



Selecting Guide Stars for the Dark Energy Survey

Research project during TRAC summer internship

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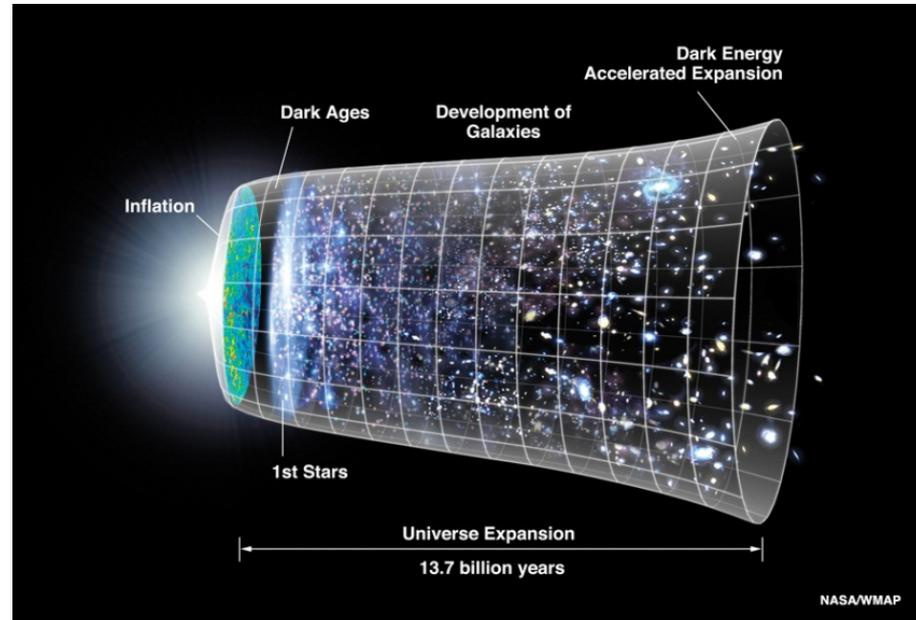
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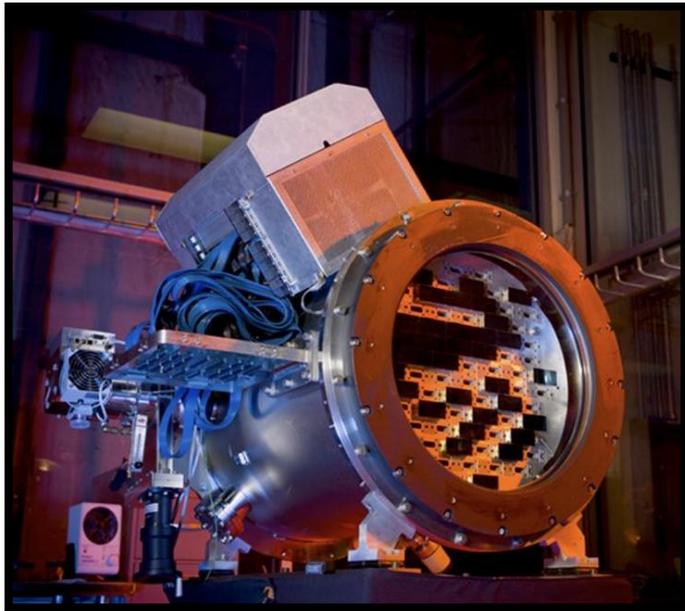
What is Dark Energy Survey Project

- **The Dark Energy Survey (DES)** is designed to probe the origin of the accelerating universe and help uncover the nature of dark energy by measuring the 14-billion-year history of cosmic expansion with high precision.



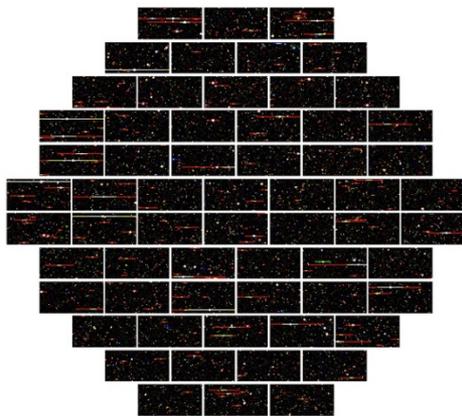
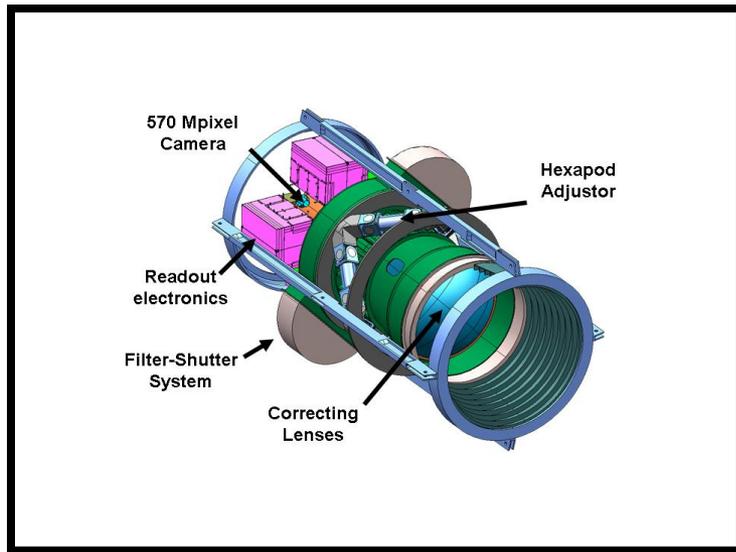
<http://www.darkenergysurvey.org>

DECam



- They completed and tested one of the largest cameras named DECam.
- It is a large, 570 Megapixel camera that will hold 74 CCDs.
- This was constructed specifically to be sensitive to the red shifted light from distant galaxies and stars.
- This will permit to measure the redshift of stars very precisely.
- DECam will have the widest field of view of the southern hemisphere in the NOAO ground-based optical/infrared system of imagers.
- The field of view is 2.2 degree in diameter, so a large view area of the sky can be imaged in each exposure.

