

The New Exploring the Planets Gallery

“Volcanoes on Io” story input from Steven H. Williams

Objective of Story: Illustration of a fundamental characteristic of scientific inquiry, the testing of a hypothesis by using it to predict something that remains to be examined.

Synopsis of Story: Observations of Jupiter from Earth and by previous fly-by missions *Pioneers 10* and *11* showed that Jupiter’s innermost large moon, Io, was unusual in a number of respects. Scientists calculated how much energy would be generated by internal tides caused by the gravity of Jupiter and its other big moons. Their results led them to predict that the fly-by of *Voyager 1* in March, 1979, could produce evidence of active volcanoes on Io. That prediction was spectacularly confirmed a mere few days after it appeared in the major scientific journal, *Science*.

How It Engages the Public: Making a bold, even audacious, prediction and then having/making it be true garners much notice/notoriety. Babe Ruth’s “Called Shot” in the 1932 World Series, deeply embedded in baseball lore, is an example of this from the world of sports. The Peale, Cassen, Reynolds prediction is an unexpected, hence engaging, similar example from the world of science.

Background: Baseball’s Famous “Called Shot”

Setting: 1932 World Series, Game 3, Yankees versus Cubs, series 2-0 Yankees

Babe Ruth and Lou Gehrig would hit two homers each that day, but Ruth’s second has entered baseball lore as one of the most famous home runs in baseball history.

Ruth was at the plate in the fifth inning, with one out and the score tied 4-4 (Ruth hit a three-run homer in first; Lou Gehrig hit solo shot in third). The Cubs bench giving Ruth a lot of grief, while Ruth worked the count to 2-2. What happened next became very famous, in part due to Ruth’s boldness, in part due to there being no good recording of the event (and many more people swore they saw it in person than would have fit in Wrigley Field!). Ruth, in response to the Cubs taunting, is alleged to have stepped out of the batter’s box and pointed to the centerfield seats prior to hitting the very next pitch directly over, far over, the indicated spot.

The audacity of predicting the homer, then delivering immediately, was indeed the stuff of legend. A recent Internet search on “Babe Ruth” “Called Shot” returned 55,800 results!

Background: The Prediction for Io

Io was known prior to *Voyager 1*’s fly-by as being rather odd. For one thing there was a cloud of sodium ions in its orbit, and it seemed to have an odd color, but Io’s true nature was unknown to us. Then, in the 2 March 1979 edition of the prestigious scientific journal, *Science*, there appeared a short paper by Stanton Peale, Pat Cassen, and Ray Reynolds, entitled, “Melting of Io by Tidal Dissipation.” The investigators had realized that Io was subjected to a gravitational “tug-of-war” between Jupiter and the other three Galilean satellites, especially the closest, Europa. Tides induced by their gravity flexed the interior of Io, generating, as they calculated, huge amounts of heat. They “pointed to the centerfield fence” with the amazingly-astute predictions that “...Io might currently be the most intensely heated terrestrial-type body in the solar system” and that “Voyager images of Io may reveal evidence for a planetary structure and history dramatically different from any previously observed,” and more specifically, that “...one might speculate that widespread and recurrent surface volcanism would occur...”

This is an excellent example of the process of scientific inquiry: observation, formation of a testable hypothesis/hypotheses, testing, then confirmation, revision, or rejection.

Background: The *Voyager 1* Fly-by

Very precise navigation was required to get *Voyager 1* safely through the Jupiter system, on the exact trajectory necessary to use the gravitational “slingshot” technique to re-direct itself to Saturn. Precise positioning information was also needed on approach in order to pre-plan the data acquisition process, which would have to be accomplished without human control since the Earth-Io signal travel time was too long for real-time management. After the fly-by, mission navigators would look back “over the shoulder” at Jupiter’s now-backlit larger moons, to gain information that would allow precise measurements of their orbits.

Part of the navigation process *Voyager* managers used was to take images of Jupiter and its moons against the background stars. They could calculate ahead of time exactly where those nearer objects should be relative to the stars, and by comparing in real-time, minute course corrections could be made. The images of Jupiter were astonishing everyone as they came in, but the navigator’s shots were not as visually impressive, since they had to be greatly overexposed to show the faint stars.

