Balloon Environment

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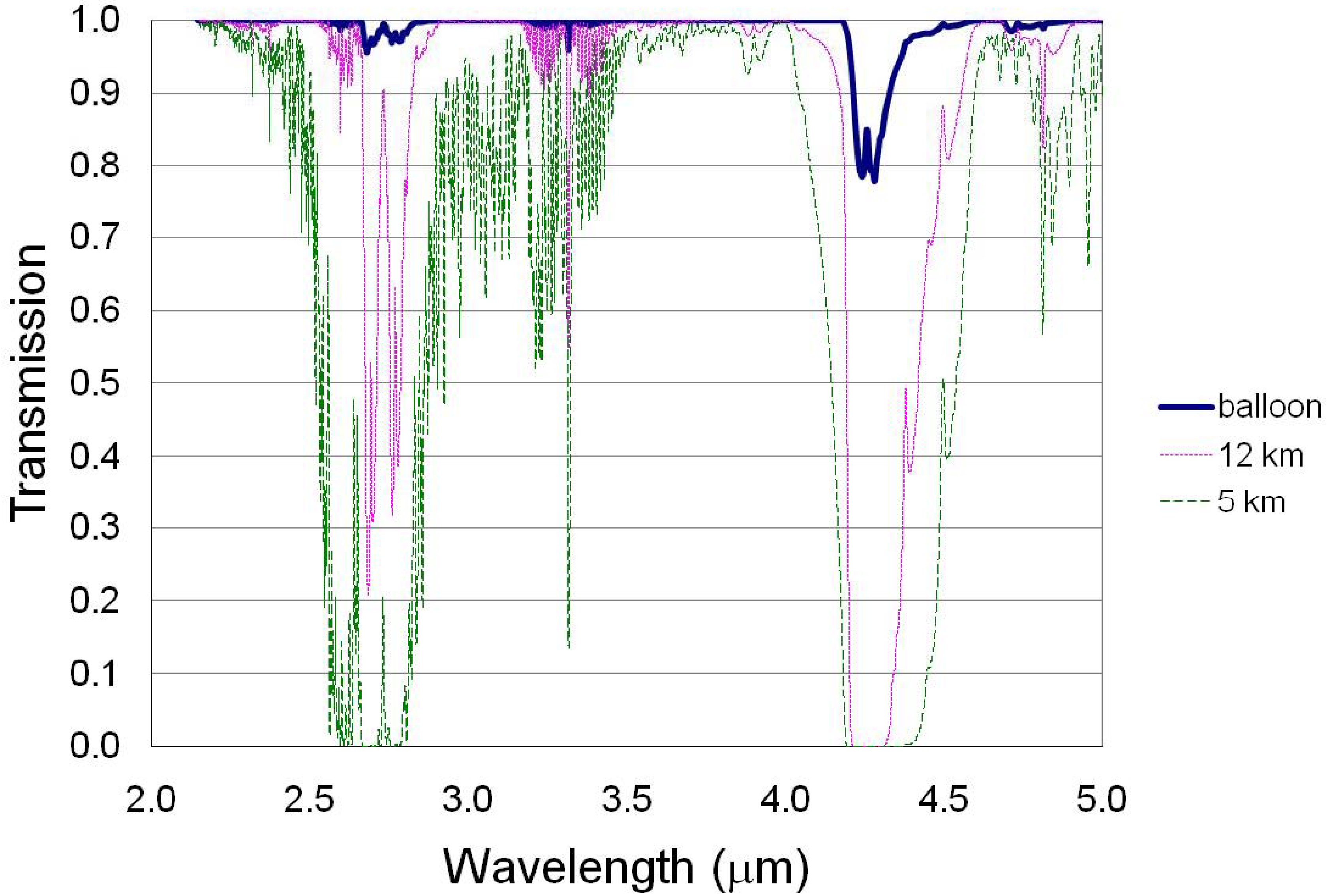
Outline

