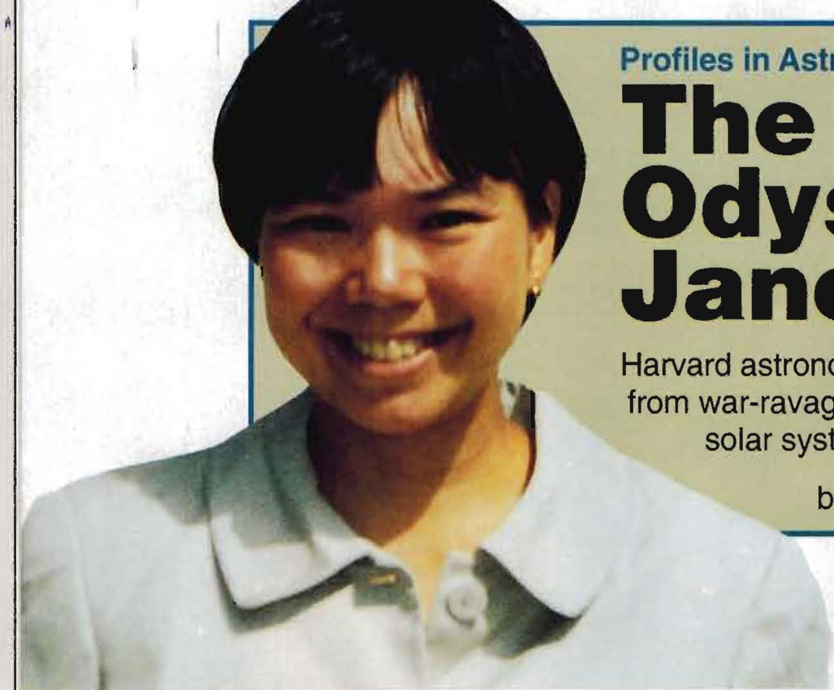


Profiles in Astronomy:

The Remarkable Odyssey of Jane Luu

Harvard astronomer Jane Luu's life journey has taken her from war-ravaged Vietnam to the outer reaches of the solar system.

by Marcia Bartusiak

With space probes examining nearly every nook and cranny of the solar system, new finds in planetary astronomy are rare. But Jane Luu of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., beat the odds in a spectacular way. In 1992 she and her longtime collaborator, University of Hawaii astronomer David Jewitt, discovered a 280-kilometer-wide object orbiting the Sun beyond Neptune and Pluto. In the intervening years, they and others have spotted 27 more of these trans-Neptunian objects.

These newly discovered bodies belong to the "Kuiper belt," a disk of icy planetesimals that had long been proposed to exist beyond the outer planets. The Kuiper belt, or Kuiper disk as some astronomers call it, consists of leftover material that never accreted into planets, meaning that Luu, in effect, helped reveal the most pristine material yet to be found from the solar system's creation 4.6 billion years ago. At the same time, she was fulfilling the dream of many planetary astronomers; she was extending the borders of the solar system for the first time since Clyde Tombaugh identified Pluto in 1930.

> *"I packed my colored pencils in secret, worried that my parents would consider them too frivolous."*

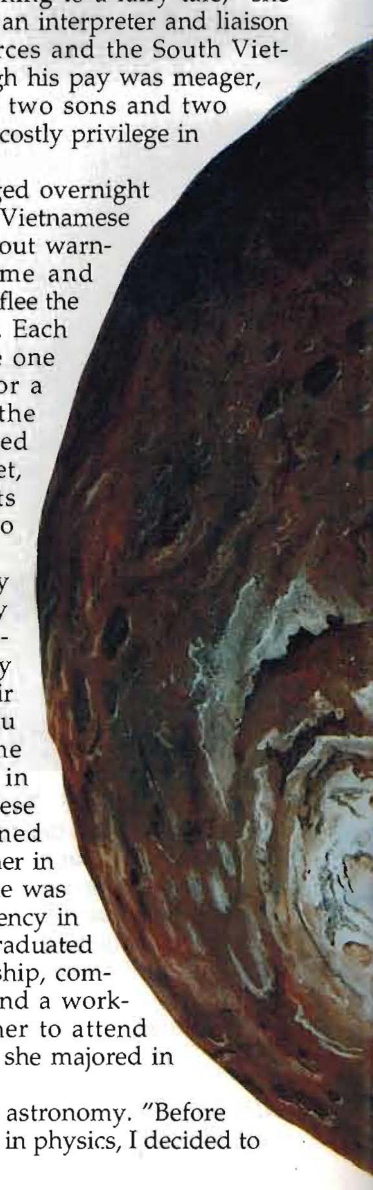
For Jewitt, the discovery was the highlight of a vocation that he has pursued since childhood. For Luu, though, it was an unforeseen development in a career filled with curious twists and turns, a life that has taken her from the war-torn country of Vietnam to an assistant professorship at Harvard University.

