sults may change as the input climate forcings and the model itself are improved. One uncertain forcing is ozone change: Recent satellite data (*14*) suggest that the tropopause ozone depletion used in the figure was too great, implying that upper level cooling may be reduced with better ozone data. Forcing by anthropogenic aerosols, which may cause tropospheric cooling, is excluded for want of aerosol data. The most relevant deficiency of the model itself is probably its poor vertical resolution, with only one to two layers in the stratosphere: This is believed to reduce the model's stratospheric response to a climate forcing.

Despite the caveats that must accompany both the data and models, the convergence of satellite data, surface data, and models is an important step toward improved understanding of climate change. We expect the correction of Wentz and Schabel to survive scrutiny, at least to first order, and that the resulting temperature distributions will lead to better understanding of climate sensitivity to forcings. In crediting Wentz and Schabel for discovering the satellite altitude effect, we should not forget the credit that Christy and Spencer deserve for pioneering MSU analysis and bringing it to the point that a correction of 0.1°C has such a large effect on interpretations of climate change.

The bottom line of this convergence could be a sea change in the global warming debate. Until now, the MSU data have been the principal refuge for those who deny the reality of global warming. We believe that warming trends of both the surface and troposphere are now sufficiently clear that the issue should no longer be whether global warming is occurring, but what is the rate of warming, what is its practical significance, and what should be done about it.

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MEETING ASTROPHYSICS

# Protostars and Planets

**Sara S. Russell and Alan P. Boss**

At the start of the century, planets and comets were nuisances that fogged the plates of astronomers and interfered with the study of stars. As the century draws to a close, the question of the origin of planets and their host stars is increasingly a quest of astronomers. Since 1995, when Geneva Observatory astronomers Michel Mayor and Didier Queloz found that the star 51 Pegasi wobbled because of a companion with a mass half that of Jupiter, the pace of discoveries and shifts in thinking on this subject has been swift. At a recent conference (*1*) in Santa Barbara, California, astronomers, planetary scientists, and meteoriticists met to review progress made on star and planet formation in the last decade. Improved observational tools have provided many exciting new discoveries (see figure), including our first peeks at other planetary systems, both mature and in the making.

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One recent observational finding has been proof of the existence of the Kuiper Belt (*2*), a swarm of icy minor planets at the edge of our solar system, at a distance of about 30 to 50 AU (1 AU = distance between Earth and the sun) from the sun. Since the first Kuiper Belt object was discovered in 1992, astronomers have found about 70 such objects. The mass of the Kuiper Belt is now estimated to be about a tenth of the mass of Earth, which is only 1% of the mass inferred to have been present in the early outer solar system. At the meeting, David Jewitt (University of Hawaii) explained that the reason for mass loss in this region is unclear but may be due to collisional grinding of the bodies, producing dust that is subsequently lost.

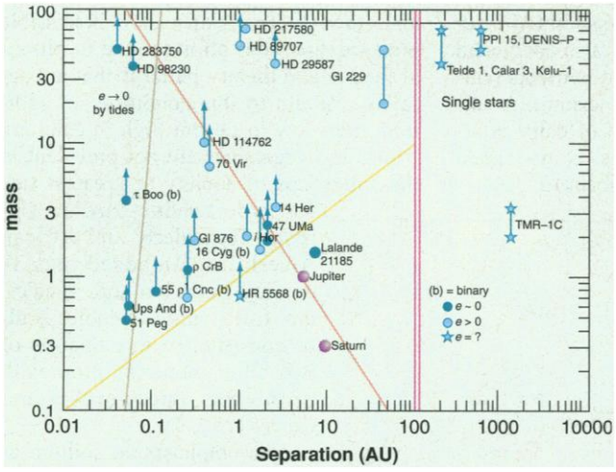
This explanation for the Kuiper Belt's paucity of mass agrees well with observations of dust belts around other stars such as Beta Pictoris, where the dust is thought to come from collisions between more massive, unseen bodies. Jane Greaves (Joint Astronomy Centre, Hawaii) and co-workers reported imaging dust emission around the nearby star Epsilon Eridani, a star only slightly less massive than the sun. Most of the dust lies between 35 and 75 AU from the star and has a combined mass of between 0.01 and 0.4 times the mass of Earth. Inhomogeneities in the distribution of dust may point to the possible presence of planets in this system, perhaps including a giant planet with an orbit at least as large as that of Neptune. Epsilon Eridani is between 0.5 and 1 billion years old, less than a quarter of the age of the sun, and it may provide an early analog to our own solar system.

Luis Rodriguez (Universidad Nacional Autonoma de Mexico, Mexico) and colleagues have used the Very Large Array of radiotelescopes to image much younger circumstellar disks with unprecedented spatial resolution. Rodriguez was able to image disks with masses of 0.03 and 0.06 solar masses around the binary protostars at the center of L1551 IRS5, the prototypical bipolar outflow. These disks, with radii of only about 10 AU, may be massive enough to be capable of forming giant planets rapidly, in which case a giant planet that forms near the edge of one of the disks is likely to be ejected outward because of gravitational tugs from the other protostar. The L1551 IRS5 system might then be an example of the type of system presumed necessary to account for the possible ejection of a giant planet (TMR-1C) from a similarly sized and extremely youthful binary protostar system, reported by Susan Terebey (Extrasolar Research Corporation) and colleagues.

Two new extrasolar planets were discussed at the meeting, bringing the total number of known extrasolar planets to about a dozen. One, found around the star 14 Herculis, was discovered by Mayor and co-workers. This planet has the longest orbital period (4.4 years) of the planets discovered by the radial velocity method. The second planet orbits Gliese 876, the lowest mass star (1/5 of the sun's mass) so far discovered to have a planet. Gliese 876's planet was found independently by groups led by Xavier Delfosse (Geneva Observatory) and Geoffrey Marcy (San Francisco State University). Interestingly, there is a strong correlation between the metallicity of these stars (the abundance of elements heavier than helium) and the presence of orbiting planets: Essentially all of the stars with planets are metal-rich.

