Towards a European Infrastructure for Lunar Observatories II

Infrared Telescopes on the Moon?

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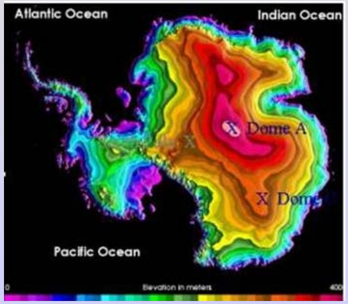
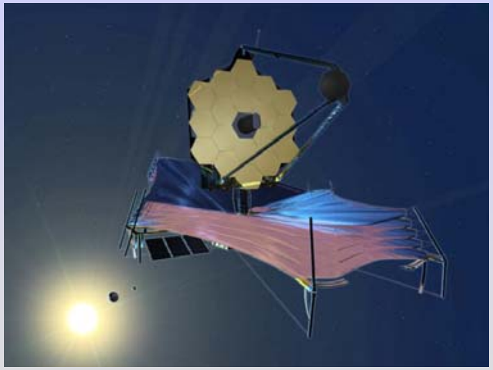
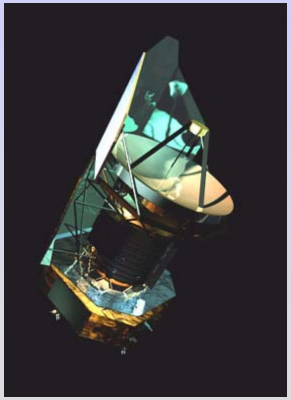
Infrared Telescopes

	+	-
1. Ground:	+ large apertures + continuous access + upgrade of instruments (+) Antarctica	- atmospheric windows - thermal background (-) seeing
2. Space:	+ medium apertures + all λ accessible + diffraction limited + active/passive cooling + continuous operation (< 10 yrs) + new missions every ~ 8 yrs	- high investment







Infrared Telescopes on the Moon?

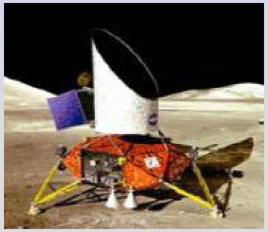
Advantages ~1970:

+ no atmosphere
+ stable thermal environment
+ cryotemperatures at poles
+ large solid surface

+ gravitation
+ slow rotation rate
+ long observing time

+ long lifetime
+ service, upgrades

But: Flights stopped 30 years ago.
No lunar observatory developed!

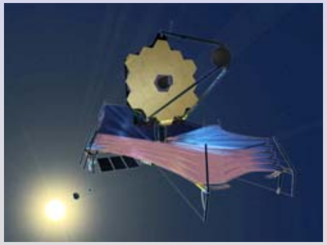


Free-flying observatories today:

- no atmosphere, no dust
- L2, trailing orbit: thermally stable
- passive T ≥ 30 K, active T ≥ 0.1 K
- sub arcsec pointing
- formation flights
- extremely light, deployment mechanisms
- coaddition of images, all sky access

- fast technical progress, frequent mission, easy station keeping

Dedicated IR missions are flexible, up to date technology, independent and frequent!



Unique or Opportunistic Science in the IR?

<u>Opportunistic</u>: **using new opportunities**

- resources and funding
- lunar station
- support by astronauts

but:

remember disappointments with Spacelab, Spacestation,...

