ASTRONOMY

Stars Are Seen Through a Cloud, Darkly, Says New Theory

On the wall of Peter Sorokin's office at IBM's Thomas J. Watson Research Laboratories in New York is a colorful poster depicting one of the greatest enigmas of astronomical spectroscopy. It shows the spectra of a cluster of stars, bright smears of color notched by scores of unexplained dark bands of varying widths. First observed over 75 years ago, these absorption bands appear in the spectra of all bright stars, and astronomers have now identified more than 200 of them. But what causes these diffuse interstellar bands, or DIBs, remains a mystery. Somewhere between the stars and Earth, a substance or substances is absorbing certain wavelengths of light and producing patterns like those on Sorokin's poster. "I've stared at it for the past 2 years," he says. "It's been like a beacon to me."

That beacon has led Sorokin and his IBM colleague James Glownia—both laser spectroscopists—to what they believe is the explanation. "We don't know astronomy and haven't really dealt with astronomers, but we think we're on to the right explanation for these phenomena," Sorokin says. The researchers believe that DIBs are caused by the simplest and most abundant molecule in the universe: molecular hydrogen, or H_2. Sounds easy, but even though they can point to some laboratory evidence as support, their complex scenario for how hydrogen creates the bands has left many astronomers skeptical. "They might get it right eventually," says Theodore Snow, director of the Center for Astrophysics and Space Physics at the University of Colorado, Boulder, "but they don't have it right yet."

Sorokin and Glownia's theory, soon to be published in *Astrophysical Journal*, is the latest in a long line of attempts to account for these puzzling absorption bands. Most astronomers now believe that DIBs occur when starlight passes through clouds of carbon compounds, either chains or ringed structures known as polycyclic aromatic hydrocarbons (PAHs). It was a search for carbon molecules able to explain DIBs, initiated by Harold Kroto of the University of Sussex, that led to the discovery of buckminsterfullerene, for which Kroto shared this year's chemistry Nobel Prize.

Sorokin, however, is sure that neither buckyballs nor PAHs are responsible for DIBs. With more than 200 distinct DIBs identified so far, the theory would require more than 200 different types of carbon molecules distributed uniformly throughout the galaxy. "It's incredible to even consider how these can be synthesized," he says.

Sorokin and Glownia propose instead that the culprits are clouds of molecular hydrogen located a few light-years away from the star. The key to the theory is the way in which the hydrogen absorbs the starlight. Most previous DIB theories were based on simple absorption, in which a passing photon with just the right amount of energy boosts an atom or molecule from its ground state to a higher energy state. Hydrogen molecules soaking up light by simple absorption would not block the right wavelengths to create DIBs. But Sorokin and Glownia's theory relies on a more complex process: simultaneous two-photon absorption.


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Chasing shadows. Peter Sorokin *(left)* and James Glownia in front of a star's spectrum marked by diffuse interstellar bands.

In their picture, a hydrogen cloud creates the bands when it is bathed in both intense ultraviolet light from the star and visible light. By absorbing an ultraviolet photon along with a visible one, a hydrogen molecule can make the jump to a higher energy level. Based on the known energy-level structure of the hydrogen molecule, the IBM scientists calculated that two-photon absorption could produce many sharp absorption bands corresponding very accurately to known DIBs.

The picture gained support after Wim Ubachs of the Free University in Amsterdam read an early version of Sorokin and Glownia's theory in 1995. Ubachs and his colleagues used a "home-built" extreme ultraviolet laser and a visible-light laser to test the theory in the lab. They were able to produce narrow and broad absorption bands that strongly resembled DIBs. At the very least, says the skeptic Snow, this work shows that "Sorokin is basically correct in his molecular physics."

Sorokin does concede a shortcoming of this theory: Although it seems to account for the frequencies of many of the DIBs, in its current form it does not predict their intensity at all well. One of the most intense bands, located at 580 nanometers, should be extremely feeble according to their calculations. "We need something else in our model," Sorokin says. "Something to act as a supercharger."

They have a candidate. Drawing from their background as laser physicists, they suggest that the intense, incoherent ultraviolet light striking the cloud could be absorbed and converted to coherent "Stokes-wave" light by a process known as stimulated Raman scattering. In effect, the cloud becomes a giant laser. The laser light pumps up the effect of the ultraviolet light, making it easier for visible light to take part in two-photon absorption. Using these ideas, the IBM researchers have been able to account for about 70 known DIBs.

But astronomers see other flaws, including Sorokin's assumption that the ultraviolet light needed to drive the process would get into the cloud in the first place. According to astronomers, the ultraviolet photons impinging on the cloud would be blocked by simple absorption and would only penetrate its outer regions. Sorokin responds that, because the hydrogen molecules in the cloud collide very infrequently, the absorption bands for single ultraviolet photons are very narrow, so only those few photons with precisely the right energies will be absorbed. Instead of being absorbed at the surface, most photons will ricochet from molecule to molecule, filling the cloud. "They just flood it," Sorokin says.

But even if the light could penetrate the cloud, astronomers question whether it would be bright enough at distances of several light-years from the illuminating star to drive two-photon absorption, which requires quite intense light. Moreover, according to Alexander Tielens at the NASA Ames Research Center, "we don't really see a correlation between DIBs and the abundance of H_2," which would be expected if the theory were true.

Sorokin and Glownia have been disheartened by the cool reception for their theory. "We're willing to listen and to hear advice, but so far the astronomers have just turned a complete cold shoulder," says Sorokin. There may be some early signs of a warming, however. Snow does admit that the vast number of DIBs suggests that several different mechanisms might be involved, and molecular hydrogen may well be one of them.

–Bruce Schechter

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