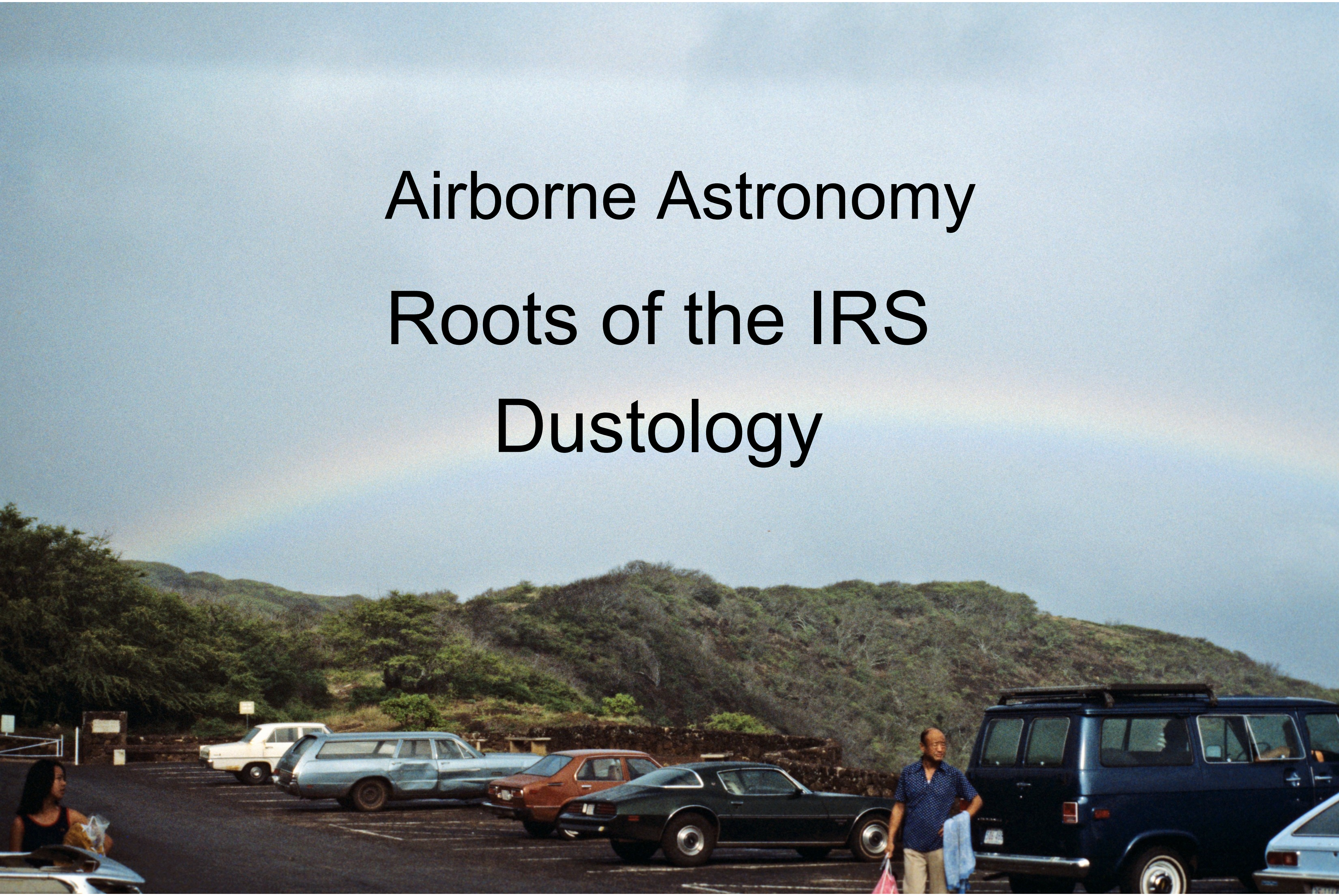
Airborne Astronomy

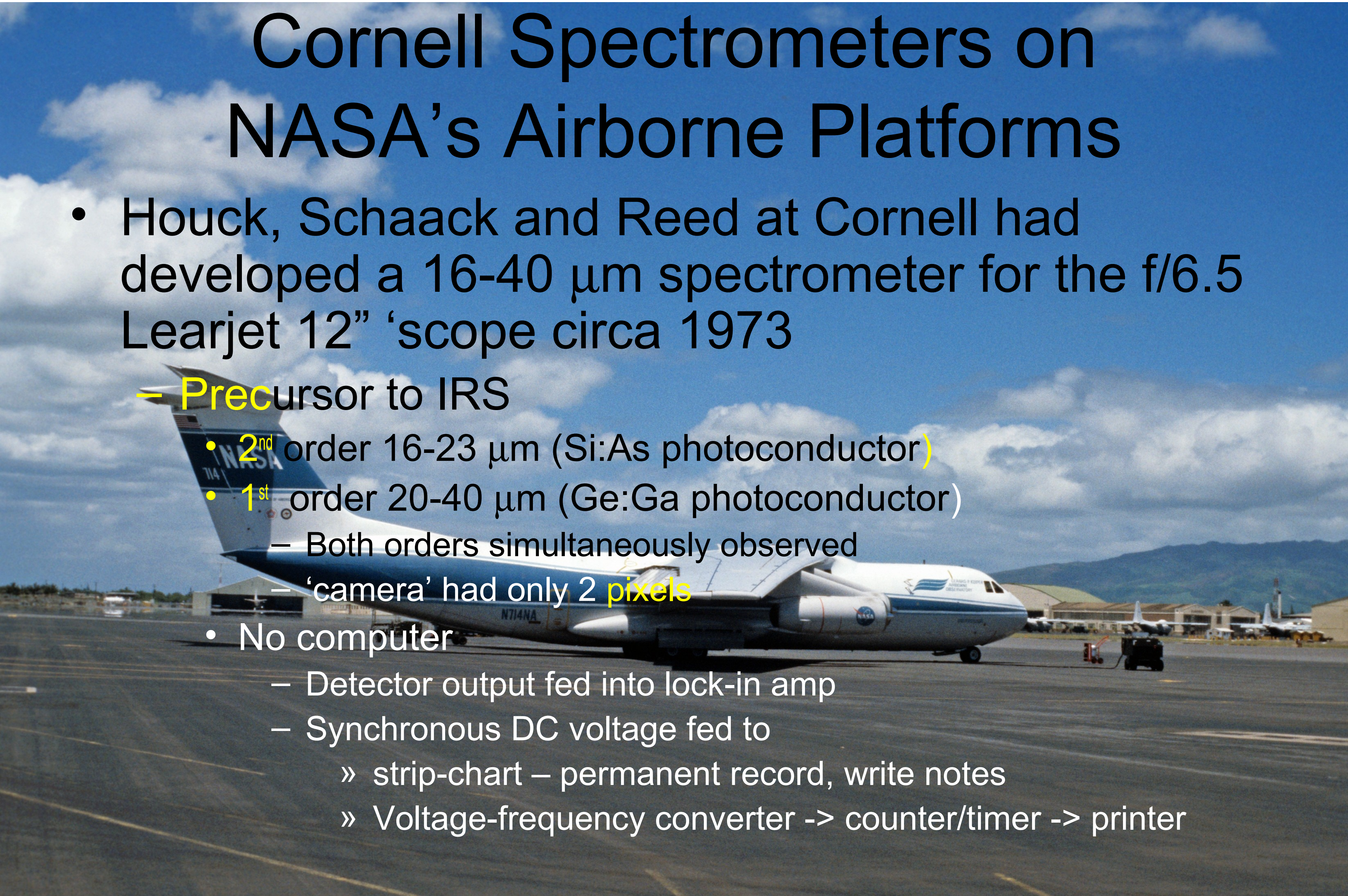
Roots of the IRS

Dustology



Cornell Spectrometers on NASA’s Airborne Platforms

- Houck, Schaack and Reed at Cornell had developed a 16-40 μm spectrometer for the f/6.5 Learjet 12” ‘scope circa 1973
  - Precursor to IRS
    - 2nd order 16-23 μm (Si:As photoconductor)
    - 1st order 20-40 μm (Ge:Ga photoconductor)
      - Both orders simultaneously observed
      - ‘camera’ had only 2 pixels
    - No computer
      - Detector output fed into lock-in amp
      - Synchronous DC voltage fed to
        - » strip-chart – permanent record, write notes
        - » Voltage-frequency converter -> counter/timer -> printer



