

The Discovery of the Kuiper Belt

David Jewitt

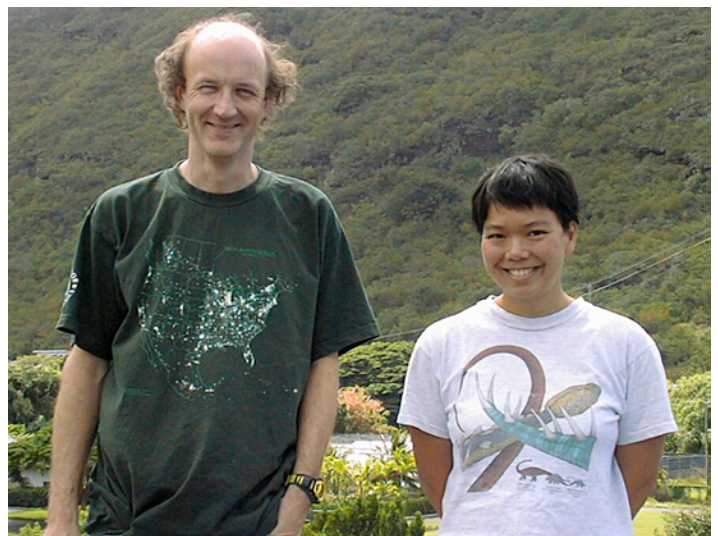
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Editor's Introduction

Only in the last two decades have astronomers been able to explore the fascinating realm beyond the outermost giant planet Neptune. Thousands of bodies are now known to be orbiting there. We asked the co-discoverer of the first of these trans-Neptunian worlds to tell us how he came to make the pioneering discovery that opened the outer reaches of our solar system to our view.

In the early 1980s I began to wonder why the outer regions of the solar system were empty. I knew that the inner solar system, in addition to housing the terrestrial planets, was abuzz with vast numbers of asteroids and comets. But beyond Jupiter lay only the planets and the strange interplanetary body Chiron (discovered by Charles Kowal in 1977). Very slowly, I realized that there could be two reasonable explanations for the emptiness of the outer solar system.

First, the outer regions could be empty because of the proximity of the giant planets, whose gravitational disturbance of nearby small bodies might have caused all such objects either to be deflected into the sun or other planets, or ejected from the solar system to join the “interstellar medium” — the material between the stars. Unfortunately, no simulations of the long-term stability of orbits between those of the giant planets had then been made, because the puny power of 1980's computers did not allow it. Anyway, it seemed reasonable that the outer regions could be “clean” for

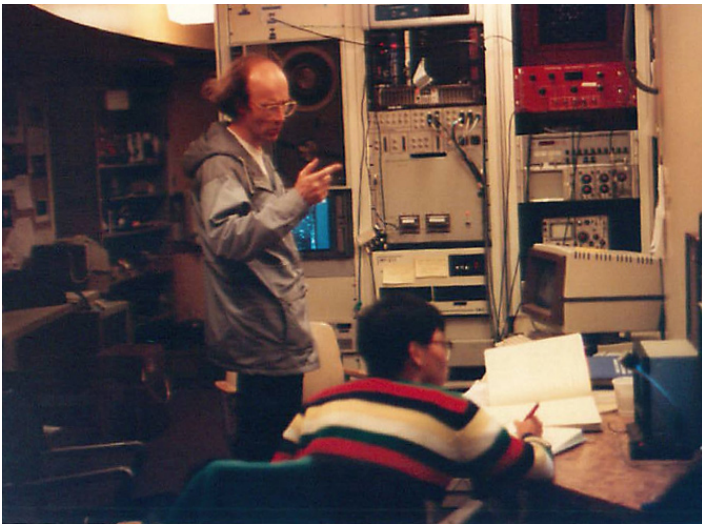


The author and Jane Luu in Manoa Valley, Oahu, 2001

this reason.

Second, the emptiness could be an artifact of the vast distances to the outer solar system. When we consider that bodies out there shine by reflecting sunlight, we realize that the brightness of an object varies with the inverse 4th power of the distance. A given body at 10 AU (an AU is the distance between the Earth and the Sun) will appear 10,000 times fainter than it would at 1 AU. Objects could exist out there, but be so faint as to have escaped detection.

Eventually, I also realized that I could test these two possibilities. In 1982, I had used one of the first charge-coupled device (CCD) cameras on the Palomar 200-inch telescope to recover the very faint returning Comet Halley. Some four years before perihelion, it



Jewitt and Luu in the control room of the UH 88-inch telescope during the SMO Survey, two years before finding 1992 QB1. The camera control computers are to the right.

was 24th magnitude¹ and at the record distance of 11 AU. If I could see the tiny nucleus of comet Halley beyond Saturn, maybe I could see other objects between the giant planets, or even beyond them.

