

DEFUSING THE DIFFUSION OF INCORRECT KNOWLEDGE: HOOKE'S PARALLAX, VAN MAANEN'S ROTATIONS, AND THE RESOLUTION OF ORION

Todd Timberlake

Berry College

Mount Berry, GA



A BIT ABOUT MY COURSES

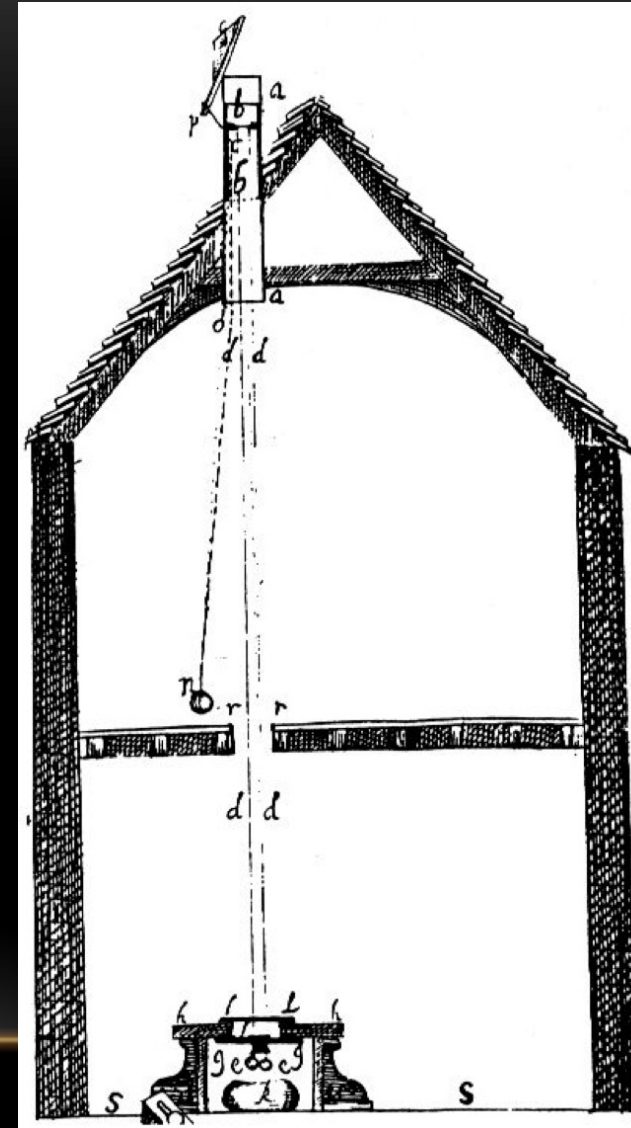
- Two astronomy courses that satisfy Berry's General Education science requirement, both taught from an historical perspective.
- One on the Copernican Revolution (planetary astronomy from Ancient Greeks to Issac Newton) and one on the Scale of the Universe (galactic astronomy and cosmology from Ancient Greeks to Cosmic Background Radiation).
- Courses emphasize the process of science rather than just the results. We spend a lot of time on "incorrect" theories.
- Courses are activity-based and make heavy use of computer simulations.
- More information is available online:
 - facultyweb.berry.edu/ttimberlake/copernican/
 - facultyweb.berry.edu/ttimberlake/galaxies/

