Air and Space this Week

Item of the Week

Nancy Grace Roman

and the Orbiting Astronomical Observatory Program

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The Hubble Space Telescope *has had a wonderful 30-year run, and is still going strong, in spite of the suspension of refurbishment visits by astronauts. The next-generation* James Webb Space Telescope *is scheduled for launch within the year. I wrote a two-part Item last March on "Great Observatories," all but one of them Space-based. But they weren't the first aloft. The idea that we could put an astronomical observatory into Space to get it above the deleterious effects of Earth's atmosphere came up at the end of WWII, and there was a series of observatory satellites that pre-date* HST *et al. – the Orbiting Astronomical Observatory program. And there was one person who sparkplugged it all…*

Introduction

Prior to the Space Age, the only way visible-light astronomers could (partially) overcome the impediments of atmosphere was to place observatories atop high mountains, getting their eyes and film cameras above at least some of the air. This strategy is still employed around the world today in places like Cerro Tololo, Mauna Kea, Pic du Midi, Palomar Mountain, and elsewhere. Since our eyes see only "visible" light, and film recording extended our vision only slightly into the infrared, that was all astronomers could do.

Then rocketry and access to Low Earth Orbit came along.

The notion of eliminating the deleterious effects of looking through Earth's atmosphere became feasible by putting an automated observatory higher than the highest mountain, either for a few moments in a sounding rocket, or for much longer time periods in LEO. [Astronomer Lyman Spitzer published a paper on the "Astronomical Advantages of an Extra-Terrestrial Observatory" in the journal, *The Astronomy Quarterly*, in 1947. A variety of satellites were created that proved the concept (*e.g.* the Orbiting Astronomical Observatory series and others), but improvements in detector technology in the 1960's and 70's, along with a lessening for funding for lunar exploration, made the next step forward possible.

Two of the OAO observatories proved very successful, and from the data they produced, astronomers had been steadily learning about the importance of observations in wavelengths normally barred to them, especially gamma rays, X-rays, and infrared parts of the spectrum. Combine that with a glance at the atmospheric transparency as a function of wavelength plot and it's pretty easy to see that a systematic observing campaign, using LEO satellites to cover those wavelength groups (and in visible light to boot) would yield a LOT of important scientific observations. The National Research Council saw this, too, and made the case for a series of four satellites in their 1979 report, "A Strategy for Space Astronomy and Astrophysics in the 1980's." [Aside: the chairperson of the committee that prepared the report, at the time of the report's release, was Harlan J. Smith, featured in a previous "Item of the Week."] Planning for a Space-based observatory for each of the four wavelength zones was already underway, but the next-generation "Great Observatories" packaging made a lot of sense.

Lyman Spitzer and Harlan Smith did play a key role in the development of the concept of spaceborne astronomical observation platforms. NASA still had to design and build them. NASA's very-first Chief of Astronomy, Nancy Grace Roman, played a pivotal role in the Orbiting Astronomical Observatory program, laying the groundwork that made the *Hubble Space Telescope* possible.

Spitzer's promotion of a Space-based telescope was so early and so vigorous that he won the informal title, "Father of Hubble," by acclimation. Roman's role was so important that she not only became known as the "Mother of Hubble," but she also is the official namesake of the next generation Space telescope.

The Orbiting Astronomical Observatory Program

The OAO program was established in 1959 as part of NASA's Physics and Astronomy program. Note the speed with which NASA turned to practical and scientific use of Low Earth Orbit, as soon as it became feasible to do so. Our first successful satellite, the tiny *Explorer 1*, was launched on 31 January 1958. Within two years, the first meteorological satellite, *Tiros 1*, was launched. The needs of astronomy required more spacecraft sophistication (especially in pointing accuracy); the launch of the first real astronomical observatory satellite would not come until early 1966.

Pre-OAO: A lot of research on high-altitude conditions and astronomical observations at inconvenient wavelengths was conducted in the late '40s, throughout the '50s (especially during the IGY), on through to today, using sounding rockets. Such rockets were available after WWII, and they are a LOT cheaper than a satellite, but they offer significant aiming difficulties and short observing times, only a few minutes per launch. But the data they produced proved the value of having more advanced instruments in LEO. A wonderful reference for the history of sounding rocket science during this period is NASA SP-4401, here.

The OAO Program: NASA's portfolio expanded greatly during the 1960s. A LOT of effort and money was expended on the manned Space program to get us to the Moon "before the decade was out." Of course, that depends on one knowing when a decade begins and ends (see the Didja Know? section).

