

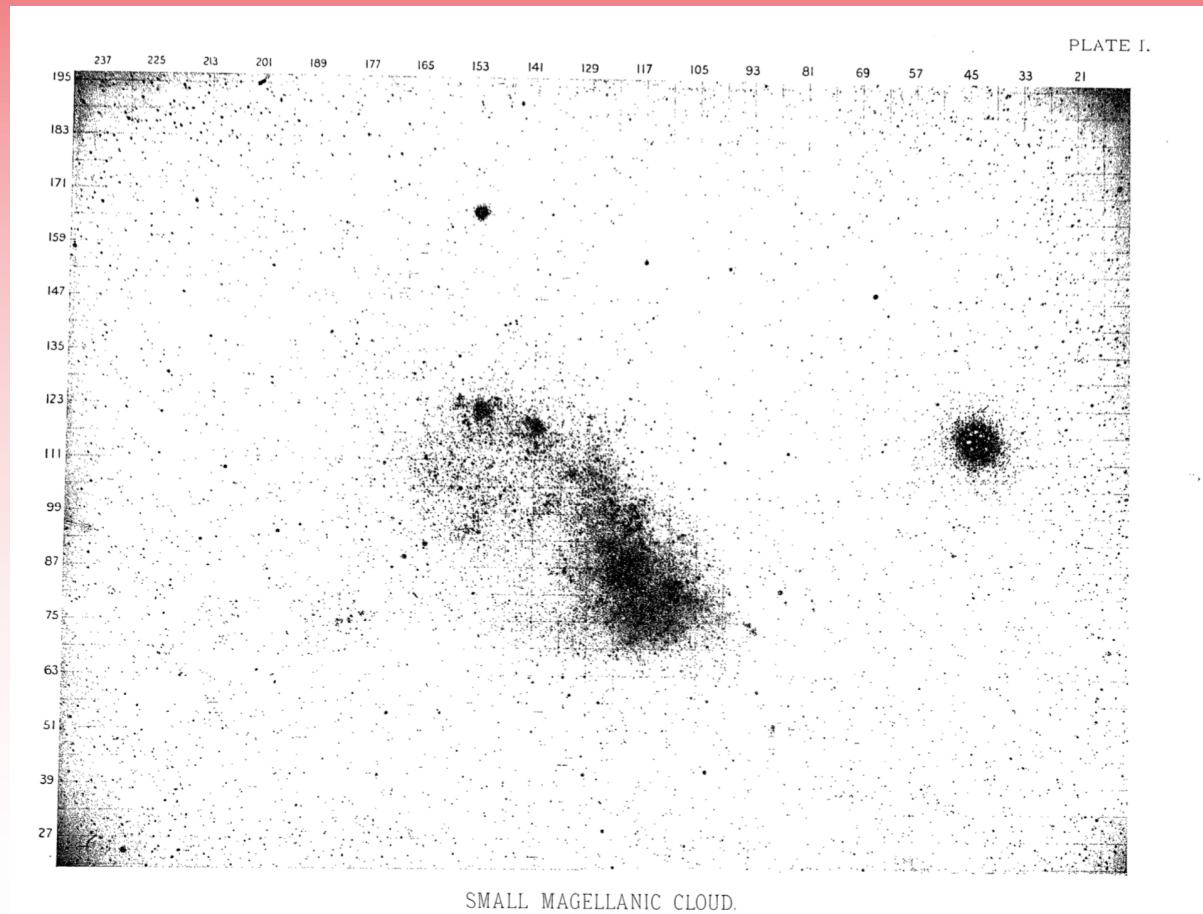
Cepheid Variable Stars from Leavitt to Hubble: The Discovery of Other Galaxies

