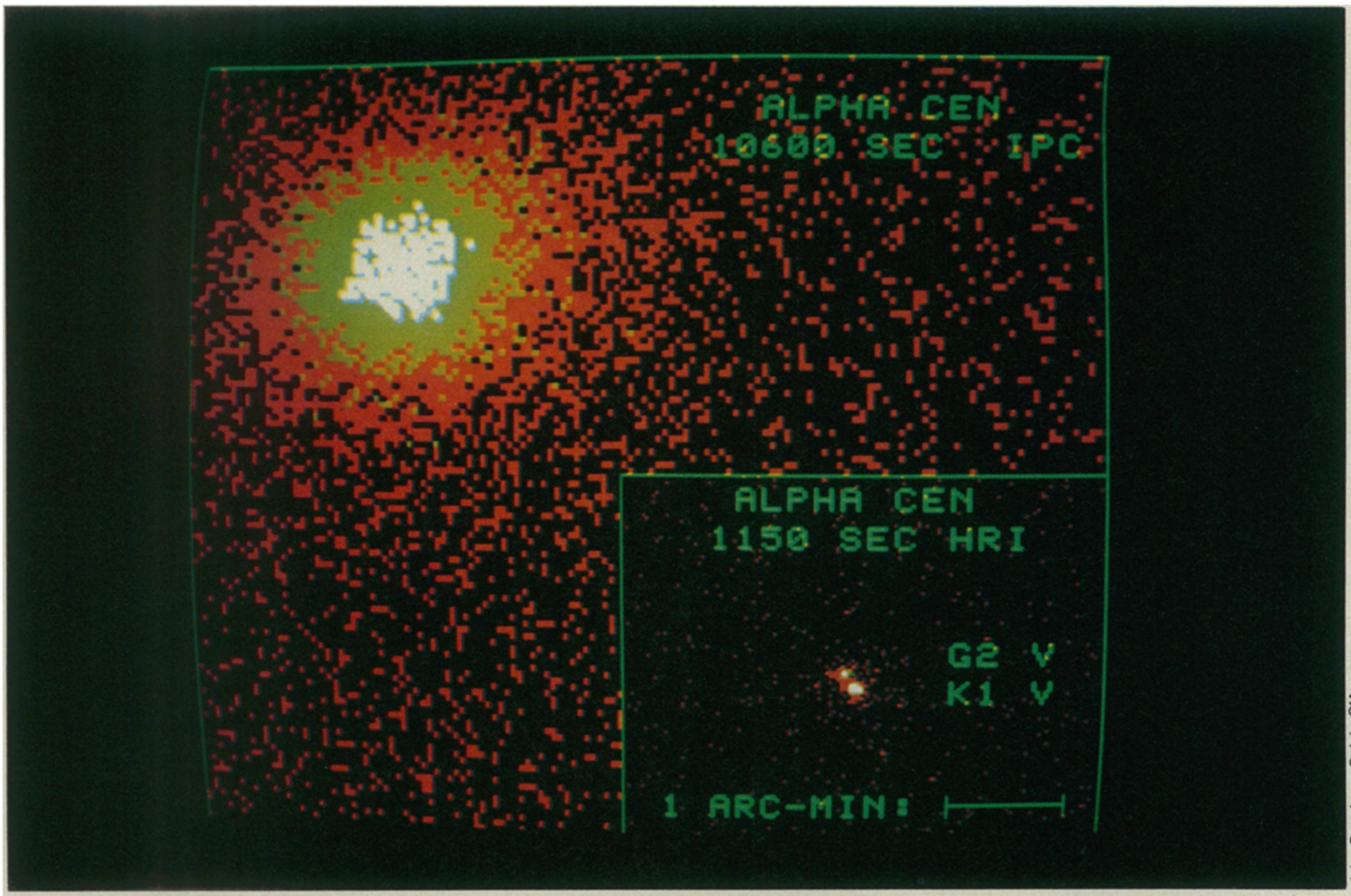
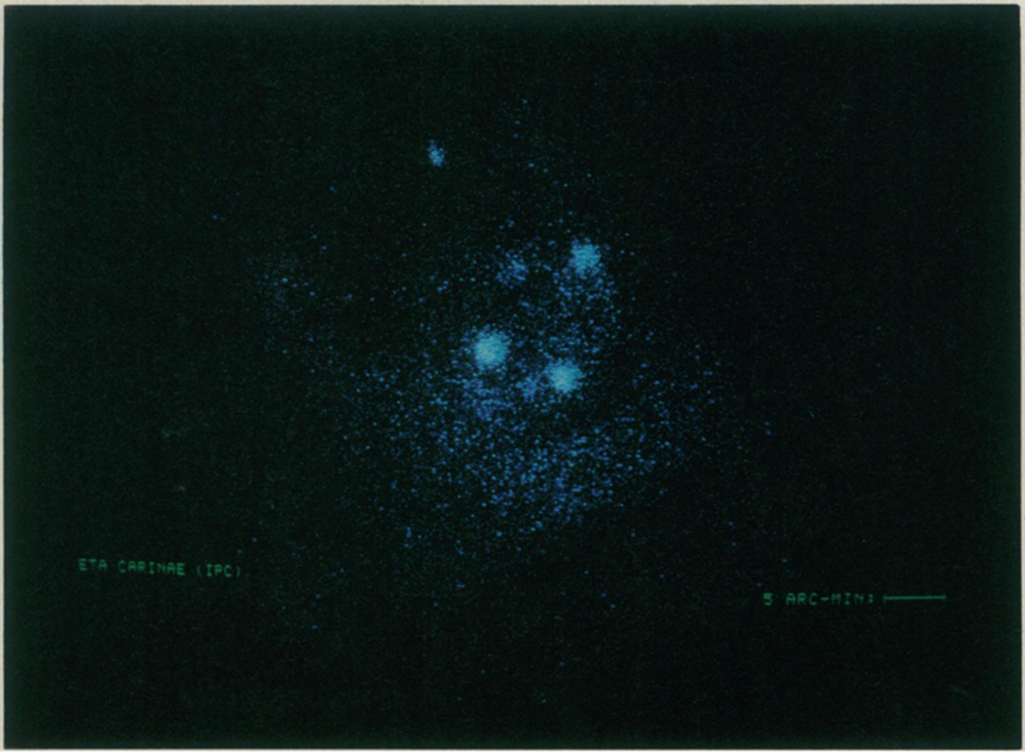
X-RAYS OF THE STARS