DECam

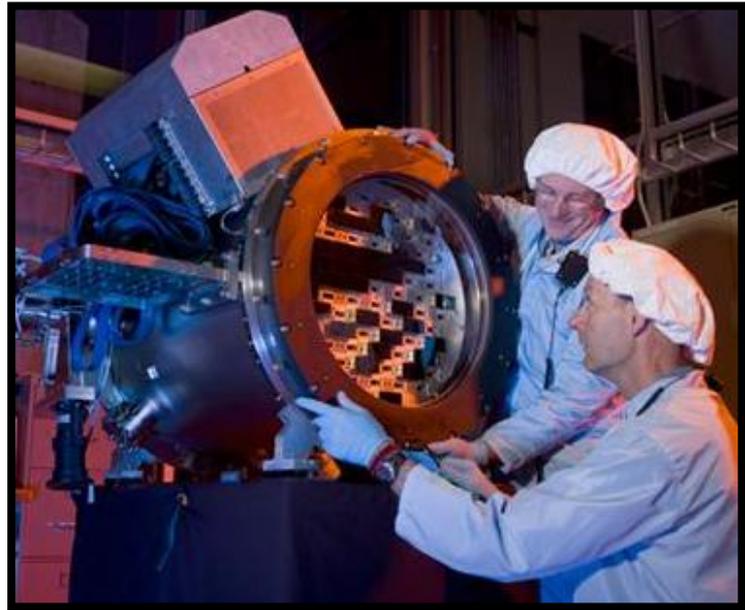


- It is capable of record data from an area of the sky 20 times the size of the moon as seen from earth.
- A system of five lenses was required to have a wide view.
- The biggest of these lenses is almost 1 meter in diameter.
- The camera is is being installed in Cerro Tololo Inter-American Observatory in Chile.
- The collection of programs used to operate the camera is called SISPI.

Brenna Flaugher (2012) and DES (2010)

Purpose of this study

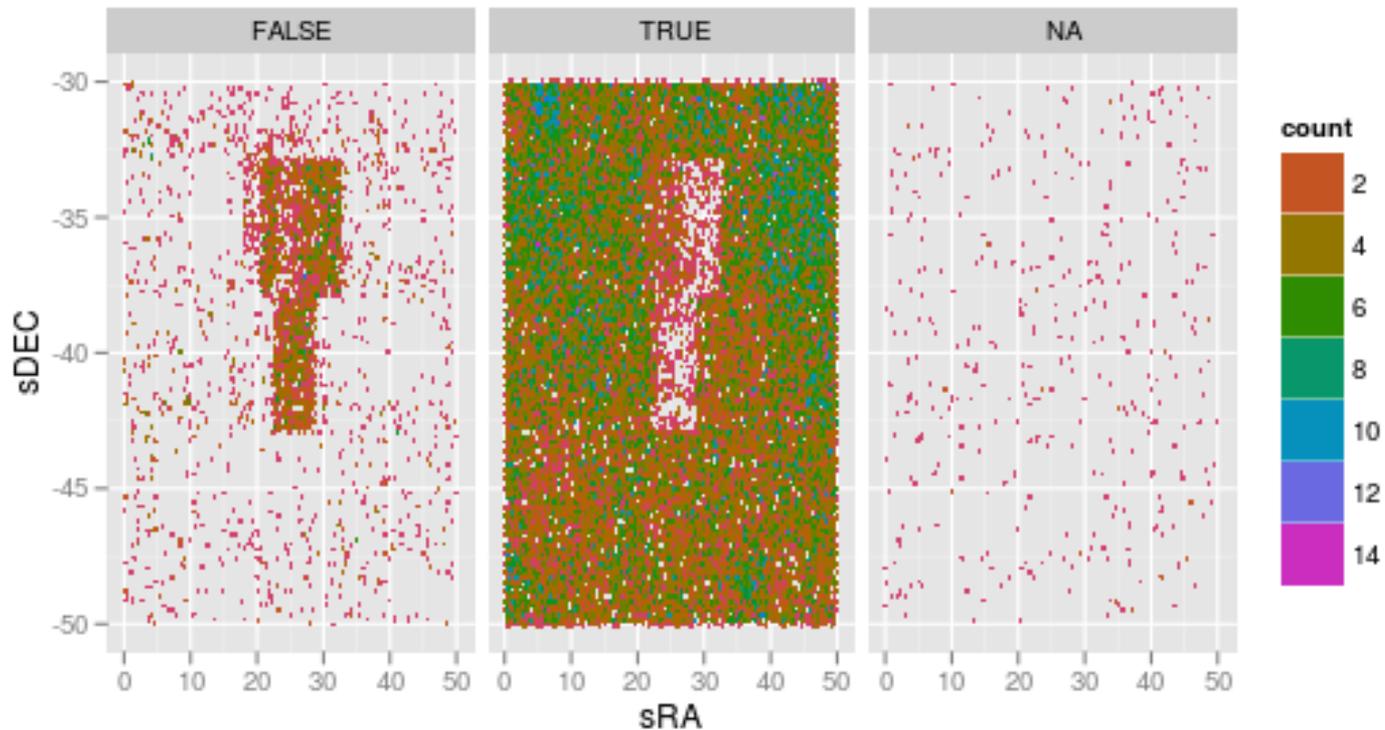
- This analysis is required in order to select stars for the guider, a SISPI program that keeps the pointing of the telescope steady during an exposure.
- Without this program it will be impossible to run the telescope in order to have good exposures with DECcam.



