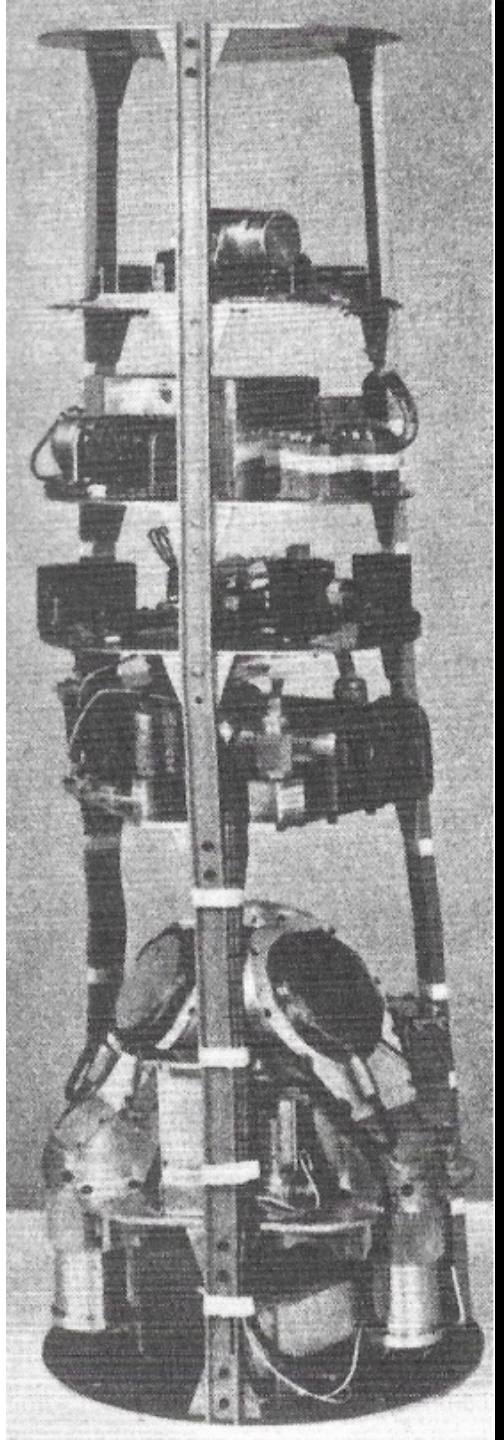
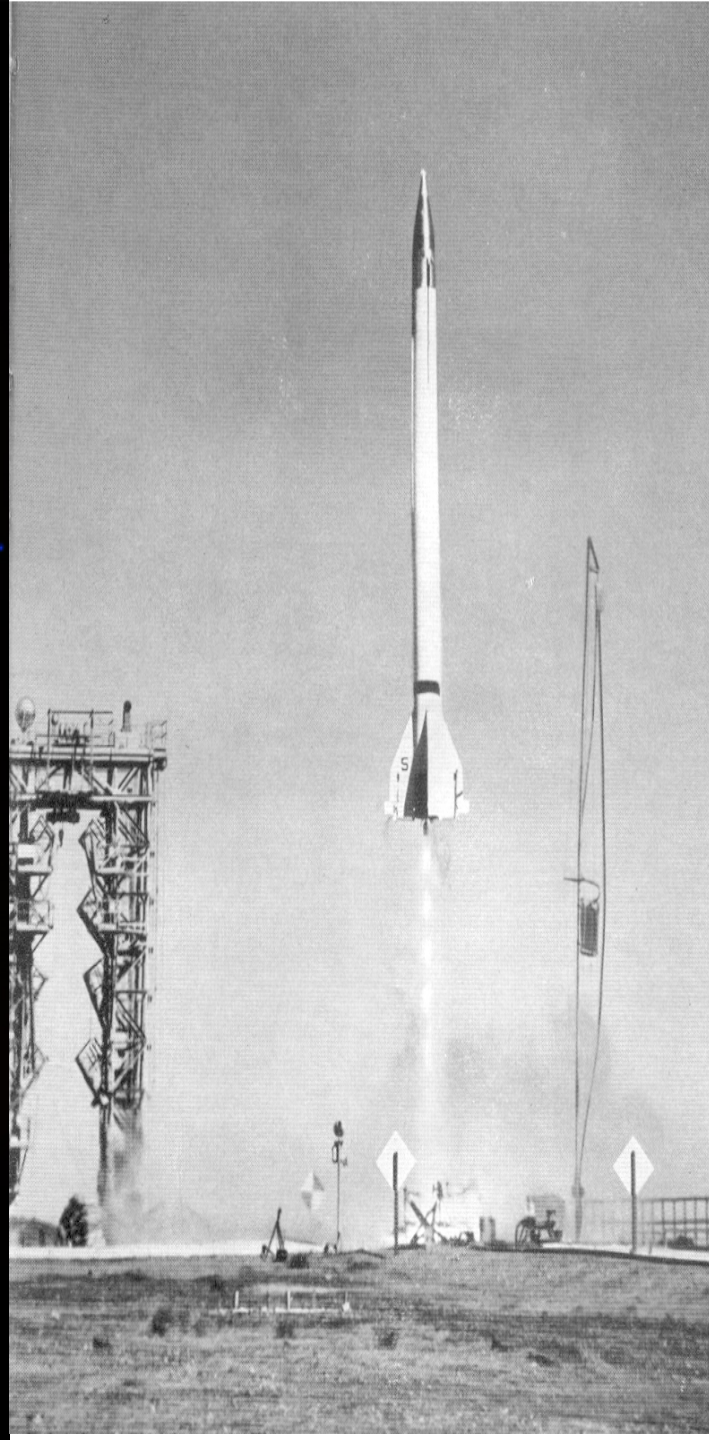
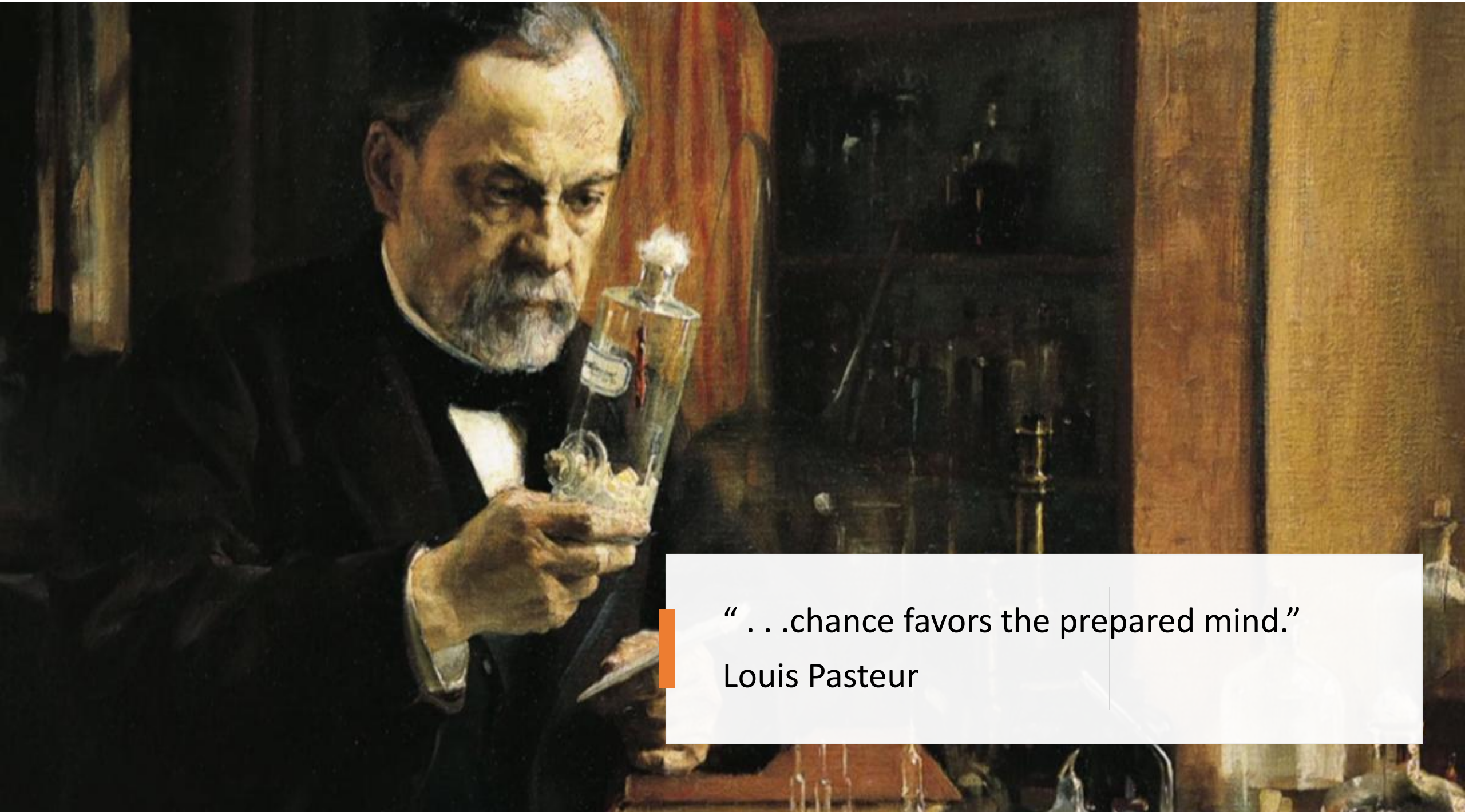