Brown dwarf stars, too low in mass to undergo sustained nuclear fusion, appear to orbit around less than 1% of solar-type

S. S. Russell is at the Natural History Museum, Cromwell Road, London, SW7 5BD, UK. E-mail: sarr@nhm.ac.uk. A. P. Boss is at the Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015–1305. E-mail: boss@dtm.ciw.edu




**Other planets.** Extrasolar planets and brown dwarfs discovered to date, shown as a function of their mass and separation from their central star. The objects to the right of the vertical double lines are not bound to any star. Eighty Jupiter masses is the dividing line between normal and brown dwarf stars. Objects detected by the radial velocity method generally have only lower limits on their masses. The oblique lines depict the approximate sensitivities of current searches by the radial velocity (light orange line) and astrometric (dark orange line) methods. The dividing line between brown dwarf stars and giant planets seems to fall at about 5 Jupiter masses. Objects to the left of the green line are so close to their primary star that they have lost all traces of any initial orbital eccentricity (*e*) because of tidal dissipation and resulting orbital circularization.

stars, whereas the giant planets found to date imply a frequency of at least 4%. The relative rarity of brown dwarf companions is consistent with the statistics for normal stars, which show that most stars have stellar companions no less than about 1/10 of their own mass; solar-type stars are about 12 times more massive than the most massive brown dwarf stars, making a solar-type star an unlikely host for a brown dwarf. The best place to find a brown dwarf star may be in orbit around another brown dwarf star. Gibor Basri (University of California, Berkeley) and his colleagues showed that the brown dwarf star PPl 15 is actually a double-lined spectroscopic binary system, the first such binary brown dwarf system discovered.

Twinned and multiple star systems are now known to be extremely common. Andrea Ghez (University of California, Los Angeles) pointed out that 50 to 80% of stars have stellar companions, with separations peaking at a distance of about 30 AU. The abundance of binary systems varies between star-forming regions, and in some regions the frequency is twice that of nearby solar-type stars. Five of the extrasolar planets discovered to date are in binary star systems—planets are not limited to single stars like the sun.

Although the rate of new discoveries has been fast and furious, the meeting underlined many gaps in our knowledge of planetary system formation and provided a sense of optimism that the next generation of telescopes will produce yet more fascinating results that will help us to understand the formation of our solar system and its relatives.

**References and Notes**

1. The Protostars and Planets IV conference was held at the University of California, Santa Barbara, from 5 to 12 July. Reviews presented at the meeting will be published as a part of the Space Science Series by the University of Arizona Press in 1999. The volume will be edited by V. Mannings, A. Boss, and S. Russell.
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PERSPECTIVES: BIOMEDICINE

# Diet and Blood Pressure—The Paradigm Shift

**David A. McCarron**

Hypertension—a serious health problem for industrialized societies—contributes significantly to the risk of coronary heart disease, congestive heart failure, stroke, and kidney failure. Among vertebrates, humans are nearly unique in their natural propensity to develop elevated arterial pressure, a fact attributed to both genetic and environmental factors. Only certain highly inbred strains of rodents and genetically engineered animals also spontaneously exhibit hypertension. Public policy has generally recommended that blood pressure can best be controlled by restricton of sodium chloride intake and with medication (*1*). Recent research has, however, emphasized the powerful role of total diet in the etiology and treatment of hypertension, suggesting that the focus of current public policy regarding nutrition and blood pressure is too narrow (see News story on page 898).

The author is at the Oregon Health Sciences University, Portland, OR 97201, USA. E-mail: mccarron@ohsu.edu

Limitation of sodium chloride in food has historically been the dietary mantra of those who set nutritional policy for hypertension. Nevertheless, the importance of salt in the pathogenesis of hypertension has long been debated (*2–4*) and remains undetermined (*5*). The intense focus on sodium began when early studies indicated that salt intake increased blood pressure. These studies, many conducted decades ago, included epidemiologic surveys in primitive societies, clinical trials in patients with kidney disease, and animal investigations in which sodium intake levels cannot be realistically extrapolated to humans (*6*). Many of these studies have since been discounted for design and methodologic flaws. But even where the methodology is sound, sodium intake cannot be linked to hypertension or higher population-wide blood pressure (*7*).

Two recent meta-analyses of randomized controlled trials—one examining the effects of sodium restriction (*8*) and the other of calcium supplementation on arterial pressure (*9*)—provide compelling evidence that adequate intake of minerals, rather than restriction of sodium, should be the focus of dietary recommendations for the general population. Assessing 56 trials of sodium restriction, Midgley *et al.* (*8*) concluded that individuals with normal blood pressure gained nothing from limiting sodium intake and that only older (>45 years) hypertensive people might benefit, a conclusion recently confirmed by other investigators (*5*). Midgley *et al.* also reported that the magnitudes of the blood pressure reductions were not consistently related to the amount of sodium intake, indicating that confounding factors were contributing to the changes in blood pressure. Indeed, in a meta-analysis of calcium supplementation trials, Bucher *et al.* (*9*) identified a small but consistent drop in blood pressure when normotensive and hypertensive persons consumed more calcium. They speculated that baseline calcium intake or increased biological need for minerals might be responsible for the blood pressure variability not otherwise accounted for in their analysis.

These two reports presaged the outcomes of two large clinical trials from the NIH, published in 1997 (*10, 11*). The Trials of Hypertension Prevention (TOHP) II is the largest and longest study ever executed