PROBE MISSION SUCCESSFUL

After a six-year odyssey the Galileo Probe plunged into Jupiter's atmosphere at 2:04 p.m. PST on December 7. During the first two minutes of entry, the craft experienced temperatures twice as hot as the Sun's surface and deceleration forces as great as 230 g's as it was slowed by the atmosphere. The Galileo Orbiter, which entered orbit around Jupiter a few hours after the Probe's descent, recorded 57.6 minutes of data from instruments before the Probe fell silent.

Because of an unexplained 53-second delay at the start of transmission, direct atmospheric measurements started deeper in the atmosphere than originally planned (0.35 bars instead of 0.1 bars). Playback of early data from the Orbiter confirmed that all six scientific instruments onboard the Probe operated properly.

NEW RADIATION BELT DETECTED

Three hours before entry, the Energetic Particle Instrument (EPI) measured the radiation in previously unexplored inner regions of Jupiter's immense magnetosphere. It detected a new intense radiation belt between the planet's thin ring and its uppermost atmosphere. About 10 times as intense as Earth's Van Allen belts, the region contains high-energy helium ions of unknown origin.

ATMOSPHERE MEASUREMENTS

As the plunge into the atmosphere began, the Atmosphere Structure Instrument (ASI) measured temperature, pressure, and density throughout the Probe's descent. Initial results show upper atmospheric densities and temperatures that are significantly higher than predicted by most models. An additional source of heating besides sunlight appears necessary to account for them. Lower in the atmosphere, temperatures were close to those expected. The vertical variation of temperature in the 6–15 bar pressure range (about 90–140 kilometers below visible clouds) indicates the deep atmosphere is dryer than expected and is convective.

ASI also measured vertical wind speeds in the lower reaches of the atmosphere and provided evidence that the deep atmosphere is highly turbulent. Data transmis-
mission ended at an atmospheric pressure of 23 bars and a temperature of 305°F (152°C). The upward and downward winds appear to be much stronger than expected, requiring a revision of ideas about the escape of heat from Jupiter’s interior.

CLEAR TO PARTLY CLOUDY?

Visibility in the atmosphere was much greater than expected in the immediate vicinity of the Probe entry site. The Nephelometer (NEP) instrument was designed to detect and characterize cloud particles throughout the descent in the immediate vicinity of the Probe by shining a laser beam across a short distance to a small mirror deployed just outside the spacecraft and measuring the scattered and transmitted light. Initial results surprised investigators. No thick dense clouds were found, contrary to expectations based on telescopic and flyby spacecraft observations of Jupiter and simple theoretical models. In fact, only very small concentrations of cloud and haze materials were found along the entire descent trajectory. Only one well-defined distinct cloud structure was found, which appears to correspond to a previously postulated ammonium hydrosulfide cloud layer.

Variation of the amounts of sunlight and infrared radiation with depth were measured by the Net Flux Radiometer (NFR) to aid in detecting cloud layers, understanding the power sources for winds, and detecting water vapor. On a clear day on Earth, the sky is quite bright in the direction of the Sun and less bright in other directions. On a very cloudy day, the sky is almost equally bright in all directions and determining the direction to the Sun is difficult. The NFR used this effect along with the Probe’s spin to locate cloud layers on Jupiter. Large variations in sky brightness in different directions were measured until an abrupt drop-off occurred at a pressure level of 0.6 bars, indicating a layer that is most likely the ammonia clouds that form the uppermost cloud layer that we observe on Jupiter.

No other significant cloud layers were found. The hazy cloud layer detected by the NEP was not seen by the NFR experiment, nor was the cloud layer observed by the NFR seen by NEP, because the NEP measured cloud particles in the immediate vicinity of the Probe while the NFR measured clouds at a greater distance away. The simplest explanation for the results from the two cloud-detecting experiments is that the Probe entered through a relatively clear area with only patchy clouds.
WINDS AT DEPTH UNEXPECTEDLY STRONG

Heating of the ammonia cloud layer by energy escaping from the interior of Jupiter also appears to be occurring and may account for the observations of Jupiter's winds. Once again the cloud structure at the Probe entry site appears to be very different than atmospheric modelers expected. Previous studies of Jupiter's cloud motions show a very unusual wind system consisting of strong alternating east-west jetstreams. The origin of these streams is not clear, because we cannot see structure below the uppermost clouds. The Doppler Wind Experiment used the Doppler effect to evaluate the vertical variation of winds. Initial results from this experiment indicate that the winds below the clouds are 540 kilometers per hour (330 miles per hour) and do not decrease with depth as most models had predicted. One implication is that Jupiter's winds do not appear to be produced by heating from sunlight or condensation of water vapor—the heat sources that power winds on Earth. A likely mechanism for powering the winds now appears to be the heat escaping from Jupiter's deep interior.

LIGHTNING ON JUPITER DIFFERS FROM EARTH'S

The Lightning and Radio Emission Detector searched for optical flashes and
radio waves emitted by lightning discharges. No optical lightning flashes were observed in the vicinity of the Probe, but many discharges were observed at radio frequencies at distances about an Earth-diameter away from the craft. Bolts are much stronger than Earth's, but radio wave intensity suggests lightning activity is 3–10 times less than on Earth. This initial analysis implies that lightning activity on Jupiter is very different than on Earth.

