Air and Space this Week

Item of the Week

Solar System Scale Models

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The Copernican Revolution took hold in the mid-1600s as more and better telescopic and positional data allowed the planets to be tracked and their orbits calculated. Scientists were struck by how large the Solar System would have to be to account for the observations being made, but they were initially hampered in that effort by only knowing the Solar System size in terms of the Earth's orbit. That would soon be resolved, but astronomers faced another problem: How can we best convey the structure of the Solar System to our colleagues, our students, and to the public? They came up with two ingenious tools, and we still use more advanced versions of them today!

OUR SOLAR SYSTEM: HOW BIG?

ORRERIES

Clockmaking predated telescopes by a long time, and by the 1700s timekeeping devices were very sophisticated mechanical devices. A number of creative people realized (semi) independently that the same type of mechanisms that make a clock function properly could be applied to building a mechanical model that would show the movements of the planets around the Sun, with a good approximation of their relative orbital speeds. Of course, even if the spacing between the planets could be modeled correctly, the size of the planets if at the same scale would be microscopic. But it was a good first start.

Early astronomical models of the Solar System aimed at demonstrating orbital periods came into being in the late 1600s, but were rare; astronomers like Christiaan Huygens and Olaf Roemer had primitive models. The first good mechanical model of the Earth/Moon system was built in 1713 by one John Rowley, for his patron Charles Boyle, the Fourt Earl of Orrery. More elaborate models soon followed, showing the major planets and the Sun, but the name for such models remained fixed, "orrery," as homage to the Earl.

The mechanical workings of some of those early orreries was quite amazing, and the models could be used to predict planetary locations well into the future (or past). But as astronomical technology advanced, the need for an orrery diminished, and they have become highly-collectable curios of the advancement of astronomical science and technology.

NASM's "Floorrery"

The concepts behind an orrery are integrated into many state education standards of learning, or orreries can still have instructional value. But instead of relying on an expensive mechanical model, some educators have moved the learning experience outside!

If there is a large flat ground near the school, say a playground or a parking lot (safety first!), it is a pretty simple exercise to chalk off a scale model of the Solar System. The planets will be too small to work with at that scale, but learning about the relative motions of the planets are still possible. Since we know the orbital period of each of the major planets in days, and we can calculate the circumference of their orbits, we can calculate and mark off how far along each orbit the corresponding planet advances in a ten-day period, for example. Put a student on each planet while the others watch, and have them advance from mark to mark on the instructor's count, and all will quickly see that the inner planets move much more quickly around the Sun than their more distant cousins. Having the students make the scale calculations themselves is a good practical exercise in applied math!

The same concept can be used in a smaller space, say the size of an average classroom. The ten-day marks will be much closer together, but pegs or similar markers could be used instead of students to show the same relative motions. The new incarnation of the Exploring the Planets gallery now under construction at the Smithsonian National Air and Space Museum will have such a "planetary racetrack" on the floor of its Education Alcove, thanks to yours truly. I am looking forward to seeing it in action! Since it is a (non-mechanical) orrery on the floor of the Gallery, it was only natural that we called it the "Floorrery."

OUTDOOR SCALE MODELS

Orreries are no doubt useful at demonstrating the movements of Solar System planets, but at a scale where the planets are too small to see. Making the planets the size of common, everyday objects is more useful, but keeping the planet size and distance scales the same would make planets portrayed at that scale be miles away! Such a model is no good for in-classroom use, but….

If one uses a scale of 1:1,000,000, the Earth would be just over half-an-inch across, and the Sun (1.4 meters across) would be 150 meters away. Pluto would be on the order of 6 kilometers from the Sun. At that scale, a medium-sized town could hold the model.

If one uses a scale based on the size of an average classroom globe of the Earth (~18"), the Sun would be 14 stories tall, three miles away. At that scale, Pluto would be about 120 miles away., and the nearest star would be three times farther away than the (real) Earth is from the (real) Moon!

A useful intermediate case is using a ping pong ball to represent the Earth. At that scale (~1:310,000,000), the size of the Sun would be that of most classrooms, and the nearest star would be only a third the Earth-Moon distance.

Permanent Solar System Scale Models

A number of communities around the world have built permanent scale models of the Solar System; there are at least 66 publicized and more are on the way. They can be a delightful way to exercise the body and the mind!

I have had personal experience with two of them, with another one coming up on April 9.