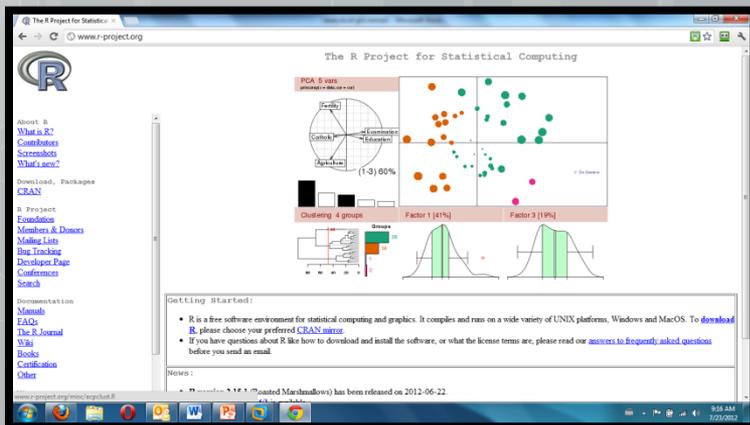
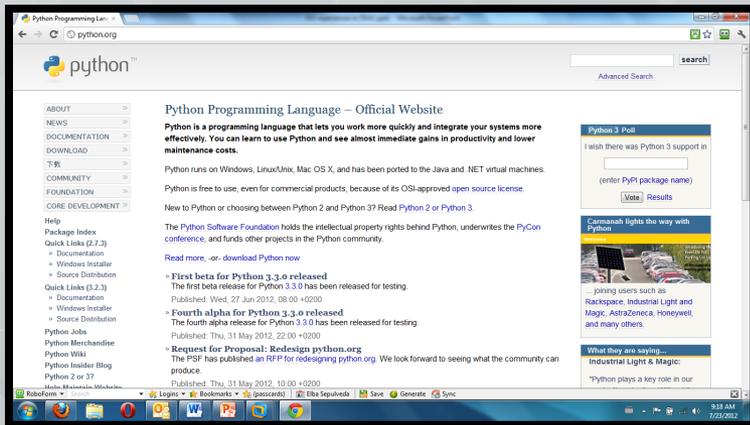
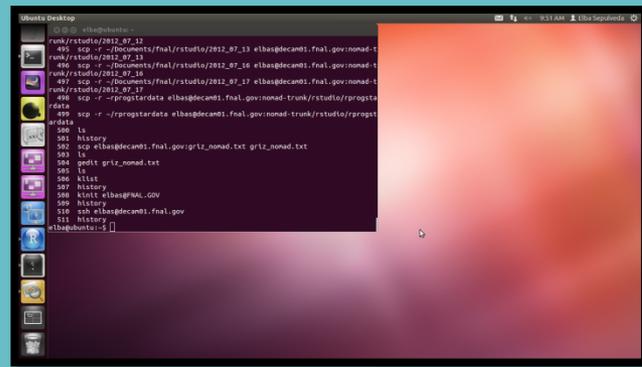
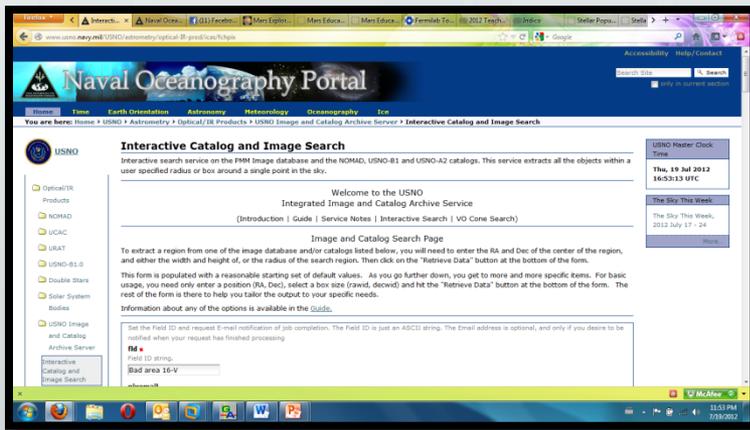
The problem:

- The Naval Observatory Merged Astrometric Dataset (NOMAD) catalog is a compilation of stellar data from many sources.
 - In some areas of the sky, in one filter the brightness reported by NOMAD can be off by many magnitudes.
 - We can attempt to either correct the problems, or avoid using the filter in which they occur.
- Is it possible to calculate useful estimates of stellar magnitudes from NOMAD, despite the problems in the NOMAD data?

Graph of the stars with magnitudes >14



- This graph showed that there is a problem with stellar magnitudes in the NOMAD catalog.