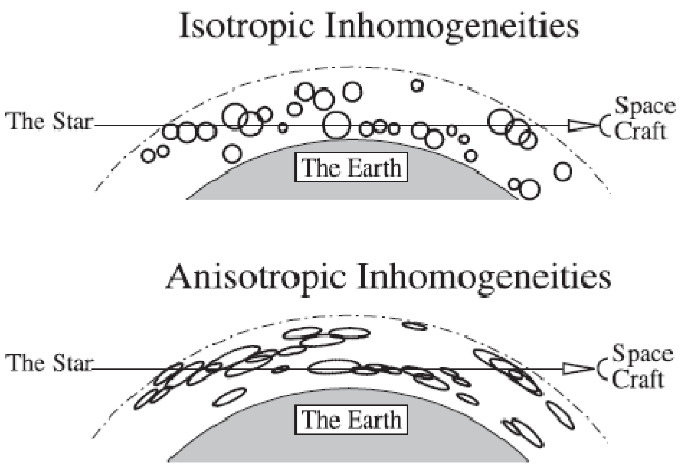
- Natural seeing, contrast limit (in terms of speckle intensity).
- Local seeing.
- Sky brightness.
- What did Stratoscope do 40 years ago?

Near-Space Transparency



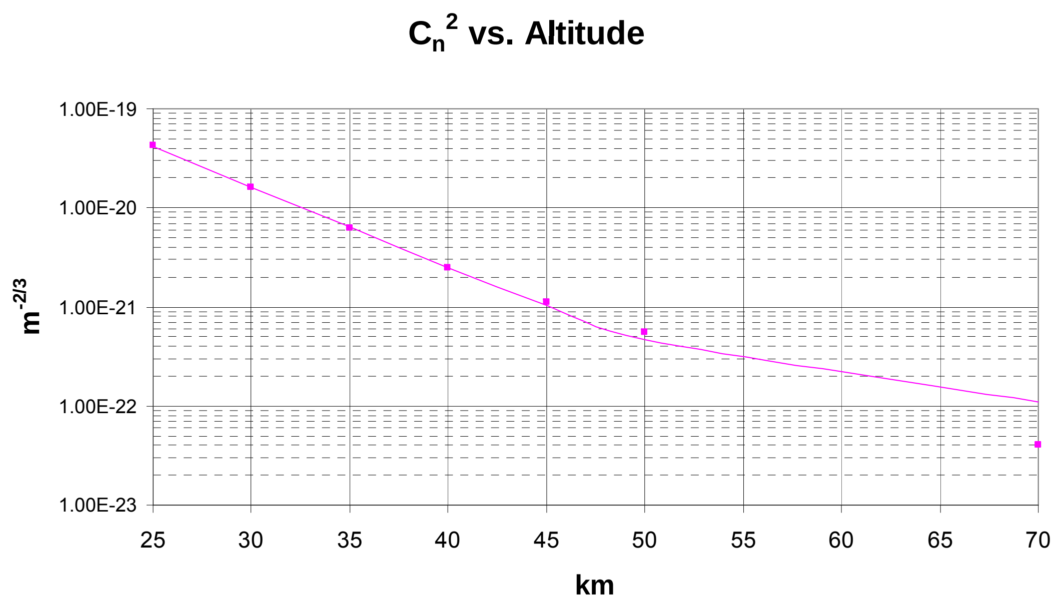
Natural Seeing

A Critical Feasibility Question: Will speckles generated by aberrations of free-atmospheric origin permit 10^{-9} contrast limit, assuming a perfect coronagraph?



