New visualization techniques yield star formation insights

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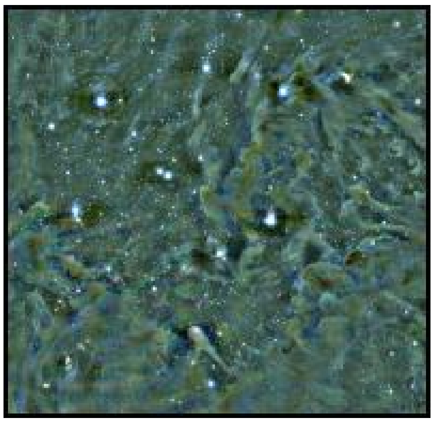

This image shows a very long-exposure view of a 1-degree- square area within the Perseus star-forming region. The colors correspond approximately to "true" color, and the regions which appear very dark show the obscuration caused by concentrations of interstellar dust associated with the star-forming cores discussed in the Letter in Nature. The image gives an impression of the generally "turbulent" (swirling) nature of interstellar material in star-forming regions. This is a "flat" image of the sky, in that it does not contain any information about depth. The "3D" images published in Nature show views of this region taken with radiotelescopes where the line-of-sight velocity of gas is used to separate regions at different distances, which appear super-imposed on each other in this more traditional flat optical image. Image courtesy Jaime Pineda & Jonathan Foster

New computer visualization technology developed by the Harvard Initiative in Innovative Computing has helped astrophysicists understand that gravity plays a larger role than previously thought in deep space's vast, star-forming molecular clouds.

The insight, to be reported in the Jan. 1 issue of the journal *Nature*, is being illustrated in the journal's online version through new three-dimensional Portable Document Format (PDF) technology that will allow readers to view the article's key graphics using free PDF software already commonly found on computers.

The work was led by Astronomy Professor Alyssa Goodman of Harvard's Faculty of Arts and Sciences, the Harvard-Smithsonian Center for Astrophysics, and the Initiative in Innovative Computing (IIC), of which she was the founding director. Goodman and colleagues used the IIC technology to examine reams of astronomical data collected on a structure known as a giant molecular cloud.

Previous technology, Goodman said, doesn't allow for careful consideration of what she described as "hierarchical" structure — essentially regions within regions — and would have obscured specific details in the molecular cloud, such as nested areas of varying density and a physical break from one area to another.

"There's no way of noticing this without being able to see this in 3-D," Goodman said.

Michael Halle, senior scientist at the IIC and instructor in radiology at Harvard Medical School and Brigham and Women's Hospital, said this research shows that visualization technology is a critical part of the analysis and discovery process and not just a way to display data once it has been gathered, analyzed, and understood.

"You're learning about your data through visualization and interaction," said Halle. "You can take all the data, selectively filter it, and look at it in a different way."

Halle praised the IIC as an important forum within which researchers with different fields of expertise can work together.

"Without the IIC's collaborative infrastructure, multidisciplinary resources, and other support, this research would not have happened," Halle said.

The research team also included Erik Rosolowsky of the University of British Columbia, Michelle Borkin of the IIC and Harvard's School of Engineering and Applied Sciences, Jonathan Foster and Jaime Pineda from the Harvard-Smithsonian Center for Astrophysics, and Jens Kauffmann of the IIC and the Harvard-Smithsonian Center for Astrophysics.

The team took advantage of tools developed by the IIC's ongoing Astronomical Medicine (A-M) project, managed by Halle, which uses technology devised for medical imaging on astronomical research. To visualize the molecular cloud in three dimensions, it used Astronomical Medicine's 3-D Slicer program, originally devised to analyze medical images.

The key advance, however, is a new computer algorithm — a set of instructions on how to handle data similar to a computer program or model. The algorithm, developed by Rosolowsky, outputs results in a "dendrogram," which is a treelike representation of data. From the dendrogram, researchers were able to create 3-D displays of the data that they could then rotate and examine from many different directions.

The data, which are part of the ongoing COMPLETE (COordinated Molecular Probe Line Extinction Thermal Emission) Survey of Star Forming Regions, measure emission from a type of carbon monoxide molecule in the cloud. The carbon monoxide serves as a proxy for the vast amounts of hydrogen that make up most of the cloud and from which stars form. In deep space's bitter cold, hydrogen gives off very little emission so a proxy such as carbon monoxide is needed.

Computer simulations are critical tools in understanding the behavior of these clouds and of star formation, Goodman said. The simulations are the only way that astronomers can watch what happens over the millions of years it takes to form a star. Past models of star formation in these clouds assumed that since gravity is a weak force over large distances, its effects are negligible in these clouds until the hydrogen atoms are very close together. These popular models, Kauffmann said, assume that most of the changes in the clouds come from turbulence and that it is only after turbulence pushes molecules close enough that gravity comes into play.

Once denser groupings of molecules are formed and gravity becomes a factor, they attract more and more particles until either something disrupts them or they have enough mass to collapse and form a star.

But it is the process up to the point where the dense groupings form that Goodman and colleagues examined. Their analysis shows that, rather than turbulence being the only significant force pushing these gas molecules around, their gravitational influence on each other is also significant. That finding means that existing models, which leave gravity out until very dense clumps have formed, would over-predict the rate of star formation in these clouds.

The research will be presented in a novel way for Nature, Goodman said. It will be the first time a major scientific journal has used a 3-D PDF of graphics in an article. The 3-D PDF format has been used before, primarily in manufacturing and advertising. The Adobe Acrobat PDF software, including the free Adobe Reader, is common on many computers.

The conversion of the 3-D images into PDF format from the more technical 3-D Slicer software used by the IIC was done using software produced by a New Zealand company, Right Hemisphere, which has been working to make 3-D publishing a mainstream technology and a way to communicate complex data, according to founder Mark Thomas.

"We see the use of 3-D in publishing by Harvard and Nature magazine to be a significant milestone in publishing history and are very proud to have been able to assist and guide the process," Thomas said.

Source: Harvard-Smithsonian Center for Astrophysics

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