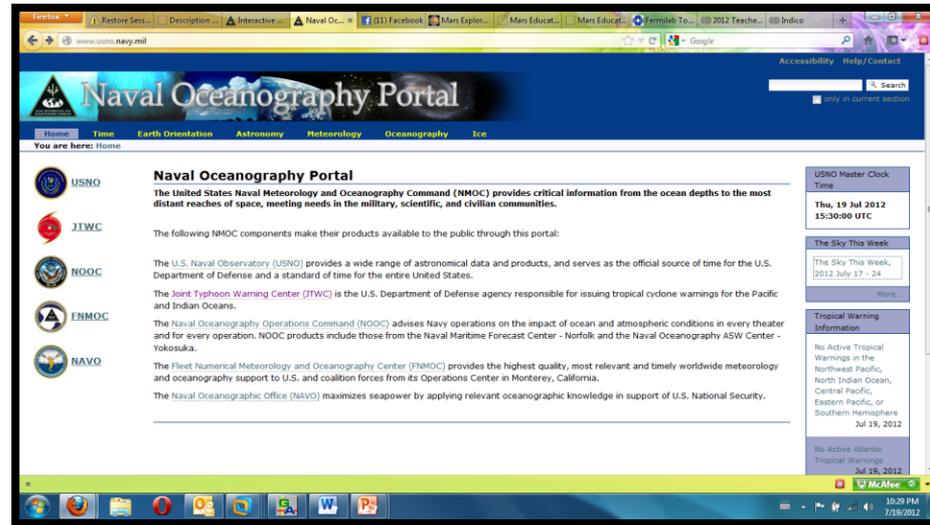


ugriz catalog of Smith, Allam, Tucker et al

Method

- A. Computer assisted database search (CADS).
- B. Analysis of magnitude and color index graphs.

Naval Oceanography Portal (NOP)

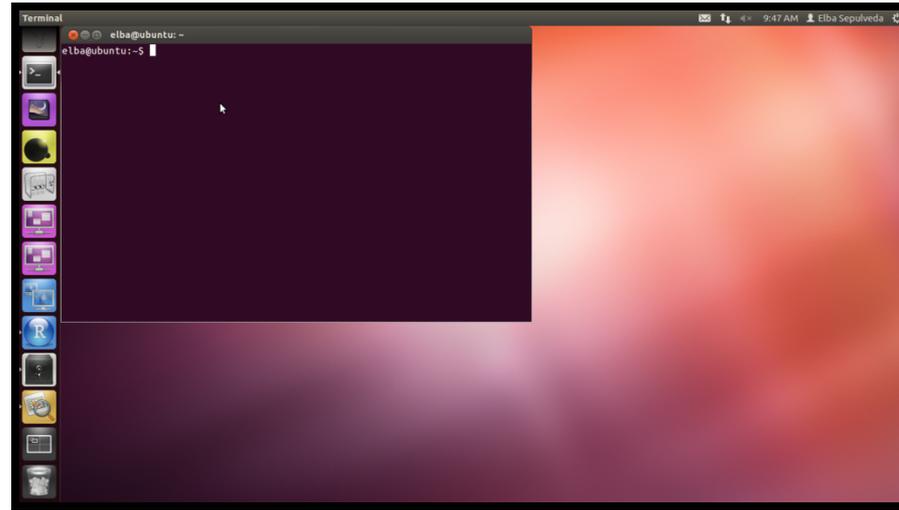


- Provides:
 - An interactive catalog made and maintained by the United States Naval Meteorology and Oceanography Command (NMOC).
 - Important information about the location of the stars in space, meeting needs in the military, scientific, and civilian communities.



<http://www.usno.navy.mil>

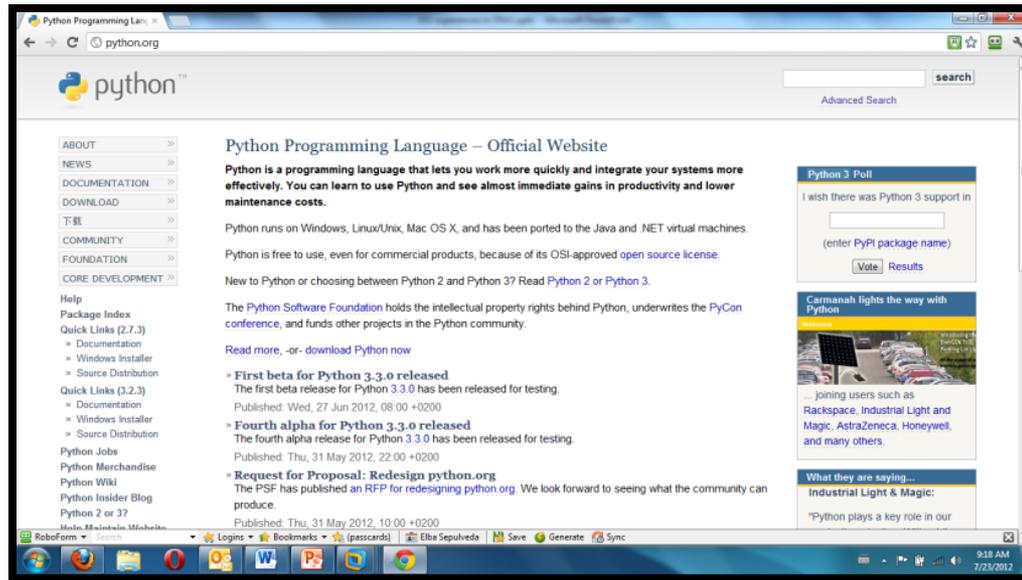
Ubuntu Linux



- Using terminal commands must be directed in the DECam01 directory.
- I used a Python Application Program Interface (API) to extract the needed data from NOMAD catalog.



