Institute in Pasadena to set up an experiment called OGLE, for Optical Gravitational Lens Experiment. The experiment uses a 1-meter telescope at the Las Campanas observatory in Chile, hooked up to a CCD camera also provided by Carnegie. The experiment, like the MACHO project, will eventually scan the halo for MACHOs. But as a first step, the researchers plan to test whether microlensing can be detected at all, by searching for the lensing effect of known objects.

Paczynski, who describes himself as OGLE's fundraiser and coordinator, says OGLE is scanning the galactic bulge, close to the center of the galaxy, in search of a class of stars called M-dwarves, which constitute the most numerous stars in the galaxy, although they can only be detected visually if they are within a few light-years of Earth. M-dwarves should "mass-produce microlensing events," says Paczynski. "Nothing hypothetical about it." Until OGLE detects these events, the researchers will not have enough confidence in their analysis programs to go after more hypothetical beasts like MACHOs. "We believe we have to experimentally verify our mission, which is experimentally unprecedented," says Paczynski.

Finally, the French researchers from the Saclay Institute, led by Michelle Spiro and Rich, have also begun taking data using both photographic plates and a CCD camera on a telescope in Chile. Their approach is two-pronged: One is to photograph a large chunk of the Large Magellanic Cloud every night, looking for month-long microlensing events; the other is to take only a few tens of thousands of stars and image them every 10 minutes with the CCD camera, looking for shorter-term events.

Whether or not these experiments will bring home MACHOs may be known relatively soon. Alcock says his group may begin presenting results within a year. Paczynski says his group archived their first data at the Goddard Space Flight Institute last December. "Anybody who has the stamina to analyze those gigabytes of data," he says, "is welcome to do it."

Kem Cook, a Livermore astrophysicist, points out that whatever they find, the MACHO-hunters should come out ahead. "A key feature of these experiments," he says, "is that they are designed to either detect MACHOs over a wide range of masses, or else put significant limits on the existence of MACHOs. Thus there is no way for us to fail —either we find MACHOs or we provide the best evidence for something more exotic."

–Gary Taubes

COSMOLOGY

Scientists Chase Gravity's Rainbow

According to the theory of relativity, whenever a massive object accelerates, it makes waves that gently ruffle the fabric of space and time. The biggest upheaval of all, the Big Bang, supposedly sent out an unmatched burst of these "gravity waves"—waves that, because they have been traveling since the beginning of time, now arc across the universe. In a popular essay, astrophysicists George Smoot of the Lawrence Berkeley Laboratory and Paul Steinhardt of the University of Pennsylvania borrow from writer Thomas Pynchon and call the primordial waves "gravity's rainbow." Smoot and Steinhardt are ready to chase that rainbow, and they know just the place to look: in the microwave background, the afterglow of the Big Bang.

In a press conference last week at the Carnegie Institution of Washington, Smoot explained that gravity waves rolling outward from the Big Bang may have left marks on the cosmic background. The marks would be subtle and easily confused with other faint irregularities. But by comparing maps of the radiation made by different instruments, Smoot says, it might be possible to identify the signature of the primordial gravity waves.

There are plenty of researchers—even some affiliated with Smoot—who say Steinhardt and Smoot's quest is something that will remain on the far side of the rainbow. Says Massachusetts Institute of Technology astrophysicist Rainer Weiss, who has worked with Smoot on studies of the cosmic microwave background, "It's total speculation." And participants in the $210 million Laser Interferometer Gravitational Observatory (LIGO), which aims to detect gravity waves directly, are quick to point out that the pair hasn't yet offered any new results yet. But if their quest succeeds, say Steinhardt and Smoot, it would help to sharpen theorists' picture of the beginning of the universe. It would also be strong indirect evidence of the reality of gravity waves, which LIGO aims to detect directly.

The prospect of seeing gravity waves from the Big Bang emerged just a year ago, when Smoot and his colleagues, analyzing data from the Cosmic Background Explorer (COBE) satellite, discerned small temperature fluctuations in this nearly perfect radiation bath (*Science*, 1 May 1992, p. 612). At the time they attributed these bumps to tiny density fluctuations in the infant universe, which may have acted as seeds for the growth of galaxies and clusters of galaxies. Now, after re-analyzing theoretical predictions, Smoot and Steinhardt say that as much as half of the bumpiness could be attributable to gravity waves.

But they say they can't yet disentangle density fluctuations from the signature of gravity waves. Doing so will take a comparison of microwave data taken by the COBE satellite, balloon-borne detectors, and ground-based instruments at the South Pole. Each detector measures fluctuations on different size scales. COBE measures only large-scale fluctuations, while other experiments are sensitive to finer scales. On those scales, the fluctuations caused by gravity waves should fade while those caused by density fluctuations should grow more pronounced. So if gravity waves made a major contribution, the microwave background's bumps should look less prominent on smaller scales than on large.

Teasing out the numbers will take 3 or 4 years, says Steinhardt. "But ultimately one should be able to detect how much is gravity waves and how much isn't."

If they succeed, Smoot and Steinhardt say their result should provide a good test of inflation theory, a popular scenario for the universe's first fraction of a second, which posits an ultra-rapid burst of expansion in the newborn cosmos. Inflation makes specific predictions about the density fluctuations in the early universe. To test those predictions, cosmologists need to know how much of the irregularity in the cosmic background is due to gravity waves, so they can subtract it out.

Success won't take the luster off experiments such as LIGO—except perhaps in the public eye. Indeed, says National Science Foundation (NSF) physics director Robert Eisenstein, a Carnegie press-release promising (mistakenly) that Smoot was going to announce the first observation of gravity waves brought phone calls to NSF asking whether the astrophysicists had scooped LIGO.

Not a chance, says Weiss. So far, he points out, "there are no new measurements and no new data analysis." Even after Smoot and company do their analysis, says Weiss, he doesn't believe it will clearly disentangle the effects of gravity waves from density fluctuations. And in any case, says Weiss, LIGO—a pair of 4-kilometer-long laser interferometers—is meant to gather direct evidence of gravity waves emanating from sources in the current universe, such as supernovae or coalescing galaxies. No matter how good Smoot and Steinhardt's analysis, say Weiss and others, the cosmic microwave background won't yield anything that convincing.

Steinhardt agrees that he and Smoot aren't about to learn much about gravity waves themselves. "We are using what we know about gravity waves to learn about inflation and cosmology," he says. "We do not want to pretend we are learning anything fundamental about gravity waves here....[Weiss] is right—If you want to see a gravity wave in action, you need to use LIGO."

–Faye Flam