**NMS YIELDS SURPRISES IN COMPOSITION**

Jupiter's composition has been thought to closely resemble the "primordial" solar system chemistry and scientists looked to direct measurements to provide clues to planetary formation and evolution processes, including the addition of materials from asteroid and comet collisions. Initial results from the Neutral Mass Spectrometer (NMS) suggest the atmosphere has less water than expected. Carbon, in the form of methane, is also less abundant, as is sulfur as hydrogen sulfide. Noble gas concentrations differ from expectations as well, including a notable depletion of neon. Little evidence for organic molecules was found. The Helium Abundance Detector found significantly less than solar abundances of helium, which may be a result of the element raining out at depths in the atmosphere as Jupiter evolves chemically over time. Ideas about the formation and evolution of Jupiter will be revised in light of these results.

**HOW TYPICAL IS THE ENTRY ENVIRONMENT?**

One important question that arises from these as well as other observations is whether the Probe's entry location is representative of most other regions of Jupiter. A simple explanation for many unexpected results is that the Probe apparently entered a rather unusual location on a quite nonuniform world.

Groundbased telescopic observations of the Probe entry site (6.5°N, 4.5°W) immediately before the Probe arrived show a region near the edge of an infrared "hot spot" where clouds appear to be much thinner or absent. Thus many of the unexpected results from the Probe instruments may reflect an entry location that is not typical of much of the jovian clouds.

**MORE DATA TO COME**

This summary of scientific findings from the Galileo Probe Mission is the result of a quick, preliminary analysis of the data. Much additional work will be done in the coming months and years. Scientific and popular publications will report further on the Galileo Probe Mission results. Additional information on the status of the data reduction and the latest results will be listed on the World-Wide Web at URL http://ccf.arc.nasa.gov/galileo_probe/.
CONFEREE PROGRAM

Technical Sessions
Technical sessions will be held at the Gilruth Center. Parallel sessions will be held in Room A (Room 104), Room B (the old gym), Room C (the new gym), and Room D (Room 206 upstairs). The preliminary program and first paragraph of the abstracts accepted for the conference are available online. Instructions for accessing this online information are included in this article.

Poster Presentations
Poster sessions have been scheduled for Tuesday and Thursday evenings from 6:30 to 9:30 at the LPI. Authors of poster presentations will be available to discuss their results in the poster area during the assigned sessions. Additionally, posters may be viewed at LPI each day of the conference. Shuttle transportation between the Gilruth Center and LPI will be available throughout the week.

SPECIAL SESSIONS

Harold Masursky Lecture
The Harold Masursky Lecture will be presented in a special plenary session at 1:30 p.m. on Monday, March 18, 1996. This year’s talk, Probing Questions About Jupiter, will be given by Dr. A. P. Ingersoll of the California Institute of Technology.

Mars Deep Interior: Geochemical and Geophysical Constraints—Special Session
Though rather detailed models have been constructed for the internal stratification of Mars, they are based on relatively few direct constraints. A number of recent developments suggest that now is a good time to reconsider some aspects of these models. Significant recent progress has been made on high-temperature and high-pressure equations of state and phase relations in candidate Mars mantle and core materials. Also, although current estimates of the moment of inertia of Mars are still model dependent, planetary orbiter and lander missions planned for the next few years will dramatically change that situation. New results relevant to the deep internal structure and composition of Mars based on laboratory experiments, spacecraft data, or modeling results will be presented in The Mars Deep Interior Special Session on Tuesday, March 19, beginning at 1:30 p.m.

Galileo Mission to Jupiter: Results from Encounter—Special Session
The Galileo probe entered the atmosphere of Jupiter on December 7, 1995. The orbiter explored the jovian system during approach and will continue to do so for almost two years. Invited talks reporting preliminary results from this historic encounter will be given in The Galileo Special Session on Monday, March 18, at 2:30 p.m. following the Masursky Lecture.

Special Poster/Display Sessions on Education
Two special poster/display sessions on education will be held at LPI on Tuesday and Thursday evenings during the regular technical poster sessions. The education special sessions will be located in and around the LPI library and will include posters, displays, computer demos, and hands-on activities.

SPECIAL EVENTS

Chili Cookoff and Barbecue Dinner
The Chili Cookoff and Barbecue Dinner will be held on Wednesday from 6:00 to 9:30 p.m. at the Landolt Pavilion. Out-of-town teams are encouraged to enter. Guest tickets may be purchased for $10.

Reception for Award Winners
A reception will be hosted by GSA on Monday at 5:30 p.m. in Conference Room A. The 1995 winners of the Stephen E. Dwornik Student Paper Awards will be honored at this time.

Computer Demonstrations and E-Mail Stations
All computer stations for demonstrations, displays, exhibits, and e-mail will be located at the LPI. The main displays will be located in the Center for Information and Research Services (library). Several stations will be available to participants for checking e-mail. The conference shuttle buses will make regular stops at LPI during the conference.

This year’s conference will begin with a reception and registration Sunday, March 17, from 6:00 to 9:00 p.m. at the Lunar and Planetary Institute. Registration will continue beginning at 7:30 a.m. on Monday morning, March 18, at the NASA Johnson Space Center. Sessions will be held at the NASA Johnson Space Center (JSC) and the Lunar and Planetary Institute (LPI) beginning at 8:30 a.m. on Monday, March 18, and ending Friday, March 22, at noon.
## 27th LPSC: GUIDE TO TECHNICAL SESSIONS AND ACTIVITIES
March 18–22, 1996

(Letter designates Gilruth Center room.)