Gurvich & Chunchuzov (2003) *JGR*, Gurvich & Brekhovskikh (2001) *Waves in Radom Media*

Seeing parameter	Balloon-borne (35 km alt.)	Ground-based
Fried r_0	41 m	0.2 m
Inner scale l_0	**2.4 m**	0.006 m
Outer scale Λ_0	44 m	27 m



Contrast levels of speckles generated by the atmosphere

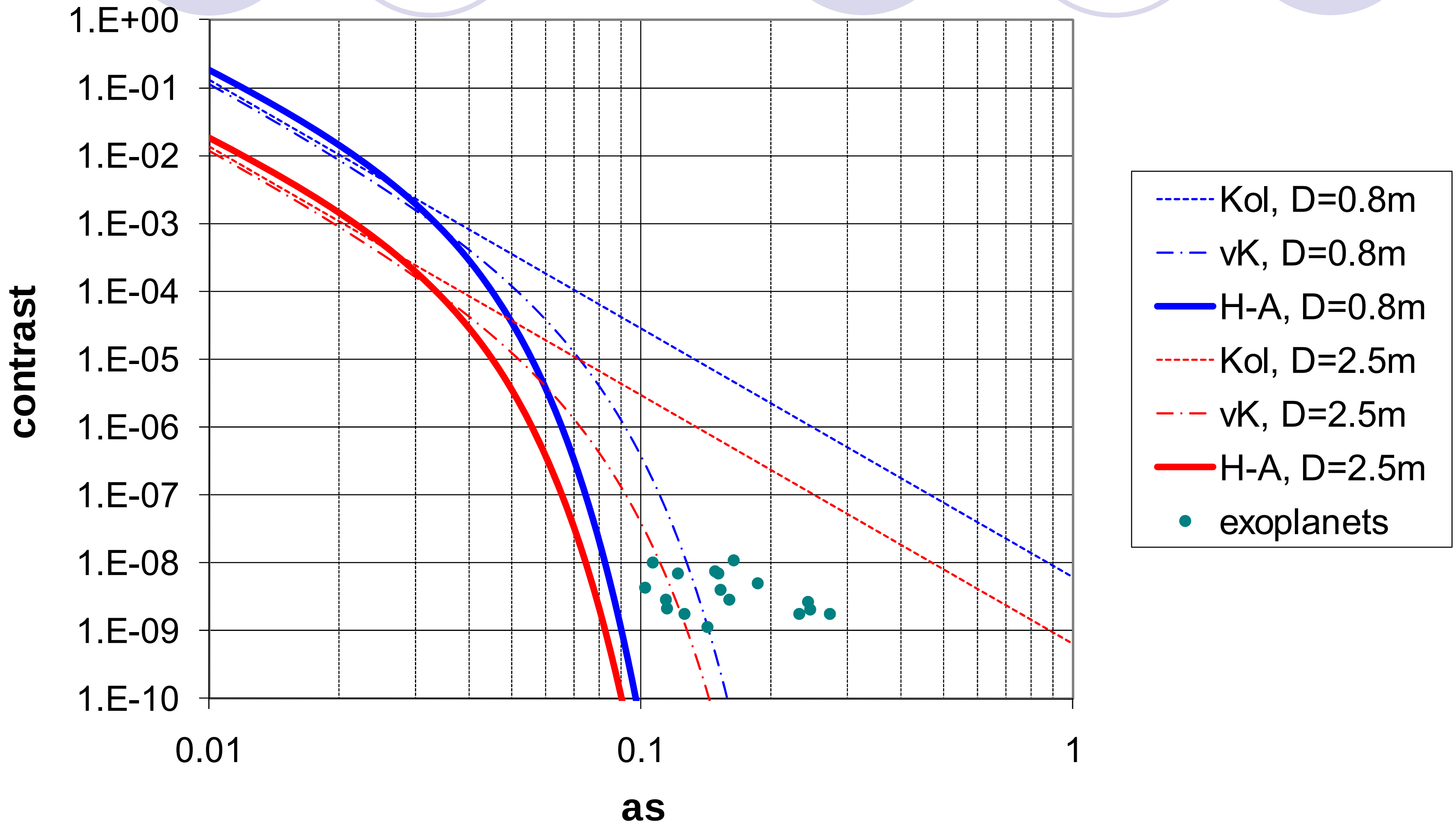
Operational parameters

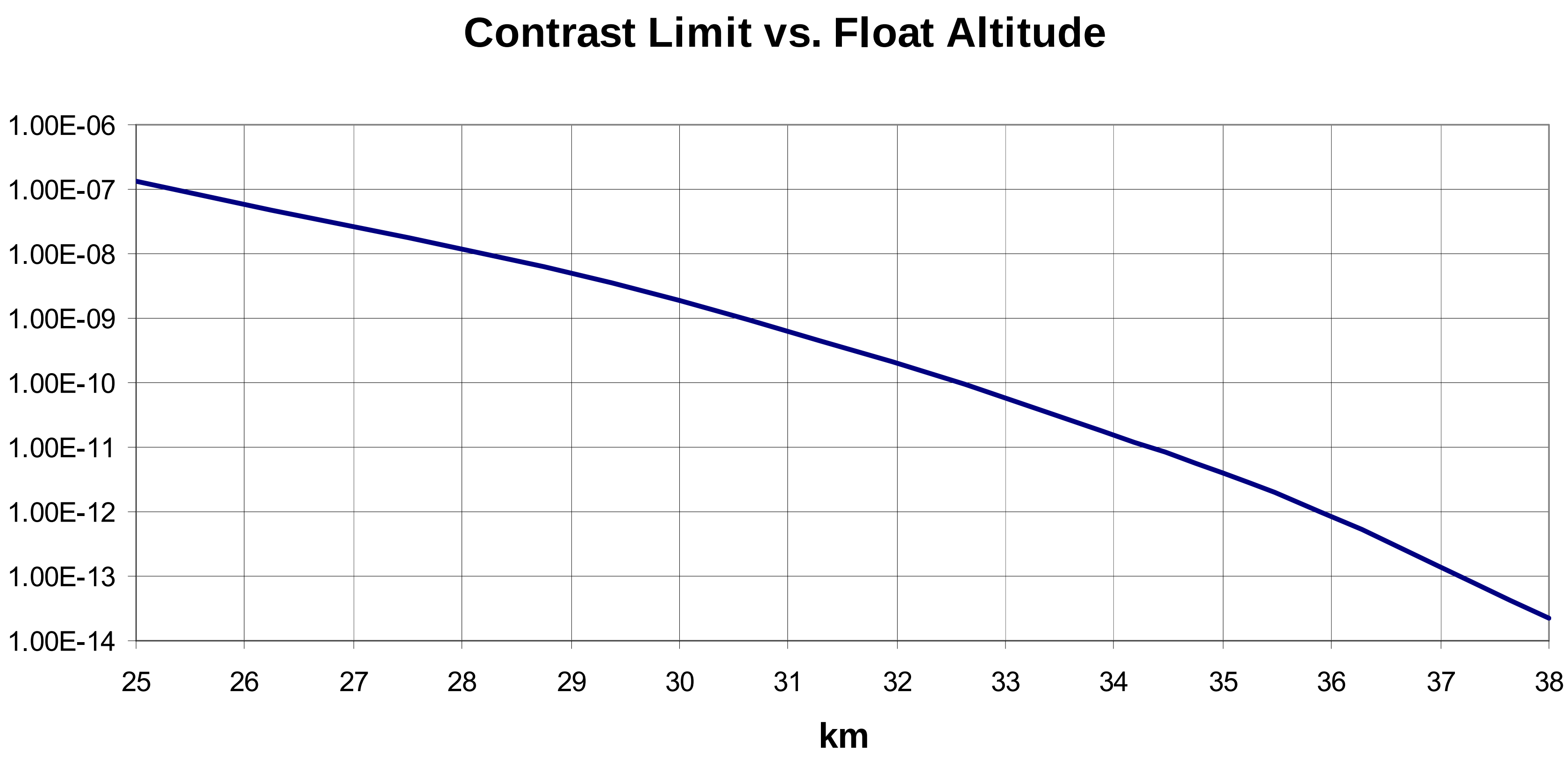
- Float altitude: 35 km
- Observing wavelength: 550 nm
- Telescope aperture diameter: 0.8m, 2.5 m

Calculation

- 2-dimensional power spectrum $\Xi(f)$ for index variations: Kolmogorov, von Karman, or Hill-Andrews model.
- For each spatial frequency *f*, integrate over a square of width *1/D* to obtain magnitude of phase perturbation, *h*. *D* is the telescope's aperture diameter.
- Take into account of Fresnel propagation using formula in Guyon (2005) *ApJ*.
- Speckle contrast level is $(\pi h/\lambda)^2$.

