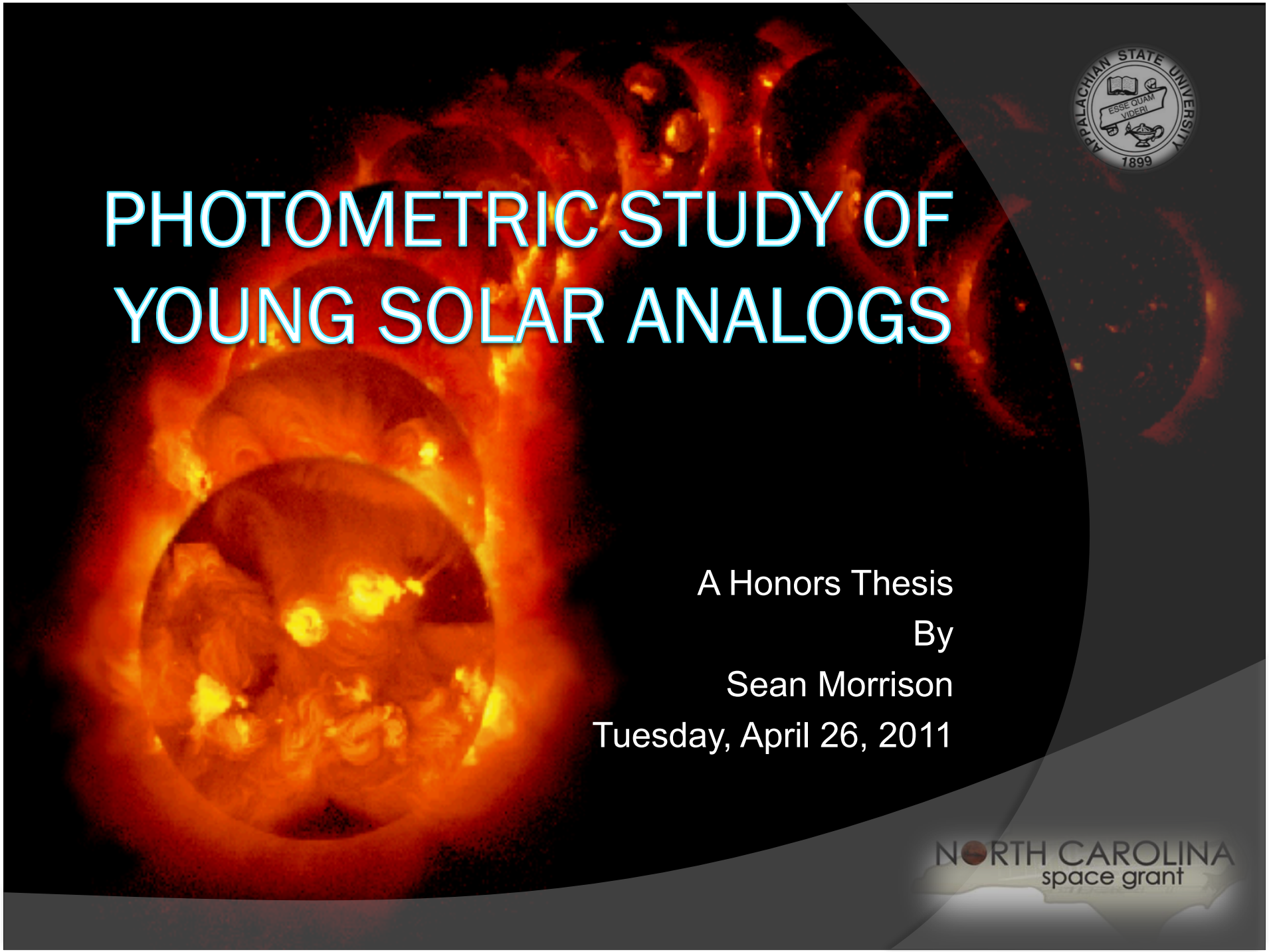


PHOTOMETRIC STUDY OF YOUNG SOLAR ANALOGS

A Honors Thesis

By

Sean Morrison

Tuesday, April 26, 2011

NORTH CAROLINA space grant

Outline

- What is a YSA?
- Theoretical Background
- History
- Selection of YSA Stars for Research
- Spectroscopic Research at Appalachian State University
- Observatories and Telescopes
- Reduction and Photometry Pipeline
- Flat-Field Experiment
- Results/Conclusion

Goal

- To gain a window into the conditions of the early solar system when life was establishing a foothold on the Earth
- To gain a window into the conditions around YSAs

What is a YSA?

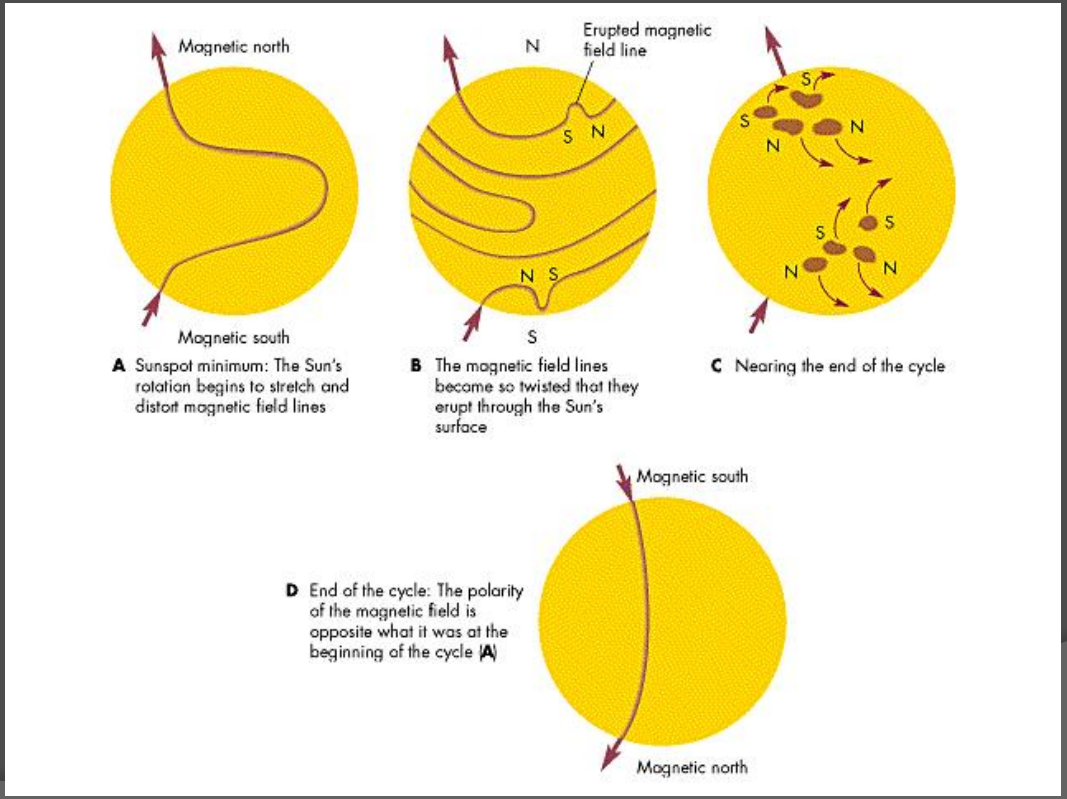
- A star with:
  - age between 0.3 and 1.5 Gyr
  - Spectral Type: Late F- to early K-type

