ASTRON

Netherlands Institute for Radio Astronomy

university of groningen / faculty of mathematics and natural sciences / kapteyn astronomical institute

LOFAR beyond LOFAR2

Harish Vedantham, ASTRON

EOSC FUTURE

NWO

erc

European Research Council

Established by the European Commission

What is coming …

~ 10^{9} € facilities being planned (SKA, ngVLA)

~ $10^{7.5\text{-}8.5}$ € facilities exploiting cheap dishes+ uncooled LNAs

Parameter	DSA2k	CHORD
Dish diameter	5m	6m
Number of dishes	2000	512
Freq. range	0.7-2GHz	0.3-1.5GHz
Tsys	25K	30K
Resolution	2”.5	3’

What are our key strengths?

Large Europe-wide radio community

High-speed fibre Infrastructure

Timing distribution expertise (LOFAR+EVN)

Advanced algorithms for low frequency interferometry

Exploiting available resources

Large Europe-wide radio community

High-speed fibre Infrastructure + HPC

- **Build on existing infrastructure**
- **Increase data bandwidth**
- **Surveys in new parameter space**
- **Long baselines**
- **Low frequencies**

Timing distribution expertise (LOFAR+EVN)

Advanced algorithms for low frequency interferometry

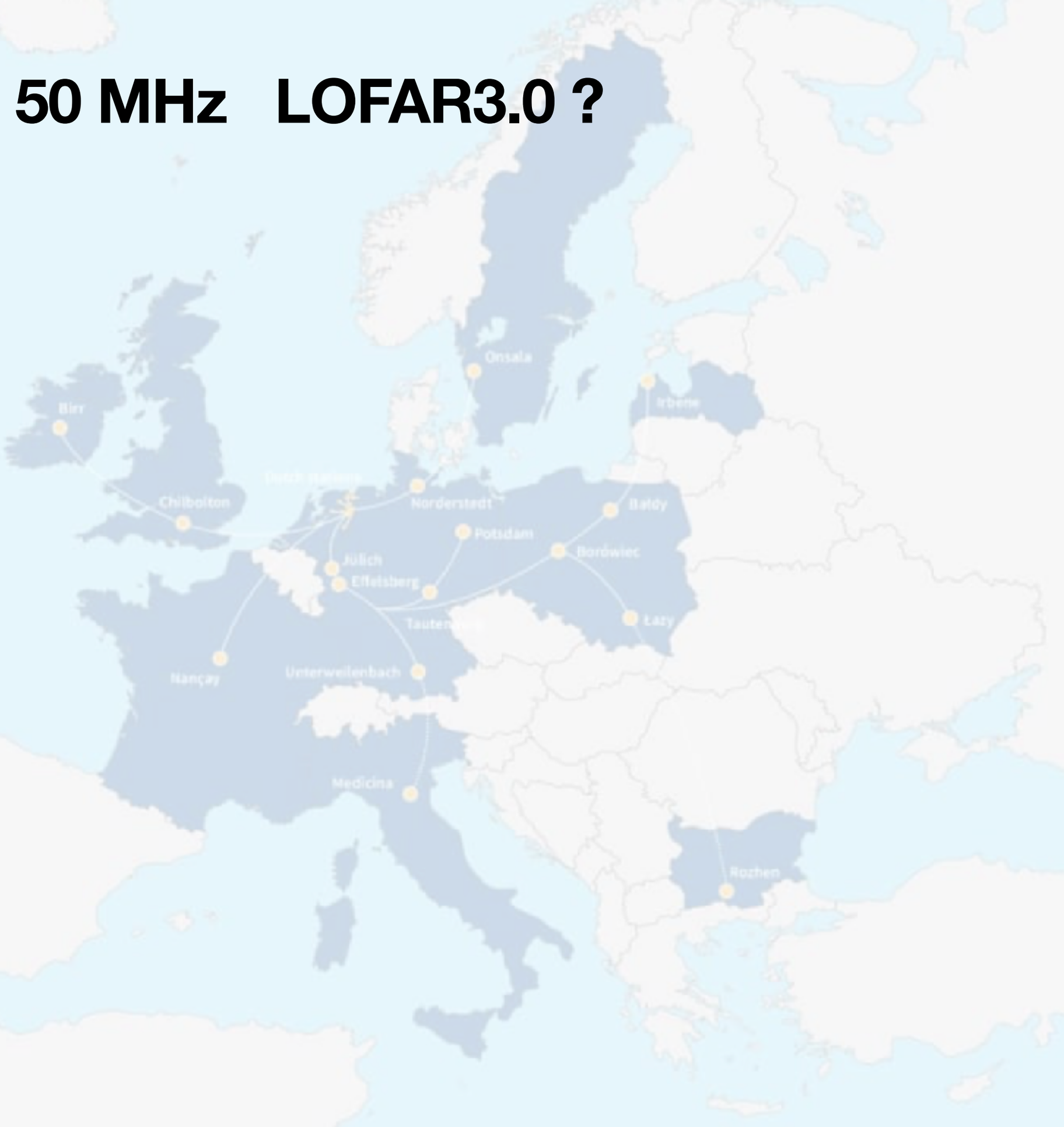
LOFAR3.0 ideas

1. LOFAR not just a telescope - real-time data transport + correlation + pipeline processing infrastructure
2. Expand to more countries (collecting area, baseline)
3. Buy sensitivity with data rate increase (50-100 HBA beams will match SKA1 survey speed)
4. SKA1 stops at 50 MHz. Lowest frequencies is a niche
5. SKA1-low has <100km max baseline. High resolution is a niche

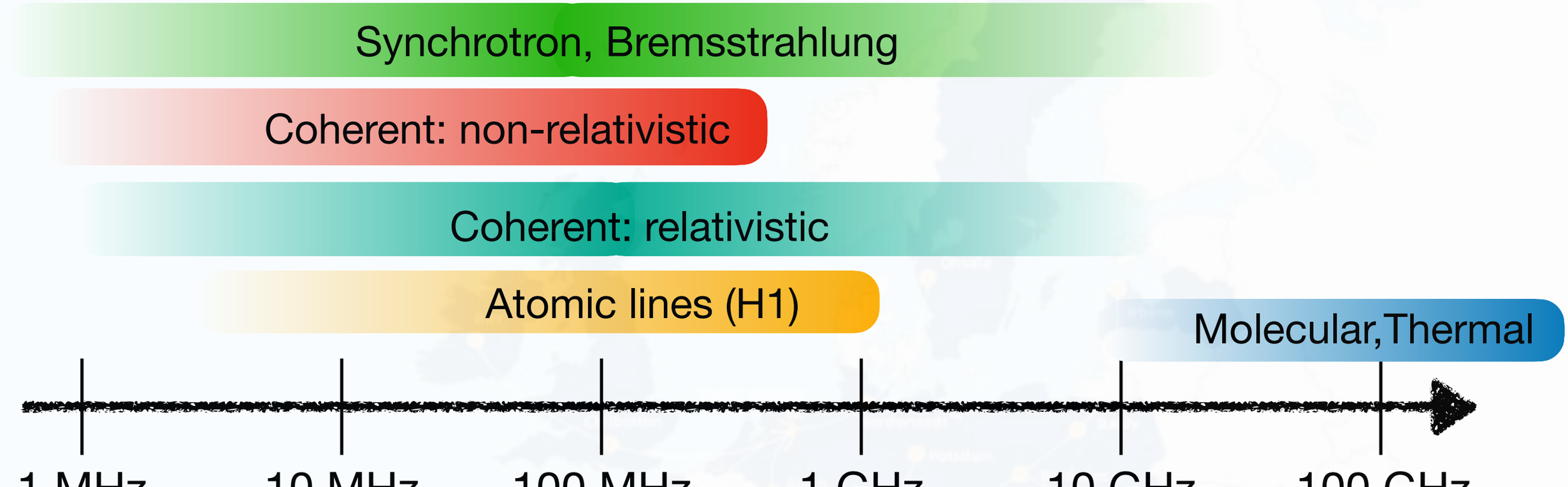
Please get involved; pitch ideas / improvements

5 - 50 MHz LOFAR3.0 ?

