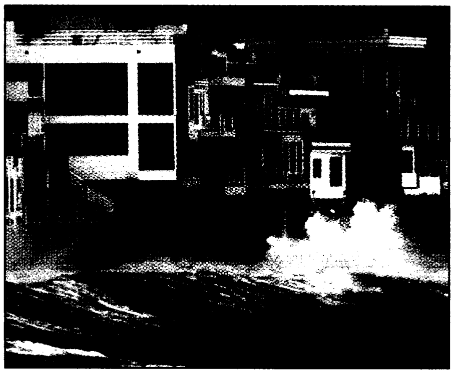
coupled models Barnston rated called for at least moderate warming in the tropical Pacific by the fall of 1997. The NCEP model, perhaps the most sophisticated of the group, predicted the strongest warming of any model, empirical or dynamical, albeit still only half the strength of the real-world event. A fifth sophisticated coupled model, run by the European Center for Medium-Range Weather Forecasts (ECMWF) in Reading, England, didn't fit Barnston's scoring because it offers predictions only 6 months ahead. But it did exceptionally well in calling for a rapid warming relatively early in 1997—a hallmark of this El Niño—and by June the ECMWF model had correctly predicted the eventual end-of-year peak temperature.

Not only did the big coupled models successfully predict El Niño's timing, they helped human forecasters do their best job ever of predicting its dramatic effects on regional weather patterns. Using their coupled model as a starting point and adding their experience with past El Niños, CPC forecasters predicted in November that in December, January, and February precipitation would be heavy coast to coast in the southern United States and light in the Ohio Valley and Montana—and generally they were right. They also predicted unusual warmth across the northern third of the United States, and again they were right. On a scale of forecasting skill that runs from 0 (no better than chance) to 100 (perfection), the precipitation forecast scored 36. That's a major accomplishment, for precipitation forecasts by the current long-range forecasting program have been stuck at 0 since they began in 1995 (*Science*, 23 December 1994, p. 1940).

Worldwide, the models also helped weather forecasters get it largely right. Dry weather struck Indonesia, northern South America, and southern Africa, and heavy rains hit East Africa, Peru, and northern Argentina. The only major failed predictions were those of a weak Indian monsoon and drought in northeast Australia.

Forecasters concede that the overwhelming power of this El Niño—one of the two strongest of the past 120 years—probably accounts for much of their success at predicting how it would alter regional weather; effects that might have been lost in the noise during a milder event stood out clearly. But they also point to signs of surprising predictive power in the coupled models. Tim Stockdale of the ECMWF notes that their model successfully predicted heavy summer rains in southern Europe and a mild winter across Europe, even though El Niño's effects there were thought to be subtle and unreliable. "The model seems to give us not just the standard El Niño," he says, "but also the difference between this event and others."

Forecasters will soon have the chance to test their models again. El Niño is only one-half of the climate cycle in the equatorial Pacific; its less famous sibling is the unusual cooling of tropical waters dubbed La Niña. It too has effects on weather in the tropics and around the world, although they are the opposite of El Niño's and are therefore less dramatic; parching South America's coastal deserts is not as devastating as is drowning them with torrential rains.



REED SAXON / AP PHOTO

Making waves. El Niño's force crashed into California beachfront homes last December.

"We've got a test ahead of us: exactly when La Niña may start," says meteorologist Kevin Trenberth of the National Center for Atmospheric Research in Boulder, Colorado. In the past, La Niña has proved even more difficult to predict than El Niño, notes Trenberth, and moderate events, which the next one is expected to be, are harder to predict than big ones.

So far, it looks like the NCEP coupled model will either win big or suffer an embarrassing defeat. All the other models—both empirical and coupled—are predicting a return to normal ocean temperatures by late summer and a continued chilling into a full-fledged La Niña by the end of the year. But the NCEP model calls for the current tropical Pacific warmth to decline but linger through the fall. The models may have turned a corner in prediction, but their creators are still anxious about their performance. "There's still a lot of nail biting going on," says Leetmaa, noting the unexpected collapse of the Lamont model. "There are still some unknowns out there."

–Richard A. Kerr

Current El Niño forecasts from many models can be found on the World Wide Web at: www.ogp.noaa.gov/ENSO/forecasts.html

ASTRONOMY

Spying on Solar Systems in the Making

Want to see how our solar system formed? Take a ride on one of the sensitive new cameras that astronomers have been pointing at young stars. These instruments are giving scientists unprecedented views of swirling disks of dust surrounding the stars—probably the nurseries of planets like our own.