### Monday Morning, 8:30 a.m.
- A Outer Planet Satellites
- B Ordinary Chondrites
- C Martian Atmospheric and Fluvial Processes

### Monday Afternoon, 1:30 p.m.
#### Special Plenary Session
Presentations to the 1995 Stephen E. Dwornik Student Paper Award Winners followed by Harold Masursky Lecture by A. P. Ingersoll
*Probing Questions about Jupiter*

### Monday Afternoon, 2:30 p.m.
- A Lunar Basins: Theory, Observations, and Experiments:
  - Session dedicated to the memory of S. Keith Runcorn
- B Stardust
- C Special Session: Galileo Mission to Jupiter—Results from Encounter
- D Reflectance Theory/Space Weathering Examples from the Moon

### Monday Afternoon, 5:30 p.m.
- A Reception hosted by GSA to honor the 1995 Stephen E. Dwornik Student Paper Award Winners

### Tuesday Morning, 8:30 a.m.
- A The Lunar Highlands: Macro to Micro
- B CAIs and Carbonaceous Chondrites
- C Mars: Volcanic and Tectonic Processes

### Tuesday Afternoon, 1:30 p.m.
- A Mare Basalts: Generation, Emplacement, Composition, and Distribution
- B Comets and Asteroids
- C Special Session: Mars Deep Interior
  - 3:00 p.m.: Planetary Interior Processes
- D Metal-rich Meteorites

### Tuesday Evening, 6:30–9:30 p.m.
- A Reception hosted by GSA to honor the 1995 Stephen E. Dwornik Student Paper Award Winners

### Wednesday Afternoon, 2:30 p.m.
- A Mars: Mineral Spectroscopy and SNC Mineralogy
- B From Stars to Solar Nebula
- C Impact Materials and Effects
- D Newest Lunar Meteorites
  - 3:45 p.m.: Solar Protons and Rare Gases

### Wednesday Evening, 6:00–9:30 p.m.
- Conference Social Event, Landolt Pavilion

### Thursday Morning, 8:30 a.m.
- A Resurfacing and Tectonic History of Venus
- B Meteorites: Martian and Others
  - 10:30 a.m.: Saturn Rings
- C Impact Story—Mechanics, Atmospheres, and World Destruction

### Thursday Afternoon, 1:30 p.m.
- A Venus Volcanism and Tectonism
- B Chondrules in Ordinary Chondrites
- C K/T Impact and Impact Vaporization

### Thursday Evening, 6:30–9:30 p.m.
- LPI Education Session Displays—Planetary Science Educational Activities and Technology
  - and Poster Session II

### Friday Morning, 8:30 a.m.
- A Origins: From Stellar Death to Lunar Birth
- B Achondrites
- C Future Planetary Missions: Exploration in Progress

### Conference Program On Line
The program and first paragraph of abstracts for the 27th LPSC are currently available on line. Late-breaking news or announcements about the conference will be posted, so we encourage you to check the LPI’s home page on a regular basis.

### How to Get There

#### World-Wide Web Access
If you are using an Internet information browser like NCSA Mosaic, the URL for LPI is:

http://cass.jsc.nasa.gov/lpi.html

#### Internet Access
At your system’s prompt, type:

telnet cass.jsc.nasa.gov
telnet 192.101.147.17

The username prompt should be displayed. Use only lower-case characters for logging onto this account.

USERNAME: cass
PASSWORD: online

#### Modem Access
For modem access (at 14.4K/9600 bps), DEC VT series terminal emulation (100 and above) is required.

713-244-2089
713-244-2090

Press <ENTER> until you receive the username prompt. Use only lower-case characters for logging onto this account.
CONFERENCE SHUTTLE SERVICES

Conference shuttle buses will provide service between selected hotels (Nassau Bay Hilton, Days Inn, Holiday Inn, Ramada Kings Inn, Quality Inn, Comfort Inn, Motel 6, and Best Western), the JSC Gilruth Center, and LPI. There will be rotational runs in the morning, during lunch, at the close of sessions, and to and from these hotels during special events. Computer displays, exhibits, poster sessions, and other conference-related events will be located at LPI; shuttle buses will make hourly stops there throughout conference week. Your conference badge will serve as your bus ticket.

LOCAL GROUND TRANSPORTATION

Ground transportation from Houston Intercontinental and Houston Hobby Airports to the local area hotels at a reasonable cost is available through two shuttle services.

Dean R. Chapman
1922-1995

Dean R. Chapman died of cancer at his home on October 4, 1995. Dean began his career at Ames Aeronautical Laboratory in 1948. As director of Astronautics in the 1970s, his administrative responsibilities involved programs such as shuttle thermal protection and the Pioneer Venus Probe/Orbiter mission.

The research that challenged Dean the most was his work on the origin of tektites. This began with a visit to the British Museum where he saw button-shaped australites that had shapes similar to those of objects produced by experiments at an Ames Research Center wind tunnel while researching the problem of protecting spacecraft from severe aerodynamic heating in hypervelocity flight. Dean successfully reproduced tektite shapes using an arcjet, which simulated atmospheric entry conditions. During his research, Dean amassed a large tektite collection, which is now at the Smithsonian Museum of Natural History.

Dean and co-workers determined the density and specific gravity of ~47,000 tektites and had 530 tektites analyzed for major- and trace-element compositions. He defined compositional trends within the Australasian strewn field and his compositional classification of Australasian tektites is still used today.

