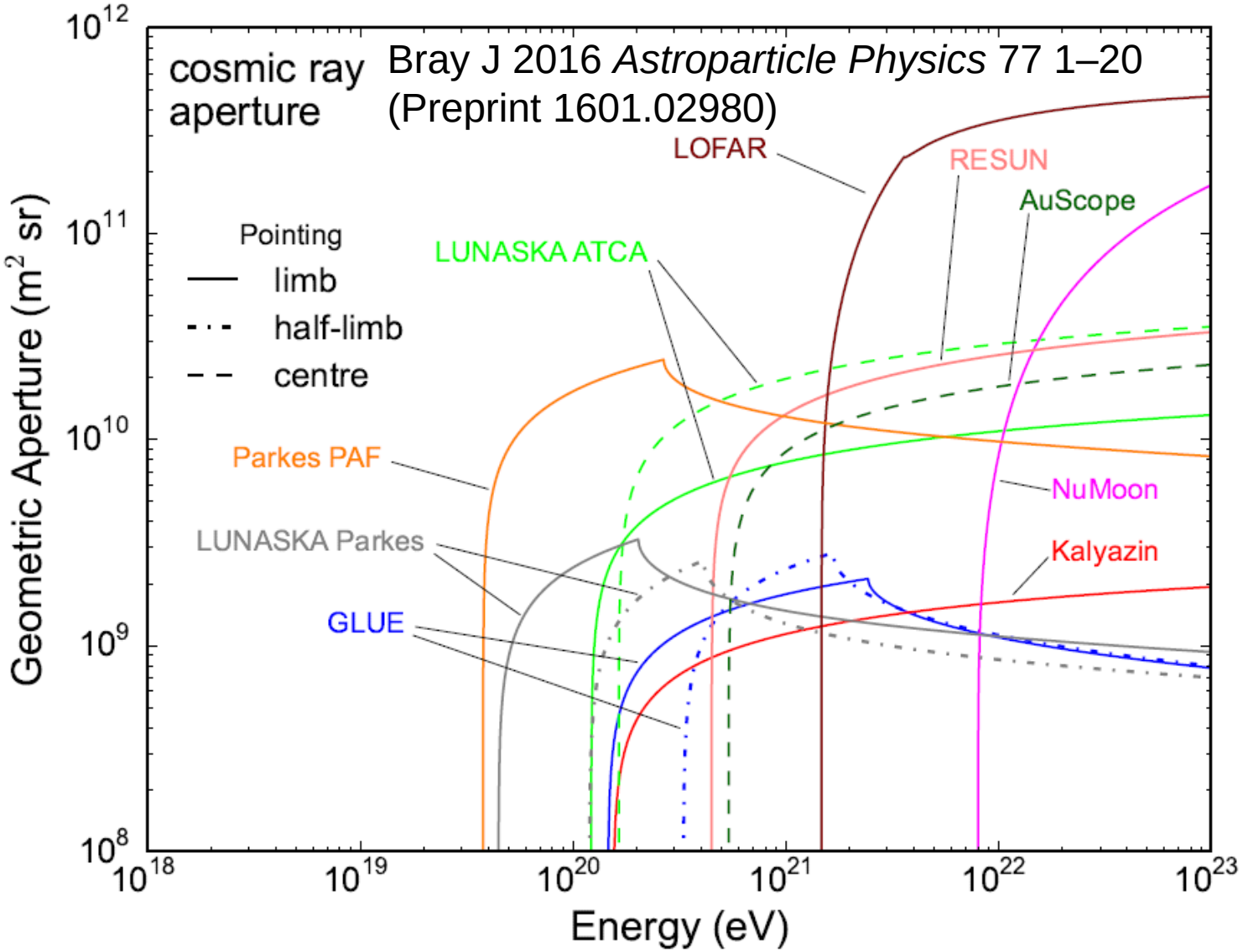
ZeVスケールの
最高エネルギー宇宙線観測

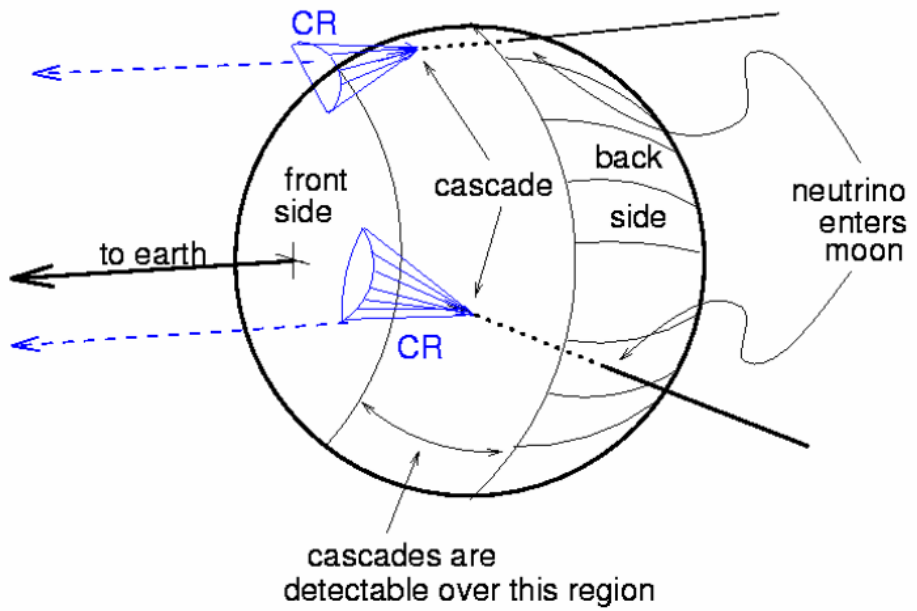
木戸英治

理研, ABBL

月を使った最高エネルギー宇宙線の観測



- Askaryan effect (Askaryan G 1962 *Sovjet Physics* J.E.T.P 14 441)
