Astro 101 Slide Set: "Inside-Out" Star Clusters

Developed by the Chandra Team

Topic:
Star clusters

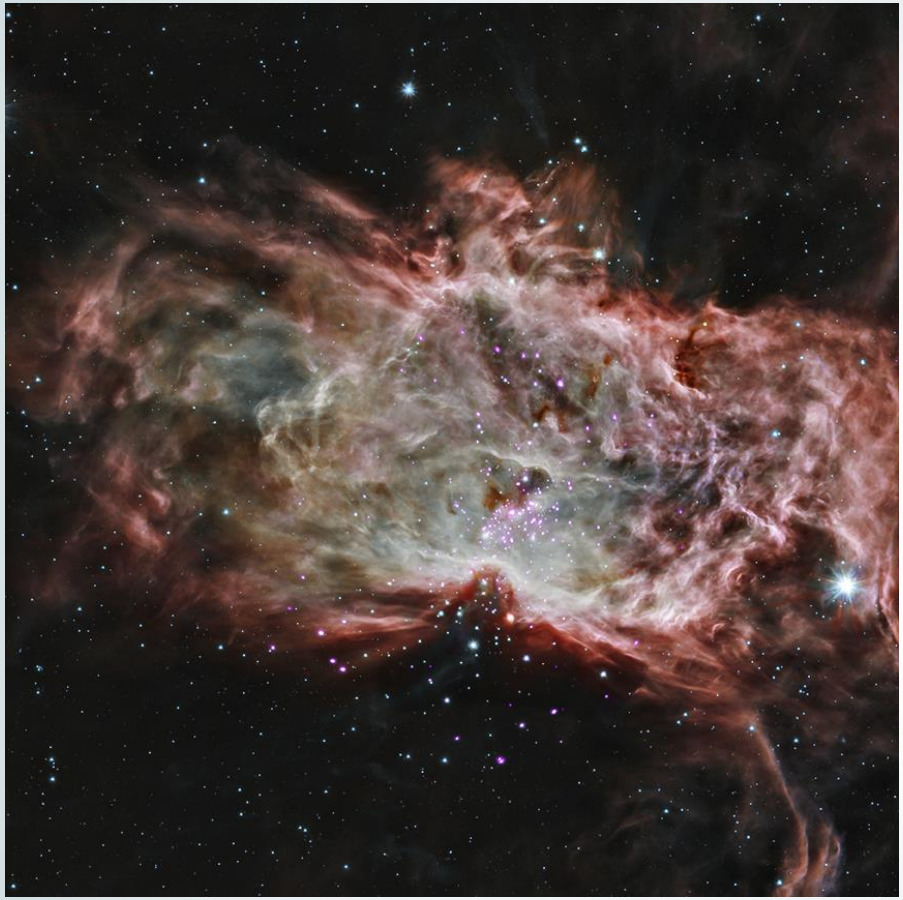
Concepts:
Stellar evolution, star formation, cluster formation, cluster dynamics

Missions:
Chandra, Spitzer

Coordinated by
the NASA Astrophysics Forum

An Instructor's Guide for using the slide sets is available at the ASP website
https://www.astrosociety.org/education/resources-for-the-higher-education-audience/

The Discovery



NGC 2024, the Flame Nebula and its associated star cluster, lies 1,400 light years away in the Orion Molecular Cloud Complex. (Credit: X-ray: NASA/CXC/PSU/K. Getman, E. Feigelson, M. Kuhn & the MYStIX team; Infrared:NASA/JPL-Caltech.)

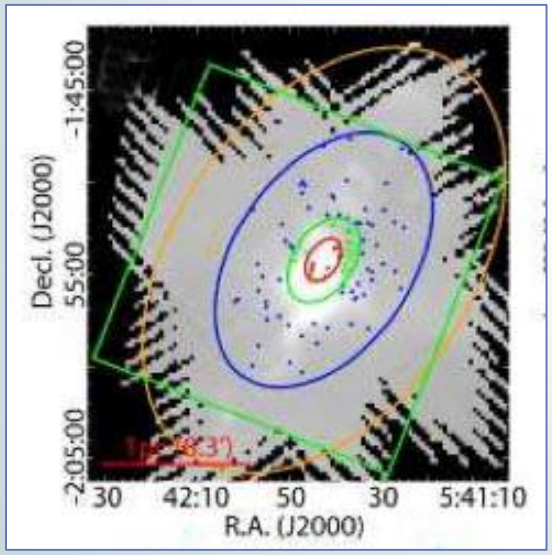
Most stars are born in clusters from huge clouds of gas and dust. The conventional wisdom has been that a cluster's oldest stars would lie in its core, where greater density of matter would form stars first.