THE IMPORTANCE OF ERROR

- Students need to know how science is done, not just what it says.
 - Science is self-correcting.
 - Usually we focus on correcting theoretical errors:
 - Naïve empiricism: theories encapsulate observations/measurements. The more data is encapsulated by the theory (without contradiction) the better the theory is.
 - Naïve falsification: theories are imaginative constructs, but we test them against data. If there is a conflict, we throw out the theory. Theories which survive the most (and most severe) tests are the best.
 - But sometimes it is the DATA that is wrong!
 - Sometimes we must throw out the data because it doesn't fit with our best theories. (We should, of course, seek justifications for throwing out the data.)
 - Three examples: Hooke's parallax, resolution of Orion nebula, van Maanen's rotations.
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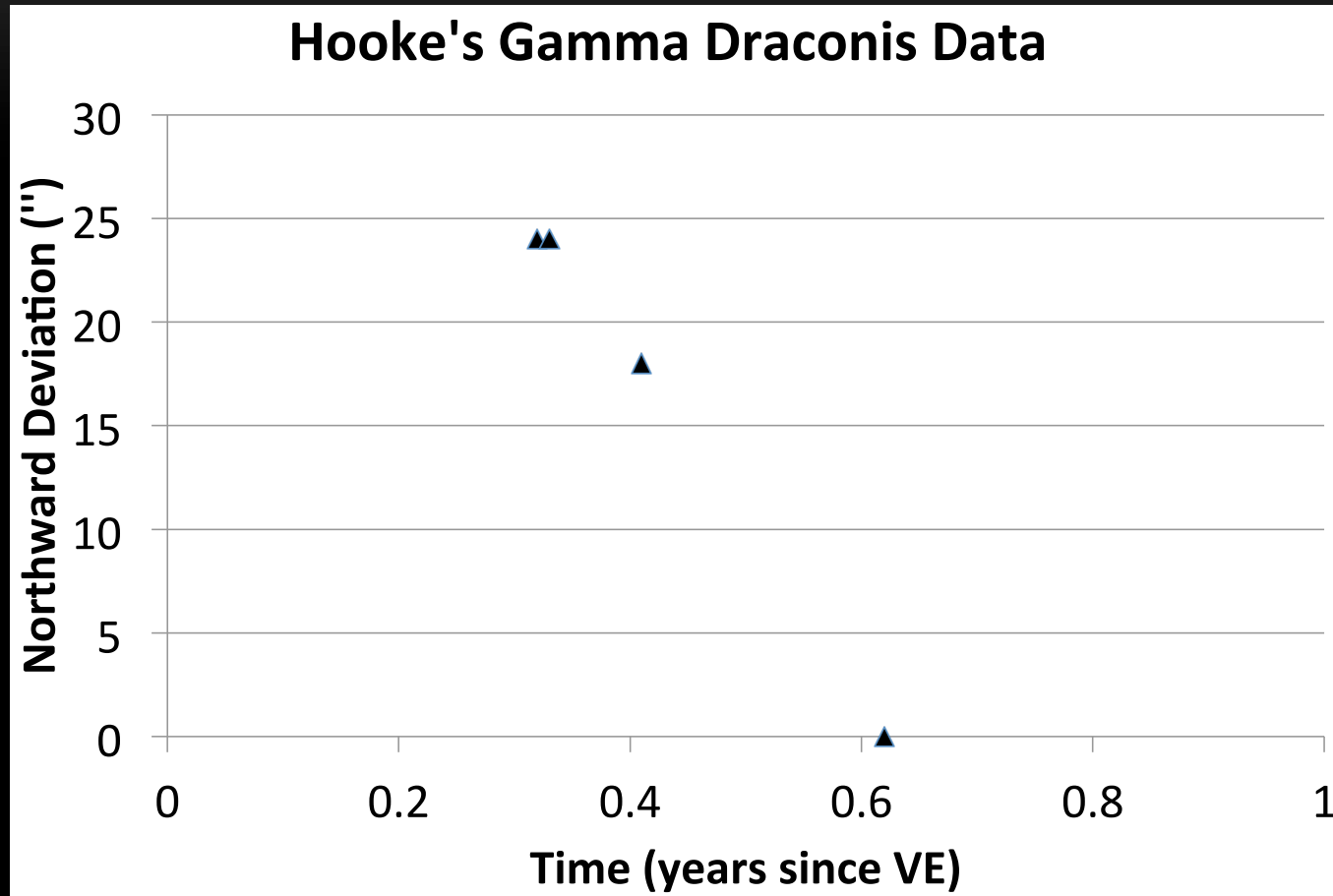
HOOKE'S 1669 PARALLAX MEASUREMENT