Born in Saigon in 1963, Luu vividly recalls the continual military strife that surrounded her as a child. She saw it as a way of life. "When my parents spoke back then of the peaceful times of their childhood, it was like listening to a fairy tale," she says. Her father worked as an interpreter and liaison between the American forces and the South Vietnamese government. Though his pay was meager, he made sure to send his two sons and two daughters to school, then a costly privilege in Vietnam.

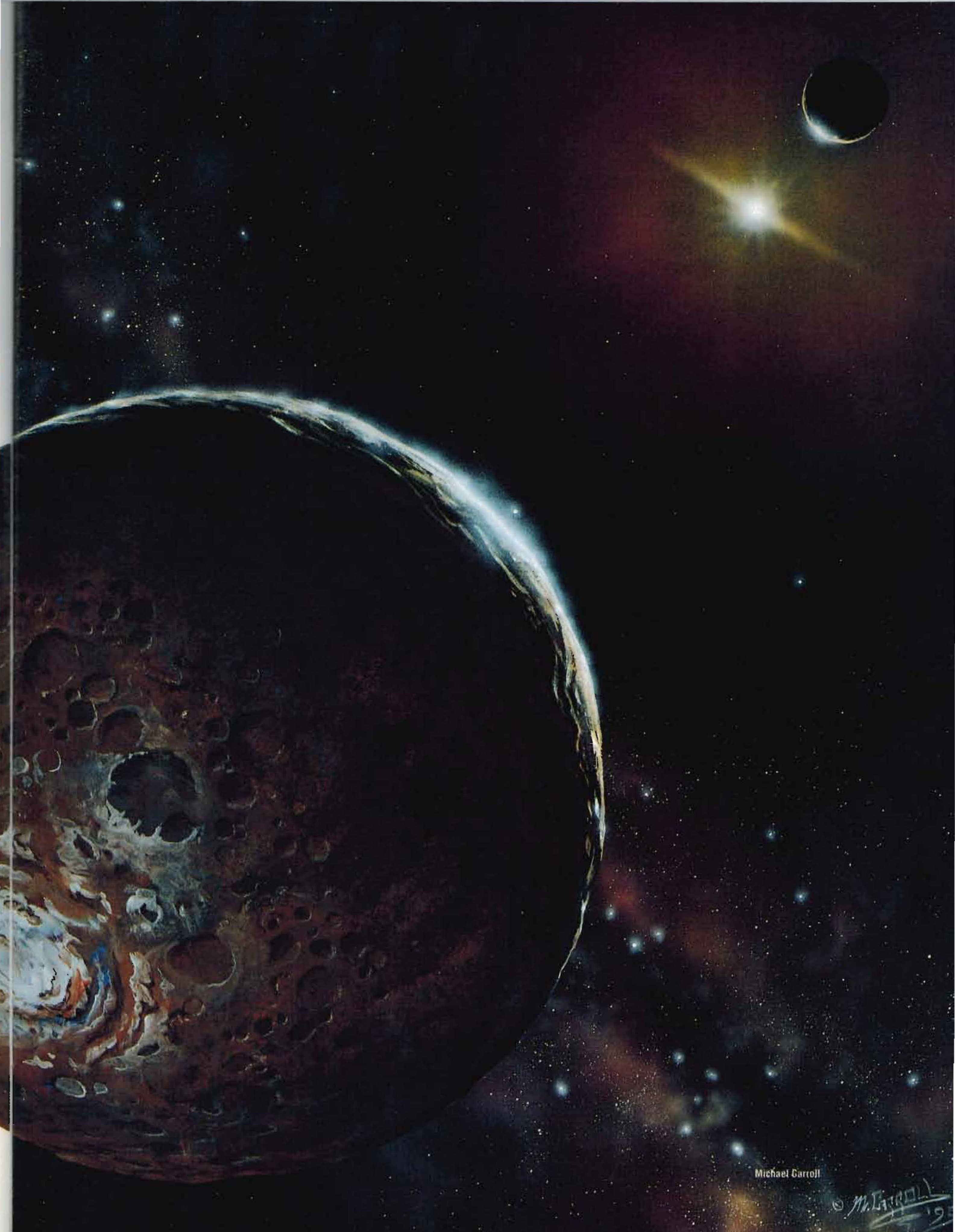
Luu's life literally changed overnight in April 1975 as the North Vietnamese army entered Saigon. Without warning, her father came home and announced that they had to flee the country the very next day. Each child was allowed to take one bag, just enough room for a change of clothes and the barest necessities. "I packed my colored pencils in secret, worried that my parents would consider them too frivolous," recalls Luu.