<u>Unique</u>: **very large telescopes, very long integration times**

$\Rightarrow$ **liquid mirror telescope (D $\geq$ 20 m) at lunar pole**

- gravity shapes surface
- slow spin $\rightarrow$ long integration
- thermal shielding $\rightarrow$ cryotemperatures
- $2 < \lambda < 12$ µm

$\Rightarrow$ **interferometer of solid mirrors (membranes?)**

- large area on solid ground required
- slow spin $\rightarrow$ aperture synthesis
- $20 < \lambda < 350$ µm

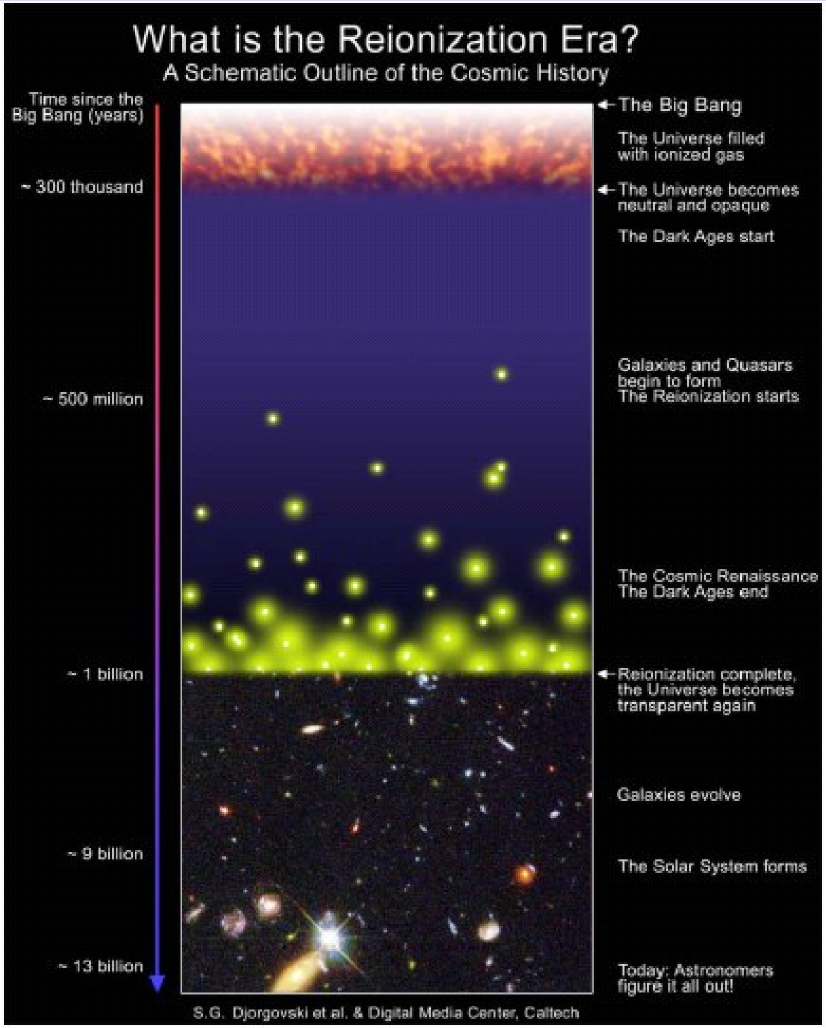
Topics of Infrared Astronomy 2006

(1 < λ < 350 µm ⇒ dust obscured, cold, highly redshifted universe)

	Lunar IR telescope?
• first stars, galaxies, quasars	✓
• reionization	✓
• evolution of galaxies, quasars	✓
• dark matter	(✓)
• accelerated expansion	(✓)
• black holes	
• cosmic accelerators	
• star formation	
• extrasolar earthlike planets	
• origin of life	

