MARTIN SCHWARZSCHILD'S DIFFRACTION LIMITED IMAGERY FROM THE STRATOSPHERE

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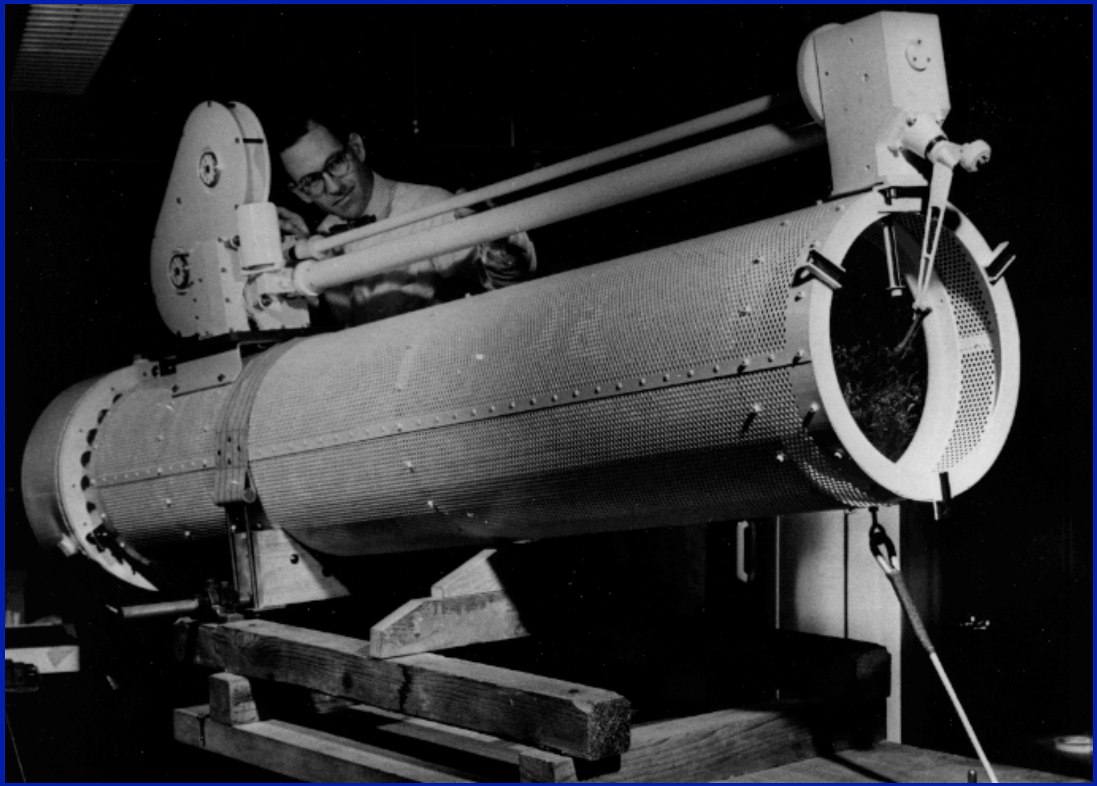
Stratoscope I	Fights 2-1957	Sputnik 1957
(12" SOLAR)	4-1959	NASA 1958
Stratoscope II	Flights 1963, 1964	OSO-1 1963
(36" STELLAR)	1965, 1966, 1967	OAO-1 1966
	1968, 1970, 1971	OAO-2 1968
		OAO-B 1970
		OAO-3 1972

At an early 1950s lunch with Lyman Spitzer, James Van Allen,and Martin Schwarzschild, it was agreed that a diffraction limited solar telescope was needed to make progress in understanding convective processes in the solar photosphere.

Spitzer was into fusion research.

Van Allen was into upper atmosphere particle research.

“They both looked at me. That is how I became involved with Stratoscope!



12 inch mirror, 8 foot focal length

25x enlarging lens, 200 foot effective focal length

1000’ 35 mm film, 8000 exposures/flight

λ= 5400±400 Å, 2 msec exposure time

FWHM = 0.38” = 0.112 mm on film
= 275 km on the sun.

Stratoscope I
350 pound telescope
1400 pound system

Two scientific flights during the summer of 1957

Solar granulation, pores, limb

2×10^6 ft^3 polyethylene balloon

to 82,000 feet

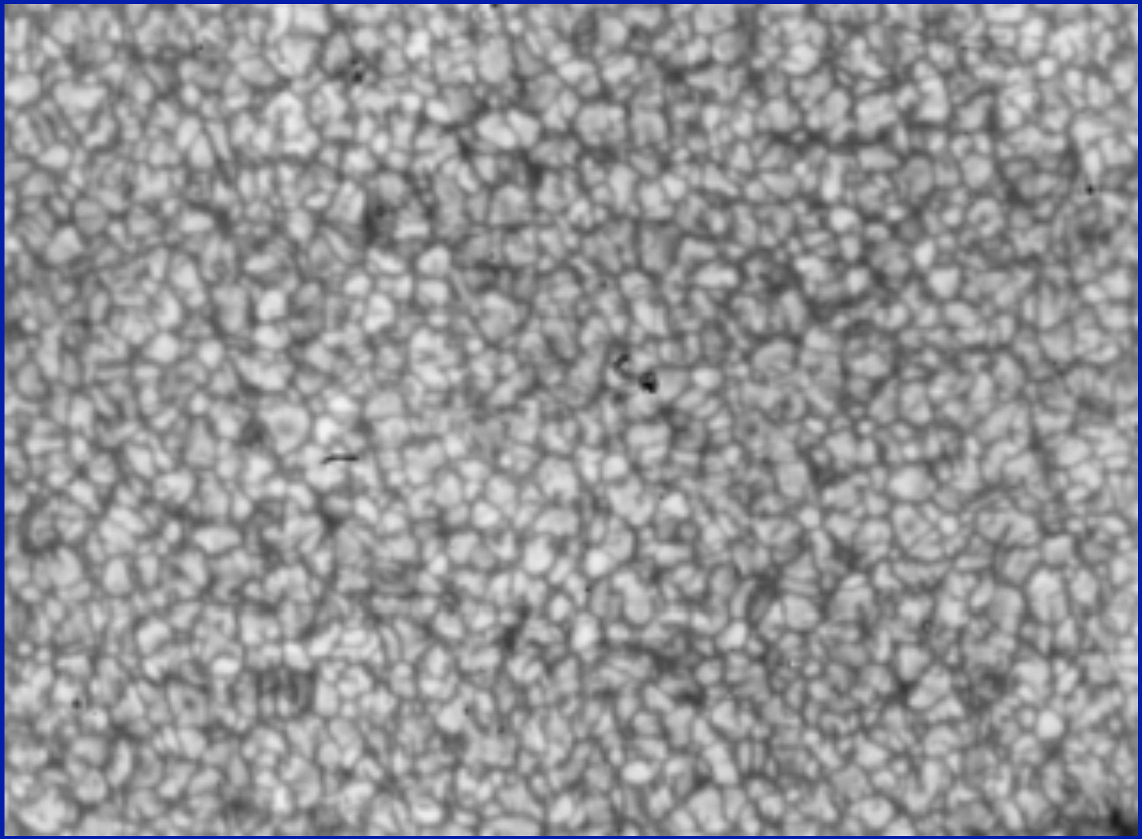
TECHNICAL ISSUES

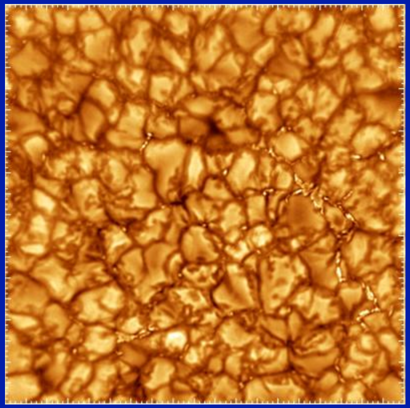
The thermal design to minimize mirror distortions and convection at altitude.