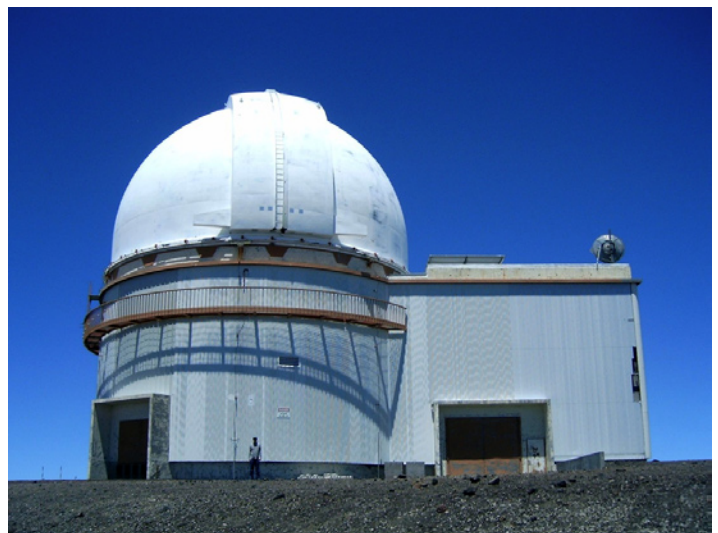
Then, in about 1986, a new graduate student at MIT asked me if I had any ideas for short-term research projects. Jane Luu's project on compact stellar X-ray emitters was not going well, she said. She wanted to start something new and was very excited about a search of the outer solar system. So we began to strategize. At first we thought that the best way to find distant objects would be through their occultation of background stars.

In an occultation, an object in our solar system moves across a distant star, obstructing its light briefly. Such occultations were intriguing because they side-step the terrible effects of the inverse 4th power law. Later, after a frustrating phone call to the Audubon Society of Arizona to ask about the number of whippoorwills flying over Kitt Peak at night, we realized that occultations were simply not going to work — they were too rare, too quick and too similar to occultations caused by birds.

Having no predictions for the numbers or brightnesses (or even the existence) of our sought-after bodies, we soon decided on a two-pronged observational approach. First, we would photograph large swaths of

the sky using conventional glass plates with Schmidt telescopes. This would allow us to find objects to about magnitude 20. At the same time, we used a more sensitive CCD camera on MIT's 1.3-m telescope to cover tiny patches of the sky in the plane of the solar system to about magnitude 24. In this way, we could detect rare, bright objects in the photographic survey and abundant, faint objects in the CCD survey.

We further decided to ignore all objects moving faster than 10 arcseconds² per hour, corresponding roughly to speeds at the orbit of Saturn. Our purpose was to avoid distractions from numerous foreground main-belt asteroids and to reduce the effects of trailing loss (loss of sensitivity caused by smearing of the light during the exposure). Based on this speed limitation, we named our project the SMO (slow-moving object) Survey.