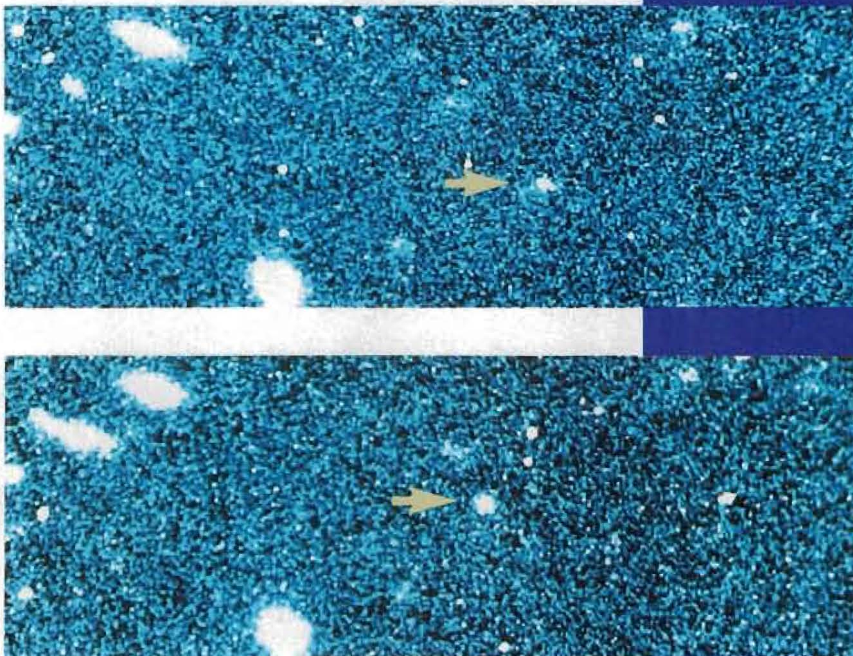
Escaping Vietnam by plane, the Luus eventually settled in southern California, where a host family promptly Americanized their names. At the age of 12, Luu Le Hang officially became Jane Luu. Already fluent in French, given her Vietnamese background, Luu learned English over her first summer in America. By high school she was displaying a nimble proficiency in her scientific courses and graduated as valedictorian. A scholarship, combined with student loans and a work-study program, enabled her to attend Stanford University, where she majored in physics.

Serendipity led her to astronomy. "Before going off to graduate school in physics, I decided to

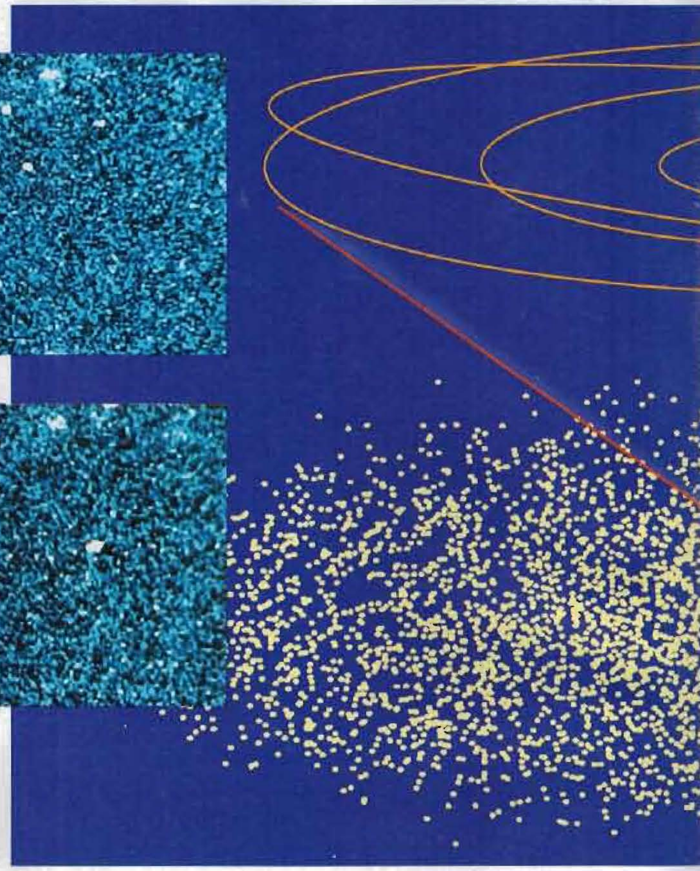


LURKING BEYOND PLUTO are ten billion Kuiper disk objects, like this one.


