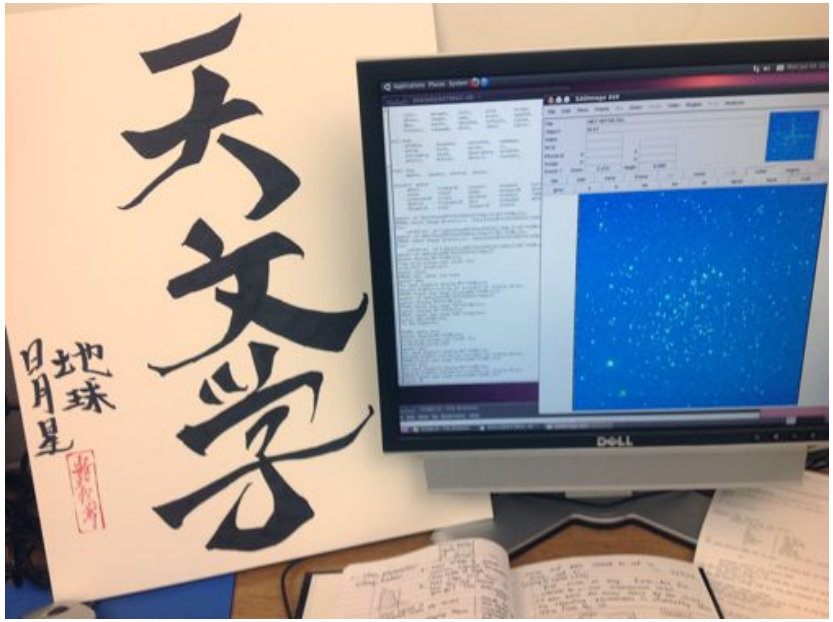
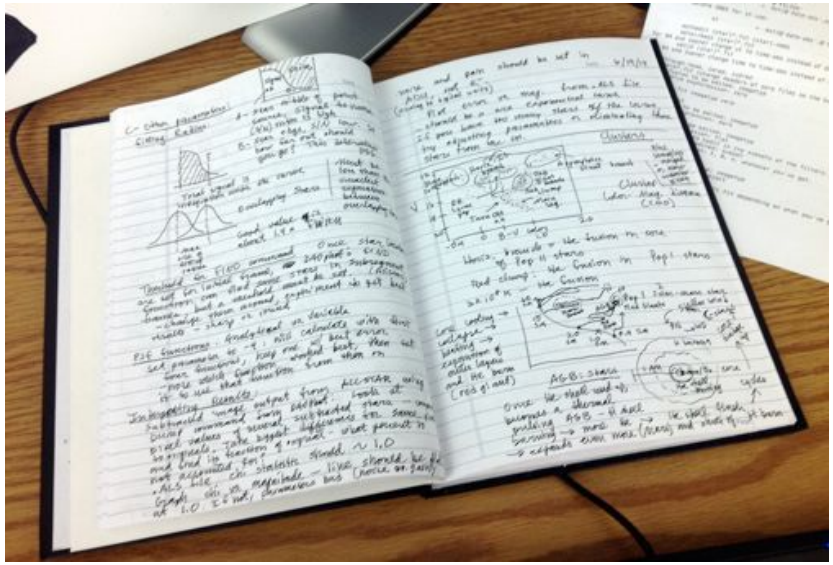


Figure 9. Color magnitude diagram of M67: V magnitude versus B-V color index. Grasslands Observatory data for 524 stars.