During the 1960s, Dean and colleagues published several papers dealing with his proposal that tektites were produced by impact cratering on the Moon. He stopped work on the tektite problem just as the Apollo program began. Samples returned by the Apollo astronauts soon proved, to most researchers, that tektites did not come from the Moon and today most investigators believe that tektites were formed by terrestrial impact.

Dean joined the faculty of Stanford University in 1980. He retired around 1994 and once again became interested in the tektite problem due to the discovery of a perfectly preserved ablated tektite recovered from the Central Indian Ocean. He is co-author of a paper that discusses the significance of this tektite. The paper has been accepted for publication in the journal Meteoritics.

—Billy P. Glass
## BOOKS

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## LPSC ABSTRACT VOLUMES

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UPDATE: Planetary Science Missions on the World-Wide Web

These World-Wide Web addresses provide access to information on current planetary science flight projects and on planning for future flight projects. Some of these sites use features from the most recent version of HTML that are at present supported only by Netscape—users of other web browsers may not be able to access all features at these sites.

All these addresses, as well as many other locations of interest, are available as hyperlinks on the LPI home page.

The LPI home page is at http://cass.jsc.nasa.gov/lpi.html and our list of web addresses is located at http://cass.jsc.nasa.gov/website.html.

NASA Solar System Exploration Division
http://www.hq.nasa.gov/office/solar_system/

Committee on Planetary and Lunar Exploration (COMPLEX)
http://www.nas.edu/ssb/complex1.html

http://www.nap.edu/nap/online/planet_sci/

Galileo
http://www.jpl.nasa.gov/galileo/

Near Earth Asteroid Rendezvous
http://sd-www.jhuapl.edu/NEAR/

Mars Global Surveyor

Mars Pathfinder
http://mpfwww.jpl.nasa.gov/

Mars Surveyor 1998 Orbiter

Russian Mars96 Mission
http://www.iki.rssi.ru/mars96/mars96hp.html

Mars Volatiles and Climate Surveyor
http://thesun.ess.ucla.edu/

Lunar Prospector
http://nssdc.gsfc.nasa.gov/planetary/lunarprosp.html

Cassini
http://www.jpl.nasa.gov/cassini/

Stardust
http://pdcsrva.jpl.nasa.gov/stardust/home.html

Pluto Express
http://www.jpl.nasa.gov/pluto/

Champollion
http://champwww.jpl.nasa.gov/champollion/

Earth Observing System Project Science Office
http://spso.gsfc.nasa.gov/spso_homepage.html
HUBBLE DEEP FIELD SURVEY REVEALS GALAXIES NEAR THE BEGINNING OF TIME

Several hundred never-before-seen galaxies are visible in this deepest-ever view of the universe, called the Hubble Deep Field (HDF), made with the Hubble Space Telescope. Besides the classical spiral- and elliptical-shaped galaxies, there is an astonishing variety of other galaxy shapes and colors that are important clues to understanding the evolution of the universe. Some of the galaxies may have formed less than one billion years after the Big Bang.

Representing a narrow "keyhole" view all the way to the visible horizon of the universe, the HDF image covers a speck of sky 1/30 the diameter of the full Moon (about 25% of the entire HDF is shown here). This is so narrow that just a few foreground stars in our Milky Way galaxy are visible and are vastly outnumbered by the menagerie of far more distant galaxies, some nearly as faint as 30th magnitude, or nearly four billion times fainter than can be seen with the naked eye. (The relatively bright object with diffraction spikes just left of center may be a 20th magnitude star.) Though the field is a very small sample of sky area, it is considered representative of the typical distribution of galaxies in space because the universe, statistically, looks the same in all directions. Thus, based on these observations, the universe may contain roughly 50 billion galaxies rather than the 10 billion of previous estimates.

The image was assembled from many separate exposures (342 frames total were taken; 276 have been fully processed to date and used for this picture) made by the Wide Field and Planetary Camera 2 for 10 consecutive days, December 18–28, 1995.

"The variety of galaxies we see is amazing. In time these Hubble data could turn out to be the double helix of galaxy formation. We are clearly seeing some of the galaxies as they were more than ten billion years ago, in the process of formation," said Robert Williams, Director of the Space Telescope Science Institute. Williams and the STScI team he assembled to conduct the observations hope they will unlock clues to fundamental cosmological questions: Will the universe expand forever? How long ago did the first galaxies appear? How have galaxies evolved over the history of the universe? Though months of detailed research and analysis lie ahead, HDF team astronomers believe they see evidence for a significant population of galaxies that existed when the universe was less than a billion years old.
HUBBLE TELESCOPE CAPTURES FIRST DIRECT IMAGE OF A STAR

This is the first direct image of a star other than the Sun made with the Hubble Space Telescope. Called Alpha Orionis, or Betelgeuse, it is a red supergiant star marking the shoulder of the winter constellation Orion the Hunter. The Hubble image reveals a huge ultraviolet atmosphere with a mysterious hot spot on the stellar surface. The enormous bright spot, more than 10 times the diameter of Earth, is at least 2000 K hotter than the surface of the star.

The image suggests that an unforeseen physical phenomenon may be affecting the atmospheres of some stars. Follow-up observations will be needed to help astronomers understand whether the spot is linked to oscillations previously detected in the giant star, or whether it moves systematically across the surface under the grip of powerful magnetic fields.

The observations were made by Andrea Dupree, Harvard Smithsonian Center for Astrophysics, and Ronald Gilliland, Space Telescope Science Institute, who announced their discovery at the American Astronomical Society annual meeting in January.