Riccardo Giacconi & X-ray Astronomy: The Discovery Years with Rockets



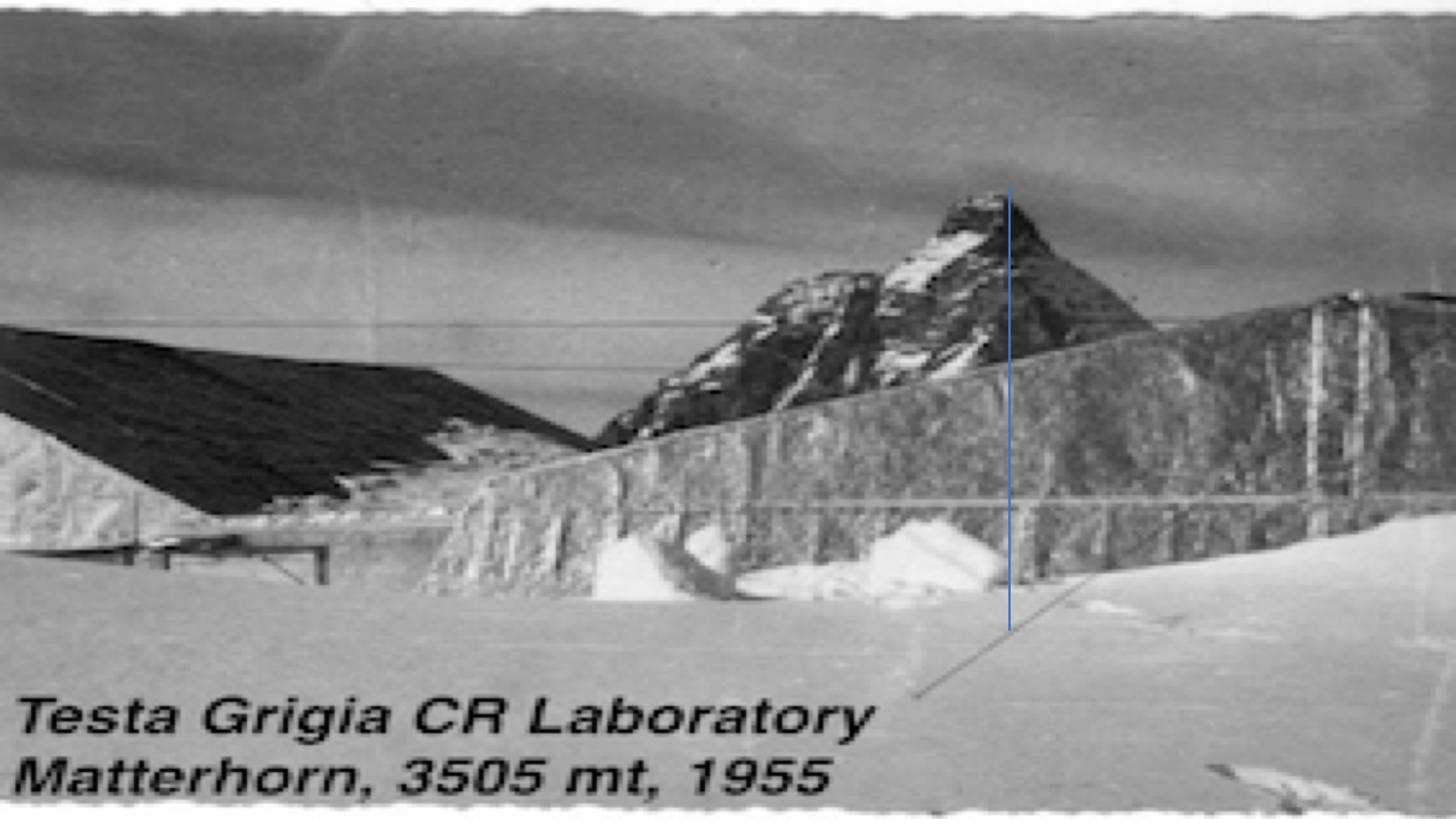
“our discourses should be about the real world, not a world on paper.” *Galileo*

“We should use modern technology for the construction of instruments powerful enough to solve physical problems by direct observation rather than by inference or speculation.“ *Riccardo Giacconi*



“ . . .chance favors the prepared mind.”

