MEETING AMERICAN ASTRONOMICAL SOCIETY

Latest Observations Bring The Unseen Into View

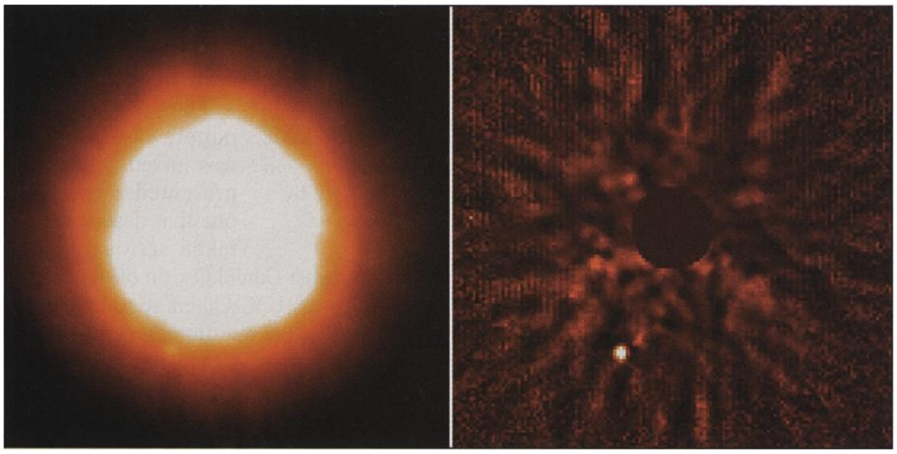
WASHINGTON, D.C.—A mere 8.33 light-microseconds from the White House and the Capitol, 2300 astronomers at the American Astronomical Society's 199th meeting gathered on 6 to 10 January to discuss cosmic issues ranging from adaptive optics and brown dwarfs to black-hole companions and galactic coronas.

Exoplanet Pix Coming Soon?

To capture their first-ever image of an extrasolar planet, astronomers may not need to wait for expensive space-based observatories. Incredibly detailed observations presented at the meeting have convinced some scientists that existing ground-based telescopes can do the job on their own. One researcher, Ray Jayawardhana of the University of California, Berkeley, says he and colleagues are monitoring a number of candidate objects and may produce an exoplanet snapshot within the year. "It's a big prize to win," he says.

Although astronomers have deduced the existence of exoplanets from the way they tug at their mother stars, no one has ever seen one. Even at infrared wavelengths, in which the glare of a sunlike star is less severe, a giant planet like Jupiter would be only a billionth as bright—far too faint to be seen. But young planets still glowing with the heat of their formation may be 10,000 times as luminous as Jupiter. "They can be detected by 10-meter-class telescopes using adaptive optics," says Jayawardhana.

Adaptive optics is the revolutionary technique in which ultrarapid undulations of computer-controlled flexible mirrors compensate for image distortions caused by turbulence in Earth's atmosphere. Using adaptive optics, ground-based telescopes can see just as sharply as the Hubble Space Telescope. But large instruments such as the 10-meter Keck telescope and the 8.1-meter Gemini North telescope, both located on Mauna Kea, Hawaii, collect much more light than Hubble's 2.4-meter mirror, so they are more sensitive to faint stellar companions.



Lights out. Processed image (*right*) picks a brown dwarf out of the glare of a nearby star.

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At the meeting, Jayawardhana and Michael Liu of the University of Hawaii, Honolulu, presented striking proofs of the technique's power. Jayawardhana announced that he and Kevin Luhman of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, had detected a dust disk around one member of a newborn quadruple star system 900 light-years from Earth in the constellation Aries. Liu and his collaborators found a faint brown dwarf—a "failed star"—orbiting close to a sunlike star 58 light-years from Earth in the constellation Sagitta. "Both discoveries are marvelous," says Alan Boss of the Carnegie Institution in Washington, D.C., "but these are really just tantalizing appetizers for things to come."

For example, Boss says, astronomers aren't sure whether the 2-million-year-old dust disk contains enough mass to form large planets like Jupiter. But if it doesn't, others will. "This is just one object—one example," Jayawardhana says. "The ultimate goal is to trace the whole process of planet formation by studying disks at various ages."

