Star Formation in the Small Magellanic Cloud: The Most Massive Stars in NGC 346

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Introduction

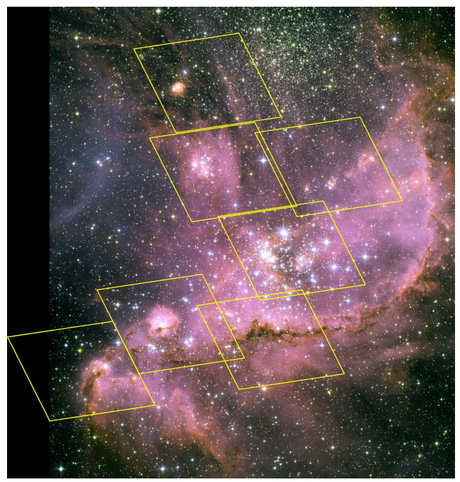
The ultimate aim of studying star formation is to improve our understanding of the evolution of galaxies. The SMC is a dwarf galaxy that is about 197,000 ly away from us. It is an ideal laboratory for studying star formation. Its close proximity to the Milky Way enables us to get an in-depth view of star formation outside our own galaxy. The SMC has a very low chemical abundance of elements heavier than Helium. Thus, it is our best known analog to dwarf irregular and blue compact galaxies. Also, because of its low metallicity, the characteristics of the SMC may bare a close resemblance to that of the early universe.

NGC 346 is the most active star forming region in the SMC. It has been well investigated both from the ground and from space. We have Hubble images of NGC 346 in the optical band and the UV band. Images of NGC 346 taken with Hubble's Advanced Camera for Surveys (ACS) / Wide Field Camera show many small compact clusters, some of which are embedded in dust.

Previous studies, conducted with the optical data, have indicated an age of about 3Myr. Other research has shown that there are sub-clusters within NGC 346 and that these sub-clusters are coeval (i.e. they all seem to have formed at the same time). Infrared data from Spitzer suggests that there is on going star formation in the region.
While studies on stellar evolution have been conducted on NGC 346, it has only been done using optical data. This summer I worked with images in the ultraviolet band and I studied the most massive stars in NGC 346.

Goals

- Refine our estimation of the age of the star population
- Find the number distribution of the stars as a function of mass
- Derive the upper mass cutoff
- Determine the spectral type of the most massive stars
- Study the UV properties of the stars to understand how the UV radiation from the most massive stars is shaping the cluster



Data

• Images in ultraviolet bands (in the 220nm and 330nm bands) taken with Hubble's ACS/High Resolution Camera
•Images of 7 regions within NGC 346
•Long (500-1000s) and short (40-80s) exposure images

Fig 1. An image of NGC 346 showing the seven different regions that I studied.

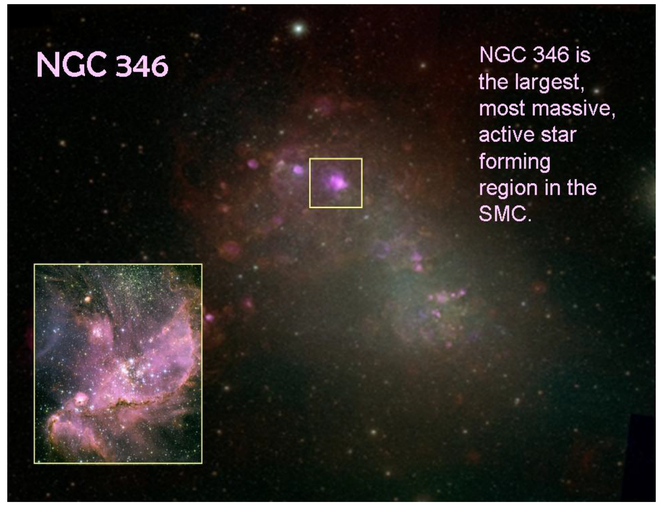
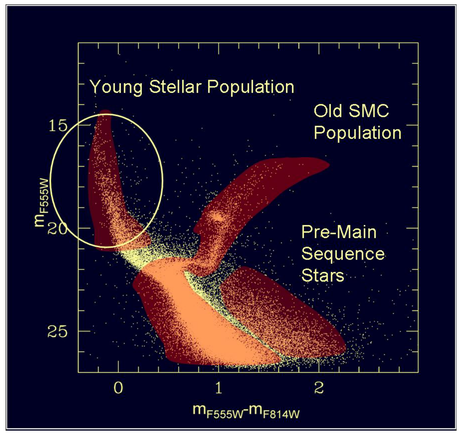


