densities of about 5×10^{13} particles/cm^3. (Tokomak T-3, Artsimovich reported, has 5×10^{13} particles/cm^3 at 0.5 keV.) If the device worked, it could be just a step away from a full-scale pilot model of a fusion reactor. The T-3 is a large toroid with 25-cm minor radius and 100-cm major radius. Magnetic field is about 25 kG.

Princeton plans to modify its Model-C stellarator to resemble the T-3. By ripping most of the straight sections out of the Model-C racetrack, they will be left with a toroid having a 15-cm minor radius and a 1-meter major radius. Maximal toroidal field will be 50 kG. Melvin Gottlieb told us that the Tokomak modification will employ mostly existing components, although it will require a new vacuum system and some more coils. Cost should be around \$200 000, he said.

Oak Ridge has built a small Tokomak model with 5-cm minor radius and 35-cm major radius. Herman Postma says that they would like to build a bigger version with the same parameters as the Tokomak TM-3: 12-cm minor radius, 40-cm major radius, maximal field of 50 kG. Later, by replacing a shell, they could make a version of T-3 size but with a smaller aspect ratio. These models would use an existing building and motor-generator sets; total hardware cost would be \$400 000.

At MIT a new type of device called TokaMIT has been designed. Bruno Coppi told us that the device combines a relatively large aspect ratio with high (150-kG) field while maintaining the simplest configuration. The device opens a new range of plasma parameters, which can test existing scaling laws and exhibit new physical effects, he said. Cost will be about \$200 000.

The University of Texas is planning a device slightly larger than the T-3, which will have separate control of turbulent heating and confinement currents (unlike the Kurchatov devices, which use the same current for heating and confinement), according to William Drummond.

At Gulf General Atomic, Tihiro Ohkawa proposed (just before Artsimovich's visit) building a larger version of his recently tested Doublet; it is a current-carrying multipole that requires no floating ring. The new machine would have plasma characteristics similar to T-3 but with a smaller magnetic field. Like a Tokomak, the Doublet uses plasma current for heating. At the same time these currents produce quadrupole-like fields, which have greater stability. Hence, Ohkawa says, larger energy densities can be contained than in the conventional Tokomak.

Amasa Bishop, who heads the AEC controlled thermonuclear research program, told us that proposals for all five facilities have been submitted and were scheduled for review by the CTR standing committee at the end of June. Bishop said that under present budget restrictions it would be very difficult to initiate a strong Tokomak effort in the US in fiscal 1970. Because of recent CTR progress, however, he feels there is still hope for financial relief.

Theorists Offer Explanation For Pulsar Speeding Up

Why did the 89-millisec period of the Vela pulsar, PSR 0833-45, abruptly decrease by 208 nanosec (sometime between 24 February and 3 March)? Theorists have risen to the challenge of explaining the observation made by Philip Reichley and George Downs (Jet Propulsion Laboratory) and independently by V. Radhakrishnan and R. N. Manchester (CSIRO).

At the Washington American Physical Society Meeting A. G. W. Cameron (Yeshiva University) described a hypothesis originated by George Greenstein (Yeshiva) and himself. Like most astrophysicists, they consider that pulsars are rotating, highly magnetized neutron stars, and that the slowing down of the frequency of pulses (already detected for eleven pulsars, including PSR-0833-45, for which $dP/dt = 4000$ nanosec/year) is due to torques applied to the surface through the external magnetic field.

Cameron and Greenstein envision a nonrigid neutron star, whose surface has been braked to a much slower spin rate than that of its core, somewhat analogous to Robert Dicke's solar model, in which the core of the sun rotates about thirty times faster than the photosphere.

In the neutron-star interior, instabilities lead to the displacement of fluid elements; when displacements of sufficient amplitude are attained, weak interactions alter the composition of the gas. The net effect is to reduce suddenly the radial composition gradients of neutrons, protons and other particles. Peter Goldreich (Cal Tech) and Gerald Schubert (UCLA) (*Astrophys. J.* **150,** 571, 1967) have shown that when the angular momentum per unit mass decreases with increasing stellar radius, concentration gradients are required to stabilize the gas against convective mixing. Cameron and Greenstein believe that the sudden adjustment in concentration gradients inside the neutron star leads to such mixing, which transfers angular momentum outwards; so the neutron-star (pulsar?) surface speeds up.

