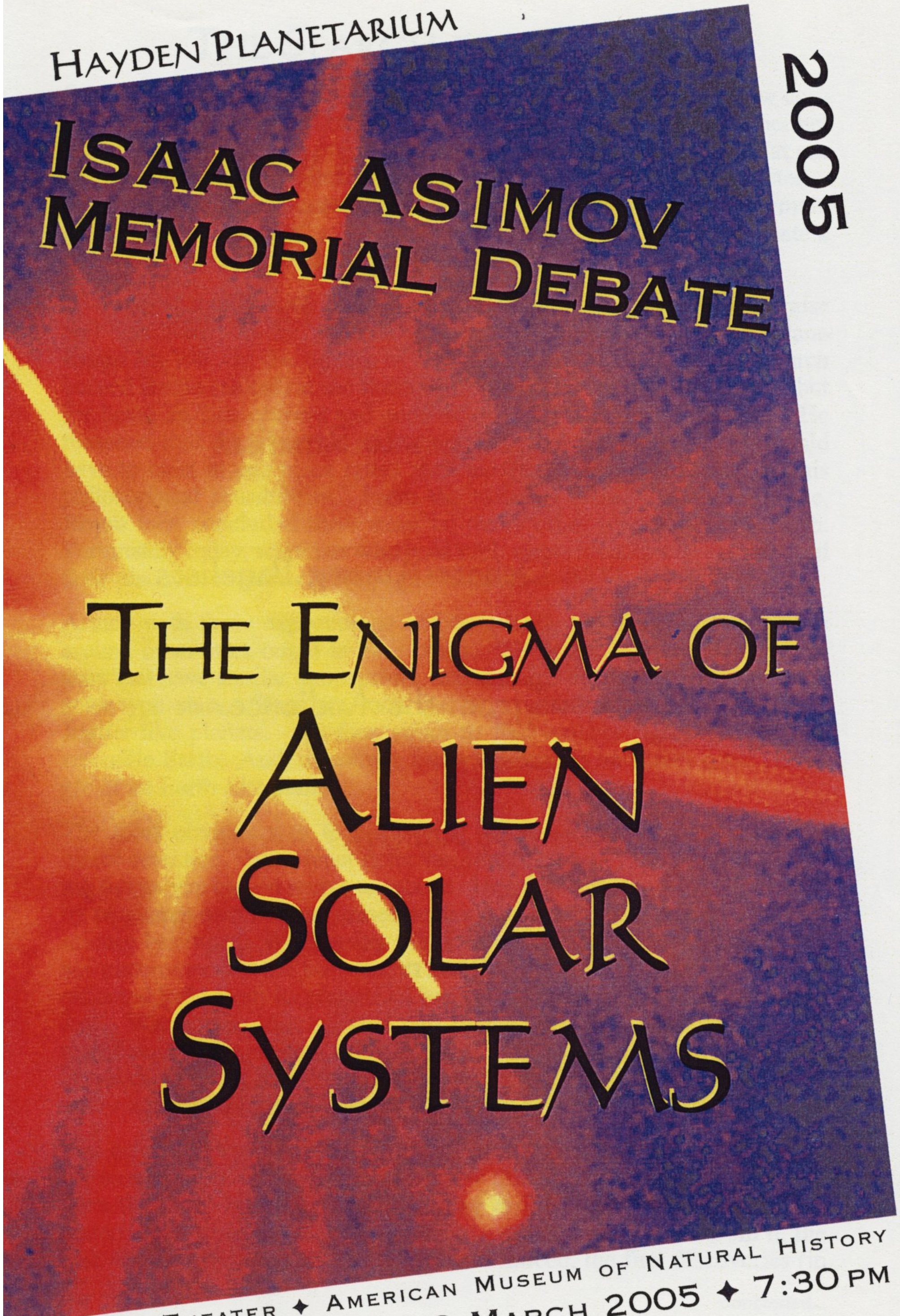
Hayden Planetarium

2005



Isaac Asimov Memorial Debate

The Enigma of Alien Solar Systems

LeFrak Theater ✦ American Museum of Natural History

Wednesday ✦ 30 March 2005 ✦ 7:30 PM

THE EVENING'S PROGRAM

Welcome & Introduction of Panelists

Opening Questions to Panelists

Directed Free Debate Among Panelists

Questions from the Audience

Closing Remarks

Adjourn

Book Sale / Book & Program Signing
Hall of Northwest Coast Indians

The Search for Planets

Often we implicitly assume that our Solar System (which we know contains life, whether or not that life can be considered intelligent) is neither special nor unusual nor peculiar. A more troublesome thought is that our Solar System is not ordinary, precisely because it possesses characteristics that led to the evolution of beings who ask these questions. I remain in the "We're ordinary" camp and proceed with the next step to create a catalog of nearby stars that make good candidate hosts for planets.

To theorize and discover other worlds was not always greeted with praise and headlines. In the year 1600, such thinking cost Brother Giordano Bruno his life. In the Square of Flowers in Rome, the Catholic Church burned Bruno (naked) at the stake — not for being an ordinary heretic but for being an "impertinent and pertinacious" heretic. Bruno's crime? He reasoned that the Universe must be infinite because otherwise it would have to exist in one place rather than another, which conflicted with his philosophical sensibilities. From the vastness of this infinite universe, Bruno then concluded there must be many other worlds beyond Earth. Fortunately today, scientists who hold such views are allowed to live. And their discoveries garner front-page headlines.

Armed with these expectations and templates, the discovery of planets around other stars ought to be a cinch. We first look in the Galaxy for stars that have similar temperature, size and age as the Sun. We call them solar-type stars. Then we look for large gaseous planets. These are Jupiter-like planets. We then strain to find smaller rocky planets that resemble Earth. And, of course, Earth happens to be a very good example of an Earth-like planet.