Fig 2. Hubble image of the Small Magellanic Cloud. The location of NGC 346 is indicated by the box. The inset is a Hubble image of NGC 346.



A color-magnitude diagram (CMD) is a plot of the star's color (the difference in its magnitude, or brightness, in two filters of different wavelengths) versus the star's magnitude in one filter. The star's color is related to its temperature and the bluer stars are to the left. The star's magnitude is related to its mass and the brighter, more massive stars, are in the upper part of the diagram.

Fig 3. A CMD of NGC 346 made using the optical data from Hubble. The region withing the circle indicates the stars in the ultraviolet data that had a couterpart in the optical data.

Why is it important to study the UV data?

- It is difficult to distinguish the properties of the hottest (most massive, blue) stars in the optical data.
- Color degeneracy affects the most massive, blue stars in the optical CMD (all the stars are crowded within a narrow color range).
- The region is shaped by the UV radiation from the most massive, stars. Thus, it is important to study the UV properties of these stars.

Data Reduction

The first step in the data reduction process was to run MultiDrizzle, a Pyraf-based script for registering, cleaning (i.e. removing bad pixels, cosmic ray hits, etc) and combining dithered images. I then ran the Daophot script in Pyraf to detect the stars in the images and measure their brightness. This procedure is particularly suitable for measuring the brightness of objects in crowded star fields. From the images I was able to create a catalogue of about 300 stars.

Results

Once I had carried out the data reduction, I was able to create the CMDs for the seven different regions. CMDs are very useful astronomical tools because we can tell a lot about a star cluster simply by looking at its CMD. From our CMD we were able to estimate the age of the star cluster, since we know that the most massive stars evolve off the main sequence more quickly than less massive stars.

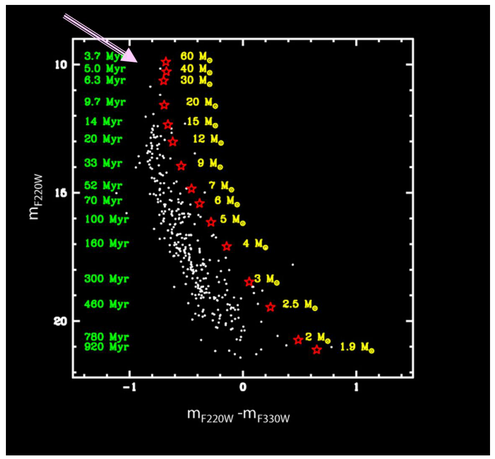


Fig 4. The CMD of the stellar population created using the ultraviolet data from the seven regions. The Padova Evolutionary Tracks have been superimposed on the CMD, enabling us to predict the age of the star cluster (by looking at the stars that are evolving off from the top of the man sequence).

Conclusions

- UV data allows us to study the most massive, blue stars. The masses of the stars vary between 2-60 M_{sun} .
- The stars in this cluster are younger than 4 Myr.
- There is differential reddening caused by dust (especially in the regions of high dust density).
- The most massive stars are forming in the richest region.
- Other data (such as IR data from Spitzer) suggests that star formation is on-going in this region. However, in UV we cannot see the younger stars because they are colder and shrouded in dust.

Future Work

- Derive the spectral energy distribution for the most massive stars.
- Derive the mass, age and luminosity of the individual stars and derive the upper mass function.
- Determine the UV flux released by the most massive stars.

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References:
Nota et al., *Discovery of a Population of Pre-Main Sequence Stars in NGC 346 from Deep Hubble Space telescope ACS images;*
Sabbi et al., *Past and Present Star Formation in the SMC: NGC 346 and its Neighborhood.*