Theoretical Background Stellar Structure and Sunspot Physics

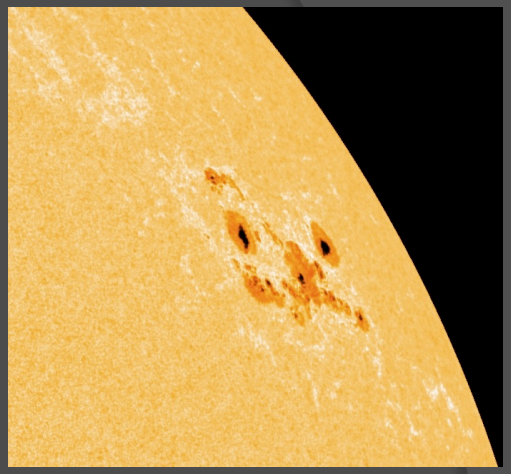
- Stellar Atmosphere
  - Photosphere
  - Chromosphere
  - Corona
- Flares
  - Extend from the photosphere to corona
  - Magnetic Reconnection
- Sunspots
  - Regions of strong magnetic fields in the photosphere

Theoretical Background
Sunspot Physics: Babcock Model

- Sunspots formed from a progressive tangling of the magnetic fields due to the differential rotation of the Sun



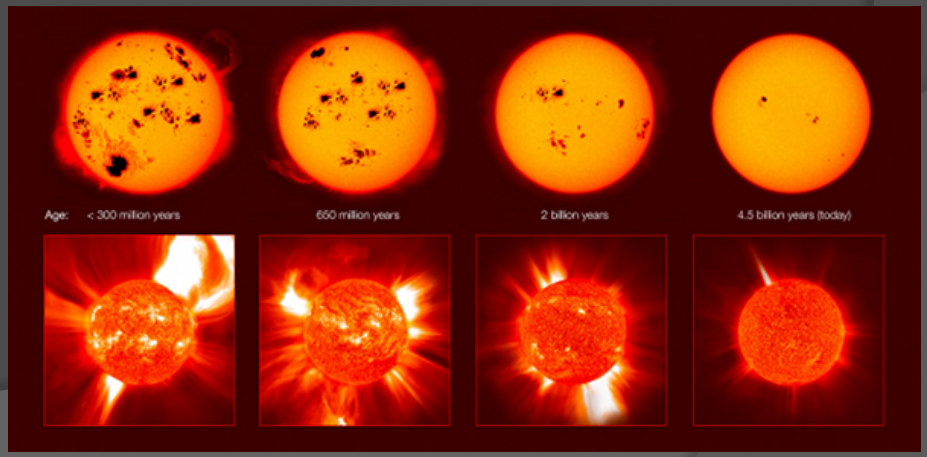
Theoretical Background Sunspot Physics



- Areas of cooler temperatures
- Intense magnetic fields inhibit convection
- Faculae:
  - Result of cluster of magnetic fields
  - Brighter then the surrounding atmosphere

Theoretical Background
Stellar Evolution

- Rotation slows as stars age due to loss of angular momentum and energy by the Solar winds
- Activity levels decrease as the star ages
  - Babcock Model
    - Entanglement is reduced



History: Early Research

Ca II K & H Monitoring at Mount Wilson Observatory

- 1966 – 2003
- Mid-F to M2
- 15 fit our definition
- Results
  - 60% - Activity cycle similar to the sun
  - 25% - No well defined cycle
  - 15% - Little to no variation in activity

"Sun in Time"

- 1988 -2008
- G0 to G5
- 50 Myr to 9 Gyr
- multi-wavelength study
- Results
  - Early Sun Rotates 10x faster then current
  - Refined the rotation-age-activity relationship of Solar like stars

History: Current Research

Lowell Observatory Solar-Stellar Spectrograph

- 1988-?
- Direct comparison between the Sun and solar analogs
- 28 stars
  - 6 YSAs
  - Rest are “Solar Twins”
- F8 to G8 (most G0-G2)
- Simultaneous Photometry and Spectroscopy
- Inverse correlation between brightness and activity in YSAs

Research At Appalachian State University

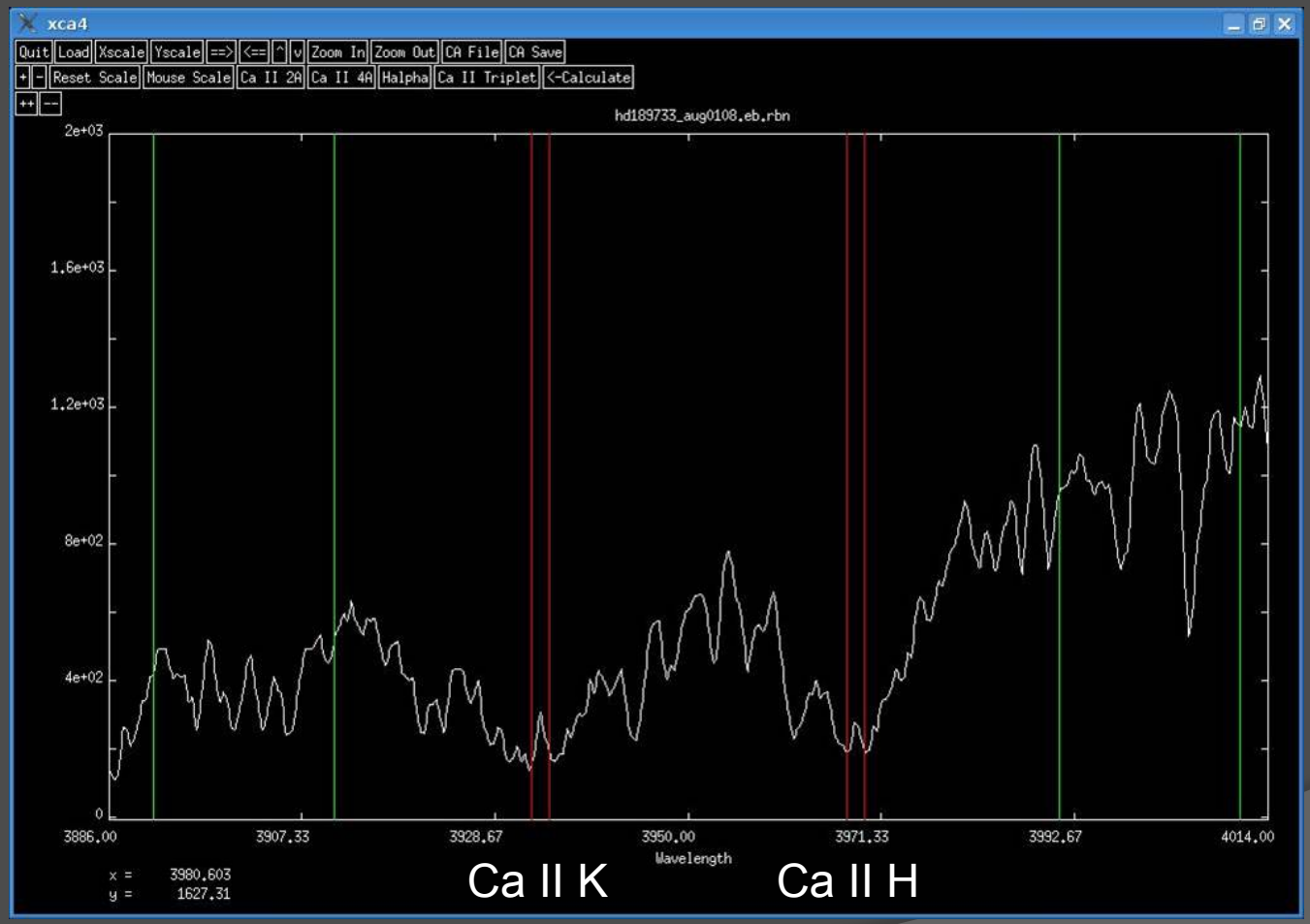
Selection of YSA Stars for Research for Spectroscopic and Photometric Research at Appalachian State University

