The Human Orrery: Putting the Solar System in Perspective

An interactive outdoor exhibit in Northern Ireland explains the motions of the Sun's family members. By Mark E. Bailey, David J. Asher, and Apostolos A. Christou

EVERY SCHOOLCHILD IS fascinated by the idea that we live on the "third rock" from the Sun, that Earth is one of nine planets orbiting a quite ordinary star in the Milky Way, and that the Sun with its retinue of planets, asteroids, and comets is just one of a hundred billion stellar systems that make up our home galaxy, itself one of trillions in the visible universe.

Despite this, remarkably few people have a full understanding of Earth's relationship to other bodies in the solar system, let alone the stars. Although the Sun can be seen on any clear day and the planets and stars on a clear night, it takes a great leap of the imagination to recognize these objects for the distant celestial bodies that they are.

One tool to help them visualize this is an *orrery,* a dynamic scale model of the solar system. Such a model can be found at Armagh Observatory, a scientific research institution in Northern Ireland founded in 1790 by Armagh archbishop Richard Robinson. Armagh Observatory's Human Orrery is a new, innovative outdoor exhibit designed to give the 20,000 people who visit the facility's grounds and Astropark each year a deeper understanding of Earth's true position in space.

First, it explains the heliocentric (Sun-centered) model of the solar system and shows the relative positions, motions, and distances of the planets about the Sun and the directions to distant stars. Second, it depicts at a glance the five principal parts of the solar system accessible to the naked eye: the Sun, the four inner terrestrial planets (Mercury, Venus, Earth, and Mars), the two outer gas giant planets (Jupiter and Saturn), the asteroid belt (represented by Ceres, the first asteroid discovered), and the comets (represented by 1P/Halley and 2P/Encke). Third, the size and layout of the orrery ensure that planetary orbits can be immediately recognized for what they are: slightly elliptical paths with the Sun at a focus rather than at the center.

A Precision Model

The scale used in Armagh's Human Orrery is one astronomical unit per meter, 1 a.u. being almost exactly the mean distance of Earth from the Sun (149,597,870 kilometers or 92,955,807 miles). At the orrery's center is a stainless-steel disk 32 centimeters (13 inches) in diameter representing the Sun. Two hundred six similar steel disks are numbered to

The Human Orrery is situated on the grounds of Armagh Observatory in Northern Ireland, about 60 kilometers (40 miles) southwest of Belfast. Inaugurated last November 26th, the £85,000 ($160,000) exhibit was funded by the Northern Ireland Department of Culture, Arts and Leisure, with educational support from the UK Particle Physics and Astronomy Research Council. Here children from the nearby Armstrong Primary School try out the orrery during the exhibit's opening-day festivities. All photographs are by Miruna D. Popescu.

The original orrery is a mechanical apparatus showing the relative positions and motions of bodies in the solar system using balls and wheelwork. It was invented in the early 18th century by English clock and instrument maker George Graham under the patronage of Charles Boyle (1674–1731), the fourth Earl of Orrery. This brass orrery made by Gilkerson and Company of London (circa 1810) is from the archives of Armagh Observatory.

denote the positions of the planets and Ceres starting at 0 hours Universal Time on January 1, 2005. We chose this date because it is approximately the 300th anniversary of the invention of the first orrery by English clock and instrument maker George Graham (1673–1751). The starting dates for the 39 steel disks for Halley and Encke correspond to the comets' most recent perihelion dates: February 9, 1986, and December 30, 2003, respectively. The positions of the terrestrial planets are given at 16-day intervals; for practical reasons, Ceres and the comets are marked at 80-day intervals, while Jupiter and Saturn are at 160 days.

What sets Armagh's Human Orrery apart from other solar-system models (*S&T:* March 1998, page 80) is its precision. The disks are laid out on the ground to an accuracy of better than 1 cm. This allows the elliptical shapes of planetary orbits to be viewed at a glance and opens the door to many possible experiments and activities.