Michael Carroll



David Jewitt and Jane Luu



EUREKA! Above is the first object ever seen orbiting the Sun beyond Pluto. David Jewitt and Jane Luu discovered the 280-km-wide object, named QB_1, by observing its motion in these two images. QB_1 is the first object to be found in the Kuiper disk (right).

work for a while at NASA's Jet Propulsion Laboratory," explains Luu. "It was a simple job, running computer programs." But each day, in her walks about the Pasadena complex, she would admire the stunning pictures of the solar system's moons and planets that lined the corridors of JPL, headquarters for the Voyager missions to the outer planets. She was hooked and soon switched her loyalties from physics to planetary astronomy. "I find the solar system far more appealing than extragalactic objects," says Luu. "In this field, we can take pictures up close."

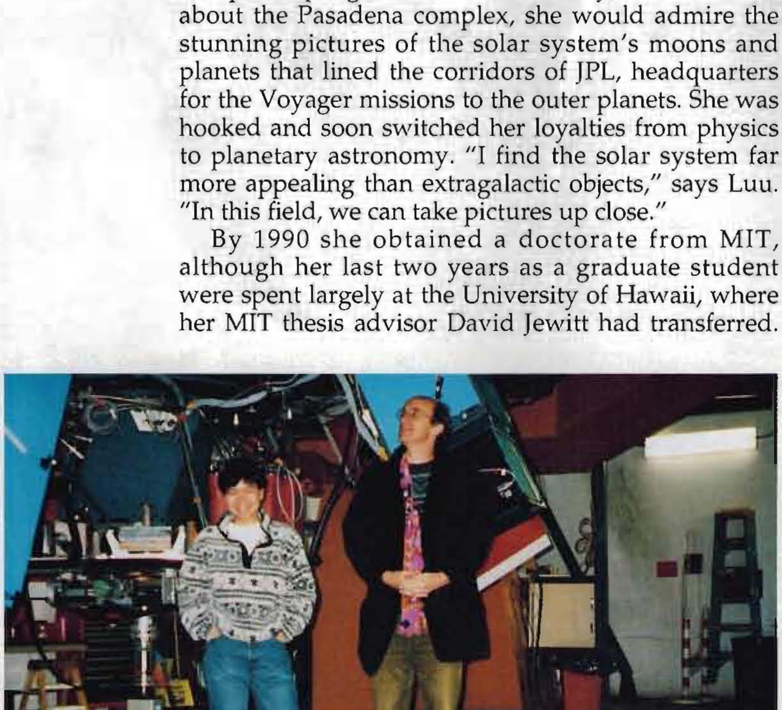
By 1990 she obtained a doctorate from MIT, although her last two years as a graduate student were spent largely at the University of Hawaii, where her MIT thesis advisor David Jewitt had transferred. For her dissertation, Luu investigated the relationship between comets and asteroids. But on the side, she joined Jewitt in his search for the "Holy Grail" of planetary astronomy — objects beyond Pluto.

In 1951 the Dutch-American astronomer Gerard Kuiper — the father of modern planetary astronomy — argued that a disk-shaped swarm of protocomets must lie in the plane of the solar system, just past the outer planets and extending outward ever thinner for billions of kilometers. "Kuiper saw no reason for the solar system to stop abruptly at Pluto," points out Luu.

In Kuiper's day, looking for cometary bodies beyond Pluto seemed pretty hopeless, like trying to spot lumps of coal in a pitch-black room. But by the 1980s astronomers developed renewed interest in the idea. For one, the space-based Infrared Astronomical Satellite (IRAS) began to spot circumstellar disks around other stars, such as Vega. And theorists running computer simulations were seeing that the short-period comets (comets with periods shorter than 200 years) would likely originate in a Kuiper-type disk.