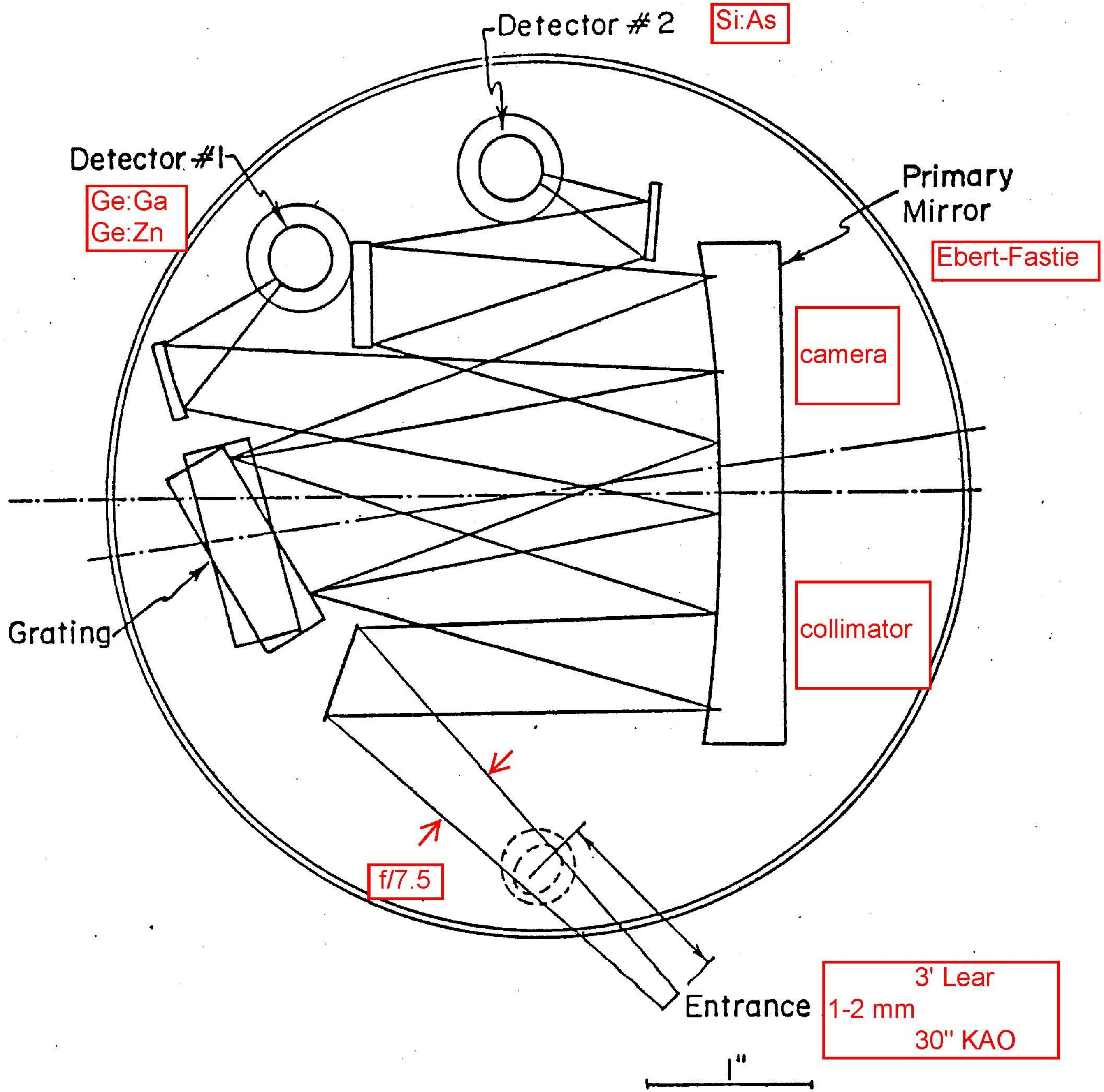
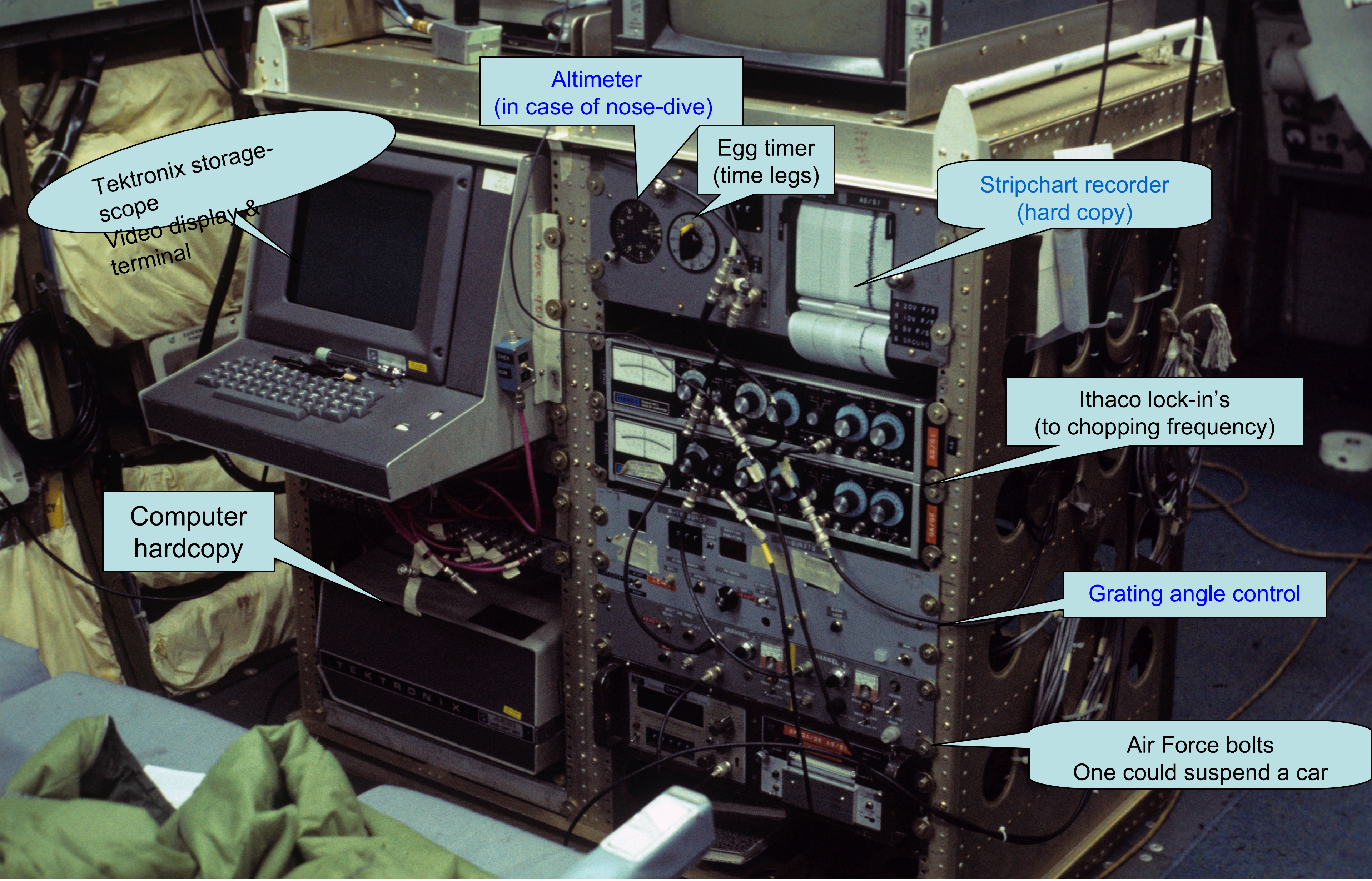

Detector #2
Si:As
Detector #1
Ge:Ga
Ge:Zn
Primary
Mirror
Ebert-Fastie
camera
collimator
Grating
f/7.5
Entrance
3' Lear
1-2 mm
30" KAO
1"

Fig. 1a

I arrived in 1975

    - The spectrometer basically worked, but
- Ge:Ga detectors not cooling down
    - GE varnish dried out, became thermal insulator
    - Heat sink optical bench with Apiezon N-grease
- Ge:Ga detector was noisy
  - Clean with cotton Q-tip and acetone
  - Reduced noise
- Computerize experiment
  - HP mini computer on KAO, paper punched tape
  - Fortran (learned on-the-job)
  - Debug on first ascent
    - It worked at altitude, but caused heartburn I'm sure