The pointing system needed to achieve < 0.1 arc sec blurring over 2 msec exposure time.

Successively operating a robotic observatory at 80,000 ft in the stratosphere where the ambient temperature is -50 C.

Stratoscope 1 Imagery of Solar granulation





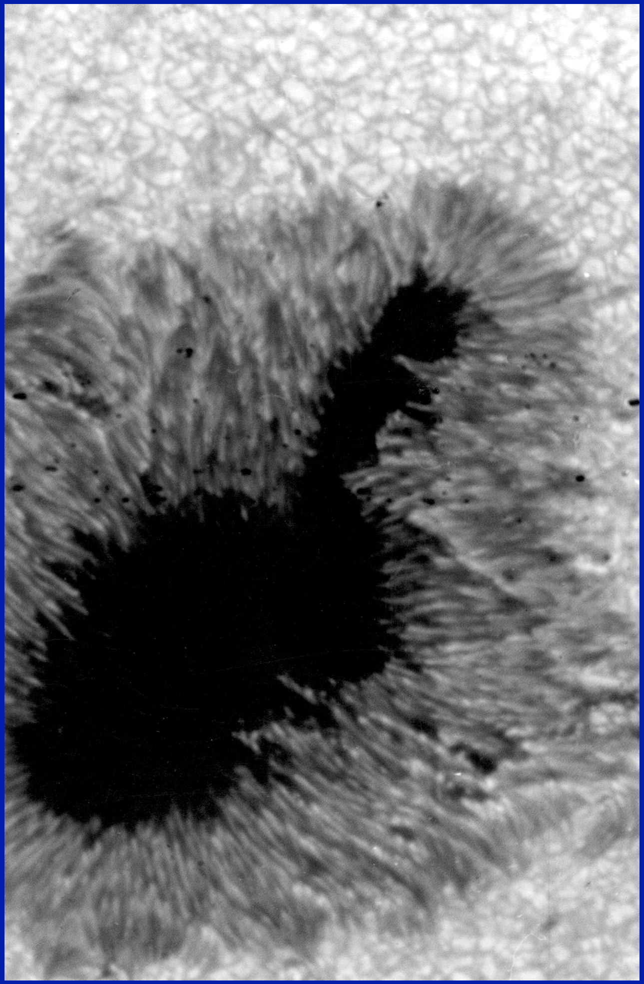
Big Bear Observatory 2008

“The bright granules, ranging in diameter from ~300 to ~1800 km, are of highly irregular, often polygonal, shape and are separated from one another by dark, often narrow lanes.”

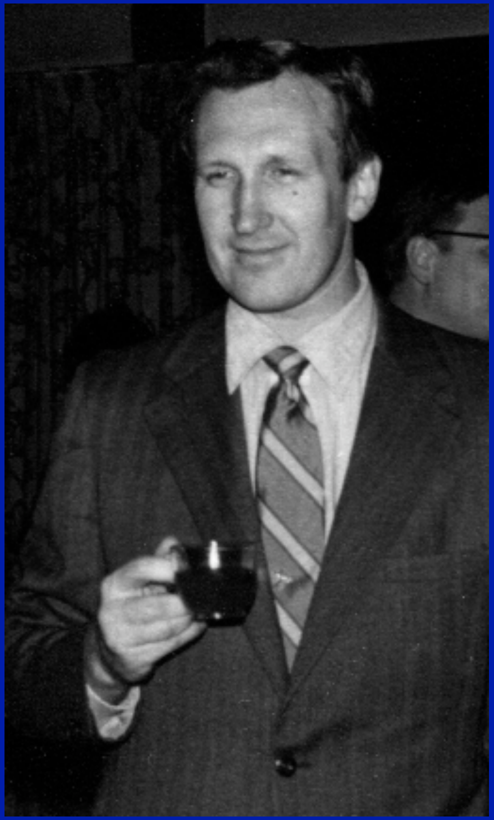
“The granulation has the character of non-stationary convection.”

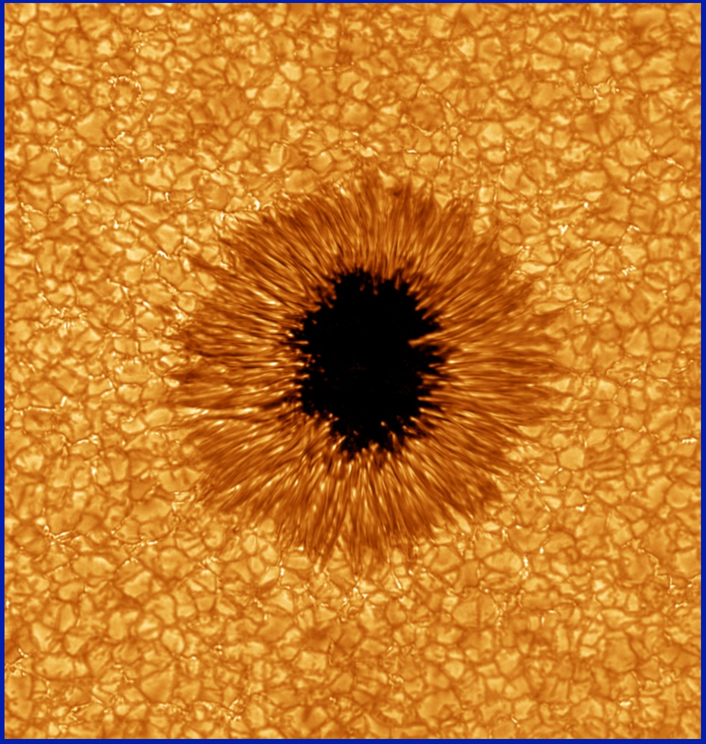
“This result came as a surprise, at least to this author (Schwarzschild 1959).”

Four Flights in 1959 with a TV system to locate solar magnetic regions and obtain photographic images.



Stratoscope I Danielson (1961)





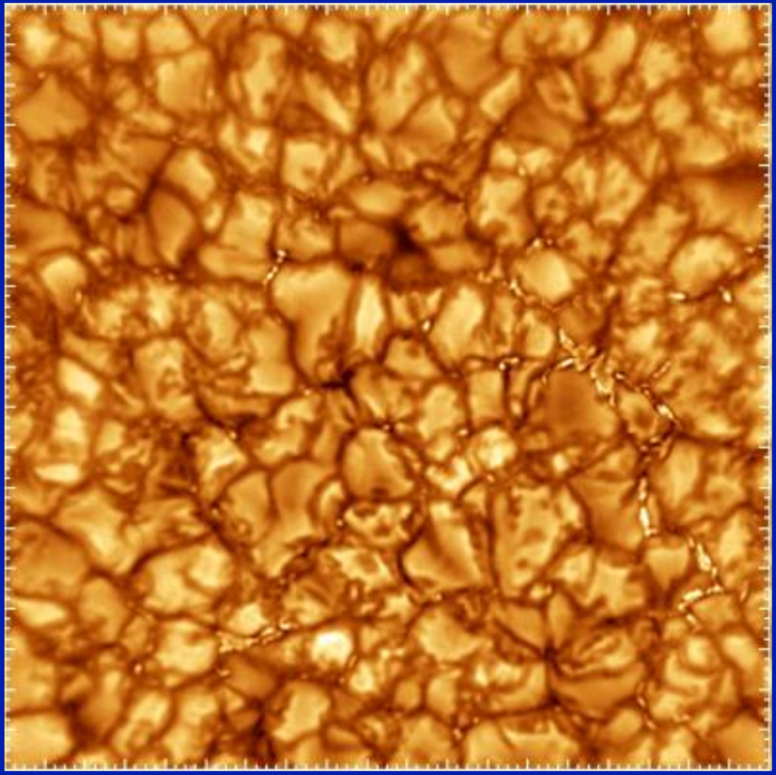
Big Bear Solar Observatory 2008

“ The penumbra is resolved into a complex array of radial bright filaments having widths of < 300 km and length of ~5000 km.