The image was taken in ultraviolet light with the Faint Object Camera on March 3, 1995. Hubble is able to resolve the star even though its apparent size is 20,000 times smaller than the width of the full Moon — roughly equivalent to being able to resolve a car’s headlights at a distance of 6000 miles. Betelgeuse is so large that, if it replaced the Sun at the center of our solar system, its outer atmosphere would extend past the orbit of Jupiter.

MILLIMETER OBSERVATIONS SUGGEST GLOBAL DUST ACTIVITY ON MARS: VISUAL CONFIRMATION SOUGHT

Todd Clancy, University of Colorado/Laboratory for Atmospheric and Space Physics, reported January 5 that observations from Kitt Peak suggest that a large-scale dust storm is probably occurring on Mars. Clancy is observing Mars with the 12-meter NRAO telescope, measuring atmospheric CO absorption lines at millimeter wavelengths. Normally, under clear atmospheric conditions, there is enough of a temperature difference between the martian surface and atmosphere to result in the formation of absorption features with high contrast. However, under dusty conditions, the surface-atmospheric temperature difference is smaller, and the absorption feature contrast is substantially decreased.

Observations from Kitt Peak in early January (at \( L_s = 222 \)) revealed lower CO absorption band contrast than usual, indicating an estimated \( \pm 20 \)K elevation in the atmospheric temperature above the 10–20-kilometer level. This amount of atmospheric heating is consistent with a global-scale dust storm, similar to, though not as large as,
Local dust storms are relatively common on Mars. They tend to occur in areas of high topographic and/or high thermal gradients (usually near the polar caps), where surface winds would be strongest. This storm is several hundreds of kilometers in extent and is located near the edge of the south polar cap. Some local storms grow larger, others die out. (Courtesy Calvin J. Hamilton, LPI, and NASA)

events reported by Clancy, Grossman, and Muhleman during April 1994 and April 1992. The storm has apparently just begun (atmospheric heating was not detected in this year’s observations prior to L,=222), and is probably only in the early to middle stages of the dust buildup. Additional millimeter observations were planned later in January in order to confirm the storm and to more accurately quantify the dust opacity.

It would be highly desirable to obtain visual confirmation of this dust event and scrutinize the storm itself, as well as to practice making ground-based support observations that are needed by the upcoming Mars Pathfinder mission. However, this is a difficult task, as Mars is currently only 4.0 arcsec in apparent diameter and only 13° from the Sun (and approaching conjunction). Both professional and amateur observers who can observe Mars are encouraged to do so to try to provide visual verification and additional information about the character of the dust storm. Unfortunately, the Hubble Space Telescope will not be able to observe Mars until September because of solar phase angle limitations. Interested colleagues should send questions, comments, or observing progress reports to Jim Bell, Cornell University, Department of Astronomy, Center for Radiophysics and Space Research, 424 Space Sciences Building, Ithaca NY 14853-6801. Phone: 607-255-5911; fax: 607-255-9002. E-mail: jimbo@marswatch.tn.cornell.edu WWW: http://marswatch.tn.cornell.edu

MORE EXTRASOLAR PLANETS?

Geoffrey Marcy, San Francisco State University, and Paul Butler, University of California at Berkeley and San Francisco State, announced evidence for planets orbiting two Sun-like stars at the American Astronomical Society annual meeting in January. Using the Lick Observatory 3-meter telescope, they compiled radial velocity data by measuring the Doppler shift of each star’s spectrum; this data represents the tug exerted by the companion object as it orbits the star.

Data from 47 Ursae Majoris, a fifth-magnitude G0-type star 46 light years away, suggest a companion 3.5 times Jupiter’s mass in a circular orbit at 2.1 AU (roughly twice the Earth’s distance from the Sun). The orbital period is about three years. The fifth magnitude, G4-type star 70 Virginis, about 78 light years away, has a radial velocity of up to 311 meters per second, which suggests a companion between 8 and 9 times Jupiter’s mass orbiting at 0.43 AU (slightly larger than Mercury’s orbit) every 117 days. The orbit is eccentric (e = 0.35) rather than circular, which suggests that the companion could be a brown dwarf rather than a true planet.

This detection technique only provides a minimum mass for a companion, however. The true mass is larger than this minimum by a factor of 1/sin i, where i is the angle between our line-of-sight to the star and the perpendicular to the orbital plane of the companion (i = 0° means we are directly above or below the orbital plane; i = 90° means that we are in the orbital plane).

According to David C. Black, Lunar and Planetary Institute, the jury is still out as to whether any extrasolar planets have been discovered. He considers the companion to 47 Ursae Majoris the only likely candidate with all others being brown dwarfs. Black notes that most people still use 10–20 Jupiter masses as the lower limit to the mass of a brown dwarf (thus anything less massive is deemed a planet), but that this number is based on what is probably the wrong mechanism for brown dwarf formation. When new theories on formation are taken into account, Black believes there could be planets more massive than brown dwarfs. ☺
**REVIEW**

**PHYSICS AND CHEMISTRY OF THE SOLAR SYSTEM**

by John S. Lewis


Hardcover, $149.00; softcover, $69.95

It is common for books whose titles suggest great scope—such as this one surely does—to contain acknowledgments to those who read and reviewed various chapters: The subject matter is just too broad for any one of us to be confident of getting it all right by ourselves. This book contains no such acknowledgments. Although I cannot be sure of the significance of that lack, I guess that no such reviews were requested. This could be the reason that the book suffers from considerable imbalance, omission, and error, but nonetheless contains a lot of information on some topics, presented in prose that is generally interesting and clear. As the intended target, according to the author, comprises upper-level undergraduates, graduate students, and practicing scientists wanting a broader context, the imbalance appears to me to be a serious flaw. The book covers ground from galaxies to the Sun and its nebula, to the major planets and their satellites, to small bodies, to the terrestrial planets, to atmospheres, and to life here and elsewhere, and so should be of general interest. Yet it is a clear demonstration of the dangers of writing outside the field of one’s own expertise.