The first is in Peoria, Illinois, some years ago. Their Sun is 46 feet across, located on the Riverfront Museum's Sun Plaza. That is a huge model Sun, and at that scale (1:99,000,000), the planets are pretty far away. Mercury is a 2" ball a third of a mile away, a 5" Earth is almost a mile away, and Pluto is over 40 miles away! At this scale, the nearest star system, Alpha Centauri, would be the Little West Crater, at the *Apollo 11* landing site at Tranquility Base.

The second is the Voyage model, installed first on the National Mall outside the National Air and Space Museum. The model Sun is on the northeast side of the NASM building, the other seven planets are north of NASM or the Hirshhorn Museum, Pluto is near the Smithsonian Castle, *Voyagers 1* and *2* are near the Washington Monument, and the nearest star is in the vicinity of San Francisco. Similar models have been installed at NASA JSC, Kansas City, and Corpus Christi, and a newer version of this model was recently installed at the University of Colorado in Boulder.

Solar System scale models are in place at museums and science centers around the world, schools and universities, and parks of various descriptions. Communities use such Solar System scale models as a statement of their support for astronomical and other learning, the same reason they seek and implement Dark Sky policies (see also here). And that brings me to the newest Solar System model…

The neighboring towns of Westcliffe and Silver Cliff, Colorado, are southwest of Colorado Springs, at the north end of the Wet Mountain Valley between the Wet and Sangre de Christo Mountains. The surrounding mountains shield them from any urban sky glow from Denver or Colorado Springs, and the neighbor towns have received official designation as an International Dark Skies community. They've enhanced that reputation with the establishment of a nice public observatory, Smokey Jack, and the area is wonderful for stargazing.

Westcliffe/Silver Cliff have now added to the (astronomical) attractiveness of their community with the creation of "Planet Walk," a 1:4,000,000,000 scale Solar System model. The Sun is 14" in diameter, with the Solar System extending into Silver Cliff and beyond. The towns really support the idea behind the Walk, and a number of people and local organizations have been involved.

The opening dedication celebration will be on Saturday, April 9, at the historic Jones Theater in Westcliffe, beginning at 4 PM MDT. I will present on our present state of understanding of the various Solar System bodies comprising the Walk, and on astronomical distance determination.

SOLAR SYSTEM MODELING, NOT MODELS

Early astronomers made mechanical models of the Sun and planets in order to showcase their ideas and to make predictions about future planetary motions/positions. In a way, their modern counterparts are doing the same thing, but with computers, not mechanical contraptions.

The Solar System as it was known prior to the discovery of Pluto seemed to be a pretty simple, regular place. But Pluto was an oddball; its orbit is much more elliptical than that of the other bodies known at the time, and the plane of its orbit was inclined much more to the Sun's equator than the other known bodies. As we learned more after WWII, there were other oddities: Uranus' obliquity was extreme, and Neptune's largest moon, Triton, was in a retrograde orbit that could be seen to be decaying. Something odd had gone on in the outer Solar System, but what? And were unexpected "irregularities" confined to the outer Solar System; what about Venus' slow and retrograde rotation?

For the past two decades, astronomical computing has become powerful enough to enable astronomers to model planetary movements and gravitational interactions far into the future, and far back into the past. What they found was astonishing! Our Solar System has been by no means static – it is a changing, evolving thing.

I'll give this subset of the Solar System Scale Model topic the full treatment in a future Item of the Week. But in a nutshell, the leading computer models have the four gas giants initially much closer to the Sun after their formation. Depending on the model, they might move in initially or not, they might exchange places or not, but all the models show that the outer planets started life much closer to the Sun than they are today.

One of the leading models is called the "Nice Model.' Not "nice," it is named for the city where the team worked to formulate it: Nice, France. It was first published in 2002, and has been updated a couple of times since. Another model is the "Grand Tack" hypothesis, because Jupiter tacks like a sailboat in it, first moving closer to the Sun and then further away.

Wikipedia has a couple of good summaries of this aspect of Solar System models:
https://en.wikipedia.org/wiki/Nice_model;
https://en.wikipedia.org/wiki/Grand_tack_hypothesis

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Orreries

One of the best collections of antique astronomical instruments in the world is at the Adler Planetarium in Chicago; see: https://adler-ais.axiellhosting.com/results

Early History: https://www.tandfonline.com/doi/abs/10.1080/00033797400200431

Scale Models

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