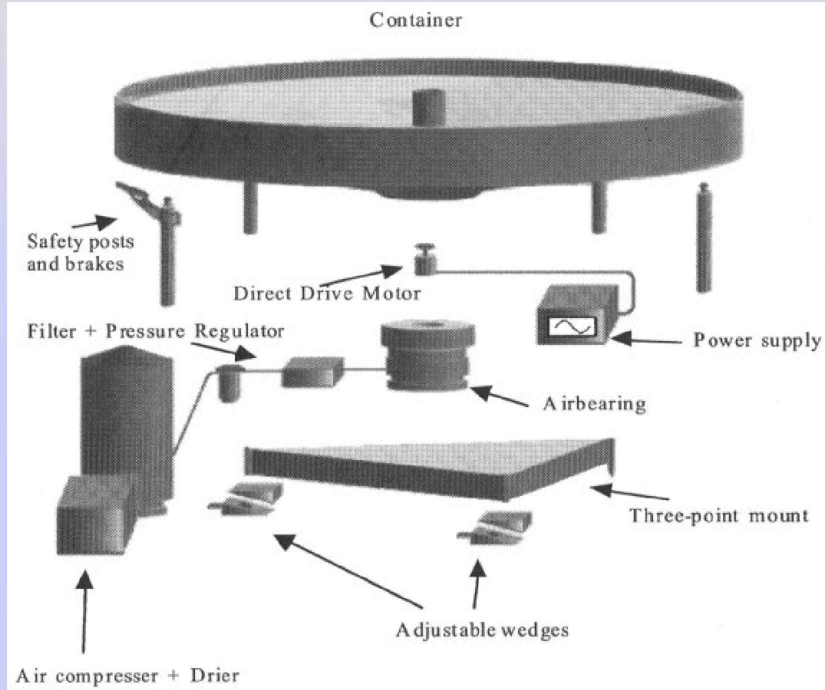
<u>Technological challenges:</u>

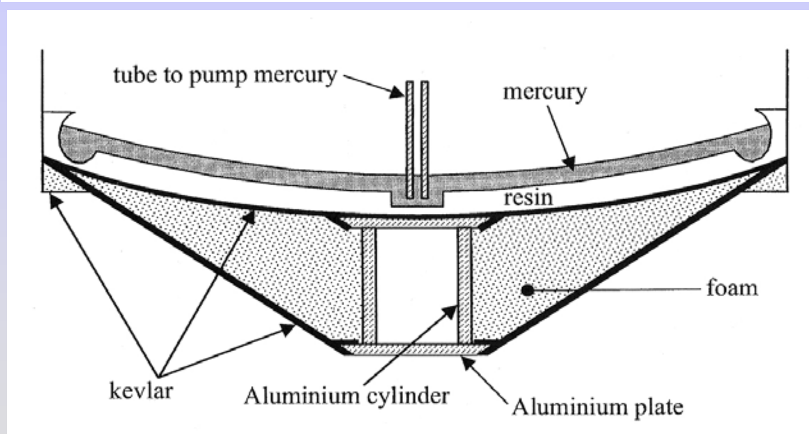
➢ higher spatial resolution
➢ larger collecting area
➢ lower background
➢ larger MIR/FIR detector arrays



Liquid Mirror Telescopes (Borra et al, Laval Univ., CND)

*Newton, Brewster/Buchan 1857,
Bürgel 1895, Wood 1908,
Borra 1980,...





