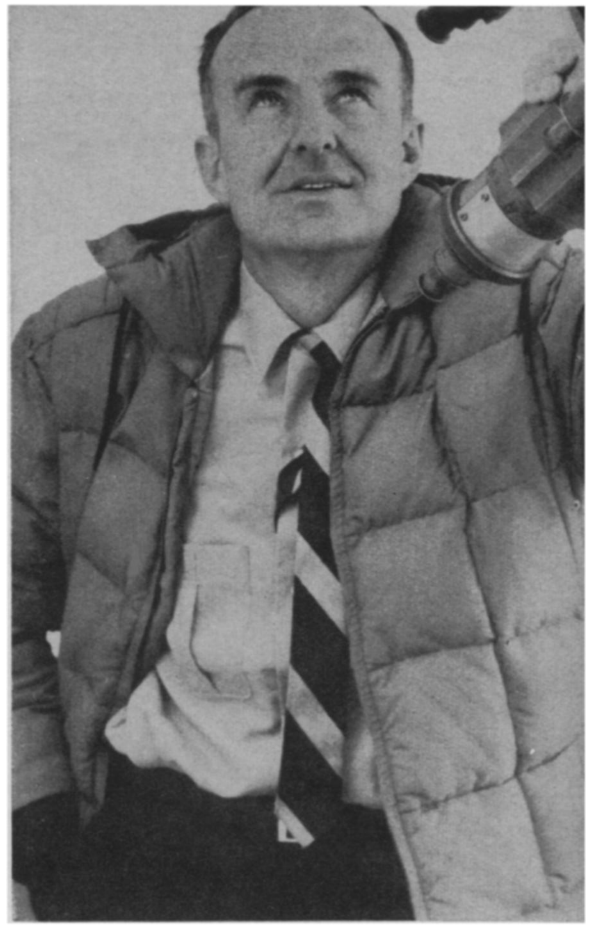
COSMOLOGY



Big bang down under

At least one astronomer hopes to settle the question of how the universe began by making systematic observations of the southern sky

by Lennard Bickel

Sandage: 1969 will be a big year.

A major proponent of one of the two opposed current theories of cosmology, Dr. Allan Sandage of Mt. Wilson and Palomar Observatories, has gone to Australia for a year of observational work at Mt. Stromlo Observatory. While he is there he hopes, by observing objects that cannot be seen from the north, to adduce overwhelming evidence in favor of his side of the arguments over the so-called big bang theory.

Even if he gains the evidence he seeks, he may not succeed in silencing proponents of the opposite theory, the steady-state cosmology. But he will make their job harder.

Both theories are attempts to deal with the observed fact that the universe is expanding.

The big bang proposes that as the universe expands, the fixed amount of matter and energy in it spreads out thinner and thinner over more space. If one looks back in time, the theory holds, the universe was ever smaller and denser back to a point of minimum size when it was so dense and hot that it exploded. That explosion—the big bang—is held to account for all the subsequent, observed outward motion.

The steady state theory proposes that the universe does not get less dense as it expands; the density of matter and energy remains constant, it argues. To make this happen, there has to be a continuous creation of matter and energy, not out of each other as is known to happen all the time, but out of nothing.

This idea is shocking to many. But some scientists are willing to accept it (SN: 6/15, p. 575) because the steady state theory preserves many of the attractive features of models in which the universe as a whole sits still, models which were current before the late Dr. Edwin Hubble and others discovered and confirmed the expansion.

What Hubble actually found was that light from all the distant galaxies was strongly shifted in wavelength toward the red. He identified this with the so-called Doppler shift, a well-known optical effect by which a light source moving away from the observer appears with its wavelengths shifted to the red. He thus concluded that all external galaxies were moving away from ours.

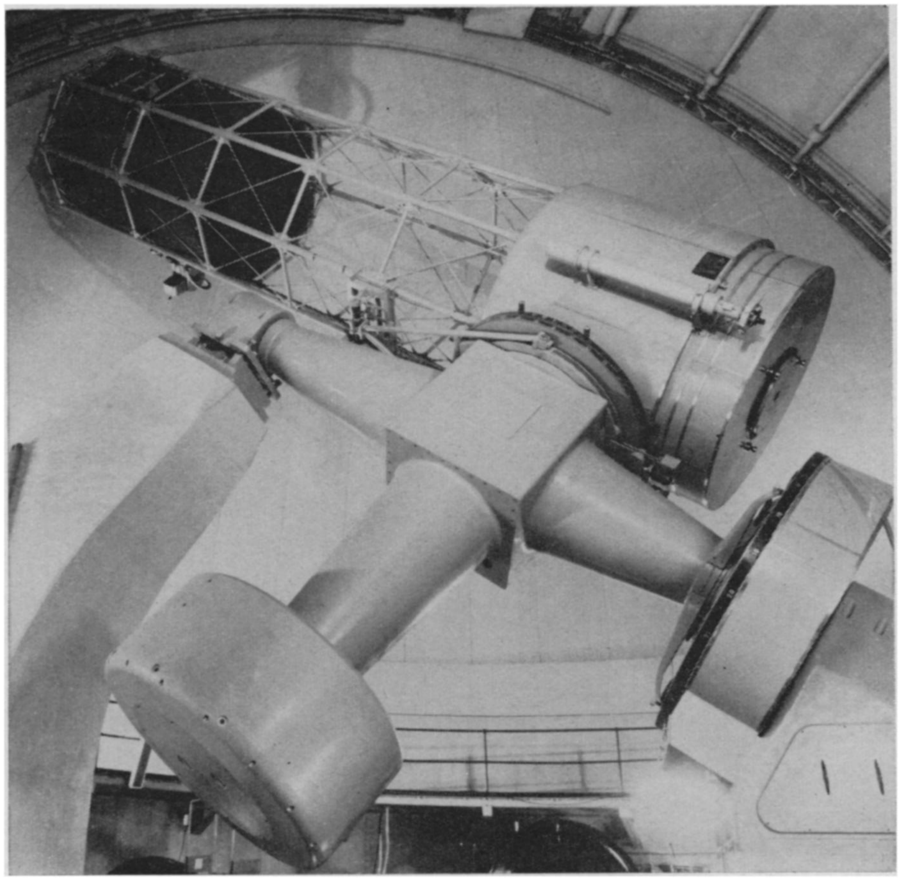
Geometrically the only way this universal recession could appear would be if the whole universe were expanding like a balloon. The situation further requires that the more distant a galaxy is, the faster it should appear to be moving away. Hubble proposed that the velocity or red shift is directly proportional to the distance to a galaxy. The amount by which the distance must be multiplied to get the velocity is called the Hubble constant.

