generate a substantial field.

This neat consistency of theory and observation changed when observations with the Goddard High Resolution Imaging Spectrometer (which was removed in 1997 from the Hubble Space Telescope) showed that red giants do indeed have hot patches of activity. Moreover, the emission lines that trace the activity are stamped with the effects of absorption in cooler material. If reconnecting magnetic loops are responsible for the activity, then they lie within the red giant's cool atmospheric envelope and close to the stellar photosphere—like the loops of the Sun's magnetic carpet.

Though acoustic waves could also be responsible, Ayres speculates that the magnetic carpet is generated by Gurney's turbulent dynamo in the upper convection zone. "And that kind of mechanism," suggests Ayres, "could work on all stars."

CHARLES DAY

Reference

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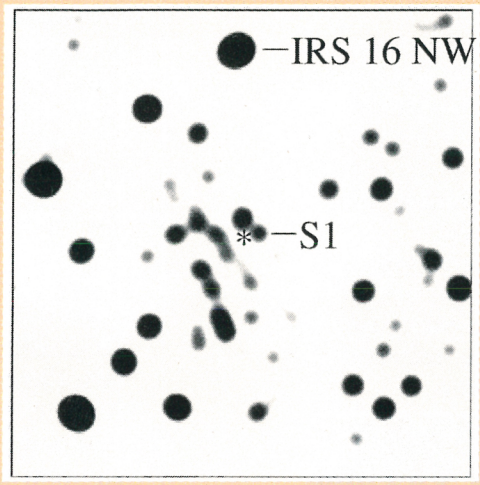
Stellar Motion Very Near the Milky Way's Central Black Hole

The extraordinary pair of images at right are near-infrared exposures, taken two years apart, of stars in the central 3 × 3-arcsecond field of our Galaxy. Andreas Eckart and colleagues at the Max Planck Institute for Extraterrestrial Physics in Garching, near Munich, have been monitoring the proper and Doppler motions of these stars since 1992 with spectacularly high-resolution infrared speckle photography and spectroscopy, using European Southern Observatory telescopes, in Chile, optimized for infrared observation. At visible wavelengths, the central precincts of the Galaxy are completely hidden by dust.



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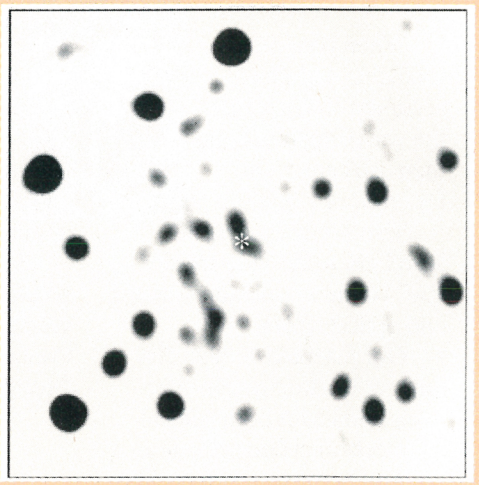
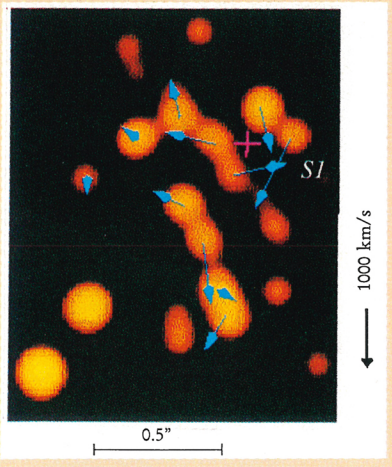


April 1996

Eckart and company describe their observations as "the first conclusive evidence for a massive black hole in the center of the Milky Way."[1] The Galactic center, 26 100 light-years from us, is associated with the very compact radio source Sagittarius A*, marked by the asterisks in the images. At that distance, 1 arcsecond = 46 light-days.

In the color closeup of the innermost arcsecond (with Sgr A* marked by the red cross), the measured proper velocities (that is, in the plane normal to the line of sight) are indicated by the lengths and directions of the blue arrows. Together with the Doppler radial velocities, they exhibit a Keplerian decrease with distance from Sgr A*. There is no obvious preferred orbital plane. The fastest moving star, marked S1, changed position quite noticeably from 1994 to 1996. Less than a light-week from Sgr A*, it has a velocity in excess of 1500 km/s. That's about four times the velocity of the star IRS 16 NW, which is more than two light-months from Sgr A*.

From the measured Keplerian stellar velocities and distances, Eckart and company conclude that Sgr A* marks a compact object of 2.6 million solar masses at the center of the Milky Way. The small distances to the innermost orbiting stars tell us that this supermassive concentration is far denser than any known star cluster. And if it were a uniquely dense star cluster, it would be unstable on a time scale much shorter than the age of the Galaxy. Furthermore, the stringent upper limit on any proper motion by the radio source Sgr A* implies that at least 10^5 solar masses are enclosed within 1 astronomical unit (the Earth's orbital radius, 8 light-minutes). "So the only plausible explanation" Eckart told us, "is a supermassive black hole."



Of course, this is not the first evidence for a great concentration of mass near the center of a galaxy. But this first observation of stellar motion within light-days of the center of any galaxy appears to exclude anything but a black hole in the case of the Milky Way. Aside from being much closer in than the gases that have been observed moving rapidly near galactic centers, stars are better gravitational test particles, because gases can be diverted by pressure gradients and magnetic fields. The Garching group's observations have now been confirmed by a University of California, Los Angeles, group doing infrared imaging with the 10-meter Keck telescope in Hawaii.[2]

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2. A. Ghez *et al.*, Proc. IAU Symp. 184 (1997). ■