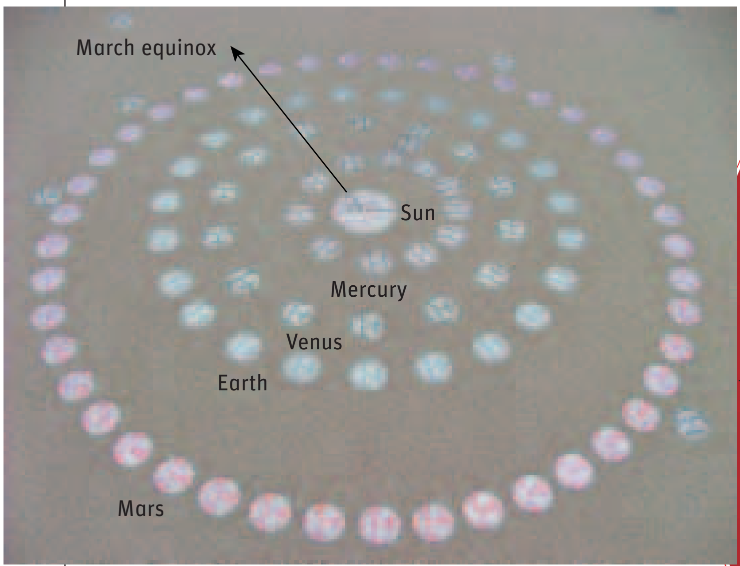
Orrery Games

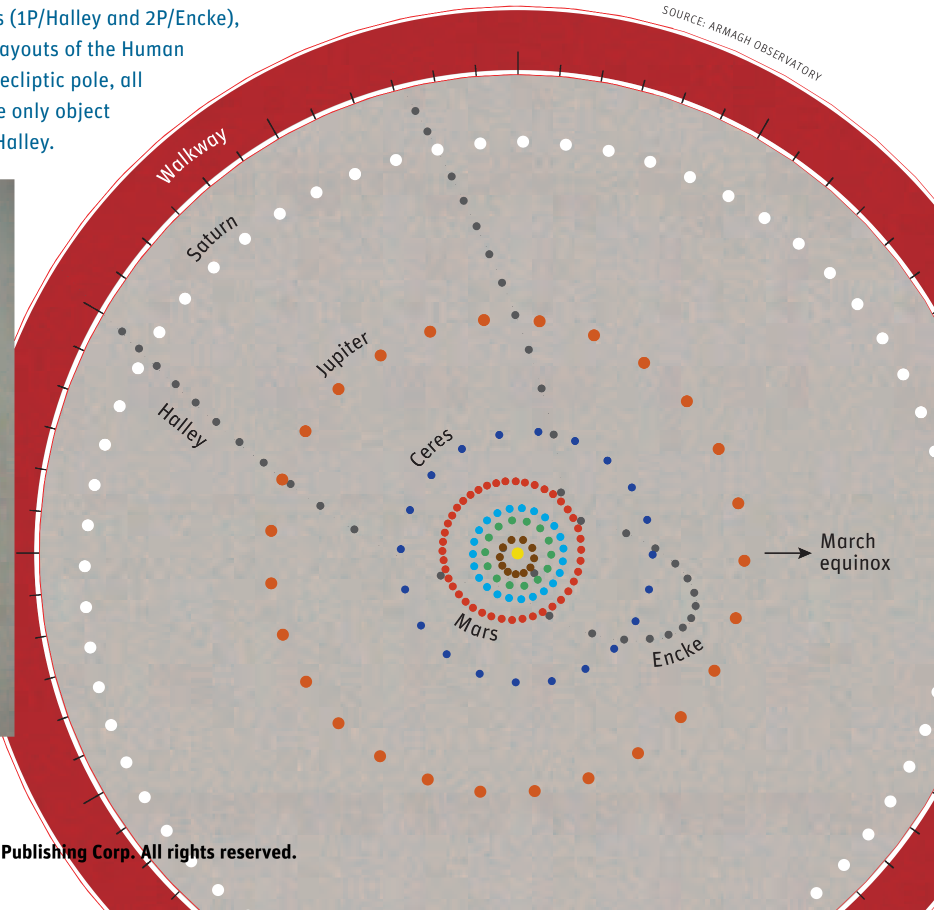
The planet disks encourage groups of friends or family members to walk the orrery, moving along the orbits in lockstep from one disk position to the next. One immediately sees that planets closer to the Sun move faster (and thus have shorter orbital periods) than those farther out. Another exercise is to check the visibility of the planets on a given date. By standing on Earth's disk and looking away from the Sun's disk, one can identify which planets are going to be visible in the night sky at that time. One can also look toward the Sun to see whether Mercury and Venus might be visible as morning or evening "stars," to the right or the left of the Sun, respectively. All these encourage people to look up and make the link between what they can see in the orrery and in the sky.

Other activities include verifying Kepler's three laws of planetary motion and demonstrating planetary alignments and conjunctions, such as the transit of Venus last year.