- Selected From the Nearby Star Project
- 31 High Priority Stars
- Within 40 pc
- F8 to K2
- 0.3 to 1.5 Gyr
- V mag: 8 to 5

YSA Sample and Stellar Characteristics

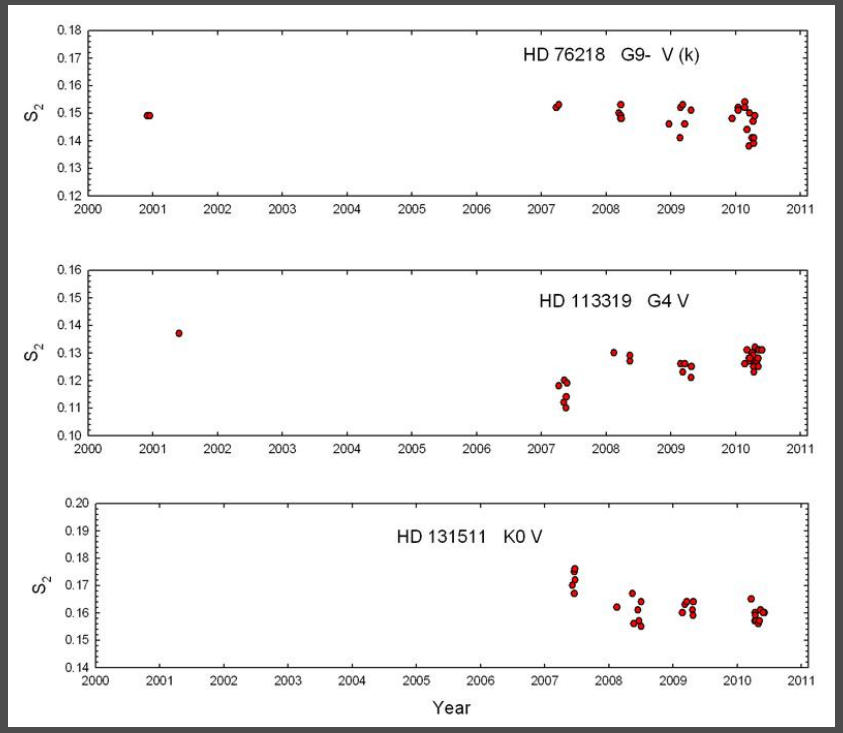
Name	SpT	V	Age (Gyr)	Name	SpT	V	Age (Gyr)
HD 5996	G9 V (k)	7.67	0.5	HD 124694	F8 V	7.19	0.6
HD 9472	G2+ V	7.64	0.4	HD 130322	G8.5 V	8.04	1.2
HD 13531	G7 V	7.35	0.3	HD 131511	K0 V	6.01	0.3
HD 27685	G4 V	7.84	0.7	HD 138763	F9 V	6.53	0.3
HD 27808	F8 V	7.12	0.7	HD 149661	K0 V	5.76	1.4
HD 27836	G0 V (k)	7.60	0.7	HD 152391	G8.5 V (k)	6.64	0.7
HD 27859	G0 V (k)	7.80	0.7	HD 154417	F9 V	6.01	0.5
HD 28394	F8 V	7.02	0.7	HD 170778	G0- V (k)	7.50	0.3
HD 42807	G5 V	6.44	0.3	HD 189733	K2 V (k)	7.68	0.5
HD 76218	G9- V (k)	7.69	0.5	HD 190771	G2 V	6.17	0.7
HD 82885	G8+ V	5.41	1.6	HD 192263	K2 V (k)	7.79	1.0
HD 96064A	G8+ V (k)	7.64	0.3	HD 206860	G0 V	6.00	0.4
HD 101501	G8 V	5.32	1.4	HD 209393	G5 V (k)	7.96	0.5
HD 102195	G9.5 V (k)	8.06	1.1	HD 217813	G1 V	6.66	0.7
HD 113319	G4 V	7.52	1.5	HD 222143	G3 V (k)	6.58	0.8
HD 117378	F9.5 V	7.64	0.5				

