A celestial supermagnet

A new way to search for stellar magnetism finds a multimillion gauss white dwarf star

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Grw + 70:8247: A white dwarf that fulfills expectations of the theorists.

According to theoretical astronomers, stars begin their existence as diffuse gaseous nebulae. These contract under the mutual gravitational attraction of their parts until they are dense enough and hot enough to begin the thermonuclear reactions that characterize the life of a mature star. After many vicissitudes and billions of years, many stars finish their lives as white dwarfs.

A white dwarf is a faint bluish-white star that occupies a volume the size of the earth but includes matter that would occupy a volume millions of kilometers across in a mature, or, as astronomers say, main-sequence star. Matter in a white dwarf is concentrated to such a density that some theorists suppose atoms in a white dwarf behave more like those of a solid than those of a gas. Along with the matter, any magnetic field that the star possessed would be concentrated and strengthened enormously.

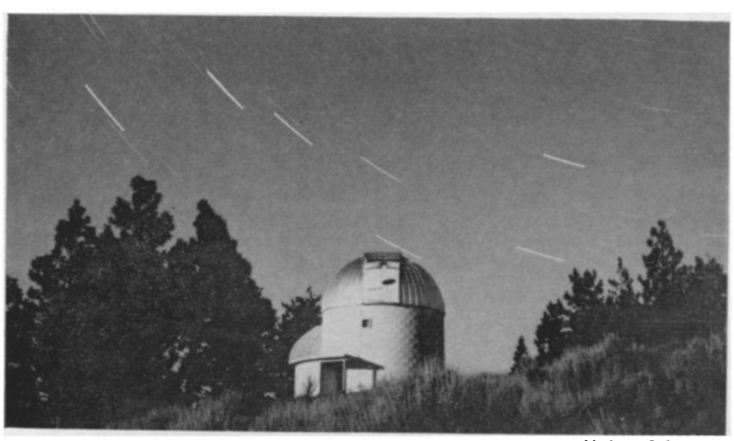
Theory has it that a main-sequence star with a magnetic field of a few gauss strength would evolve into a white dwarf with a field strength in the hundreds of thousands or millions of gauss. (For comparison, the earth's field is about half a gauss; toy magnets run in the hundreds of gauss; the best laboratory magnets generate a few hundred thousand gauss.) Such a magnetic field has now been discovered in a white dwarf designated Grw + 70: 8247. It lies in the northern constellation Draco at right ascension 19 hours 00.6 minutes and declination plus 70 degrees, 34 minutes. Its field is at least 10 million gauss and may be as much as 100 million gauss, by far the largest observed so far in the universe.

The discovery was made by Dr. James C. Kemp and graduate student J. B. Swedlund of the University of Oregon at the university's Pine Mountain Observatory. It was confirmed shortly afterward by Drs. J. R. P. Angel and J. D. Landstreet of Columbia University, who were working at the Kitt Peak National Observatory near Tucson, Ariz.

Magnetic fields in celestial bodies are usually measured by the Zeeman effect, the splitting of single spectral lines into several nearby ones when a magnetic field is imposed on the source of the light. But white dwarf spectra often have no lines, and when they do, the lines are frequently so broad that split lines overlap and the splitting cannot be detected.

To fit this case Dr. Kemp has developed a theory of another magnetic effect on light: circular polarization. In any light beam the waves vibrate in directions perpendicular to the direction the beam is going. Any axis perpendicular to the direction of propagation is possible, and in an ordinary unpolarized beam the direction of vibration changes at random from time to time. In a circularly polarized beam, the changes in the direction of vibration are not arbitrary, but proceed in an orderly rotation around the axis of propagation. Thus a circularly polarized wave twists in corkscrew fashion as it proceeds.

According to Dr. Kemp's theory of what he calls gray-body magnetoemission, if an incandescent body is placed in a magnetic field, the electrons that emit the light will move in little orbits around the field lines. They will impart this motion to the light they emit, and light emitted in the direction of the field will be circularly polarized. Cir-



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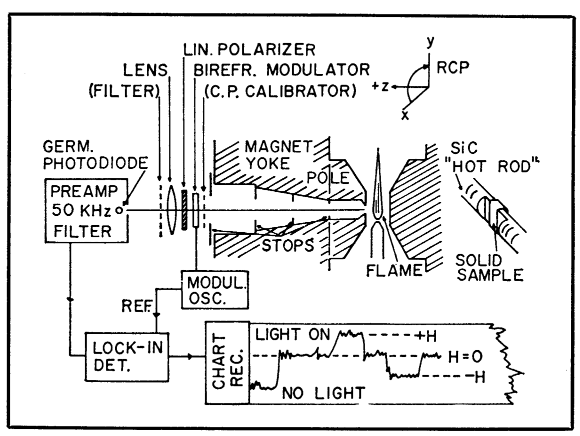
Polarized white dwarf was observed at Pine Mountain.