1976 KAO 2-ch Spectrometer -- computerized

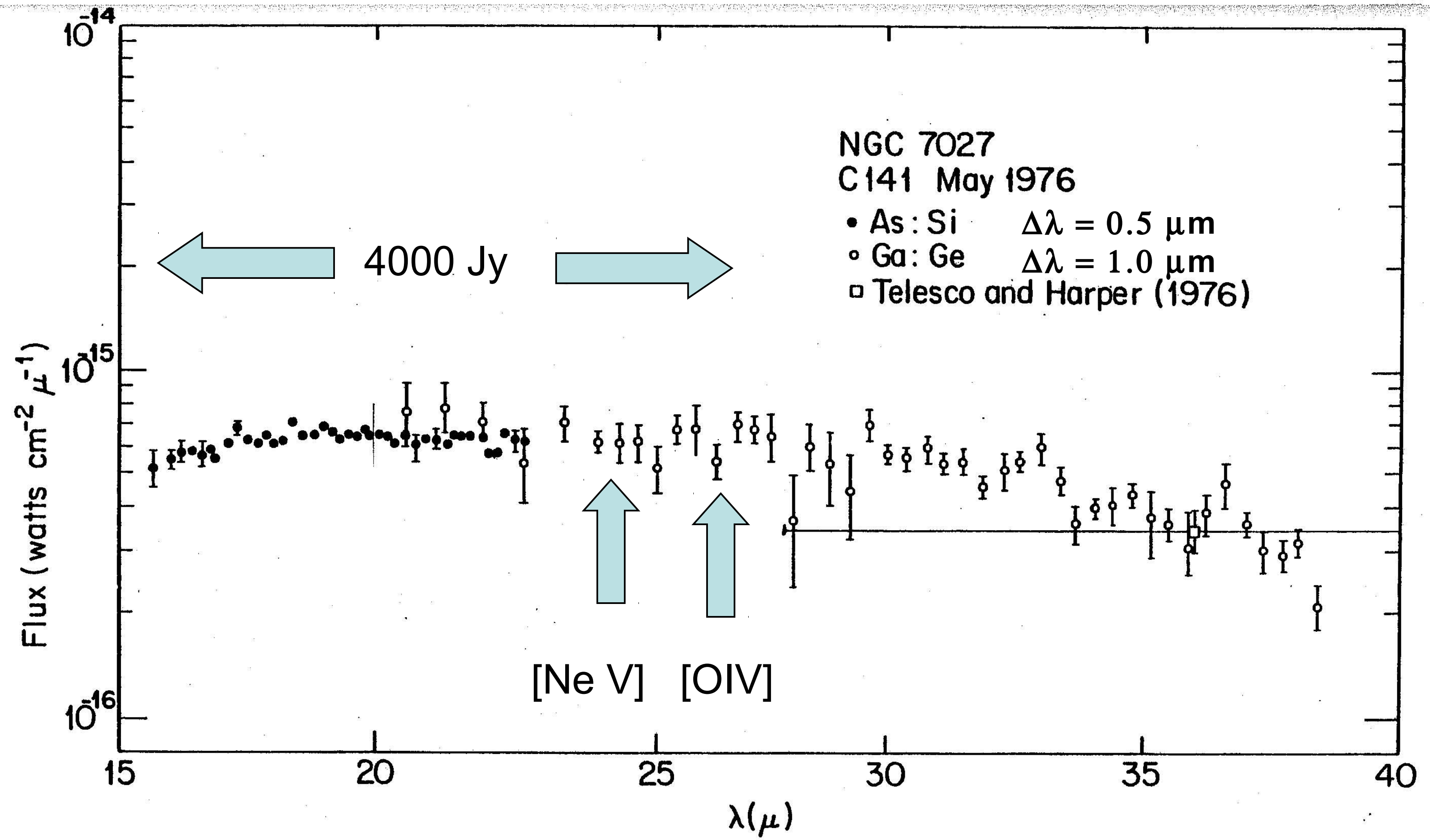
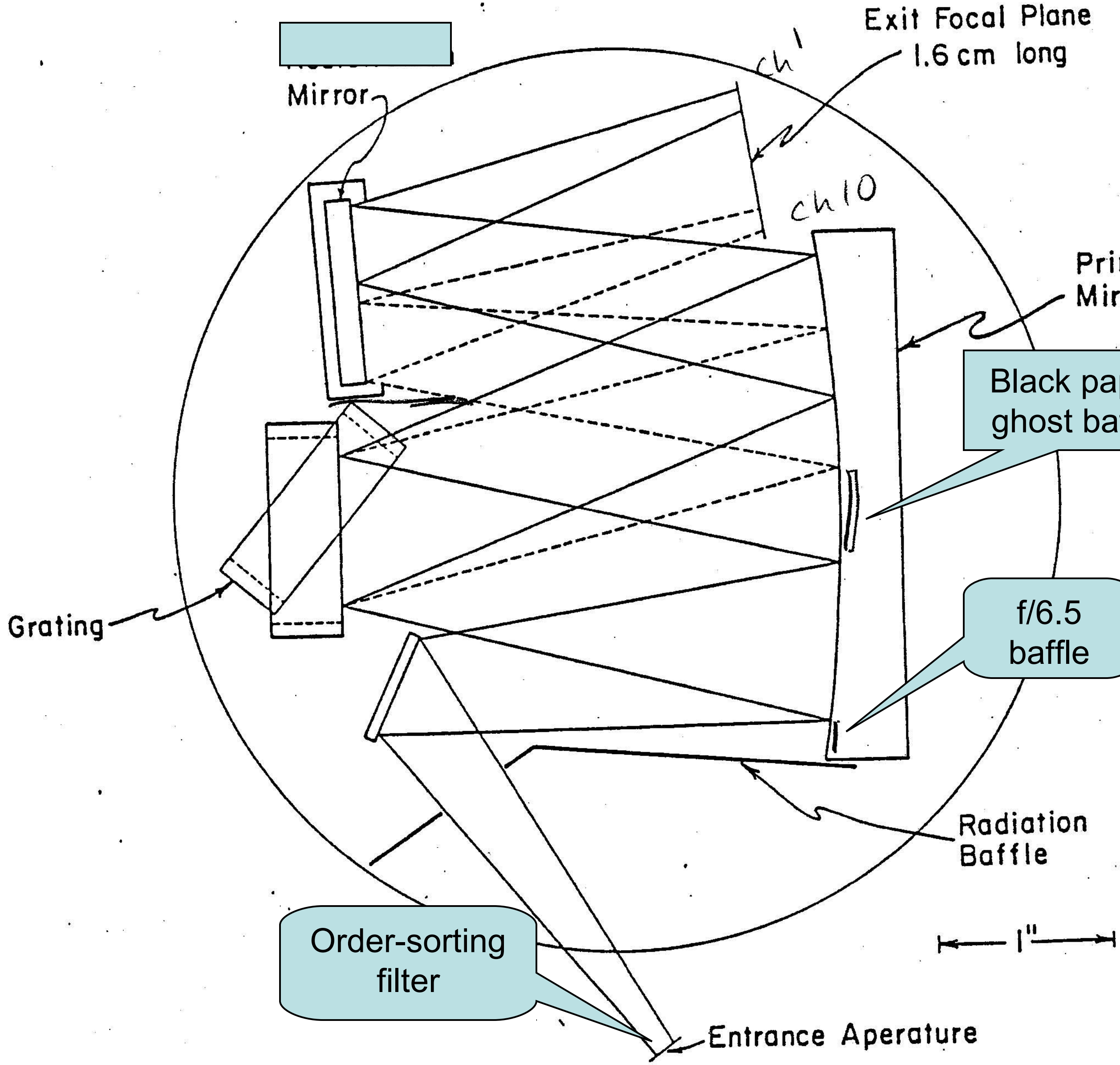


Figure 4

Our limiting flux was approximately 1000 Jy!

NGC 7027 showed no broad dust features, drats!

Our spectral resolution and S/N ratio were inadequate to detect Ne V and O IV, drats!