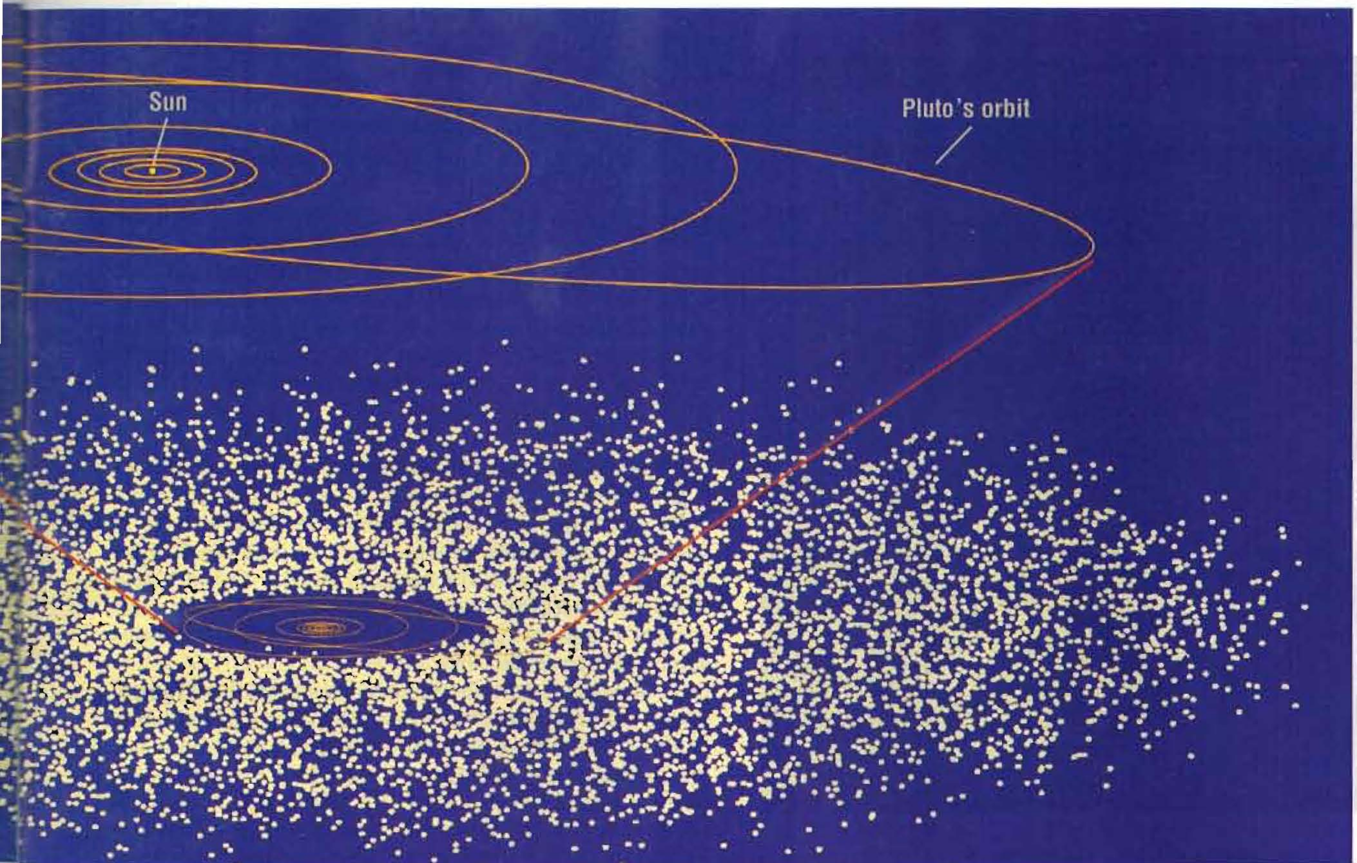
In 1987 Jewitt also realized that new technologies, especially the arrival of sensitive charge-coupled devices (CCDs) — digital cameras — at last made looking for these faint objects worthwhile. Moreover, speedier computer processing allowed Jewitt and Luu to examine their images at the telescope in real time, a necessity for tracking and confirming a find.

Rewards were far from immediate, though. Jewitt and Luu looked for five years and saw nothing. Mean-



David Jewitt and Jane Luu

THE DISCOVERERS, Jane Luu and David Jewitt at the University of Hawaii's 2.2-meter telescope.



while, Luu graduated and moved on to a postdoctoral position at the Center for Astrophysics. Over these years, the survey continued. They worked as a cohesive team, with Jewitt usually pointing the telescope and Luu operating the computer and CCD. Their strategy was to look at the dark, outer regions of the solar system two times a year, in March and September, when the bright glow of the Milky Way is not obstructing the ecliptic, the plane of the solar system. It was a big gamble, and they knew it. Indeed, Jewitt and Luu were denied time on national telescopes, since the odds for spotting an object beyond Pluto were considered too low.