Lewis’ expertise is nebular condensations, atmospheres, and theoretical modeling, not the analysis of materials at sample or orbital scales. The sections about the Sun and the solar nebula, about the major planets, and about the atmospheres of the larger terrestrial planets are thus full and the known parameters and models well covered. They have generous helpings of equations and derivations and lots of plots showing how things behave, or how theorists think they should behave—for me at least, the helpings were too generous. Similarly, the perspective on nucleosynthesis is more than adequate for a book of the stated purpose. Some things will be confusing at the introductory level—for instance, a table of elemental abundances of the solar system has no units, and it is not stated that the abundances (mass, or number of atoms??) are normalized to silicon. The actual units are well known to those in the business but surely not to others. These chapters have a much greater emphasis on the chemistry than on what I might consider the physics, but subjects such as “Radio Wave Propagation in Space Plasmas” are included. The chapter “Comets and Meteors” appears to me to be a balanced introduction to both physics and chemistry, and is up-to-date enough to include some discussion of the Shoemaker-Levy 9 collisions with Jupiter.

In the fields outside Lewis’ main interests, however, the book falls short. Thus whereas trace elements including the rare earths have assumed a prominent role in planetary geochemistry papers over the last couple of decades, not a single rare earth diagram appears in this book, and their use in tracing mantle characteristics and processes is absent. Similarly absent is the use of radiogenic isotopes as tracers, and element tracers of core formations and crust-mantle separation. And there is no related experimental petrology either; petrology is limited to stating the concepts of Bowen from 50 years ago. Considering the amount of attention and discussion given to petrogenesis and differentiation of terrestrial planets by magma
oceans over the last two decades, the absence of any discussion of the physics of magma oceans, even in the section about our Moon, is a mistake. Missing from the index are the likes of neutron activation, partition coefficients, the rare earth elements (as a group or as individuals), magma ocean, and either core or core formation. There is no discussion of analytical techniques, so that mass spectrometry, electron microprobes, and X-ray fluorescence are out. Interferometry is in, presumably because it is a planetary astronomy technique and obtains atmospheric molecule data.

The Earth is intentionally left until late (in the introduction we are told this is to defer its complexity; when we get to it, we are told this is to minimize the tendency to anthropomorphize). Yet, despite what Lewis might wish, the Earth—and, since the Apollo voyages, the Moon—provides our greatest source of information, our most keen insights into what planets are, and our testbeds for the creative speculations of planetary theorists. Lewis seems to be painfully unaware that our understanding of the Moon gained through the Apollo program has greatly influenced our view of all other planets. Yet he devotes as much space to each of Io, rings, and the Venus atmosphere and its possible interaction with the venusian surface—all based on an incredibly small and unreliable database—as he does to the entire Moon. The discussion of Earth’s history includes a misunderstanding of the basis of stratigraphic division, an erroneous view of what an early Catastrophist was, and a garbled description of Darwin’s natural selection mechanism that omits variation from its basis and even suggests that Darwin and his contemporaries knew about genes (though this is probably just poor wording).

The current lull in planetary missions, says the author, is one inspiration to write this book—to avoid instant obsolescence. I cannot judge the entire contents of the book in this regard, but the Moon chapter would have been obsolete and error-ridden 20 years ago. I have mentioned the omission of magma oceans, an important paradigm in many lunar studies. Not only is the Clementine mission omitted (perhaps forgiveably as it is so recent, but Shoemaker-Levy 9 was later still and is included), but the only table of chemical analyses is Surveyor data! We are told that mare basalts have refractory elements such as U and the rare earths enriched compared with CI chondrites by a factor of about 100, when in reality only a rare few approach such perilous heights. The only reference to radiometric ages, an important basis for understanding lunar history, comes almost irrelevantly in a section on magnetics. According to this book, fine-grained basalts are called Type A and coarse-grained ones Type B, which is a holdover from Apollo 11 that was rapidly replaced by more fundamental chemical groupings. Supposedly both types show abundant vesicles (that is just wrong!). A diagram of mare basalt pyroxenes is imaginary and misleading. A list of “the most important lunar minerals” includes graphite and perovskite (their existence on the Moon has never been substantiated), and native copper, chalcopyrite, and quartz that are extremely rare (I have never seen them in 20 years of studying lunar thin sections). Olivine, a fundamental mineral in petrogenesis, is relegated to the role of a minor mineral. We are told that the highlands are dominated by anorthosites (an exaggeration) and anorthitic pyroxenites (a garbled term, and whatever they are, they do not exist in the lunar sample collection). Remote sensing of the Moon is virtually ignored. Virtually no discussion whatsoever is given to large multiring basins (not in the index) anywhere in the solar system. We are told that they are similar in appearance to ripples in water (!!!), when such an analogy is pointless in substance, erroneous in reality, and misleading in concept. Rings are scarps that have steep sharp inner slopes and gentle outer slopes, caused by faulting that is absent in ripples.