Physics 090

2020-05-06



Leavitt, 1908, 1777 Variables in the Magellanic Clouds



Leavitt and
Pickering, Period
Luminosity
Relationship

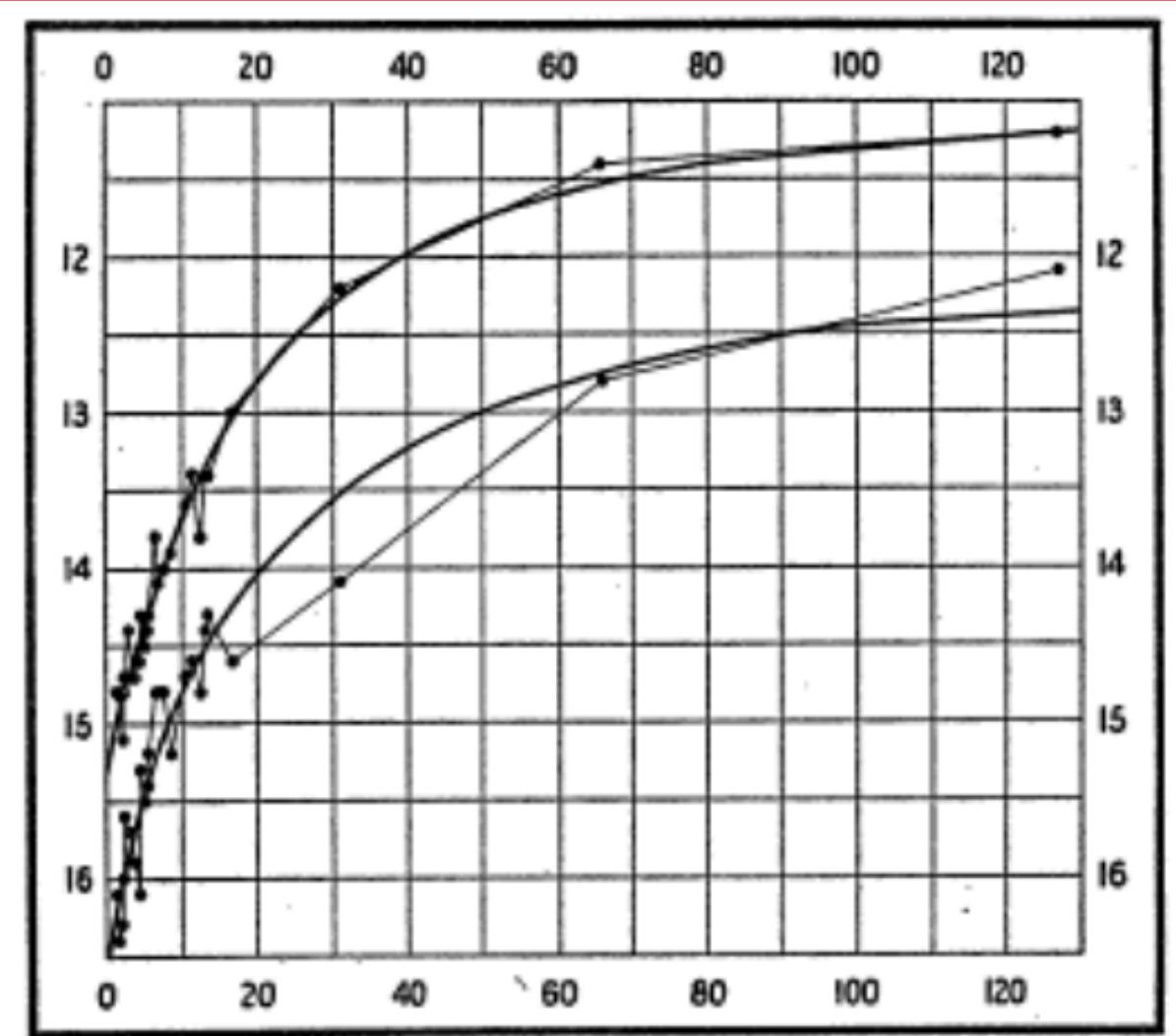


FIG. 1.

variables alike, is about 1.2 magnitudes. Since the variables are probably at nearly the same distance from the Earth, their periods are apparently associated with their actual emission of light, as determined by their mass, density, and surface brightness.