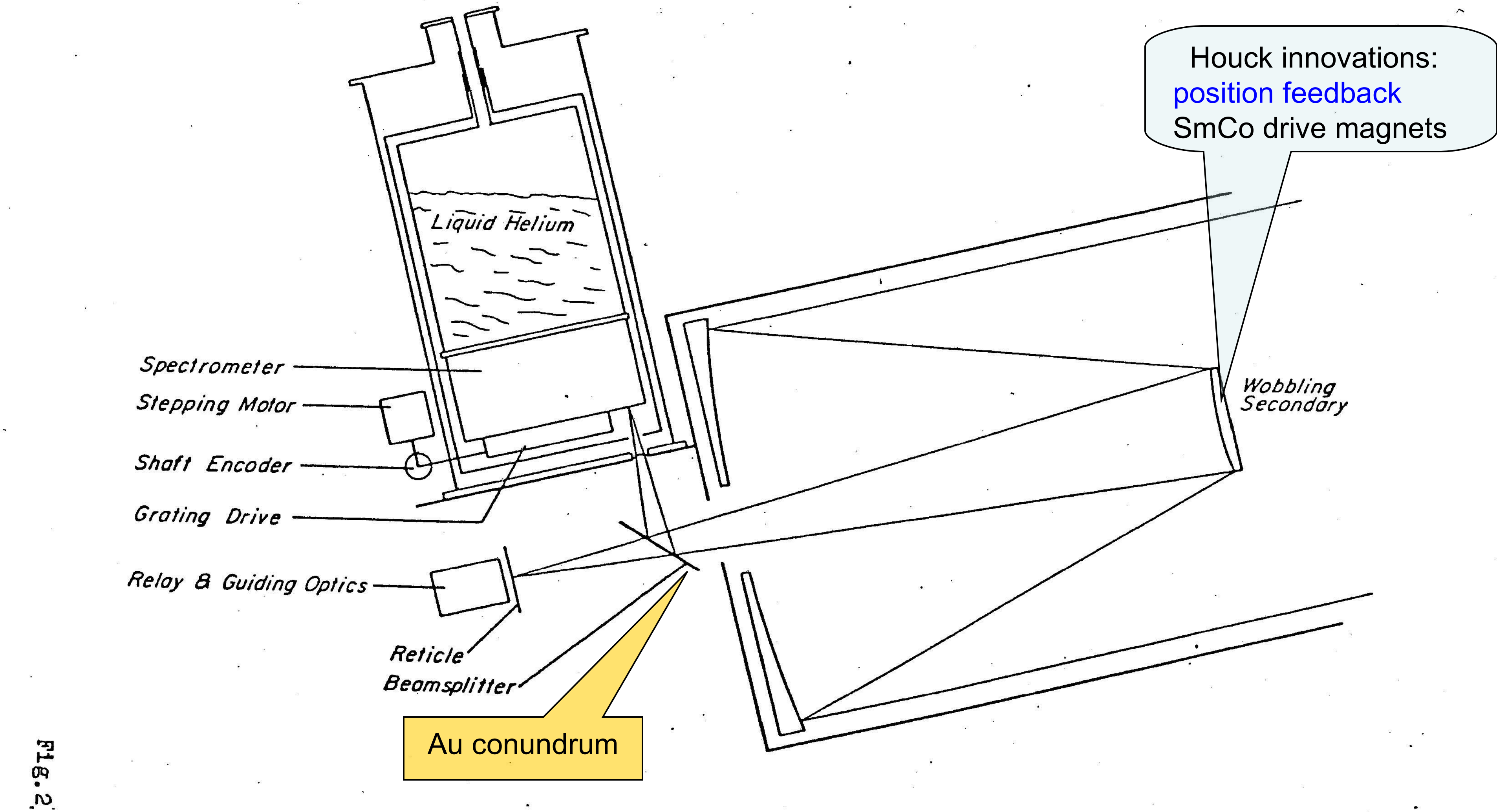


MULTIPLE DETECTOR SPECTROMETER F/6.5

Factor 10 speed gain

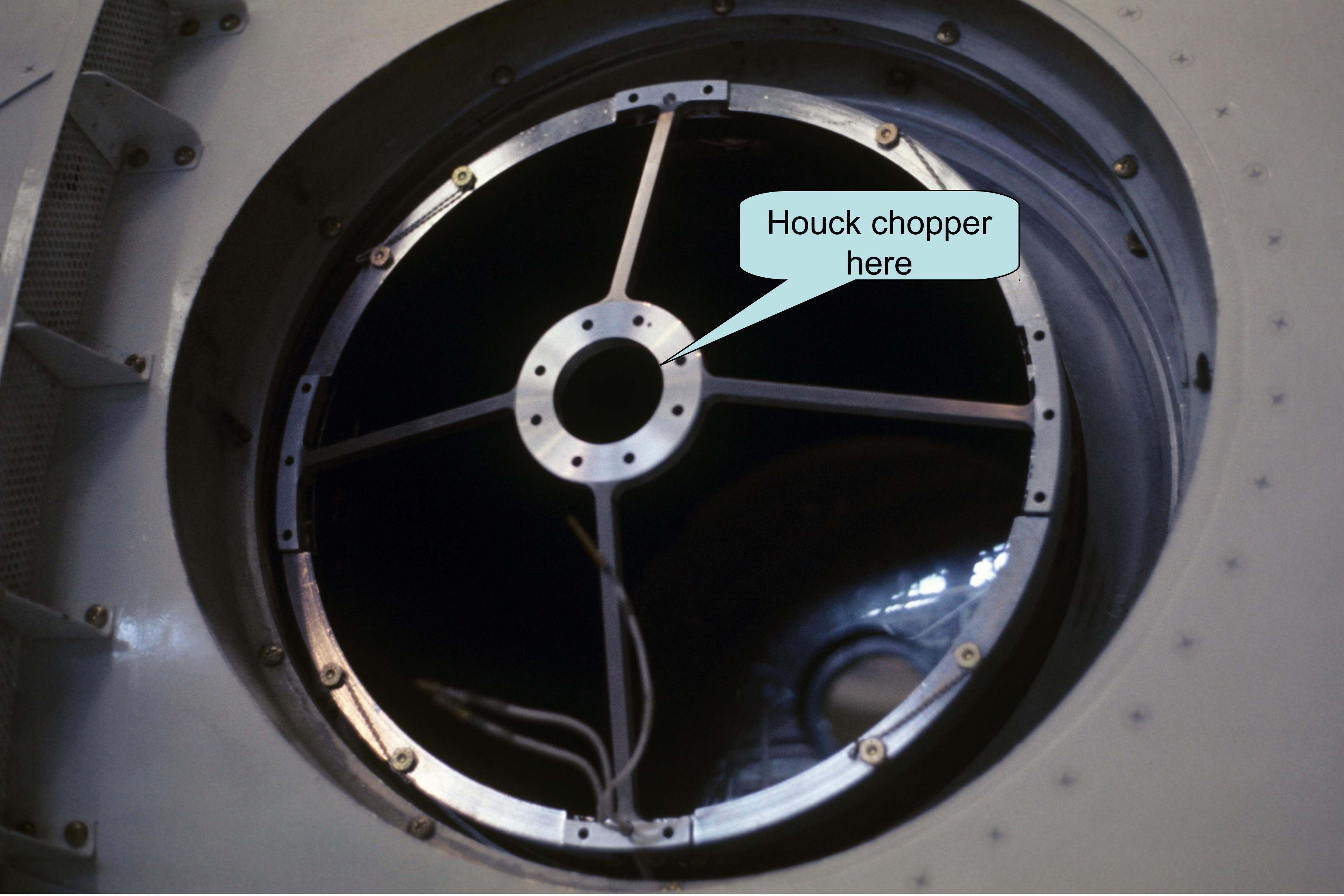
Fig. 1b

- 10-ch spectrometer
  - 1x3x3 mm Si:Sb pc
  - 10-ch TIA amp
    - G 118 MosFETs 2K
  - 0.2 um FWHM
  - 16-30 um spectrum
    - 10 grating positions
- Spectral 'ghosts'
  - Double bounce off grating
  - Black paper baffle glued to mirror with rubber cement fixed
  - Ghosts used different part of spherical mirror
- $\forall$ λ > 16 μm filter at entrance aperture
  - Order selector
- Flat mirror over grating
  - Enhanced S/N for peakup
  - Speedometer cable operated
  - Microphonic noise obviated any S/N improvement
    - Aircraft vibrated
- Use 'sum channel' for peakup
  - SqRoot(10) S/N improvement



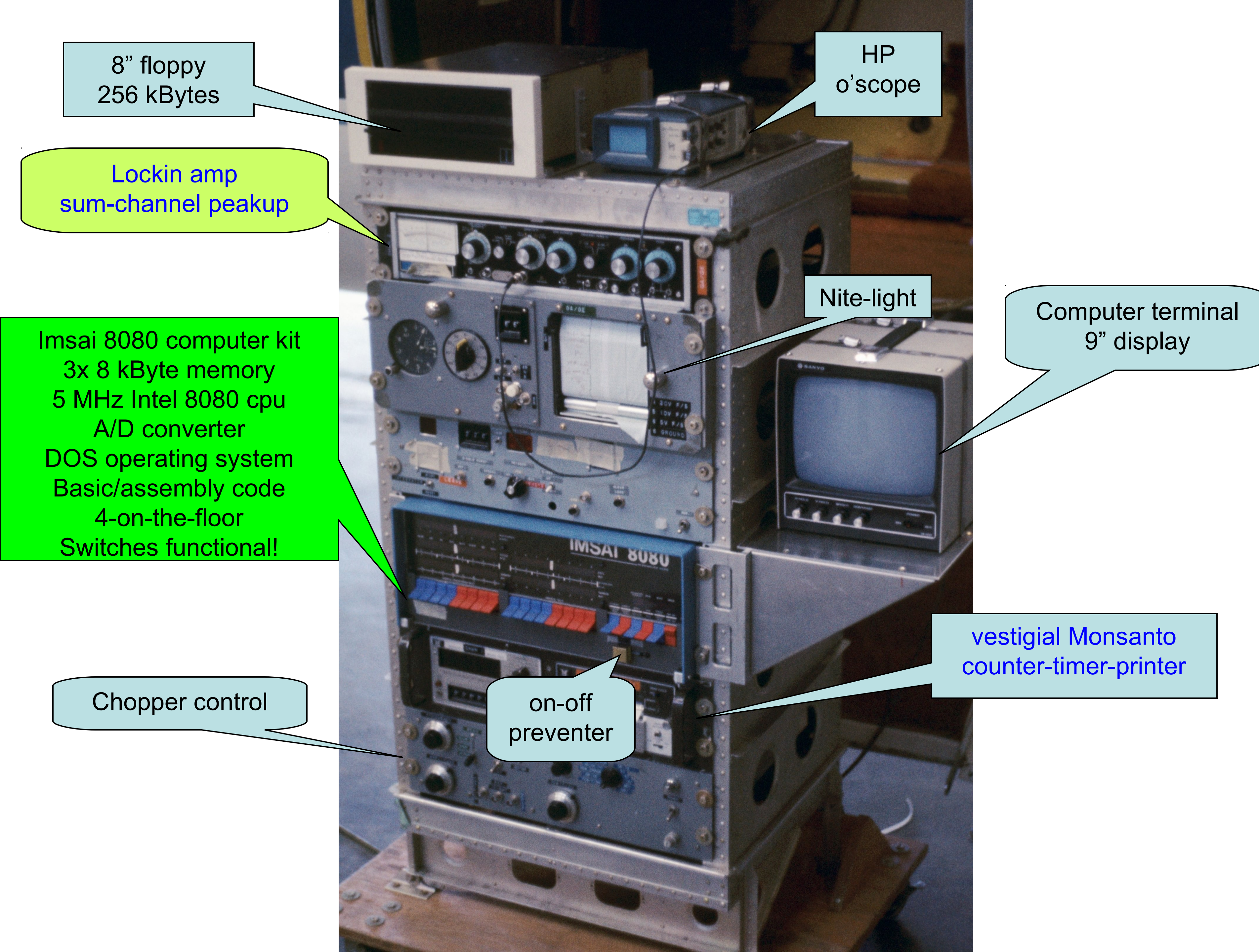
’10-ch’ first operated with 2 Ge:Cu photoconductors to study the 16-28 μm spectrum of Jupiter 1973-74

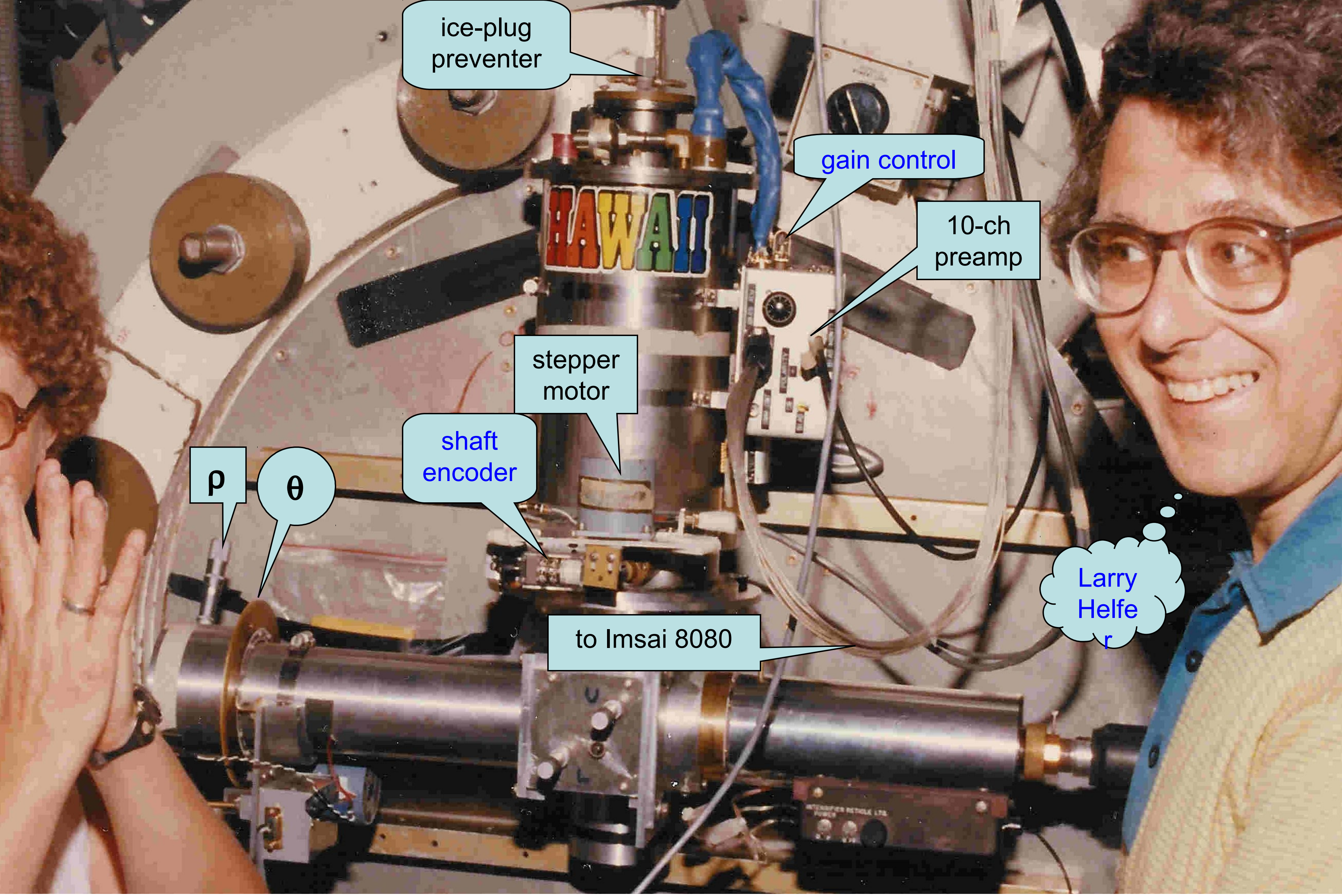
Au conundrum: more Au gives more IR reflection, but less visible guiding light. The compromise (more IR) gave a limiting guiding magnitude brighter than 9th on the C-141. Solution: IR 81E coated glass from Ford Aerospace (high IR reflection *and* visible transmission) – used on skyscrapers to minimize air conditioning.

