

First photograph of the exploding galaxy M 82, taken in 1962.

A COSMIC SYNCHROTRON

*New photographs of an exploding galaxy
reveal that the object is a celestial particle accelerator.*

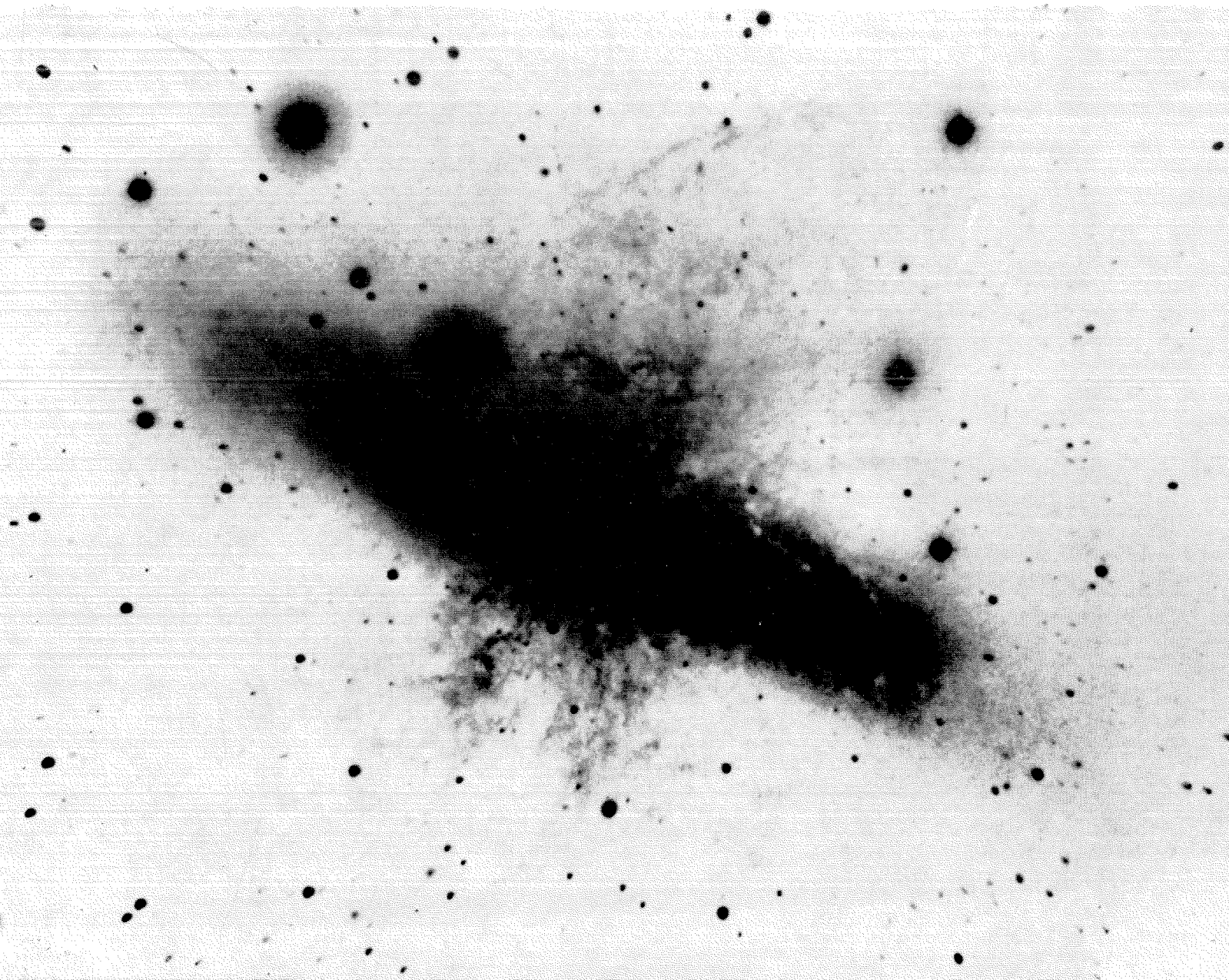
A magnetic field like that which surrounds the earth is most easily thought of in terms of magnetic lines of force affecting a moving charged body. Such fields are caused by large electric currents — but how these currents are generated and transmitted in the stars or in space has yet to be determined.