The most obvious way to discover a planet around another star is by direct detection. But planet detection remains one of the most challenging things you can do with a telescope. Heroic efforts have been launched by persistent astronomers armed with clever techniques and state-of-the-science hardware. When using the visible-light part of the spectrum, it's not uncommon for the host star to be 100 million times brighter than the reflected light from its planets. Therein lies most of the detection problem. When using the infrared part of the spectrum, however, the star might be only ten million times brighter. The energy radiated by planets, however feeble it may be, typically peaks in the infrared, which maximizes a planet's chances of being detected.

You might also want to detect a planetary system in the act of forming. Current theories of star formation show that as a gas cloud collapses to form the host star, an extended orbiting disk of gaseous, rocky, and icy material can be left behind. Like the planets that are formed from it, the disk can also be detected in the infrared. Indeed, the first discoveries (in

continued...

ABOUT THE PARTICIPANTS

PANELISTS

FRITZ BENEDICT is Senior Research Scientist at McDonald Observatory, University of Texas. He received a B.S. in both Physics and Astronomy from the University of Michigan in 1967, followed by a Ph.D. in Astronomy from Northwestern University in 1972. Benedict's use of astrometry (the precise measurement of angular distances between objects in the sky) from the Hubble Space Telescope resulted in the serendipitous discovery of the lowest mass extrasolar planet now known. He now serves as Co-Investigator on the NASA Space Interferometer Mission (SIM) Mass-Luminosity Key Project. SIM, when launched, will permit discovery of earth-mass objects around a few nearby stars—but it will also find and characterize many planetary systems, allowing a better comparison with our own Solar System.

R. PAUL BUTLER is a Staff Scientist at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. He received his B.S. in Chemistry and M.S. in Physics from San Francisco State University and his Ph.D. from the University of Maryland. With his long time collaborator Geoff Marcy (U.C. Berkeley), Butler has discovered two-thirds of the known extrasolar planets. He designed and built Lick Obervatory's Iodine absorption cell system, which resulted in the discovery of five of the first six known extrasolar planets: the instrument has been requested by the Smithsonian Institution upon its retirement.