But it has not been easy to evaluate that constant because distances to the galaxies are not easy to determine.

In some cases, especially the nearer galaxies, distances can be determined by observation of Cepheid variable stars, so-called because the first of their number was found in the constellation Cepheus.

The brightness of the Cepheids fluctuates in precise cycles that last several days. Studies of Cepheids within our galaxy have determined that the length of the cycle is related to the intrinsic brightness of the star. Seeing a Cepheid of a certain period in a distant galaxy, an observer knows its intrinsic brightness. Comparing this to its apparent brightness viewed from the earth, he can calculate the distance, since the amount of dimming then depends principally on how far away it is.

But for a long time the Cepheids in the galaxies were wrongly identified. There are actually two classes of Cepheids, and the same fluctuation period can belong to two quite different intrinsic brightnesses, depending on class. The estimated galactic distances are now 10 times what Hubble proposed; a precise value of the Hubble constant is far from being determined. Some observers wonder whether the constant is indeed constant; they suggest it may be a variable factor and that the relation between velocity of galaxies and their distance may be more



Mt. Stromlo's 74-inch telescope is being used to study distant galaxies.

complicated than a simple proportion.

One of the things Dr. Sandage hopes to accomplish in Australia is a better determination of the Hubble constant, by observing southern sky objects invisible from California where he usually works.

This work is "clobbered in the north," he says, by too much perturbation as a consequence of galactic motions that are not connected with the Hubble hypothesis. In the south he finds not only the nearest external galaxies, the Magellanic Clouds, but a stepwise outward progression of 30 to 40 galaxies so untroubled by perturbation that he says they look like pure Hubble flow.

"The south is nirvana for astronomy," he says, "virgin rich territory. The clouds are the touchstones. Nearer by a factor of 10 over any others, they turn a 74-inch telescope into a 740-inch monster."

Calculations from Cepheid variables are now down to accuracy limits of 10 percent, and Dr. Sandage sees little further possibility of improving that level of precision. But he feels he can make a similar use of the oldest and brightest red stars in the galaxies as distance indicators. These appear at about tenth apparent magnitude in the Magellanic Clouds, and with big telescopes they can be seen out to twenty-third apparent magnitude in galaxies that have big enough red shifts so that their evidence on the Hubble problem is not spoiled by random motion.

Work with these may give a sharper edge to the Hubble constant, which Dr. Sandage now suspects lies between 75 and 50 kilometers per second velocity per megaparsec of distance. (One megaparsec is about 3.3 million light years.)

The upper limit yields a time of 13 billion years since the big bang; the lower gives 19 billion years. Crucial to the settlement of the problem of the difference is the determination of whether the universal expansion is slowing down or not, as well as of the rate of any deceleration.

Dr. Sandage believes in a pulsating universe. For him the gravitational forces among the parts of the universe are slowing, and will eventually stop, the expansion. Then the universe will begin to collapse until it again reaches an explosive concentration, at which time the cycle starts over again.

One such cycle, in his view, covers about 80 billion years. Thus he finds us now about a quarter of the way on the outward stroke with about 30 billion years to go before the collapsing phase starts.

The deceleration rate, Dr. Sandage suspects, together with an estimated universal mass density of 10^{-29} grams per cubic centimeter (about one gram in 100,000 billion cubic kilometers) and

Prof. Olin Eggen directs Mt. Stromlo.

considerations from Einstein's general relativity theory, also leads to a time of about 13 billion years since the last cataclysm.

Independent evidence for the big bang theory comes also from the cosmic blackbody radiation (SN: 6/15, p. 575), which gives a time span of the same order of magnitude.

(Most recently, however, infrared observations (SN: 11/30, p. 543) have raised questions about the correctness of interpreting the universal background radiation as a blackbody.)

In addition, Dr. Sandage finds agreement with his 13 billion years in the ages of the oldest stars and the relative abundance of the chemical elements.

While these agreements do not prove the steady state theory wrong, they do remove many of the time disagreements that led to its invention.

Dr. Sandage expects that 1969 will provide the answer to the Hubble problem and that the following years of Australian work will fix an acceptable date for the big bang.

"That doesn't mean we can ever close the books finally. On an absolutely detailed level we are not sophisticated enough to say what happened in that primordial event—any more than looking back over the last 30 years we can project the discoveries we'll make by A.D. 2000, although I'm sure they'll be the greatest yet."