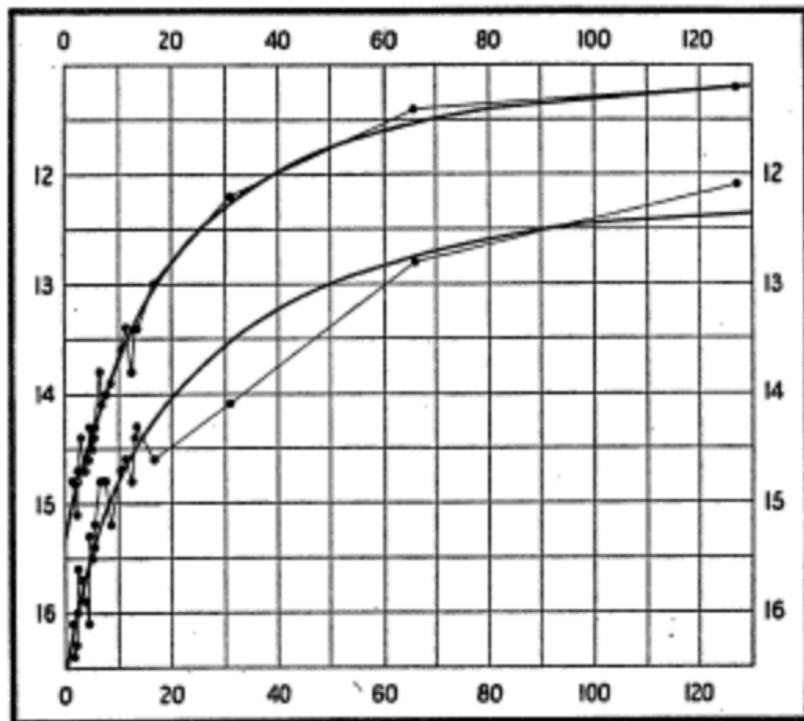


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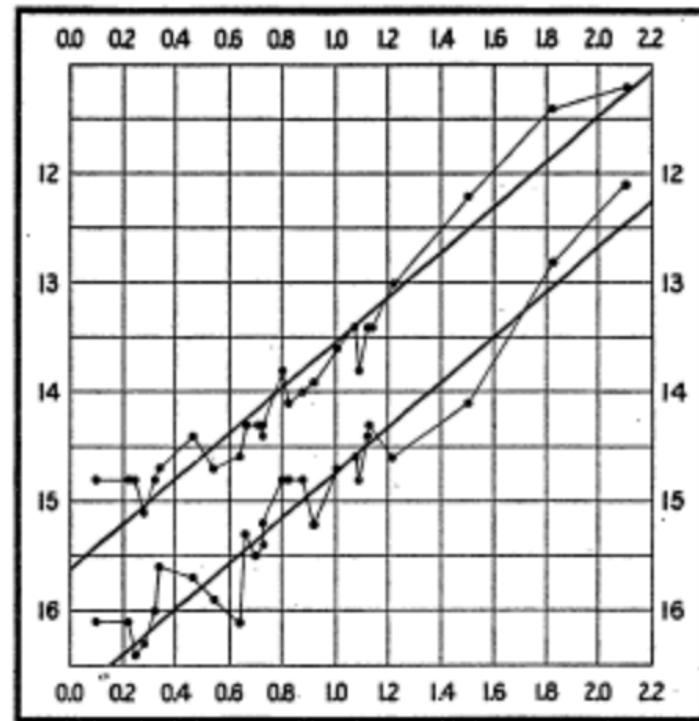


FIG. 2.

The faintness of the variables in the Magellanic Clouds seems to preclude the study of their spectra, with our present facilities. A number of brighter variables have similar light curves, as UY Cygni, and should repay careful study. The class of spectrum ought to be determined for as many