Python programming

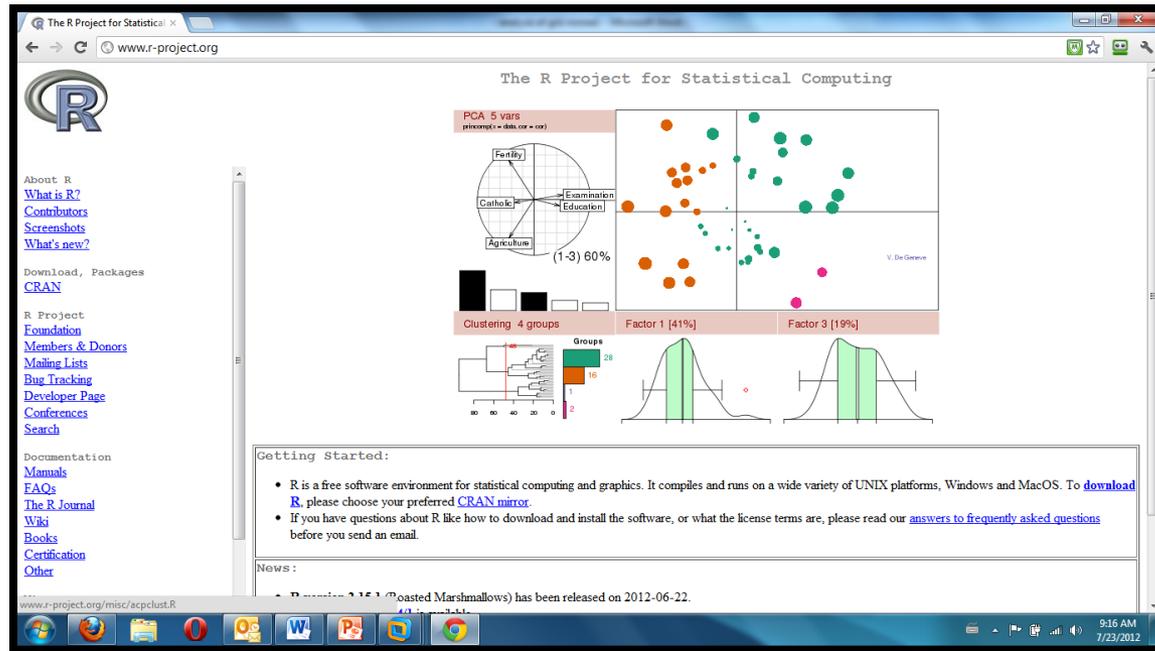


- Python is an open source software, object-oriented scripting language that is freeware, portable and powerful. Is supported by the Python online community. Provides the simplicity and ease use of scripting language, along with advanced programming tools.

Lutz and Ascher (1999) <http://python.org>



R



- Venables and Smith (2004) indicate that R is an integrated suite of software environment for data manipulation, calculations, and a graphical display. R is available as free software.

<http://www.r-project.org>



- McDonald Observatory (2012) was the first to develop **UBVRI** filter system in the 1950s and has become standard in astronomy. 

- Fukugita, Ichikawa, Gunn, Doi, Shimasaku and Schneider (1996) explains that the **u'g'r'i'z'** are the five color bands for calibration of the Sloan Digital Sky Survey Photometric System. 

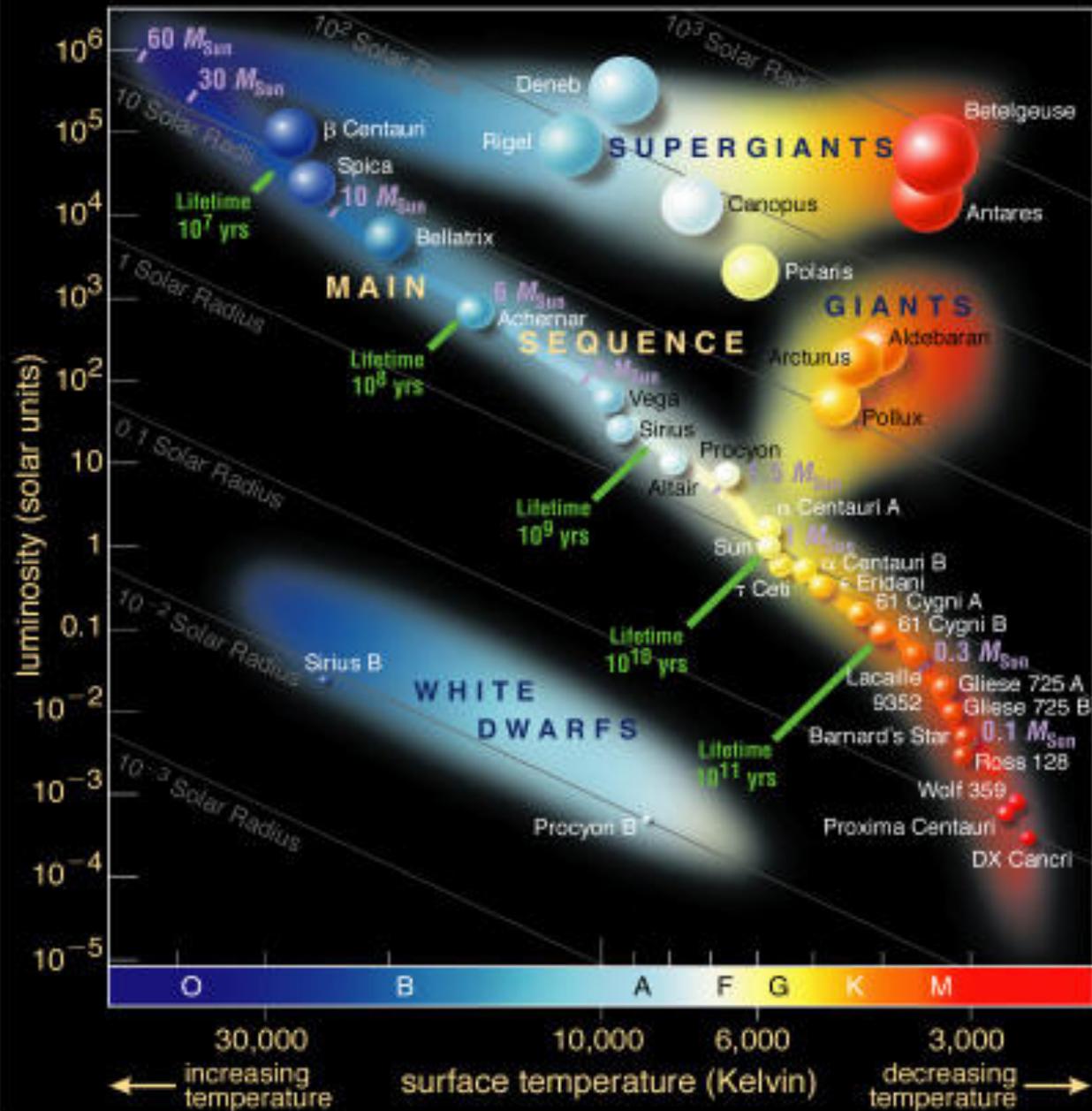
- Chromey (2010) explains that the color index is:
 - $CI = m_{\lambda \downarrow \text{shorter}} - m_{\lambda \downarrow \text{longer}}$