Louis Pasteur

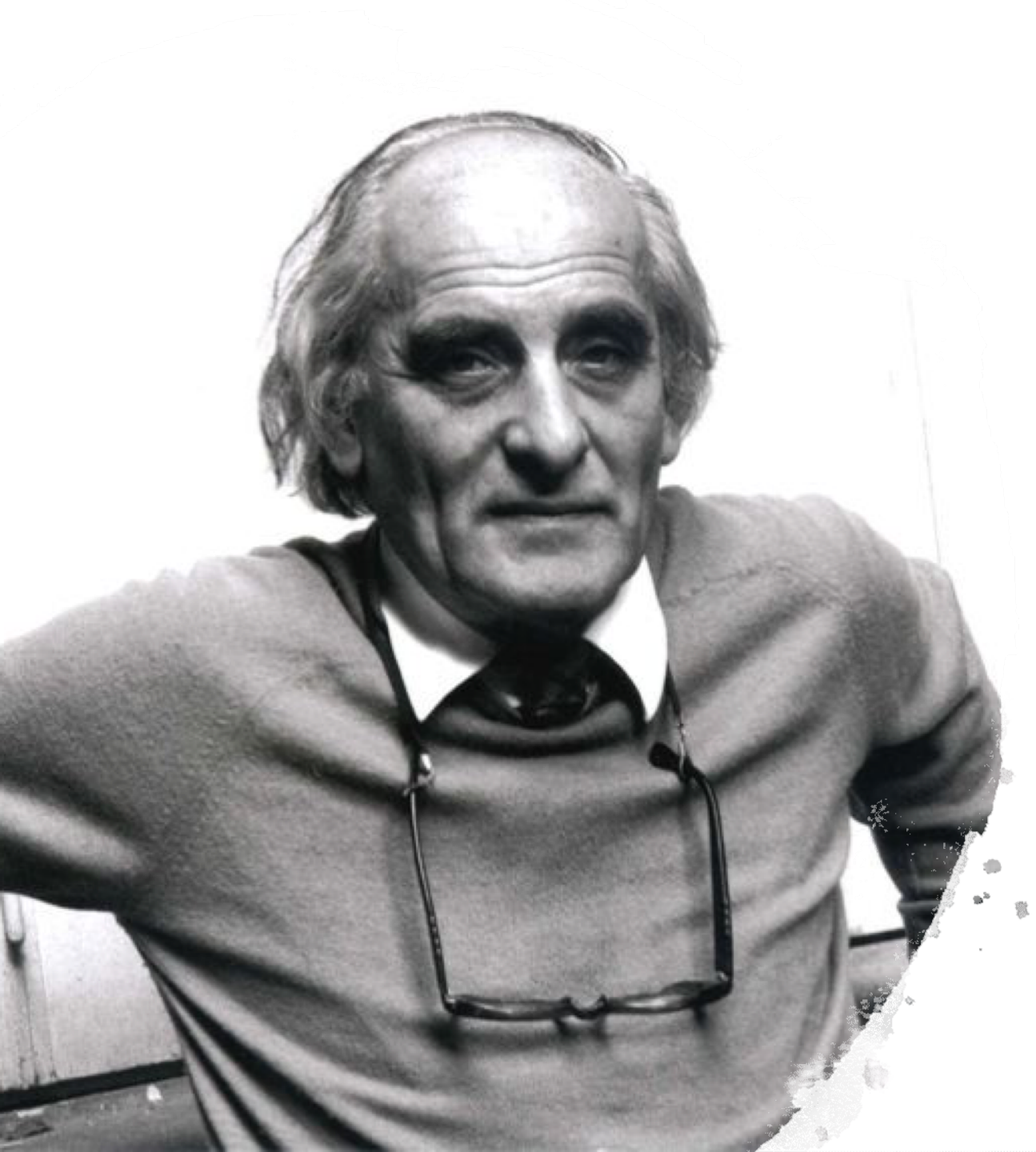


Testa Grigia CR Laboratory
Matterhorn, 3505 mt, 1955

”Life at the laboratory was rough; we lived in a Quonset hut, melted snow to obtain our water, and suffered episodes of scurvy brought on by vitamin deficiencies. I spent, on and off, two years there to obtain 80 proton events that formed the basis of my thesis.”

Riccardo Giacconi
Secrets of the Hoary Deep (2008)

80 proton events in 2 years! ! . . . I dreamed of concentrating cosmic rays on my instrument by means of a magnetic funnel.



“Go west, young man.”

Guiseppe (Beppo) Occhialini ,
Riccardo Giacconi’s thesis advisor

The Hoosier Years: Sep. 1956 – Sep. 1958

"As a Fullbright fellow at the University of Indiana, I learned a method for managing projects from the physicist Robert W. Thompson that I would describe simply as LEARN-THINK-PLAN-DO. . .

– Riccardo Giacconi

Learn, think, plan, do.

Rule#1: Look carefully at a problem and then try to design an experime with the maximum likelihood of obtaining critical results.

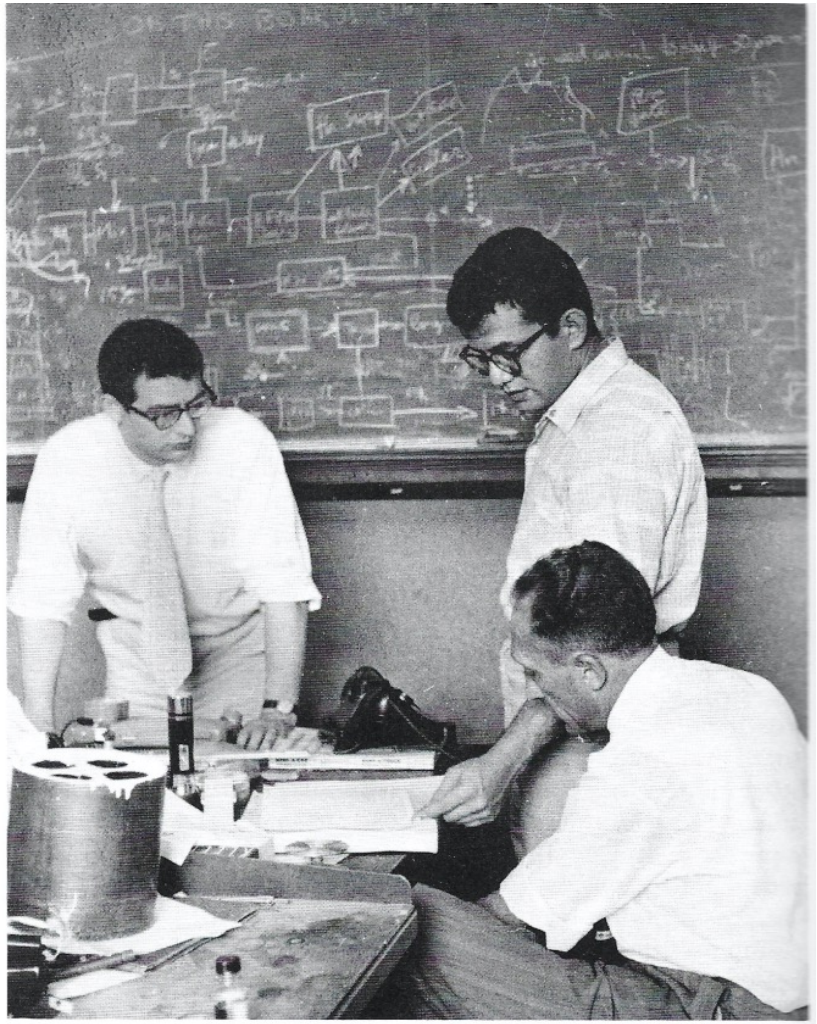
Rule #2: This process often required not just a small improvement of the previous state of the art but a major jump in sensitivity by the use of new technologies.”

Sep. 1958 – Sep. 1959
Two Herbs & Serendipity at Princeton

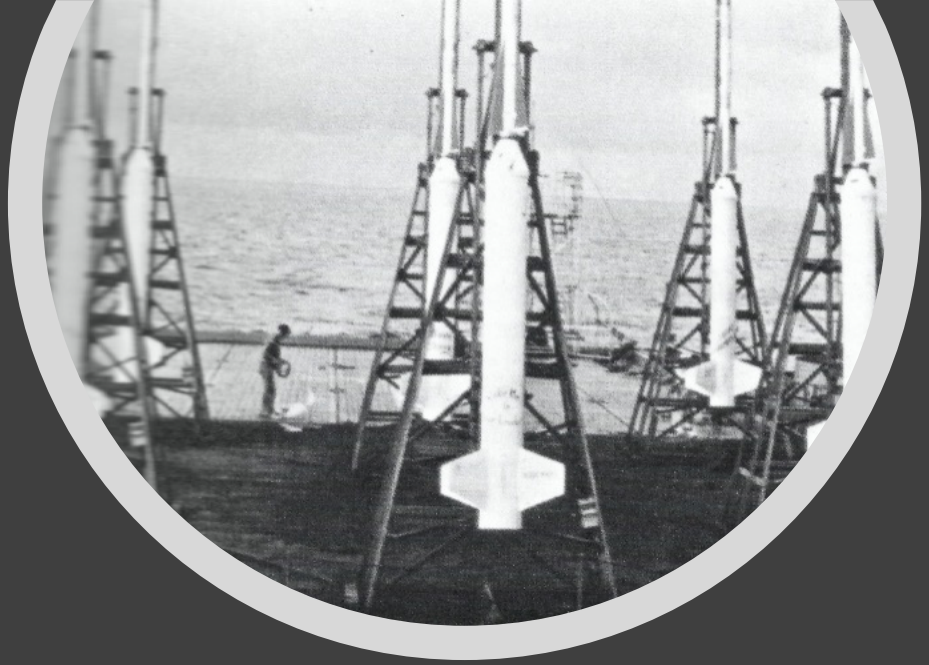
While working at the Cosmic Ray Laboratory at Princeton, Riccardo met Herb Gursky (pictured) with whom he was working, and Herb Bridge, who was visiting from MIT.