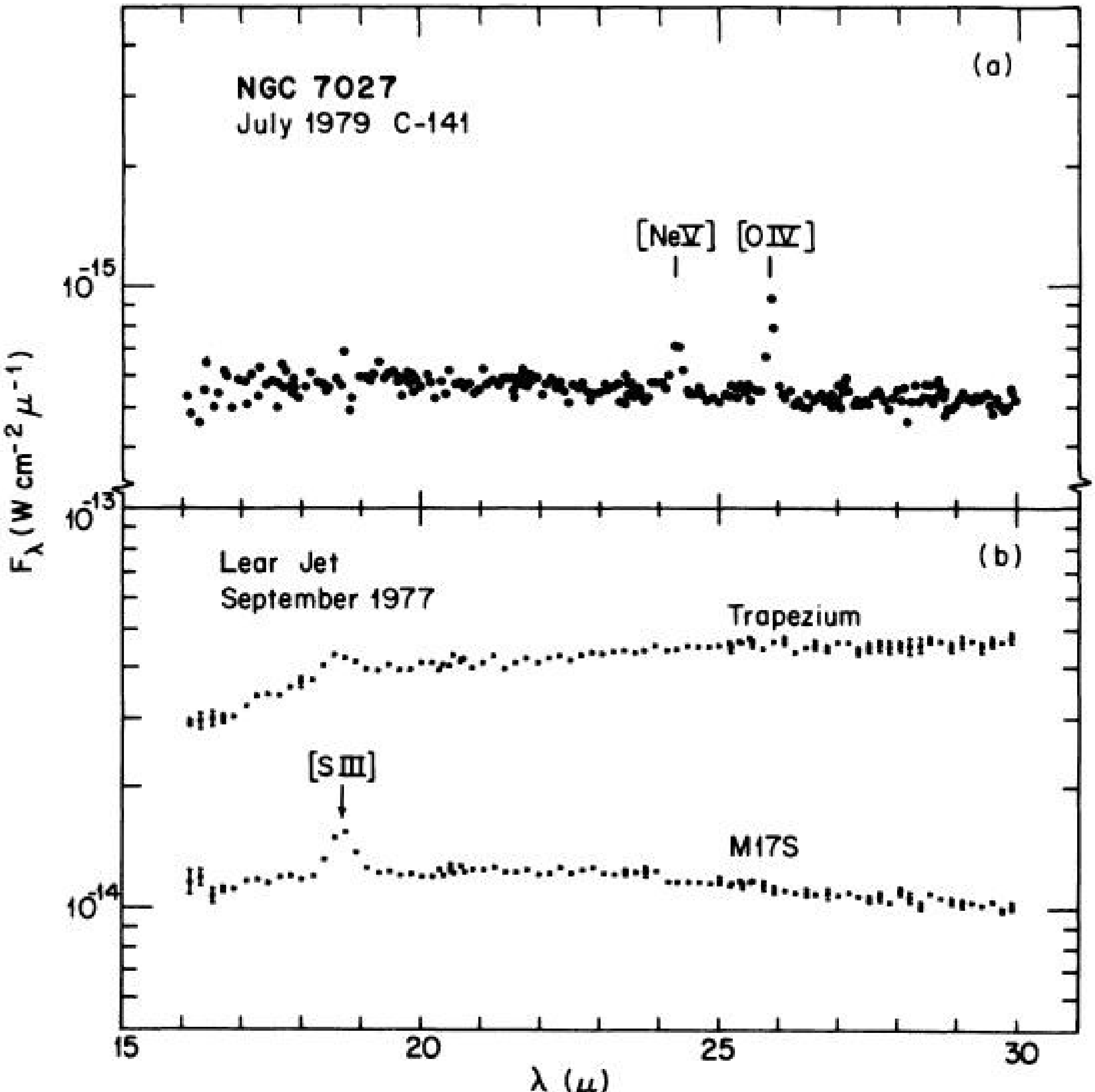


Learjet 12” ‘scope showing boundary control gadget and (missing) Houck chopper July 1977

Stables Inn (now Antlers) Varna, NY 1978


8” floppy
256 kBytes
HP
o’scope
Lockin amp
sum-channel peakup
Nite-light
Computer terminal
9” display
Imsai 8080 computer kit
3x 8 kByte memory
5 MHz Intel 8080 cpu
A/D converter
DOS operating system
Basic/assembly code
4-on-the-floor
Switches functional!
IMSAI 8080
vestigial Monsanto
counter-timer-printer
Chopper control
on-off
preventer

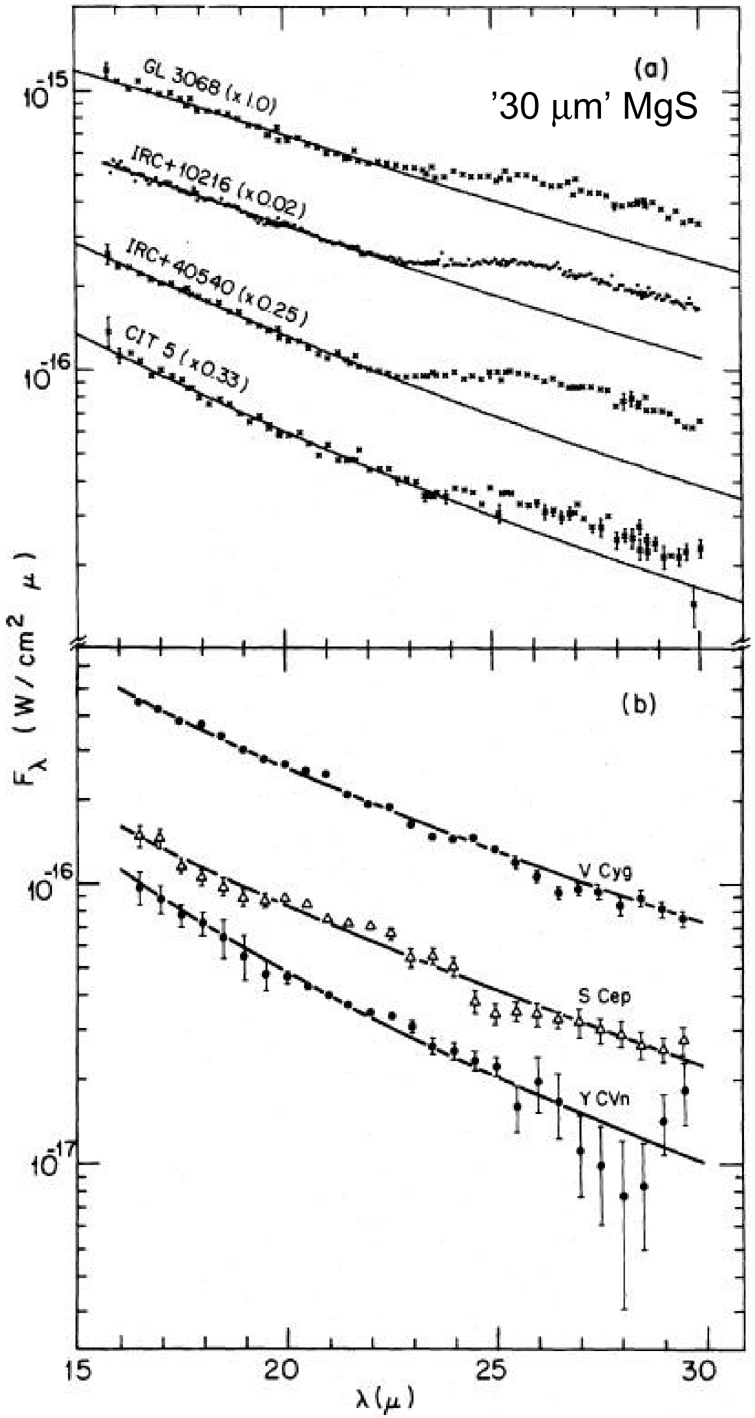

ice-plug preventer
gain control
10-ch preamp
stepper motor
shaft encoder
ρ
θ
to Imsai 8080
Larry Helfe r
HAWAII



10-ch spectrometer, with better sensitivity and higher (0.2 μm) resolution clearly detected Ne V And O IV in PNebula N7027.

