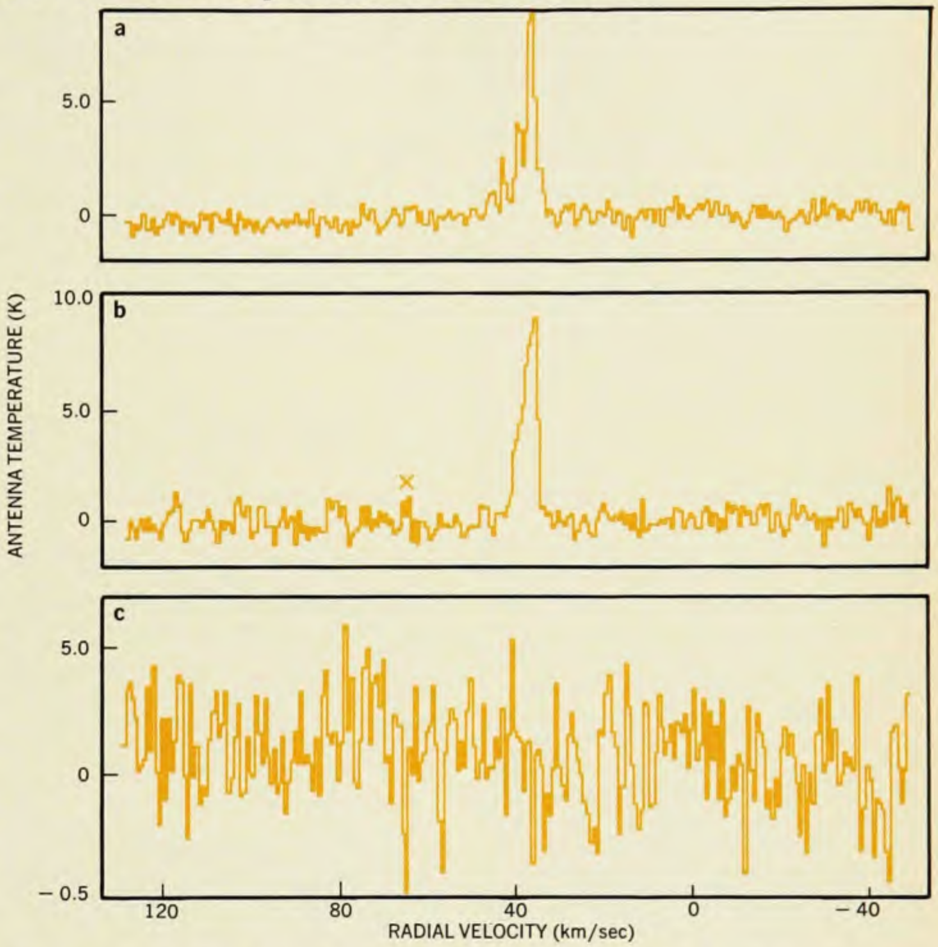
search & discovery

Silicon-monoxide masers show up in infrared stars

Radio telescopes, scanning the heavens at millimeter wavelengths, have detected maser emissions on several lines from vibrationally excited states of silicon monoxide. Until now, the only maser emissions from space have come from OH and H_2O molecules, at centimeter wavelengths. The OH and H_2O masers are located both in infrared stars and interstellar clouds, but the SiO masers have been seen only in the red giant variable stars. It is not surprising to find SiO in these regions, but it is puzzling to speculate about what processes in these stars might have sufficient energy to excite the vibrational states.

Observations. The signals from the SiO maser were first observed last December by Lewis Snyder of the Joint Institute for Laboratory Astrophysics, who was at the time a visiting fellow from the University of Virginia, and David Buhl of the Goddard Space Flight Center (NASA). They were examining a region of the Orion Nebula at a wavelength around 3.48 mm (corresponding to a frequency of 86.2 GHz)[1] with the 36-foot radio telescope of the National Radio Astronomy Observatory. The narrowness of the unidentified lines, their limited spatial extent and their complex structure suggested to Snyder and Buhl that these lines were maser emission. This idea was reinforced by Norio Kaifu of NRAO, who noted similarities with the velocity pat-

continued on page 20



Doppler velocity patterns helped identify new signals as SiO maser emission. Observations on W Hydra (from ref. 5) indicate lines for the rotational transition $J = 1 \rightarrow 0$ in the $v = 2$ and $v = 1$ vibrational states (a,b) but not in the $v = 0$ ground state nor in the $v = 3$ state (not shown).