Using IRAF and DAOphot

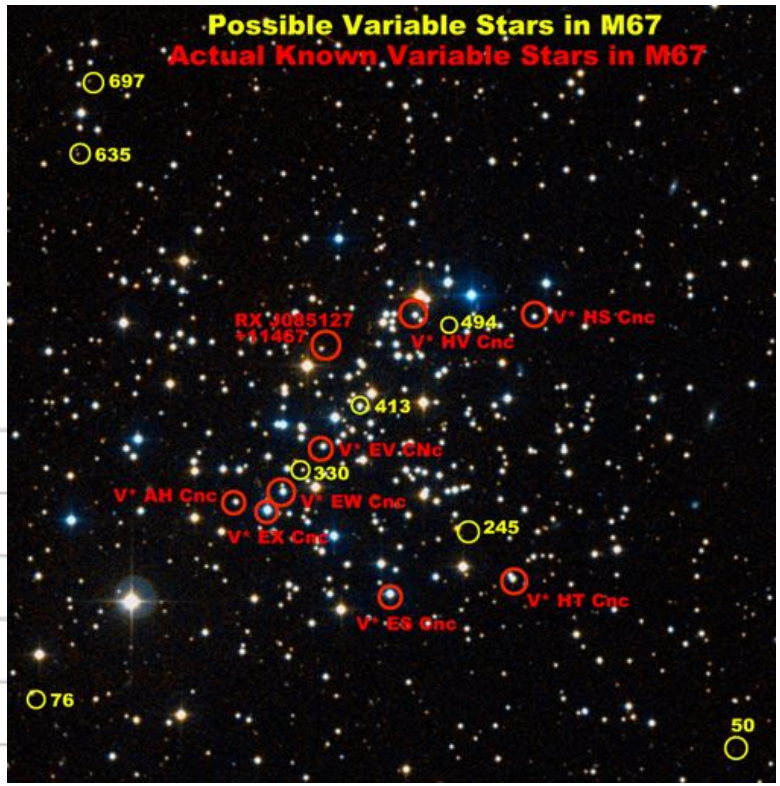


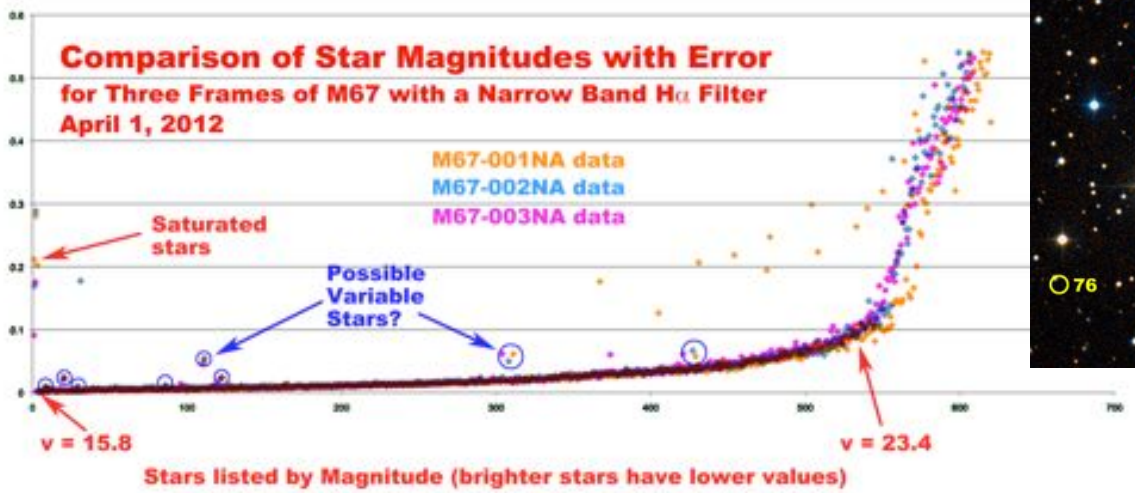


- Using IRAF: Command line, non-GUI interface. Works with DS9 for viewing .fits images.
- To do photometry on star clusters where overlapping stars are common, it is best to use DAOphot package.
- Complex process including determining parameters, setting parameters, creating coordinate files, setting the point spread function, and calculating magnitudes.

+ Determining Error vs. Magnitude

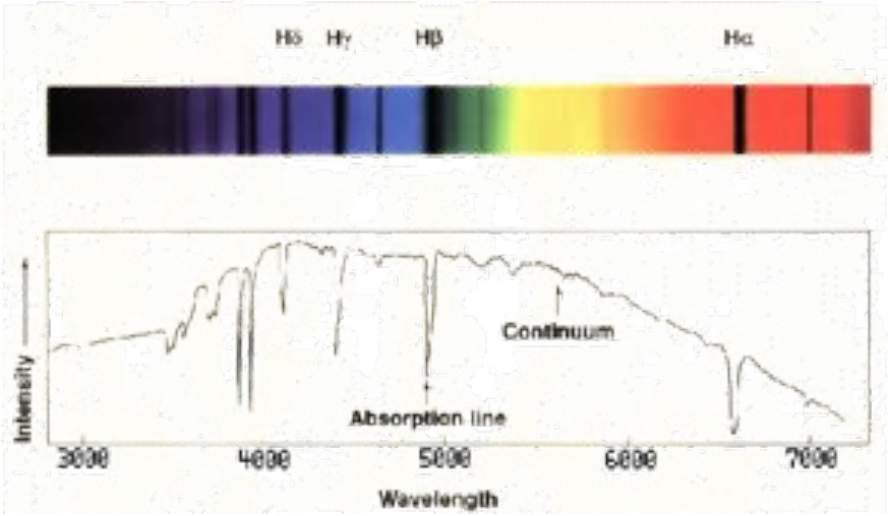
- Getting the .txt file into Excel and cleaning it up.
- Analysis: Magnitude vs. Error
- A detour into variable stars. Don't correspond to actual variables. Probably bad pixels in CCD.
- Data trustworthy between magnitudes 16 and 23.