1. LOFAR Low
2. Really LOFAR
3. Very LOFAR
4. Super LOFAR



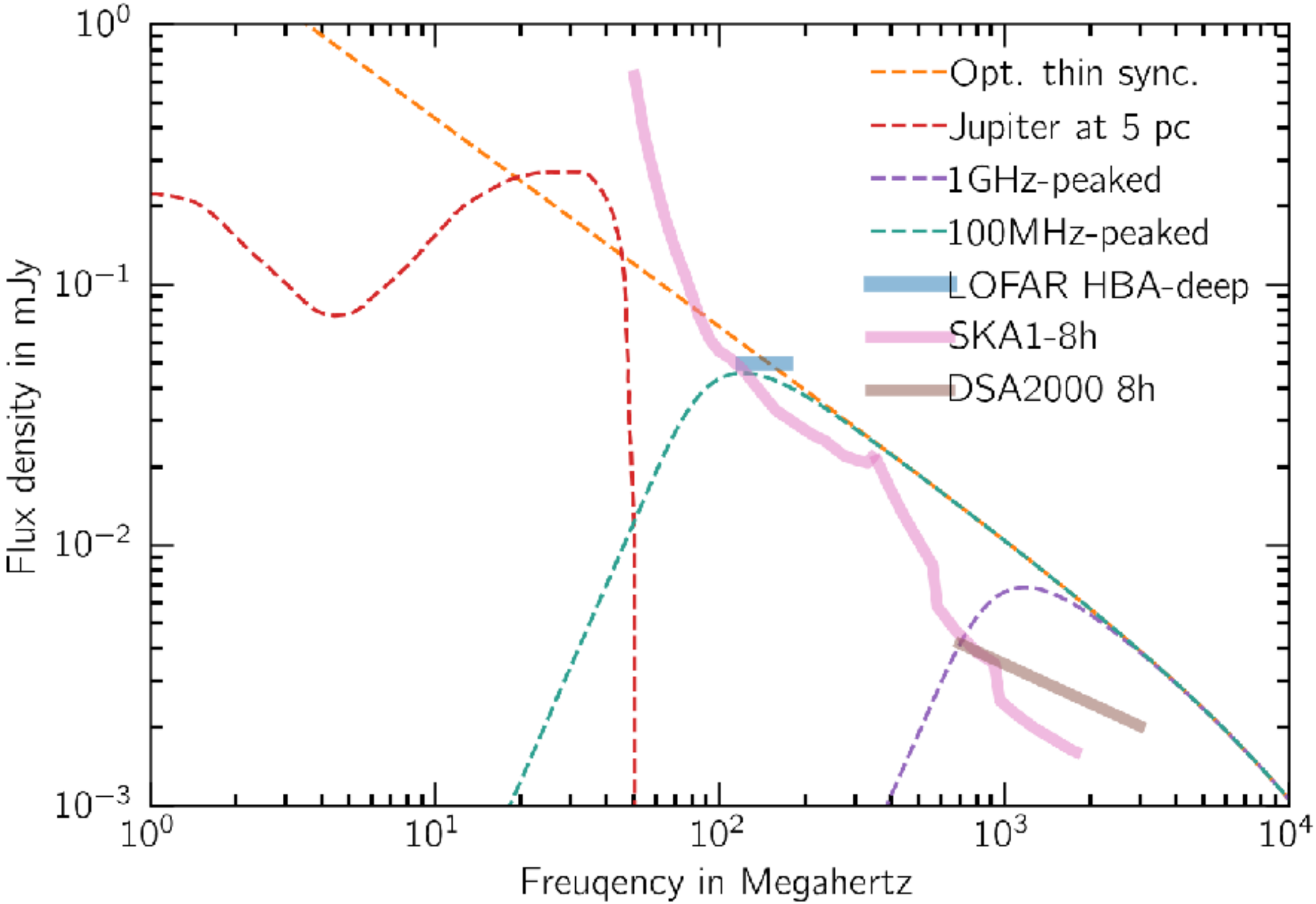
Radio-wave bands and science cases



Decametre	Metre	Decimetre	Centimetre	Millimetre
AGN, Jets Microquasars Clusters, Relics Cosmic rays SNR, star formation Galaxy evolution Supernovae, GRBs Wind nebulae HII regions WHIM Dark energy	Pulsars Fast radio bursts ISM, CGM, IGM Stars Brown dwarfs Exoplanets	Star formation ISM Galaxy evolution Dark matter/energy Cosmic dawn/EoR		Star/planet formation Cosmic dawn/EoR Galaxy evolution ISM