such objects as possible. It is to be hoped, also, that the parallaxes of some variables of this type may be measured. Two fundamental questions upon

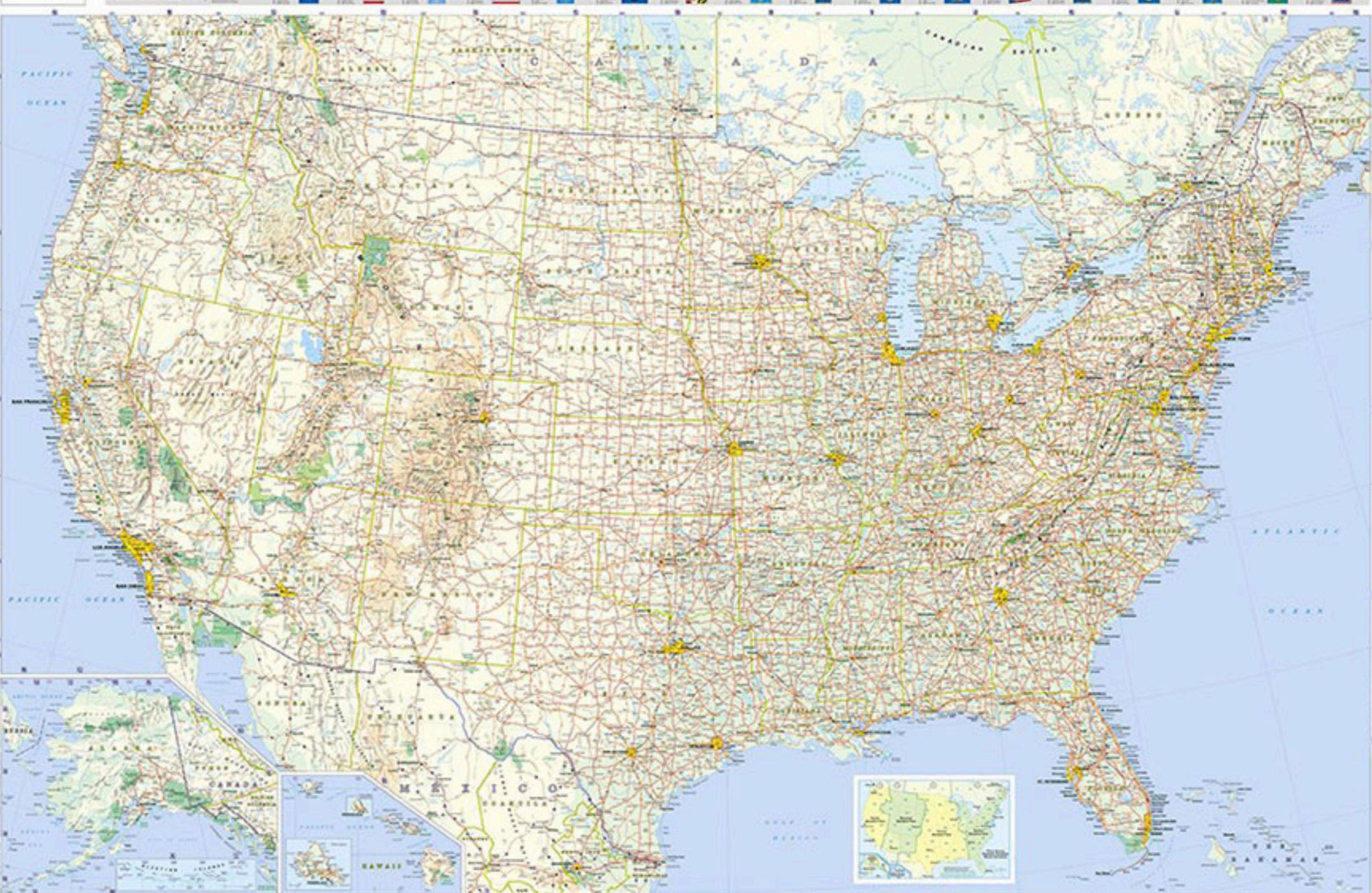
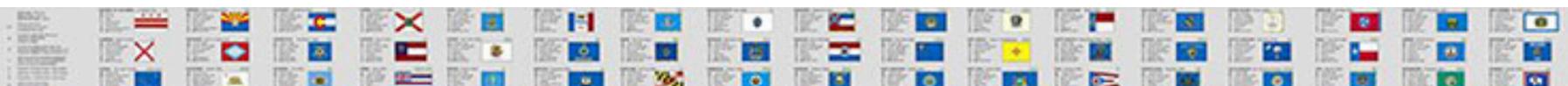
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Hubble image of variable star RS Puppis, one of the brightest known Cepheid variable stars in the Milky Way galaxy. Credit: NASA/ESA/Hubble Heritage Team