As for the brown dwarf, Liu says the low-mass companion could be as close to the central star as the planet Uranus is to the sun. "It's the closest brown dwarf companion found so far," he says, but its true distance from the star is unknown. Future observations will shed light on the brown dwarf's orbit and on the abundance of these objects around sunlike stars.

If adaptive optics can make discoveries like those, a young Jupiter-like planet around a nearby star should be easy to spot, says Jayawardhana, who is carrying out an adaptive optics survey of 150 sunlike stars within a distance of 300 light-years. Jayawardhana says he already has detected "a few candidates"—faint companions to stars whose identities he won't reveal yet—although more observations are needed to confirm that they are real planets and not unrelated background objects. That may take anywhere between 6 and 18 months, he says.

Boss agrees that the first image of a newly forming protoplanet will probably be announced within the next few years, maybe sooner. Such a planet would mark an important step toward showing that "our solar system is not the fluke in the universe," he says. Meanwhile, Jayawardhana and Luhman are planning follow-up observations on their candidate objects. "There's a race going on," Jayawardhana says. "If we don't succeed, someone else will do it."

Black Holes: Mass Matters

For years, astronomers have puzzled over the nature of a class of strange cosmic middleweights: black holes far less massive than the monstrous beasts that lurk in the cores of many galaxies, but apparently much heftier than the run-of-the-mill stellar black hole that remains after a massive star explodes as a supernova. These intermediate-mass black holes have been known only by the x-rays they emit—until now. Astronomers at the University of Michigan, Ann Arbor, have spotted light from stars whirling around them, an important first step toward determining their true character. And other studies suggest that these objects could be surprisingly numerous.

Black holes do not emit radiation, so they can't be seen directly. Instead, astronomers observe the x-rays from hot gas clouds that swirl around the hole before they are sucked into oblivion. Common wisdom among astrophysicists has it that more-massive black holes suck in more gas, so they emit more-powerful x-rays.

If that simple relation holds, the ultraluminous x-ray sources discovered a few years ago in the outer regions of some spiral galaxies must be black holes hundreds or even thousands of times the mass of the sun. No single supernova explosion could ever produce such massive black holes, so astronomers assume that they have grown fat by merging with others (*Science*, 23 April 1999, p. 566; 29 June 2001, p. 2426).

To check this scenario, astronomers need to have an independent—and more accurate—way to determine the mass of the presumed middleweights. Finding the so-called optical counterparts of the x-ray sources is a crucial step toward that goal. By carefully matching observations from NASA's Chandra X-ray Observatory with photos made by the U.S.-European Hubble Space Telescope, Joel Bregman, Jifeng Liu, and Patrick Seitzer identified the faint optical counterparts of a handful of middleweight black holes in the galaxies M81 and M51.

The optical light must come from a normal star that orbits the black hole while slowly but surely being devoured by the hole's strong gravitational pull. Measuring the orbital velocities of these stars, using spectroscopy at large ground-based telescopes such as the Keck telescope in Hawaii, would provide astronomers with a solid mass determination for the black hole. According to Liu, such velocity measurements are already planned.

"Getting velocities would be great," agrees John Tomsick of the University of California, San Diego. "It would be the best evidence" for the high mass of the black hole. But Tomsick points out that the black holes for which the counterparts have been found are not extraordinarily bright in x-rays. As a result, "their masses may be relatively low," he says. "It would be more interesting to find a counterpart to the ultraluminous x-ray source in the galaxy M82," which shines about 1000 times as brightly in x-rays.

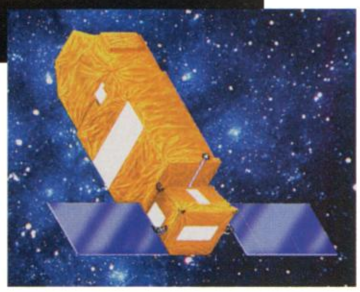
Meanwhile, other researchers are finding that middleweight black holes may be more common than astronomers have believed until now. Theoretical studies by Kayhan Gultekin, Coleman Miller, and Douglas Hamilton of the University of Maryland, College Park, also presented at the AAS meeting, show that such black holes may form through gravitational interactions and mergers of smaller black holes in the cores of globular clusters—great spherical aggregates of old stars that populate the halo of the Milky Way galaxy.