PETER GOLDREICH is Lee A. DuBridge Professor of Astrophysics & Planetary Physics at Caltech. After receiving his B.S. in Engineering Physics in 1960 and his Ph.D. in Physics in 1963, both from Cornell University, he served as a Postdoctoral Fellow at Cambridge University. A longtime member of the National Academy of Sciences, he received the Gold Medal of the Royal Astronomical Society in 1993 and National Medal of Science in 1995. Goldreich's work on magneto-hydrodynamic turbulence deeply informs the processes by which planetary systems form, and he has studied the evolution of planetary systems over time.

Scott Tremaine is a Professor in the Department of Astrophysical Sciences at Princeton University. Born in Toronto, he received his B.A. in Physics from McMaster University in 1971 and his Ph.D. in Physics from Princeton in 1975. His various research interests include the study of planetary formation and dynamics, which includes the evolution of planetary orbits and the manner in which they can become disrupted over time. He has also written "Planet-finding prospects for the Space Interferometry Mission (SIM)," in which he simulated SIM observations and estimated the ability of SIM to detect planets with given masses and orbital periods.

Margaret Turnbull is a National Research Council Postdoctoral Fellow at the Carnegie Institution of Washington. Hailing from Antigo, Wisconsin, she did her Bachelor work at the University of Wisconsin-Madison in Astronomy and Physics, then relocated to the University of Arizona for Ph.D. work in Astronomy and Cell Biology. Turnbull collaborated with Dr. Jill Tarter of the SETI Institute on a catalog of "habstars" that, based on their astrophysical characteristics, could be habitable to life as we know it on Earth. Turnbull has since expanded this work for NASA's Terrestrial Planet Finder (TPF) mission, which will search for Earth-sized planets in the habitable zones of nearby stars.

Host & Moderator

Neil deGrasse Tyson is the Frederick P. Rose Director of the Hayden Planetarium. Born and raised in New York City, Tyson attended the Bronx High School of Science and later earned his B.A. in Physics from Harvard and his Ph.D. in Astrophysics from Columbia. In addition to professional publications, Tyson is an essayist for *Natural History* magazine. Among his seven books is his memoir *The Sky Is Not the Limit* and the companion book to the 2004 PBS-NOVA mini-series *Origins*, co-written with Donald Goldsmith. Last year, President Bush appointed Tyson to serve on a nine-member commission on the Implementation of the US Space Exploration Policy.

the 1980s) of stuff orbiting stars other than the Sun, were of these proto-planetary disks.

But for studies of proto-planetary disks, many questions remain unanswered. Are they more predominant around low mass stars or high mass stars? Suppose the system gives birth to binary or multiple stars (which account for nearly half of all star systems in the Galaxy); what then becomes of the disk? What determines how far away from the host star a massive planet like Jupiter can form? Is a nine- or ten-planet system common? Or does the typical planetary system have just one or two (or thirty or forty) planets? Are there some stars that form disks but that never collapse further to form planets? Are we asking the right questions?

The best we can do now is collect as much data as is technologically possible and slowly fill in the holes left by our ignorance of planet formation.

A powerful method to detect planets, but does not result in a headline-ready picture, uses the time-honored Doppler shift in the frequency of light from the host star — named for Christian Johann Doppler, the nineteenth century German physicist who first measured a shift in the pitch of sound of a train whistle as it approached and then receded. The shift turned out to be a general feature of all waves emitted (or reflected) by something in motion, including light waves.

Contrary to common expectations, planets do not orbit stars that are fixed at the center of the system. Both planets and stars orbit their common center of gravity, which is not always (in fact, is almost never) at the center of the host star. As planets swing in their orbits, the star responds by making tiny loops of its own. The more massive the planet, and the larger its orbit, the bigger the loop that the star makes in response. When seen approximately edge-on, the wavelength (or frequency) of a star's light will shift back and forth as the star executes its tiny orbits around the system's center of gravity. The Doppler shift allows us to deduce the corresponding back-and-forth motion of the host star and infer the presence of one or more planets. When there is a single planet, the Doppler shift is simply periodic. For multiple planets, however, the Doppler shift can have a complicated signature of multiple jiggles, which must be decoded to infer the exact number of planets that are responsible.