- Big questions in 17th century: does Earth really orbit the Sun? How far away are the stars?
- In 1669 Robert Hooke attempted to measure the annual parallax of the star gamma Draconis.
- Built a zenith telescope to measure north-south variations in transit position (changes in declination).
- Published an account of his careful measurement procedures and his results in *An Attempt to Prove the Motions of Earth by Observations* in 1674.
- Reported only four measurements, showing variation of about 25".
- "Tis manifest then by the observations ... that there is a sensible parallax of Earth's Orb to the fixt Star in the head of *Draco*, and consequently a confirmation of the Copernican System against the *Ptolomaick* and *Tichonick*."
- Implied a distance to gamma Draconis of no more than 16,500 AU (0.26 light years).



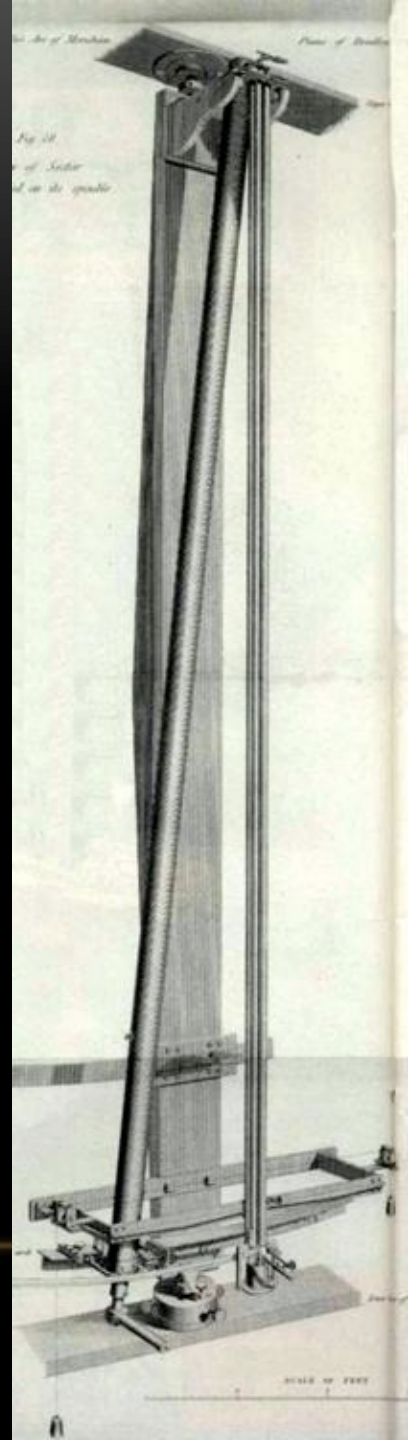
HOOKE'S DATA

- Seems to fit the pattern for the parallax of gamma Draconis.