Navigation and study of orbits this way required, with 1970’s technology, a team of navigators and data handlers. One of those folks was Linda Morabito, who was working on the data needed for moon orbit refinement four days after the fly-by (March 9). The viewing and illumination geometries meant that Io, her first target that morning, was mostly backlit, making Io show a thin crescent phase. But the non-illuminated part of Io was visible, too, reflecting not direct sunlight but that light that bounced toward the spacecraft after reflecting off Jupiter, just as “The Old Moon in the New Moon’s Arms” (aka “Earthshine”) causes under favorable conditions on Earth. The navigators didn’t like working with crescents, since they needed to determine the visual center of the moon being used, on the other hand, it was easier seeing faint stars near the non-lit side of Io. In any case, Ms. Morabito had her work cut out for her that morning.

Io was not present in the first image she examined, and one of the stars she expected to see near Io in the second image was not visible. She then moved to a fainter star should lie near the darker edge of Io, and she began to use a contrast stretch image enhancement to make that star more visible. But as she did so, something appeared that made her forget about that star or navigating the Jupiter system. It looked like there was *another* moon peeking out from behind Io! But Ms. Morabito was very familiar with the location of the other larger satellites of Jupiter, and quickly determined that there was no other moon anywhere near that particular line of sight. She and Steve Synnott, one of the scientists involved in the orbit determination effort, quickly eliminated other possible causes of this plume-shaped spot on Io’s limb. Then some of the science team got involved. The phenomenon, whatever it was, triggered several “Wow!” moments as possibilities were considered.

The location of the plume-shaped spot relative to surface features on Io previously observed was determined to sit directly over one of the largest surface markings on Io. A lot of folks were involved now, and it was becoming clear that Io had active volcanism; by March 12 a number of volcanic areas, active and not, had been identified. The “homer” predicted by Peale, Cassen, and Reynolds cleared the designated spot in center field by a considerable margin!

Voyager 2 was four months behind *Voyager 1*, en route to the first pass on what would become the Grand Tour of the outer solar system (to this day, our only close-up images of Uranus and Neptune and

their moons came from Voyager 2). There was time to alter the trajectory of *Voyager 2* to get a follow-up look at Io's volcanic plumes for confirmation and observation of changes.

Other Germane Items

Babe Ruth was a Baltimore native, and the Babe Ruth Birthplace and Museum is located 216 Emory Street, three blocks from Camden Yards.

Information Links

Peale, S.J., Cassen, P. and R.T. Reynolds, 1979, Melting of Io by Tidal Dissipation," *Science*, v. 203, 02 March 1979, pages 892-892. Available via JSTOR at: <http://www.jstor.org/stable/1747884>

Strom, R.G. and others, 1981, Volcanic eruptions on Io, *Journal of Geophysical Research*, v.86, no. A10, pages 8593-8620. Link: <http://onlinelibrary.wiley.com/doi/10.1029/JA086iA10p08593/epdf>

Linda Morabito's account of her role:

http://www.calacademy.org:8080/sites/default/files/assets/docs/pdf/discovery_of_volcanic_activity_on_io.pdf

There are numerous on-line and print resources for information on Io, for example:

- <http://www.universetoday.com/122972/jupiters-planet-io>
- <http://volcano.oregonstate.edu/io>
- <http://volcano.oregonstate.edu/studying-io>
- https://science.nasa.gov/science-news/science-at-nasa/1999/ast04oct99_1
- The Io volcano story (and the resemblance of Io to a pizza) got a lot of public attention in *NOVA*, *Time*, *Newsweek*, and other newspapers and magazines of the day.
- I would not normally include a Wikipedia entry for something like this, but in this case, the entry is pretty good: https://en.wikipedia.org/wiki/Volcanology_of_Io

The *Galileo* orbiter returned much better images of Io and its volcanoes in the late 1990's and early 2000's; for example:

- NASA SP-479, *Galileo: Exploration of Jupiter's System*
- https://science.nasa.gov/science-news/science-at-nasa/1999/ast11oct99_2/

The *Hubble Space Telescope* also monitors Io volcanic activity, for example:

<https://www.spacetelescope.org/images/opo9721a>

Babe Ruth Birthplace and Museum: <https://baberuthmuseum.org/exhibit/babe-ruth-an-american-icon>