Unfortunately, Earth-size planets do not induce a large enough jiggle in a host star to be detected with the limited precision of current instruments. Earth is less than one three-hundred-thousandths the mass of the Sun. Understandably, Jupiter-sized planets do leave a detectable Doppler signature in the light of the host star, which accounts for why nearly all of the detected planets around ordinary stars were Jupiter-size planets: they are simply easier to find.

The number of exosolar planets, now rising through 140, includes several host stars that are bright enough to be seen in the nighttime sky with binoculars. Those that initially received quite a bit of press included 51 Pegasi, 47 Ursae Majoris, and 70 Virginis, each discovered by the American planet-hunting team of Geoffrey Marcy and Paul Butler. These genitive code-names are simply the number, in order of brightness, of the stars in the constellation Pegasus (the Flying Horse), Ursa Major (the Great Bear — a part of which we all call the Big Dipper), and Virgo (the Virgin). No surprises here. All these stars resemble the Sun in age and temperature, and sure enough, they each have a Jupiter-sized planet.

Things got weird, however, when we learned that the Jupiter-like planets around 51 Pegasi, and 70 Virginus are uncomfortably close to their host stars. We had no theory for a jumbo gaseous planet to form, much less survive, in close orbit to a host star. For a nascent planetary system we might expect the central star to compete for material with the innermost planets. We know that high-velocity gas, spews forth from newborn stars and forms strong "winds" that blow away nearby material, thus inhibiting the formation of close-in, Jupiter-style planets. The planet around 51 Pegasi is a mere 5 million miles from its host star. At one-eighth Mercury's average distance from the Sun, we thought it had no business being there.

One of NASA's stated goals is to obtain an image of a rocky (Earthlike) planet with high enough resolution to identify continents and oceans. How? With kilometer-long arrays of space-based telescopes that are programmed to function as though they were a single, large telescope with super-duper high resolution. Telescope arrays such as these are known as interferometers and have always provided, in their many applications, the highest resolution measurements of any available technology.

In selecting a planet to visit, assuming you want to discover life, much can be learned from the analysis of its atmosphere. With space-based spectrographs, you can also decode the light and deduce the chemical composition of the planet's atmosphere. The composition of Earth's air distinguishes us from the other planets in the Solar System because oxygen (O_2) is common in the presence of photosynthesis, where carbon dioxide (CO_2) gets its oxygen stripped while donating its carbon atom to the growth of life. Oxygen also allows for the development of an ozone (O_3) layer, which shields a planet's surface from harmful ultraviolet rays allowing complex molecules to thrive.

And if our sensitive spectrographs also detect smog, ozone-destroying chloro-fluorocarbons, hydrocarbon contaminants, soot from global deforestation, and localized atmospheric radiation belts, we will know for sure that we have found intelligent life.

Loosely adapted from *Origins: Fourteen Billion Years of Cosmic Evolution*, 2004, by Neil deGrasse Tyson & Donald Goldsmith, WWNorton, NY

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The late Dr. Isaac Asimov, one of the most prolific and influential authors of our time, was a dear friend and supporter of the American Museum of Natural History. In his memory, the Hayden Planetarium is honored to host the annual Isaac Asimov Memorial Debate — a panel series, generously endowed by relatives, friends and admirers of Isaac Asimov and his work. The Isaac Asimov Memorial Debate brings the finest minds in the world to the Museum each year to debate a pressing question on the frontier of scientific discovery. Proceeds from ticket sales of the Isaac Asimov Memorial Debates benefit the scientific and educational programs of the Hayden Planetarium.

2001 Theory of Everything
2002 Search for Life in the Universe
2003 Big Bang
2004 Dark Side
2005 Enigma of Alien Solar Systems

NASA Hubble Space Telescope Image of the first discovered Brown Dwarf — Gl 229B by Ben Oppenheimer, now Assistant Curator in AMNH's Department of Astrophysics

program by Stephanie L. Parello