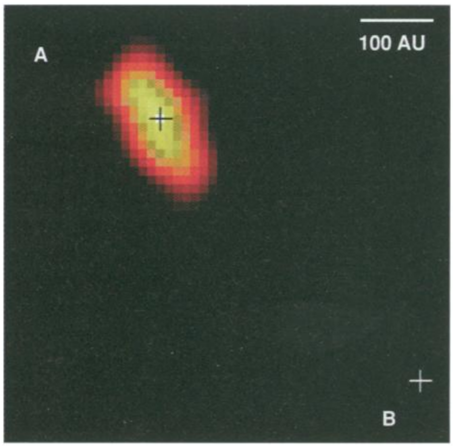
A crop of new images unveiled this week shows several disks with mysterious bulges—perhaps dust-cloaked giant planets—and others with holes torn in them, apparently by the gravitation of planets. "What we see is almost exactly what astronomers orbiting nearby stars would have seen if they had pointed a … telescope at our own sun a few billion years ago," says Jane Greaves of the Joint Astronomy Center (JAC) in Hawaii. In one case—the youngest disk ever seen around a full-grown star—astronomers may be spying on the very moment of planet birth.

These views come courtesy of a new generation of electronic detectors, sensitive to the midinfrared and submillimeter wavelengths in which the disks are brightest. Greaves and her colleagues on a British-American team led by Wayne Holland of JAC and Benjamin Zuckerman of the University of California, Los Angeles (UCLA), used a camera called SCUBA, mounted on the 15-meter James Clerk Maxwell submillimeter telescope at Mauna Kea, Hawaii, to observe the stars Vega, Fomalhaut, and Beta Pictoris. Fifteen years ago, the American-Dutch Infra Red Astronomical Satellite had shown that these three stars (and a handful of others) emit more infrared radiation than expected, probably because they are ringed with disks of warm dust.

The Beta Pictoris disk has already been photographed in visible light. But the SCUBA images, which appear in this week's *Nature*, offer the first direct views of the dust disks around Vega and Fomalhaut. The images of Vega and Beta Pictoris also show the mysterious bright blobs, at distances from the star several times greater than Pluto is from the sun. The view of Fomalhaut shows that the disk peters out close to the star. The missing dust, says Holland, "might have formed rocky planets like the Earth."

The stars that host those disks are all several hundred million years old—well past prime planet-forming age. But two other groups of astronomers have now made a similar finding around a much younger star, HR4796A, in the southern constellation Centaurus. Last month, using a midinfrared camera called OSCIR on the 4-meter telescope at the Cerro Tololo InterAmerican Observatory in Chile, Ray Jayawardhana of the Harvard-Smithsonian Center for Astrophysics and his colleagues from the University of Florida, Gainesville, spotted a flattened dust disk around the star. At a mere 10 million years old, the star is a "perfect [age] for planets to be forming in its disk," says Jayawardhana. A second team, from the California Institute of Technology and Franklin and Marshall College in Lancaster, Pennsylvania, independently photographed the disk with the 10-meter Keck II Telescope on Mauna Kea. Both groups announced their findings at a press briefing last Tuesday.

Earlier measurements by Michael Jura of UCLA had suggested that HR4796A has a dust shroud in which planets could be coalescing. Jura couldn't see the disk directly, but by measuring the infrared brightness of the star at various wavelengths, he calculated that it is surrounded by dust with an average temperature of about 110 kelvin. Because dust close to the star would be much warmer, Jura concluded that the dust must be sparse in the inner regions of the disk, perhaps because planets are forming there. Astronomers are also intrigued by the discovery because, like more than half of the stars in our galaxy, HR4796A is part of a binary star system. It has a faint companion star orbiting it at a distance of some 75 billion kilometers. Some theorists had thought that the gravitational effects of a companion might prevent a star from sprouting a protoplanetary disk.



R. JAYAWARDHANA ET AL.

Planetary nursery. The HR4796A dust disk. Crosses indicate the star and its companion.