- 月の岩中で、空気シャワーから電波が発生→地球のアンテナで観測
- 見積もりの正確さは疑問



Gorham et al.

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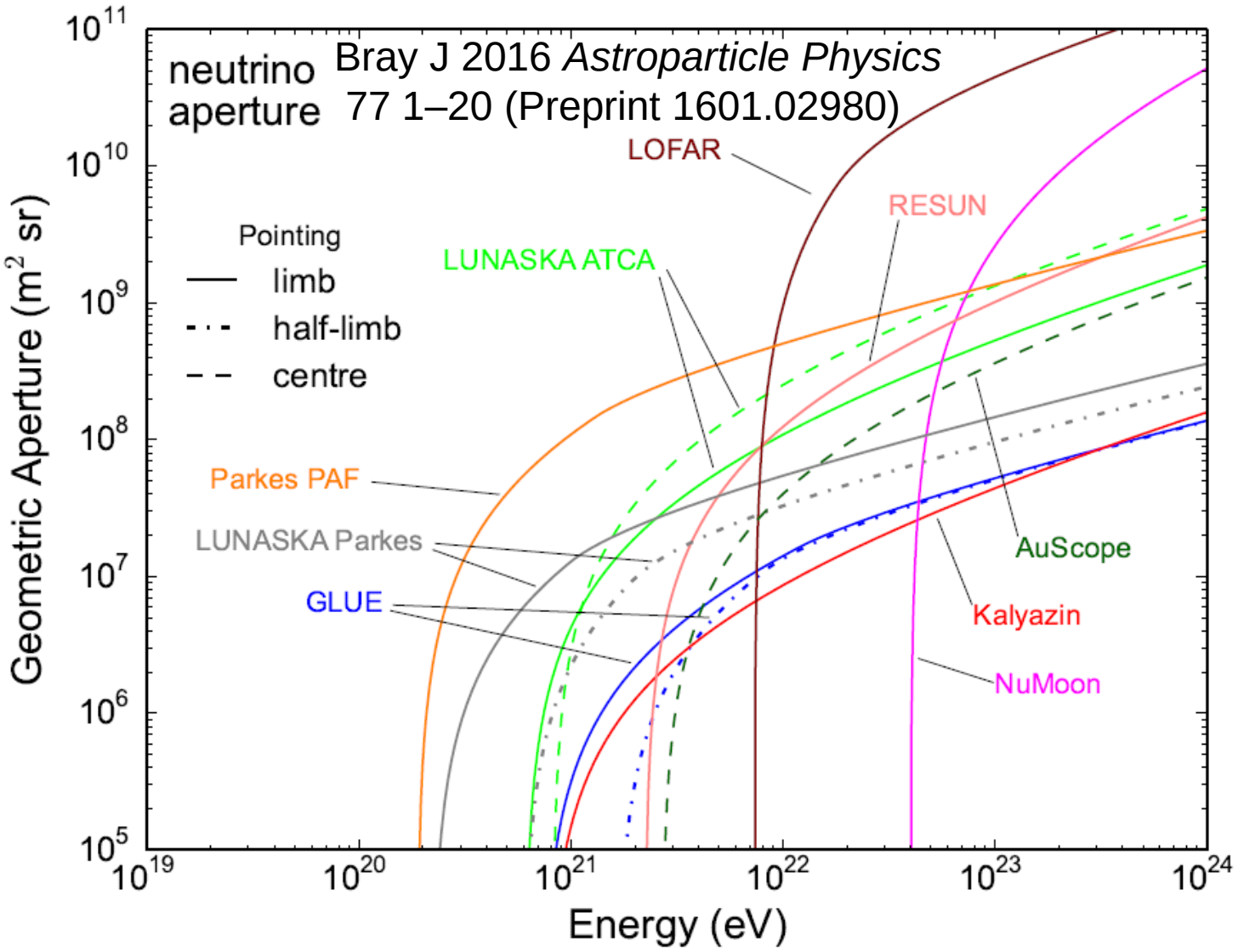