Now, one of the most direct proofs that magnetic fields exist in distant galaxies has been found by Allan Sandage, staff member of the Mount Wilson and Palomar Observatories. Recent photographs of an exploding galaxy have revealed the presence of high energy electrons in the outer filaments streaming from the galaxy's nucleus. This

evidence may provide clues to the origin of cosmic rays, and may even reveal how nature accelerates them to such enormous energies.

The object known as M 82 was photographed for the first time as an exploding galaxy in 1962 by the 200-inch telescope at Palomar Observatory. (*E&S*, October 1963). The galaxy is comparatively nearby (only 60 billion billion miles or 10 million light years away). The photographs revealed that tremendous jets of matter, stretching out 60 billion million miles (10,000 light years), streamed out from the galaxy's nucleus.

Spectral work on the galaxy, done at Lick Observatory by Dr. C. R. Lynds of the Kitt Peak



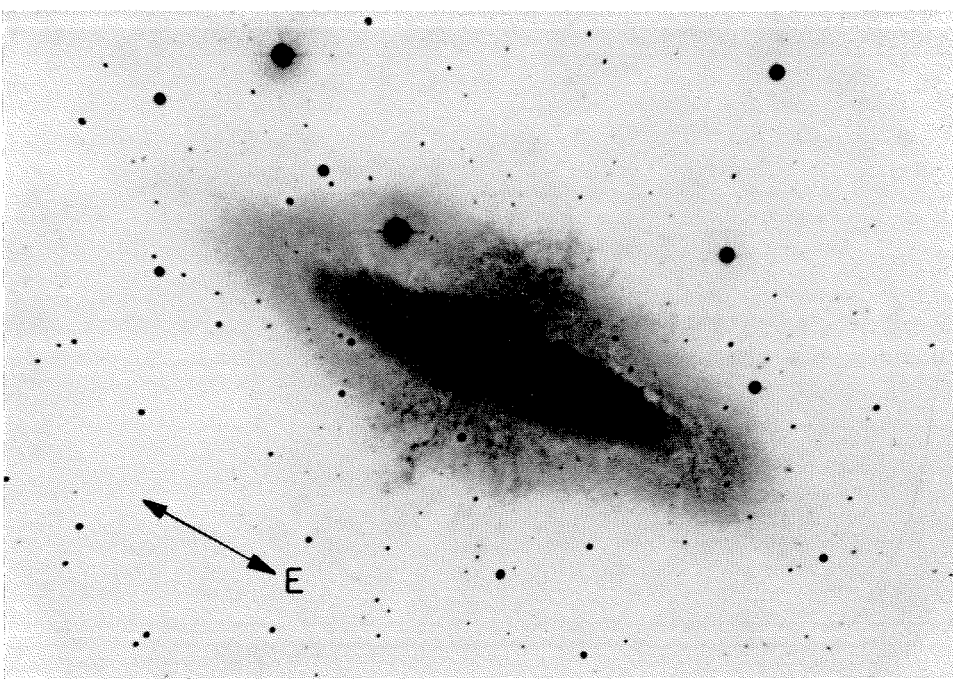
The exploding galaxy M 82, photographed in February 1964. In this picture, taken in blue light, the filaments extend much farther beyond the galaxy than the bright hydrogen filaments shown in the original photograph. This second set of filaments radiates in continuous light, indicating the presence of high energy electrons.

National Observatory, revealed the presence of a vast system of hydrogen filaments of several million solar masses, expanding outward from the galaxy at speeds up to 20,000,000 miles an hour. The evidence suggested that an explosion had taken place in the center of this galaxy about a million and a half years ago (as seen from the earth).