Unfortunately, 7027 failed to contribute to dustology here, None of the Bucky-ball features eventually detected by Spitzer IRS in other PNebulae!

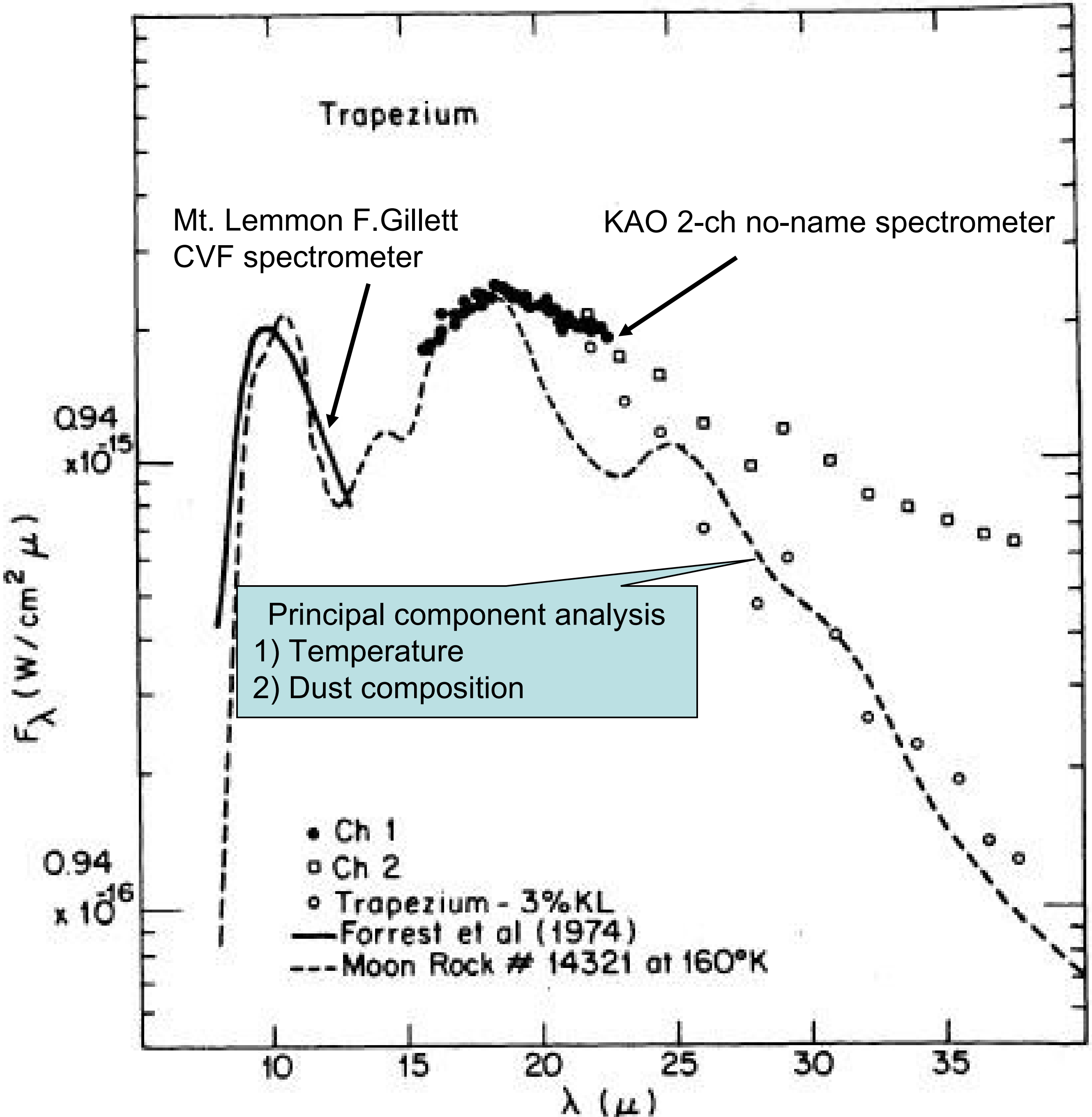
Not even a '30 μm' feature!



Carbon Stars

Our first (only?) triumph of dustology was the '30 μm' feature seen in Carbon stars and Carbon-rich Planetary Nebulae.

Preferentially in high mass-loss stars.



Fair fit to optically thin Trap spectrum with small silicate grains of Moon rock 14321 material.

Fine structure from minerals absent.

Search must continue for mineral features:

- ISO SWS
- Spitzer IRS

Two temperature (warm & cold) model

$$F_\nu(\lambda)^{\mathrm{mod}} = B_\nu(\lambda, T_c)\left[\Omega_c + \sum_i a_{c,i}\kappa_i(\lambda)\right] + B_\nu(\lambda, T_w)\left[\Omega_w + \sum_j a_{w,j}\kappa_j(\lambda)\right] ,$$

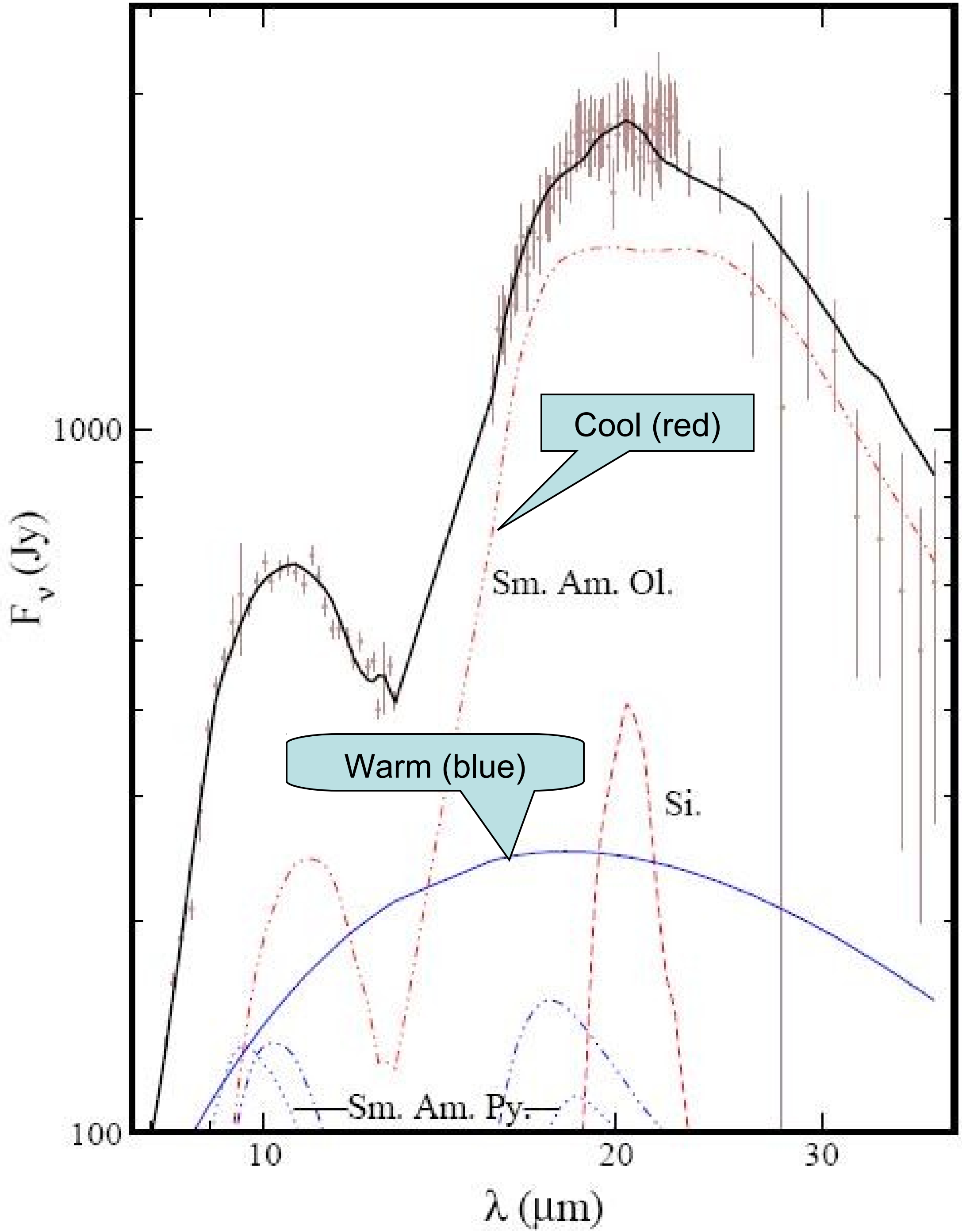
Principal Component analysis

18 components - 2 temperatures – 2 solid angles – 14 dust components

amorphous olivene, forsterite, silica, enstatite, etc.

κ(cm^2/gm) are small grain opacities, a's are the mass/d^2 of that component.
Solid angles represent optically thick disk + carbon + very large silicates.