alpha Cen: Leon Golub. CfA

X-ray stars are depicted in false color diagrams, in which color relates to X-ray brightness. The Hyades, on the cover, are fairly early spectral types. The three components of alpha Centauri (two are resolved in the inset) are fairly late types (above). Odd stars emit X-rays, too, such as the erratic variable eta Carinae (below).



eta Carinae: Smithsonian Institution

They show outsides rather than insides, but they are welcome sources of new data

BY DIETRICK E. THOMSEN

To the human eye the most numerous objects in the sky are stars. A radio antenna sees a much different sky. Many point sources of radio waves can be identified with visible objects, but those objects are mostly outside our galaxy: They are other galaxies or quasars. The visible radio sources in our galaxy are nearly all exotic or unique objects of some kind. Ordinary stars nearly all do not show up on radio maps.

When it became possible to observe the X-rays emitted by celestial objects, astronomers pretty generally expected that a similar situation would obtain: X-ray astronomy would probably discover some classes of objects previously unknown. Quasars and galaxies would probably show up in X-rays and maybe some of the exotic nonstellar objects in our galaxy. But ordinary stars wouldn't show in any numbers. Those who are interested in stars would still be restricted to the visible range of the electromagnetic spectrum as they have been since the days of the ziggurats and the temples of Osiris.

As it turned out, that last expectation was quite mistaken, though all the previous ones were correct. The sky survey done by the Einstein Observatory, the X-ray-observing satellite, that completed its flight a short time ago (SN: 2/7/81, p. 88), shows stars in abundance, stars of all kinds, all ages, all spectral classes. At the recent meeting of the American Astronomical Society in Albuquerque, those who heard G.S. Vaiana of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. (and the Osservatorio Astrofisico di Palermo in Italy), give a brief review of Einstein's stellar results seemed quite pleased. One astronomer pointed out that this is a kind of new moment in astronomy because for the first time stellar astronomers have a new range of the spectrum to work in and a way of getting new kinds of information about the stars.