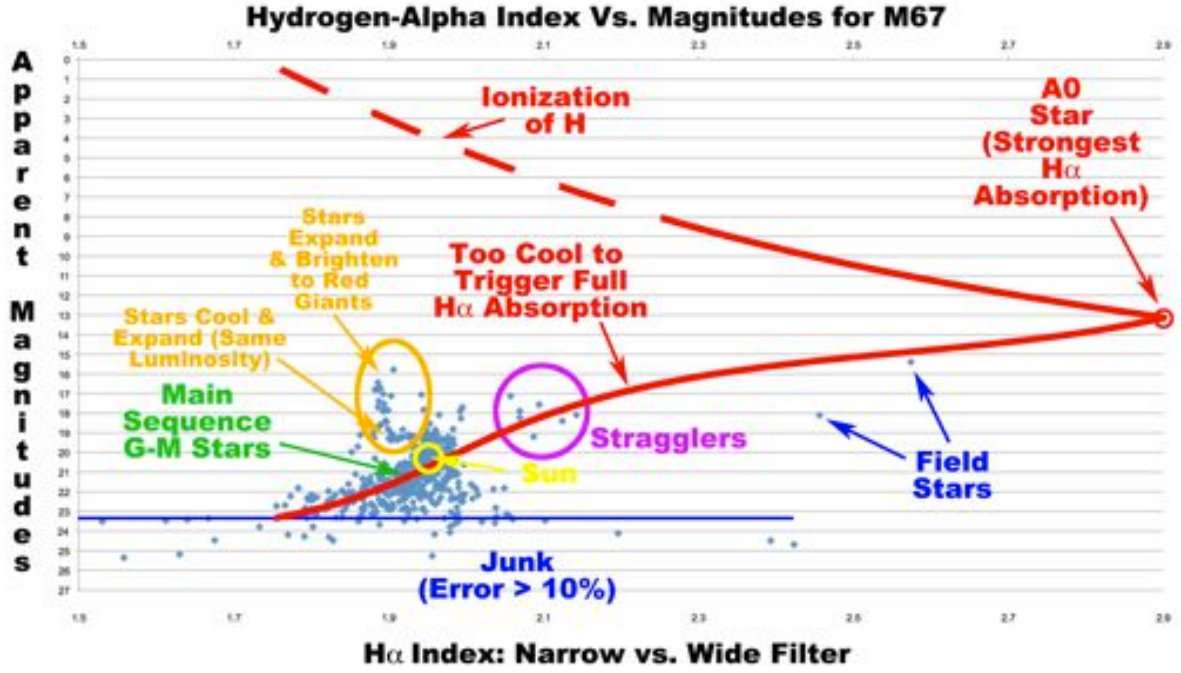




Hydrogen Alpha Index

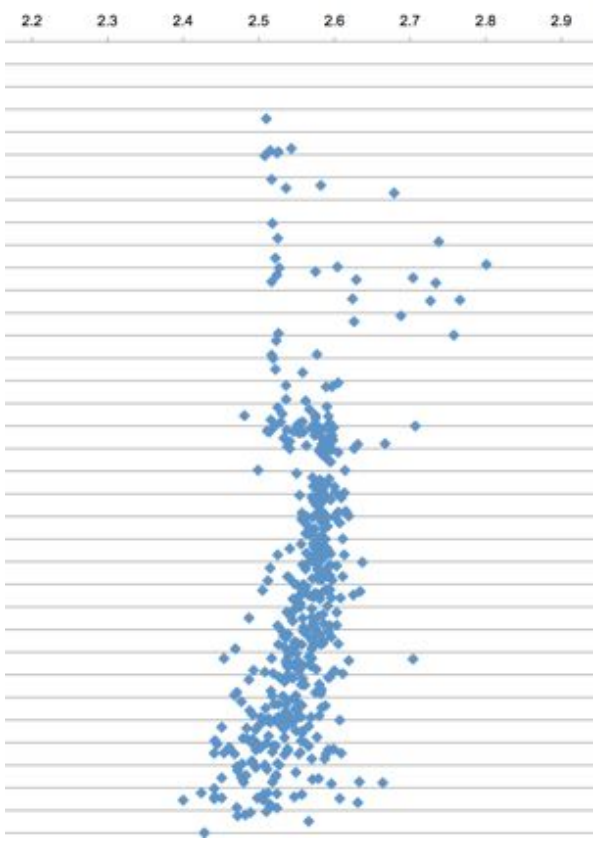
- Looking at same frames with narrow band vs. wide band Hα filters.
- When difference (Hα index) was charted against magnitude, I got an expected result showing the tail end of the Main Sequence and the RG Branch for M67.
- Fits well with expected curve – I must be doing something right.





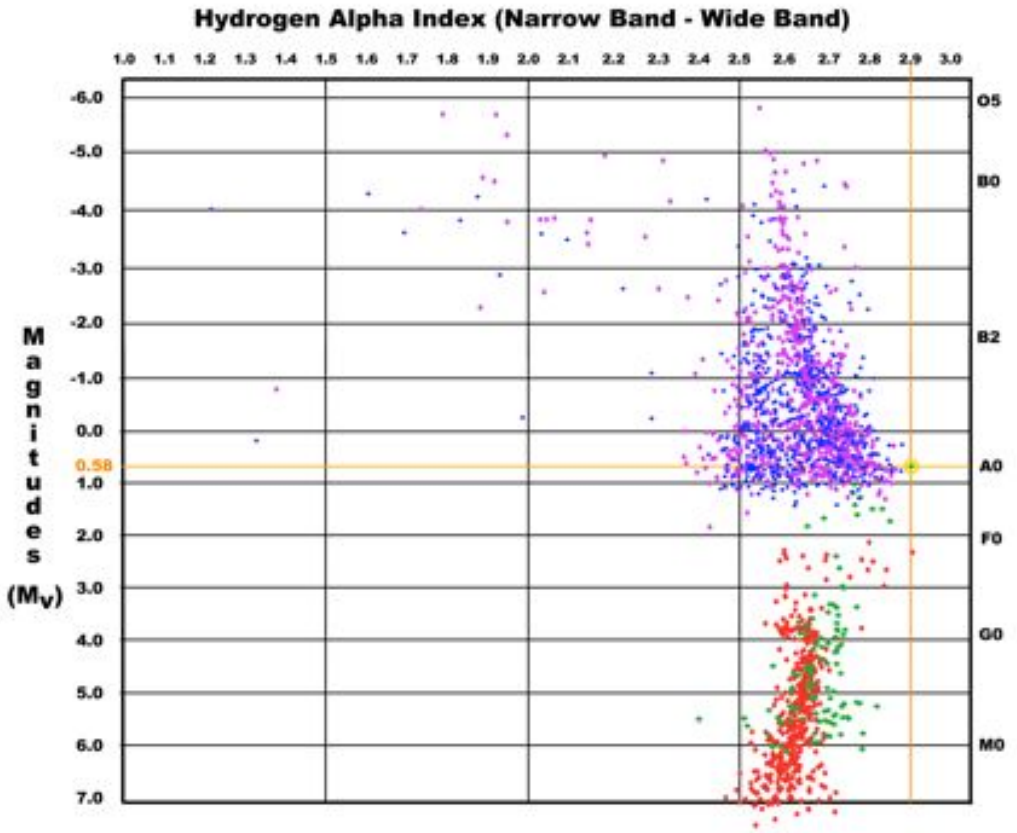
Charting Hα Index for Four Clusters

- Comparing young clusters (NGC 663 and NGC 659) with older clusters (NGC 752 and M 67).
- Chose 25 Jan. 2014 as comparison, since all four clusters were photographed with the same telescope that night.
- Used DAOphot to determine the magnitudes using a point spread function.
- Found Hα narrow minus Hα wide (Hα index) for all clusters.
- Charted Hα index vs. Hα Narrow Magnitudes and combined charts.
- NGC 752 has a standard A0 star – used this for calibrating the Hα Index scale (A0 = 2.9).
- Used Distance Modulus formula to calibrate for distance and convert to Absolute Magnitudes.