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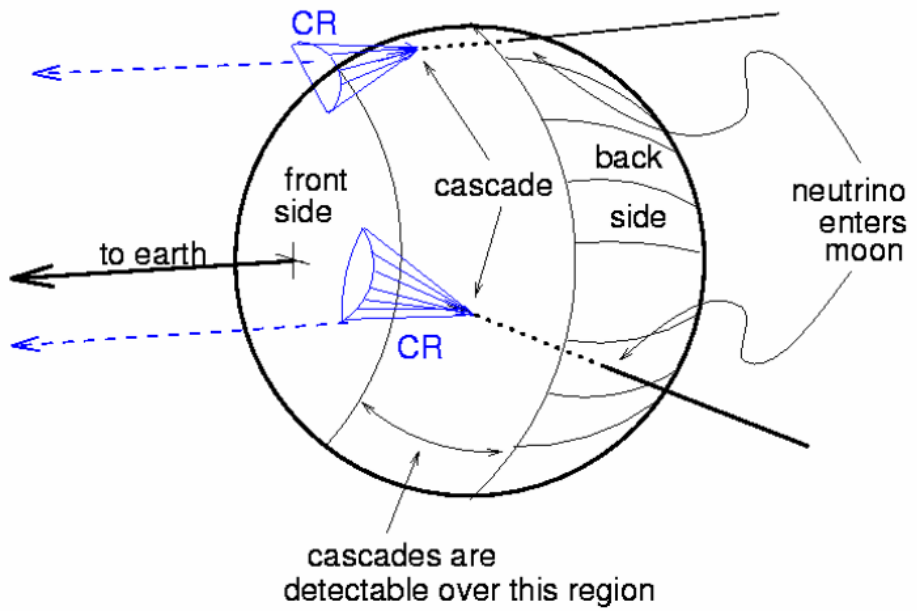
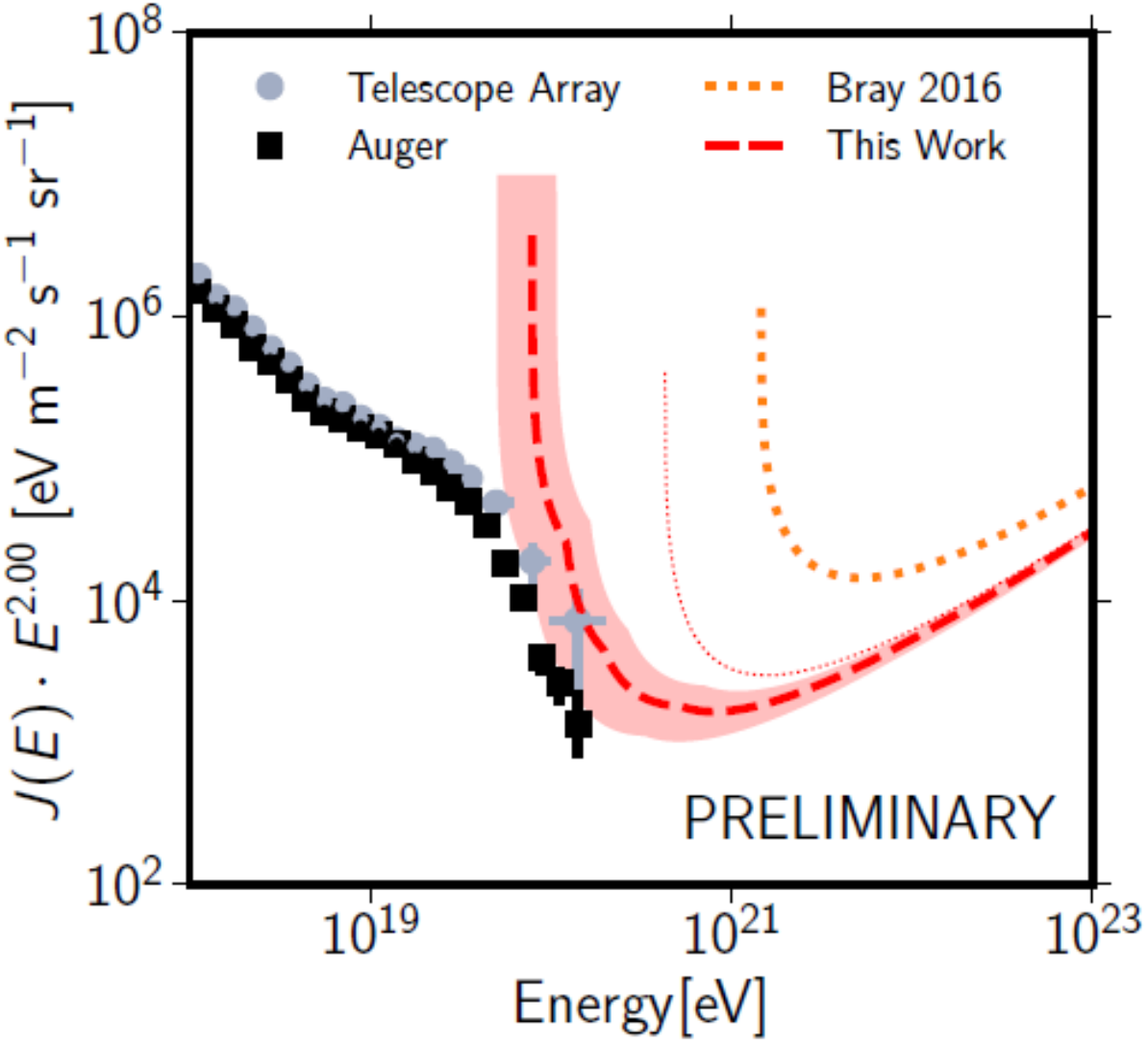