The next day, Kip Thorne (Cal Tech) described a different explanation, due to Malvin Ruderman (New York University), for the abrupt period change of PSR 0833-45. Speaking at the Symposium on Pulsars of the National Academy of Sciences, he reviewed Ruderman's suggestion last year (*Nature* **218,** 1128, 1968) that when the temperature of the outer layers of a neutron star is less than 10^8 K, those regions may become crystallized, and the surface may show deviations from smooth topography, perhaps with "mountains" several meters tall. On the other hand, the interior should still be highly nonviscous, and perhaps may even be a superfluid. So one could imagine discontinuous changes in the stellar structure that would be adequate to explain the speeding up. In fact, the adjustment in moment of inertia necessary to explain the measured period change of PSR 0833-45 is equivalent to a compression of only one centimeter in the radius of the neutron star (a mini-starquake).

X Rays from Crab Have Period of Radio Signals

The Crab Nebula is emitting x rays that pulse with the same frequency as the radio signals from the pulsar NP 0532, according to recent observations by several groups. Earlier, NP 0532 had been found to pulse optically with the same frequency as the radio signals (PHYSICS TODAY, March, page 60).

Gilbert Fritz, Richard Henry, John Meekins, Talbot Chubb and Herbert Friedman of the Naval Research Laboratory reported (*Science*, 9 May, page 709) that the pulsed radiation is about 5% of the total x-ray power being emitted by the nebula (in the energy range 0.8–4 keV).

In 1964 the NRL group had observed a lunar occultation of the Crab x-ray emission. Because the flux dropped off gradually during the covering of the nebula, the group believed that the x-ray emission was neb-

X-Ray Emission from Crab Nebula			
Group	*Energy range (keV)*	*% of source luminosity*	*Date of observation*
NRL	0.8–4	5	13 Mar. 1969
Columbia	5–20	6.5 ± 5	7 Mar. 1969
Rice	>30	7 ± 2	4 June 1967
MIT	1.5–10	9	27 Apr. 1969
Goddard	2–10	15 ± 3	16 Mar. 1968

ular rather than stellar. Their result cast doubt for a while that the Crab contained a neutron star. However, the NRL group notes in their latest report, their earlier observation could not have detected a 5% stellar contribution.

The new NRL experiment also showed that NP 0532 was emitting two pulses, a main one and an interpulse occurring 12 millisec later, similar to the behavior already found both in the optical and radio regions.

Meanwhile a Columbia group (Roger Angel, Robert Novick, Paul van den Bout, Martin Weisskopf and Richard Wolff) was analyzing Crab x-ray data from a flight launched six days earlier than the NRL rocket. The Columbia group was searching for x-ray polarization from the nebula. The Crab is known to emit strongly polarized radiation in the visible and radio regions; if x-ray polarization were found, too, it would be strong evidence that the Crab x-ray emission results from synchrotron radiation. When the Columbia experimenters heard of the NRL result, they examined their data for pulsing and found (International Astronomical Union circular no. 2142) pulsing with a peak value $(6.5 \pm 2.7)\%$ of the average source luminosity. Further analysis suggests a value of $(6.5 \pm 5)\%$.

A group at Rice University (Robert Haymes, G. J. Fishman and F. R. Harnden Jr), analyzing balloon-flight data from 4 June 1967, also confirmed the pulsing (circular no. 2143). Comparing the 1967 x-ray period with 1969 optical data, the Rice group calculated linear slowdown rate over a 575-day interval as 36.51 ± 0.02 nanosec/day.

