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Hint of a burst of supernova activity in a superluminous galaxy

The cosmic zoo holds many strange creatures, but NGC 6240 stands out as a particularly intriguing example. Catalogued as a galaxy, it displays a contorted structure and disturbed dust clouds — features commonly seen when two spiral galaxies are in the process of merging. At the same time, it is about 1,000 times as luminous as the Milky Way. Even more remarkable, much of its light shines in the form of infrared radiation, especially those wavelengths emitted by excited molecules of hydrogen.

Two astrophysicists have now constructed a scenario to account for a key feature of that infrared spectrum. The scenario suggests NGC 6240 may be going through a period of unusually high supernova activity, with as many as three massive stars exploding every year. The supernova rate for the Milky Way is only a couple per century.

The argument, put forward by Bruce T. Draine of Princeton (N.J.) University and D. Tod Woods of the Lawrence Livermore (Calif.) National Laboratory, hinges on the strength of a single spectral line. In 1988, Dan F. Lester and his colleagues at the University of Texas at Austin reported the results of a detailed study of the spectrum of molecular-hydrogen lines emitted by NGC 6240. With the exception of one line that was much weaker than expected, they found that the intensity of the molecular-hydrogen lines fitted a model in which the emissions are caused by heating due to shock waves propagating through the galaxy's dense dust clouds.

"That [weak line] was a notable discrepancy that we didn't seem to be able to account for on the basis of our data," Lester says. "It was very perplexing to find that nine or so molecular-hydrogen emission lines all fit the model perfectly and then to find one that was a factor of 10 fainter than what the model predicted it should be. It was as if one line had been erased from the spectrum."

With that observation as a starting point, Draine and Woods looked for a mechanism that would change just this one line in the molecular-hydrogen spectrum. The line corresponds to a transition from one excited rotational and vibrational energy level of the molecule to a lower energy level. It happens that a molecule can stay in the higher excited state for a long time, which allows the molecule time to absorb, say, ultraviolet radiation to reach an even more excited state. Such a molecule has many paths by which it can release energy, so the intensity of the expected molecular-hydrogen line would be much reduced.

Draine and Woods say transient X-ray sources could provide the radiation necessary to heat and ionize gas, thereby exciting hydrogen atoms, which would then emit the ultraviolet light. One possible X-ray source could be the interaction of ambient dust clouds with material ejected by supernova explosions. A burst of star formation millions of years ago could have produced a large number of massive stars, which are now dying off.

"In order for our mechanism to work, we have to invoke a high supernova rate, even considering the large luminosity of this galaxy," Draine says. "We just calculate the X-ray flux that would emerge from a cooling blast wave, and we look at what that X-ray flux would do to the surrounding material."

"I think it's a really neat idea," Lester says. "Any explanation for what's happening has to be a clever one."

One way to check the scenario is to measure the intensity of additional molecular-hydrogen emission lines, especially those difficult to detect through the Earth's atmosphere. The model suggested by Draine and Woods predicts that other, not-yet-observed emission lines should also be weaker than expected.

— *I. Peterson*

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receptors — is unusually sensitive. After a few weeks of clomipramine treatment, he suggests, the pendulum swings the other way: Relentless stimulation causes serotonin receptors to decrease in number or sensitivity, ultimately damping the serotonin system. Symptoms fade as the effect of oversensitive receptors dwindles, he reasons.

"I don't buy it," declares McGill's de Montigny, who bases his argument mostly on studies of serotonin-reuptake blockers used to treat depression. While de Montigny agrees that receptor sensitivity serves as an important regulator of serotonin action, he says it's hard to imagine that a drug flooding hypersensitive serotonin receptors could cause them to develop below-normal sensitivity or density. If that were true, "our brain would not function very well at all," he contends.

Treating depression is "one of the most striking roles" of serotonin-influencing drugs, says Hopkins' Molliver. He calls fluoxetine, a serotonin-reuptake blocker approved by the FDA last year, "the most dramatically successful antidepressant drug developed in the last decade." Nonetheless, "it's still confusing how [such drugs] work."

Several studies suggest a link between depression and decreased serotonin activity. During 1987 and 1988, for instance, George R. Heninger, Pedro L. Delgado and their colleagues at the Yale University School of Medicine and the Connecticut Mental Health Center in New Haven studied the effects of L-tryptophan, a serotonin precursor, on 21 patients who had recovered from depression — including Ann, the middle-aged widow described earlier. On some days the patients received a placebo drink; on others, they drank a chocolate-flavored concoction of amino acids that deplete L-tryptophan. They showed no significant change in behavior after drinking the placebo, but 60 percent suffered a short-lived relapse of depression after partaking of the amino acid mixture.

In previous, smaller studies, the researchers had observed that the drink elicited only mild responses in healthy people who have no history of depression. Heninger says their more recent results, presented in preliminary form at three scientific conferences last year, will be published early next year.

"We have robust evidence that there is something wrong with the 5-HT system in depressed patients," says de Montigny. If a decrease in serotonin activity can indeed exacerbate depressive tendencies, that might explain why the recovered depressives in Heninger's study suffered a temporary relapse after drinking the fluid.

But work has really just started on what makes the serotonin system tick. At Stanford, Peroutka and his colleagues use a compact disk loaded with data on drug shapes to determine which might bind to the 5-HT_3 receptor. In an analysis of the structure of 40 drugs already known to react with the 5-HT_3 serotonin receptor, the computer calculated the correct reactivity for 38 compounds, he says.

Most tantalizing of all, says Peroutka, is the prospect of constructing hybrid compounds that target many different serotonin receptors simultaneously to elicit multiple desired effects. "Our goal is to combine the effects of different [receptor] subtypes," he says. "For example, some drugs that lower high blood pressure have depression as a major complication. We may be able to construct a hybrid drug that can [help patients] avoid depression *and* reduce high blood pressure."

With such a multipurpose approach, researchers untangling the serotonin system might someday turn its baffling complexity to their own advantage. □