Textbook Analogy — Suburbs of Los Angeles





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A mad rush to study nearby variable stars begins.

Crowd-sourced science.

American Association of Variable Star Observers formed 1911.

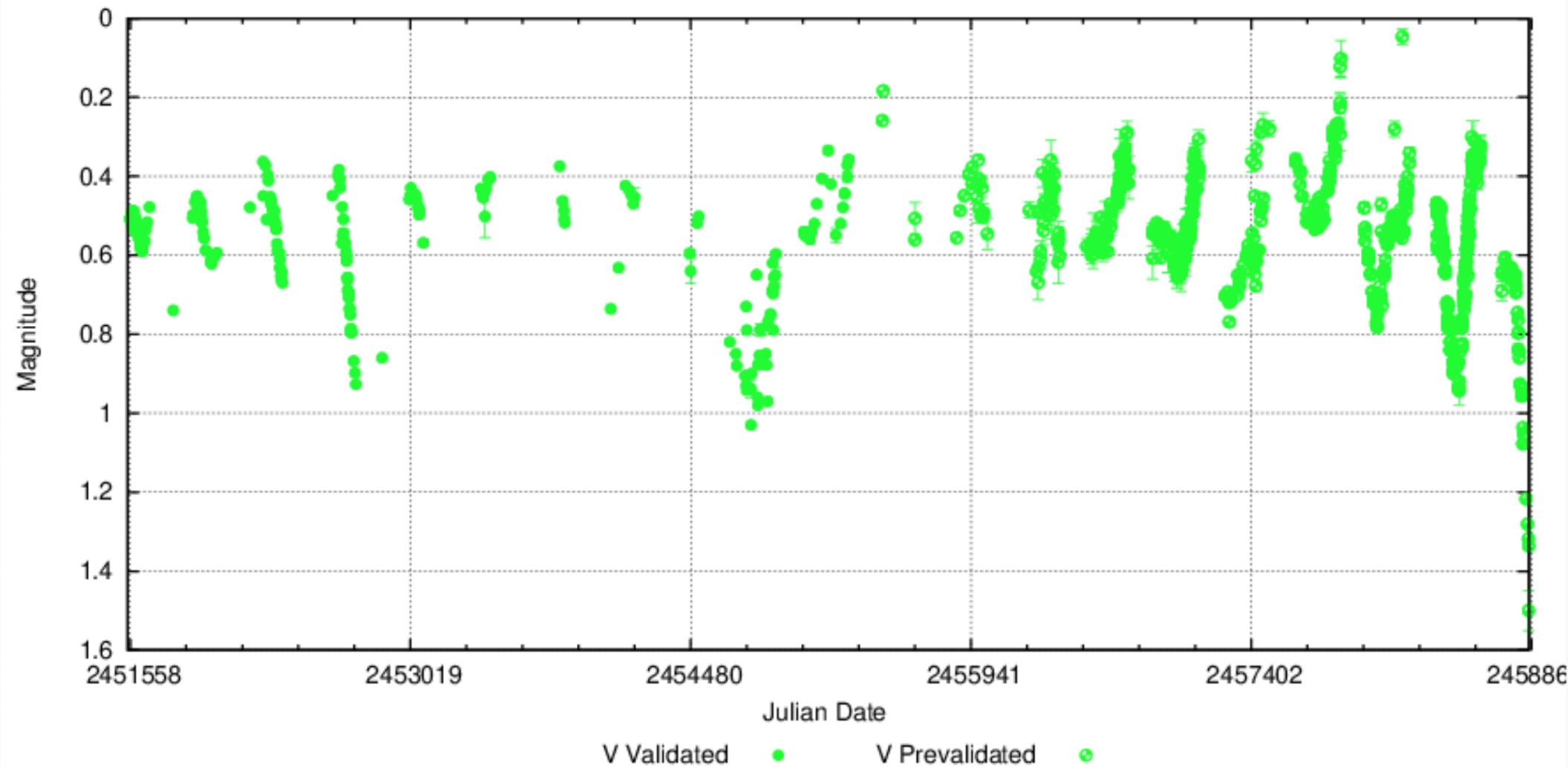


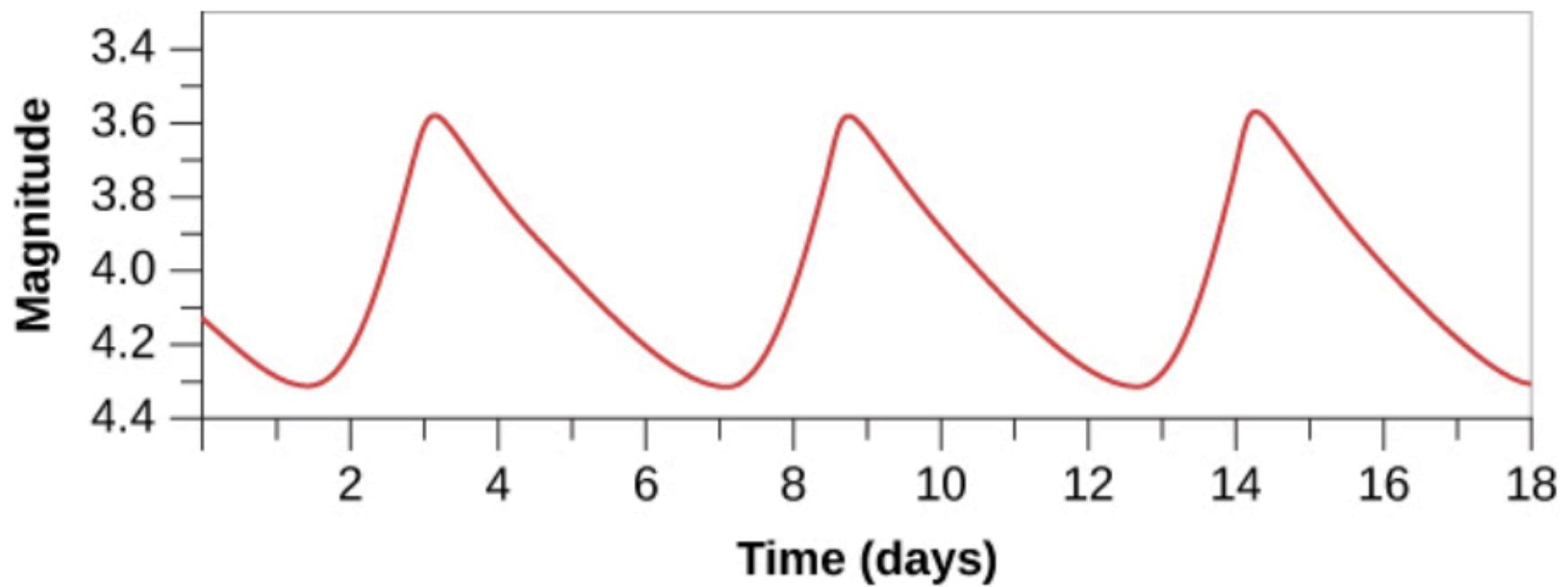
Attendees of the very first AAVSO Annual Meeting,
Cambridge, Massachusetts, November 10, 1917