Model tested against full self-consistent radiative transfer model on IS Tau (Sargent et al. 2006) and the 8-40 μm spectrum of the

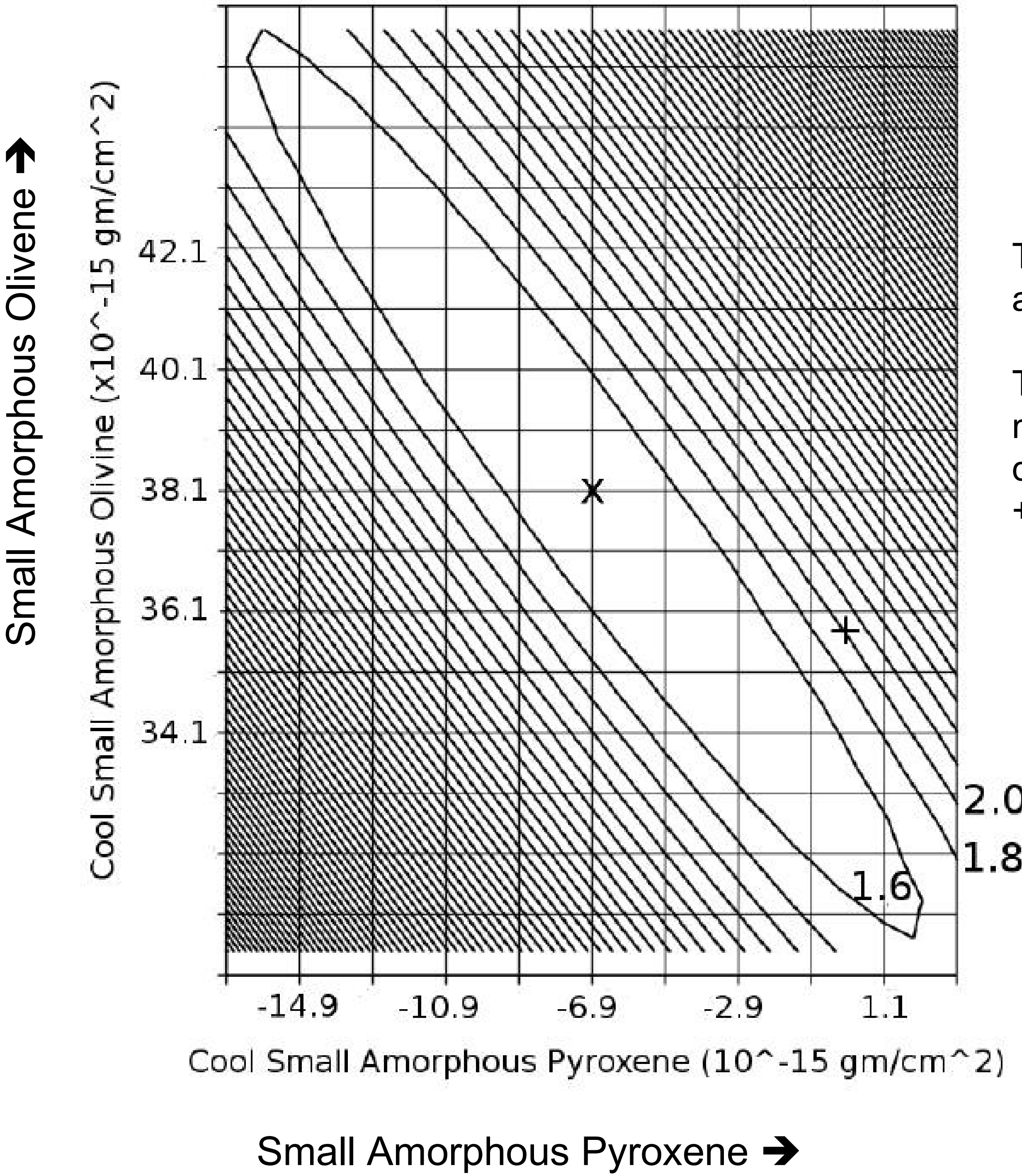


New fit to same Trapezium spectrum

Sub-micron amorphous silicates fit well

Silica (Si.) probably not significant

Amorphous silicates in the ISM confirmed by nano-analysis of small pre-solar grains (found in primitive meteorites and Interplanetary Dust Particles).

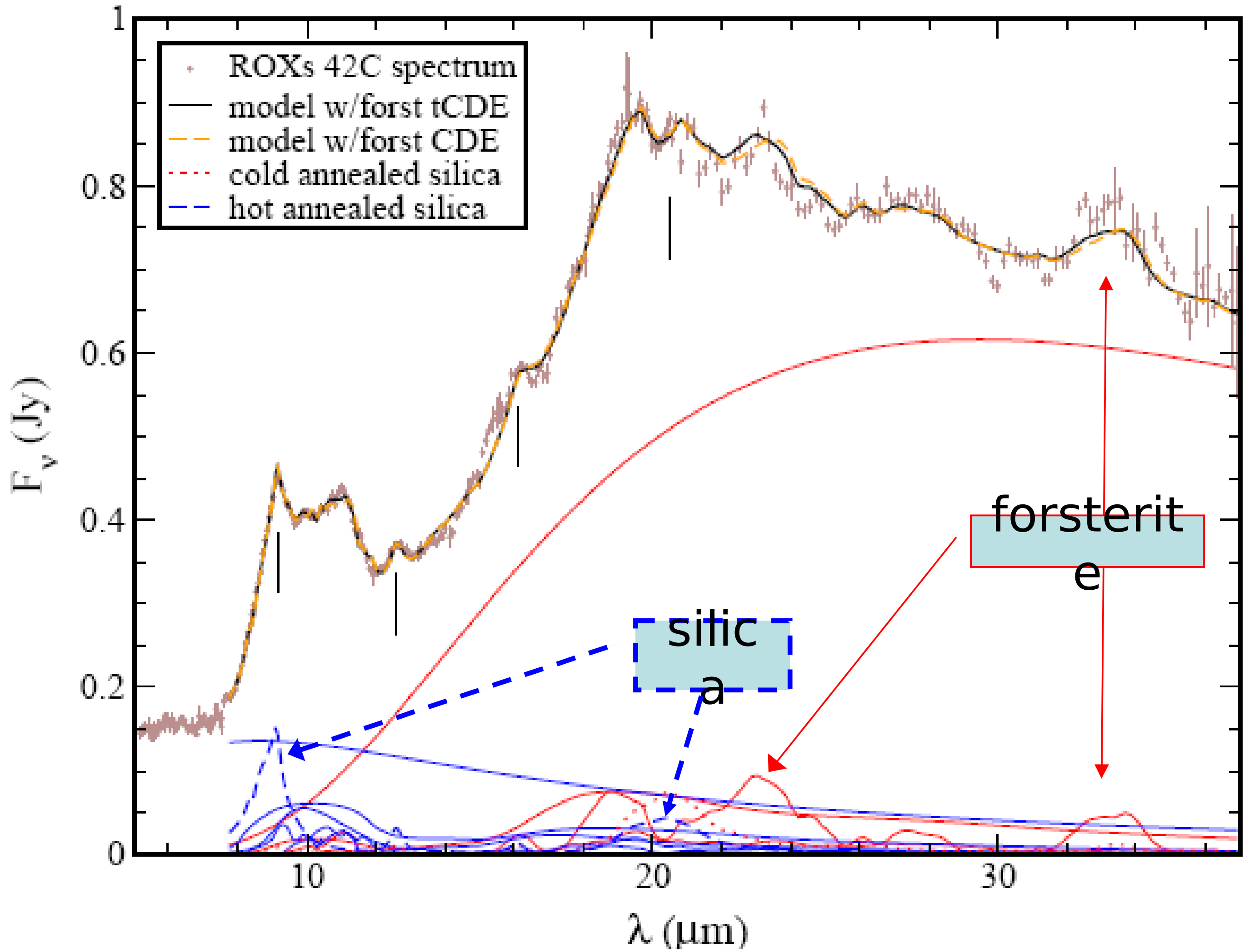


Two of our principal components are ambiguous/degenerate.

The long narrow valley of χ^2 minimum indicates we can determine the sum of Pyroxene + Olivene, not each separately.

ROXs 42C fit with annealed silica (vertical bars)

In addition to the prominent silica features, our stars show evidence of amorphous silicates (large and small) , forsterite, and enstatite. By tuning our opacities for these components, we effectively isolate the silica features.



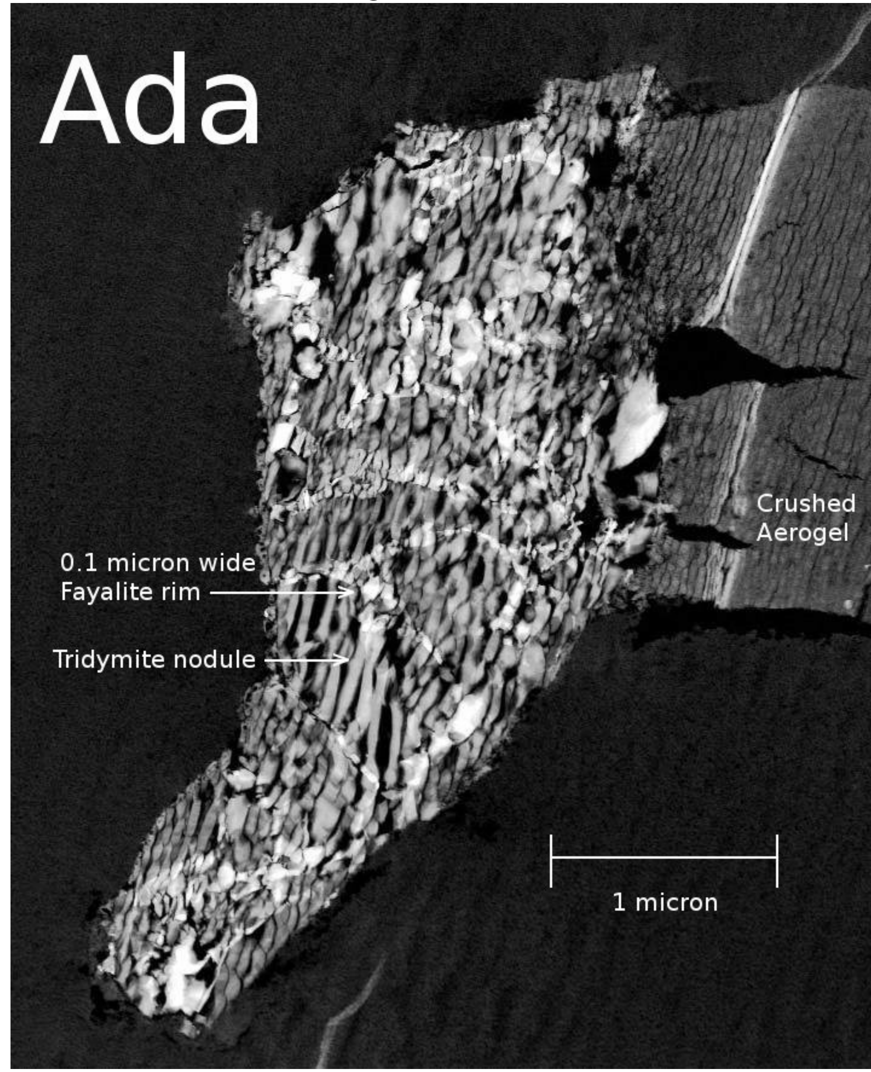
Silica from comet Wild 2 is tridymite

This, and a second grain (Mikouchi et al. 2007) from Wild 2 (Stardust mission), both indicate the high temperature forms of silica (cristobalite and tridymite).