continued on page 19
MARCH

11–14
Infrared Space Interferometry Workshop: Astrophysics & The Study of Earth-like Planets, Toledo, Spain. Contact: Carlos Eiroa, Chairman LOC, Dpto. Fisica Teorica, C-XI, Facultad De Ciencias, Universidad Autonoma de Madrid, Cantoblanco, 28049 Madrid, Spain. Phone: 34-1-397-5567; fax: 34-1-397-3936. E-mail: irinter@astro1.ft.uam.es ftp: laeff.esa.es /pub/irinter

18–22
27th Annual Lunar and Planetary Science Conference, Houston, Texas. Contact: Publications and Program Services Department, LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113. Phone: 713-486-2166; fax: 713-486-2160. E-mail: simmons@lpi.jsc.nasa.gov

APRIL

1–4
ESO Workshop on The Early Universe with the VLT, Garching bei Munchen, Germany. Contact: European Southern Observatory, VLT96, attn. Ch. Stoffer, Karl-Schwarzschild-Str. 2, D-85748 Garching bei Munchen, Germany. Phone: 49-89-320-060; fax: 49-89-320-06-480. E-mail: VLT96@eso.org

MAY

3–4
Space Horizons: Space Initiatives at a Crossroads, Boston, Massachusetts. Contact: David Goldstein. Phone: 401-331-8975. E-mail: David_Goldstein@brown.edu WWW: http://www.newspace.com/horizons/

19–25
20th International Symposium on Space Technology and Science and 8th International Astrodynamics Symposium, Gifu, Japan. Contact: Tomifumi Godai, 20th ISTS General Chairman, 1-29-6 Hamamatsu-cho, Minato-ku, Tokyo 105 Japan. Phone: 03-5473-7014; fax: 03-5473-7814.

20
Earth System Science: Internet-based summer course, Department of Space Studies, University of North Dakota. Contact: Henry Borysewicz, Distance Education Coordinator, Department of Space Studies, University of North Dakota, Grand Forks, ND 58202. Phone: 800-828-4274; fax: 701-777-3711. E-mail: borysewi@aero.und.nodak.edu WWW: http://neptune.space.und.nodak.edu/

JUNE

1–6
Space 96: The Fifth International Conference and Exposition on Engineering, Construction, and Operations in Space and RCE II: The Second Conference on Robotics for Challenging Environments, Albuquerque, New Mexico. Contact: Dr. Stewart W. Johnson, Chair, Space and Robotics Conferences, Johnson and Associates, 820 Rio Arriba, S.E., Albuquerque NM 87123-5103. Phone: 505-298-2124; fax (by arrangement): 505-298-2124. E-mail: StWJohnson@aol.com

2–5
Statistical Challenges in Modern Astronomy II, University Park, Pennsylvania. Contact: Gutti Jogesh Babu, Department of Statistics, The Pennsylvania State University, 319 Classroom Building, University Park PA 16802-2111. Phone: 814-863-2837; fax: 814-863-7114; e-mail: babu@stat.psu.edu. Or: Eric Feigelson, Department of Astronomy and Astrophysics, The Pennsylvania State University, 525 Davey Laboratory, University Park PA 16802-6305. Phone: 814-865-0162; fax: 814-863-3399. E-mail: edf@astro.psu.edu WWW: http://www.stat.psu.edu/astrostat/

16–18
Planetary Formation in the Binary Environment, Stony Brook, New York. Contact: Michal Simon, Astronomy Program, SUNY, Stony Brook, NY 11794-2100. Phone: 516-632-8226 or Andrea Ghez: 310-206-0420. E-mail: origins@sbst1.ess.sunysb.edu msimon@sbst1.ess.sunysb.edu ghez@urania.astro.ucla.edu

17–20
IAU Colloquium 159: Emission Lines in Active Galaxies: New Methods and Techniques, Shanghai, People's Republic of China.
JUNE (CONTINUED)

Contact: IAU Colloquium 159, Department of Astronomy, Ohio State University, 174 West 18th Avenue, Columbus OH 43210. Fax: 614-292-2928.
E-mail: iau159@payne.mps.ohio-state.edu
ftp bessel.mps.ohio-state.edu or ftp 128.146.37.206
WWW: http://www-astronomy.mps.ohio-state.edu/iaul59.html

18–21
ESO Workshop on Science with the VLT Interferometer, Garching bei München, Germany. Contact: F. Paresce or O. von der Lühe, European Southern Observatory, Karl-Schwarzschild-Str. 2, D-82478 Garching b. München, Germany. Fax: 89-320-2362.
E-mail: fparesce@eso.org

20–27
Fourth International Conference on Nuclei in the Cosmos, Notre Dame, Indiana. Contact: Michael Wiescher, Department of Physics, University of Notre Dame, Notre Dame IN 46556. Phone: 219-631-6788; fax: 219-631-5952.
E-mail: NIC96@nd.edu
WWW: http://www.nd.edu/~nic96

24–26
From Stardust to Planetesimals: A Scientific Symposium, Santa Clara, California. Contact: Yvonne Pendleton, M/S 245-3, NASA Ames Research Center, Moffett Field CA 94035-1000.
E-mail: stardust@galileo.arc.nasa.gov
WWW: http://www-space.arc.nasa.gov/~stardust

25–27
E-mail: Genta@polito.it

JULY (CONTINUED)

Observatoire de Paris, F-92195 Meudon Cedex, France. Fax: 33-1-45-07-28-06.
E-mail: sl9jupiter@megasx.obspm.fr

8–12
Asteroids, Comets, Meteors, Versailles, France. Contact: ACM, Aeronomie CNRS, BP3, 91371 Verrieres, France.