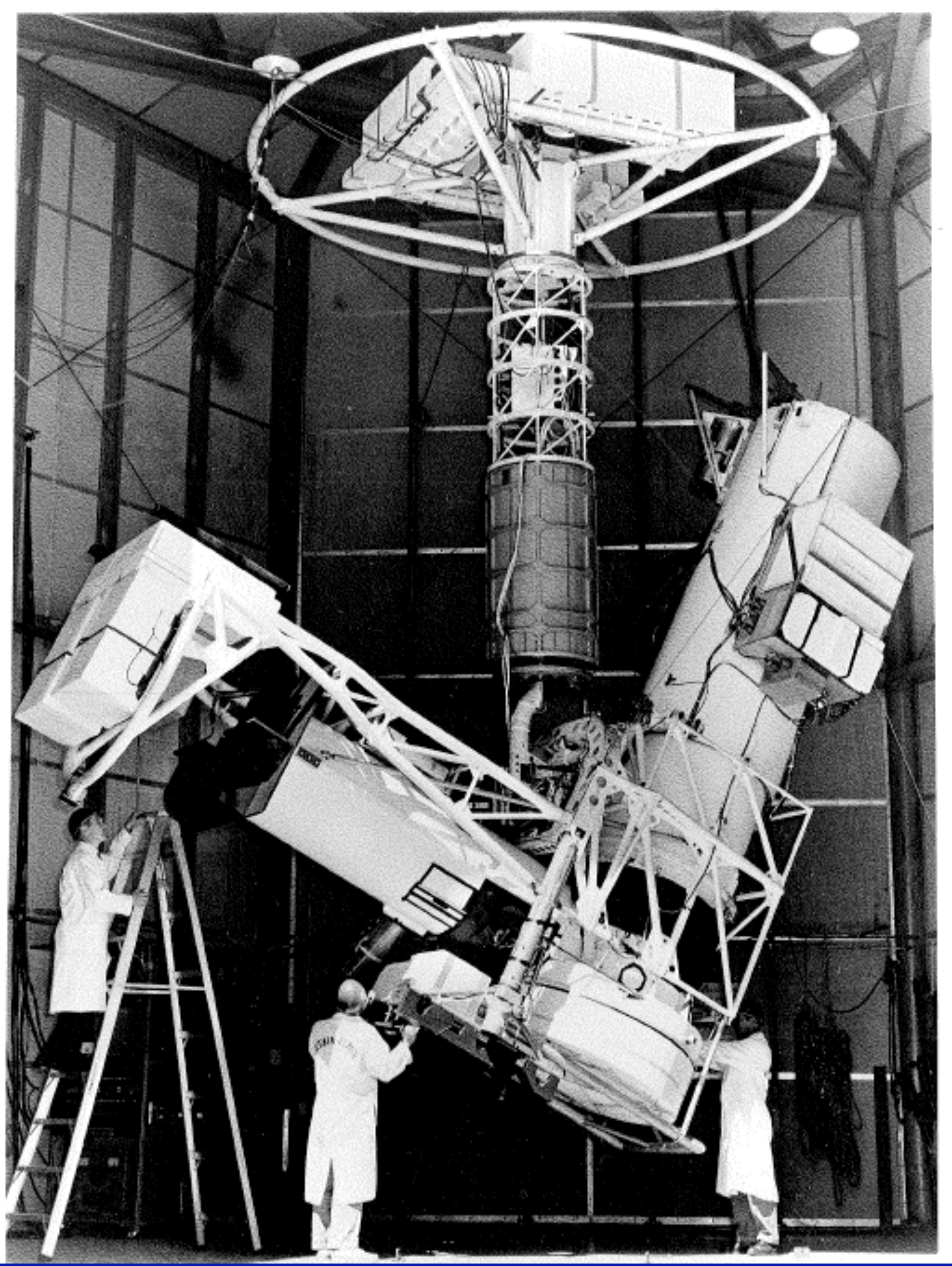
“Bright dots are observed in sunspot umbras” (Danielson 1963)

Some years after the flights of Stratoscope I,
Don Morton remembers Martin saying:

"The most significant result of those flights was to simulate ground based solar observers to devise the techniques to obtain sharper images from the ground."



Big Bear Observatory 2008



STRATOSCOPE II

started in 1960

Martin Schwarzschild

Robert Danielson

Fused quartz 36” primary mirror

1/50 λ rms surface accuracy

Photographic camera at f/100 final focus.

TV acquisition cameras

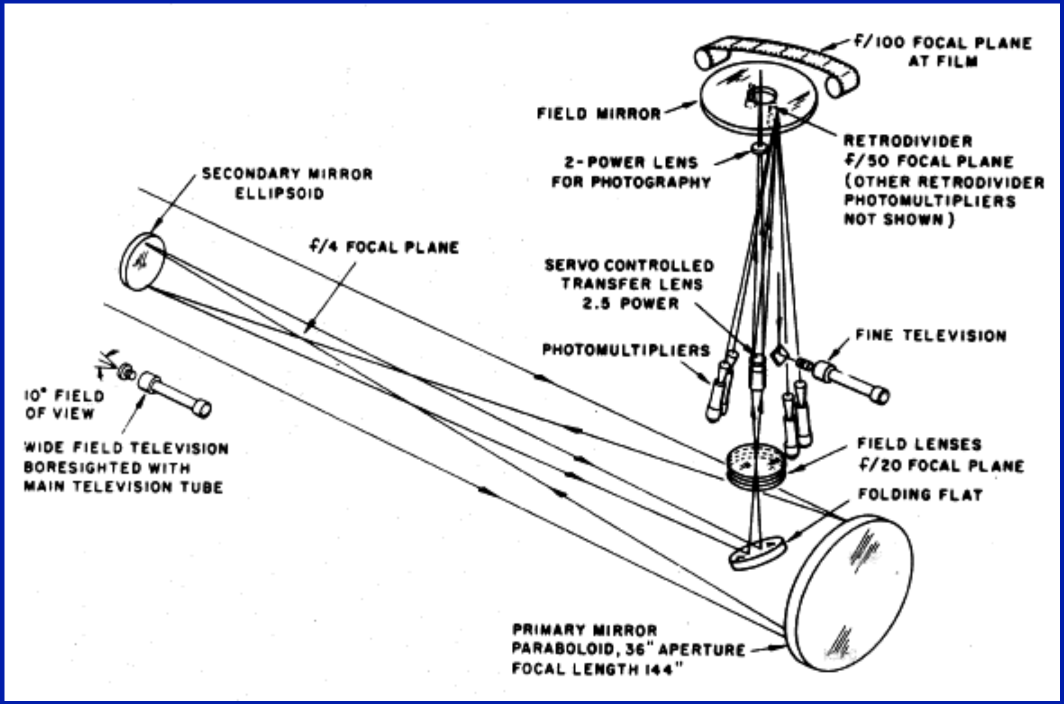
3200 kg observatory

Mirror pre-cooled to -50 C

Alti-azimuth mount with mercury azimuth bearing.

