Detailing an active galaxy's structure

For eight months starting in December 1988, more than 100 astronomers focused their instruments on a single galaxy known as NGC 5548. Their objective was to obtain the first detailed picture of the density and physical state of the blanket of gas enveloping a mysterious, compact source of intense radiation at the galaxy's core.

The unprecedented campaign to pin down the size and characteristics of the gas flows swirling around the galaxy's core required the coordination of observations made by the International Ultraviolet Explorer (IUE) spacecraft and more than a dozen ground-based telescopes.

"We threw a lot of resources at it," says Bradley M. Peterson of Ohio State University in Columbus. "We agreed to collect and publish the data together. A number of essentially competing groups are now trying to interpret the observations." A paper describing the IUE results appears in the Jan. 1 ASTROPHYSICAL JOURNAL. A second paper, set for publication in the same journal in February, will present the ground-based observations.

NGC 5548 is a Seyfert galaxy, one of a class that harbors what astronomers call an "active galactic nucleus." Such a galaxy contains an extremely compact object — possibly a massive black hole — that feeds on the rest of the galaxy. This mysterious, central object draws in vast quantities of dust and gas, thereby generating sufficient power over a wide range of wavelengths to outshine the rest of the galaxy.

The region where all this activity takes place is too small for astronomers to map by direct observation. Instead, they deduce its geometry by observing the light given off by gas clouds surrounding the source.

Radiation from that central source provides energy for heating and ionizing atoms within these clouds. Atoms of each element emit characteristic wavelengths of light, and astronomers can measure changes in the intensity and width of the resulting emission lines in the spectra they observe. The amount of radiation coming from the central source can vary by a factor of two or three in just a few weeks. These surges in energy output cause corresponding increases in the intensities of emission lines. By analyzing the differences in how rapidly various emission lines respond to these fluctuations, researchers can learn something about the size and shape of the light-emitting gas clouds and estimate the central object's mass.

For such a strategy to be effective, astronomers must make frequent, regular observations covering many different wavelengths over a long period of time — a regimen beyond the reach of an individual or even a small team of astronomers. "We decided that to do this right, we were going to have to join forces," says Jean Clavel of the European Space Agency IUE Observatory in Madrid, Spain. "None of us could get enough time on a large instrument to do this project alone."

The campaign organizers targeted NGC 5548, a galaxy about 200 million light-years from Earth, because it appears quite bright, seems to typify Seyfert galaxies and has a well-documented history of variability in energy output. "People knew that it varied dramatically on rather short time scales," Peterson says.

Using the spectral measurements, the researchers established that atoms in gas clouds respond quickly to any changes in the central source's energy output. This observation confirms earlier suspicions that these light-emitting regions are quite small and that much of their material lies close to the central source, possibly only light-days or light-weeks away.

The researchers also noticed that highly ionized gas seems to respond to surges more quickly than does gas with a lower degree of ionization. Such differences in response time suggest the light-emitting gas clouds have a complicated structure. One possibility is that the highly ionized material lies in a sphere surrounding the central source, whereas the low-ionization material forms a disk or ring.

"Our older models were too simplistic. You don't have a unique cloud at a unique distance," Clavel says. "You probably have a range of clouds with different physical conditions and a range of different radial distances from the central source."

The spectral observations also suggest that the central object has an immense mass. "All the indications are that the central object has a mass of around [10 million] solar masses, which puts it in the supermassive-black-hole range," Peterson says.

Astronomers using ground-based telescopes continue to monitor NGC 5548, and a second campaign, focused on the Seyfert galaxy NGC 3783, is in the works. This time, the organizers hope to include X-ray measurements from the ROSAT spacecraft, along with ultraviolet and optical observations. That project will give astronomers a better sense of how typical NGC 5548 really is and how much they can generalize their results to other active galactic nuclei.

— I. Peterson

Greek site delivers historical monument

A team of researchers scouting the boundary between two ancient Greek cities has unexpectedly uncovered a long-lost inscribed monument previously known only through a first-century A.D. document written by the Greek historian Plutarch.

Though the team discovered the partially destroyed monument last February, the Greek government delayed announcement of the find. The report finally emerged last week at the Archaeological Institute of America meeting in San Francisco.

"This was a rare find of an historically attested inscription," John Camp of the American School of Classical Studies in Athens, Greece, told SCIENCE NEWS.

Camp and four graduate students from the University of California, Berkeley, found the monument atop a hill near the archaeological site of Chaironeia, Plutarch's hometown. Their discovery clearly establishes the location of a battle between the Roman army occupying Greece and invaders from the Black Sea area in 86 B.C. Classical scholars had proposed several hills around Chaironeia as possible battle sites on the basis of Plutarch's description of the event.

The archaeological team also found about 150 stone blocks near the base of the hill, apparently the remains of a temple dedicated to the sun god Apollo during Plutarch's time, Camp says. The blocks possess stylistic features typical of ancient Greek civilization.

In Plutarch's "Life of Sulla," the historian tells how two Chaironeia townsmen aided a great military victory for the Roman general Sulla. Troops from Pontus, a kingdom near the Black Sea, had camped on a river plain north of Chaironeia, with one detachment perched on a hill known as Thourion.

Sulla placed his foot soldiers between the main body of the Pontus forces and Chaironeia, but could not repel the hilltop squadron until two townsmen, Homoloichos and Anaxidamos, offered to lead Roman soldiers up a back pathway on Thourion to surprise the invaders.

The plan worked perfectly, according to Plutarch; 3,000 soldiers from Pontus died on Thourion's rocky slopes, allowing a successful Roman attack on the river troops. Plutarch noted that Sulla then erected two stone trophies to celebrate the victory — one on the plain and the other on Thourion, in honor of the heroic townsmen.

The 3-foot-wide, 1-foot-high marble block found by Camp and his co-workers amid a pile of rubble contains three words: "Homoloichos," "Anaxidamos" and "aristis," the Greek word for "heroes."

— B. Bower