30 Doradus: Birthplace of giants and dwarfs

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June 7, 2012
Outline

1. How stars form and evolve;
2. How we can use star clusters to better understand high redshift galaxies;
3. Characteristics of the Large Magellanic Cloud;
4. How and why the large mosaic of 30 Doradus was made;
5. What can we learn from the Tarantula Nebula and 30 Doradus.
How do stars form?

Stars form in clusters in a short interval of time (few million years)

Stars form from the breaking of giant clouds of gas in smaller and smaller pieces.

These clouds are between 50 and 300 light years in diameter, and their masses are between 10,000 and 1,000,000 times the mass of our Sun.
Why do giant clouds form stars?

Molecular clouds float freely in galaxies. Sometimes a cloud can cross a spiral arm...

...hit another cloud...

...or pass-by a star that is exploding as a supernova

The cloud contracts because of the compression and starts to break into smaller pieces.
Where does the energy of the stars come from?

The new stars continue to contract because of gravity. The increasing pressure heats the nucleus of the star and makes it shine.

If gravity was the only source of energy our Sun would shine for less than 18,000,000 years. There must be another source of energy.

Wait!!!

\[ \frac{U}{L_{\odot}} = 18,000,000 \text{ years}?? \]

We need much more energy!
In 1920 Arthur Eddington realized that the nuclear fusion of hydrogen into helium is the main source of energy in stars.
Why does star formation stop?

Only 10-40% of the gas goes into stars.

Stellar winds, jets and supernova explosions blow away the gas from the cluster and stop any further star formation.

Stars in clusters have very similar ages.
1. The majority of the stars are aligned on a Main-Sequence.
2. The Main-Sequence is the place where stars spend the majority of their life and where they convert H into He.
3. The luminosity of a star in Main-Sequence is proportional to its mass.
Star clusters reveal how stars evolve

NGC 3603
2-3 million years

NGC 290
60 million years

M80
12.5 billion years

4.5 billion years

Hubble image

E. Sabbi - HSB
1. The majority of the stars are aligned on a Main-Sequence.

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4. We can find bright massive stars only in young clusters.

5. Very old star clusters contain only small, red, cold stars.

Massive stars evolve much faster than low mass stars: a few million years vs. several billion years.
High-Redshift Galaxies

At high redshift even gigantic star forming regions (several hundred light years in diameter) look like little bright blue dots.

Why should we care? Because most of the stars in the Universe were formed in those dots between 8 and 12 billion years ago (roughly between redshift 1.5 and 3).
High-Redshift Galaxies

- The majority of the galaxies at high redshift are dwarf.
- High-redshift galaxies are rich in gas.

- The chemical composition of their stars is not as complex as that of our Sun (galaxies were metal poor).
High-Redshift Galaxies

- High redshift galaxies often interact with each other, and merge to form bigger galaxies.
- Small galaxies are often cannibalized by the bigger one.

The Milky Way ate several small galaxies in the past, and now is devouring the Sagittarius galaxy.

Martinez-Delgado & Perez

Hubble images
The Large Magellanic Cloud: a high redshift galaxy around the corner

• Stars in the Large Magellanic Cloud have half the metals compared to our Sun.

• The Large Magellanic Cloud is a gas-rich irregular galaxy.

• Its irregular shape is the result of its interaction with the Milky Way and the Small Magellanic Cloud.

• The Large Magellanic Cloud is so close to us (“only” 160,000 light years away) that with Hubble, we can see stars as small as ½ the Sun even in the most crowded star clusters.
The Large Magellanic Cloud

The Large Magellanic Cloud is the 3rd closest galaxy to the Milky Way after the Sagittarius and Canis Major galaxies. It is 160,000 light years away from us, corresponding to 10,000,000,000 times the distance between the earth and the sun.

If we are in the southern hemisphere we can see the Large Magellanic Cloud with the naked eye in the Dorado constellation.