Helium-three magnetic behavior becomes more complicated

Evidence is mounting that the correct model of solid helium-three cannot be the simple one that long seemed adequate. The He^3 nucleus, consisting of two protons and one neutron, is a fermion of spin ½. Because of the large probability of individual He^3 atoms exchanging places, the solid acts as a kind of atomic magnet. Until only a few years ago theorists were able to treat solid He^3 in terms of an extremely simple magnetic model—a Heisenberg Hamiltonian that included only interactions between nearest-neighbor atoms, neglecting higher-order interactions and coupling with phonons—and no experimental data contradicted them. In 1971, however, some studies of magnetic pressure versus temperature at high magnetic fields[1] could not be fitted into the theory, and efforts were made to revise the theory by adding higher-order interactions.[2] And now, two groups of experiments, one at Cornell University (William Halperin, Charles Archie, Finn Rasmussen, Robert Buhrman and Robert Richardson)[3] and the other at the University of California, La Jolla (Jeffrey Dundon and John Goodkind)[4] indicate that the magnetic behavior of solid He^3 is much more complicated than the He^3 theorists had presumed. The Cornell adiabatic-solidification studies suggest that the magnetic ordering transition in the solid occurs at about half the predicted temperature and that it is a much sharper transition than expected. The La Jolla group sees unexpected structure in the variation of heat capacity with temperature and also infers that the transition temperature T_s is below the predicted value.

Halperin and his colleagues measured the latent heat of solidification of He^3 at a point on its melting curve and found a sharp decrease in the magnetic entropy of the solid (from 0.5 R log 2 to 0.1 R log 2 within 1×10^{-4} K, where R is the gas constant) as it is cooled through a transition temperature of 1.17 mK. Dundon and Goodkind, measuring the specific heat of solid He^3 between 1 mK and 25 mK, found a variety of unexpected changes in heat capacity experiment could be wrong only if a series of unlucky coincidences had occurred. He commented that the evidence could be strengthened by studies with an O^{16} beam. Ghiorso himself was very confident of his group's results; he felt that production of element 106 was proved better than any other element in history. —BGL

References

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Silicon-monoxide maser

continued from page 17

tern from 18-cm OH masers. With the aid of Frank Lovas and Donald Johnson of the National Bureau of Standards, they tentatively identified the complex spectrum as the Doppler velocity shifting of the rotational $J = 2 \rightarrow 1$ transition of the first vibrational state ($v = 1$) of the SiO.

Subsequently, several sets of observations confirmed this analysis. The first was made by John Davis, Guy Blair and Howard Van Till of the University of Texas and Patrick Thaddeus of the Goddard Institute for Space Studies, who used the 16-foot antenna of the Millimeter Wave Observatory at the University of Texas. They detected a line in Orion near 129.3 GHz that could be the $J = 3 \rightarrow 2$, $v = 1$ transition in SiO.[2] Next, Thaddeus, John Mather (Goddard Institute for Space Studies), Davis and Blair used the same telescope to find lines at 43.1 GHz that would correspond to the $v = 1$, $J = 1 \rightarrow 0$ transition. These lines were sighted in both Orion and in the M-type star W Hya.[3]

In a survey of maser emission from the $v = 1$, $J = 2 \rightarrow 1$ transition of SiO, Kaifu, Buhl and Snyder of NRAO found that the only sources outside Orion were a number of late M-type variable stars, many of which have both OH and H_2O emission.[4] Buhl, Snyder, Lovas and Johnson have since observed the $v = 2$, $J = 1 \rightarrow 0$ transition and have failed to find the $J = 1 \rightarrow 0$ transition of either the third vibrational state or the ground state[5] (see figure). The missing lines place constraints on any models of pumping mechanisms.