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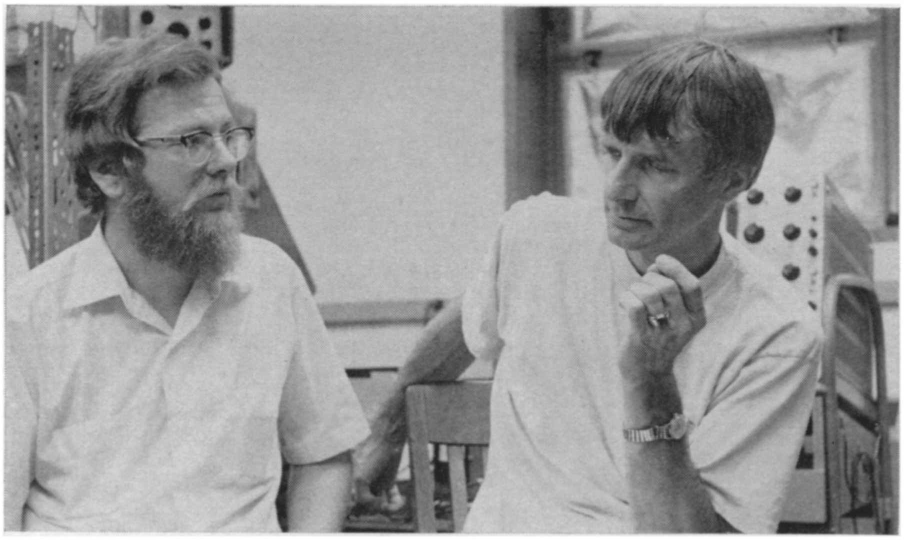
Checking gray-body magnetoemission in the lab.



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Swedlund and Kemp: 10 million, maybe 100 million gauss.

cular polarization comes in two varieties, right or left, depending on whether the direction of vibration sweeps to the left or the right.

If the two kinds of circular polarization are present in equal strength in the light from any source, they will cancel each other and there will be no net polarization. This is very nearly the case for large incandescent bodies, but Dr. Kemp's theory, which has not yet been published in full detail, predicts a very slight predominance of one side over the other and a small net circular polarization in one direction or the other. The percentage of polarization depends on the strength of the magnetic field.

Since the behavior of light emitters in magnetic fields has been studied for more than half a century, Dr. Kemp says he is a little surprised that no one thought of this particular effect before, but apparently no one did.

Before looking in the sky, Dr. Kemp, Swedlund and Bruce D. Evans tested the theory in the laboratory by investigating flames and incandescent solids. They found that the effect did indeed occur and that a field of 20,000 gauss gave a polarization of 0.01 percent.

In the sky Dr. Kemp and Swedlund looked at several white dwarfs and found no polarization. Then they looked at Grw + 70:8247 and got a reading of 1.7 percent circular polarization. This would correspond to a field of between 10 million and 30 million gauss. However, Dr. Kemp thinks the field may be directed obliquely to the line of sight and that therefore the observers are seeing a reduced component of it. "The field is really about a hundred million gauss," he says.

Dr. Kemp telephoned the news of the observation to Drs. Angel and Landstreet, who were at Kitt Peak looking for magnetic white dwarfs by means of the Zeeman effect. They put polarization filters into the 36-inch telescope at Kitt Peak, turned it on Grw + 70:8247 and quickly confirmed the result. They also provided evidence on the way the polarization changes with frequency. This does not happen exactly as Dr. Kemp's theory predicts, but he feels that further theoretical work will do away with the discrepancy.

The most important point about the discovery, says Dr. Kemp, is that it goes to prove that white dwarfs are really very small objects. Magnetic fields have a tendency to expand. Since the field lines are anchored to the atoms that generate them, the expansion, if it happens, will drag the atoms apart from one another.

If a star of the size and density of the sun had a magnetic field as strong as Grw + 70:8247, the expansion of the field would tear it apart. But, says Dr. Kemp, a star of the supposed size and density of a white dwarf would have cohesive forces strong enough to overcome the disruptive tendency of the field.

Even smaller than white dwarfs are the no-longer-so-hypothetical neutron stars. Supposedly the result of explosive compression of ordinary stars, neutron stars are considered to be superdense bodies only a few kilometers in diameter. Most students of pulsars believe that pulsars are neutron stars, though there is no certain proof of it yet.

Pulsar neutron stars should have tremendous magnetic fields. All theoretical attempts to explain the radio emissions of pulsars require them. Estimates go to the billions of gauss and higher. Since there is one pulsar that emits visible light, NP 0532 in the Crab nebula, Dr. Kemp's method gives a way of finding out. "It's on my list of things to do," he says. □