The mass of the Large Magellanic Cloud is 1/100 of the Milky Way, making it the 4th largest galaxy in the Local Group after Andromeda, the Milky Way and the Triangulum Galaxy.
The Tarantula Nebula

- The most-famous and brightest known star-forming region of the Local Group is in the Large Magellanic Cloud.

- The Tarantula Nebula glows because hydrogen atoms are excited by the gigantic hot stars amassed in its central cluster 30 Doradus.
How the HST 22\textsuperscript{nd} anniversary image was made

There are 4 instruments on Hubble for science:

1. The Advanced Camera for Surveys (ACS);
2. The Wide Field Camera 3 (WFC3);
3. The Space Telescope Imaging Spectrograph (STIS);
4. The Cosmic Origins Spectrograph (COS)

The 3 FGS (Fine Guidance Sensors) are used to allow Hubble to follow its target during an observation.

We can use ACS and WFC3 at the same time to observe regions of the sky at the same time
How the 22\textsuperscript{nd} anniversary image was made

A mosaic of 150 HST images
Why the 22\textsuperscript{nd} anniversary image was made

Stars form in cluster

The majority of the massive stars are binaries

In the crowded core of a star cluster encounters between binaries and a 3\textsuperscript{rd} star are frequent

Under the right conditions the 3\textsuperscript{rd} star can take the place of one of the other two stars in the binary.

The star that is ejected from the binary gains such a high speed that sometimes it can leave the star cluster, becoming a runaway star.

Hubble images
Why the 22\textsuperscript{nd} anniversary image was made(2)

There are many very young (1 or 2 million years old) stars outside 30 Doradus.

Did they form in isolation, or were they ejected from 30 Doradus?

Measuring how stars move on the sky will tell us where the star was born!

We will observe 30 Doradus again in 2 years, and we will look for stars that have changed position.

This will tell us where these stars formed.
Tarantula Nebula (30 Dor, NGC 2070) in the Large Magellanic Cloud

Hubble Space Telescope

WFC3/UVIS F775W
ACS/WFC F775W
Hodge 301

20,000,000 years old

40 supernovae already exploded, blowing away most of the gas
NGC 2060 - 10,000,000 years old.

It hosts the most powerful X-ray pulsar known.
30 Doradus- 2,000,000 years old
More than 10,000 stars, some 300 times more massive than our Sun.
Too young for supernovae. The gas is blown away by stellar winds
Stellar nursery: supernovae and stellar winds do not have only a destructive effect; by compressing the gas at the boundaries of a cavity, they can start a new episode of star formation.
In the Bryce Canyon, hard stones protect the columns of softer clay from wind, rain and ice erosion, allowing the formation of the characteristic hoodoos.

Baby stars protect the column of dust and gas from the powerful radiation from hot stars that would otherwise destroy the dust and blow away the gas.

Hoodoos in the Bryce Canyon

Tarantula Nebula - HST image (detail)
Different telescopes see different things

Hubble
Space
Telescope

Chandra
X-ray
Observatory

Spitzer
Space
Telescope

Galaxy
Evolution
Explorer
Supernovae heat the gas up to millions of degrees. This very hot gas shines in X-rays.
Hot stars are the brightest sources in the ultraviolet
Infrared wavelengths can find dust and stellar nurseries.
Summary

1. Gigantic regions of star formation are complex systems where different generations of star affect each other’s evolution

2. At high redshift we cannot see the complexity of the star forming regions, and we derive a simplified history of star formation

3. A comparison between what we see in nearby and distant galaxies tells us how to interpret the early universe, and to reconstruct its evolution with time.
The Local Group

- The Local Group counts more than 54 galaxies (the majority are dwarf galaxies).
- Its center is somewhere between the Milky Way and the Andromeda galaxy (M31).
- Its diameter is ~10,000,000 light years.
- The total mass of the Local Group is ~$10^{12}$ the mass of our sun, and more than 2 times the total mass of the Milky Way.
Thank you for your time!!