The turning point came when Jewitt was able to use a new CCD recently mounted on the University of Hawaii's 2.2-meter telescope atop Mauna Kea, which offered a clearer view than their previous observing site on Kitt Peak in Arizona. More important, the new CCD was twice as sensitive, and its field of view was four times greater than their previous one, enabling them to spot fainter objects in a larger patch of sky.

Results came swiftly. On August 30, 1992, just their second night using the new camera, Jewitt and Luu spotted something. "Our procedure was to take three consecutive images of a region, each exposure taking 15 minutes. And then we would 'blink' them," says Luu. In other words, they would switch quickly from one picture to the next on the computer monitor and see if anything had moved from frame to frame.

"I don't like to blink after just two images because there can be so many false candidates, like two cosmic rays that happen to be near each other. But Dave is very gung ho about this," explains Luu. "On that night he immediately started blinking with two images and said, 'Jane, come look at this.'"

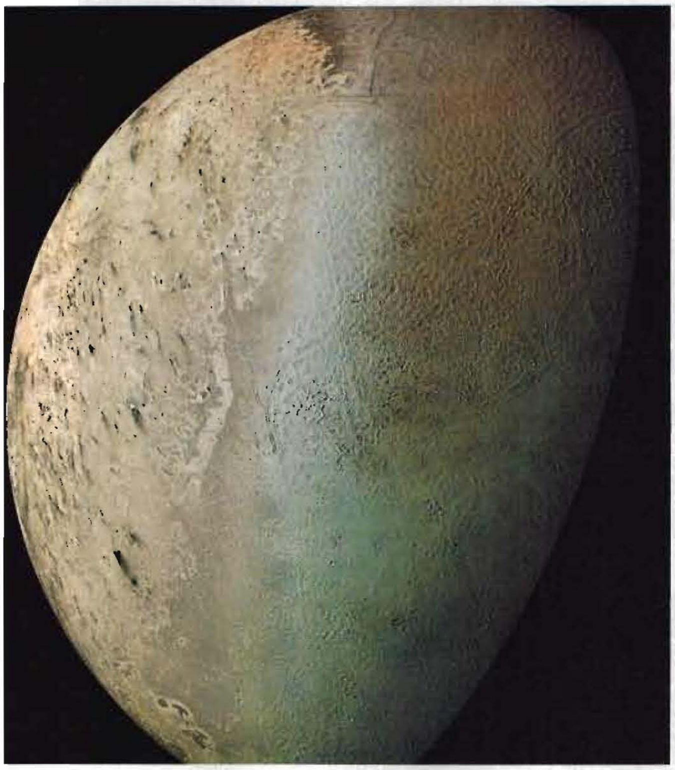
They saw something that didn't look like the dot-like imprint from a cosmic ray. Instead of being a sharp spot, it was rather fuzzy. They took a third image and saw that the 23rd-magnitude fuzzy spot had moved farther along. "We told each other to calm down and within a couple of hours took a fourth image," says Luu. "We didn't dare hope for too much because we had been doing this for five years."

In fact, they didn't report their find until they confirmed the sighting on the remaining nights of their five-day observing run. Its official name became 1992 QB_1, but Jewitt and Luu had already nicknamed it "Smiley," after the noted spy in a series of John Le Carré spy novels. It was a fitting name for a cosmic intruder lurking in the dark reaches of space.

Jewitt and Luu nicknamed QB_1 "Smiley" after the noted spy in a series of John Le Carré novels.

1992 QB_1 revolves around the Sun in a near-circular orbit at a distance of 6.6 billion kilometers (or 44 astronomical units in astronomers' parlance, 1 AU being the average distance between the Earth and the Sun). With a diameter of 280 kilometers, 1992 QB_1 is roughly one-eighth as wide as Pluto.

Six months after the discovery of 1992 QB_1, Jewitt and Luu spotted a similar object in another part of the sky and christened it "Karla," Smiley's nemesis. The next three they found also got monikers care of Le Carré: Control (Smiley's boss); Hayden (a double



NASA

INTERLOPER from beyond. Neptune's satellite Triton probably originated in the Kuiper disk and was captured by the planet.