Source: www.aavso.org/AAVSO-History

20 Years of Betelgeuse Observations — AAVSO

AAVSO DATA FOR BETELGEUSE - WWW.AAVSO.ORG





A Cepheid Light Curve

Estimate its Period

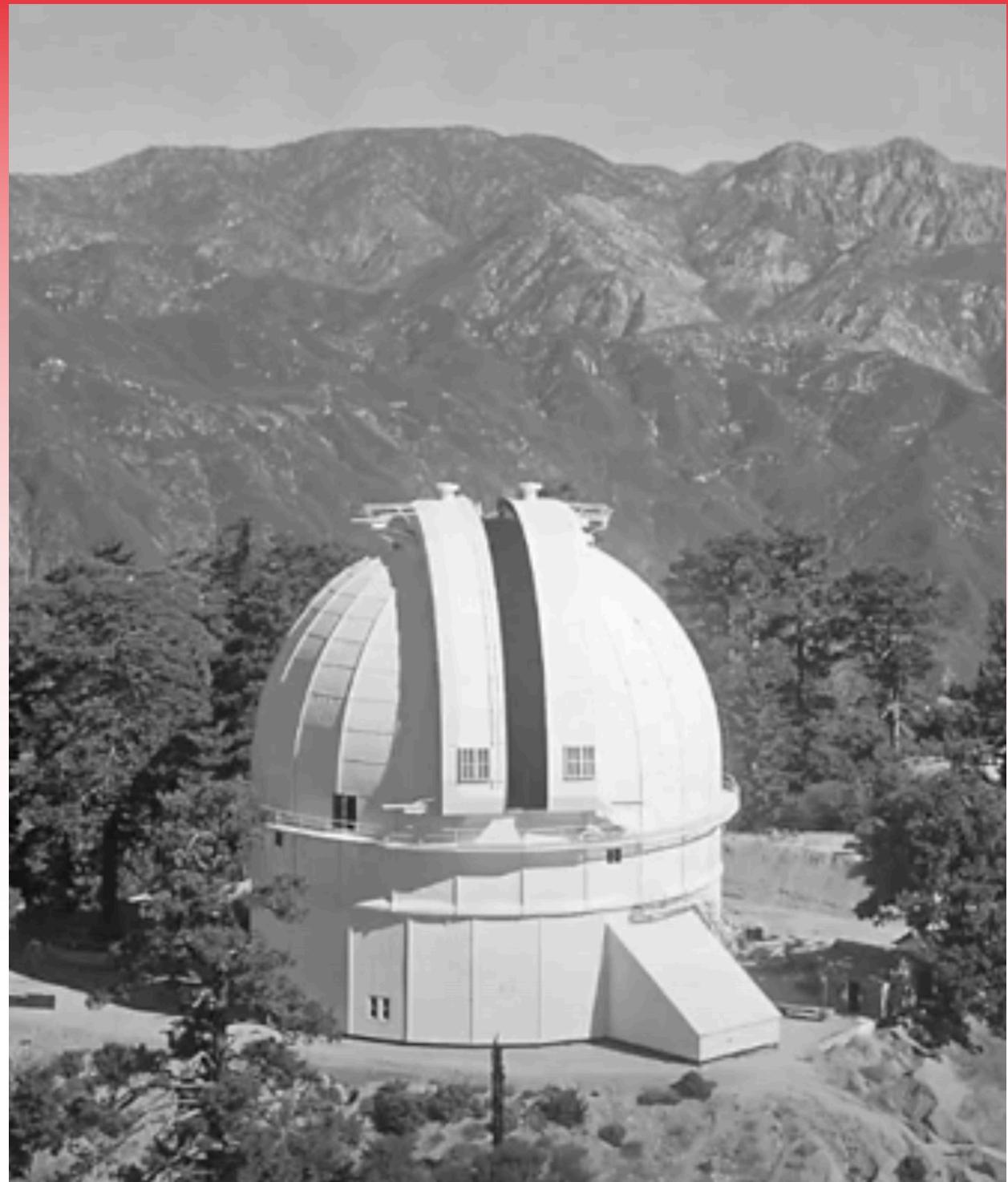
Source: OpenStax

Summarize the Argument

- Leavitt: Apparent Brightness of Cepheids
- Leavitt and Pickering: Period-Luminosity Relationship
- AAVSO Observers of Nearby Cepheids *plus Parallax*
=====> Absolute Brightness of Cepheids
- Absolute Brightness Plus Apparent Brightness
=====> Get Distance!

Result of the Argument (modern values):

Large Magellanic Cloud: 163,000 light-years away
Small Magellanic Cloud: 200,000 light-years away



Leavitt Dies, 1921

Hubble Announces "Island Universes" in the New York Times, in 1924

FINDS SPIRAL NEBULAE ARE STELLAR SYSTEMS

Dr. Hubbell Confirms View That They Are 'Island Universes' Similar to Our Own.

WASHINGTON, Nov. 22.—Confirmation of the view that the spiral nebulae, which appear in the heavens as whirling clouds, are in reality distant stellar systems, or "island universes," has been obtained by Dr. Edwin Hubbell of the Carnegie Institution's Mount Wilson observatory, through investigations carried out with the observatory's powerful telescopes.

The number of spiral nebulae, the observatory officials have reported to the institution, is very great, amounting to hundreds of thousands, and their apparent sizes range from small objects, almost star-like in character, to the great nebulae in Andromeda, which extends across an angle some 3 degrees in the heavens, about six times the diameter of the full moon.

"The investigations of Dr. Hubbell

were made photographically with the 60-inch and 100-inch reflectors of the Mount Wilson observatory," the report said, "the extreme faintness of the stars under examination making necessary the use of these great telescopes. The revolving power of these instruments breaks up the outer portions of the nebulae into swarms of stars, which may be studied individually and compared with those in our own system."

