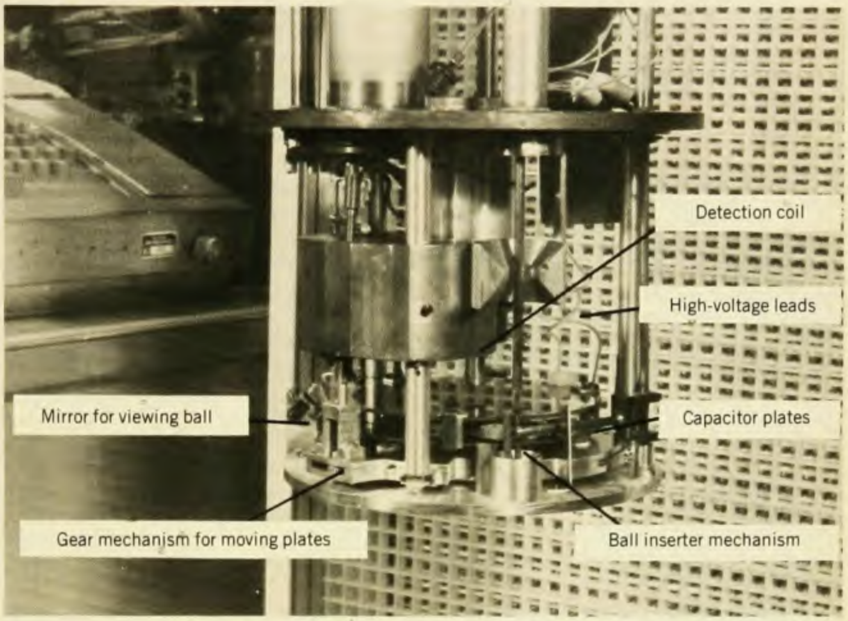
search & discovery

Stanford group shows apparent evidence for quarks

After twelve years of effort, William Fairbank and his collaborators believe they have found evidence for fractional charge on two levitated niobium balls. His collaborators are George LaRue, who is writing his PhD thesis at Stanford University on the Millikan oil-drop type experiment, and Arthur Hebard (now at Bell Labs), who also wrote a PhD thesis on the Stanford experiment. They reported their results in a postdeadline paper given before a packed room at the Washington meeting of The American Physical Society. The announcement caused great interest and excitement. Many are adopting a "wait and see" attitude, but it is clear that the Stanford experimenters have given a great deal of attention to eliminating sources of error.

After Murray Gell-Mann and George Zweig (both of Caltech) independently proposed the existence of quarks in 1964, a wide variety of searches were conducted for fractionally charged particles using accelerators, in cosmic rays and in stable matter. Convincing evidence for the observation of quarks was not forthcoming. Meanwhile, over the past few years, many theorists argued that quarks must inevitably be confined. There are strong phenomenological indications that there is a force between a quark inside a particle and the remaining quarks, which remains constant as the quark is withdrawn. This would mean that an arbitrarily large amount of energy would be needed to remove one quark from a particle.



Measuring region of apparatus used to search for fractional charge. The superconducting niobium ball is floated on the magnetic field. An alternating square-wave voltage is applied at the natural resonant frequency, and the Stanford group observes the change in amplitude as the ball is driven.

Within the framework of quantum chromodynamics, it has not been possible so far to deduce that quarks must be absolutely confined, although this belief is commonly held. At the same APS meeting, Stanley Mandelstam (University of California at Berkeley) presented a sketch proof of confinement in quantum chromodynamics. The bag model actually assumes that quarks and colored gluon fields have to be confined in a region of space. Another model, proposed by M.

