This edition of the **Institute Newsletter** *continues to reprint science articles from NASA's annual* Hubble 2009: Science Year in Review. *We are pleased to continue this series with "High-Speed Ballistic Stellar Interlopers" by Raghvendra Sahai and "Starbursts in Dwarf Galaxies" by Kristin McQuinn.*

High-Speed Ballistic Stellar Interlopers

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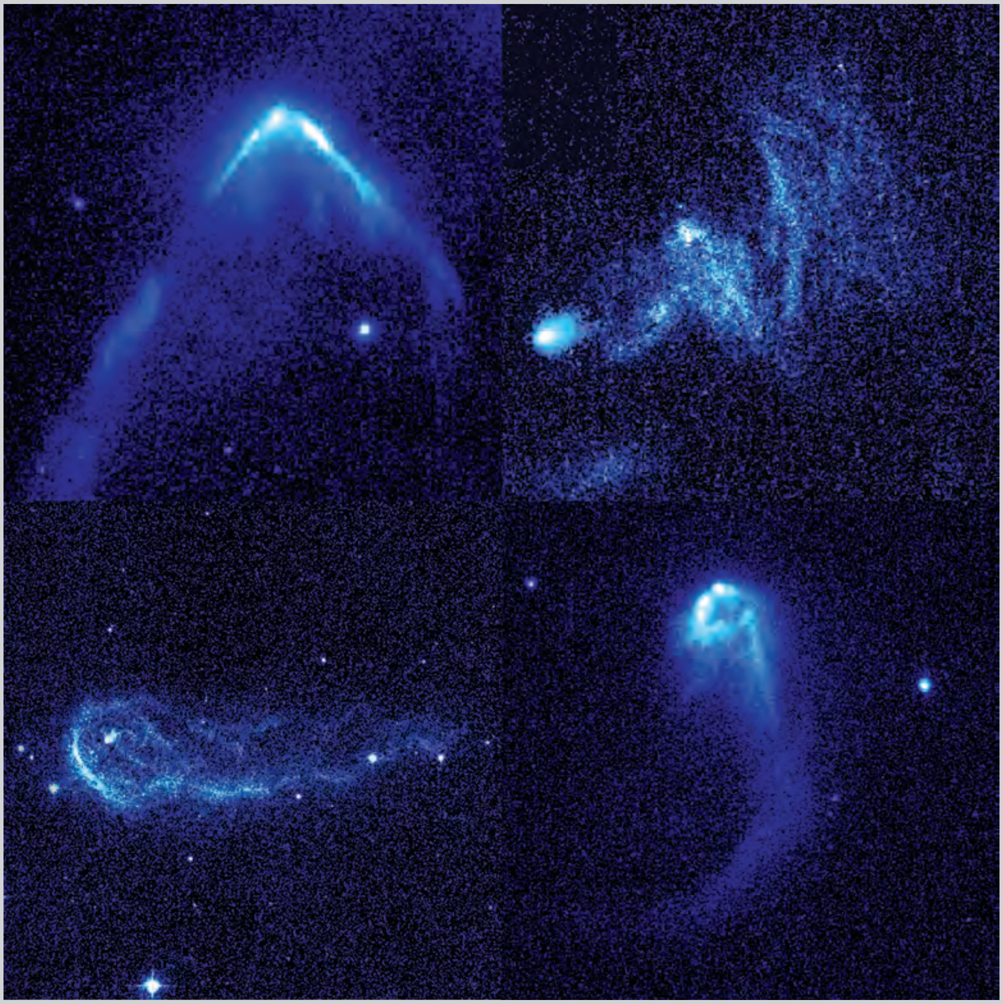
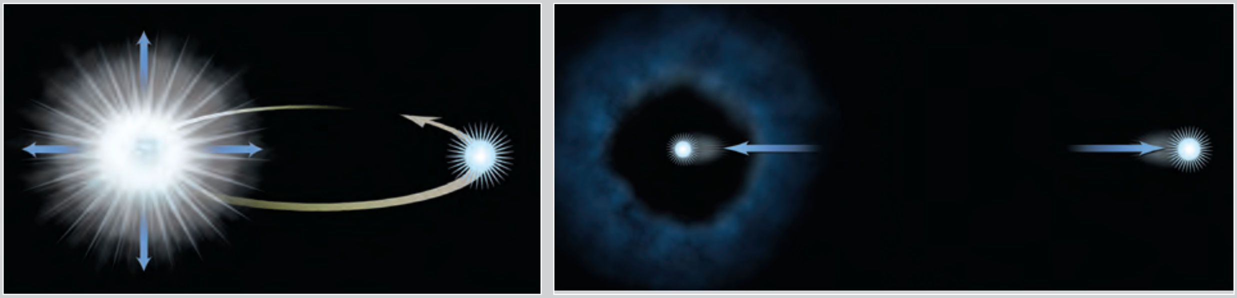
Astronomers have discovered a new class of bright, high-velocity stars speeding through the galaxy. Called “ballistic stellar interlopers,” the stars are plowing through dense regions of interstellar gas at velocities possibly as high as 100,000 miles per hour. As they do, they create brilliant arrowhead patterns and trailing tails of glowing gas. Fourteen such stars have been identified using *Hubble*’s Advanced Camera for Surveys.