"From an investigation of the photographs thirty-six variable stars of the type referred to, known as Cepheid variables, were discovered in the two spirals, Andromeda and No. 33, of Messier's great catalogue of nebulae. The study of the periods of these stars and the application of the relationship between length of period and intrinsic brightness at once provided the means of determining the distances of these objects.

"The results are striking in their confirmation of the view that these spiral nebulae are distant stellar systems. They are found to be about ten times as far away as the small Magellanic cloud, or at a distance of the order of 1,000,000 light years. This means that light traveling at the rate of 186,000 miles a second has required a million years to reach us from these nebulae and that we are observing them by light which left them in the Pliocene age upon the earth.

"With a knowledge of the distances of these nebulae we find for their diameters 45,000 light years for the Andromeda nebulae and 15,000 light

years for Messier 33. These quantities, as well as the masses and densities of the systems, are quite comparable with the corresponding values for our local system of stars."

FUNDS FOR SCHENCK HOUSE

William C. Redfield Says It Was Built of Timbers of Old Ship.

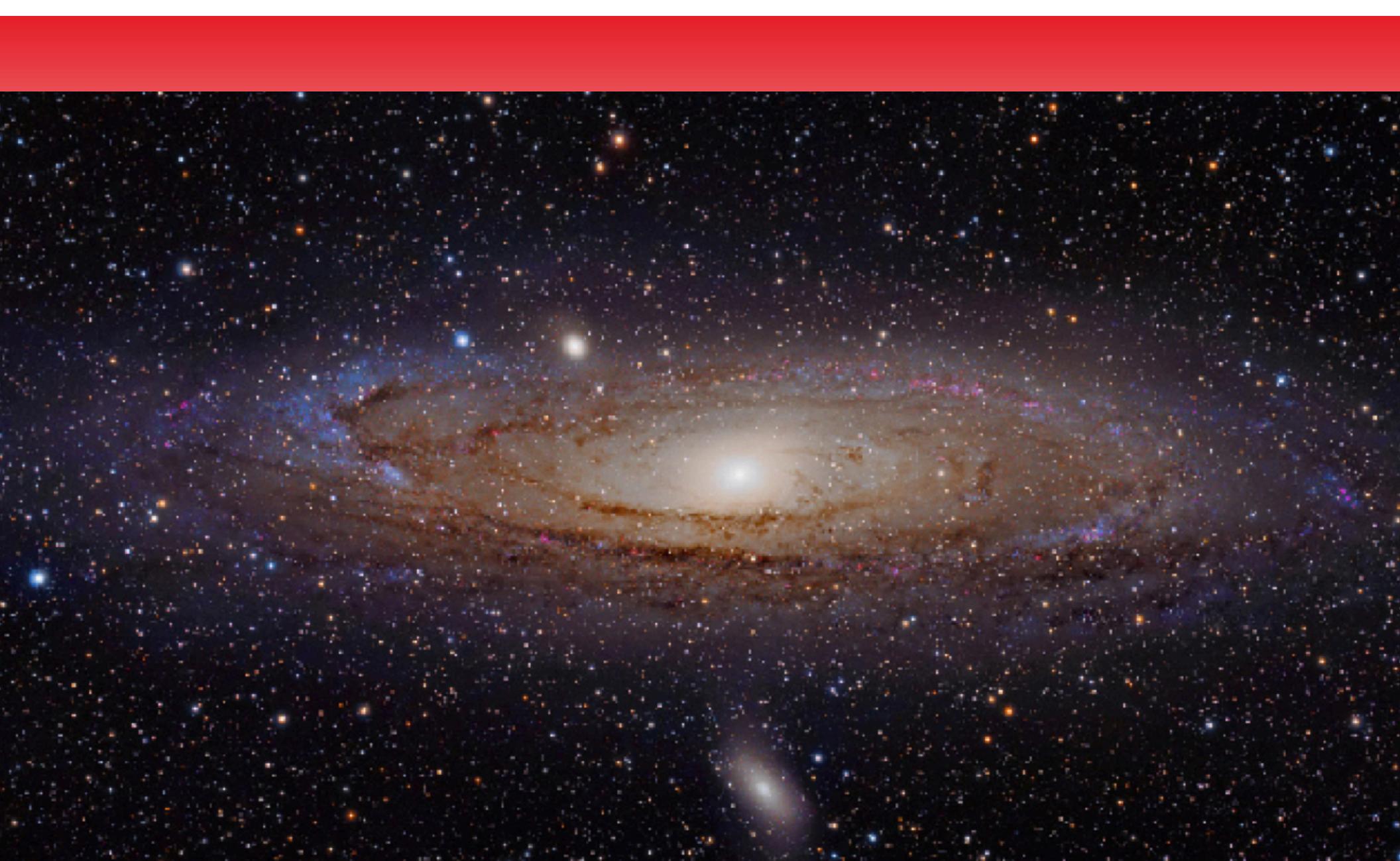
William C. Redfield, formerly Secretary of Commerce and now the President of the Netherland-America Foundation, 17 East Forty-second Street, was one of the many who were interested in the news printed in yesterday's Times that an offer had been submitted to Murray Hulbert, President of the Board of Aldermen, to sell to the city for \$10,000 the old Schenck homestead at Mill Basin, Brooklyn, which is believed to be the oldest house in New York City.