Speckle Intensity vs. Angular Distance from Star



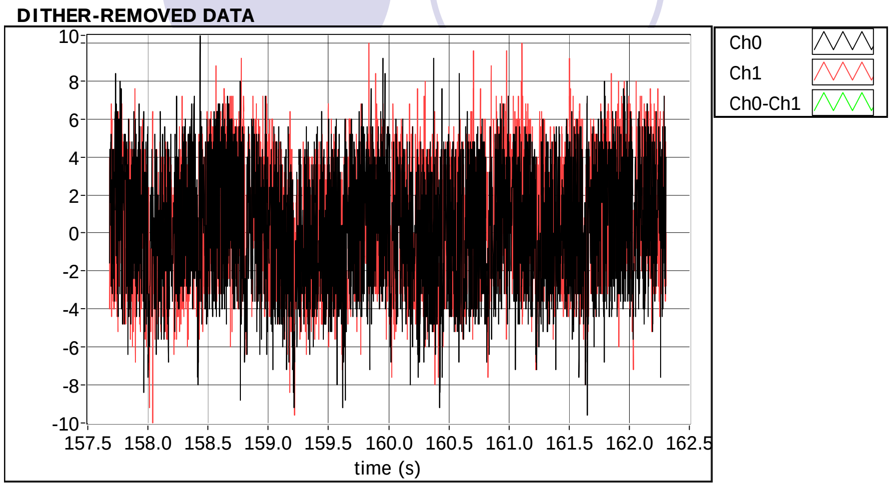


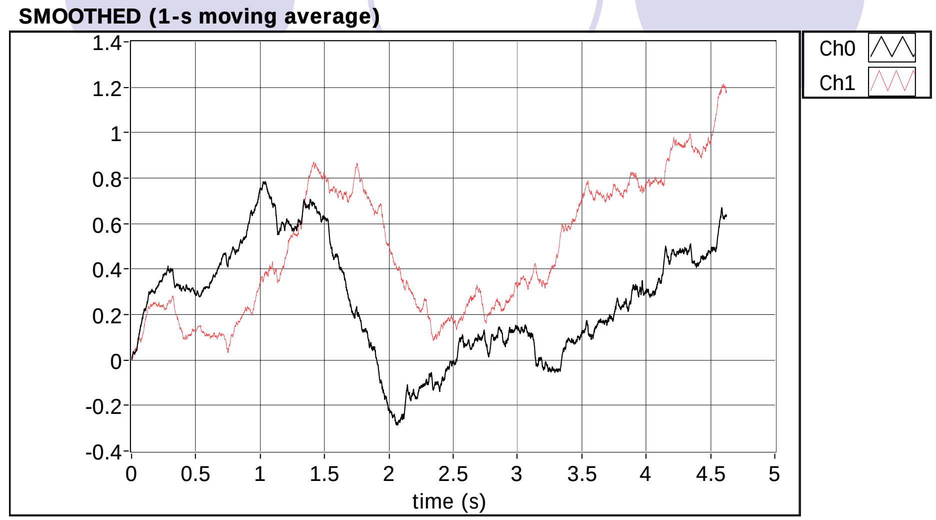
- 2.5 m telescope, at 0.2”