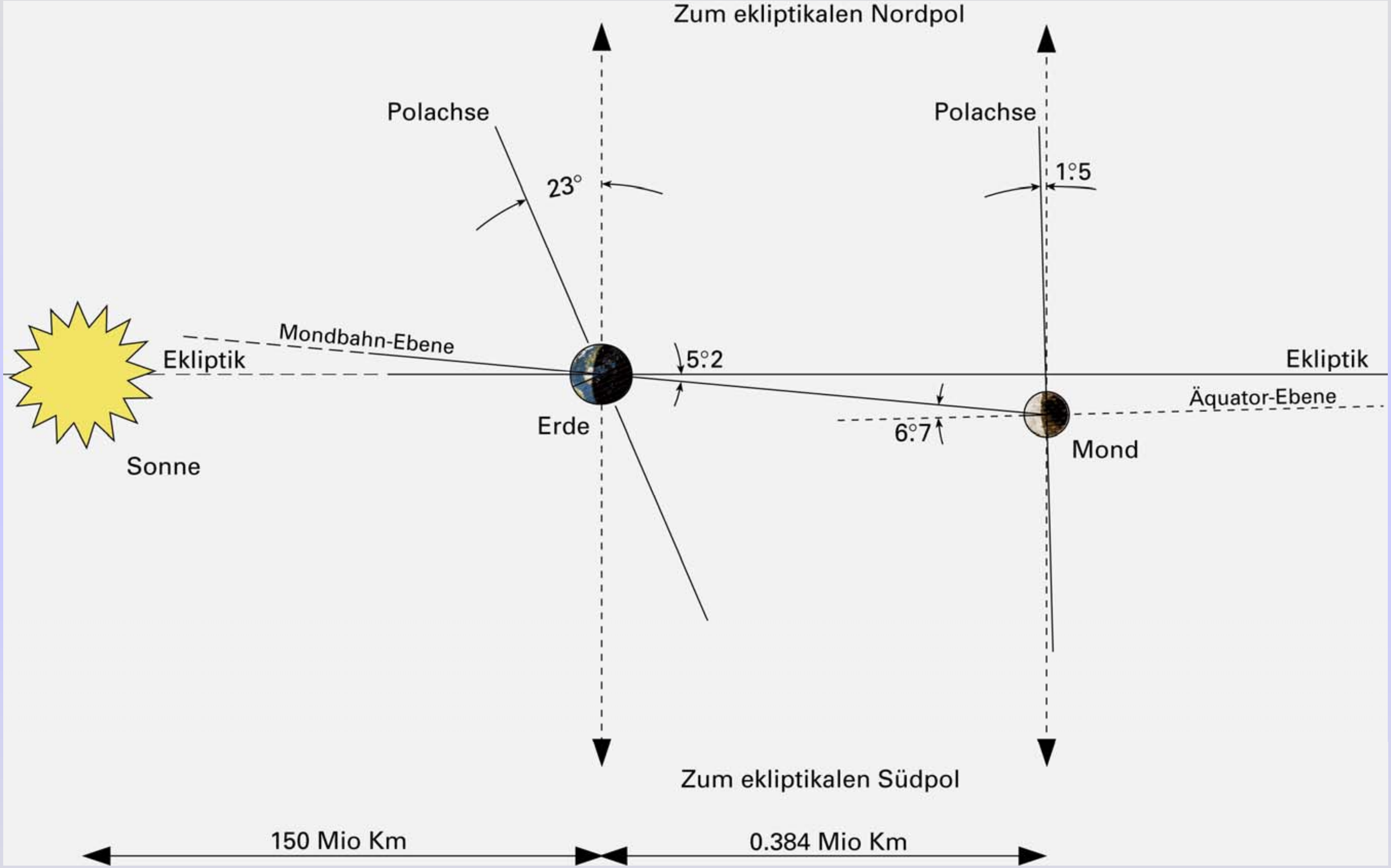
Earth

+ large telescopes
+ 1/100 of costs
- zenith

Moon

+ very large telescopes
+ easy transport (containers)
- cooling

Location of Lunar Liquid Mirror Telescope



→ **location at lunar N or S pole**

→ **zenith telescope: no steering, easy mounting**

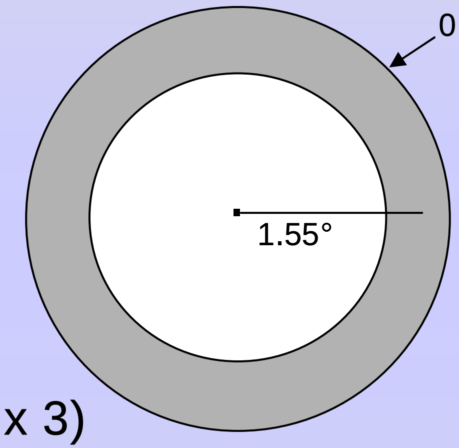
Observing with Lunar LMT

Telescope permanently views the ecliptic pole

→ IR zodiacal light at minimum ($\varepsilon \sim 10^{-8}$, T ~ 240 K)