Herb Gursky became a valued colleague and friend for 48 years.

Herb Bridge (not shown here) was impressed by Riccardo and told Martin Annis, president of American Science & Engineering, that Riccardo would be a good person to hire.



During this period, the availability of rockets was opening new avenues of exploration



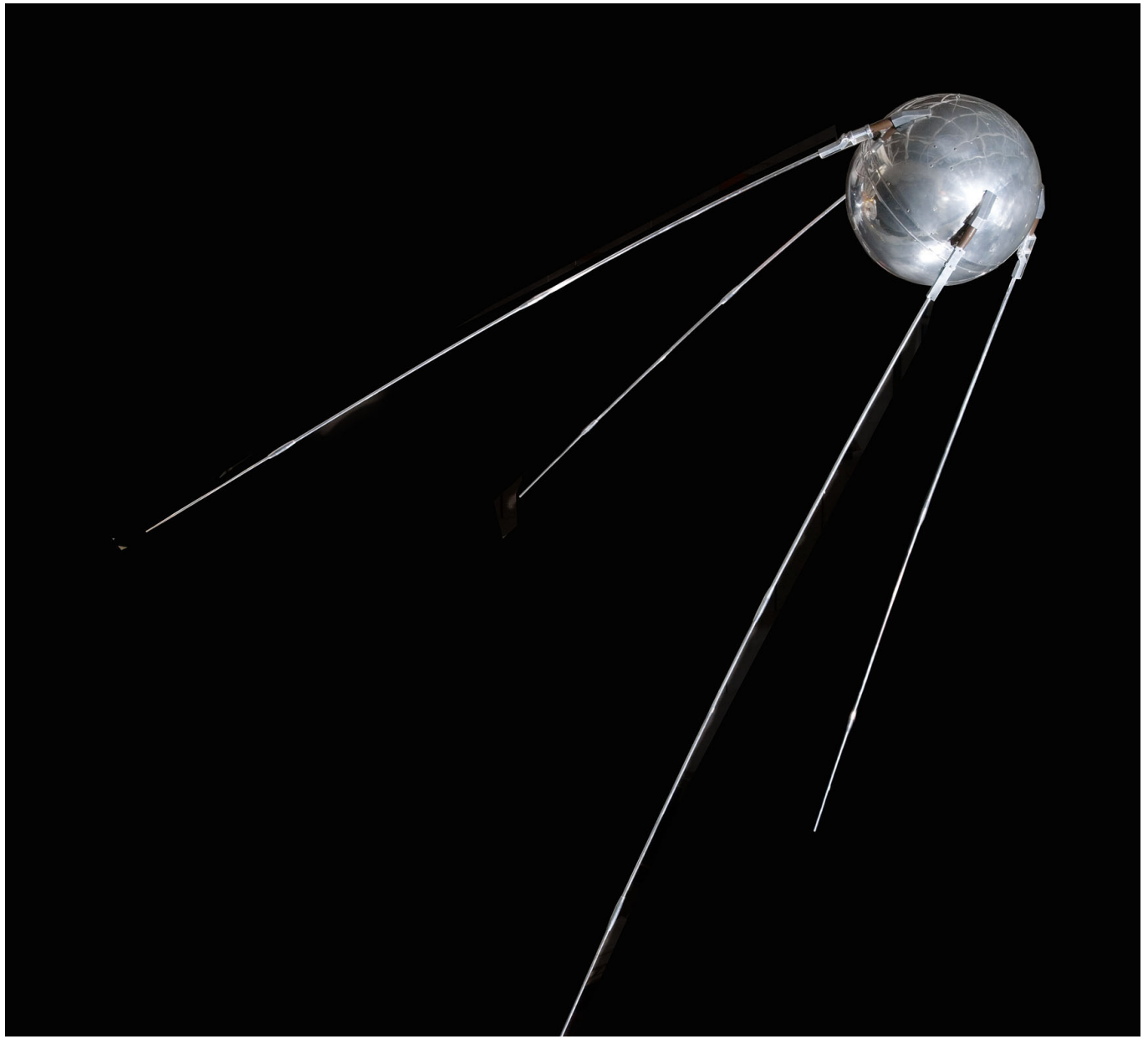
Herb Friedman
Naval Research Laboratory

* Pioneered X-ray observations of the Sun from 1949 with first detection of solar X-rays, observation of flares, etc.

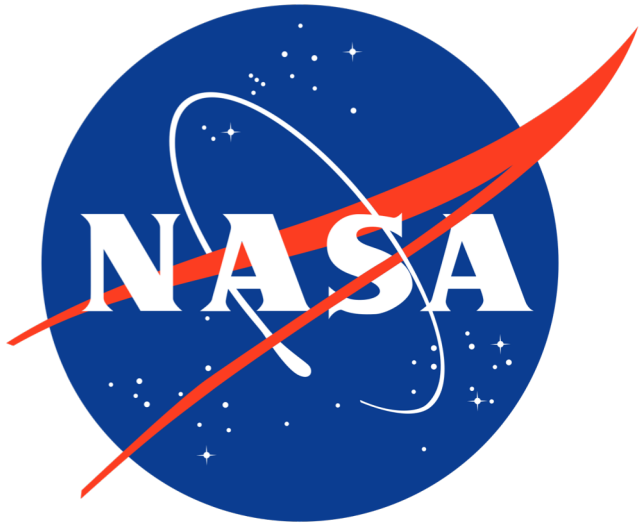
Meanwhile, “Back in the USSR . . .”

October 4, 1957

Sputnik 1 launched!



U.S. Response to Sputnik



October 1, 1958

American Science & Engineering (AS&E)

* Founded in 1958 by Martin Annis, an MIT graduate
* Annis received his Ph. D working for Bruno Rossi
- Supported mainly by research grants from DoD on effects of nuclear weapons
- Had 27 employees in 1959
- Giaccconi began working at AS&E in Sept. 1959. He had no security clearance at first, so couldn’t do defense work.

