

'Yellowballs' offer new insights into star formation

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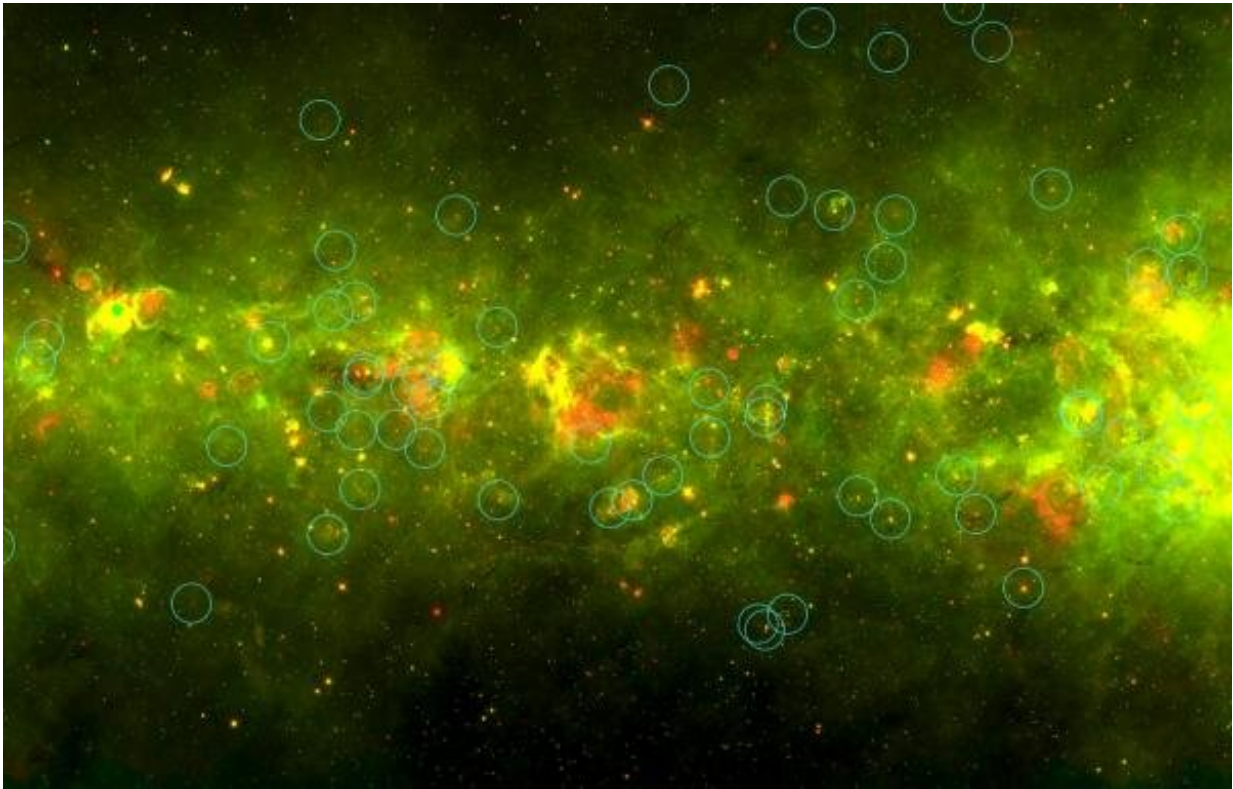
An example of a yellowball (left, circled) and a bubble (right, circled) as seen in infrared images from NASA's Spitzer Space Telescope. A typical yellowball has a diameter of about a light-year, while a bubble can grow to tens of light-years. This false-color image uses a blue-green-red color scheme to depict infrared wavelengths used in the Milky Way Project and gives rise to the 'yellow' color of the feature. Credit: NASA/JPL-Caltech

A serendipitous discovery by citizen scientists has provided a unique new window into the diverse environments that produce stars and star clusters, revealing the presence of "stellar nurseries" before infant stars

emerge from their birth clouds, according to Planetary Science Institute Senior Scientist Grace Wolf-Chase.

"Yellowballs are small compact features that were identified in infrared images acquired by the Spitzer Space Telescope during online discussions on the Milky Way Project, an initiative on the online citizen science platform zooniverse.org, that asked citizen scientists to help identify features associated with young, [massive stars](#) greater than 10 solar masses," said Wolf-Chase, lead author of "The Milky Way Project: Probing Star Formation with First Results on Yellowballs from DR2," which appears in the *Astrophysical Journal*. "Early research suggested yellowballs are produced by young stars as they heat the surrounding gas and dust from which they were born."

The yellowballs discovered by citizen scientists shed [infrared light](#) on a very early stage in the development of star clusters, when they are a 'mere' hundred thousand years old. "This is the point at which their presence is first revealed, but they remain embedded in their dusty birth cocoons," Wolf-Chase said. "This allows us to link the properties of stars with their birth environments, as if a human were giving birth to a hundred or so infants at once."



This image shows a swath of part of the Milky Way used in the analysis presented in the yellowballs paper. Yellowballs that represent regions which aren't associated with massive stars are circled. The image uses a green and red color scheme to highlight complex organic molecules and dust. Credit: Charles Kerton, Iowa State University/NASA/Spitzer

The research shows that forming star clusters—protoclusters—of essentially all masses go through a yellowball stage. Some of these protoclusters form massive stars greater than 10 [solar masses](#) that will sculpt their environments into "bubbles" through strong stellar winds and harsh ultraviolet radiation, while others won't. Over the course of a million years, bubbles can expand to tens of light years across.

"We also showed that we can glean information about the masses and

ages of developing [star clusters](#) through the infrared 'colors' of yellowballs alone, without other extensive observations such as spectroscopy," Wolf-Chase said. "This is important because observing time is limited and if we can tell a lot about thousands of these objects from a few, relatively simple observations, it's a great time-saver and helps us identify particularly interesting yellowballs for future higher-resolution observations."

During the course of searching for 'bubbles' in the Milky Way Project, [citizen scientists](#) used the project's discussion board to tag small, roundish, objects that appear "yellow" in the representative color infrared images. "Scientists initially thought these might be very young versions of the bubbles and we included identifying yellowballs as a principal goal in a version of the Milky Way Project that was launched in 2016," Wolf-Chase said. "This resulted in the identification of 6,176 yellowballs over more than one-third of the Milky Way. Their distinctive 'yellow' appearance relates to wavelengths that trace complex organic molecules and dust as they are warmed by very [young stars](#) embedded in their birth clouds."

"Our paper analyzes a subset of 516 yellowballs and shows only about 20% of yellowballs will form the bubbles associated with massive stars, while about 80% of these objects pinpoint the location of regions forming less massive stars," Wolf-Chase said. "This work shows the great value of citizen science in opening a new window into our understanding of [star formation](#)."

More information: The Milky Way Project: Probing Star Formation with First Results on Yellowballs from DR2. *Astrophysical Journal*, doi.org/10.3847/1538-4357/abe87a

Provided by Planetary Science Institute

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