The HR4796A disk implies that this restriction doesn't hold, at least for binaries as widely separated as this one. Together with the holes and bulges seen in the other stars' disks, it suggests that once a star has a dust disk, planets are likely to follow, says Rens Waters of the University of Amsterdam. "Apparently, it's not hard to make planets," he says. "As soon as a star is surrounded by a disk of gas and dust with the right density and composition, you end up with a solar system."

–**Govert Schilling**

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.

GEOCHEMISTRY

Catalytic Explanation for Natural Gas

DALLAS—Frank Mango believes that the textbook version of how natural gas forms in Earth's crust is all wrong. As geology books tell the story, natural gas deposits occur at or near hot spots where high temperatures break down the long hydrocarbon chains in petroleum to the short hydrocarbons found in natural gas: methane, ethane, propane, and butane. But in recent years, Mango, a geochemist at Rice University in Houston, has argued that it's not heat that breaks down petroleum but catalytically active metals in the ground. At a meeting of the American Chemical Society here earlier this month, Mango offered new evidence to support this view: laboratory results showing that the catalytic breakdown of petroleum produces component gases with the exact same mixture of heavy and light carbon isotopes as is found in natural gas deposits.

"I think he's on to something," says Everett Shock, a geochemist at Washington University in St. Louis, of Mango's latest work. But not all geochemists are won over to Mango's ideas. Martin Schoell, a geochemist and natural gas expert with the Chevron oil company in La Habra, California, says he finds Mango's experiments "elegant and very interesting." But, he adds, "I feel his mechanism does not explain what we observe in nature." In particular, it has trouble explaining the relative amounts of the four component gases of natural gas in certain types of rock formations.

Ironically, it was the distribution of the component gases that first pushed Mango toward the notion that catalytic metals must be involved in the creation of natural gas. In most natural deposits, methane comprises at least 80% of the total gas present, with the other light hydrocarbons accounting for the rest. Yet, when elevated temperatures are used in the lab to break down petroleum into lighter hydrocarbons, the result is a very different mix, with methane making up between 10% and 60% of the total. Other lab studies suggest that at temperatures at which petroleum is thought to break down in the Earth—between 150 and 200 degrees Celsius—the heavy hydrocarbons are so stable that this mechanism cannot account for the formation of natural gas even over the eons of geologic time.

In 1992, Mango and his Rice University colleagues suggested that transition metals such as nickel and vanadium, which are invariably found in petroleum, may act as catalysts to speed the reactions along. Since then they've also shown that the types of rock where natural gas is commonly found carry transition-metal compounds that are catalytically active and that passing a stream of petroleum through these rocks liberates methane and other light hydrocarbons in the same proportions that are commonly found in natural gas reservoirs deep in the Earth.

At the Dallas meeting, Mango described new lab experiments that further bolster his hypothesis. He looked at the isotopic composition of the gases that were formed as petroleum was catalytically broken down into lighter hydrocarbons. In typical natural gas deposits, the components not only follow a standard distribution pattern, but each gas typically has a distinctive ratio of heavy to light carbon isotopes—carbon-13 to carbon-12. Methane, for example, is richer in carbon-12, while the heavier gases contain progressively more carbon-13. And when Mango catalytically broke down petroleum using nickel and cobalt catalysts, he found that the product gases came out with the most common isotope mixes found in natural deposits. This supports but doesn't nail down the theory, says Mango, as isotopic measurements from some heat-driven petroleum breakdown experiments produce similar results.

Schoell argues that the catalytic mechanism doesn't explain everything. Three years ago, for example, he and his colleagues published a study of a natural gas deposit in North Dakota, known as the Bakken formation. It is thought that most natural gas arises in source rocks that are rich in organic matter and then migrates through porous rocks to a reservoir where it's confined. In the Bakken formation, however, the natural gas did not filter to a new home but has remained locked in the source rock. And when Schoell and his colleagues looked at the distribution of component gases and their isotopic concentrations, they found that they closely matched the results of pyrolysis experiments, the lab tests which simply use high temperatures to transform petroleum to natural gas. "If we look into the kitchen of natural gas formation, we find that they are not methane-rich gases but the gases we see in pyrolysis experiments," says Schoell.

Schoell suggests that natural gas deposits found in reservoir rocks end up rich in methane because as the gases flow through the porous rocks, the higher hydrocarbons are filtered out. Regions like the Bakken formation, he adds, represent just the first step in