Angular resolution ~ 0.2 arc sec

rms pointing stability~ 0.02 arc sec

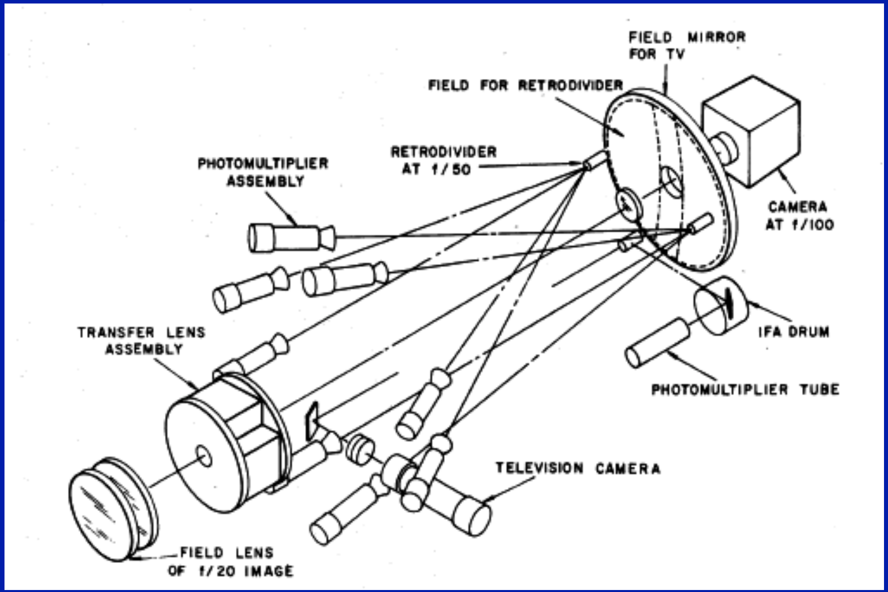


36 inch f/4 primary mirror

Final focus at f/100

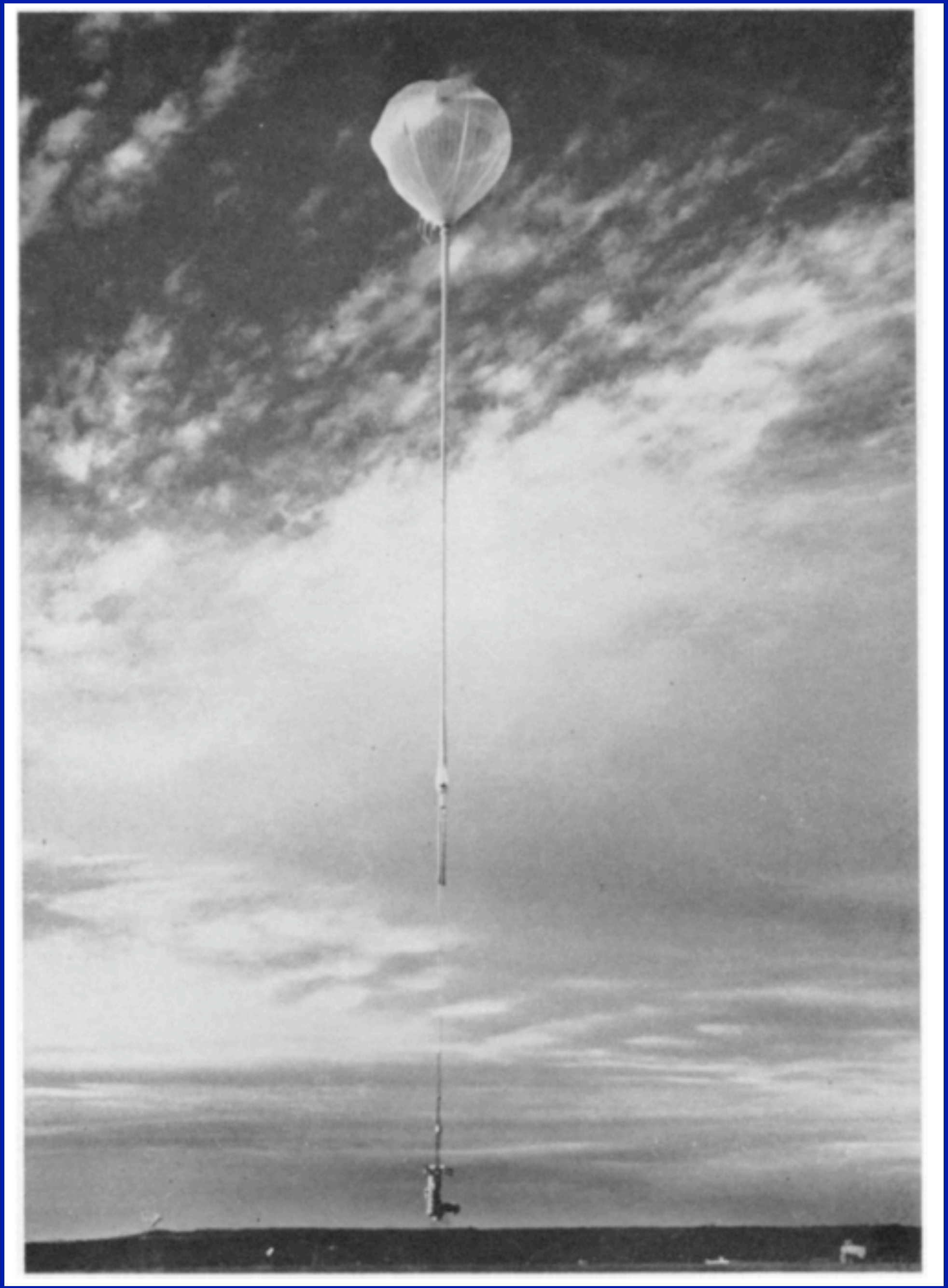
Imaging onto 70 mm film.

Integrating intensified TV system was considered too risky for the science detector.



Magnetically suspended 2.5 power transfer lens for image stabilization with error signals derived from guide stars.

TV acquisation system for locating the guide stars and the scientific targets.