Ca II K & H

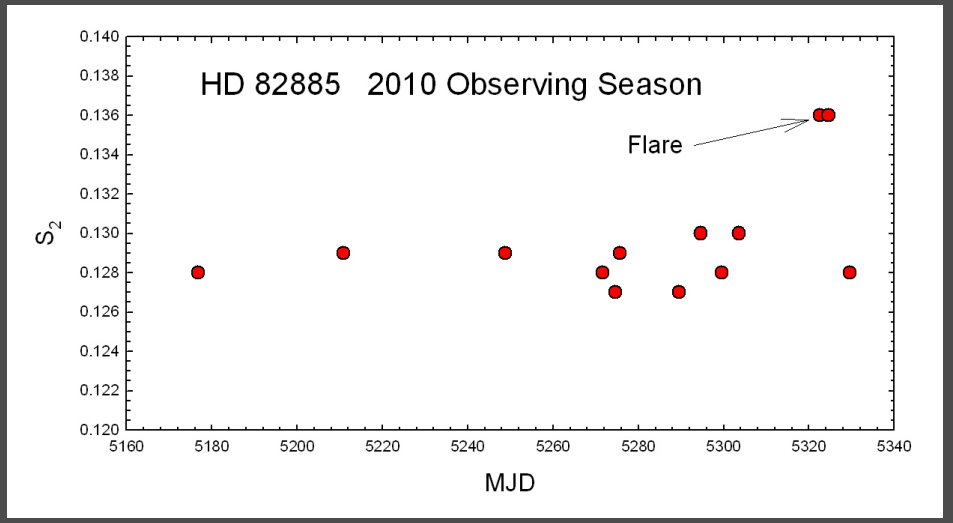

xca4
Quit Load Xscale Yscale ==> <== ^ v Zoom In Zoom Out CA File CA Save
+ - Reset Scale Mouse Scale Ca II 2A Ca II 4A Halpha Ca II Triplet <-Calculate
++ --
hd189733_aug0108.eb.rbn
2e+03
1.6e+03
1.2e+03
8e+02
4e+02
0
3886.00
3907.33
3928.67
3950.00
3971.33
3992.67
4014.00
Wavelength
x = 3980.603
y = 1627.31
Ca II K
Ca II H

Dr. Gray's Spectroscopic Research at Appalachian State University: Ca II K & H

Activity Cycles



Flare Events



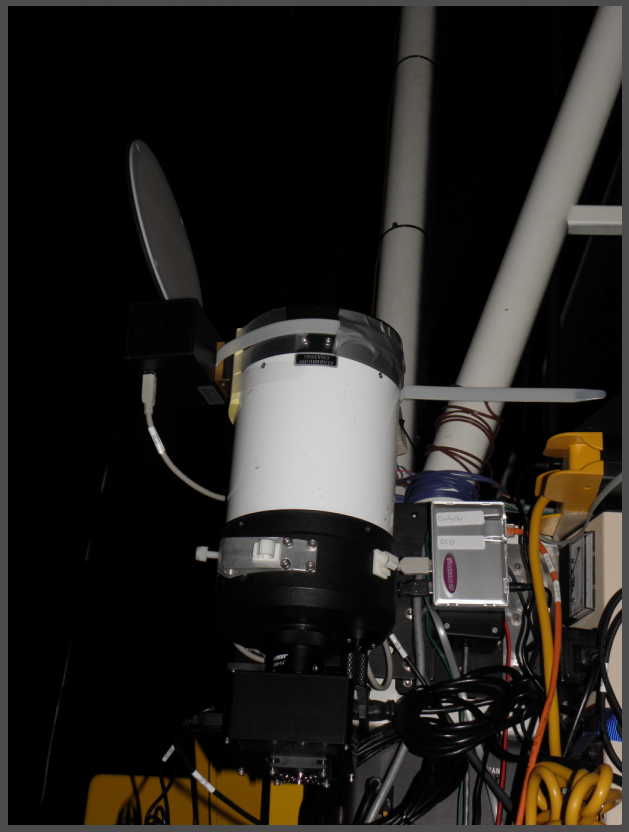
OBSERVATORIES AND TELESCOPES

University of North Carolina at Chapel Hill's PROMPT Array/Skynet

- 0.41-m Ritchey-Chretien telescopes
- Rejected in the long run because of limitations in precision
- Flat-fields exhibit gradients and abnormalities
  - Clamshell dome
  - Open truss design

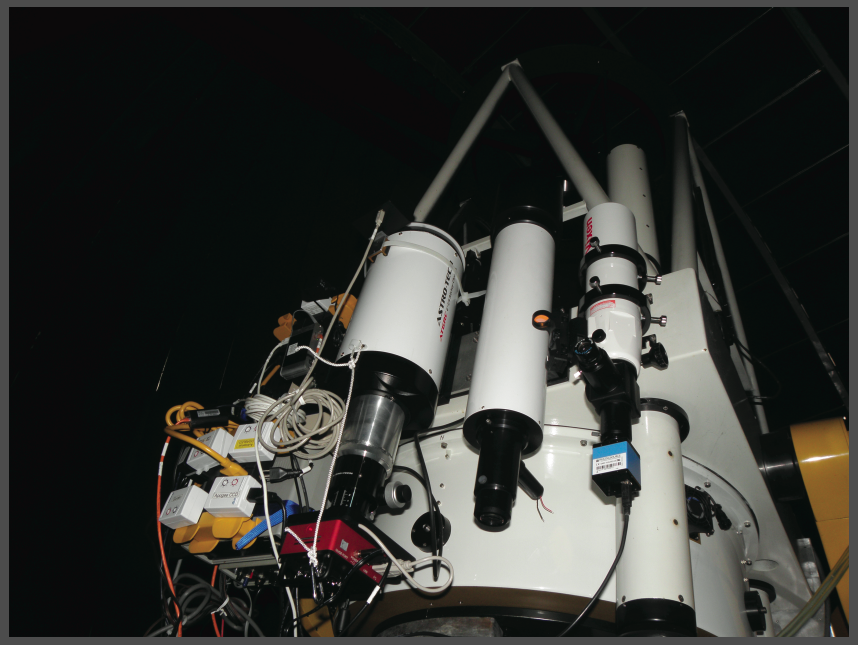
Appalachian State University Dark Sky Observatory:

Piggyback Telescope on the DSO 0.8-m



5-inch (0.127-m) f/10 Celestron
SBIG ST-402ME CCD

6-inch wide-field f/9 Ritchey-Chrétien telescope
SBIG ST-8300 CCD



Appalachian State University Dark Sky Observatory:

The Automated Photometric Telescope on a Robotic Mount

Orion Apex 102mm
SBIG ST-402ME CCD

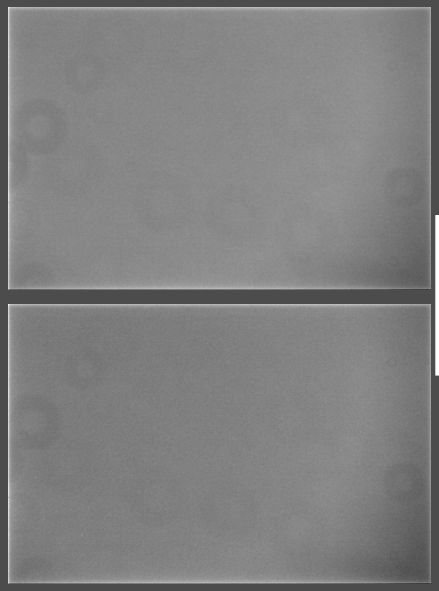
6-inch wide-field f/9 Ritchey-Chrétien telescope
SBIG ST-8300 CCD