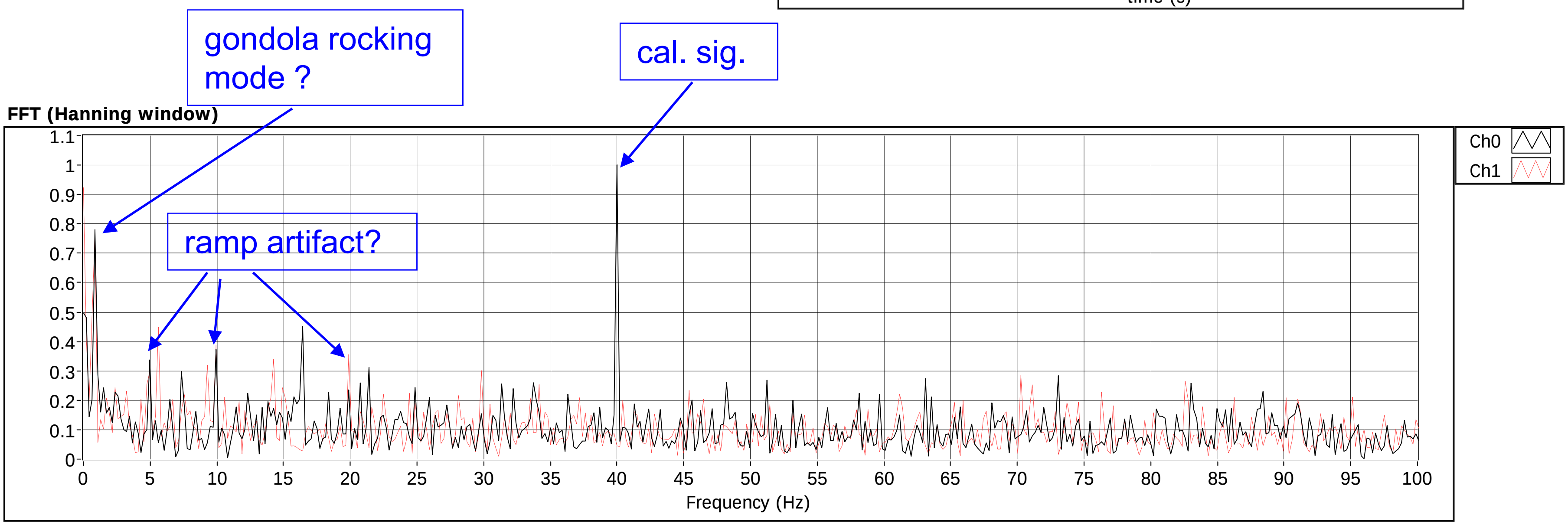
Local seeing

Potential local sources of aberration include the following.

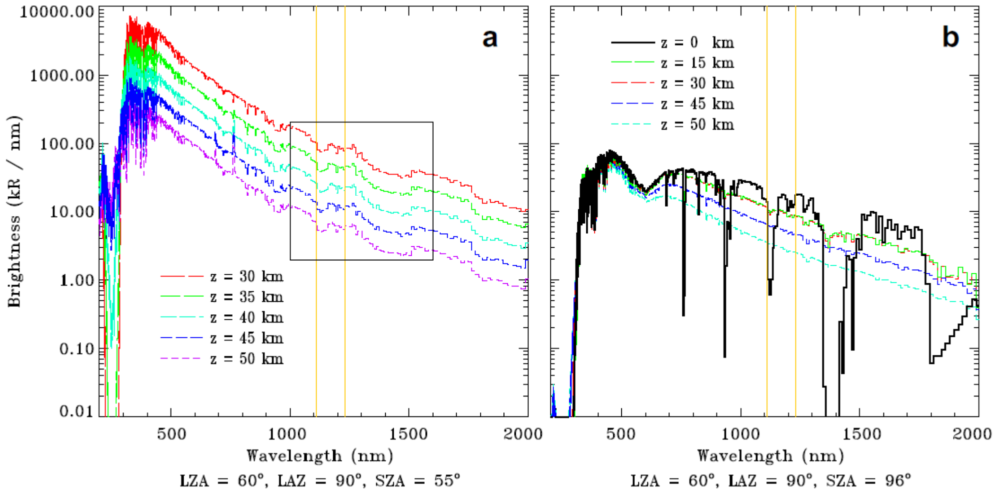
- Air flows that are either *turbulent* or laminar but *change slowly over time* can result from:
  - Thermal gradients due to onboard heat sources.
  - Thermal gradients due to the warmer earth scene *vs*. space.
- We flew a laser metrology instrument in September, 2007 to measure optical pathlength changes in a 1-m path on the exterior of a balloon borne telescope payload.