Magnitude of a star
 $m_a - m_b = -2.5 \log(F_a / F_b)$

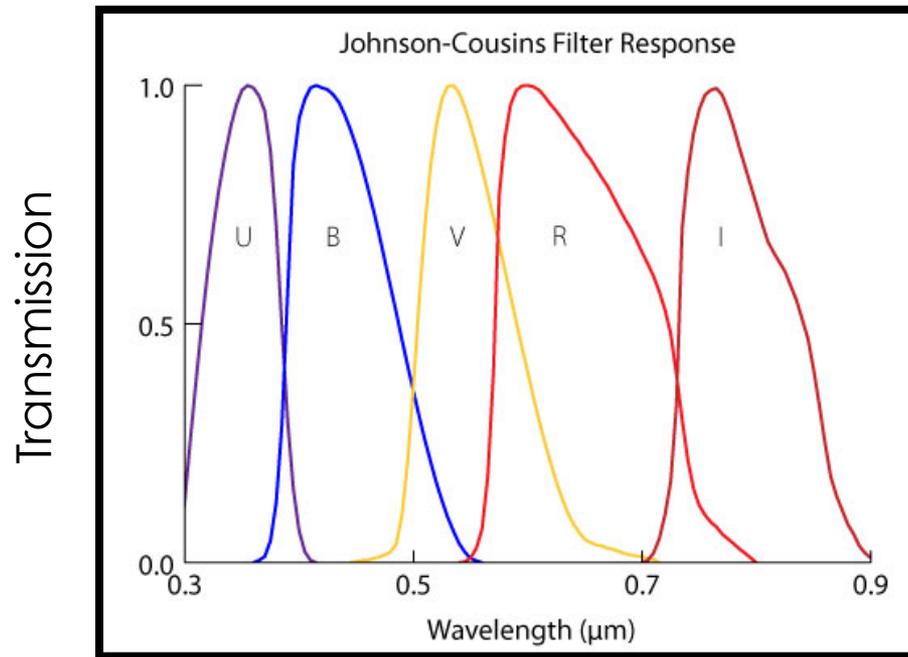
Color index

Inglis (2004) defines it to measure the difference in the apparent magnitude of a star at the two (2) standard wavelength used as a measure of the star's color and temperature.

HR diagram



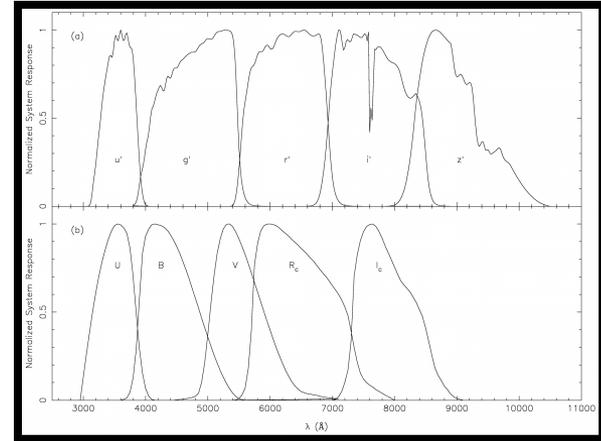
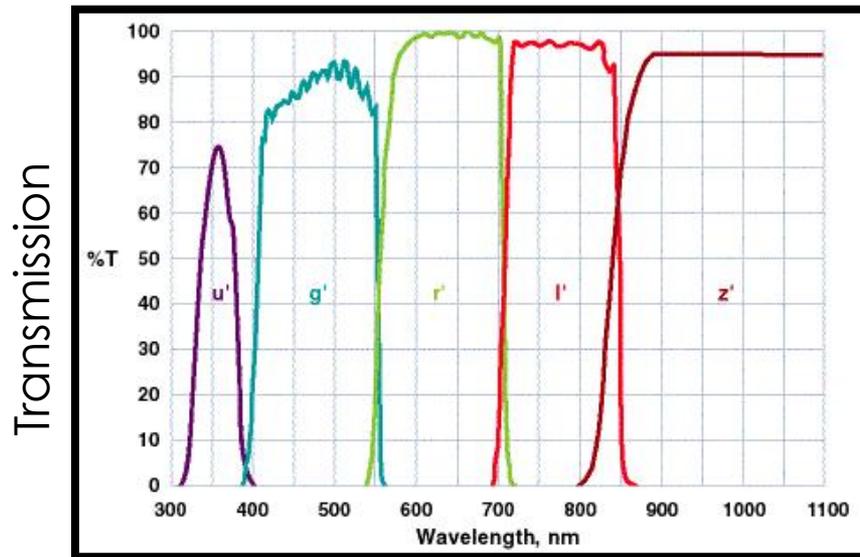
Johnson-Cousins Filter