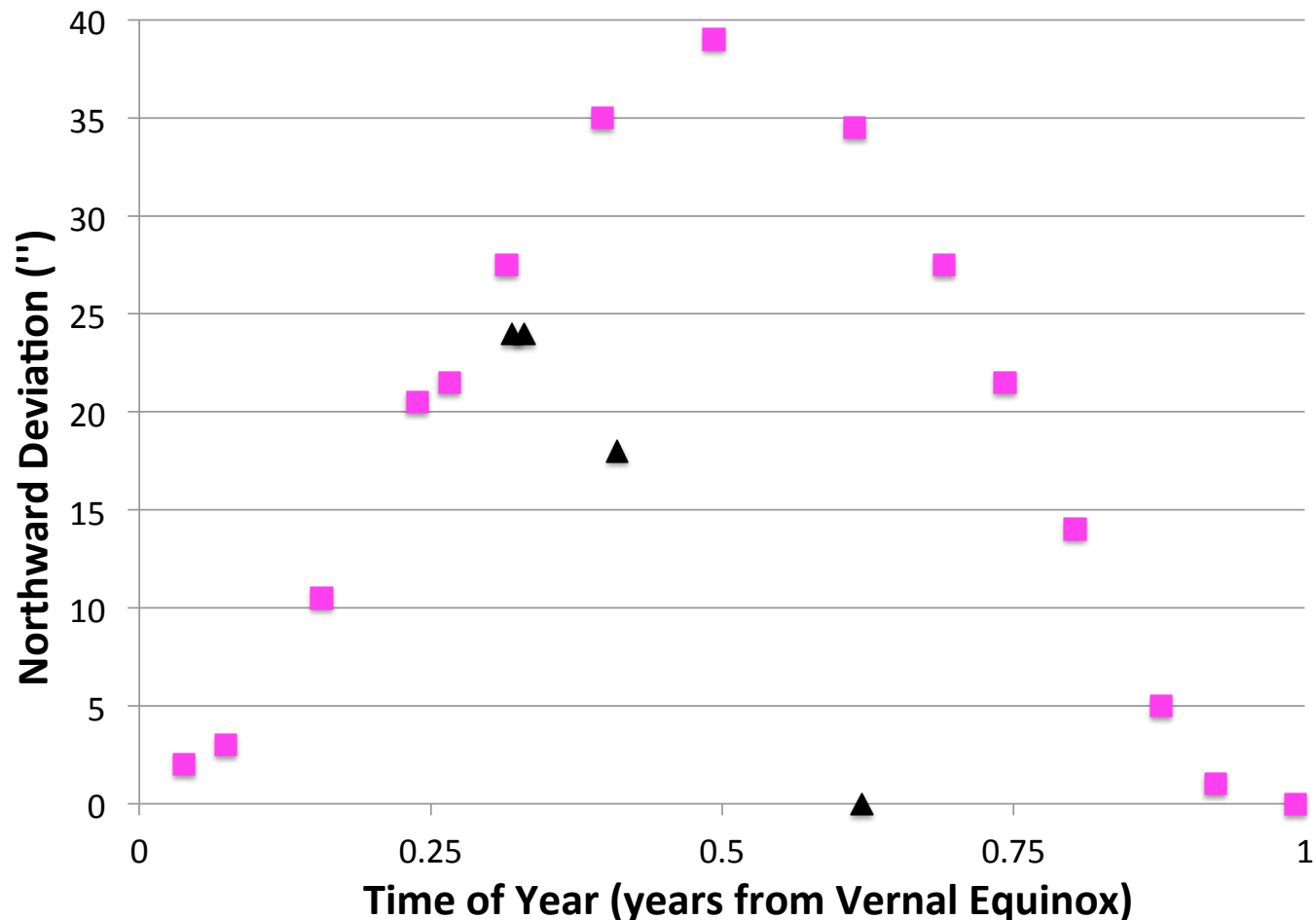
EVALUATING HOOKE'S MEASUREMENT

- Unreliable telescope.
- Only four measurements.
- Flamsteed's parallax for Polaris (40" variation).
- Cassini: Flamsteed's data didn't fit the expected pattern.
- Bradley: aberration of starlight, due to Earth's orbital motion and finite speed of light.
- Flamsteed's data fits the pattern for aberration, but what about Hooke's?