But studies of two nearby clusters (NGC 2024 and the Orion Nebula Cluster) suggest that some "infant" stars on the outskirts are older than similar stars in the central regions.

These "inside-out" star clusters may require rethinking of how and when stars form in clusters from large clouds of gas.

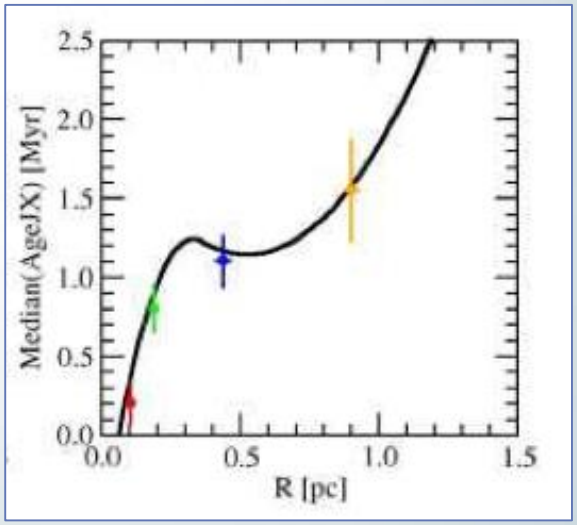
How Was the Discovery Made?

- Scientists divided the clusters into the core and elliptical sampling rings indicated by the different-colored boundary lines in the figure below.
- They sampled “pre-main sequence” stars (infant stars not yet fusing hydrogen into helium to produce energy) in each area, using Chandra X-ray data to determine masses and Spitzer infrared data to determine brightness, and combining this information with theoretical models to estimate star ages.
- The results showed:
  - Pre-main sequence stars in NGC 2024 are about 200,000 years old in the center versus 1.5 million years old at the periphery.
  - The Orion Nebula Cluster star ages are 1.2 million years in the center versus 2 million years around the edges.



Left: the diagram shows color-coded sampling areas for NGC 2024 (with stars superimposed on a 500 micron image from the SPIRE infrared imager aboard the Herschel spacecraft). The core is enclosed within the red ellipse; green, blue and yellow ellipses enclose sampling areas successively farther from the core. (The green square outlines the Chandra study field.)

Right: the graph shows the median age of the stars in the core and surrounding sampled areas plotted against distance in parsecs from the core center. The plot shows that stars in the core (red point) are much younger than stars farther out, and the most distant stars (yellow point) are the oldest.



The Big Picture

Most stars form in clusters when great masses of gas and dust concentrate in space.

General theories suggested cluster stars form all at once or progressively outward from the center:

- Stars form more quickly where matter is densest, more slowly where matter is less dense.
- Thus, the centers of clusters were thought to have the oldest stars, while the outer regions have the youngest.

But these new estimates for the ages of pre-main sequence stars seem to reverse this assumption, with the oldest stars on the outside and the youngest stars inside.

Theories of cluster evolution—how gas, dust and stars behave and interact with each other—may need to be revised to explain the new findings.

Composite image of the Orion Nebula Cluster, with stars seen in X-ray light and the surrounding nebula in optical light. This cluster also ~~seems to~~ shows younger PMS stars in the center and older stars around the outside. Credit: X-ray: NASA/CXC/Penn State/E.Feigelson & K.Getman et al.; Optical: NASA/ESA/STScI/M. Robberto et al.

How Does this Discovery Change our View?

If the results are confirmed in other clusters, scientists must explain how clusters can have younger pre-main-sequence stars in their centers and older such stars In outer regions:

- Possibility One: if star formation continues over time in clusters, it may cease in the outer regions when gas becomes too depleted to form more stars, but continue in the interior where gas is denser—thus producing younger stars than exist at the edges.
- Possibility Two: older stars—those forming first in the center—have more time to drift to the periphery or get kicked out there through gravitational interactions with other stars, creating an older population in the outer regions.
- Possibility Three: stars could be formed later in massive filaments of gas that fall toward the center of the cluster, producing a younger population there.

More than one possibility may apply.

NGC 3603 (not studied in this paper). Credit: NASA, ESA, and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration.