Leap Steps and Leap Stops

Questions relating to time and distance scales and the spatial relationships between solar-system bodies inevitably lead to issues concerning the calendar and time. Although we designed the Human Orrery to show each planet's position accurately, no single time step is exactly commensu-





The orbits of the six classical planets, two periodic comets (1P/Halley and 2P/Encke), and the Main Belt asteroid Ceres are indicated on these layouts of the Human Orrery. Looking down on the solar system from the north ecliptic pole, all the planets revolve around the Sun counterclockwise. The only object shown here that goes in the opposite direction is Comet Halley.

Other Solar-System Models

Many places have constructed (or are in the process of constructing) static, linear models of the solar system at various scales. Here are a few examples:

SpacedOut, Jodrell Bank Observatory, UK
www.spacedout-uk.com

Voyage, National Mall, Washington, DC
www.voyageonline.org

Dynic Astropark Orrery, Kyoto, Japan
www.dynic.co.jp/astro/index_i.html (in Japanese)

Stromlo Orrery Project, Australian Capital Territory, Australia
www.rsphysse.anu.edu.au/admin/php/orrery

Sweden Solar System, Stockholm
www.astro.su.se/swesolsyst

Planet Walk, St-Luc, Switzerland
www.saint-luc.ch

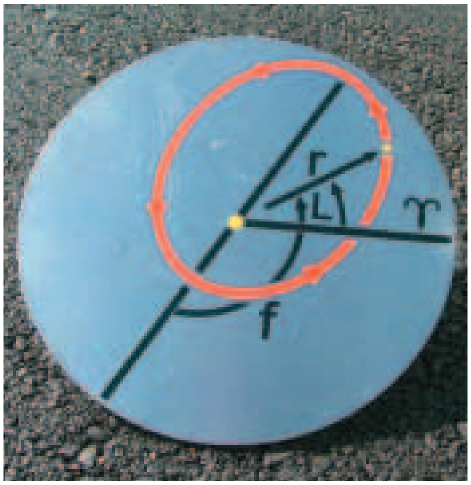
For more links and information, go to the Solar System Scale Model Meta Page at www.vendian.org/mncharity/dir3/solarsystem.

rate with the number of days in every planet's year. A planet's position as indicated by its disk number will inevitably drift ahead of or behind its true position given by ecliptic longitude. In fact, we chose the 16-day interval to minimize the accumulation of these small errors.

The least accurate example is represented by Earth's motion. To keep its orrery position in line with its true position, a person stepping from one disk to the next (exactly 16-day intervals) must take an extra step — a *leap step* — every six revolutions. This process has an exact analogy with the Julian calendar system — that is, the need to introduce a *leap day,* February 29th, every four years to keep the months in step with the seasons. By contrast, Mercury completes two revolutions in almost exactly 11 time steps, so it remains reasonably close to its true position for up to 520 revolutions, or about 125 Earth-years, before requiring a leap step.

Mars also needs a similar adjustment after 16 revolutions (30 Earth-years), but Venus, Jupiter, and Saturn require the omission of a step — that is, a *leap stop* — after 23, 13, and 4 revolutions (14, 154, and 118 Earth-years), respectively. This is analogous to omitting the leap day every 100

The Sun disk *(left-hand image)* features a yellow dot 9.3 millimeters in diameter, which represents the size of the Sun at the scale of the Human Orrery. Each planet disk contains the astronomical symbol and name of the planet; its number (beginning with zero at the object's start date) and corresponding calendar date; ecliptic longitude, *L* (measured counterclockwise from the First Point of Aries, ♈); distance, *r*, from the Sun in astronomical units; and true anomaly, *f* (measured from perihelion in the direction of the object's orbital motion).



years (for example, 1900), unless the year is divisible by 400 (for example, 2000, which was a *leap year*). Ceres wins the orrery's precision stakes — it requires a leap stop just once every 50 revolutions, or 230 Earth-years!

If further minor corrections are made (corresponding to the shift from the Julian to the Gregorian calendar), the Human Orrery can show planetary positions with reasonable accuracy for hundreds of years on either side of the present day. Of course, it's impractical to imagine counting 16-day intervals over centuries, so the orrery is complemented by a table of planetary positions covering a range of interesting dates (for example, famous planetary alignments or turning points in history). Moreover, choosing a date far in the past inevitably raises questions of the reckoning of time and whether the date is recorded in the Julian or Gregorian system or in some other scheme. An excellent review of this subject is provided in the book *Marking Time: The Epic Quest to Invent the Perfect Calendar* by Duncan Steel (John Wiley & Sons, 1999).

Thus, the Human Orrery is more than a two-dimensional map of the solar system. The connection between leap steps and leap stops, as they occur, and leap years provides a powerful tool for developing a greater understanding of time.