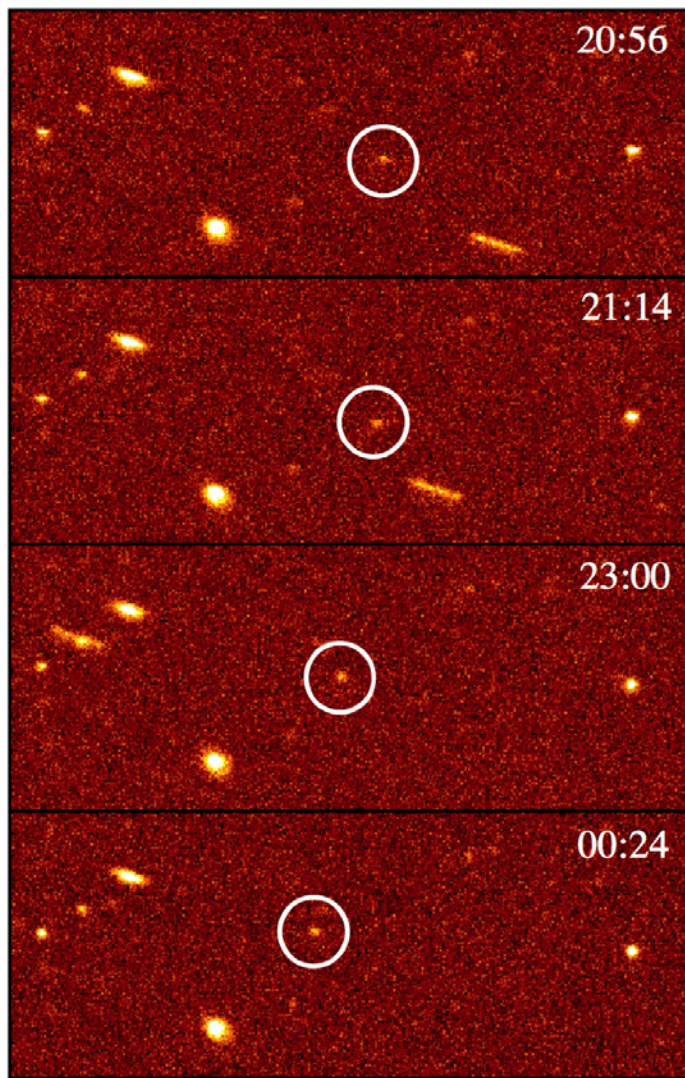


The University of Hawaii 88-inch telescope building atop Mauna Kea, Hawaii. The box structure to the right houses a large, now unused Coude spectrograph and a considerable quantity of junk. Note wind damage to the building on the far right.

By late 1987, we had taken many images and detected zero SMOs. We wrote a paper for *The Astronomical Journal* to report this fact and it was published in 1988. We also decided that the photographic observations were so physically and mentally painful that we did not wish to continue with them. Thereafter we used only CCDs for our search, albeit bigger and better ones as time passed.

1. Magnitudes are a system for keeping track of how bright celestial objects appear. The bigger the number, the dimmer the object looks in the sky.

2. An arcsecond is a measure of angle, and is equal to 1/3600th of a degree.



Discovery images of 1992 QB1 recorded on 1992 August 30th. The object is circled. The numbers are the times at which the four images were taken.

Also in late 1987, my MIT planetary scientist colleague Jim Elliot told Scott Tremaine (from another MIT department) about our SMO Survey. Scott visited me the next day to say that he was trying to use computers to simulate the capture of short-period comets from a distant source. Until then, most astronomers had believed that short-period comets were captured from the long-period (Oort Cloud)³ population but did not have the computing power to test this belief. Scott's new simulations instead pointed towards a closer disk-like or ring-like source just beyond the planets, something to which our observations would be sensitive. I think we were both surprised: me, that someone else was

3. The Oort Cloud is a huge reservoir of icy chunks at great distances from the Sun (50,000 AU on average). It is thought that comets that have long periods of return come from the Oort Cloud.

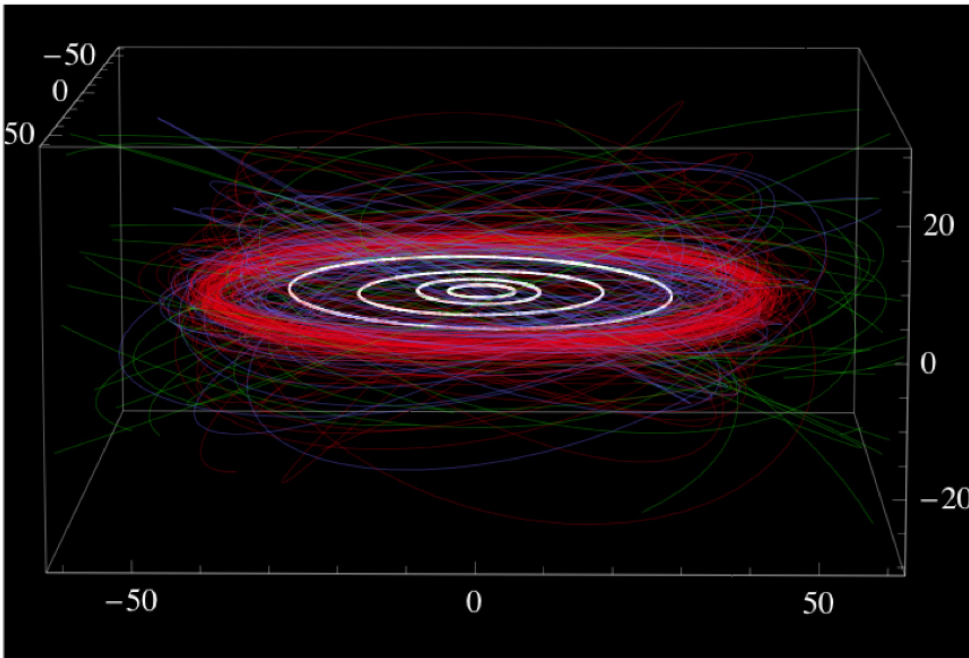
thinking about the outer regions of the solar system and Scott that others were already looking for objects there. Strangely, the two efforts were both underway at MIT, a coincidence for which I have no explanation.