Heavy Lift Balloon

Launch balloon $3.05x10^5$ ft^3

Main balloon $5.3x10^6$ ft^3

0.35 mil mylar/ dacron mesh

660 ft tall at launch

monitor observatory status

unlatch telescope at altitude

open mirror door

move to correct azimuth and elevation

balance the telescope

find the guide stars

establish servo system guide star lock

focus and align the optics

record scientific images

move to the next object

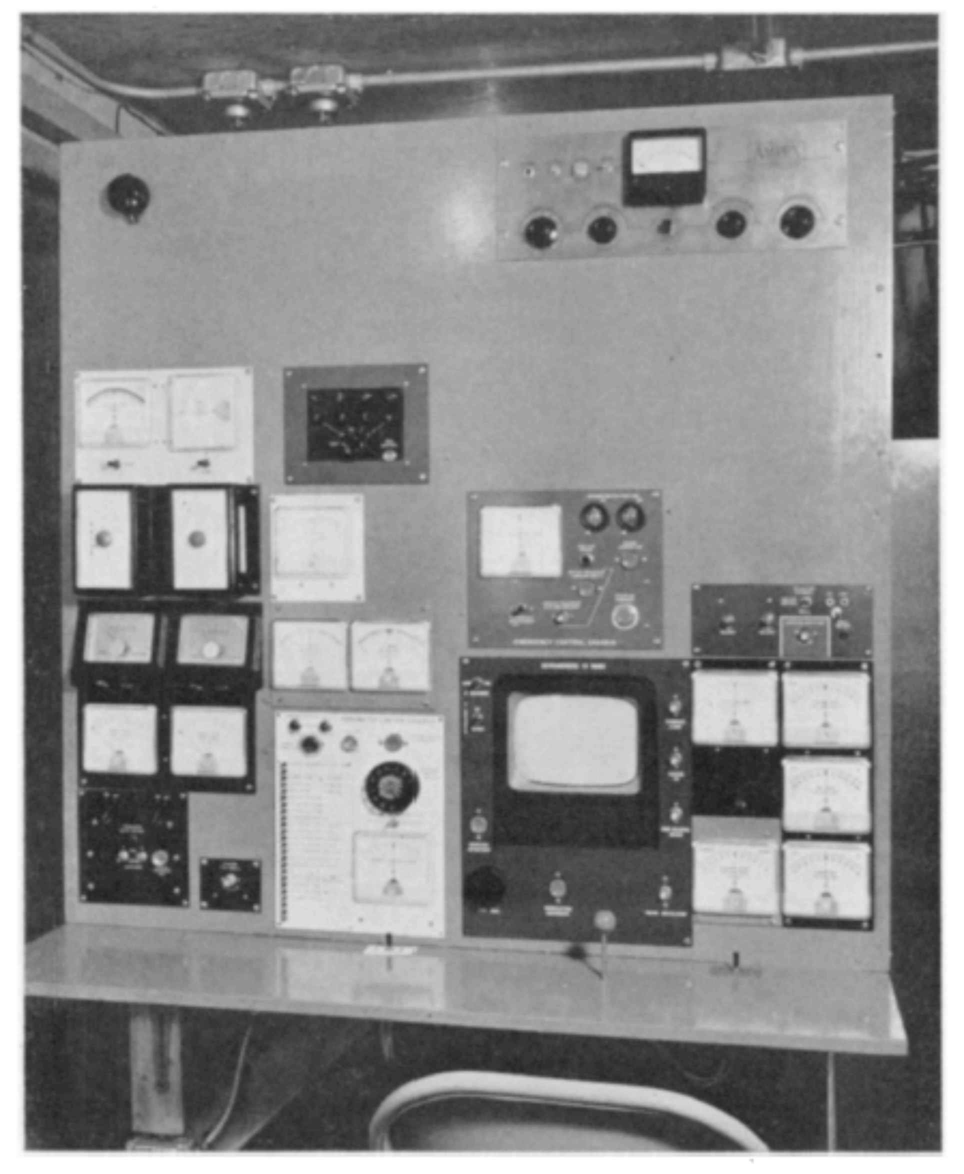
etc.

close mirror door

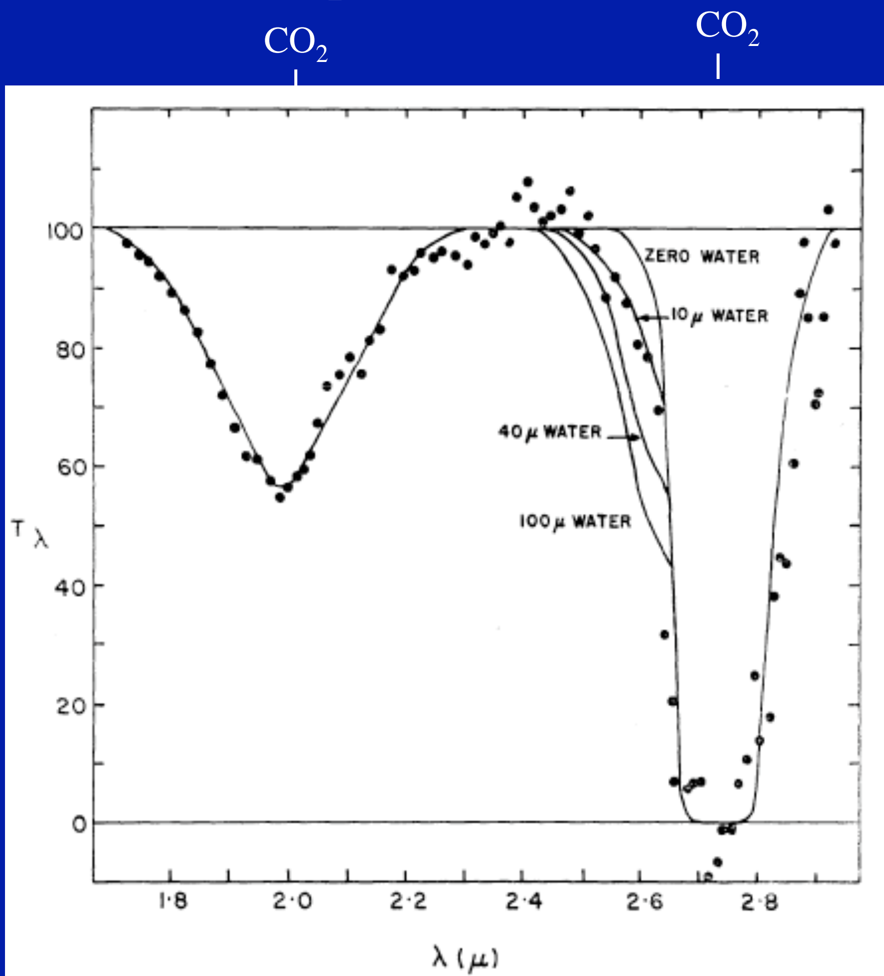
latch telescope

Release He for controlled decent

The Stratoscope II Control Room in a Truck



IR Spectrum of Mars



The IR spectrum of sirius reveals the stratosphere above 80,000 is very dry and a good site for IR astronomy.