Gorham et al.

Expectation of LOFAR lunar mode 200 hours observation

Winchen+ arXiv: 1903.08472

Lunar mode自体は開発中



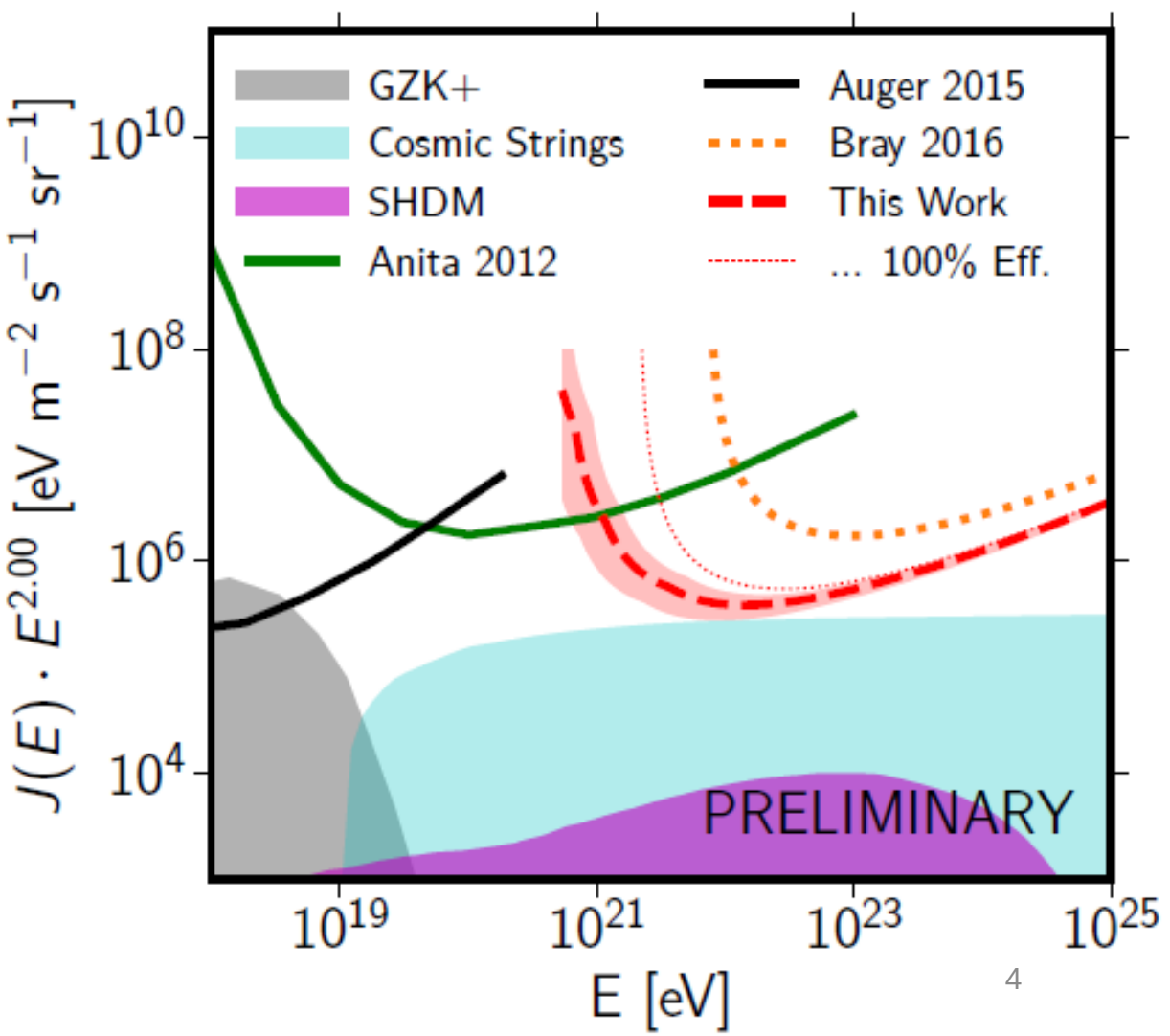