There was, however, enough funding to allow NASA to pursue the first generation of Space-borne telescopes, the Orbiting Astronomical Observatories. There were four of them planned, all covering primarily the ultraviolet and shorter-wavelength part of the spectrum, almost all of which is completely blocked by Earth's atmosphere. Two failed miserably, and two were wildly successful. Nancy Grace Roman was the Program Scientist on the first two; more on that later.

OAO-1: The first satellite in the OAO program carried instrumentation for making UV, X-ray, and gamma ray observations. It was launched successfully on 8 April 1966. Shortly after attaining LEO, a massive electrical problem disrupted spacecraft operations. Its solar panels could not deploy and *OAO-1* died when its batteries drained. It never had a chance to even power up its instruments.

OAO-2**:** The second OAO satellite two suites of detectors, comprising a total of 11 telescopes operating in different parts of the spectrum, from 1000 to 4250 Angstroms. [BTW: The Principal Investigator of one of the instrument sets was Fred Whipple, a name that long-time readers of A+StW should recognize. He's perhaps best known for his "Dirty Snowball" model for comets, but he also studied the threat to LEO operations posed by micrometeoroid impact and developed the still-used "Whipple Shield" to provides some protection. He also helped develop the use of "window" radio/radar jamming in WWII (and no, Charmin was not part of the jamming process!)]

OAO-2 was launched on **7 December** 1968, the anniversary we celebrate together with this Item. *OAO-2* was a tremendous success, in operation until February, 1973! *OAO-2* data were used to make several important discoveries such as the behavior of stars immediately after going nova (they were dimming in visible spectrum in the aftermath of going nova while at the same time, they were getting brighter in the UV part of the spectrum), and the observation of large clouds of hydrogen gas surrounding the nuclei of active comets.

OAO-B: Next up was a stinker that didn't even last long enough to get a number in the OAO mission sequence. Launched on 30 November 1970, *OAO-B* had UV sensors of greater size and sensitivity than their *OAO-2* counterparts, which would have allowed astronomers to see objects much fainter than *OAO-2* could. If *OAO-B* could make LEO. Shades of *Mariner 3* and *Gemini 9*'s "Angry Alligator" – the aerodynamic shroud protecting the spacecraft failed to jettison, and the resulting spacecraft plus shroud was too heavy to attain orbit.

OAO-3 (aka "Copernicus"): Sometimes satellite nomenclature can be confusing, especially when the fourth OAO satellite is named "OAO-3." [*OAO-1* made orbit, and got the number; *OAO-B* did not make orbit.] *OAO-3* had an improved UV spectrometer and three X-ray telescopes, collectively covering a range of wavelengths from 1-3000 Angstroms. The Principal Investigator of UV telescope experiment was, fittingly, one Lyman Spitzer, whose advocacy helped make orbital telescopy possible in the first place! *OAO-3* was launched on 21 August 1972, a few weeks before Gene Cernan made the final (for now!) footprint on the Moon, and was in operation for almost an entire decade, terminating in February, 1981.

Nancy Grace Roman

Dr. Nancy Grace Roman, as mentioned above, is considered the "Mother of Hubble," due to her hard work and tireless advocacy for Space-based astronomical research. She passed away on 12/26/2018, and her career is celebrated by the official naming of the wide-angle telescope now under development, the *Nancy Grace Roman Space Telescope*.

Nancy Grace Roman was born on May 16, 1925, in Nashville. Her father was a scientist and her mother taught music. Both were strong supporters of learning, and fostered an interest in the natural sciences in young Nancy. She was interested in astronomy in particular, and she organized a school astronomy club when she was only 11. She blew through the primary and secondary grade levels, graduating high school a year early. She went to Swarthmore College to study astronomy. Astronomy was dominated by men, and she found discouragement at every turn, except for a crumb of opportunity from the Astronomy Department chair, who taught her the basics and let her use the school's student telescopes. By her sophomore year, she was working in Swarthmore's Sproul Observatory, processing astronomical photographic plates. The Astro chair appreciated her efforts, and gave her a solo lecture course on positional astronomy, which required her to become very familiar with the school's astronomy library and how to use it. She graduated from Swarthmore in early 1946, and at the Astro Chair's suggestion, she applied for graduate study in astronomy at the University of Chicago. Higher education was in somewhat of a state of rebuilding after WWII and, like a baseball team that is "rebuilding," had a few star astronomy researchers and were looking to add more to the faculty.