Buhl and Snyder point out that the pumping of the observed maser lines requires excitation temperatures as high as 3520 K (for the second vibrational state). Red giants possess the required energy but interstellar clouds do not, in agreement with the observations. The problem is to explain how this tremendous amount of energy is transferred to the SiO molecules. Possible mechanisms have been proposed by theorists such as Charles Townes and Thomas R. Geballe of the University of California at Berkeley,[6] John Kwan (Institute for Advanced Studies) and Nicholas Scoville (Cal Tech)[7] and Mather and Marvin Litvak (Harvard) who described their model at the American Astronomical Society meeting at the University of Rochester in August. However, most agree that it is too early to comment on these models.

Thaddeus felt that the models of the SiO maser may prove to be more tractable than those of either the OH or H_2O masers; SiO has neither the chemical interactions of the OH molecule (because of its closed shell) nor the complicated rotational structure of the H_2O molecule. Townes further commented that we know the location of the SiO molecules better than we do that of OH or H_2O.

Applications. The new maser emissions may teach us something about the infrared stars from which they come. Buhl explained that the velocity spectra contain information about processes in the circumstellar envelope; the large Doppler shifts observed in all maser radiation indicate the very turbulent motion that occurs both as matter rushes outward in the death of a star and as it rushes inward in the formation of a star. Thaddeus pointed out that because the SiO maser is a point source it can reveal something about the small regions of space, especially when combined with optical observations of the same star. Further, each of the several observed transitions in SiO is an independent channel of information.

The maser lines may have some very important practical applications as well. Because they are point sources, the SiO masers can be used to test the millimeter-wave interferometers now being developed. Townes said that, in turn, these interferometers may better resolve the location of the maser sources and may possibly indicate how large the infrared stars are. Because the maser lines from the first vibrational state are so strong, Snyder feels they can be used to detect new infrared stars. Finally, the SiO masers can serve as point sources for the calibration of millimeter-wave telescopes, and Buhl and Snyder have already devised such a calibration technique for the NRAO dish.

Many astrophysicists are very excited at this first maser in the millimeter region and look forward to perhaps more maser discoveries at still shorter wavelengths. —BGL

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Bevalac makes a successful debut

On 1 August, physicists at the Lawrence Berkeley Laboratory successfully accelerated carbon-12 ions in the Bevalac. This new heavy-ion accelerator is a hybrid of existing accelerators; the SuperHILAC serves as the injector and the Bevatron provides the final acceleration (see PHYSICS TODAY, June, page 20). On the initial run, the carbon ions achieved an energy of 2.1 GeV per nucleon. Before the Bevalac, the most powerful heavy-ion accelerator was one in Canberra, Australia, with an energy of 20 MeV/nucleon.

Now in routine operation for nuclear physics and biomedical research, the Bevalac has accelerated neon as well as carbon, with intensities of 5×10^8 and 4×10^9 particles/pulse respectively, and, most recently, argon (2 GeV/nucleon). The Berkeley group will have to improve the vacuum system before still heavier ions can be accelerated.

Construction of the Bevalac began some eighteen months ago under the direction of Hermann Grunder. Albert Ghiorso, also of LBL, originally conceived the idea of pairing the two accelerators. Future plans include a time-sharing system, to be completed next spring, that will enable the SuperHILAC to be time-shared between the Bevalac and its own experimental program.

Stellarator moves from Culham to Wisconsin

The small stellarator, Proto-Cleo, which has been in use at Culham Laboratory (UK) for five years, has been moved to the University of Wisconsin, Madison. J. L. Shohet heads the NSF-sponsored move. Believed the largest fusion experiment to be transported, Proto-Cleo is the first complete fusion-experiment system to cross the Atlantic. Initial operation of the system in its new home is expected later this year.

With the coming of Proto-Cleo, the US will once again have a stellarator facility in operation. The large stellarator, Model C, was modified into the ST Tokamak at Princeton in 1969. □