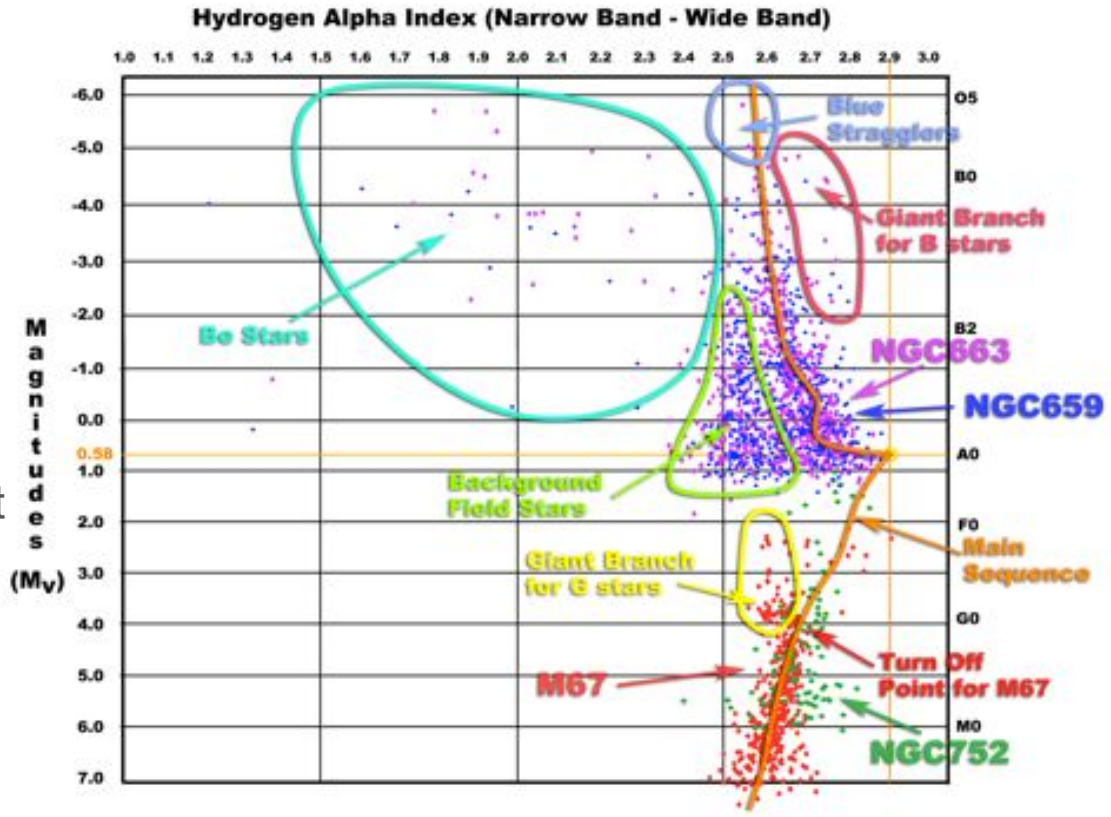
+ Results

- The Hα Index can be used to determine open cluster ages.
- B emission stars (Be) have an Hα emission line inside the Hα absorption line. This indicates dust/gas surrounding the star.
- Identified ~24 Be stars: the literature claims 22-26 Be stars in NGC 663.