Wolff, Schwarzschild & Rose (1964)

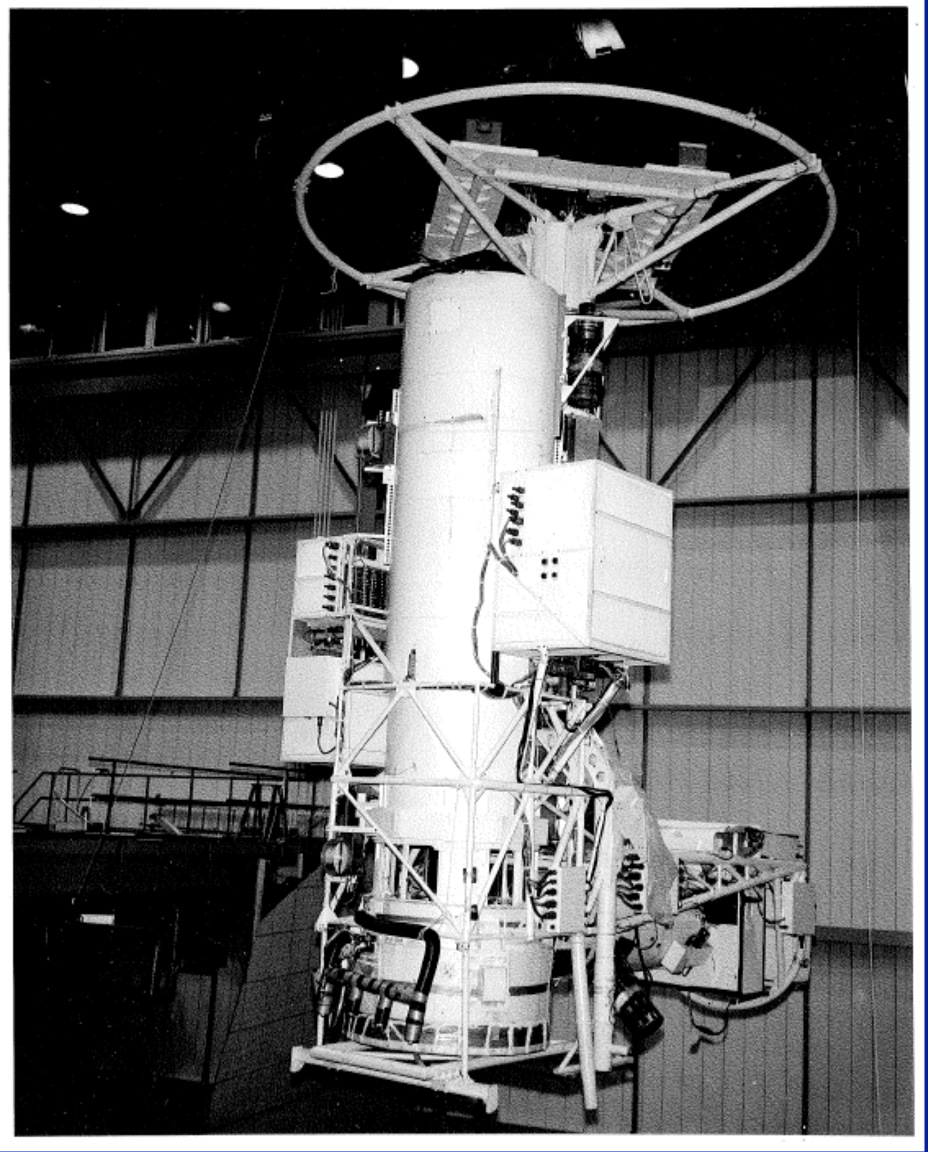
The 3.1 μm H_2O Ice feature was not detected in the spectrum of μ Cep. No more than 25% of interstellar reddening is due to ice.

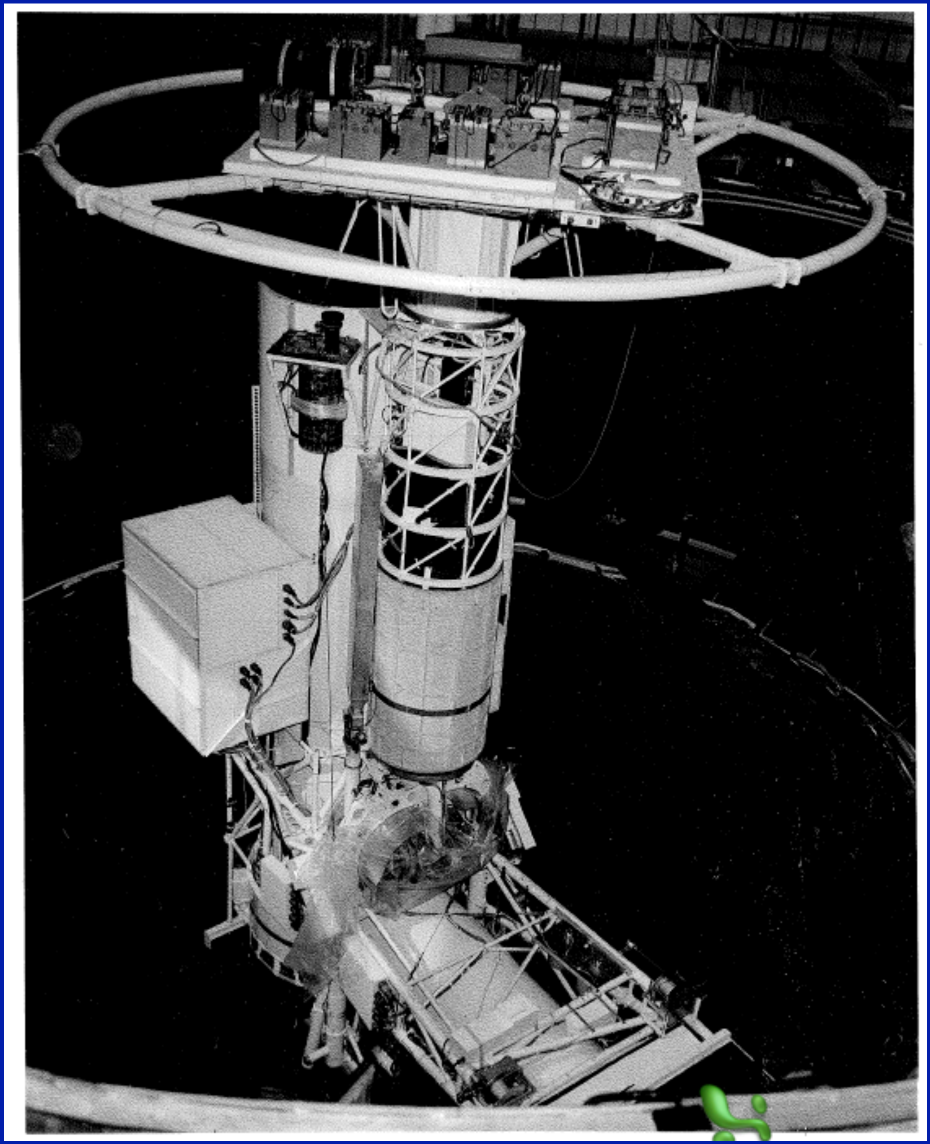
Danielson, Woolf & Gaustad (1965)

There is < 40 μm of H_2O in the atmosphere of Mars

Danielson, Gaustad, Schwarzschild, Weaver & Woolf (1964)

After flight failures in1965,1966 and1967 due to mechanical problems, Stratoscope II underwent environmental testing at Valley Forge, PA in 1967-68





Result from the 1968 imaging flight

(residual seeing in the main telescope tube)

An Upper Limit to the Angular Diameter to the Nucleus of NGC 4151

Danielson, Savage & Schwarzschild (1968)

half intensity angular diameter < 0.18 arc sec

Results from the 1970 flight (NGC 4151 and Uranus)

An Upper Limit to the Angular Diameter to the Nucleus of NGC 4151

Schwarzschild (1973)

half intensity angular diameter < 0.08 arc sec

"The inferred stellar collison rate is so high it provides a strong indication of the extra ordinary conditions apparently prevailing within the nuclei of Seyfert galaxies."