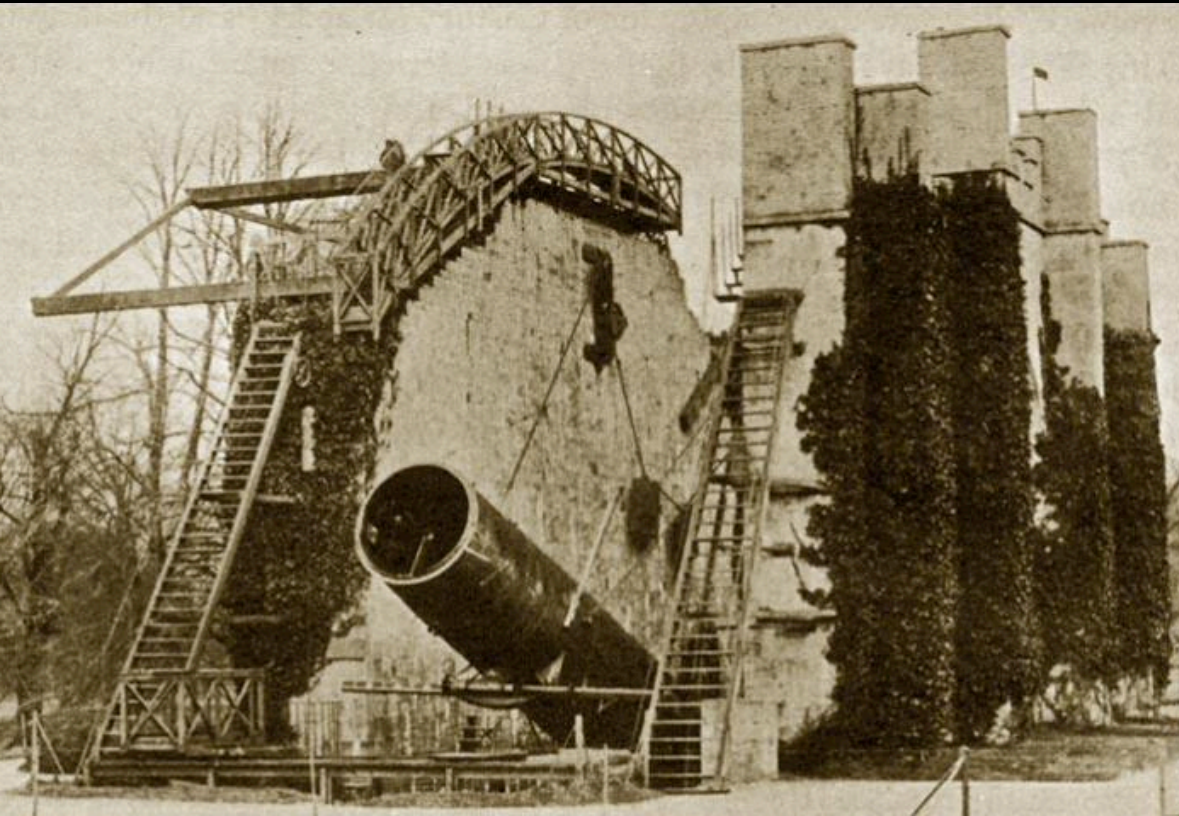
HOOKE AND BRADLEY ON GAMMA DRACONIS

- Hooke's data (triangles) does not match Bradley's (squares), nor the expected pattern for aberration.
- It DOES fit the pattern for parallax. Hooke was looking for an effect that was smaller than his instrument could detect and seeing what he wanted to see.



RESOLVING THE ORION NEBULA

- The Leviathan of Parsonstown: 6' reflector constructed by William Parsons, Lord Rosse at Birr Castle in Ireland. Began operation in early 1845.
- Famed for discovery of spiral structure in some nebulae.