Mr. Redfield, in a letter to Mr. Hulbert yesterday, said that the Schenck house was built out of the timbers of an ancient ship. The old beams are visible and the knees of the old vessel still support the upper floors.

"I earnestly hope that funds may be made available, in order that this exceptional landmark of our city's history may be preserved," wrote Mr. Redfield. Mrs. Redfield is connected by marriage with the Schenck family.

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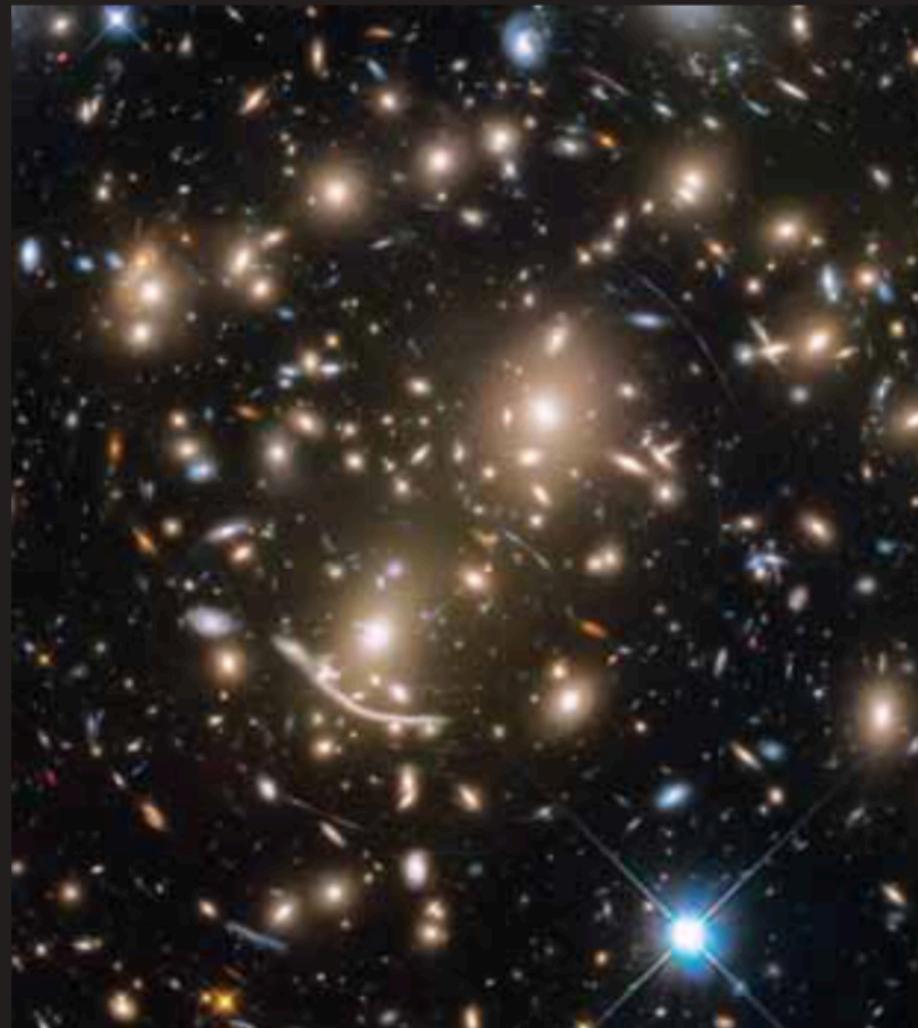
Andromeda Galaxy
Source: OpenStax, Adam Evans

Abel, Corwin, Olowin 370 ☺

Galaxy cluster Abell 370, in the constellation Cetus, contains an astounding assortment of several hundred galaxies tied together by the mutual pull of gravity. Photographed in a combination of visible and near-infrared light, the brightest and largest galaxies are the yellow-white, massive, elliptical galaxies containing many hundreds of billions of stars each. Spiral galaxies have younger populations of stars and are bluish. The mysterious-looking arcs of blue light are distorted images of remote galaxies behind the cluster. The cluster acts as a huge lens in space that magnifies and stretches images of background galaxies.

The Abell catalogue of more than 4,000 galaxy clusters was initially compiled by the American astronomer George O. Abell in 1958 using plates from the Palomar Observatory. This catalog was expanded by Harold Corwin and Ronald Olowin with the 1989 publication of "A Catalog of Rich Clusters of Galaxies" in the *Astrophysical Journal Supplement*.

Photo: Hubble Space Telescope, NASA, ESA, and J. Lotz and the HFF Team



Abell, Corwin, Olowin Catalog Signage at the Geissberger Observatory Pad