Her coursework only whetted her appetite for more learning opportunities, so she asked three prominent astronomers in the department for additional projects she could work on. Otto Struve gave her theory-based project; George van Biesbroeck gave her a project involving data analysis, but the third, William W. Morgan, delighted her with an observation-based project. She earned a Ph.D. in Astronomy in 1949, with a dissertation on galactic motion.

Now ***Dr.*** Nancy Grace Roman, she spent a couple of months at Case Western's observatory, then post-Doc'ed with Morgan at U. Chicago's Yerkes Observatory (hey gang, how's that for a connection with the fifth "Great Observatory" in the earlier two-part Item!?). Her primary research area was stellar spectroscopy, but she was developing a greater interest in galactic structure and the use of radio telescopes in the effort. She also was an active supporter of the use of the latest data acquisition/processing equipment and techniques, sometimes to the point of annoying her senior management. She some important advances in the understanding of stellar ages and motions. Those, and a fortuitous observation of AG Draconis, an odd variable star, made her a rising star (sorry) in the field.

Up to this point, Dr. Roman had encountered a considerable amount of discouragement in the sciences due to her gender, but had so far persevered. She had worked her way up the ranks and was now on the faculty of Chicago's Astronomy Department. For whatever reason, she did not feel she would earn tenure, in spite of her success to date, which would normally have ensured promotion.

Gerard Kuiper, one of the few planetary scientists of the time, knew of Dr. Roman's interest in galactic structure and similar topics, which require the use of radio astronomy data. He also knew she might be looking for a change. After all, Yerkes/Chicago had no radio astronomy capability. He knew about a radio astronomer position available at the Naval Research Laboratory in DC, and suggested to Dr. Roman that she apply. She did, and got the job.

Dr. Roman found the research work enjoyable, but ultimately it would prove to be a poor fit for her. Radio telescopes were in their infancy at that time, and just about any radio astronomer then working also had to be their chief engineer for their antennae and equipment, something not in Dr. Roman's wheelhouse. But she pursued several productive topics, nonetheless, including the study of the propagation of sound underwater and the use of radar in geodesy, including figuring out how to determine the mass of the Earth based on precise radar determination of the Earth-Moon distance (and ultimately, with laser ranging, the Earth-Moon distance proves the rate of slowing of the Earth's rotation due to tidal friction, and that allows confirmation of the accuracy of radiometric dating over eon-long time periods; a topic for a future Item of the Week).

In the course of three years at the NRL, Dr. Roman's work earned her greater responsibility, heading the microwave spectroscopy unit. Her earlier work with stellar spectroscopy and made her well-known in the astronomical community, and she has opportunities to consult for NRL on a wide variety of topics, including astronomy consulting with Project Vanguard, and for conference travel, which burnished her professional reputation considerably. For example, she was invited to attend the dedication of the new Byurakan Observatory in Soviet Armenia in 1956, the first American scientist to visit that country during the Cold War.

There was one element of foreshadowing that appeared at that time. She wrote a Letter to *The Astronomical Journal*, printed in October, 1959, entitled, "Planets of other suns," where she states that planets the size of those in our Solar System, orbiting Alpha Centauri at the distances our planets do, could be directly imaged by telescopes then available, "…if our terrestrial atmosphere did not limit our resolution." This is a dozen years after Lyman Spitzer started clamoring for Space-based telescopes, and with this Letter, Dr. Roman is clearly echoing the sentiment.

Life is all about timing, and location. Dr. Roman had come to DC to be a radio astronomer, and she's realized that she is on the wrong career path for her. She's been quite successful, but then….

Newly-created NASA came to call. Dr. Roman was a well-known astronomer (both nationally and internationally), had demonstrated she could run research projects, and was "local." They asked her for advice on creating a program for Space-based astronomy, and Dr. Roman stepped up and applied for the job herself. She later related how it was a career-watershed decision she never regretted. She knew that the Head of Observational Astronomy position would be entirely administrative; taking it would end her research career. But she realized that she could best serve the cause of Science by taking the position, and "running interference" for talented teams rather than be the kind of administrator that "causes interference" for demoralized teams. And she was right.

Dr. Roman inherited a program portfolio that included the topics of geodesy and relativity studies, along with the Orbiting Solar Observatory program under development. She was very skilled at organization and network building, and was promoted in 1960 to the position of Chief of Astronomy at NASA, the first actual astronomer to have that position, and the first time NASA had a woman in a senior management position.