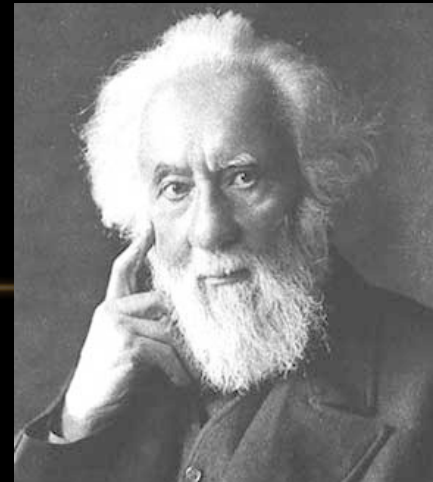
THE NATURE OF THE NEBULAE



- Big question in 19th century: are all nebulae star clusters, or does “true nebosity” exist?
- Rosse and Thomas Romney Robinson (director of Armagh Observatory) claimed resolution (or “resolvability”) of several previously unresolved nebulae (Crab, Ring) with Rosse’s 3-foot telescope.
- With the Leviathan:
 - Robinson in 1845: “of the 43 nebulae which we have examined *All have been Resolved.*”
 - Rosse in February 1846: “We are still in doubt as to the resolvability of the Nebula in Orion.”
 - Rosse in March 1846: “there can be little if any doubt as to the resolvability of the [Orion] nebula. ... we could plainly see that all about the trapezium is a mass of stars; the rest of the nebula also abounding with stars, and exhibiting the characteristics of resolvability strongly marked.”
 - Scottish astronomer John Nichol in 1851: “Every shred of that evidence which induced us to accept as a reality, accumulations in the heavens of matter *not stellar*, is for ever and hopelessly destroyed.”

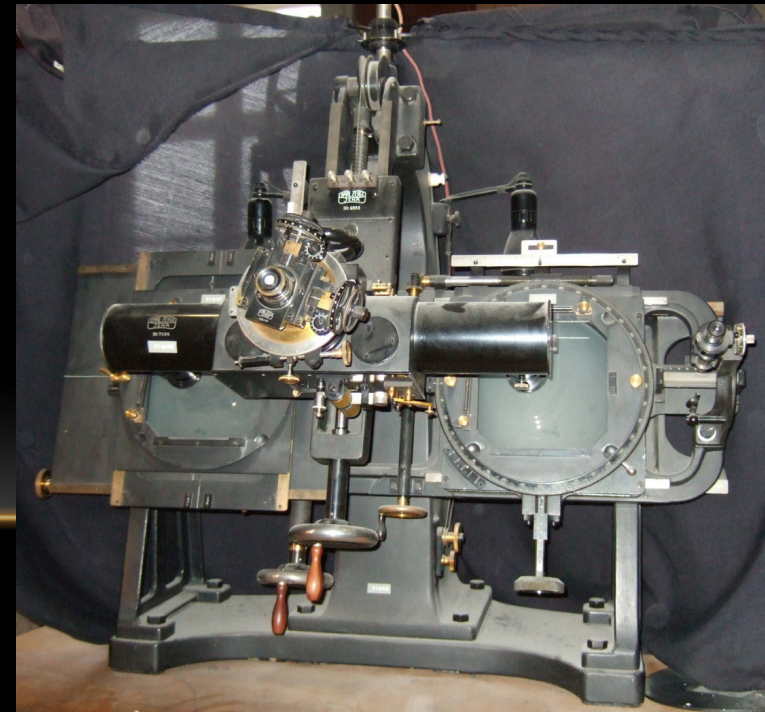
EVALUATING THE BIRR CASTLE RESOLUTIONS

- Doubts: John Herschel's observations of resolved clusters and nebulosity in the Magellanic Clouds, apparent changes in some nebulae (Hind's nebula, maybe even the Orion nebula).
- Spectroscopy in the 1850s: stars and other condensed objects give off a continuous spectrum (possibly with some absorption lines), while diffuse gasses give off a bright line spectrum.
- William Huggins in 1864: Cat's Eye Nebula (a planetary nebula) has a bright line spectrum.
- Huggins: "Out of sixty of the brighter nebulae and clusters, I found about one-third, including the planetary nebulae and that of Orion, to give the bright line spectrum."
- The Orion, Ring, and Crab nebulae are mostly diffuse gas ("true nebulosity"), though the Orion nebula does contain newborn stars as well.
- The Birr Castle astronomers were seeing what they wanted to see.