DITHER-REMOVED DATA
Ch0
Ch1
Ch0-Ch1
time (s)

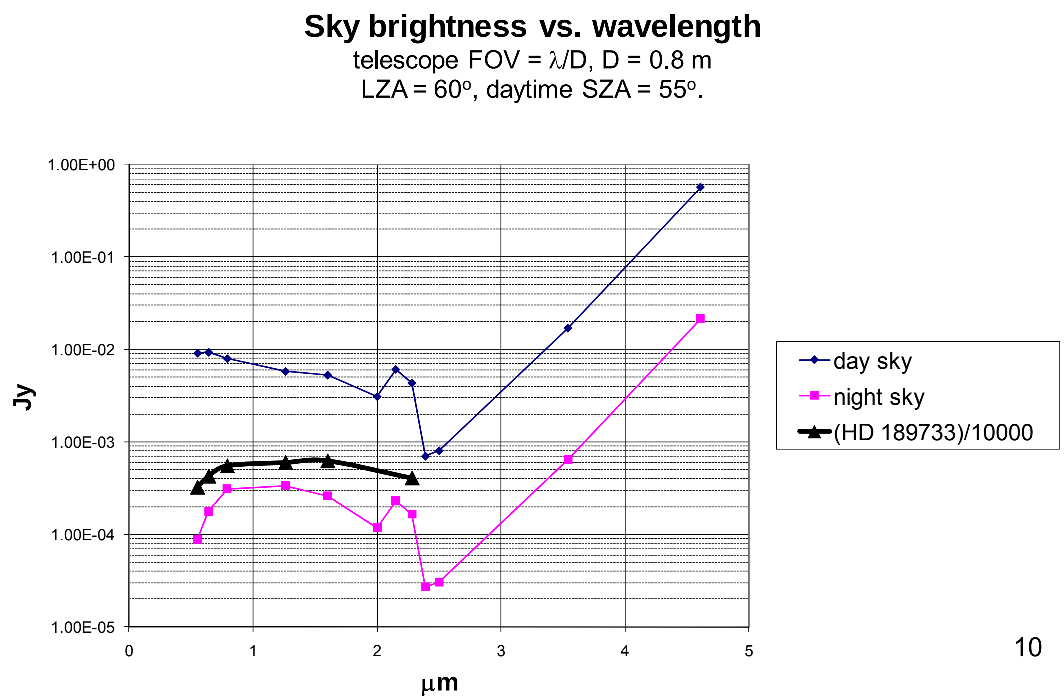

SMOOTHED (1-s moving average)
Ch0
Ch1
time (s)


gondola rocking mode ?
cal. sig.
FFT (Hanning window)
ramp artifact?
Ch0
Ch1
Frequency (Hz)

Sky Brightness



- Zhou *et al.* (2008) *Adv. Space Res*
- Mandolesi *et al.* (1998) *Astron. Astrophys.*
- $\lambda < 2.3\ \mu$m: OH airglow emission dominates (80 – 100 km).



