Shadow matter and 'black widow' pulsars

Radio pulses streaming from a source 3,000 light-years away from Earth tell the dramatic story of a rapidly spinning neutron star that seems to be destroying its stellar companion. Designated PSR1957+20, this recently discovered "black widow" pulsar now spins at the dizzying rate of 622 revolutions per second, completing a rotation in 1.6 milliseconds. Only one known pulsar spins faster.

Astrophysicists speculate that when it first formed 100 million years ago, the pulsar spun more slowly and its companion was a normal star much like the sun. As the companion star exhausted its hydrogen fuel, it swelled into a red giant, and gas from its outer layers began to funnel toward the pulsar. The addition of this gaseous material made the pulsar whirl faster and emit increasing amounts of radiation. That radiation is now blasting what's left of the companion star, forcing it to slough off even more of its mass. The radiation is so intense the companion is likely to vanish within the next 100 million years (SN: 7/30/88, p.72).

This scenario and the pulsar's observed characteristics provide a rich ground for theoretical speculation. In the Dec. 8 Nature, David Eichler of Ben-Gurion University in Beer Sheva, Israel, suggests looking in the vicinity of isolated millisecond pulsars for traces of dark matter – invisible material, detectable only through its gravitational influence, that could make up as much as 90 percent of the mass in the universe.

"Some forms of dark matter could collect in stellar cores and settle into a sufficiently compact form that it would survive disruption of the host stars," Eichler says. This "shadow" matter could take the form of quark nuggets that become coupled with ordinary matter, or miniature black holes created by the stellar capture of hypothetical particles known as WIMPs (weakly interacting massive particles).

The PSR1957 scenario indicates that isolated millisecond pulsars probably once had companions. Carefully measuring the spin rates of such pulsars may permit researchers to detect the influence of an exotic companion as small as one-billionth of a solar mass. "If pulsars evaporate their companions, leaving behind exotic matter remnants in places where they can be detected, then a survey of pulsars should be capable of finding the remnants, or of determining that they do not exist," Eichler says.

The characteristics of rapidly spinning neutron stars, composed almost entirely of densely packed neutrons, may also provide useful information about the equation of state for nuclear matter. That equation expresses the relationship between the pressure in a material and its density. Experiments to determine this pressure-density relationship for nuclear matter – and whether neutron stars are "stiff" or "soft" – are practically impossible to perform on Earth.

Noting that the two fastest known pulsars may be spinning near or at their limiting frequencies, John L. Friedman of the University of Wisconsin-Milwaukee and his colleagues suggest, also in the Dec. 8 Nature, that the equation of state for a neutron star must be highly incompressible, or stiff. In other words, if material at the star's equator is rotating near the maximum velocity it can have without flying off, then such a star's nuclear matter would strongly resist compression. This answer has important astrophysical implications because the outcome of supernova explosions – whether the result is a pulsar or a black hole – depends on how nuclear matter responds to gravitationally induced compression.

However, the argument presented by Friedman and his colleagues doesn't settle the question. The discovery of a pulsar with an even shorter period would negate their argument, whereas the discovery of a neutron star more massive than 1.5 times the sun's mass could destroy other arguments in favor of a "soft" equation of state. Nevertheless, says Gerald E. Brown of the State University of New York at Stony Brook, "their conclusion will invigorate the continuing debate on whether nuclear matter is stiff or soft."

– I. Peterson

Ferrets, looking loudly, hear the light

In a series of unusual experiments, scientists have rewired the brains of newborn ferrets so the animals, in a sense, hear things they would normally see. The research provides the strongest confirmation yet for a theory of brain function that deems the visual, auditory and other "higher" parts of the brain as fundamentally alike in computational function – resembling, at least in early stages of development, interchangeable parts.

Moreover, the research supports the notion that these higher, or cortical, parts of the brain "learn" how to perform many of their sensory or motor functions from early cues in the environment. While that theory is not new, the experiments appear to underline the importance of sensory experiences before birth and during infancy in determining an individual's ability to process information later in life.

Mriganka Sur and his co-workers at the Massachusetts Institute of Technology in Cambridge rerouted retinal neurons – which normally send sensory data from the eyes to the visual cortex in the brain – in 16 ferrets so that the data went instead to the animals' auditory cortex. Cortical areas process raw bits of data into more useful "patterns" of information. The researchers studied the response patterns of cells in the auditory cortex while showing the ferrets various visual cues.

"The basic issue is: Does all cortex perform basically the same operation, and do the different outcomes only depend on putting different inputs in?" says Jon Kaas, an experimental psychologist at Vanderbilt University in Nashville, Tenn. "Functionally, each area of the cortex is doing something quite different. But is each area somehow doing the same sort of calculations with whatever input it gets?"

The answer appears to be yes, the MIT researchers report in the Dec. 9 Science. They found that some cells in the auditory cortex "transform" raw data into "oriented rectangular receptor fields" – a type of patterned response to stimuli that has until now been clearly identified only in the visual cortex.

The finding is somewhat surprising, Sur and others say, since auditory information processing – which includes calculations of frequency changes and phase shifts to locate sound in space – seems in some respects quite different from the operations required to sense visual patterns. So while the finding supports the theory that all cortical tissue organizes information similarly, Sur says it also suggests that whatever detailed differences may exist among auditory, visual and other cortical operations are "learned" differences – the result of specific neural wiring patterns somehow programmed by early sensory inputs.

"This means there is nothing intrinsic about the auditory cortex that makes it auditory," Sur says. "It depends on what kind of input it gets" early in life. The finding, he adds, could help explain the enormous capacity of the young brain for recovery of function (SN: 4/30/88, p.280). "So if early in life there are . . . lesions in some part of the brain, other parts of the brain have the capacity to sort of chip in or help in the recovery of function."

Moreover, Kaas says, the research has potential significance for learning theory. "As we understand the role of the environment in the developing nervous system, we'll understand how to modify [prenatal and early childhood experiences] in ways that are desirable, or perhaps more importantly to prevent stimuli that are undesirable." *– R. Weiss*