Reduction and Photometry Pipeline

- Image Reduction and Analysis Facility (IRAF)
  - imageproc_final.cl
    - Forms master darks and flats for each filter and applies them to the images
    - Combines the images in a series for each filter in to a combined image for each filter.
      - For a higher signal to noise
  - Imexamine (iraf task)
    - full width at half maximum (FWHM) and sigma of the point spread function
  - photometry.cl
    - DAOFind
    - Phot

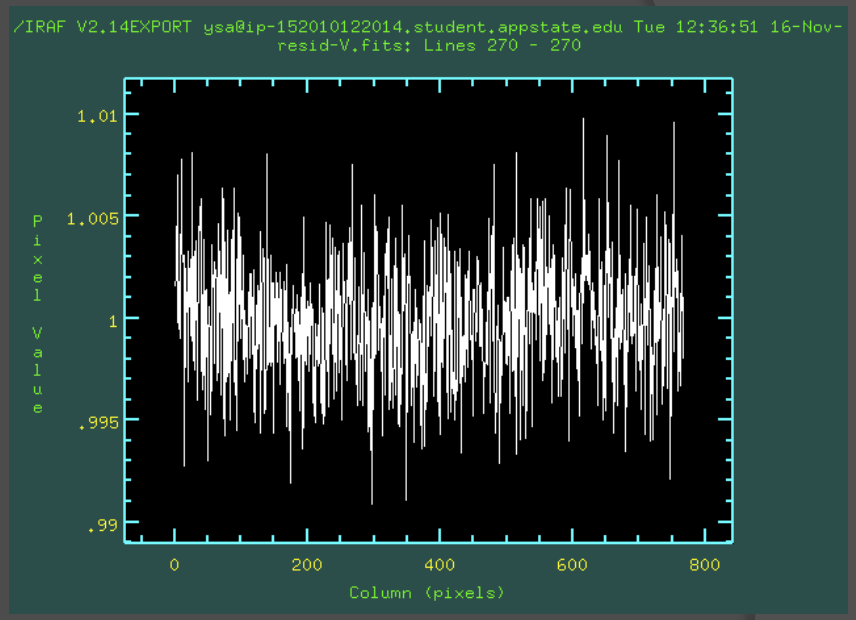