⇒ very deep images

Sky coverage



Annulus 0.25° x 9.7°

~ 2.5 sqd in 18 yrs

HUDF ~ 0.003 sqd

Sensitivity

20m LMT → 10 x JWST area

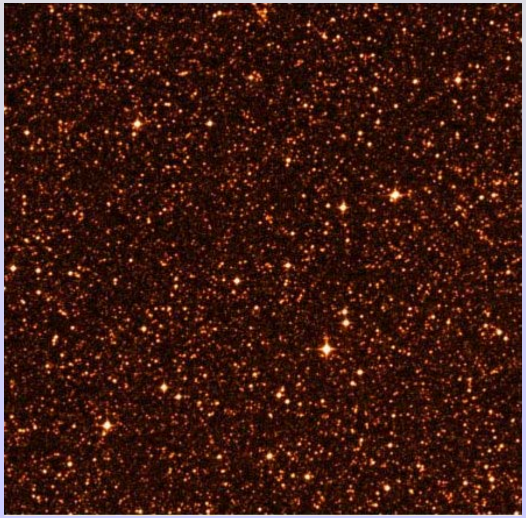
→ higher spatial resolution (~ x 3)

→ longer integration time (~ 6 months)

↷ **First stars** (~ 100 M_{sun}, z ~ 20...25, F ~ 100 pJy) **should be detectable**

↷ λ ~ 2...5, 5...12 µm

Location: North of South Pole?



South Ecliptic Pole 15 x 15 arcmin

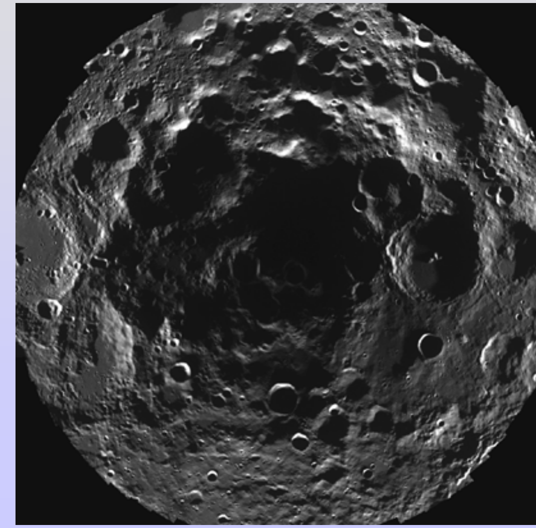
Shackelton crater

+ permanent shadow, very cold

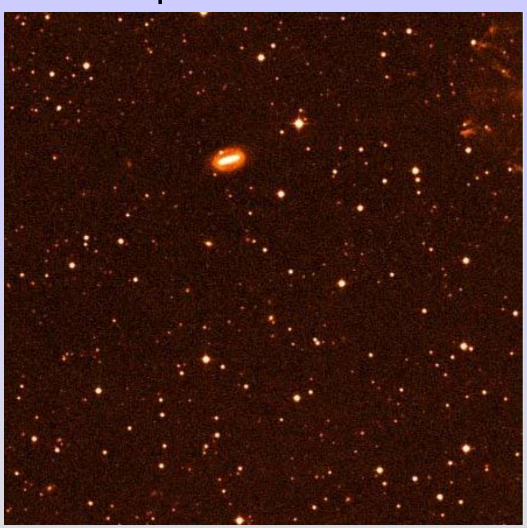
+ eternal light on rim

- mining (dust, distortion,...)?