Stratoscope II images of Uranus 1970

(Danielson, Tomasko & Savage 1972)

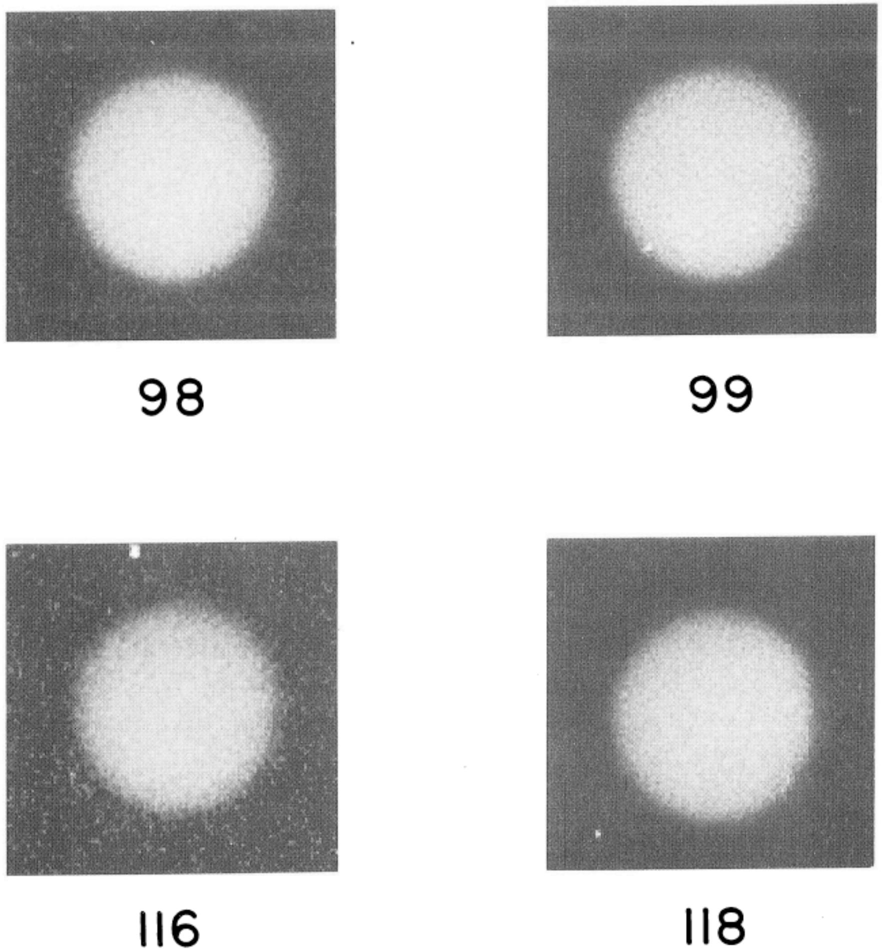
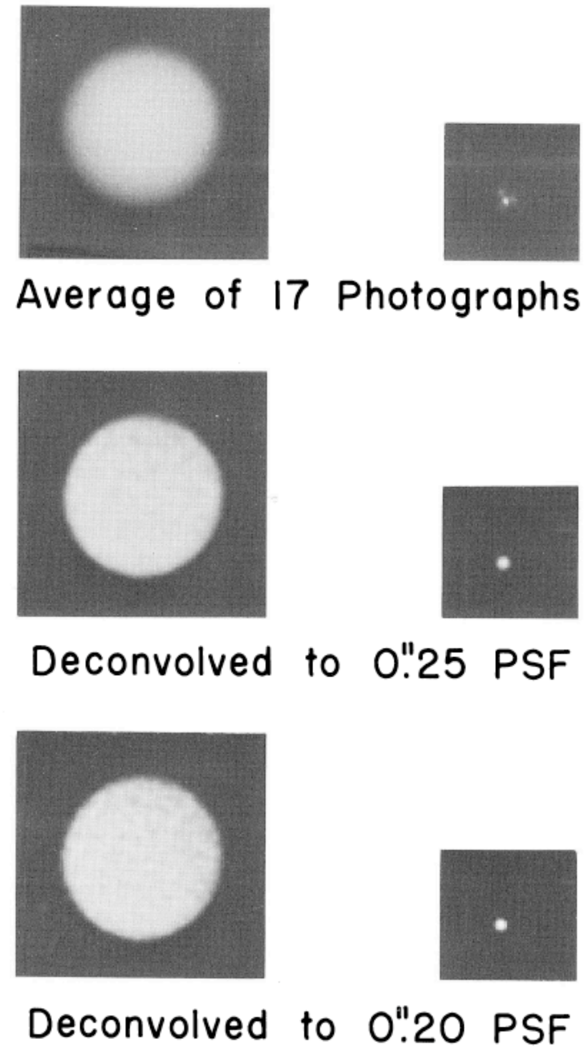


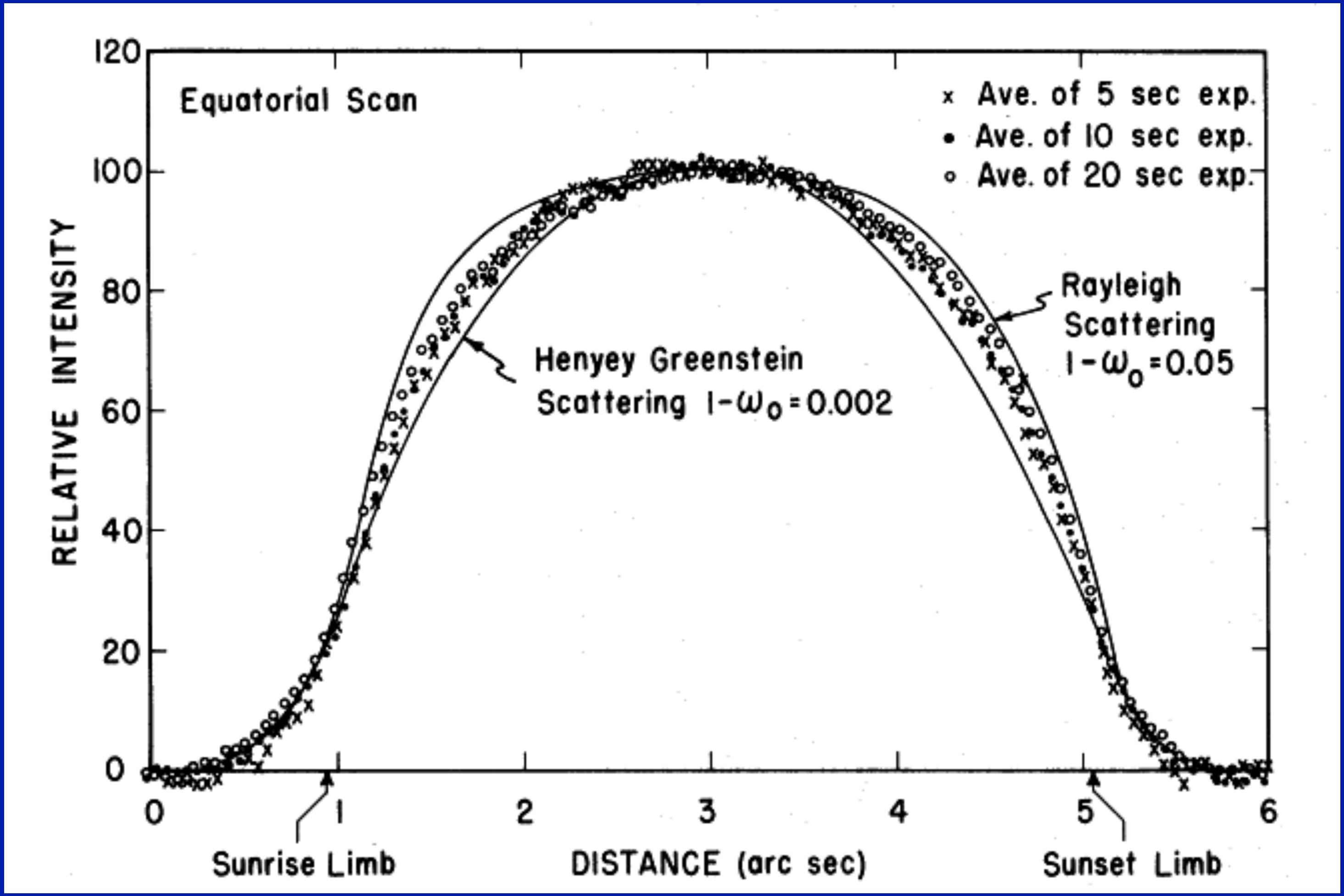
FIG. 7.—Four original images of Uranus

DANIELSON *et al.* (*see* page 892)



No evident surface features with > 5% contrast. Limb darkening is apparent.