Another possible birthplace is the dense central region of a smaller cluster of newborn stars, according to detailed computer simulations by Steve McMillan of Drexel University in Philadelphia and Simon Portegies Zwart of the University of Amsterdam. "There may be at least 10 intermediate-mass black holes in the Milky Way alone," Gultekin says.

Milky Way Gains a Crown

Using NASA's Far Ultraviolet Spectroscopic Explorer (FUSE), astronomers have discovered that the Milky Way galaxy sits in the middle of a huge bubble of hot gas. Temperatures in this tenuous "corona" are about 1 million degrees, but the average gas density is less than a billionth of a billionth of an atmosphere.

The existence of hot gas around our galaxy was first predicted in 1956 by the late Lyman Spitzer of Princeton University. Spitzer realized that supernova explosions in the Milky Way's disk would energize the interstellar medium, which would then expand into a bloated halo, much as Earth's upper atmosphere expands when it is struck by solar flares. FUSE confirmed Spitzer's general idea a few months after its launch in 1999 by glimpsing the halo. But the extended corona that the satellite has now discovered is much larger than Spitzer imagined and may have been formed by a different mechanism. It may extend as far as the Magellanic Clouds, the closest neighboring galaxies of the Milky Way, says team leader Ken Sembach of the Space Telescope Science Institute in Baltimore.



Fiery gaze. Images from FUSE (*right*) show that the Milky Way is swathed in a previously undetected bubble of hot gas.

Working with Blair Savage, Bart Wakker, Philipp Richter, and Marilyn Meade of the University of Wisconsin, Madison, Sembach mapped the corona by studying clouds of gas that rain down on the Milky Way. Like meteors penetrating Earth's upper atmosphere, their surfaces are heated by friction between the clouds and the corona. By observing these hot cloud boundaries, the team was able to deduce the properties of the corona.

The gas clouds, which consist mainly of neutral hydrogen, are known as high-velocity clouds because they fall toward the Milky Way with speeds of a few hundred kilometers per second. According to Hugo van Woerden of the University of Groningen, the Netherlands, some high-velocity clouds may consist of gas that has been blown out of the plane of the Milky Way in a "galactic fountain" and now falls back. Others may represent genuine infall from intergalactic space—evidence that the Milky Way is still accreting mass.

Oxygen atoms in the outer parts of the high-velocity clouds are heated so much that they lose five of their eight electrons. This ionized oxygen absorbs radiation from more distant objects. Sembach and his colleagues studied the far-ultraviolet radiation of dozens of distant quasars and found the telltale absorption features at velocities that matched those of the high-velocity clouds.

Sembach says that the original, smaller halo and the new, extended corona are probably two different things. "The corona is not produced or maintained by events in the disk of the galaxy," he says. Van Woerden agrees: "Such an extended corona cannot be produced by supernovas. It must be a relic of the formation and the continuous evolution of the Milky Way."

Looking farther from home, a team led by Edward Murphy of the University of Virginia in Charlottesville studied a smaller halo of hot gas above and below the central plane of the galaxy NGC 4631, also known as the Whale galaxy because of its apparent shape. This starburst galaxy, 24.5 million light-years from the Milky Way, produces many supernova explosions and is known to be embedded in a cloud of x-ray–emitting gas. "But the x-rays represent less than 1% of the total supernova energy," Murphy says. FUSE solved the mystery by showing that the gas releases its energy in the far ultraviolet. "We are seeing the gas cooling off" before it falls back into the galaxy, Murphy says.

FUSE has been out of order since 10 December 2001 because of a problem with one of its reaction wheels, which are used to point the telescope. Flight controllers hope to resume science operations within a few weeks, and scientists are keeping their fingers crossed.

–GOVERT SCHILLING

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.