Resources

Press release

- Chandra release
  http://www.chandra.harvard.edu/press/14_releases/press_050714.html

Image releases

- Chandra releases
  http://chandra.harvard.edu/photo/2014/flame/
  http://chandra.harvard.edu/photo/2007/orion/

Scientific articles

- Getman, K. et al, 2014, ApJ; arXiv:1403.2741
- Getman, K. et al, 2014, ApJ; arXiv:1403.2742

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BONUS CONTENT

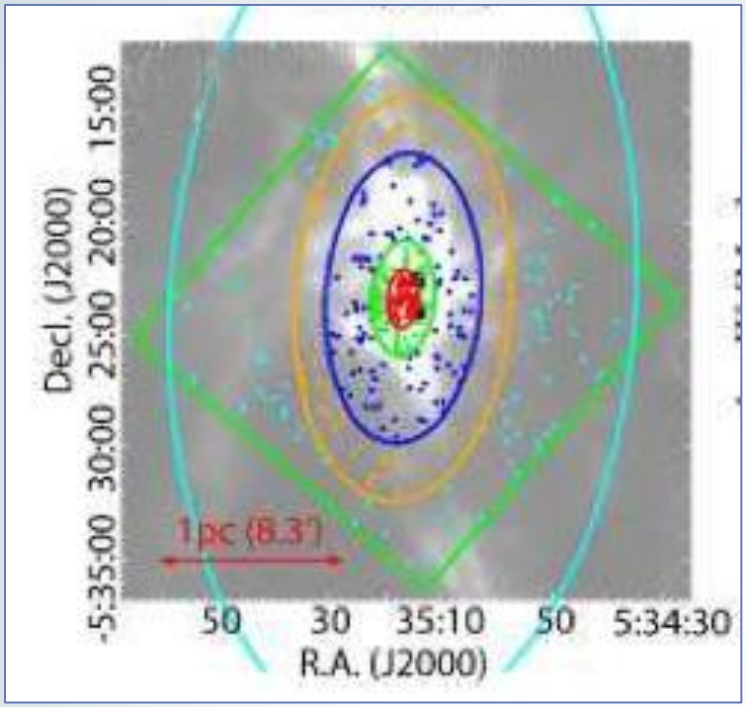
Composite Image Animation

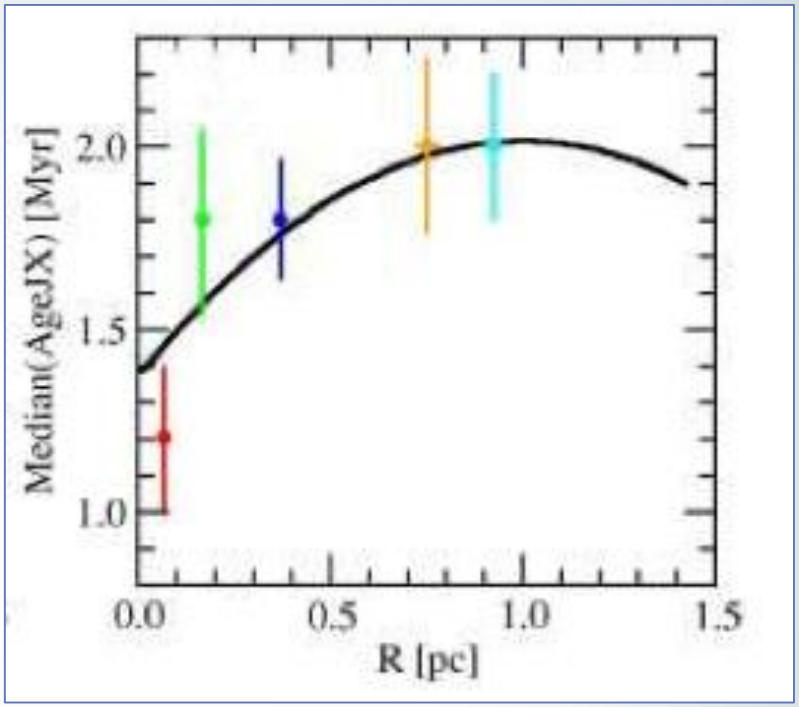
Composite of Chandra and Spitzer images of NGC 2024.

Chandra X-ray image of NGC 2024.

Spitzer infrared image of NGC 2024.

Additional Images





Left: the diagram shows color-coded sampling areas for the Orion Nebula cluster, the second cluster in the study (with stars superimposed on a 500 micron image from the SPIRE infrared imager aboard the Herschel spacecraft). The core is enclosed within the red ellipse; green, dark blue, yellow and light blue ellipses enclose sampling areas successively farther from the core. (The green box is the border of the Chandra study field.)

Right: the graph shows the median age of the stars in the core and surrounding sampled areas plotted against distance in parsecs from the core center. The plot shows that stars in the core (red point) are much younger than stars farther out, and the most distant stars are the oldest.