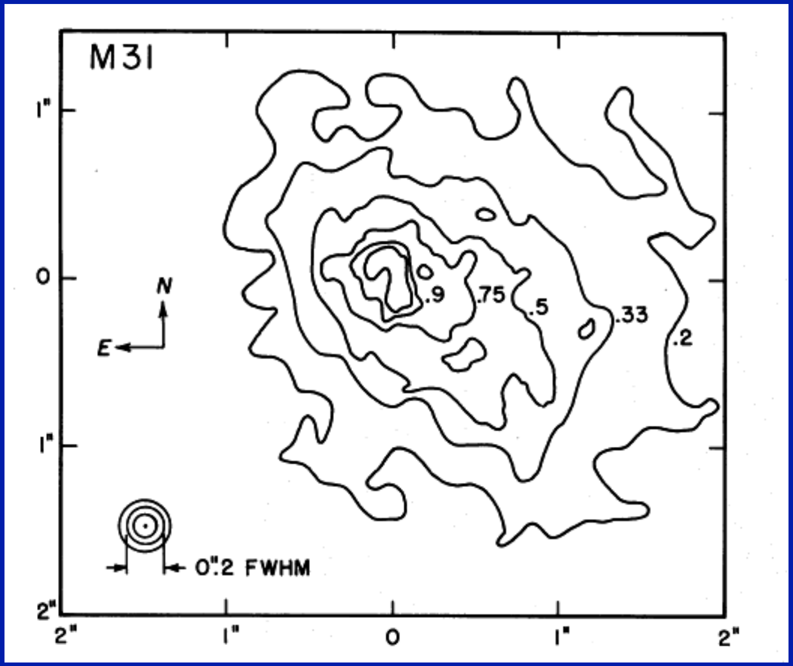
Limb darkening is consistent with a finite Rayleigh scattering H_2 Atmosphere ($\tau \sim 0.5$) over a cloud deck (likely methane ice).



D_{eq}= 51,800±600 km vs 51,118±4 km from Voyager

Flattening = 0.01±0.01 vs 0.0229±0.0008 from Voyager

Last flight of Stratoscope II in 1971



The Nucleus of M31

Light, Danielson & Scharzschild (1974)

direct 24 min exposure 0.2 arc sec resolution

"The SS II observations appear to have fully resolved the nucleus of M 31. The size of the nucleus is 0.28 arc sec. The offset with respect to the outer portions of the nucleus is puzzling."

HST Planetary Camera

Planetary Camera Observations of the Double Nucleus of M31

Lauer et al. (1993)

deconvolved image

THE ROLE OF STRATOSCOPE II TO THE FOLLOWING DEVELOPMENTS IN SPACE ASTRONOMY

NAS Astronomy Survey Committee (Greenstein1972)

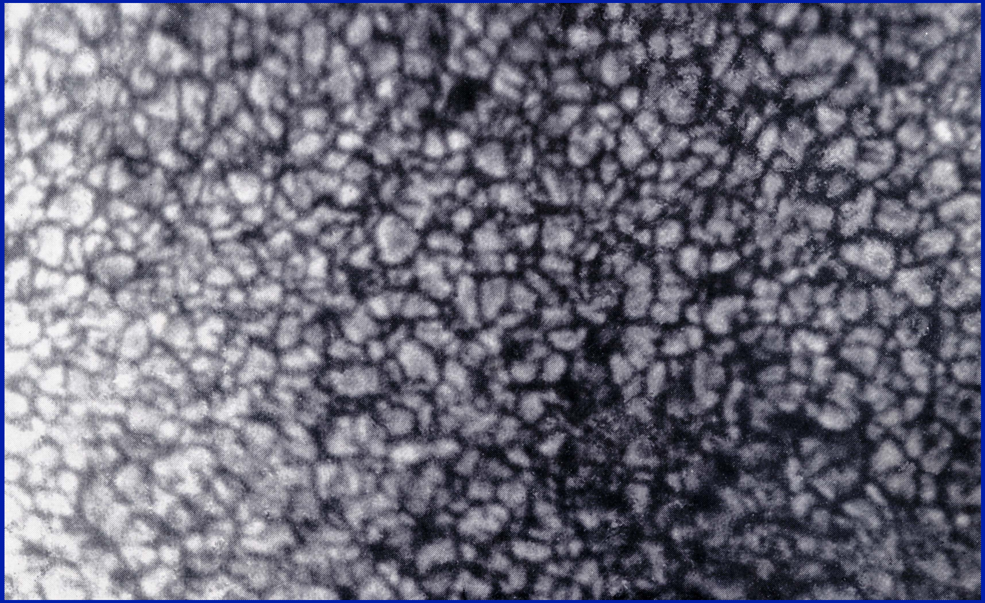
"The committee feels that the LST has extraordinary potential for a wide variety of astronomical uses and should be a major goal in any well-planned program of ground and space based-astronomy."

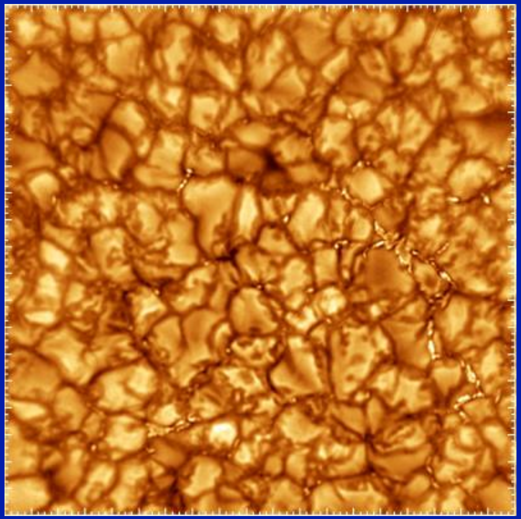
History of the LST (Spitzer 1974)

"It is no coincidence that these strong recommendations came at a time when large optical space instruments were achieving important scientific results. The Stratoscope II 36-inch balloon telescope had very successful flights in 1970 and 1971, achieving photographs of planets, satellites and galactic nuclei with an instrumental profile of about 0.2 arc sec. ---
-----------------OAO-2 & OAO-3-Copernicus-----------------------------------."

THANK YOU MARTIN FOR LEADING US DOWN THE PATH TO MAJOR ASTRONOMICAL OBSERVATORIES IN SPACE!

Stratoscope I   Imagery of Solar granulation





Big Bear Observatory 2008

Stratoscope I   Schwarzschild (1959)

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