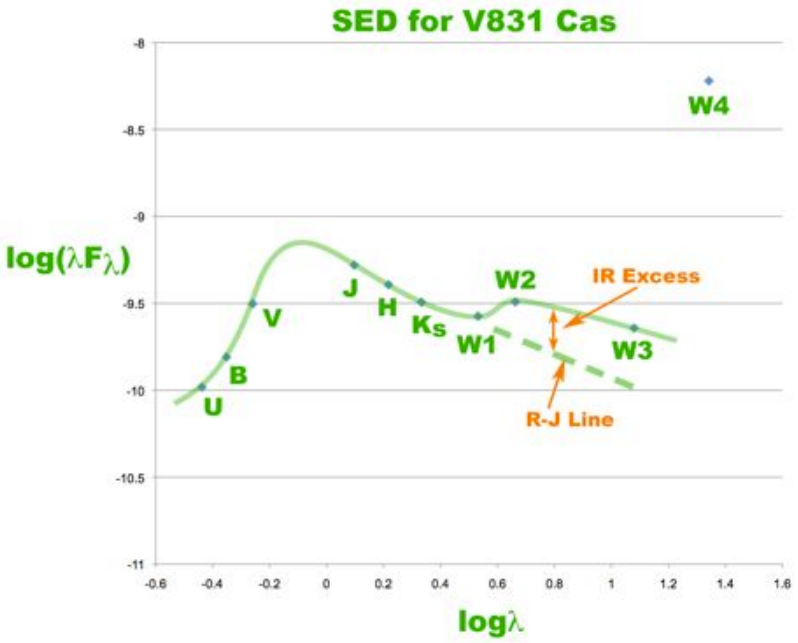
Features of the Chart

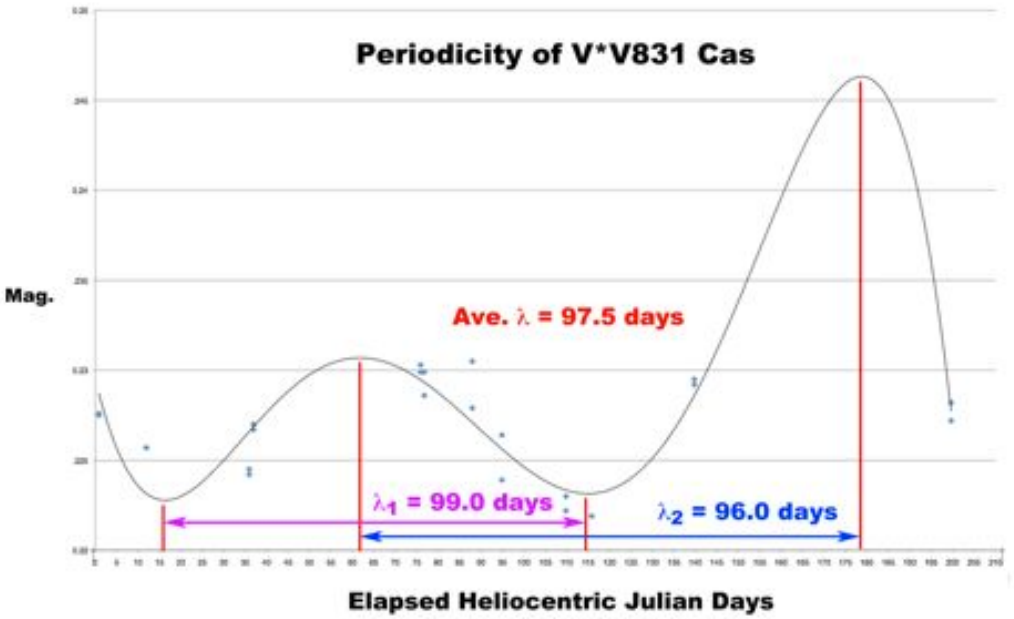
- Be stars are located left of the main sequence line (orange curve) since the Hα emission line weakens the absorption levels.
- Turn-off point for NGC 663 is at about B0, indicating age of 15-25 million years. NGC 659 appears to be slightly older.
- Blue stragglers are “late bloomers”: probably smaller stars that have merged to form O and B stars.
- Field stars are in the image but not part of the cluster – weaker Hα index due to greater distance and nebula behind NGC 663.
- Nice turn-off point and Red Giant branch for M67 (goes left, then up). Turn-off points also seen for NGC 663 and NGC 659 (stars go right and down toward A0 point).