Three further silica grains from Wild 2 have been identified as crystobalite.

This suggests the dust processing in the solar nebula 4.6 Gy ago was similar to what we're seeing in 1-3 My old protoplanetary disks right now.

The identification of the high temperature forms of silica in this comet (and enstatite chondritic meteorites, e.g. Dodd (1981),



Courtesy Dave Joswiak, U. Wash.

Hickam Field Hawaii after 8 hour flight from Moffett Field observing the Galactic Center.
Carl Gillespie asked the pilot for a small course correction. He got no reply, so went to the flight deck. The pilot and copilot were asleep in the bunks. The navigator was asleep at the controls.

Instead of Sleazy 8 in Mountain View (murders), we stayed in a nice hotel on Wai Ki Ki beach

Coco Head Hanuema Bay

snorkeling Hanuema Bay

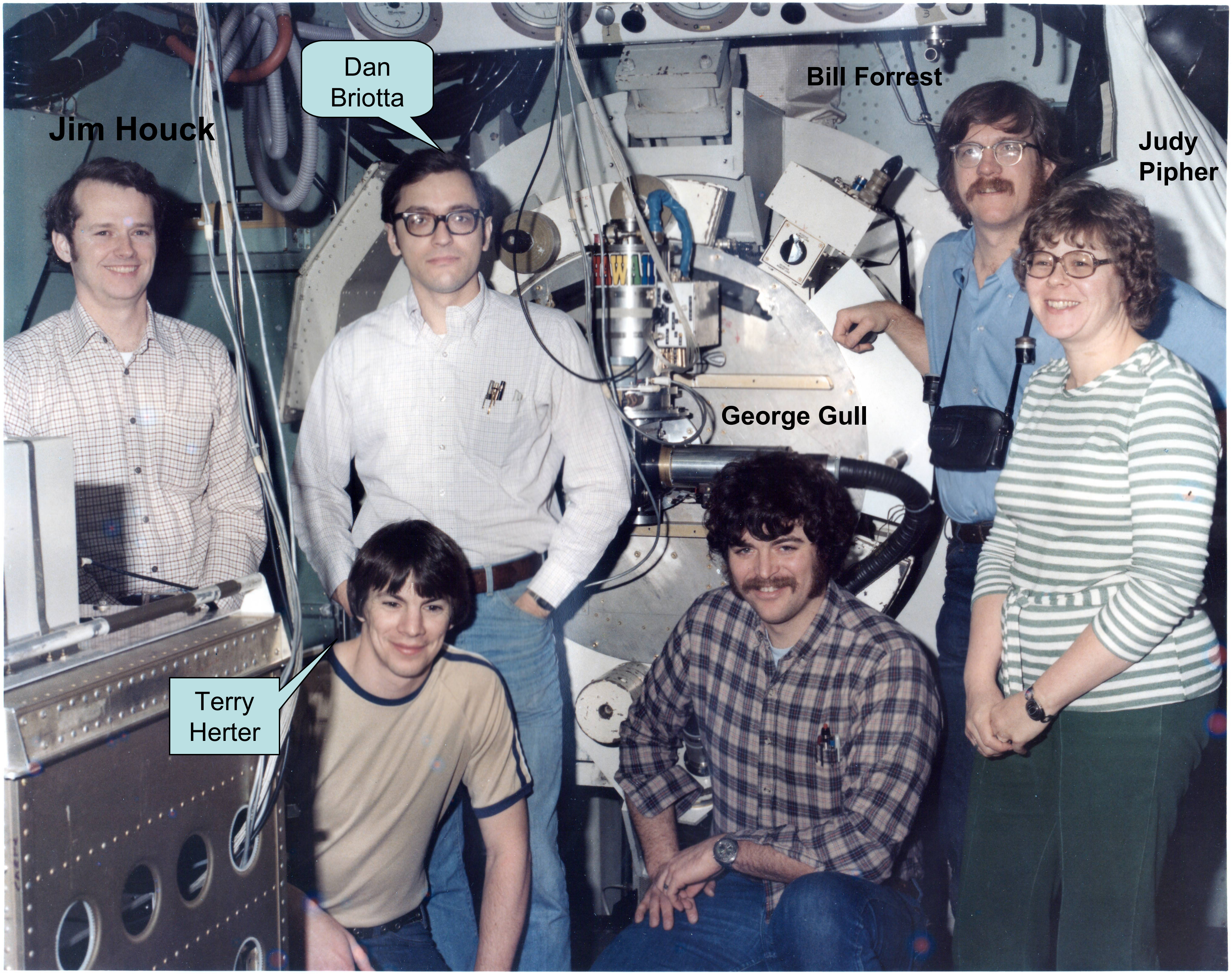
Jim Houck

Hawaii is definitely beautiful

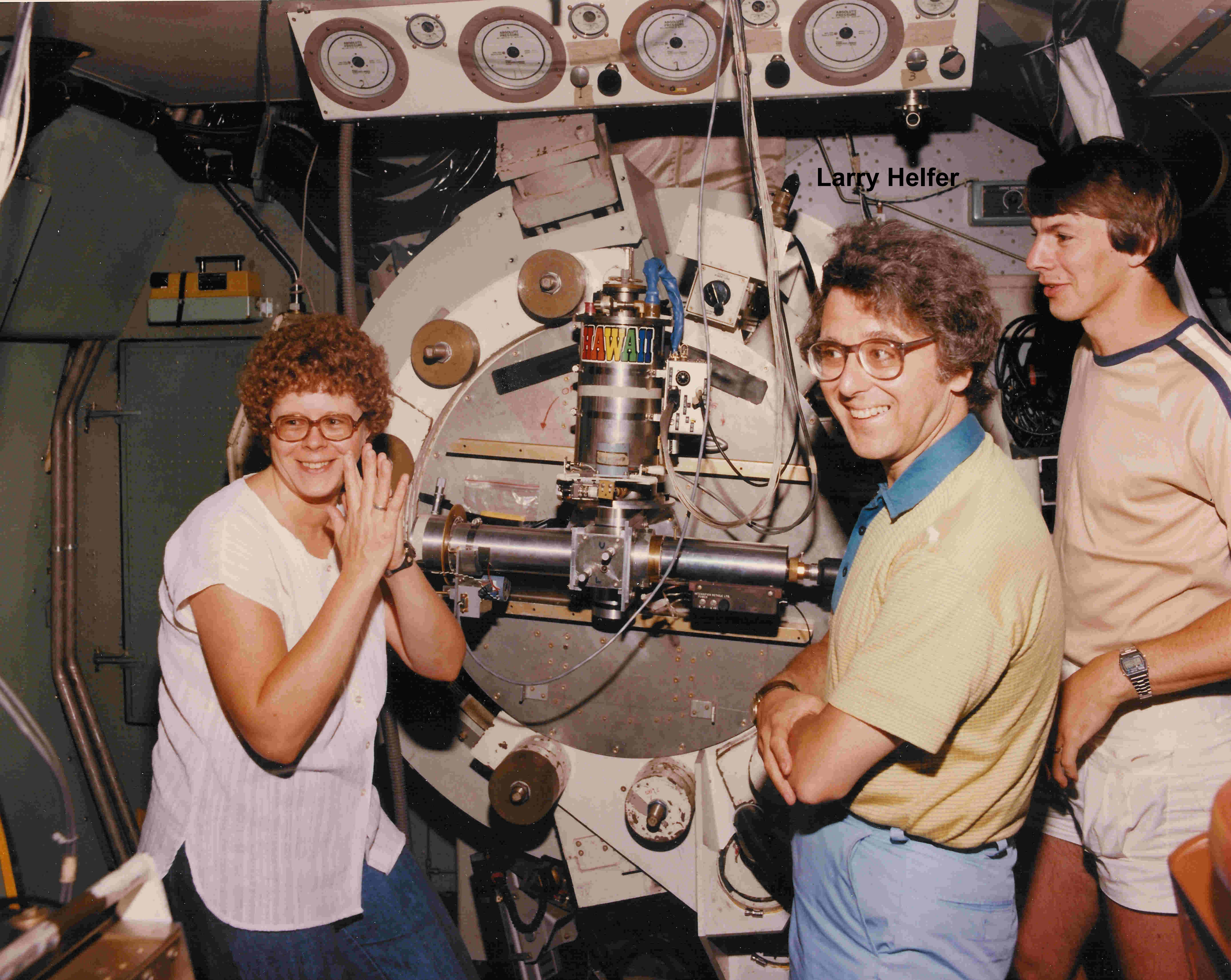
Hickam Field, back to reality

Left to right:
John McCarthy
Dan Briotta
Jim Houck

Off to California


Jim Houck
Dan Briotta
Bill Forrest
Judy Pipher
George Gull
Terry Herter

1979



1979

1983 – On to the IRS and Spitzer