Flat-Field Experiment

Flip-Flat-Field



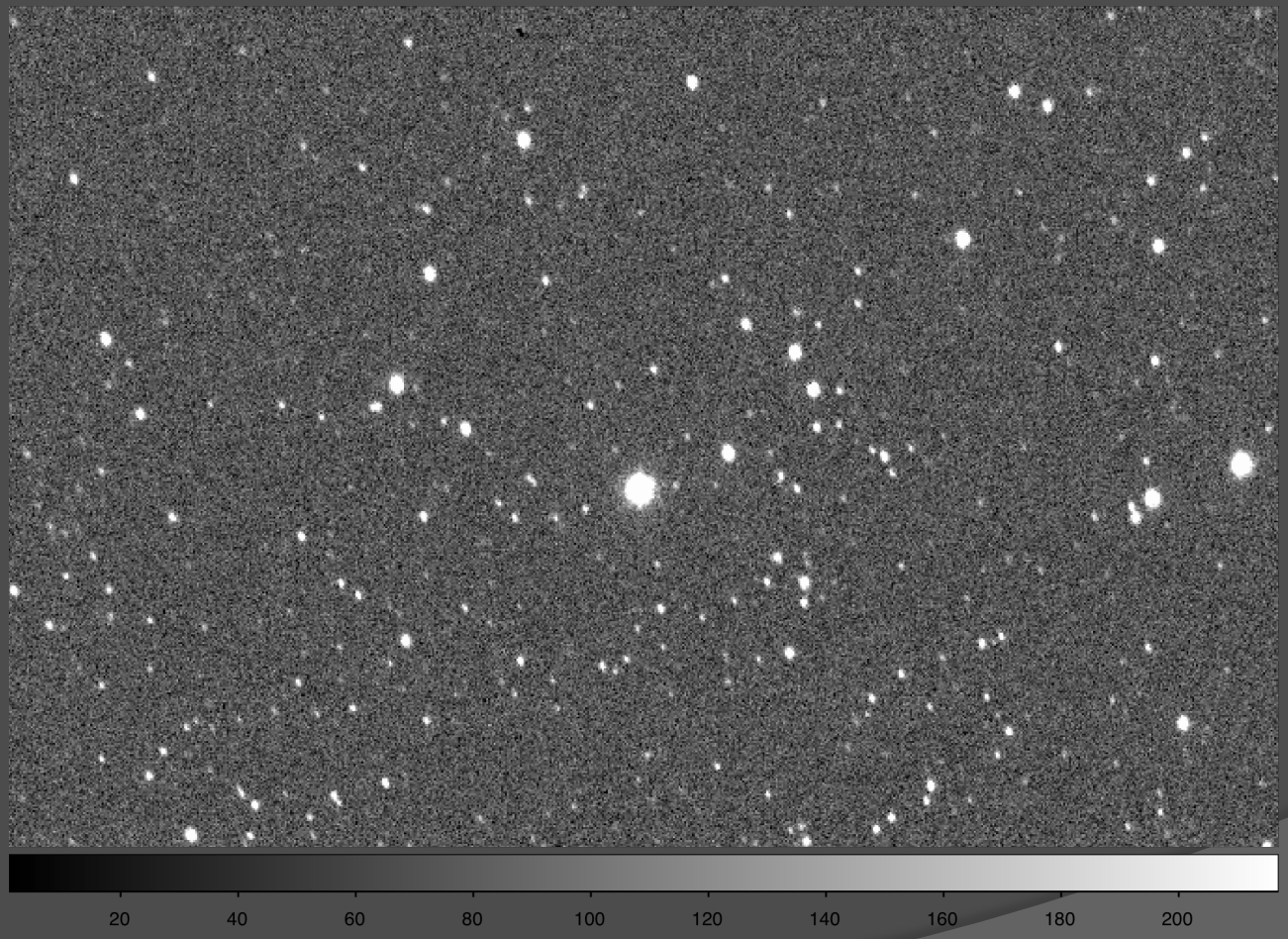
Sky Flat-Field

Flip-Flat/Sky Flat

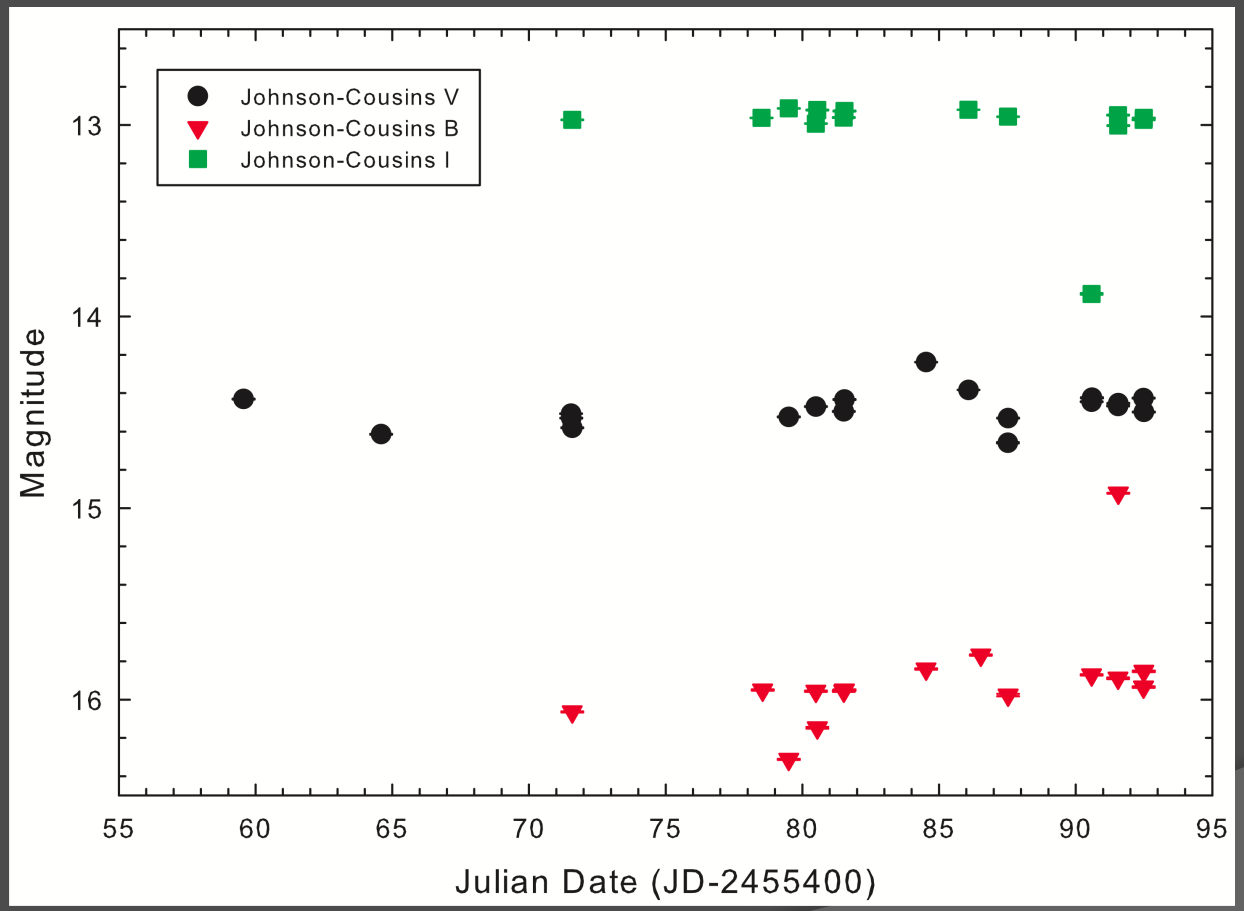


Filter	Mean	STDDEV	Min	Max
B	1	0.004093	0.9823	1.043
I	1	0.005586	0.8959	1.069
V	1	0.003117	0.9860	1.022

Results
HD 189733: Sample Image



Results
HD 189733



Results
HD 189733 Multiple Comparison Star Test

HD 189733 V Series 1

Star	X	Y	V mag	err
1	378	249	11.588	0.003
2	551	382	14.727	0.033
3	248	304	14.559	0.028
4	700	262	12.826	0.027