Band	Range	
	Minimum	Maximum
U	3200 Å	4000 Å
B	4000 Å	5000 Å
V	5000 Å	7000 Å
R	5500 Å	8000 Å
I	7000 Å	9000 Å



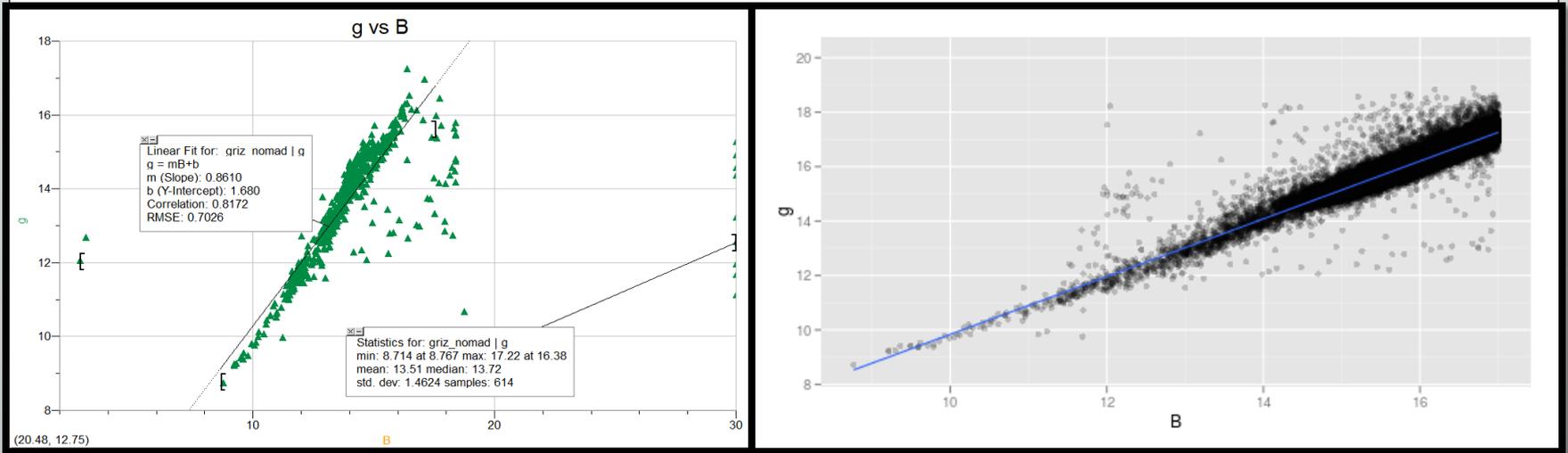
U'g'r'i'z' filter



Filter	Wavelength	Width	Color
u'	3500 Å	600 Å	
g'	4800 Å	1400 Å	Blue green
r'	6250 Å	1400 Å	Red
i'	7700 Å	1500 Å	
z'	9100 Å	1200 Å	



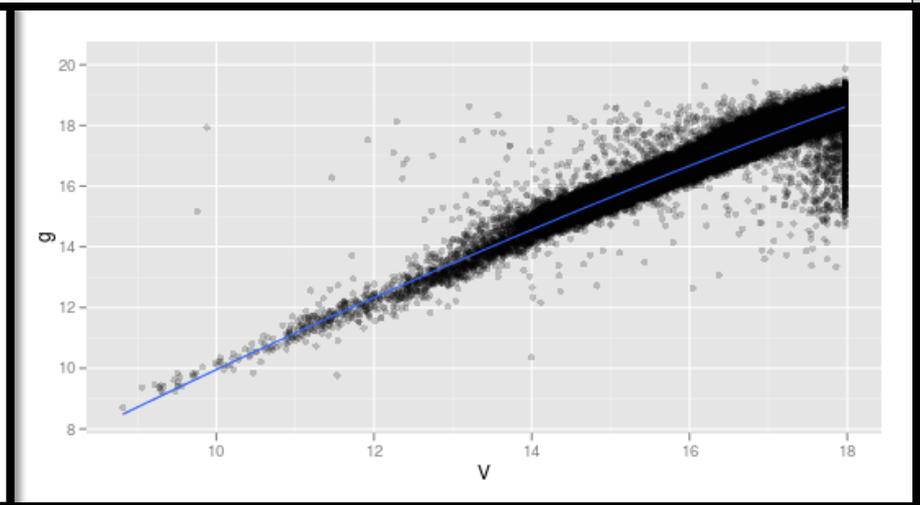
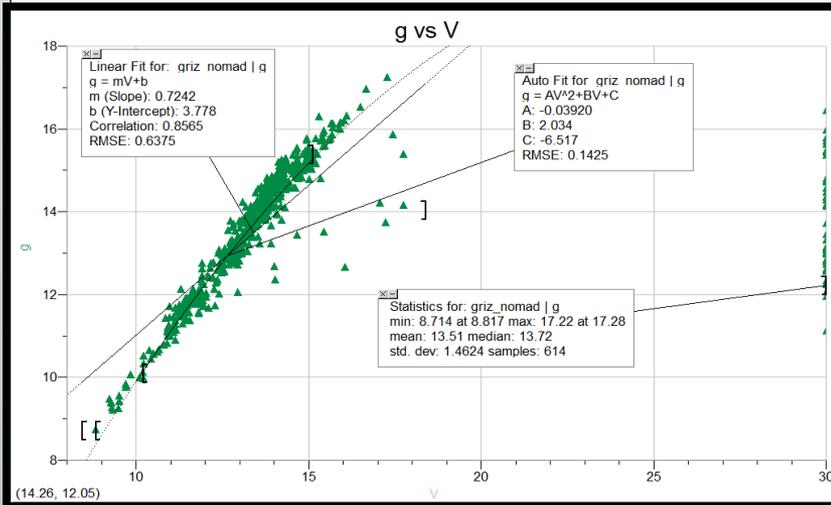
Magnitude graphs: g vs B



- Preliminary and final results for 103,547 stars.
- Linear behavior of selected stars in NOMAD and the ugriz catalog of Smith, Allam, Tucker et al.
 - $g_0 = 1.2067787$ $\Delta g / \Delta B = 0.915597$
 - $STE\ g_0 = 0.0116$ $STE\ \Delta g / \Delta B = 0.0007$
- The slope of 0.915597 is very near 1.0 meaning that both **g** and **B** are very similar in values. While the magnitude of B increases, the magnitude of g also increases at a constant rate.