- Large Magellanic Cloud



Shackleton crater



North Ecliptic Pole 15 x 15 arcmin

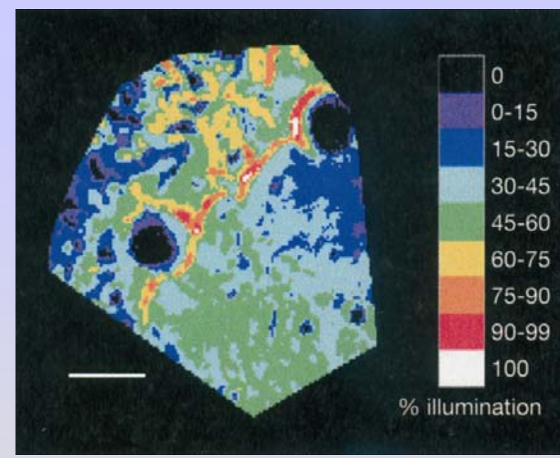
Peary crater

+ empty sky

+ less distortion?

o eternal light

in winter ~ 15 km (SMART)



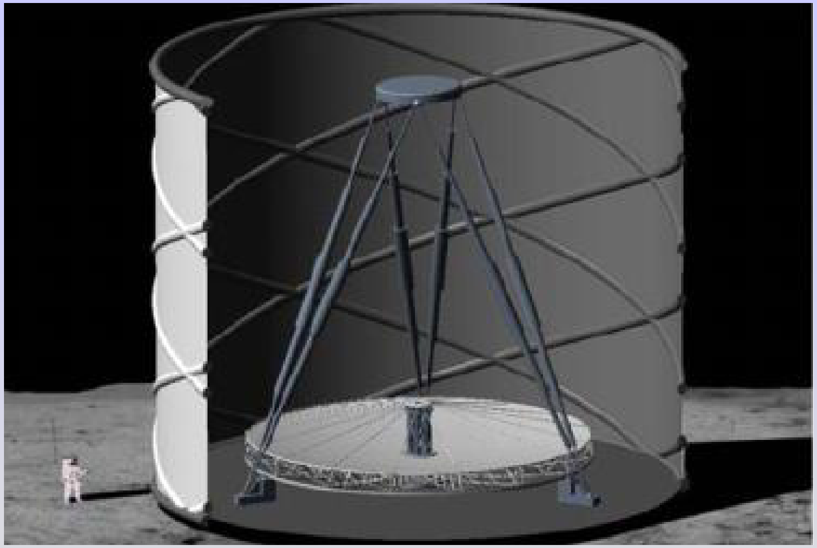
Bussey et al 2005

Technological Challenges of a Lunar LT

- Liquids: Hg, eutectics, liquified gases, silicon oil,... (C4H8 triple point ~ 88 K, inflammable) } low vapour pressure, low freezing temperature, high viscosity
- Coating: vaporizing, nano particles,...?
- Central bearing: hydraulic, superconductive,...?
- Deployment: robotic, man-assisted?
- IR Cameras: 4 K x 4 K (HgCdTe, Si:As), ~ 100 X, data acquisition/compression/transfer

Precursor missions (polar regions) → robotic deployment

- 0.5 m solid mirror: ground layer dust?
  high dust layer? volcanic gases?
  sky brightness?
- 1.5 m LMT: technology of lunar LTs,
  telescope shielding and cooling
  detector cooling, data handling,
  lifetime



R. Angel, T. Connor 2004

Open Issues for Preparatory Studies

1) **moon environment**: dust? sky brightness? passive cooling? surface?...
2) **north or south pole**: sky background? power? cooling? interfering activities? service?...
3) **liquid mirrors**: liquids, coating, bearing, radiative cooling,...
4) **deployment of LMT**: robotic, astronaut support, data transfer,....
5) **unique science**: ultradeep surveys beyond JWST, strawman instrument, PI instrument or committee enterprise?...

⇒ **Gain support of scientific community!**

- convincing unique science case } **SPITZER, AKARI, HERSCHEL, PLANCK, WISE, SPICA, JWST, SPECS, SPIRIT, FIRI, SAPHIRE,...**
- compare costs with free-flyers
- avoid risks
- compare schedules free flying vs. lunar observatories
- avoid competition for funding