V mag avg(2,3,4) = 14.037
mag(1) – avg(2,3,4) = -2.449

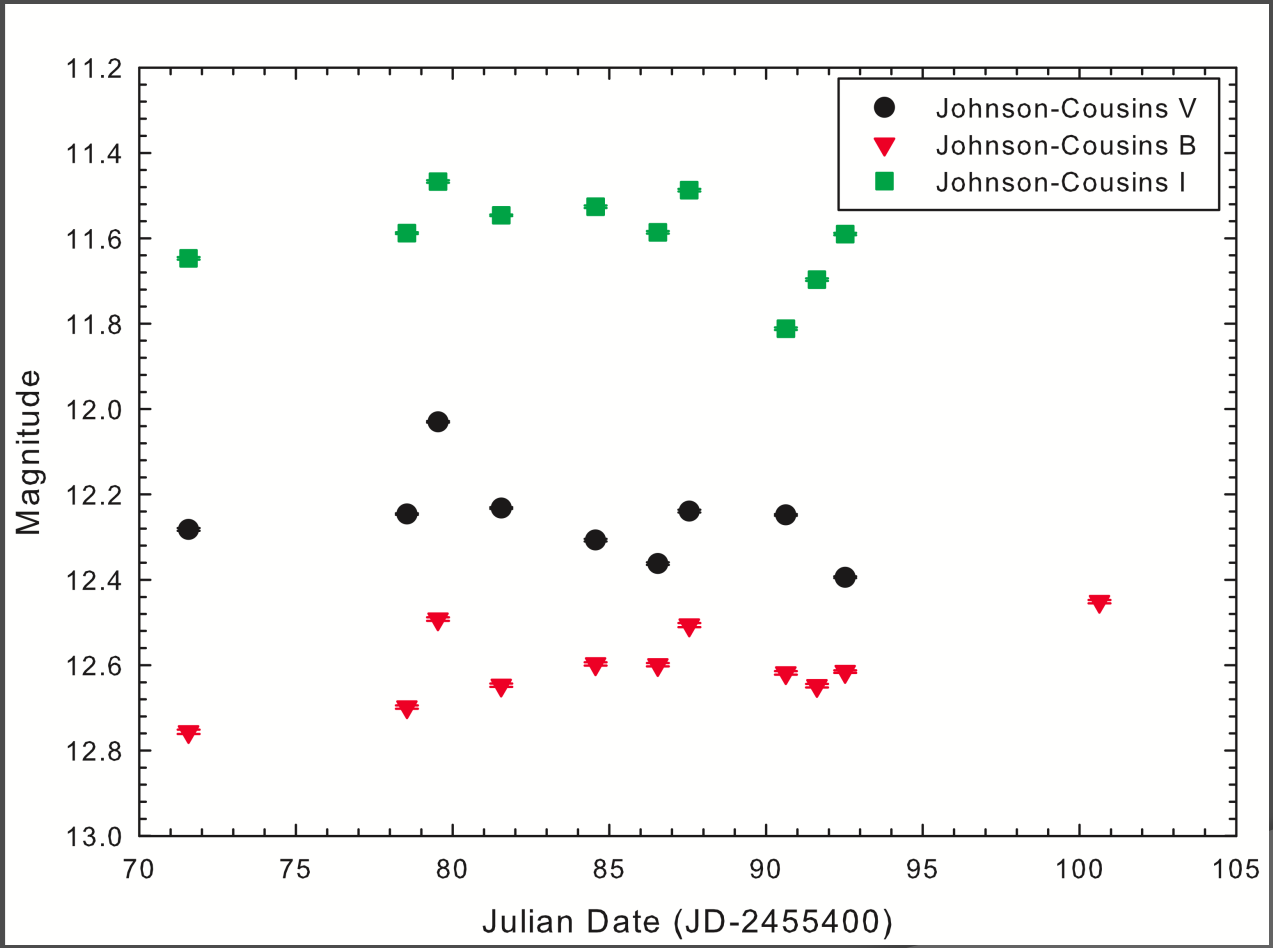
HD 189733 V Series 2

Star	X	Y	V mag	err
1	372	243	11.591	0.003
2	545	376	14.715	0.029
3	242	299	14.573	0.026
4	694	256	12.843	0.007

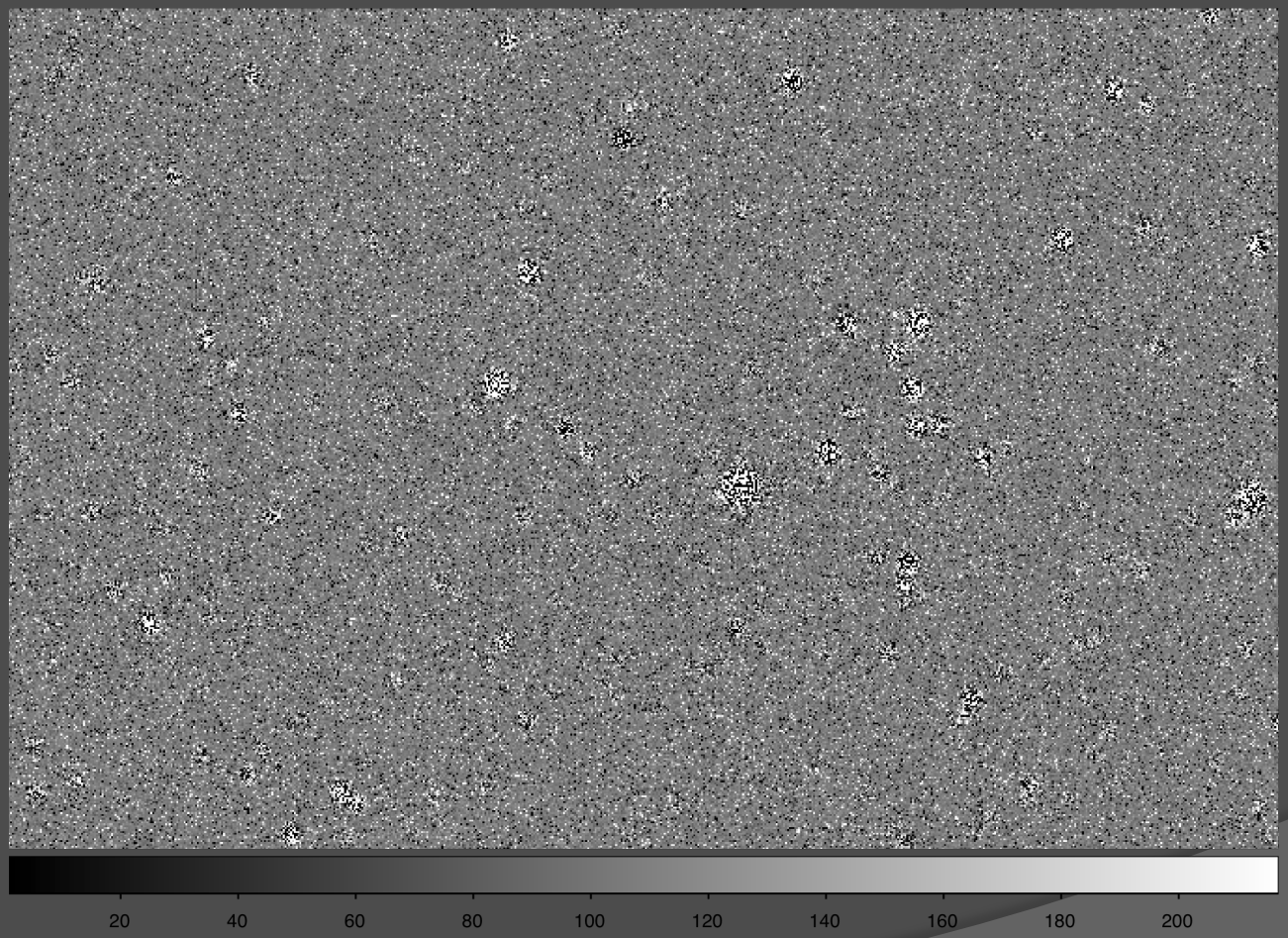
V mag avg(2,3,4) = 14.044
mag(1) – avg(2,3,4) = -2.453