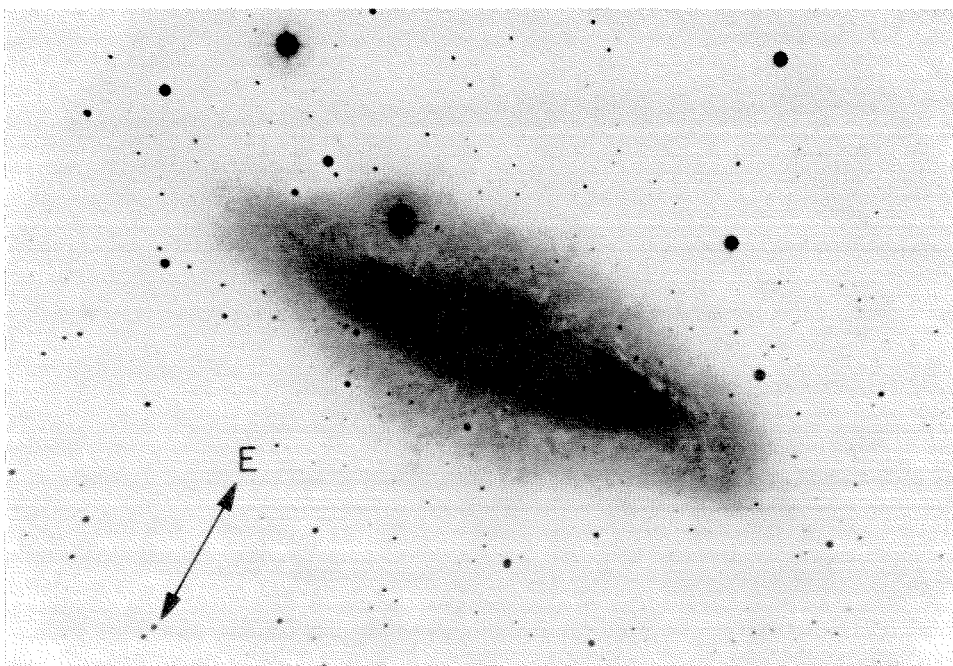
One of the important problems raised by the original photograph of M 82 was the source of the energy required to ionize the hydrogen that is combining and recombining in the galaxy. The astronomers found partial evidence that optical synchrotron radiation caused by ultra-high energy electrons might be present. The electrons are accel-

erated to such high energies that they radiate radio noise and visible light.

In February 1964 Dr. Sandage obtained new photographs of M 82 with the 200-inch telescope, and William C. Miller, staff photographer of the Mt. Wilson and Palomar Observatories, used a special technique of reproduction to bring out faint details. These pictures revealed a second set of filaments streaming out beyond the first set, but radiating light in a continuous spectrum. The astronomers are convinced that these filaments are due to acceleration radiation which is produced by the same mechanism which causes electrons to radiate in a particle accelerator.



The second set of filaments in M 82 is clearly revealed when the polaroid sheet in the plate holder on the telescope is aligned parallel to the major axis of the galaxy, as indicated by the arrow E.



When a photograph is taken with the electric vector of the polaroid sheet perpendicular to the major axis of the galaxy, the filaments almost completely disappear, proving the existence of synchrotron radiation.

This type of radiation has the unique property of being almost 100 percent linearly polarized; that is, the light is vibrating in a single plane.

To test this requirement, photographs were made on the filaments in M 82. The upper picture on this page shows that the filaments shine brightly when the electric vector of the polaroid sheet in the plate holder of the telescope is aligned parallel to the major axis of the galaxy. The lower photo is from a second series of photographs taken with the electric vector perpendicular to the major axis. Here, the filaments almost completely disappear. This discovery suggests that a remarkably regular magnetic field exists in M 82 at large distances

(13,000 light years) above and below the fundamental plane seen in the original photograph of the galaxy taken in 1962. Calculations show that these electrons must have very high energies — nearly 500 times that of the electrons produced in the Caltech synchrotron.

Although more research is needed to define the exact configuration of the magnetic field, these new results appear to prove the existence of magnetic fields and also to indicate the presence of high energy electrons in radio galaxies. Thus the information learned from M 82 could very well be a part of the pattern of research revealing clues to the origin of cosmic rays.

A CLOSER
LOOK AT AN
EXPLODING
GALAXY

An enlargement of a portion of the photograph on page 9 shows the intricate loop structure and fine detail of the filaments in blue light.

An enlargement of a portion of the upper photograph on page 10, taken with the electric vector of the polaroid sheet aligned parallel to the major axis of the galaxy, shows the brightly shimmering filaments.

The filaments are almost completely gone in this enlargement of a portion of the lower photograph on page 10, taken when the electric vector of the polaroid sheet is aligned perpendicularly to the major axis of the galaxy.