The general results and conclusions will also appear in a paper in THE ASTROPHYSICAL JOURNAL over the names of R. Pallavicini, L. Golub, R. Rosner, and Vaiana of the Center for Astrophysics, T. Ayres of the Laboratory for Atmospheric and Space Physics and J.L. Linsky of the Joint Institute for Laboratory Astrophysics in Boulder, Colo. As Vaiana mentioned in his talk and as is also stated in the paper, in addition to the Center for Astrophysics survey and the work of Ayres and Linsky as guest observers, work of the Columbia University survey (principally K.S. Long and R.L. White), the Stanford University-Jet Propulsion Laboratory Survey, and of J.P. Cassinelli of the University of Wisconsin Washburn Observatory and other guest observers contributed to the conclusions drawn.

There were physical reasons for expecting that stars would not show up in X-ray sky surveys. Observable X-rays from the stars have to come from coronas, extremely hot, tenuous clouds of ionized gas (plasma) that constitute the outermost layer of the star where they exist. Coronas are at a temperature where X-rays can be generated, and X-rays leaving them are unlikely to be reabsorbed on the way. If X-rays are made deep inside stars, they are most likely to be absorbed and reprocessed on the way out. The sun has a corona, but in that it was thought to be unusual. Only a few older, quieter stars should have coronas, it was thought. These might even be too faint in their X-ray production to be seen from earth.

It seems that those thoughts were mistaken. Einstein with its systematic surveys has made a diametric change in X-ray astronomy, says Vaiana. X-ray astronomy, he continues, is no longer the domain of galaxies, no longer the domain of exotic and unusual objects. It now deals with all classes of objects studied by optical astronomy.

Einstein found, Vaiana says, a "ubiquity of stellar X-ray emission." It could do this because it was a satellite and had time to spend a few thousand seconds looking in each direction chosen for it. In time spans like that the stellar images built up. The stars it found come from all over the Herzsprung-Russell diagram. (The H-R diagram is a graph of stars, placed according to their luminosity and spectral class. Astronomers use it to orient themselves regarding a star's astrophysical capabilities and possibilities.) Vaiana says the X-ray stars "come from the entire main sequence [of the H-R diagram], much of the giant branch up to [spectral class] K2 and the supergiant branch to spectral type

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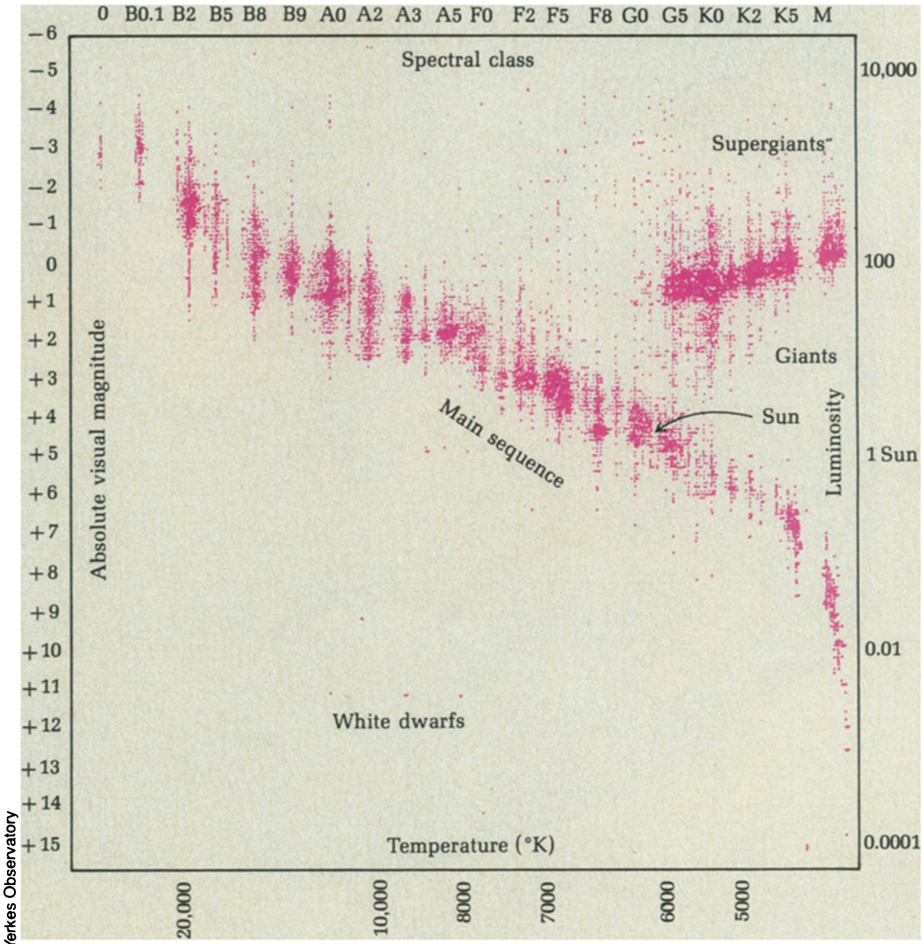