9–19
E-mail: simmons@lpi.jsc.nasa.gov

22–26
59th Annual Meteoritical Society Meeting, Berlin, Germany. Contact: Publications and Program Services Department, LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113. Phone: 713-486-2166; fax: 713-486-2160.
E-mail: ssc@aquila.infn.it

AUGUST

4–14
30th International Geological Congress, Beijing, China. Contact: Zhao Xun, Deputy Secretary General, 30th IGC, P.O. Box 823, Beijing 100037 P.R. China. Phone: 86-10-8327772; fax: 86-10-8328928.
E-mail: zhaox@bepc2.ihep.ac.cn

26–Sept 6
International School of Space Science 1996 course on Space Science from the Space Station, L’Aquila, Italy. Contact: International School of Space Science, c/o Dipartimento di Fisica, Università degli Studi dell’Aquila, Via Vetoio, Coppito, 67100 L’Aquila, Italy. Phone: 39-862-433016; fax: 39-862-433033.
E-mail: ssc@aqulila.infn.it

SEPTEMBER

11–13

OCTOBER

7–10
Hypervelocity Impact Symposium, Freiburg, Germany. Contact: Susanne Deschoux, 1996 HVIS, Ernst-Mach-Institut, Fraunhofer-Institut
CALENDAR 1995–96

OCTOBER (CONTINUED)

fur Kurtzeidynamik, Eckerstr. 4, D-79104 Freiburg I. BR, Germany.
Or: Mark Boslough, MS 0821, Sandia National Laboratories, P.O. Box
E-mail: mbboslo@sandia.gov

16–18
Workshop on Evolution of Igneous Asteroids: Focus on Vesta and
the HED Meteorites, Houston, Texas. Contact: Publications and
Program Services Department, LPI, 3600 Bay Area Boulevard, Houston
TX 77058-1113. Phone: 713-486-2166; fax: 713-486-2160.
E-mail: enticknap@lpi.jsc.nasa.gov

22–25
28th Annual Meeting of the Division for Planetary Sciences of the
Larson, Lunar and Planetary Laboratory, University of Arizona, Tucson
AZ 85721. Phone: 520-621-4973; fax: 520-621-4933.
E-mail: slarson@lpi.arizona.edu

28–31
Annual Meeting of the Geological Society of America, Denver,
Colorado. Contact: Vanessa George, 3300 Penrose Place, Boulder CO

NOVEMBER

4–7
IAA Symposium on Small Satellites for Earth Observation, Berlin,
Germany. Contact: Bernd Kirchner, Symposium and Program Coordina-
tor, DLR/WS. Phone: 49-30-69545-545; fax: 49-30-69545-532.
E-mail: iaa.symp@dlr.de

DECEMBER

2–5
Aerospace Technologies in Earth Sciences, Moscow, Russia. Contact:
MIIGAIK, 103064, Gorochovskiy per., Moscow, Russia. Phone: 7-095-
267-5436; fax: 7-095-267-4681. Or: Russian Aerosol Society, 103064,
Vorontsovo pole str., 10, NIFHI, Moscow, Russia. Phone: 7-095-916-
6389; fax: 7-095-147-4361.
E-mail: kirill@cc.nifhi.ac.ru

1997

JULY

17–19
Workshop on Parent Body and Nebular Modification of Chondritic
Materials, Maui, Hawaii. Contact: Publications and Program Services
Department, LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113.
Phone: 713-486-2166; fax: 713-486-2160.
E-mail: simmons@lpi.jsc.nasa.gov

AUGUST

30–Sept 5
Sudbury 1997: Large Meteorite Impacts and Planetary Evolution,
Sudbury, Ontario. Contact: Burkhard Dressler, LPI, 3600 Bay Area
Boulevard, Houston TX 77058-1113. Phone: 713-486-2112; fax: 713-
486-2162.
E-mail: dressler@lpi.jsc.nasa.gov

NEW IN PRINT continued from page 16

This book would have been improved by a coherent discussion
of the bulk chemical compositions of the planets. While some
bulk chemical properties are given, scattered about the book, this
does not apply to the major elements. Some import is attached to
an elevated FeO for the Moon, especially for its origin, but there
is no discussion of the derivation or reality or even the magnitude
of this “fact.” Tables of our best estimates for the bulk composi-
tions of the terrestrial planets, and the basis for those estimates,
would have been extremely useful for those trying to acquire a
general knowledge of the solar system.

For the subject matter with which I am most familiar, including
impacts, meteorites (so little on the martian meteorites or the
eucrite family!), and the geology and chemistry of the terrestrial
planets, this book is sadly lacking. Given that the author is part of
an institution with considerable expertise in solar system chemis-
try and physics, including sample analysis and impact mechanics,
I find it surprising that the book has such imbalances and errors as
it does. I would recommend other works to satisfy a desire for
knowledge about the physics and geochemistry of at least the
solid planets, including S. R. Taylor’s Solar System Evolution
(Cambridge University Press, 1992). The book does not include
running references, but has suggested general and review readings
for each chapter. Strangely, those for the Moon do not include
The Lunar Sourcebook (eds. G. Heiken, D. Vaniman, and B.
French; Cambridge University Press, 1991), an up-to-date mine
of lunar chemical and physical information.

—Graham Ryder

(And Ryder is a Staff Scientist at LPI)
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