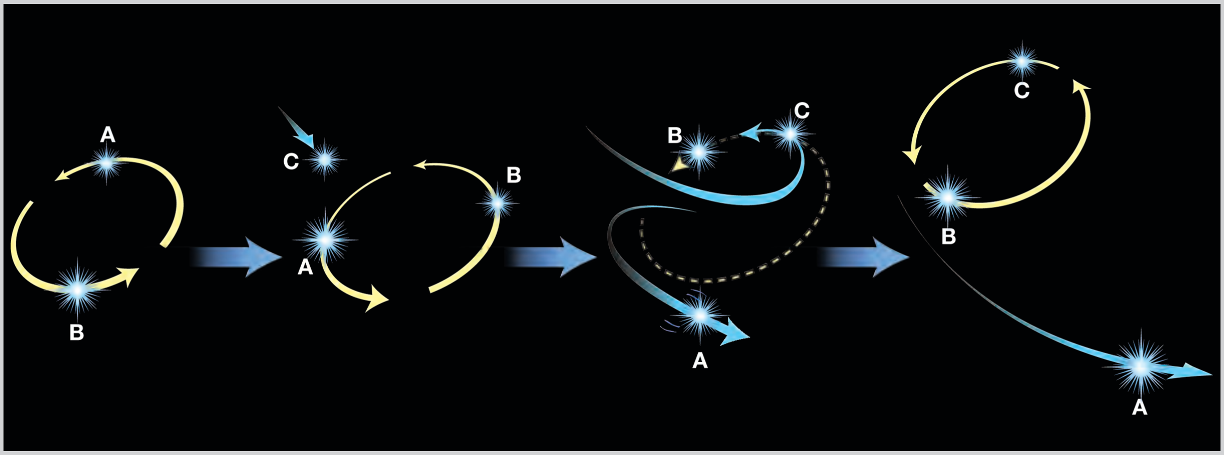
Superficially resembling comets, these stars display bow shock features, which occur when the stars’ powerful stellar winds—streams of matter flowing from the stars—collide with the surrounding dense gas. The phenomenon is similar to the wake created when a speedboat pushes through water on a lake. *Hubble*’s high resolution has revealed new details in the structure and shape of these bow shocks, enabling better analysis of the physics involved.



Resembling comets streaking across the sky, these four speeding stars are plowing through regions of dense interstellar gas and creating brilliant arrowhead structures and trailing tails of glowing gas.



One scenario in which a runaway star could be accelerated is if one star in a binary system explodes as a supernova and the partner gets kicked out.



Another possible scenario is a collision between two binary star systems or a binary system and a third star. One or more of these stars could pick up energy from the interaction and escape the system.