Bruno Rossi

* Professor at MIT

* Thesis advisor for Occhialini, Thompson, Bridge, Annis and George Clark

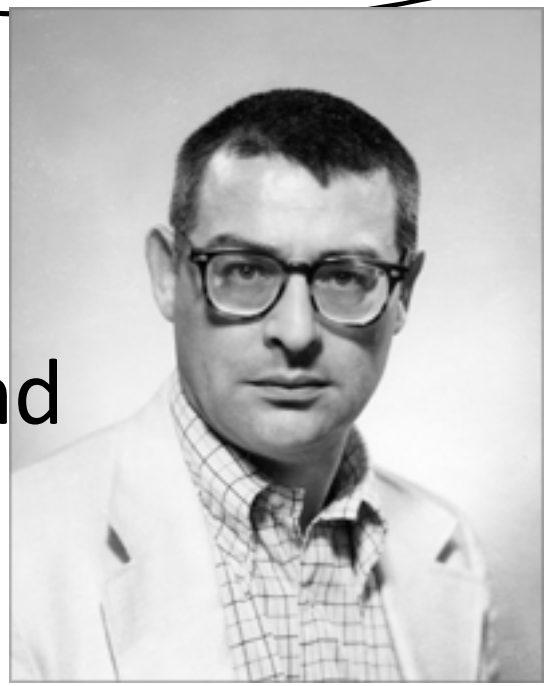
* Member of Space Science Board of National Academy of Sciences

* Became Chairman of Board of AS&E in 1959

* Rossi: AS&E should get into X-ray astronomy

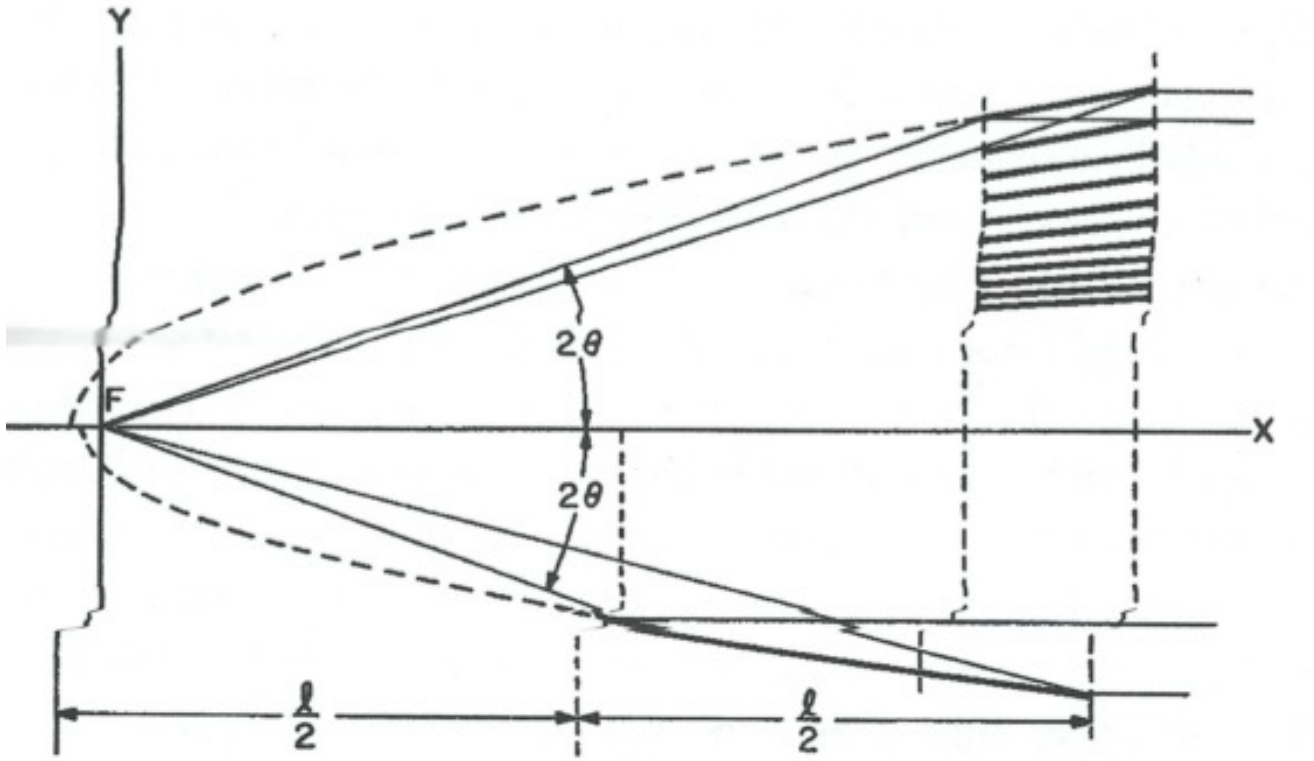
* Annis: Let's get the new guy to do it.

After a review of the literature on cosmic X-rays, I found myself once again mired in a field in which the sparseness of data would prevent fundamental discoveries.



“Then I remembered my beloved projective geometry and understood that I could build a mirror that could concentrate X-rays! “

R. Giacconi & B. Rossi 1960 “A `Telescope' for Soft X-Ray Astronomy”
Journal of Geophysical Research, Vol. 65, p.773



However: Need very smooth (<20 A) surfaces, and two reflections to produce images over a finite field of view -> years before such a telescope could be developed.

Fall of 1961 – Summer 1962:

Classified research at AS&E expanded rapidly :

*19 rocket flights from Johnston Island

* Six satellite payloads launched from Vandenberg Air Force Base

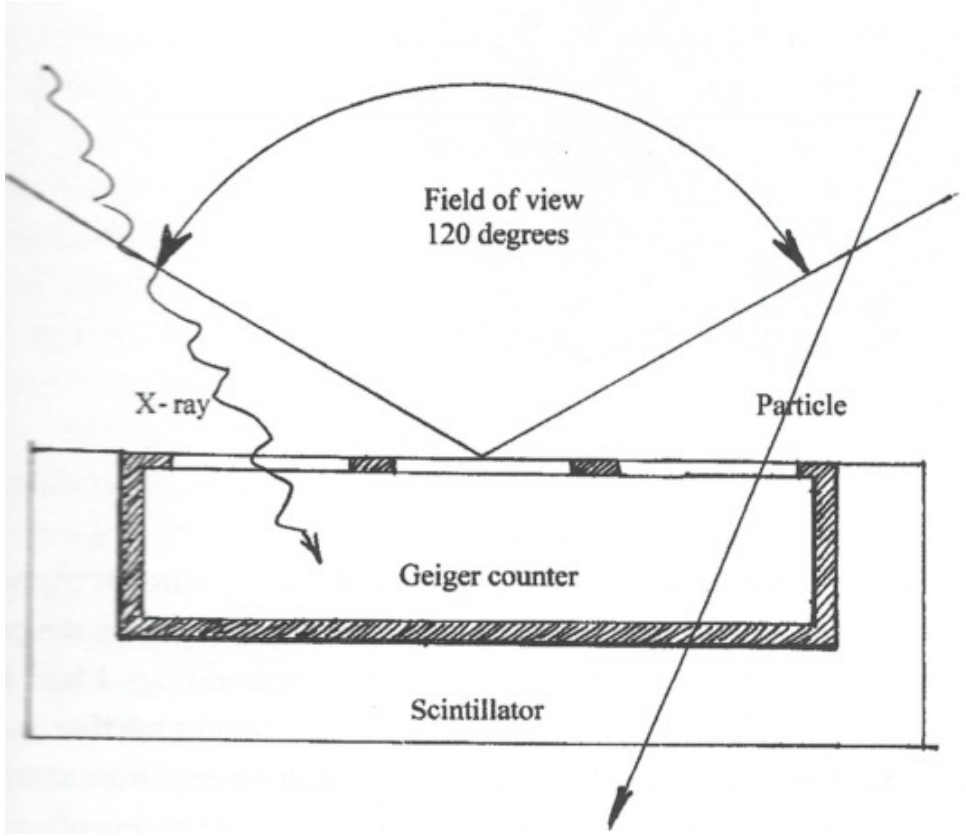
As well as unclassified work in the same period:

*Four rockets to search for noctilucent clouds

*One rocket flight to search for X-rays (failed because door didn't open)

Mostly funded by the Air Force Cambridge Research Laboratory (AFCRL), **including the flight on June 18, 1962 from White Sands, NM**