Difference:
-2.449-(2.453)=0.004

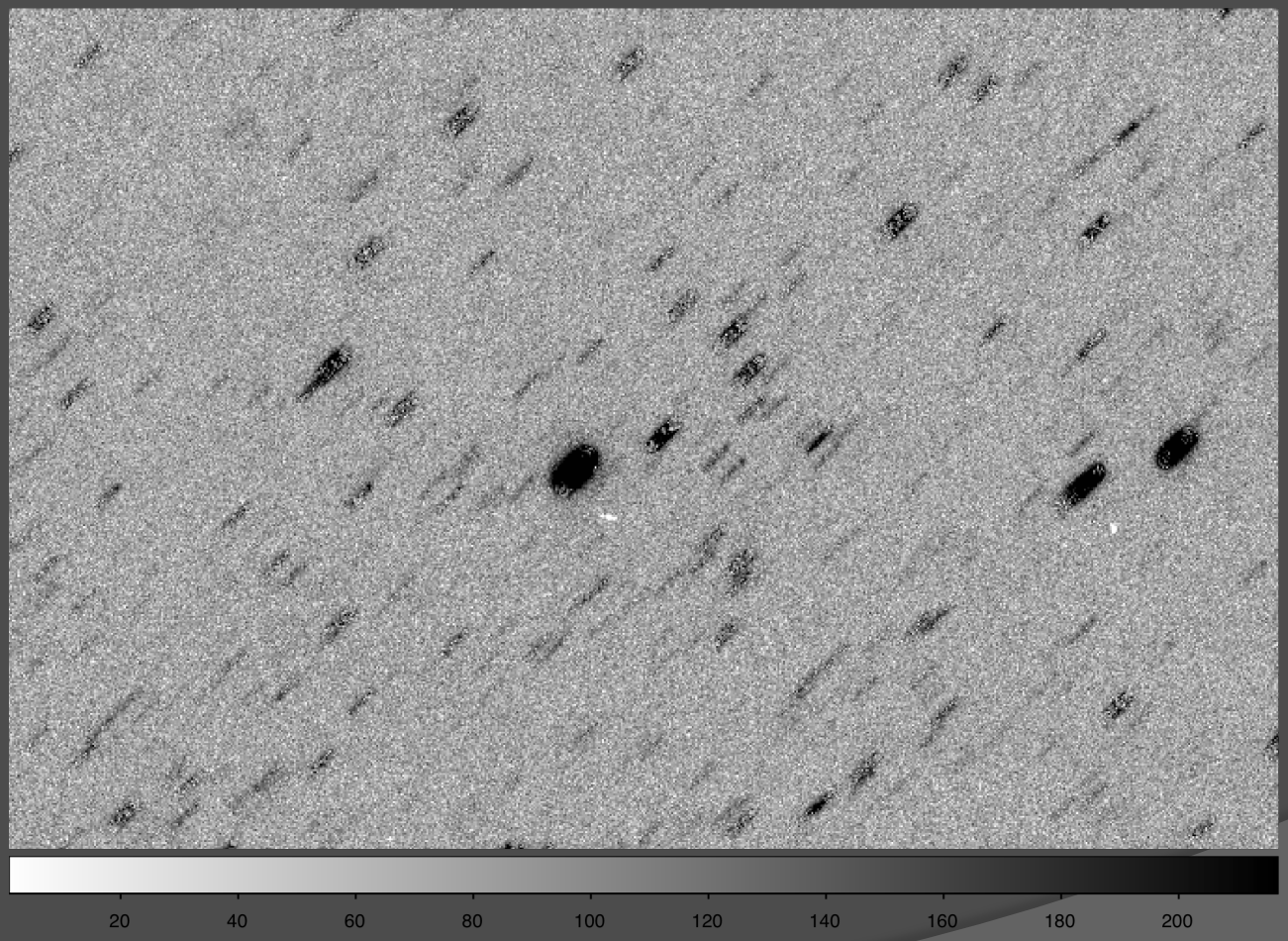
Results
HD 209393



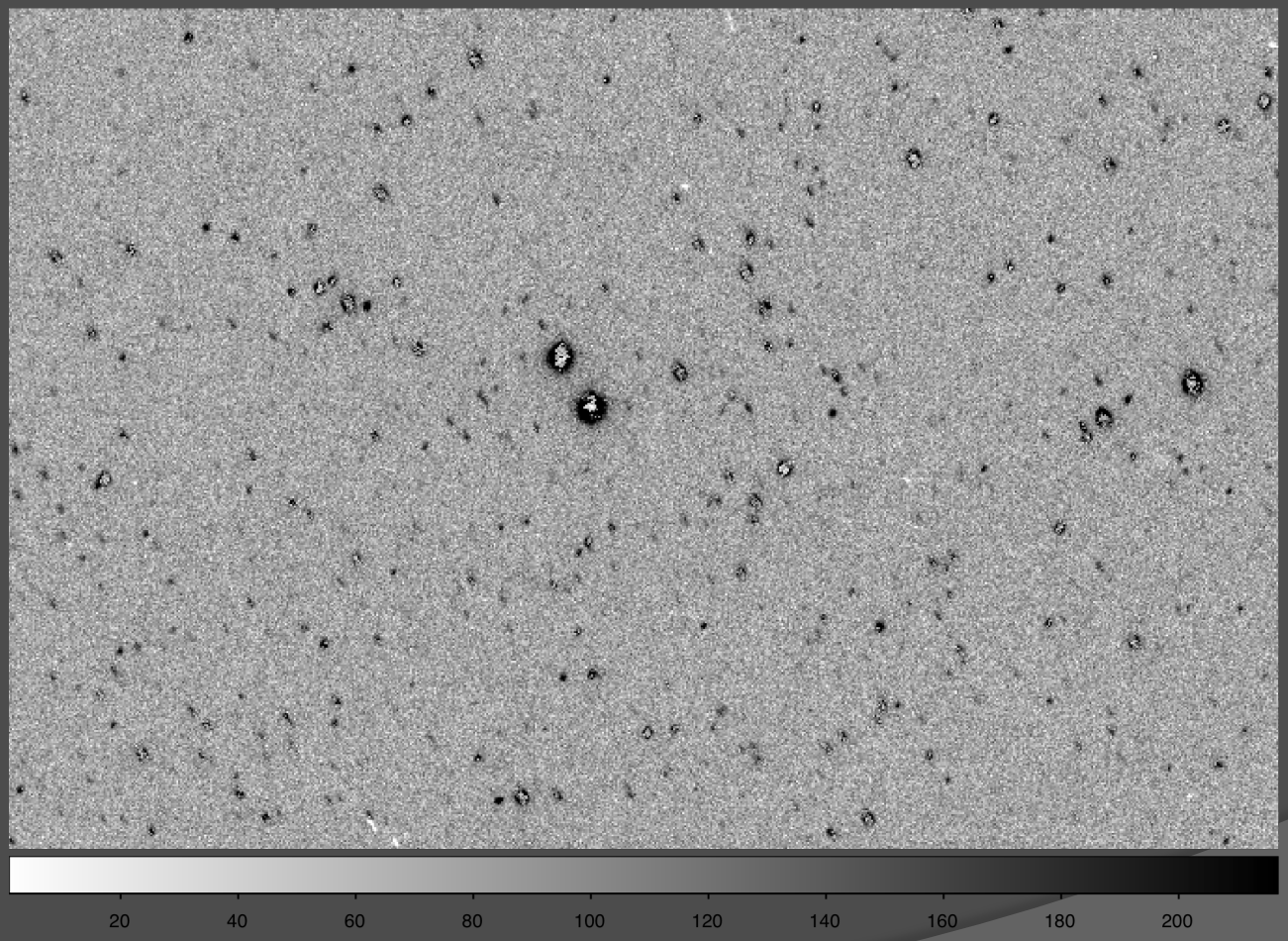
The Effect of Clouds on the Combined Images



The Effect of Telescope Drift on the Combined Images



The Effect of Focus Change on the Combined Images



Conclusions

- PROMPT results disappoint
  - systematic and random errors on the 4% level
  - Small field of view (10')
- Luminescent Flip-Flat
  - photometry stable to better than 1%
- Light Curves
  - Periodic variations visible in the light curves.
- Multiple Comparison Star Techniques
  - milli-magnitude precision
- Things to Consider
  - Effect of weather
  - Pointing issues on the DSO 0.8m
- Techniques, procedures, and equipment that I have establish will be used in the long term project.

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