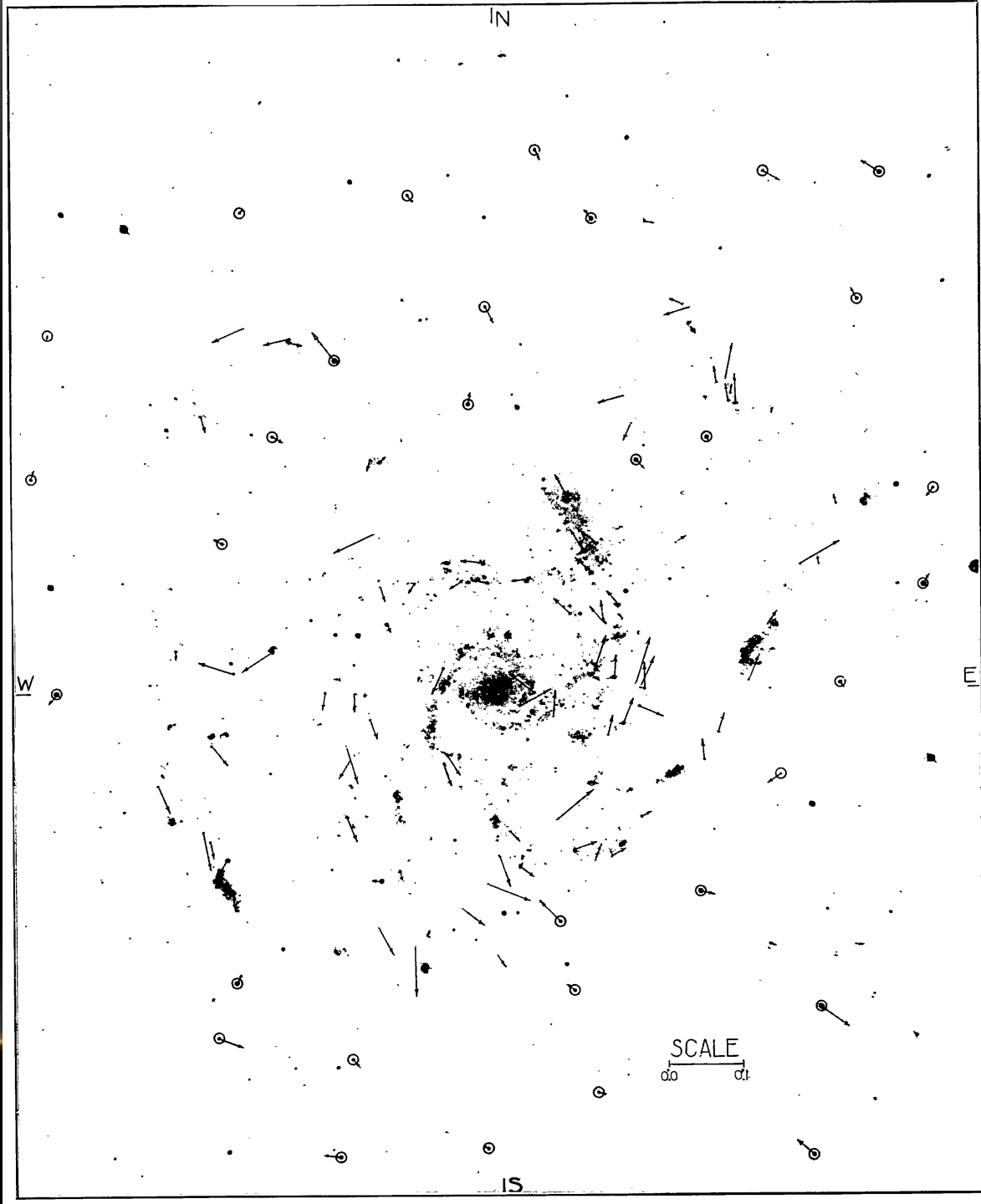


INTERNAL MOTIONS IN SPIRAL NEBULAE

- Big question in early 20th century: are spiral nebulae “island universes”?
- Spiral structure suggests rotation.
- Slipher in 1917: tilt of spectral lines in edge-on spirals shows rotation.
- Van Maanen in 1915: compared photos of M101 ranging from 1899 to 1915 with a stereocomparator.
- Claimed rotation of $15''.13$ per year, or rotational period of 85,000 years, with spiral arms leading.
- Outward radial motion: movement along spiral arms?
- Rotations in other spirals: M 33, M51, M81.