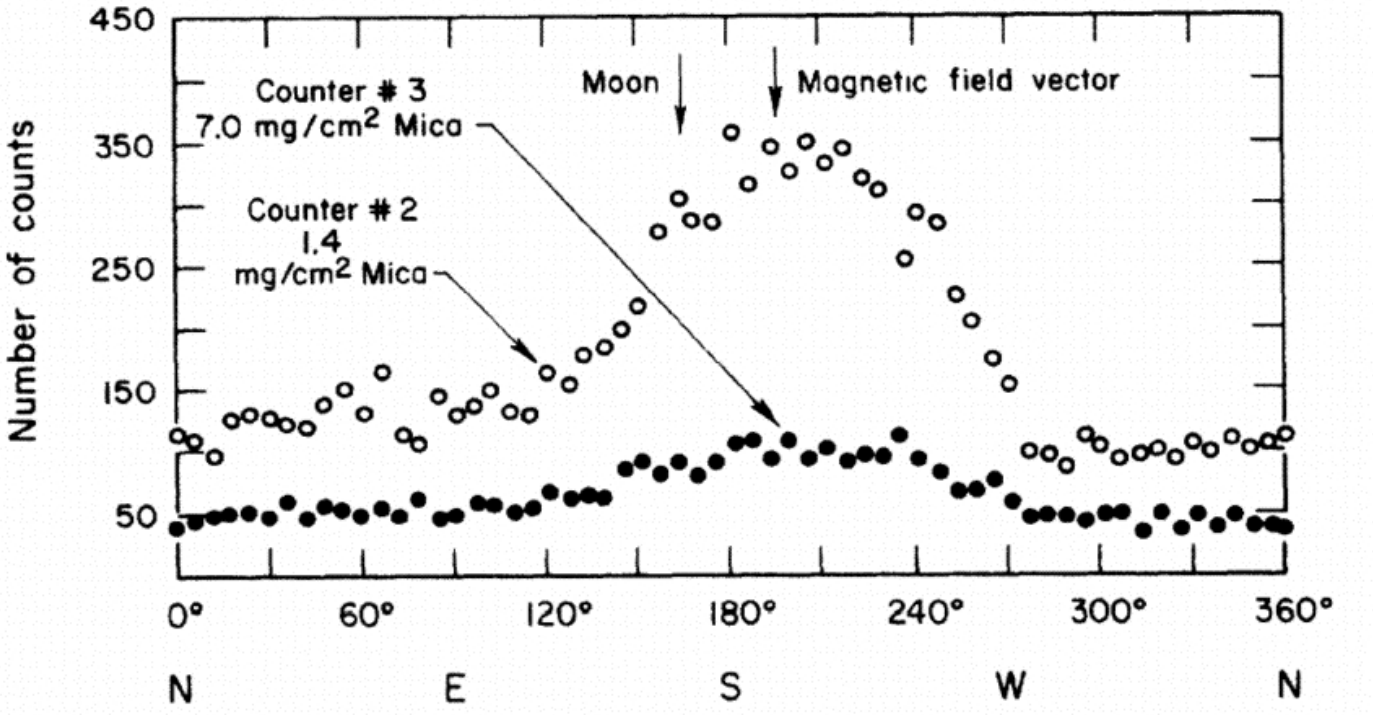
Back **to** proportional counters, and rule #2: Strive for a major jump in sensitivity



- Schematic of 1962 detector
- Larger area
- Wider field of view
- Anti-coincidence system to reduced background caused by cosmic-ray particles

- Bottom line: 100x more sensitive than previous detectors

R. Giacconi, H. Gursky, F. Paolini & B. Rossi 1962 “Evidence for X-rays from Sources Outside the Solar System”, Phys. Rev. Letters 9, 439

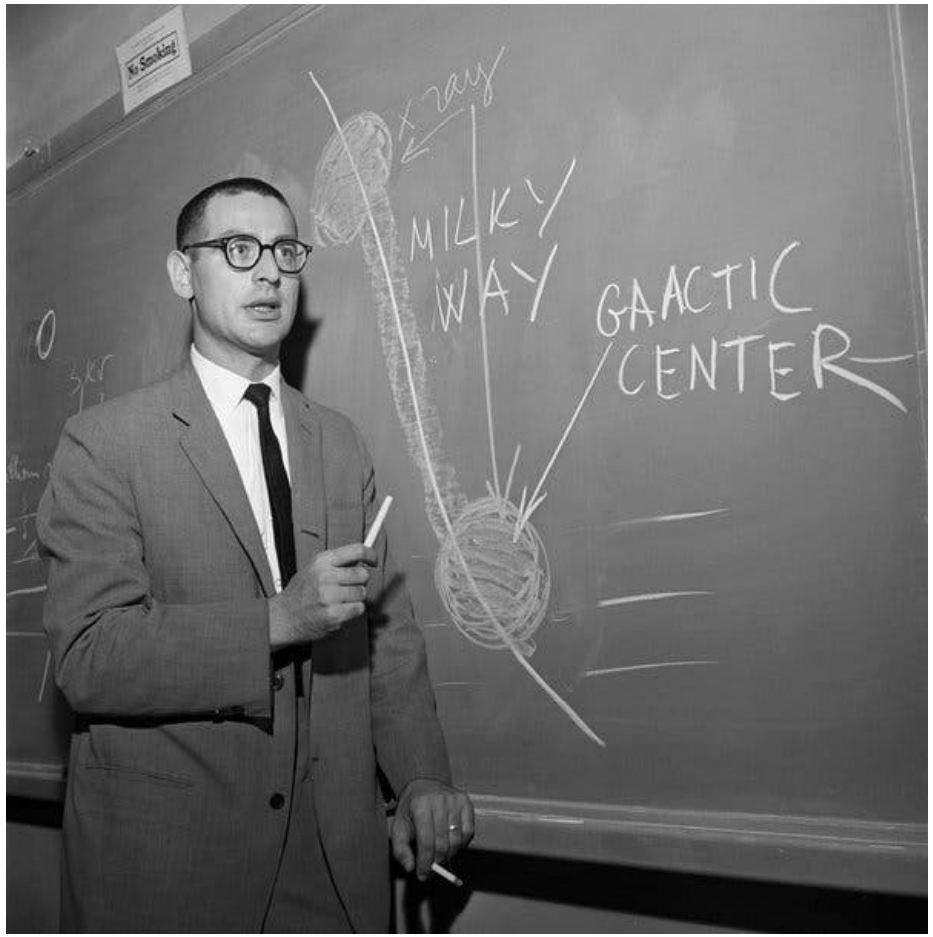


Number of counts versus azimuth angle. The numbers represent counts accumulated in 350 seconds in each 6- degree angular interval.

Giacconi presented the results at a symposium at Stanford U. in August, 1962

Some scientists in the audience were skeptical.