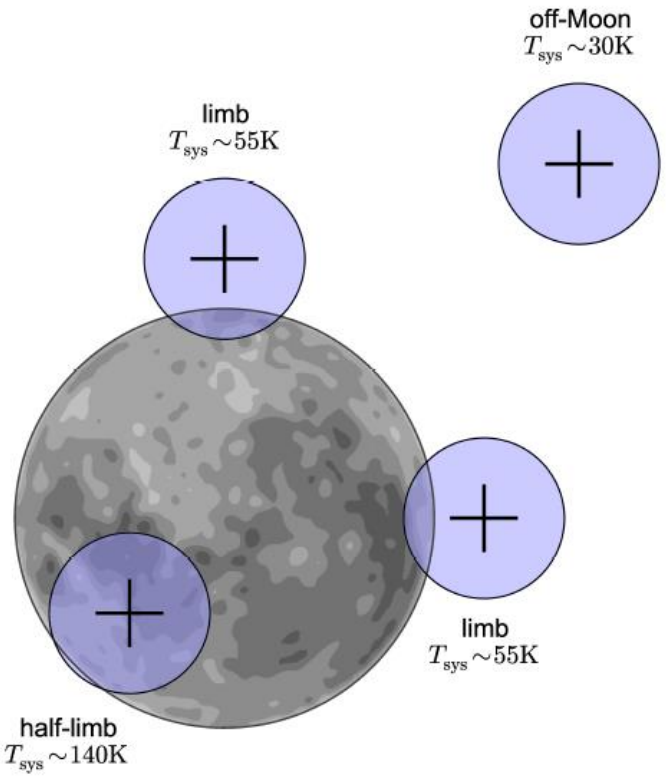


Table 1: Observation parameters for past and near-future lunar radio experiments.