Centaurs

Object	Minimum Distance from Sun	Maximum Distance from Sun	Average Distance from Sun	Eccen.	Inclin.
Saturn	9.02	10.09	9.55	0.056	2.5
Uranus	18.33	20.11	19.22	0.047	0.8
Chiron	8.45	18.97	13.71	0.383	6.9
Pholus	8.69	31.96	20.32	0.573	24.7
1993 HA_2	11.82	37.70	24.76	0.523	15.6
1994 TA	10.69	24.84	17.76	0.398	5.4
1995 DW_2	18.83	30.87	24.85	0.242	4.2
1995 GO	6.78	32.12	19.45	0.651	17.5

Transneptunian Objects

Object	Minimum Distance from Sun	Maximum Distance from Sun	Average Distance from Sun	Eccen.	Inclin.
Neptune	29.84	30.38	30.11	0.009	1.8
Pluto	29.58	49.39	39.54	0.250	17.2
1992 QB_1	40.87	47.15	44.01	0.071	2.2
1993 FW	41.56	46.04	43.80	0.051	7.7
1993 RO	31.49	47.36	39.42	0.201	3.7
1993 RP	34.86	43.80	39.33	0.114	2.6
1993 SB	26.75	52.16	39.45	0.322	1.9
1993 SC	32.14	47.19	39.67	0.190	5.2
1994 ES_2	39.84	52.09	45.96	0.133	1.1
1994 EV_3	41.32	44.71	43.01	0.039	1.7
1994 GV_9	41.89	45.43	43.66	0.041	0.6
1994 JS	32.70	53.07	42.88	0.238	14.0
1994 JV	35.25	35.25	35.25	0.0	18.1
1994 JQ_1	43.00	45.28	44.14	0.026	3.7
1994 JR_1	34.74	44.91	39.83	0.128	3.8
1994 TB	26.89	52.07	39.48	0.319	12.1
1994 TG	42.25	42.25	42.25	0.0	6.8
1994 TH	40.94	40.94	40.94	0.0	16.1
1994 TG_2	42.45	42.45	42.45	0.0	2.2
1994 VK_8	43.45	43.45	43.45	0.0	1.4
1995 DA_2	32.14	40.55	36.35	0.116	6.6
1995 DB_2	40.58	46.41	43.49	0.067	4.3
1995 DC_2	45.21	45.21	45.21	0.0	2.1
1995 FB_{21}	42.43	42.43	42.43	0.0	0.7
1995 GJ	39.01	46.81	42.91	0.091	22.9
1995 GA_7	34.75	44.16	39.46	0.119	3.5
1995 GY_7	41.35	41.35	41.35	0.0	0.9
1995 HM_5	32.52	46.55	39.53	0.178	4.6
1995 KJ_1	43.47	43.47	43.47	0.0	2.7
1995 KK_1	31.98	46.97	39.48	0.190	9.3

agent); and Anne (Smiley's wife). But the unofficial nicknames had to stop once the list started growing too speedily. At the time this article went to press, 28 large objects have been sighted, situated between 35 and 46 AU. Jewitt, Luu, and University of Hawaii graduate student Jun Chen discovered 21 of them. And as the known population grows, astronomers are building a more confident picture of the Kuiper disk.

The disk's total population could consist of as many as ten billion objects, most of them small, but a few tens of thousands are likely to be at least 100 kilometers across. The fact that the Kuiper disk is not perceptibly tugging on the Pioneer and Voyager spacecraft as they fly through the outer solar system suggests that no more than five Earth masses can be tied up in the disk.

This past June astronomers using the Hubble Space Telescope reported they may have sighted some of the smaller bodies, comet-sized chunks about ten kilometers wide (see "First Drops in a Comet Reservoir," October 1995). Luu and Jewitt are hoping to check this finding with the 10-meter Keck Telescope on Hawaii's Mauna Kea. At 28th magnitude, such objects should be observable with Keck. If confirmed, this would prove that short-period comets originate in the Kuiper disk.

"The things that astronomers are learning about the Kuiper belt are beyond what we had dreamt," says Luu. "When we started on our survey, we just wanted to know if the outer solar system was empty. And if so, why? But now some very interesting questions are being answered by the new evidence."

There's the matter of Pluto, for instance. "The confirmation of the Kuiper belt changes our perception of the solar system," says Luu. "What we thought of as a planet is probably just the biggest member of a rather large population of objects." Pluto moves in a particular orbit — a special "resonance" at the innermost edge of the Kuiper disk — that remains quite stable as it weaves in and out of Neptune's orbit. Pluto orbits the Sun twice each time Neptune goes around three times.

Pluto's moon, Charon, likely came from the Kuiper disk as well. Indeed, several of the Kuiper-disk objects that Jewitt and Luu have discovered are in stable orbits at distances similar to Pluto's (around 40 AU), which inspired Jewitt to dub them "Plutinos." In a way, Neptune acts as a gravitational shepherd, its very presence at a distance of 30 AU from the Sun sets up a series of stable and unstable orbits within the Kuiper disk.