Beyond Saturn

Armagh's Human Orrery will be completed this spring with a circular walkway beyond Saturn's orbit (marked in red in the diagram on page 108). This walkway will be bounded by two stainless-steel rings. The inner ring will contain a scale of the ecliptic longitude, the direction of

event calendar

S&T: GARY SERONIK

Attendees at California's annual RTMC Astronomy Expo, to be held on Memorial Day weekend, May 27–29, will have a variety of telescopes to marvel at amid the scenic backdrop of the San Bernardino National Forest.

MAY 1–8
Texas Star Party
Fort Davis, Texas
Anne Adkins, tspreg@texasstarparty.org

MAY 4–8
Desert Sunset Star Party
Three Points, Arizona
Pat or Arleen Heimann, chartmarker@cox.net

MAY 5–8
International Telescope Meeting Vogelsberg
Feldatal-Stumpertenrod, Germany
Martin Birkmaier, info@teleskoptreffen.de

MAY 5–8
Frozen Banana Star Party
Powassan, Ontario, Canada
Harold Healy, 705-669-7750; hhealy@sympatico.ca

MAY 5–8
Rencontres Astronomiques du Pilat
Craponne sur Arzon, France
Jacqueline Rousson, astrorap@tiscali.fr

MAY 6–8
Georgia Sky View
Jackson, Georgia
Dawn Knight, sdknight@flintriverastronomy.org

For more astro events go to SkyandTelescope.com/resources/calendar

MAY 7–10
Beginning & Advanced Adult Astronomy Camp
Mounts Lemmon and Bigelow, Arizona
Don McCarthy, 520-621-4079; dmccarthy@as.arizona.edu

MAY 13–16
Ukrainian Astronomical Forum
Kharkov, Ukraine
Denis Svechkarev, denis@ukrastro.org

MAY 14
Lake Hudson Star Party
Jackson, Michigan
Bob Frybarger, bfrybarger@ameritech.net

the First Point of Aries, ♈ (the Sun's position as seen from Earth at the spring equinox, which is March 20th this year), and the boundaries of Ophiuchus and the 12 zodiacal constellations through which the Sun passes during a year. The outer ring will contain arrows pointing to the January 1, 2005, positions of Uranus, Neptune, Pluto, and the recently discovered trans-Neptunian object 90377 Sedna, as well as selected stars and nebulae.

The zodiacal markers will provide opportunities to explain the historical development of astronomy, including its origin in astrology, as well as concepts such as the ecliptic coordinate system and the precession of the equinoxes. The outer ring can be used to explain which stars are visible from Earth on any given night and to introduce a great variety of topics in astrophysics and observational astronomy.

For more information about the Human Orrery, go to http://star.arm.ac.uk/orrery.

Mark Bailey *is the director of Armagh Observatory, and* David Asher *and* Apostolos Christou *are staff astronomers at Armagh. Their research focuses on computational studies in solar-system dynamics, particularly meteoroids and satellites of the outer planets, and the origin of comets.*

May 25–26
SAS Symposium on Telescope Science
Big Bear Lake, California
Lee Snyder, 775-841-2040;
snyder@physics.unr.edu

May 27–29
RTMC Astronomy Expo
Big Bear City, California
Robert Stephens, 909-948-2205;
registrar@rtmcastronomyexpo.org

June 2–5
Wisconsin Observers Weekend
Waupaca, Wisconsin
Tom Riederer, 920-734-0248;
hubris47@yahoo.com

To list an event, e-mail your announcement and contact information (with complete details) to calendar@SkyandTelescope.com at least three months in advance. Late or incomplete submissions will not be considered. Not all events will be listed.

community news *by edwin l. aguirre*

AAVSO's New Director Named

AAVSO

Last January 28th the American Association of Variable Star Observers (www.aavso.org) announced Arne A. Henden as its new director, succeeding Janet A. Mattei (*S&T:* December 2003, page 82), who passed away on March 22, 2004. A longtime AAVSO member and observer, Henden was formerly a senior research scientist at the US Naval Observatory's Flagstaff Station in Arizona.

Henden is considered to be one of the premier mentors of the amateur astronomical community, especially in the photometry of variable stars and astrometry of minor planets. A regular contributor to numerous online discussion groups, he is an active proponent of professional-amateur collaboration. Henden was influential in founding the AAVSO's High Energy Network, which searches for optical afterglows left behind by gamma-ray bursts.

S&T: RICHARD TRESCH FIENBERG

David Lunt (1942–2005)

David Lunt, the founder and principal optical designer of Coronado Technology Group in Tucson, Arizona, passed away on January 16th after a 22-month battle with cancer. He was 62. He is survived by his wife and business partner, Geraldine Hogan, and their seven children.