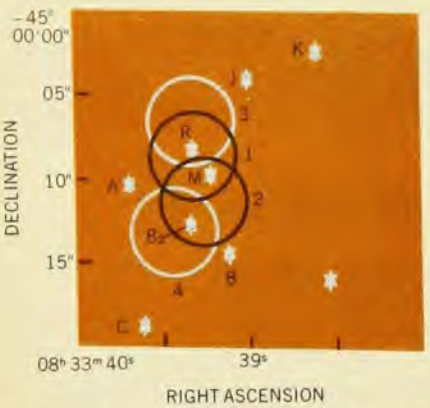
continued on page 19

Anglo–Australian team observes Vela pulsar optically

Astronomers at the Anglo–Australian Telescope have observed flashing optical light from the Vela pulsar, PSR 0833-45. They detected very faint double pulses, with the same period as the radio pulsar, in measurements with the new 3.9-meter telescope near Coonabarabran, Australia. With an apparent time-averaged magnitude of about 25.2, the pulsar is the faintest object ever detected photoelectrically. (The only other pulsar yet detected optically, the Crab, has a magnitude of 17.0.) Among the many faint stars known to be within the region of the pulsar, the observers at the AAT have tentatively identified one as the most likely candidate to be PSR 0833-45. The participants in the measurements were Pat Wallace, Bruce Peterson, Paul Murdin, John Danziger (all from the Anglo–Australian Observatory, Epping, New South Wales), Richard Manchester, Andrew Lyne, Miller Goss (all from CSIRO Division of Radiophysics, Epping), Graham Smith, Mike Disney, Kent Hartley, Derek Jones and Gordon Wellgate (all from the Royal Greenwich Observatory, UK).[1] This group was the first to use a recently completed determination of the pulsar radio position.[2]

The optical observations were done during the three nights January 24–27. The telescope was used at the $f/15$ focus, and the photometer had twin apertures, each 5.0 arc sec in diameter. Each hour or so, the telescope was moved, so that the candidate position was alternated between the two apertures, minimizing the possibility of mistaking spurious electronic timing signals for pulsar signals. As a control, the observers also looked at the Crab pulsar each night. The light intensity was recorded on magnetic tape and synchronously integrated on line at the apparent pulsar period during the observations. The period data used to average the optical pulses were obtained from concurrent radio pulse timing observations at the NASA Deep Space Station, Tidbinbilla.

During the past few years, several other groups have been looking for optical signals from the Vela pulsar. Because the pulsar is at declination 45 deg, it cannot



Stars in the neighborhood of the Vela pulsar. The radio position established by Miller Goss et al. (ref. 2) is labelled "R"; the other lettered positions follow Barry Lasker's scheme (ref. 3). Astronomers at the Anglo-Australian Telescope detected optical pulses within the areas shown as circles 1 and 2, but not in circles 3 and 4. This figure, adapted from reference 1, retains the shear distortion introduced by the TV monitor.

be observed for more than a short time from the major northern-hemisphere observatories. Photographs taken two years ago at the Cerro Tololo Interamerican Observatory in Chile showed several "candidate" stars close to the radio position.[3] None of these stars appeared to be emitting pulsed optical radiation.

The optical observations with the AAT allow the possibility that one of the stars photographed by Barry Lasker and his colleagues at Cerro Tololo (Lasker's "star M") may be the Vela pulsar, and the AAT group now locates M at the coordinates $\alpha = 08^h\,33^m\,39.22 \pm 0.03^s$; $\delta = -45°00'10.1 \pm 0.3''$ (1950). Observations went on for a total of about ten hours, at four positions. At only two of these positions—one centered at the new radio position and the other, about 3 arc sec away, near star M—were optical pulses detected, and these pulses were slightly more intense at the position with M closer to the center of the aperture.

For the Vela pulsar, pulsation has now been observed at optical, gamma-ray and radio frequencies. The optical and gamma-ray pulses are both double; that is, two of these pulses occur for each radiofrequency pulse. These radio pulses occur every 89 millisec, the third shortest period known for any pulsar. The optical components are separated by 22 ± 2 millisec (with the second pulse somewhat stronger) and the first of these appears 20 $\pm$ 2 millisec after the radiopulse. The optical peaks are centered symmetrically between the two gamma-ray peaks, which are themselves 35 millisec apart in time; that is, although the pulses do not themselves coincide, their midpoints do.