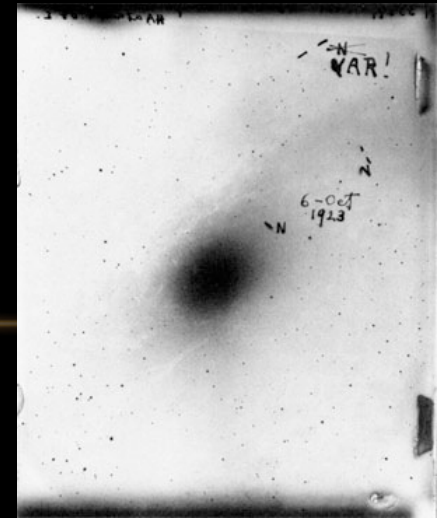


VAN MAANEN'S M101 RESULTS



EVALUATING VAN MAANEN'S ROTATIONS

- If spirals were island universes, then van Maanen's data indicated that they were rotating at speeds faster than that of light.
- Proponents of the island universe theory rejected van Maanen's results.
- Schouten in 1919: M51 is rotating, but with arms trailing.
- Evidence for island universe theory was mounting (Curtis, Great Debate of 1920).
- Van Maanen in 1923: motions not due to error in telescope, photographs, stereocomparator, or measurement methods.
- Lundmark in 1923: re-measured the photographs and found no systematic motions.
- Jeans in 1923: van Maanen's motions can't be due to gravity.
- Hubble in 1924: Cepheids in M31 and M33 show that these spirals are about 1 million light years distant. Rotation must be undetectable at such distances.
- Hubble, Nicholson, and Baade in 1935: re-measured van Maanen's plates and found no motions. Van Maanen was seeing what he wanted to see.



LESSONS ABOUT SCIENCE

- False measurements are not failures of science, they are part of the normal process. When science works well, incorrect results will be corrected.
 - Bad data may lead us to false conclusions, but eventually other data and successful theories will conflict with the bad data or the false conclusions.
 - We may throw out bad data because it conflicts with better data of the same type (Bradley's observations of gamma Draconis versus Hooke's) OR because it conflicts with conclusions drawn from theories we trust (Huggins' spectroscopy of the Orion nebula versus the Birr Castle resolutions, or Hubble's Cepheid distances versus van Maanen's rotations).
 - Science progresses not only by establishing new measurements and new theories, but also by correcting bad measurements and discarding false theories.
 - Ultimate goal: wide scope AND coherence.
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A FEW REFERENCES

- Hooke's parallax
 - Hoskin, "Hooke, Bradley and the Aberration of Light" in *Stellar Astronomy* (1982).
 - Timberlake, "Seeing Earth's Orbit in the Stars: Parallax and Aberration," forthcoming in *The Physics Teacher*.
- Birr castle resolutions
 - Hoskin, "Rosse, Robinson, and the Resolution of the Nebulae," *Journal for the History of Astronomy*, **21**, 331-344 (1990).
- Van Maanen's rotations
 - Hetherington, "Adriaan van Maanen and Internal Motions in Spiral Nebulae: A Historical Review," *Quarterly Journal of the Royal Astronomical Society*, **13**, 25-39 (1972).
- My course materials
 - facultyweb.berry.edu/ttimberlake/copernican/
 - facultyweb.berry.edu/ttimberlake/galaxies/