We continued the survey using telescopes in Arizona until mid-1988, when I moved to the Institute for Astronomy in Hawaii. Jane remained a PhD candidate at MIT (graduating in 1990), but continued the SMO Survey and other planetary projects in Hawaii. All through this time and after, we obtained SMO Survey observations, taking advantage of newer, bigger and better CCDs as they became available, and procuring telescope time by hook or by crook. By the time of our first success, in the autumn of 1992, we were using cameras having 20 times more pixels than our first device, on a telescope with twice the collecting area. In addition, the seeing in Hawaii was twice as good as on Kitt Peak, our earlier telescope site in Arizona, so we could see much fainter in a given amount of time.

The discovery observations began before midnight on August 30th, 1992 at the University of Hawaii 2.2-m (88-inch) telescope on the summit of Mauna Kea. We had taken the first two of four images of part of the sky in the plane of the solar system and were visually blinking them on a computer while the third exposure was underway. Two pictures of the same piece of sky displayed in quick succession (i.e. "blinked") will show that the stars and galaxies remain in the same place while solar system objects will have moved during the time between the two images.

Immediately, a candidate having all the right characteristics stood out. The motion was slow (about 3 arcsec per hour) and in the right direction (westwards). The object was faint enough that no-one would have seen it before, yet bright enough that the movement could not be due to noise in the data. Still, cosmic rays occasionally mimic stars in CCD images and we knew that adjacent cosmic rays could mimic an SMO. And, after so many years of searching, we hardly dared believe that this could be real. We also knew that we only had to wait a few minutes to find out. I think we both held our breath for the readout of the third image. It was beautiful, as was the fourth: the slow, westward motion of our faint object seen from the first two images continued into the third, the fourth and beyond. The SMO was real.

While still observing, we calculated the distance



Perspective view of the solar system, showing the orbits of the giant planets (white) and those of Kuiper belt objects. The latter are color-coded according to various dynamical sub-types discovered by our survey.

from the speed, and then estimated the size from the brightness and the distance. We also calculated the number of similar objects to be found if we could continue our survey over the whole sky in the plane of the solar system. By the end of the night, we knew that we had found a solar system object far beyond Neptune and more distant than any seen before, that it was about 250 km in diameter, and that there were thousands of similar objects awaiting discovery. And, as Jane said after the third image readout, “So, that’s the end of Pluto”.

The new object came to be known as 1992 QB1, a name that reflects the order of its discovery in the lists of small solar system objects in 1992. The assemblage of its trans-Neptunian cohorts was called the Kuiper belt, after the astronomer who had discussed the outer solar system in 1951. We had broken a barrier: after finding the first one, finding other SMOs was easy, and presently more than 1300 are known. Jane’s comment about Pluto was prescient, since Pluto is now considered part of this belt, and there is at least one member, Eris, which may be larger than Pluto, seriously reducing claims to Pluto’s uniqueness.

Nowadays, our SMO Survey is sometimes described by others as a search for the Kuiper belt, but it was nothing of the sort. Kuiper did not predict the belt (he anti-predicted it by asserting that this region would be

empty) and, even if he had, we were ignorant of his papers until the visit from Scott Tremaine. Predictions for the belt have also been retroactively claimed for Kenneth Edgeworth (in 1943), Fred Leonard (in 1930) and others. All this reminds me a little of Nostradamus, whose 16th century predictions of apocalyptic world events are regularly trotted out, but curiously only after those events have materialized. The point is that sufficiently vague statements that had no impact when they were made can be retroactively interpreted in almost any way you like.

A more convincing case can be made for Uruguayan astronomer

Julio Fernandez who, in a 1980 paper, argued that the Oort Cloud was not a likely source of short period comets and that an inner belt was probably required. But none of the predictions, whether imagined or real, played a role in the formulation or conduct of the SMO Survey, or in its eventual success. The Kuiper belt was discovered because we asked an extremely simple question about the emptiness of the outer solar system and because we pursued the answer to the end.

About the Author

David Jewitt is a professor of planetary astronomy in the Department of Earth and Space Sciences and holds an appointment at the Institute for Geophysics and Planetary Physics, both at UCLA. He is especially interested in observational approaches to understanding the origin of the solar system. Most of his work addresses the physical properties of small bodies (cometary nuclei, asteroids, and poorly understood hybrid objects). He discovered the Kuiper belt comet reservoir with Jane Luu in 1992 and the



main-belt comet reservoir with Henry Hsieh in 2006. He previously worked at MIT and at the University of Hawaii.

Resources for Further Information:

David Jewitt's Kuiper Belt Web Site:

<http://www2.ess.ucla.edu/~jewitt/kb.html>

International Comet Quarterly Page on the Nature of Pluto:

<http://www.cfa.harvard.edu/icq/ICQPluto.html>

Why the Name "Kuiper Belt"?:

<http://www2.ess.ucla.edu/~jewitt/kb/gerard.html>

Astronomy Beat 23: *The Discovery of Pluto* by Clyde Tombaugh

Astronomy Beat 17: *What's in a Name: The Discovery of Makemake* by Michael Brown ✨

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