Coronado is the world's leading manufacturer of specialized narrowband hydrogen-alpha (Hα) filters and dedicated solar telescopes and accessories. First introduced in the late 1990s, the company's line of affordable, easy-to-use Hα products has made viewing the Sun's dynamic chromosphere and the ever-changing spectacle of prominences, filaments, plages, and flares in real time more popular than ever before (February issue, page 96).

Born in Denbigh, Wales, Lunt was a consultant for the US Strategic Defense Initiative ("Star Wars") program in the 1980s and developed the mirror for NASA's first Orbiting Solar Observatory. In 1997 he and Hogan established Coronado, and since then demand for its products has been increasing. Last October, they sold the company to California telescope giant Meade Instruments. For more information, go to www.coronadofilters.com.

Lunt's family has established an astronomy scholarship in his memory at the University of Sonora in Hermosillo, Mexico. To contribute, contact Hogan at ghogan2@comcast.net.

SOHO Comet No. 900 Discovered

RAINER KRACHT

On January 15th, just seven months after the 800th comet was found in images obtained by the SOHO (Solar and Heliospheric Observatory) spacecraft, SOHO No. 900 was discovered by a German amateur astronomer.

Rainer Kracht, a 56-year-old high-school teacher living in Elmhorn near Hamburg, detected the object in images taken with one of the spacecraft's LASCO coronagraphs. Kracht downloaded the images from the LASCO Web site (http://lasco-www.nrl.navy.mil/lasco.html). The new interloper turned out to be a member of the Kreutz family of "sungrazing" comets, which usually get vaporized during their close encounters with the Sun. To date, Kracht has discovered 139 SOHO comets, including SOHO No. 500 in August 2002 (http://home.t-online.de/home/R.Kracht/soho.htm).

Launched in 1995, SOHO's primary mission is to continuously monitor the Sun's activity. It has now become the most prolific comet "discoverer" in history. Kracht is one of a growing number of successful SOHO comet hunters worldwide who regularly scan LASCO images, which are posted in near-real time on the Internet (*S&T:* October 2000, page 89). To join in the search, go to http://ares.nrl.navy.mil/sungrazer.

Orion Telescopes Sold to Imaginova

On January 13th Imaginova Corporation (www.imaginova.com), a New York–based multimedia content and commerce company founded in 1999 by columnist and TV anchor Lou Dobbs, announced its purchase of Orion Telescopes & Binoculars (www.telescope.com). The terms of the transaction were not disclosed.

Headquartered in Watsonville, California, Orion is a major manufacturer and direct seller of telescopes and observing accessories for the amateur-astronomy market. It was established in 1975 by Tim Gieseler as Optronic Technologies, which specialized in drive correctors. The company soon expanded its product line, and, by the 1990s, Gieseler shifted the emphasis to its own Orion-brand products, especially equipment geared for beginning stargazers. Gieseler is now retired from the company. According to Orion, the company's day-to-day operation will not change for now, and it will remain in Watsonville.

Biosphere 2 on the Block

Decisions Investments Corporation, the Fort Worth, Texas, company that owns Biosphere 2, announced last January 3rd that it was looking for a new owner or partner for Biosphere 2's 250-acre campus and laboratory in Oracle, Arizona, 56 kilometers (35 miles) north of Tucson.

The brainchild of billionaire Edward P. Bass, president of Decisions Investments, the $200 million facility was built in the late 1980s and features a three-acre glass-encased complex that aims to simulate Earth's rainforest, desert, and ocean ecosystems. But technical and logistical problems plagued the project, and in 1996 Columbia University took over the responsibility of managing the complex, converting it into a research and education facility, complete with a 0.6-meter (24-inch) robotic telescope (*S&T:* April 2002, page 68). In 2003 Columbia decided to pull out, and Biosphere 2 has been kept open for paid public tours since then. For more details see www.bio2.com.

New Planetarium Opens in China

After three years of construction, the new, state-of-the-art Beijing Planetarium opened to the public last December 12th. The $36.1 million facility replaces the city's old planetarium, which first opened in 1957. The new facility has a total floor area of 20,000 square meters (220,000 square feet) and features an advanced 200-seat SGI digital universe theater with a Zeiss laser all-dome projection system. In addition, there are a solar vacuum telescope and a 0.4-meter (16-inch) Schmidt-Cassegrain telescope for public viewing, as well as a 3-D motion theater, exhibition halls, and a library. On hand for the planetarium's opening was Yang Liwei, the country's first astronaut. ✷

RENJIANG XIE

Residents of Beijing, China, line up to see their city's new planetarium.