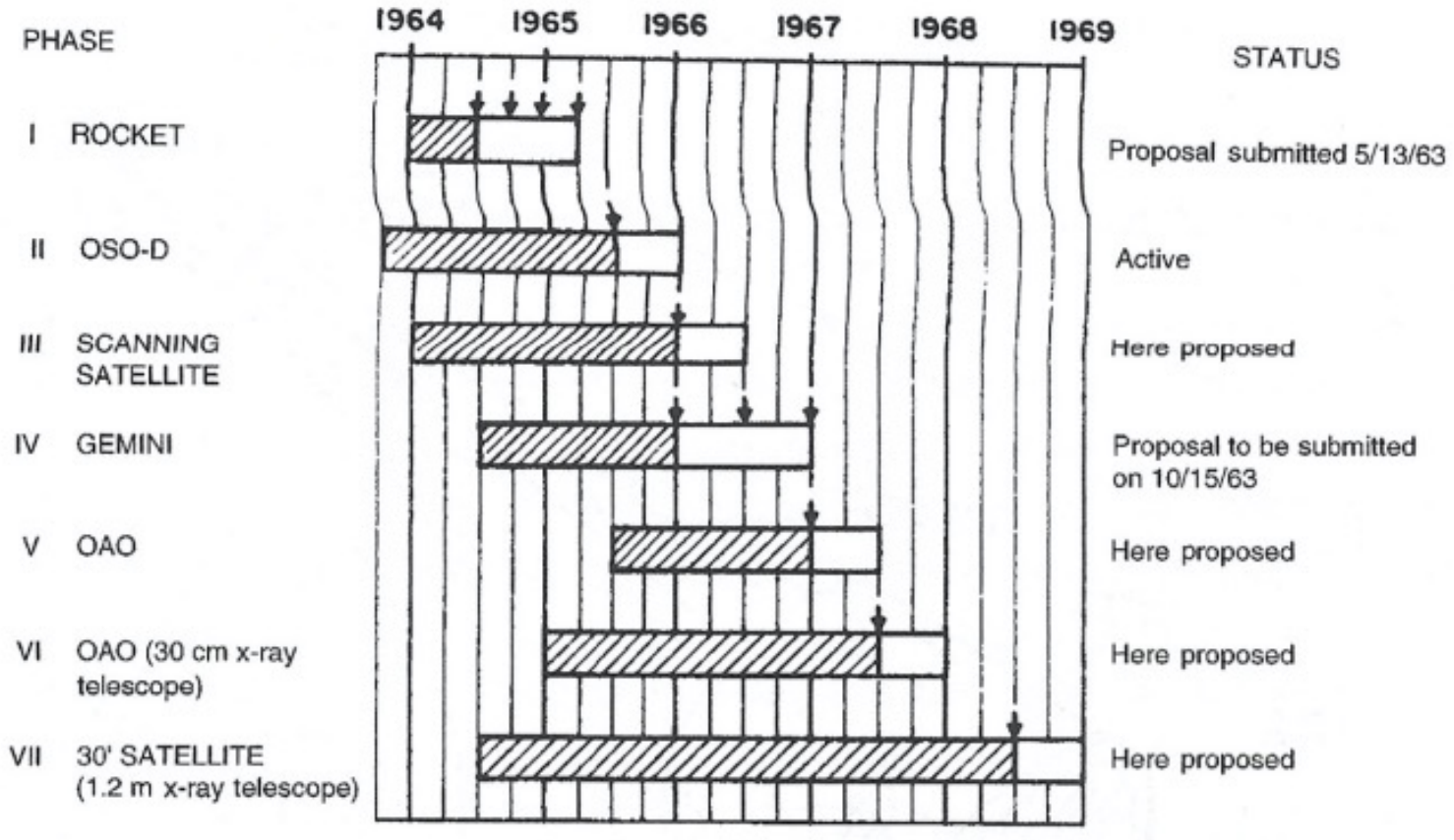
Not Herb Friedman, who realized he had been scooped. He graciously congratulated Giacconi and went to work.



Oct 1962 – June 1963
Two more rocket flights

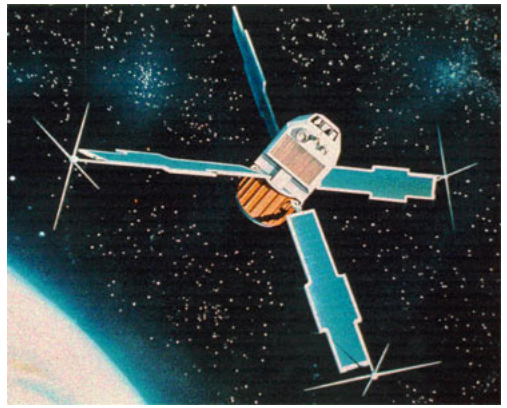
- Detected Crab Nebula as an X-ray source
- Discovered Cygnus X-1
- Confirmed Sco X-1
- Confirmed cosmic X-ray background radiation

Plan for X-ray astronomy submitted to NASA in Sep. 1963

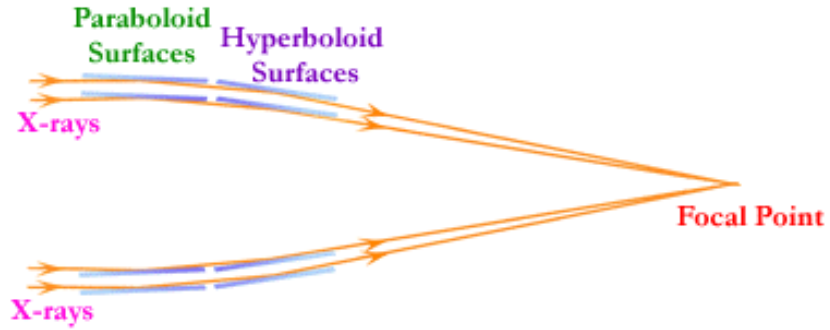


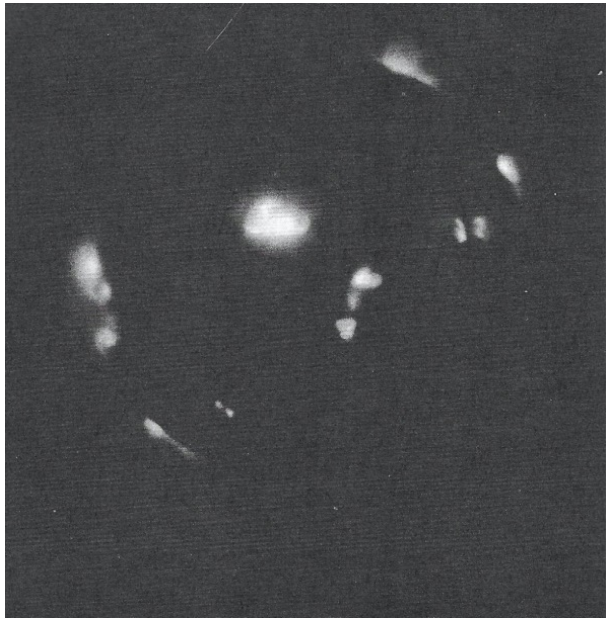
I was amazed and delighted when … we were encouraged to submit an unsolicited proposal or the scanning satellite."