A collaboration (Hale Bradt, Saul Rappaport and W. Mayer of MIT, Ed Nather, Brian Warner and Malcolm MacFarlane of McDonald Observatory, Texas, and Jerome Kristian of Mt Palomar) looked at the pulsar with a rocket-launched x-ray detector, the 200-inch Palomar telescope and the 36-inch McDonald telescope (*Nature*, 24 May). They confirmed the earlier observations and demonstrated that the pulsar blinks at both x-ray and optical wavelengths simultaneously, within 1 millisec.

Analyzing 1968 rocket data, a team from Goddard Space Flight Center (Elihu Boldt, Upendra Desai, Stephen Holt, Peter Serlemitsos and Robert Silverberg) confirmed pulsing. Their luminosity value is substantially higher than the other observations.

Crystal Acts Like a Two-Dimensional Antiferromagnet

A single crystal of K_2NiF_4 acts like a two-dimensional antiferromagnet above a critical temperature $T_n = 97.1$ K, according to a recent experiment at Brookhaven. At the critical temperature the crystal undergoes an extremely sharp phase transition to long-range order in three dimensions. Then below that temperature the magnetization varies as $(T - T_n)^\beta$ where $\beta = 0.15$, again suggesting that the magnetic behavior is two dimensional.

Robert Birgeneau (Bell Labs and Brookhaven), Howard Guggenheim (Bell) and Gen Shirane (Brookhaven) reported their results in *Phys. Rev. Letters* **22**, 720 (1969). The group believes that theirs is the first observation of two-dimensional scattering in a magnetic system.

The experimenters expected that K_2NiF_4 would show such behavior, Birgeneau told us, because its structure favors strong interactions within crystal planes and no interactions between nearest-neighbor planes. Nearest-neighbor nickel ions that are within the plane possess molecular orbitals that point directly at each other, thus producing a huge exchange interaction. Also, the crystal was known to be antiferromagnetic, its spins lining up antiparallel.

To do the experiment, the group bombarded the single crystal with monochromatic neutrons from the Brookhaven High-Flux Reactor, and they observed scattering as a function of angle as the temperature was lowered. As the temperature neared the critical point, the spins in a given plane lined up head to tail over very long crystalline distance: Spins were almost perfectly correlated over lengths up to 500 nanometers. These enormous spin globules showed no awareness of the spins in another plane until the critical point was reached.

The data show that within the plane in two dimensions, you have normal critical scattering peaks. On the other hand, if you scan through the crystal planes, the scattering cross section is essentially independent of momentum in the direction perpendicular to the plane. So you observe, instead, a "critical ridge."

As the critical point is approached, the correlation length grows, Birgeneau said. Once the crystal has nearly perfect long-range order, with globules containing more than a million spins, the net coupling between the crystal planes apparently commences to matter. Just at the critical point, when the system is about to become completely ordered, it simultaneously orders in three dimensions.

Below the critical point, the K_2NiF_4 system again acts two dimensionally. Many critical-point experiments on three-dimensional systems have shown magnetization to vary as $(T - T_c)^\beta$ with $\beta = 0.33$ to 0.4. In 1944 Lars Onsager, using the two-dimensional Ising model, had predicted $\beta = 1/8$. The Brookhaven result is $\beta = 0.15$, which is about 1/7. This equation fits the data over the complete temperature range the group studied, from 97.0 to 5.0 K. —GBL

Berkeley Group Reports Discovery of Element 104

A Berkeley group says it has positively identified two isotopes of element 104, $_{104}X^{257}$ and $_{104}X^{259}$. Speaking at the American Chemical Society's Mendeleev Centennial Symposium, Albert Ghiorso said that they also think they have found $_{104}X^{258}$, but are not yet sure. The group was unable to observe $_{104}X^{260}$, which Georgi N. Flerov and his collaborators at the Joint Institute for Nuclear Research, Dubna had reported in 1964 (and named kurchatovium).

In the Berkeley experiments, $_{98}Cf^{249}$ was bombarded with carbon ions from the HILAC device. The experimenters, to identify isotopes 257 and 259, first directly observed their alpha decay to nobelium, measuring the alpha-decay energy. Then they measured the de-