Yerkes Observatory

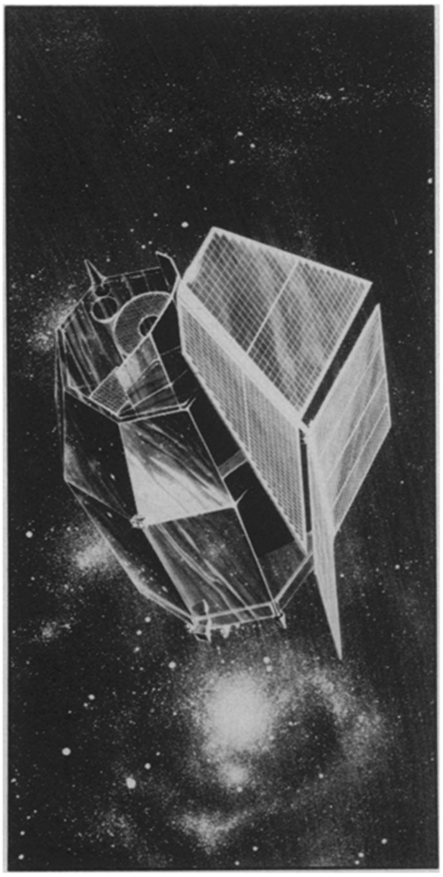
Herzsprung-Russell diagram.

... X-ray stars

F8." Thus there are both early and late type stars.

Vaiana gave a kind of astronomer's tour of the X-ray star population, starting with a classic example of young stars, the Hyades cluster. Thirty stars in that cluster were observed. Some of them have X-ray luminosities 100 times the sun's. "If one goes to stars yet younger, one sees still more vigorous X-ray emitters," Vaiana relates. These appear for example, in the Orion nebula, in the OB2 association in Cygnus, with X-ray luminosities up to 100,000 times the sun's. The general conclusion from these observations is that early type stars are vigorous X-ray sources and that their X-ray luminosity is related to their optical luminosity.

At the other end of the H-R diagram, Canopus is one of the later supergiants observed with an X-ray luminosity 1,000 times the sun's. Alpha Orionis and alpha Scorpii are two red supergiants with an order of magnitude less X-ray luminosity than Canopus. Going down to the main sequence, the Center for Astrophysics group has detected single spectral class A stars at solar luminosity such as Sirius A, Sirius B, Vega and Altair. M stars have been detected from solar luminosity to 1,000 times solar luminosity. M's are variable stars, and different ones have been seen in the inflating state or the deflating state.


NASA

Einstein Observatory satellite.

The data seem to show that for early type stars from spectral classes O to A X-ray luminosity is dominated by a monotonic decrease from O to A. For later type stars, classes G to M, there is a wide range of X-ray luminosities for each spectral type. Late type stars have X-ray luminosities that are correlated to their rotation rates. Spectral class F seems to be a transition group.

According to Vaiana, the general conclusion is that "there must be hot plasma throughout the H-R diagram," not only on a few older, quieter type stars. Youngness in a star is associated with strong X-ray emission. The emission could be due to a relation connecting hot plasma, magnetic dynamos and surface turbulence. For the late type stars a model is suggested in which the whole surface of the star is covered by magnetic activity (instead of small portions as on the sun), and the star's rotation causes this to become a large dynamo, heating the corona. But the paper to be published warns that there is not enough energy present in a star's rotation to provide the observed X-ray luminosity even if totally converted. Some other energy source must be cooperating.

Thus, observation will go on. The field is certainly open to astronomers who can get their instruments aboard a satellite. Pressure is likely to be felt for more X-ray satellites. Will that pressure succeed? □