f

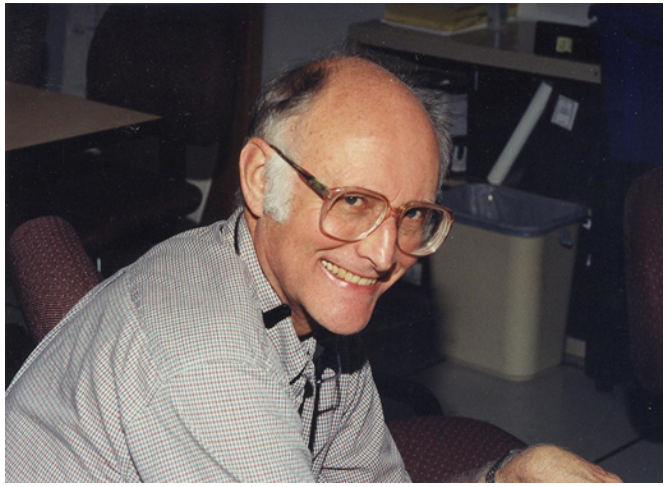


1968 Solar X-ray telescope with 5” imaging

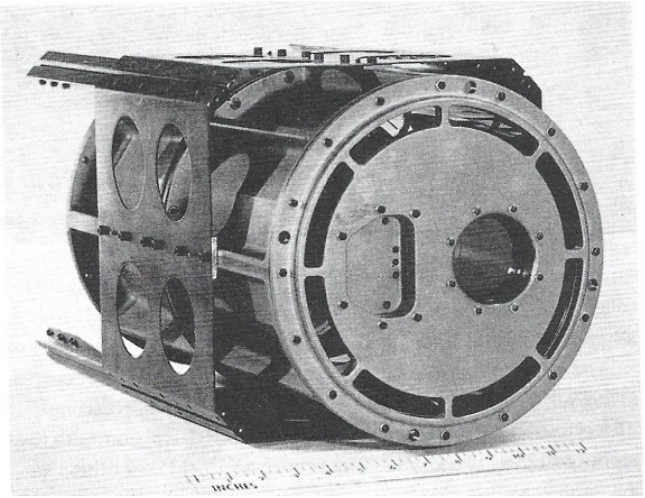




Guiseppe Vaiana



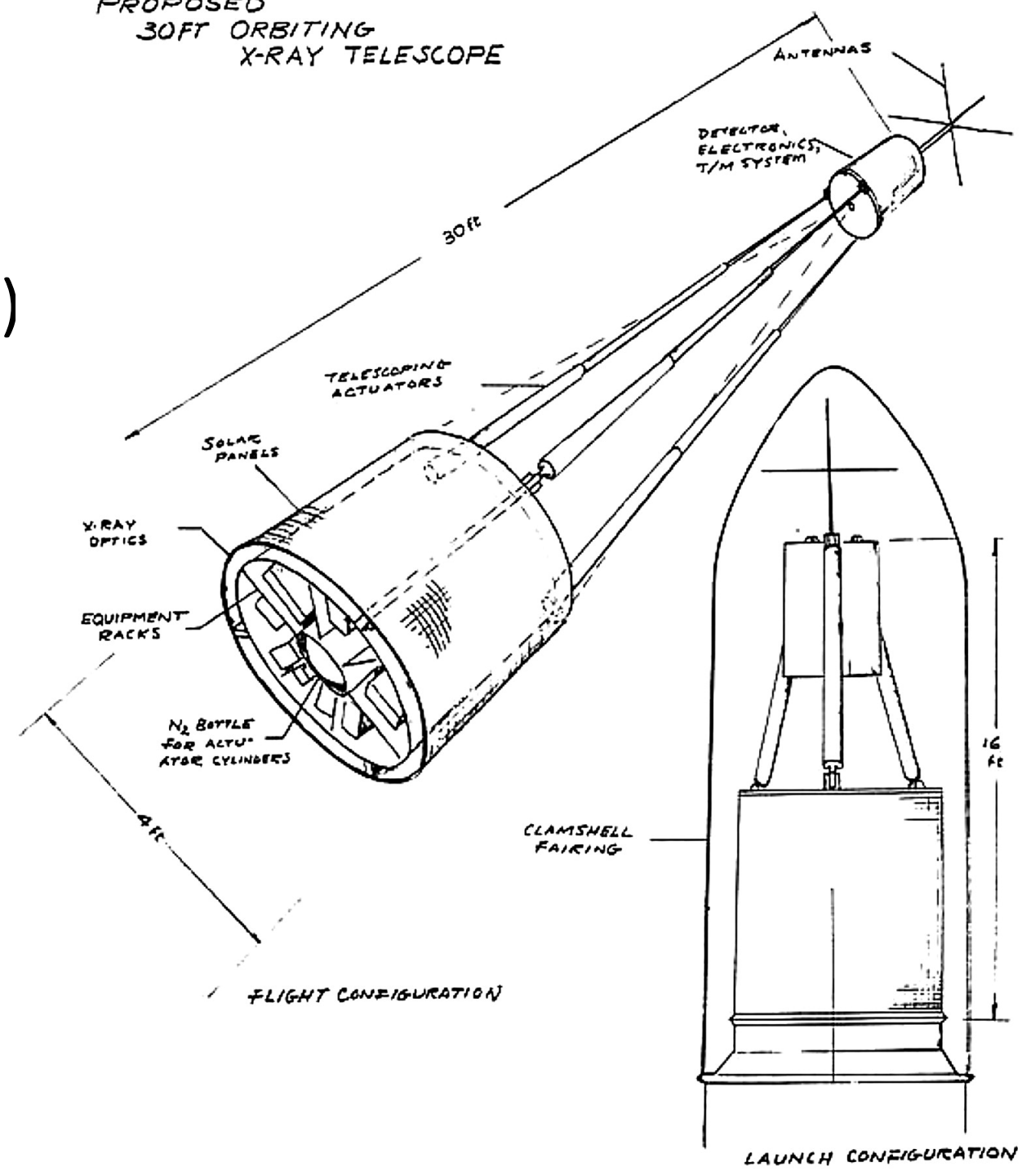
Leon Van Speybroeck



LOXT proposal (1970)

Observing capabilities:

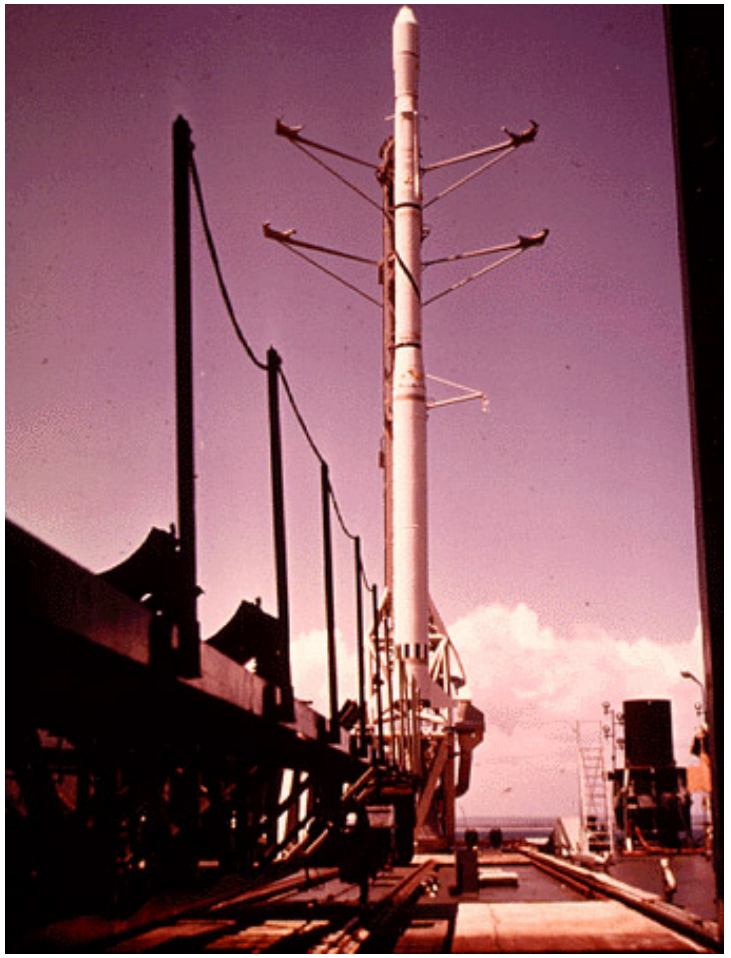
- 0.2 – 7 keV
- < 5 arcsec angular resolution
- 10^{-7} Crab sensitivity
- 1 eV energy resolution
- 1% Crab polarization in 1 day
- 0.1 msec time resolution



State of X-ray astronomy at the end of the rocket era (Dec. 1970)

- ~ 50- 60 X-ray sources known (J > 0.1 photon $cm^{-2}s^{-1}$)
- X-ray stars, e.g. Sco X-1, Cyg X-2
- Flaring X-ray objects, e.g. Cen X-2, Cyg X-1
- Crab pulsar
- Crab, Tycho, Cas A SNR
- LMC,
- M 87
- 3C273
- X-ray Background Radiation
- Ref: J. Dolan, 1970, AJ 73, 223

Dec 12, 1970: Uhuru is ready for launch!



- Riccardo Giacconi with Luigi Broglio, head of Italh's Centro Ricerche Aerospaziali on the *San Marco* launch platform off the coast of Kenya