Experiment	Pointing ($\times n_{\text{beams}}$)	ν (MHz)	$\Delta\nu$ (MHz)	$\mathcal{E}_{\text{min}}$ (μV/m/MHz)	$\mathcal{E}_{\text{max}}$ (μV/m/MHz)	ζ (%)	t_{obs} (hr)
GLUE	limb	2200	150	0.0221	0.3695	11	73.5
	half-limb	2200	150	0.0500	0.2527	20	39.9
	centre	2200	150	0.4737	0.2527	100	10.3
Kalyazin	limb	2250	120	0.0235	—	7	31.3
LUNASKA ATCA	limb	1500	600	0.0153	—	36	13.6
	centre	1500	600	0.0207	—	100	12.6
NuMoon	limb ($\times$2)	141	55	0.1453	—	14	46.7
RESUN	limb ($\times$3)	1425	100	0.0549	—	100	200.0
LUNASKA Parkes	limb ($\times$2)	1350	300	0.0053	0.0241	16	127.2
	half-limb	1350	300	0.0142	0.0489	15	99.4
Future experiments							
LOFAR	face ($\times$50)	166	48	0.0313	0.0768	100	183.3
Parkes PAF	limb ($\times$12)	1250	1100	0.0043	0.0303	100	170.0
AuScope	centre	2300	200	0.0830	—	100	2900.0

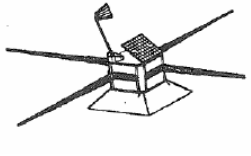
Bray J 2016 *Astroparticle Physics* 77 1–20 (Preprint 1601.02980)



H. Flacke 2006

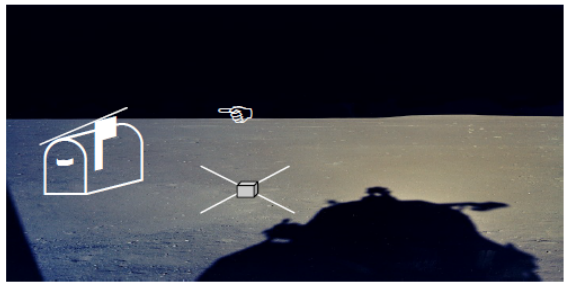
Lunar LOFAR: Distributed array of radio sensors

- Frequency range: 0-30 MHz, optimized for 1-10 MHz
- Antenna element: full-polarization short tripole antennas
- Tripole length: 7.5 m ($\lambda/4$, resonant at 10 MHz)
- explore very short, tripole "balls" ⇒ need lot of power
- Installation:
  - Short baselines (1km) and short tripoles:
    - javelin launcher.
    - Power supply through cable
  - Long Baselines (10-100 km), long crossed dipoles:
    - Rover
    - Self-sufficient antennas
    - Flat on ground



crossed dipole

LOIS tripole antennas



H. Falcke

Lunar LOFAR Scientific Topics

	Min # of Dipoles	Frequency	Baseline
Global EOR	1	1-100 MHz	0
Solar System	4-10	0-10 MHz	0.1-1 km
Local Bubble 3D-Tomography	10-100	0.1-3 MHz	30-1000 km
Extragalactic Surveys	10-100	3-30 MHz	1-100 km
Neutrinos	10-100	1-100 MHz	10 km
Exoplanets	100-1000	0.1-10 MHz	1-10 km
Dark Ages	1000-10000	1-80 MHz	1-10 km

H. Falcke

- 10年以上前から提案自体はされている
- 2018年ぐらいに中国とやるような記事もあった

https://www.sciencemag.org/news/2018/05/china-s-moon-mission-will-probe-cosmic-dark-ages