She was a dynamo. She developed and executed the eight-mission OSO program, which were launched over the period from March, 1962 to June, 1975. At the same time, she was supervising the development of the OAO program, and served as the Program Manager for *OAO-1* and *OAO-2*.

Over the next few years, Dr. Roman oversaw the development and launch of the *Uhuru* X-ray satellite (1970), the *Small Astronomy Satellite 2* gamma-ray telescope, the *Small Astronomy Satellite 3* X-ray telescope, and a variety of smaller projects. In her spare time, she set up NASA's scientific balloon program and NASA's airborne astronomy program, including its first telescope-in-a-Lear-Jet and the follow-up Kuiper Airborne Observatory (the discovery of the rings of Uranus were made on the KAO). During her tenure, the *COBE* program was started (two of its scientists would win the Nobel Prize), as was the *Infra-Red Astronomy Satellite*, the *International Ultraviolet Explorer*, and finally, the *Hubble Space Telescope*.

Dr. Roman, flush with the success of OAO-2, had upped her level of promotion of the idea of orbiting a large Space-based telescope. NASA liked the idea, it got an endorsement from the National Academy of Science, in 1971. Dr. Roman set up an advisory committee, the Science Steering Group for the Large Space Telescope, and appointed the appropriate engineers and scientists to it. Roman was deeply involved in the planning for the LST and setting up its program structure, work that would lead to the creation of the Space Telescope Science Institute (STScI). She pushed hard to secure the necessary funding, and paid particular attention to the LST having the best imaging system possible. As the result, the *HST* (nee LST) would end up being the first (non-military) observatory anywhere using CCD-base imaging, a major advance.

Dr. Roman would retire from NASA in 1979, but continued on as a consultant to finish setting up the STScI. She also served as the head of the Astronomical Data Center at NASA-Goddard (find more on the ADC's history here). Not exactly a leisurely retirement! If that weren't enough, she then taught advanced high school students and K-12 science teachers in underserved districts. She had always been an advocate for women in science, individually, and with the American Association of University Women.

The awards and recognition given Dr. Roman over the course of her illustrious career are too long to list here, but I'll include two as examples of the breadth to which her influence on society reached. She was selected in 2017 to be one of the "Women of NASA" portrayed in a LEGO set (along with Margaret Hamilton of *Hidden Figures* fame, astronaut Mae Jemison, and astronaut Sally Ride). NASA re-named the *Wide Field InfraRed Survey Telescope* in her honor; it is now officially the *Nancy Grace Roman Space Telescope*.

Resources

NGR interviews might be of interest to you, or your (grand)daughter, or son, for that matter:

> https://solarsystem.nasa.gov/people/225/nancy-roman-1925-2018
>
> https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4846
> (conducted by NASM's David DeVorkin!)

NASA's: Nancy Roman: https://solarsystem.nasa.gov/people/225/nancy-roman-1925-2018

NASA (3/31/17): https://www.nasa.gov/image-feature/dr-nancy-grace-roman-astronomer

Info on OSO and OAO: https://history.nasa.gov/SP-4012/vol3/ch3.htm

OAO: The Orbiting Astronomical Observatories, *Space Science Reviews*, v.2, issue 5, pp. 621-652, November, 1963

Lyman Spitzer: https://www.discovermagazine.com/the-sciences/farewell-to-nasas-heat-vision-space-observatory

HST at 30: https://www.popularmechanics.com/space/satellites/g32266058/hubble-telescope-history

NOTE

I received some immediate feedback on this particular Item, something I am delighted to get from anyone, and I thought it would be a good idea to share it with you. SHW

"Roman's relations with scientists were very complex. She had to campaign for astronomy on the one hand within NASA, and also control astronomers' enthusiasms on the other. Especially with what became OAO2 – see DeVorkin, David H. 2018. Fred Whipple's empire: the Smithsonian Astrophysical Observatory, 1955-1973. Washington, DC: Smithsonian Institution Scholarly Press. https://doi.org/10.5479/si.9781944466176

https://repository.si.edu/handle/10088/55494"

Dr. Roman did not want to separate the OSO and OAO programs, nor did she want interference with her prioritizing instrument payloads, "especially when she knew she would be dealing now with each of the PIs, none of whom were shrinking violets. Neither, of course, was Roman."

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