Now that more than one pulsar has been optically identified, what can we expect from the theorists? Which pulsar model will be buttressed by the new data, and which will have to be revised? A closer examination of the relative radio and optical intensities, pulse phases in the various wavelengths, and so on should yield good new checks on different theoretical models for neutron-star magnetospheres. —MSR

References

1. P. T. Wallace, B. A. Peterson, P. G. Murdin, I. J. Danziger, R. N. Manchester, A. G. Lyne, W. M. Goss, F. G. Smith, M. J. Disney, K. F. Hartley, D. H. P. Jones, G. W. Wellgate, Nature **266**, 692 (1977).
2. W. M. Goss, R. N. Manchester, W. B. McAdam, R. H. Frater, Mon. Not. R. Astr. Soc. (to be published).
3. B. M. Lasker, Astrophys. J. **203**, 193 (1976).

High-conductivity graphite compounds

The measurement of high electrical conductivity in a synthetic metal at room temperature was one of many observations discussed at the Conference on Intercalated Compounds of Graphite held in La Napoule, France last month. Although these compounds have been studied—largely by chemists—for some 40 years, physicists have recently taken a renewed interest in them because they offer the potential for technological applications as well as the opportunity to explore electronic and other properties of materials of variable dimensionality.

A striking property of graphite intercalation compounds is their greatly enhanced basal-plane conductivity compared to that of the original graphite. This property was first studied starting in the early 1960's by A. R. Ubbelohde and his colleagues at Imperial College, London[1] and by Gerhard Hennig at Argonne National Laboratory,[1] but only recently have conductivities of practical significance been reported.

A team from the University of Pennsylvania consisting of Geoffrey M. T. Foley, Claude Zeller, E. Robert Falardeau and F. Lincoln Vogel announced at the March APS meeting in San Diego that they had measured a conductivity $6.3 \times 10^5\ (\text{ohm cm})^{-1}$ comparable to a value of $6.29 \times 10^5\ (\text{ohm cm})^{-1}$ for silver.[2] The measurements were made on near-single-crystal samples of graphite intercalated with arsenic pentafluoride, a compound first reported by a group at the Hebrew University of Jerusalem.[3] The conductivity was measured by a contactless rf induction technique. The conductivity from optical reflectance data on the same compounds, which was consistent with the direct measurements of conductivity, were presented at the same meeting by Lawrence Hanlon and John E. Fischer, also of Pennsylvania.

Even larger conductivities had been reported a year earlier by the Penn group at the March APS meeting in Atlanta but results had been received with some skepticism. There, Vogel reported experiments made on composite wires that consisted of a powdered graphite core intercalated with antimony pentafluoride encased in a thin copper sheath.[4] Doubts were raised over the poorly characterized composition of the core and over the interpretation of the data. This earlier experiment used a dc four-point resistance method to determine the conductivity. Subsequent bridge measurements on the same intercalate—antimony pentafluoride—but diffused into a different form of graphite—highly oriented pyrolytic graphite rather than the drawn wire—have found conductivities only about one third that of copper.[5,6] However, the Penn group feels that the anisotropy in the resistivity is so high that the bridge method is inappropriate for measuring the conductivity of these compounds. Jimy Gan and Vogel reported in La Napoule the results of more recent experiments, which they feel substantiate the existence of high conductivity in graphite intercalated with antimony pentafluoride.

Industry may well be interested in a high-conductivity substitute for copper, especially one that might be lighter, cheaper and more free of resource constraints. Graphite compounds might potentially offer some of these advantages, but many problems remain to be solved before they can be considered for use in commercial electrical wiring. The compounds must be well encapsulated to prevent exposure of the superacid intercalants, which are corrosive and unstable in air. They must have high tensile strength and must be designed to form good electrical and mechanical connections. Clearly it is premature to judge either their technological potential or their economic viability.

While industry ponders the application of intercalated graphite compounds, scientists may ponder the cause of their high conductivity. Intercalation of graphite, the diffusion of atomic and molecular species into the interstices of the lamellar host, results in compounds that have widely varying properties. The approximately 60 species known to intercalate can be divided into two general groups, those that act as electron donors (for example, alkali metals) and those acting as acceptors (halogens, acids, etc.). A long and widely held hypothesis is that the enhanced conductivity results from an increase in free carrier density, which accompanies a transfer of charge between the donor or acceptor intercalate layer and the graphite. The high conductivity can be achieved with lower carrier concentrations than those for normal metals