Hubble's 25th Anniversary: Hubble's Views of Star and Cluster Formation

Drs. Carol Christian, Antonella Nota, and Brad Whitmore

May 7, 2015
Stars / Star Clusters

Carol Christian

- Stars form from gas and dust clouds
- The clouds collapse due to gravity
- Also the clouds can collide / compress
- Stars form in the condensed material
- Stars very often form in groups (called star clusters)
- Stars vary in mass from much less than the Sun to more than 100 x Sun
Star Clusters

- As the most massive stars start to shine, they ionize the gas
- A cavity is formed with the cluster in it
- The gas and dust can be pushed away, collide with other material, and start new formation
- Clusters vary in size from a loose grouping (10s of stars) to dense objects (millions of stars)
- Depends upon formation process and environment
Cluster and Starforming Region Westerlund 2

Westerlund 2

NASA and ESA • Hubble Space Telescope ACS/WFC WFC3/IR • STScI-PRC15-12a
Westerlund 2 is a very young cluster. The way it looks now is the way it formed (has not had time to change).
The Westerlund 2 region is abundant in gas and dust.
We map the dust location

We make a “reddening” map

We correct the brightness of each and every star using the “reddening map”
We measure the brightness and color of all stars in Westerlund 2
We correct for dust absorption
We compare with models

We derive an age for Westerlund 2 of 0.5 - 2 Myr
Estimating the Ages of Star Clusters in M83: The Southern Pinwheel Galaxy
Most of the stars that form a galaxy are born in gravitationally bound star clusters. Many of these clusters fall apart, their stars spreading out into the field to form the galaxy as a whole.

To study the life cycle of star clusters, astronomers need to be able to determine their ages. Today I will teach you how to do this too.
Slightly older clusters will have enough time to blow a bubble.

Here are some very young clusters, with lots of pink light (Hydrogen) around them.
Intermediate age clusters have no pink light associated with them, and you can still see the individual stars.

Ancient clusters have lost their blue stars so they look like fuzzy, slightly reddish blobs.

Old clusters look like a diffuse fuzzy blob.
Here is the full sequence:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Young</td>
<td>Small regions of pink light (Hydrogen) around them.</td>
</tr>
<tr>
<td>Young</td>
<td>Intermediate age clusters have no pink light associated with them, and you can still see the individual stars.</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Slightly older clusters have enough time to blow a bubble.</td>
</tr>
<tr>
<td>Old</td>
<td>Ancient clusters have lost their blue stars so they look like fuzzy, slightly reddish blobs.</td>
</tr>
<tr>
<td>Ancient</td>
<td>Old clusters look like a diffuse fuzzy blob.</td>
</tr>
</tbody>
</table>
Astronomers actually use more precise measurements of the colors of clusters to determine their ages, as shown in the plots.

Data points in the upper left of these plots are young clusters (1 million years old) while those in the bottom right are old (10 billion years old).

You can see that our simple estimates based on their appearance get pretty much the same answers!
Last year at about this time we teamed with ZOONIVERSE to produce a citizen science project to use these simple ideas to measure the ages of star clusters in M83.
Let’s walk through some of the pages of the STARDATE: M83 citizen science project and see how it worked.
After answering a few questions, the software has determined that this cluster is “Old” (e.g., no pink hydrogen gas – the cluster is diffuse).

In this step they also help us measure the size of the clusters.
If hydrogen emission is present (pink) we have them measure the size of that as well.

The citizen scientists are then invited to explore the image and find other object such as background galaxies.
After classifying the cluster, we show them where it is in the galaxy.

They learn that the young clusters are generally found along the spiral arms.

The older clusters are generally found between the arms.
Let's try a few together!
 Lets try a few together !
M31 (Andromeda)
Carol Christian

Panchromatic Hubble Andromeda Treasury (PHAT)

- M31 is nearest large galaxy – companion to our own Milky Way
- Survey used mosaic of HST data obtained over several years
- Covered 1/3 of M31 in 828 orbits using 6 filters (~40,000 exposures)

Andromeda Project: Citizen Science

Find the Clusters!

• 8 science team members
• One month searching the first ~20% of the survey’s imaging
• Found ~600 likely star clusters
• 4x number previously known in same region

Andromeda Project

• Too much data for science team alone
• Volunteers examine images
• Classify objects as clusters (and other)

Two Rounds of searching in 2012 and 2013

• Volunteers examine ~20,000 images
• ~10,000 unique visitors
Andromeda Project: Citizen Science

- More than 100,000 image classifications in the first day in December 2012
- Overall classification rate that is greater than one per second!
- More than 2 million classifications
- 80 individual classifications per image cutout

At least 3000 clusters found by volunteers
Detailed analysis being conducted by science team
Many other ancillary objects found in data also
Star / Star Clusters: Why?

To understand

- Star formation (and planetary system formation)
- How clusters form
- How parent galaxy environment affects formation
- How galaxies form
- Clues to early universe galaxies