Interview: Dr. Robert A. Brown

Tracking planetary targets with the Space Telescope

Planetary scientist Robert A. Brown joined the Space Telescope Science Institute in Baltimore, Maryland in 1982. He became Project Scientist for the Space Telescope in 1983 on a two-year appointment, moving to the Marshall Space Flight Center in Huntsville, Alabama to fill that role. He is now back at the Institute as an Associate Astronomer. Brown was interviewed by David Cherry, associate editor of 21st Century Science & Technology, *on April 5.*

Q: What were your duties as Project Scientist in Huntsville, and what kind of work have you been doing since you returned to the Institute?

Brown: My job there was to be the chief scientific spokesman for the Space Telescope, and to be the chairman of the science working group for it. The key function in that job was to advise the project manager on all aspects of development and testing of the telescope that have to do with its scientific functionality. The year before, when I had first come to the Institute, I was the first planetary scientist to be hired, and my responsibility was to assure that the capabilities for studying planets would be understood, and developed.

I came back to the Institute, and have been working on a variety of problems including the planetary capabilities problem. But my work has been much broader than that. Over the past couple of years, I've been working on questions of what kind of educational programs might be associated with the telescope that could turn this country into a nation of 250 million astronomers.

Q: Have planetary observations been one of the objectives of Space Telescope planning from the beginning?

Brown: The history of the telescope and its planetary capabilities can be traced at least as far back as the Announcement of Opportunity that NASA issued in 1977, which was a call to the scientific community to propose to build instruments—to join instrument development teams—and to define the initial science program. In the document NASA lays out the kinds of things that it expects HST is going to be able to do. Several of the objectives relate to planetary science. And then there is the other question: What can the space telescope do to find and study planets around other stars? That idea is in the original 1977 announcement also.

Q: It appears that perhaps the biggest problem, technically, for planetary operations, is that the planets move across the sky relative to the stars. So, while the telescope apparently has excellent pointing capability and can lock onto a star while the scope continues to move in its orbit, the computer programming available now does not also provide the capability to track planets.

Brown: For the telescope, the easiest thing to do is to point at something that doesn't move, you are right. But then if you are going to point at something that is moving, there are two things you need to do, and you mentioned one of them, which is to track it. The other is that you need to acquire it. To acquire it you have to be able to predict where the planet is going to be on the whole sky, and to select—given *when* you want to make the observation—a pair of guide stars that is going to be nearby at that time. Once you lock onto a pair of guide stars, then you need to be scooting off from them in a pattern that corresponds to the pattern that the planet is going to take with respect to the background stars.

Q: I guess that there is no way a little slot of real-time control could help, because things are moving too fast?

Brown: In fact, you need a real-time interaction to get the best pointing, but it's not for the reason that you're thinking. The planets do move fast enough so that you need to plan a specific observation at a specific time, and so you need to do that on the ground system. The real-time interaction is actually needed to bootstrap the pointing accuracy, the acquisition accuracy, from about the one or two arc-second level, down to a factor of 10 or even 50 better than that, down to the level of 0.2 arc-seconds or better.

The reason for that is very fundamental. We know extremely accurately where the planets are, because we send spacecraft there. So we know where the planets are in the dynamical system of the solar system, but where the stars are—which we know to the level of the 13th to 14th magnitude stars—is much less certain. The reason that it's uncertain is that all the work that has gone into figuring out where the stars are has been done on the ground through telescopes that don't have better than one or two arc-second image quality, and furthermore, the little buggers move. The guide star catalogue for the Space Telescope has about 20 million stars in it, stars that are available for locking onto them. Each one of them moves a little bit, every day, year by year it moves, so we have a saying in the Space Telescope project that about every five or six years the sky "goes out of spec."

They do move in straight lines, to very good accuracy, so we've based our initial catalogue of 20 million stars on a survey that has been done, at a definite time, and now we will go back and remeasure with the Space Telescope, take new points, to show where they are at a new time. We will be able to figure in that linear motion and predict where they are for all useful time in the future.

The problem has to do with reference frames. There is a reference system in the solar system in which the places of the planets are predicted very accurately. Then there is the astrometric system of where the stars are, based on all the plates and all the surveys and the work of astronomers and observatories over the last couple of hundred years. Now the problem is that those two systems are not well rectified to one another. They are well coupled down to the one or two arc-second level, but they are not well coupled to a factor of 50 finer than that.

So what you can do, based on preplanning, is to get the telescope to acquire accurately a planetary target, within one or two arc seconds, anywhere in the sky. But then you need an additional bootstrap, which is just to take a picture of that point, and then you have set forever the relationship between guide stars and where the planet is, because you took a picture of the planet while you were locked on the stars. It was not understood how to do this job operationally, what it would require in terms of flight software and ground software, until the mid-1980s. And so part of our job is to go back and fill in the computer programming that would let any given observation go through that series of steps.

The planet side of the story has a kind of richness of its own. At this point, the kinds of questions that we're asking are really rather specific. We already have a very good picture of Jupiter, and now what the scientists want to do is to make very specific measurements here, there and then over there. So you need to know the longitude and latitude of what you are talking about. You are pointing a small-aperture instrument at Jupiter and you want to acquire and track it in a definite point.

If you write down all the different kinds of planetary motions, it is really rather complex. You've got rotating planets, then you've got atmospheres that move. On Jupiter, for example, you've got different longitude systems, because each of the longitude systems rotates at a different rate. You've got the satellites, and the satellites also rotate, of course.

You probe a satellite's atmosphere by looking at starlight that comes to you from beyond it, but due to refraction in the atmosphere, the star appears to move. So you've got all kinds of wonderful complexities. It was kind of a shock to the engineers and managers that the telescope was really going to be useful for planetary science.

So that's the basic reason why this job is such a difficult challenge for the Space Telescope: Its pointing relies on "walking on stars."

Q: Let's consider some of the science projects that have already been approved. As I have talked to the scientists, I have tried to understand what the conceptual frameworks were within which the different projects were conceived. There are at least two, although they are rarely explicit: One is that of learning how the solar system came into being. The other is that we are continuing our mapping of the solar system, and it's like the mapping of the New World in the 15th and 16th centuries, in that we are going to continue to go to these places and there are lots of us who think that Mars could be a nice place to live, relatively speaking.

Brown: Yes. I think that there will be more observations like that, because of the Human Exploration Initiative announced by President Bush. I think that there is a role for the telescope in making Mars investigations, for example, that relate directly to human exploration, and some of it will have to do with site selection and surveys, and so forth.

More importantly, in the case of Mars, there are questions about the variable nature of Mars, its weather, the growth and evolution of dust storms, which are marvelous, and obviously have great importance for humans being there. That implies scientific investigations that could be done by the Space Telescope, or could be done with a future telescope I'd like to call the Eye on Mars. This country is setting out on a great course, towards Mars, and we really need a telescope that is dedicated to synoptic studies. Today, there could be a dust storm arising on Mars and the American people wouldn't even read about it in the newspapers! We need to have not only scientific investigations, but a kind of Mars consciousness, that can be achieved through having a fairly modest telescope that is dedicated to that objective.

The Space Telescope, first of all, is not optimized for tracking planets, and secondly, it's got priorities of other kinds, it's just not set up in that way. It's not set up as a support to the exploration of the solar system. Whereas a telescope could be set up in that way. If you designed a telescope for studying planets, you would go about it in a different way. Obviously you'd track on the object itself, you'd get your basic tracking signal from the object, and not from the stars.