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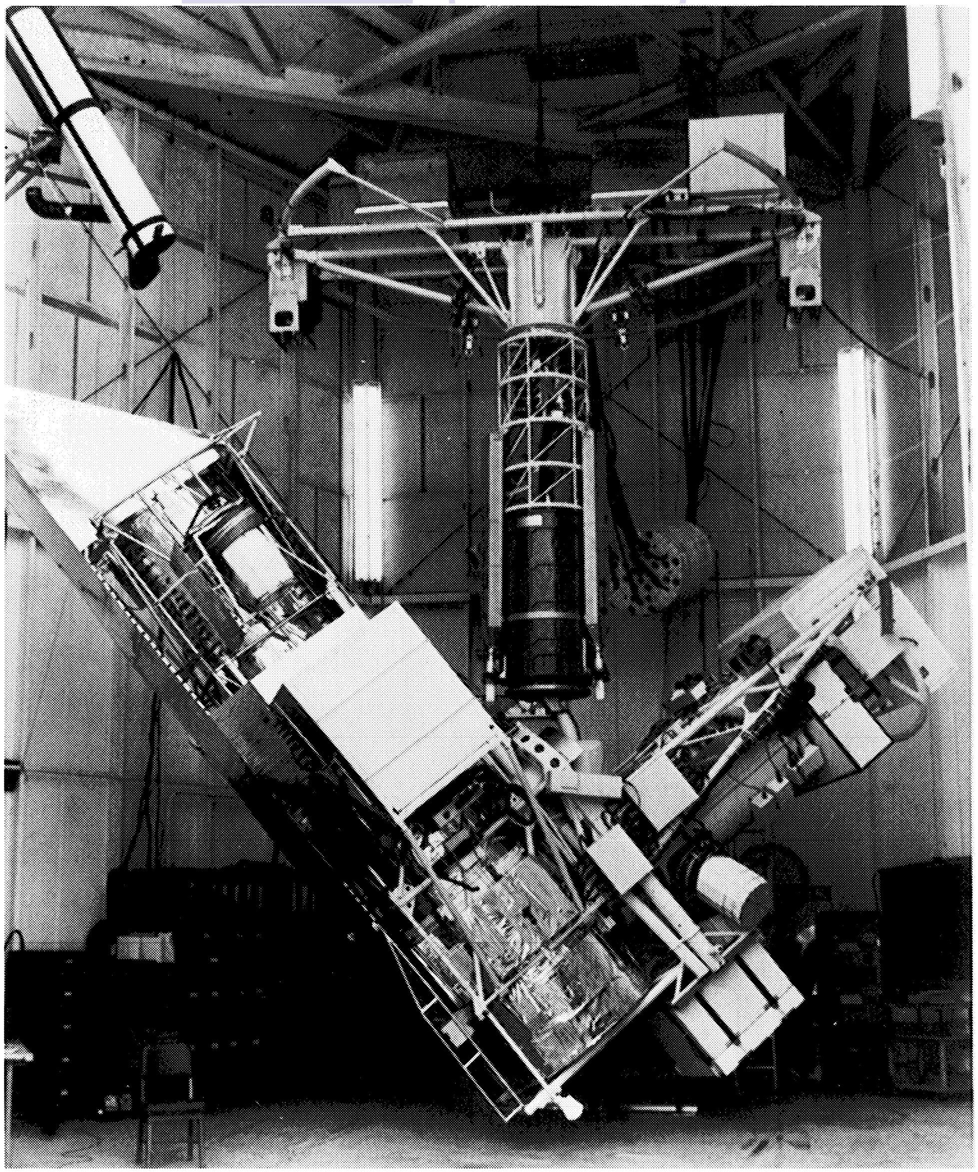
Stratoscope



- Danielson *et al.* (1964, 1972) *Ap.J*.
- 0.9 m telescope.
- "L" structure 2300 kG (5000 lbs) floats on 1.6 mm (1/16") Hg.
- Flexure elevation bearings.
- 0.2 arcsec PSF FWHM
- Pointing accuracy 3".
- Transfer lens stabilized image to 0".02 rms (cf. 0".008 requirement for Planetscope).
- Thermal control a challenge
  - Precooling primary mirror cell, and lower main tube.
  - Heaters to counter rad. loss from main-tube opening.
  - ±1K uniformity, except lower main tube +4K.

Conclusions

- Natural seeing: Contrary to the ground-based case, the **inner scale of turbulence** (l_0) plays a crucial role at float altitudes for balloon-borne observatories.
- Thus far, no discovery of fundamental show-stoppers to 10^{-9}-contrast observations for directly characterizing exo-Jupiters.