Astronomer Raghvendra Sahai of NASA's Jet Propulsion Laboratory in Pasadena, California, and his team (Mark Claussen, NARO; Mark Morris, UCLA) have estimated the ages, masses, and velocities of these interlopers. The stars appear to be young—just millions of years old. Their ages are based partly on their strong stellar winds. Most stars produce powerful winds either when they are very young or very old. Only stars greater than 10 times the Sun's mass have stellar winds throughout their entire lifetimes.

But the objects observed by *Hubble* are not very massive, because they do not have glowing clouds of ionized gas around them. They are medium-sized stars that are a few to eight times more massive than the Sun. The stars are also not old because the shapes of the nebulas around aging, dying stars are very different from those where interlopers are found, and old stars are almost never found near dense, interstellar clouds.

Depending on their distance from Earth, the bullet-nosed bow shocks could be 100 billion to a trillion miles wide. This indicates that the stars are traveling fast with respect to their surroundings—roughly five times faster than typical young stars. The interlopers were most likely ejected from massive star clusters. Assuming their youthful phase lasts only a million years and they are traveling 100,000 miles per hour, the stars have traveled about 160 light-years.

There are actually two proposed ways the runaway stars could have been accelerated. In one scenario, a star in a binary system explodes as a supernova, pushing its companion away at high speed. The other, more likely possibility is the close approach between two binary star systems—or a binary system and a third star. In such cases, one or more of the stars can pick up enough energy through gravitational interaction with the others to be thrown from the system.

Determining how many stars have been ejected from their neighbors is important to conducting an accurate census of the various types of stars born in an interstellar cloud. Scientists try to understand how efficiently the cloud makes stars; but if stars are being ejected, the total number might be underestimated.

Runaway stars have been seen before. The *Infrared Astronomical Satellite* (*IRAS*), which performed an all-sky infrared survey in 1983, discovered a few similar-looking objects which were examined more closely in the late 1980s. But those stars produced much larger bow shocks than the stars in the *Hubble* study, suggesting that they are more massive stars with more powerful stellar winds.

The stars in this *Hubble* study are likely the lower-mass and/or lower-speed counterparts to the massive stars with bow shocks detected by *IRAS*. The stars seen with *Hubble* may represent the bulk of the population, both because many more lower-mass stars inhabit the universe than higher-mass stars, and because a much larger number are subject to modest-speed kicks.

Sahai and his team used *Hubble*'s Advanced Camera for Surveys to examine 35 objects that appeared as bright infrared sources in the *IRAS* archive. They were looking for long-lived, pre-planetary nebulas—puffed-up, aging stars on the verge of shedding most of their outer layers to become glowing planetary nebulas. Instead, the astronomers stumbled upon the ballistic stars.

The team is planning follow-up studies to search for more such stars, as well as to conduct more detailed observations on selected objects to understand how they affect their environments. The astronomers want to determine if the strong winds from interlopers stir up the clouds where they are found, and discover how interlopers affect the formation of the next generation of stars—important considerations in understanding how galaxies change over time.

Further Reading

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Dr. Raghvendra Sahai is a Principal Research Scientist with the Jet Propulsion Laboratory/California Institute of Technology. He has published more than 80 articles in which he has employed high-resolution imaging, spectroscopy, and telescopic surveys to study the full lifecycle of stars. His studies utilize multiwavelength observations spanning the radio to X-ray wavelength range, obtained with the *Hubble Space Telescope*, *Chandra X-Ray Observatory*, *Spitzer Space Telescope*, and *GALEX*, as well as leading ground-based telescopes and interferometers. Dr. Sahai is a member of the Design Reference Mission for the *James Webb Space Telescope*, and the Science Team for the *ECLIPSE* coronagraphic telescope mission concept to search for extra-solar giant planets. He is a full member of the American Astronomical Society and the International Astronomical Union, and a founding member of the European Astronomical Society. He earned his Ph.D. from the California Institute of Technology in 1985, and his M.S. in Physics from the Indian Institute of Technology, Kanpur, India in 1978.