Tracking V*V 831 Cas

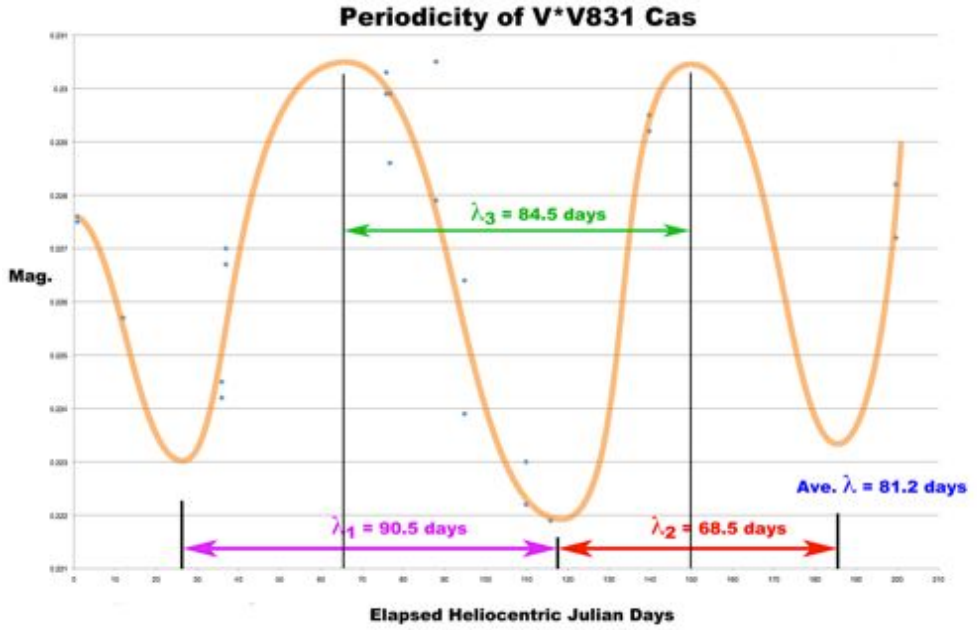
- Spectral Energy Distribution (SED) chart in multiple wavelengths shows an IR excess (ring of gas).
- Multi-aperture photometry over all nights it was observed (using AstroImage J) shows variability.
- Excel plot agrees well with AAVSO data: period = 97.5 days.

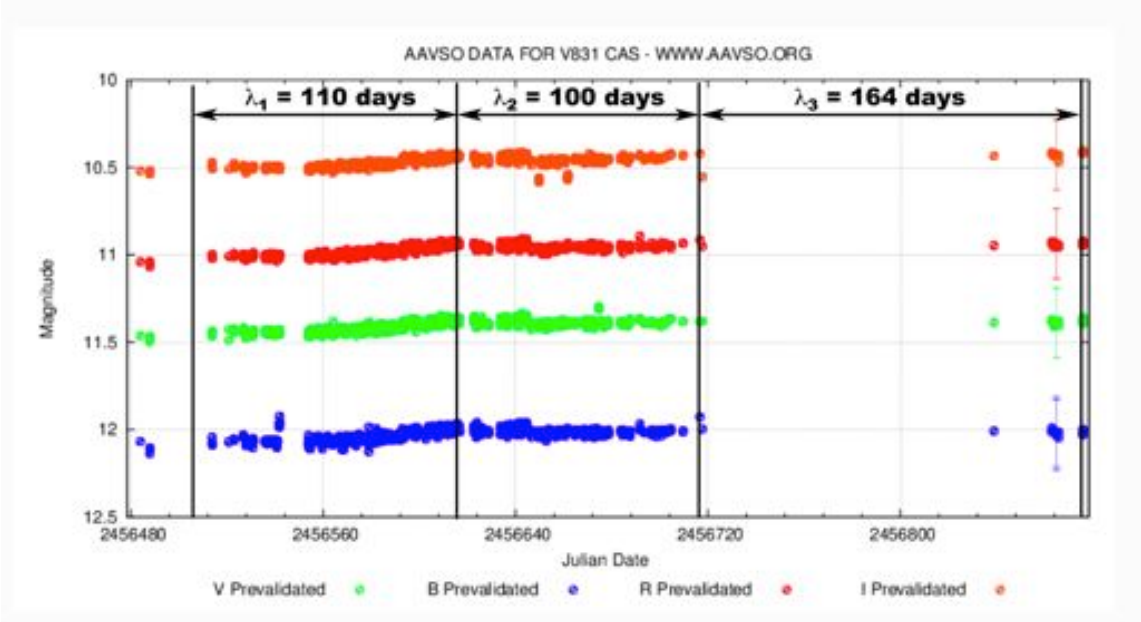




More Results: V831 Cas

- My own attempt at plotting a curve has a more regular amplitude but a smaller period of 81.2 days.
- AAVSO data shows a period of about 105 days.





Back at School

- Test the tutorials/guides which I developed at BYU.
- Purchase a telescope, mount, filters, and CCD camera capable of doing photometry.
- Develop student projects: Hα Index for open clusters, tracking variable stars, locating Be stars, creating B-V Color Magnitude Diagrams, SEDs, etc.
- Follow up on the NITARP project (IR excesses of K-giants).
- Report on our projects on my blog at: http://spacedoutclass.com.