The objects in unstable orbits are prime candidates to become future comets, specifically the short-period comets that periodically orbit the Sun every 20 or so years in the inner regions of the solar system. Computer simulations suggest that Neptune acts as the gatekeeper, its gravity drawing the cometary bodies in from the Kuiper disk and setting them up in an orbital dance around the outer planets. If these objects survive and get near Jupiter, though, their fate is sealed:

Jupiter's powerful gravitational pull either sends them in toward Earth, ejects them out of the solar system entirely, or, like Shoemaker-Levy 9, captures them once and for all.

Theorists have been modeling these movements on computers for years and are elated by the new wealth of observational data. Jewitt credits Luu for forging unifying links between objects that were once considered separate and distinct in the outer solar system. "I'm pretty critical, but this description fits — she's a superstar," asserts Jewitt. "She's building bridges in a pioneering field."

"I don't think it would have been possible anywhere else to go from a refugee to a professorship."

The once mysterious object named Chiron particularly interests Luu (see "Chiron: Interloper from the Kuiper Disk," August 1994). Discovered in 1977 out near Saturn, this interloper was first classified as an asteroid, even though it was far from an asteroid's usual territory, the vast expanse between Mars and Jupiter. But a decade later reports came in that Chiron was fluctuating in brightness, a sure sign of cometary activity. Five other objects that cross the orbits of the giant planets have since been found: Pholus, 1993 HA_2, 1994 TA, 1995 DW_2, and 1995 GO. To Luu and others, these objects, now called Centaurs, serve as the missing links between the Kuiper disk and short-period comets; they are the latest icy chunks to have left the disk and ventured into the established solar system.

"Pholus gained fame because it was so red," points out Luu, "one of the reddest things in the solar system after Mars." Laboratory studies suggest that organic materials have built up over the icy body due to irradiation by the high-energy particles that fly about in space. Interestingly, 1992 QB_1 is also very red, which means it may share a common origin with Pholus.

"What we're most likely seeing in these Kuiper belt objects are pristine comet nuclei before they develop their obscuring coma," explains Luu. But the Kuiper disk objects are not all red; the bodies detected so far, in fact, display a wide variety of colors. It's possible that whenever some of these objects collide they are fracturing their outer mantles and exposing their interiors to various degrees.

"These objects," says Luu, "are the most primitive material to be found in the solar system, formed when the solar system was born. So, by studying them, we get to look back in time, much the way cosmologists look back in time by observing more and more distant galaxies. Theoretically, we might be able to work backward and determine what the original solar nebula was like."

The following sites on the World Wide Web provide up-to-date orbital information on Centaurs and Trans-Neptunian objects:

http://cfa-www.harvard.edu/cfa/ps/lists/Centaurs.html
http://cfa-www.harvard.edu/cfa/ps/lists/TNOs.html

Jon Chase/Harvard University

With the discovery of 1992 QB_1, Luu's professional life was soon devoted to the study of the Kuiper disk, first as a Hubble Fellow at Berkeley and Stanford and now as an assistant professor at Harvard. But travel is her passion. It's the one subject, aside from science, that she talks about with ease and a ready smile. Her travel stories are plentiful: her prowess at moving about Europe without a passport as a student; her visit to Nepal during monsoon season; a trek to Tibet and her first taste of yakburgers. She recently returned from a trip to Mongolia.

Each exotic journey only reaffirms to her what it means to reside in America, where a foreign ancestry is more readily accepted. "I don't think it would have been possible anywhere else to go from a refugee family to a professorship at a prestigious university," she says. Recent cuts in government-sponsored research, the kind that supported her rise through the academic ranks, greatly concern her. "I worry how it will affect the education of less-privileged young people. I know what it's like for them firsthand."

Currently, she and Jewitt are extending their searches and tracking down the details of the Kuiper-disk objects: their colors, shapes, rotational characteristics. Jewitt and Luu's collaboration has now lasted nearly a decade. "We're well matched," says Luu. "When we get to the telescope, we have the routine down pat. David watches over the instrumentation, such as setting up the filters and such, while I take care of the computing." Only the choice of CDs is a bone of contention: Jewitt, five years older than Luu, likes to listen to his deathcore rock music while observing ("It's the kind of music that Bob Dole and his pals would like to ban," says Jewitt). Luu, who plays the cello, prefers classical.

But whatever their choice of music within the control room, their work is allowing the music of the spheres to be heard a little farther out, past Pluto and beyond. □

Massachusetts-based science writer Marcia Bartusiak has been reporting on physics and astronomy for more than a decade. Her most recent book, Through a Universe Darkly *(HarperCollins/Avon), discusses the search for the elusive dark matter.*