**STE=Standard Deviation Error

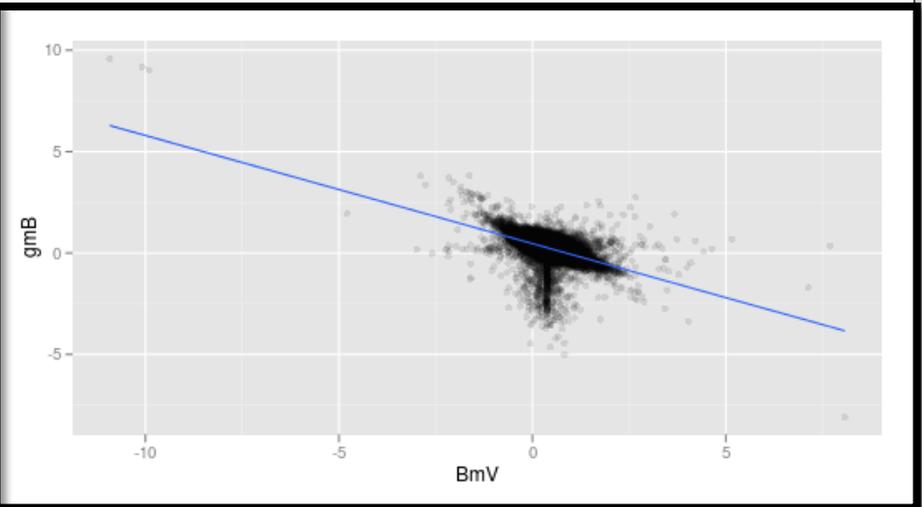
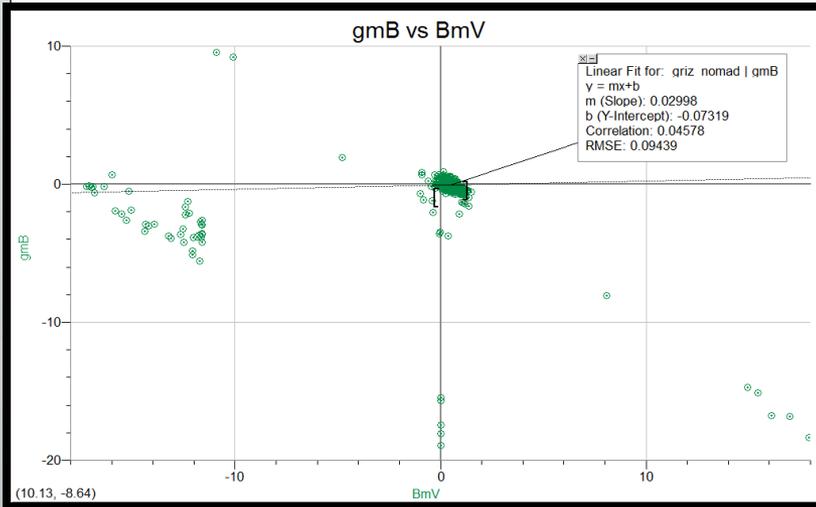
Magnitude graphs g vs V



- Preliminary and final results for 103,547 stars.
- Linear behavior of selected stars in NOMAD and the ugriz catalog of Smith, Allam, Tucker et al.
 - $g_0 = 0.5527$ $\Delta g / \Delta B = 0.9290$
 - $STE\ g_0 = 0.0114$ $STE\ \Delta g / \Delta B = 0.0007$
- The slope of 0.9290 is very near 1.0 meaning that both **g** and **V** are very similar in values. While the magnitude of V increases, the magnitude of g also increases at a constant rate.

**STE=Standard Deviation Error

Color index graphs: g-B vs B-V



- Preliminary and final results for 103,547 stars.
- Linear behavior of selected stars in NOMAD and the ugriz catalog of Smith, Allam, Tucker et al.
 - $g_0 = 0.57$ $\Delta gmB / \Delta BmV = -0.65$
 - $STE g_0 = 0.0010$ $STE \Delta gmB / \Delta BmV = -0.0024$
- The slope of -0.65 is very near 0.0 meaning a **shallow slope**, or the line is almost horizontal.

**STE=Standard Deviation Error

Analysis of Data

- The same process of plotting magnitudes and color index graphs were performed for the following pairs of variables:
 - r' vs V
 - $r'-V$ vs $B-V$
 - i' vs J
 - $i'-J$ vs $V-J$
 - $i'-J$ vs $J-K$
 - z' vs J
 - $z-J$ vs $V-J$
 - $z-J$ vs $J-K$

Conclusion

- The NOMAD catalog includes stellar magnitudes in the B, V, R, J, H, and K bandpasses.
- We see evidence that there are large errors in the R band magnitudes in some areas of the sky.
- We measure strong correlations between the B, V, and J magnitudes in NOMAD and the g, r, i, and z band magnitudes that will be used in DES.
- Therefore, we can estimate DES magnitudes from the good data in NOMAD, and avoid using the problematic R band data.

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July 2012