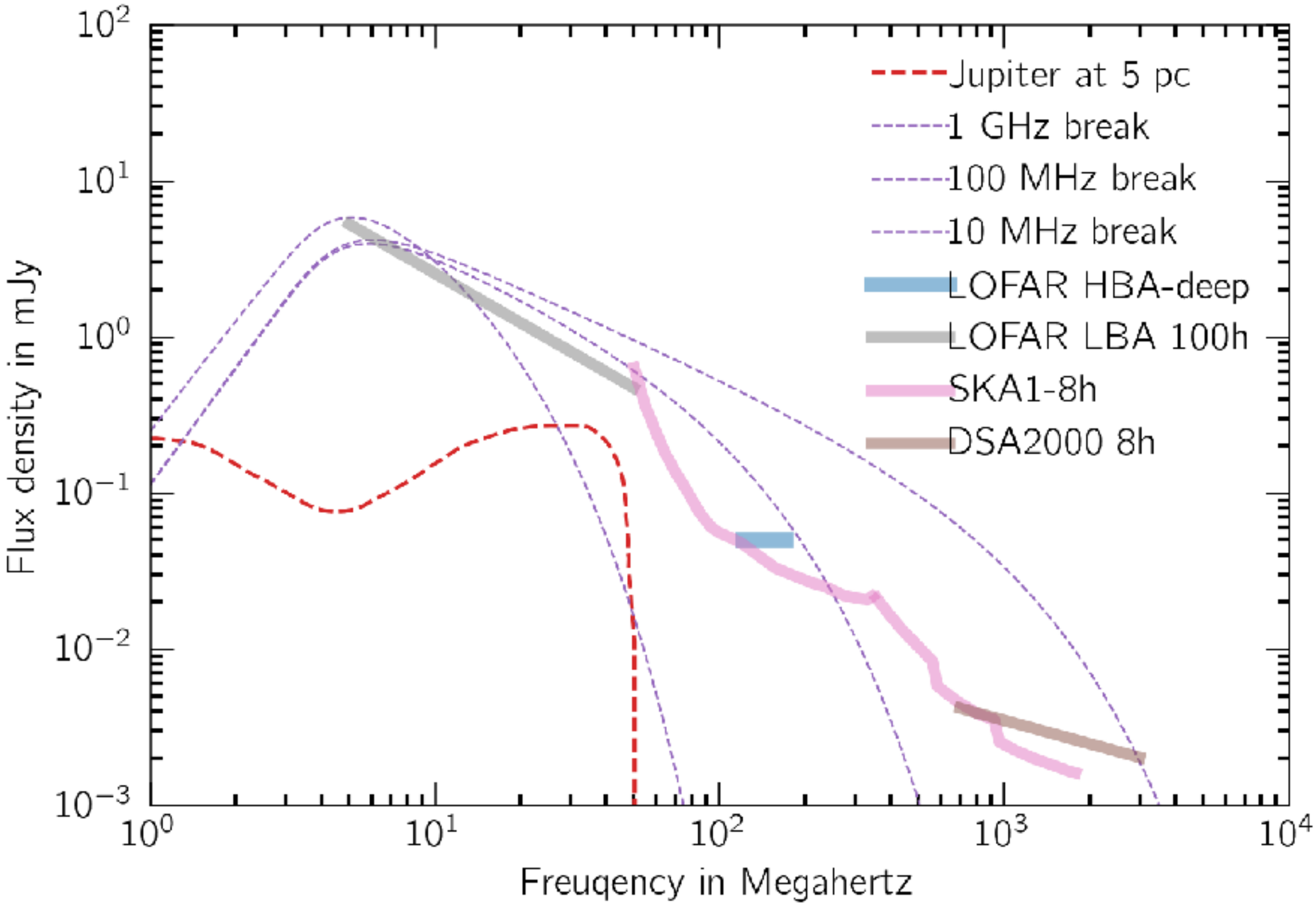
Imminent push to sub-μJy noise in decimetre band

Note: Synchrotron + free-free is "bread and butter" for lot of us (and under threat)



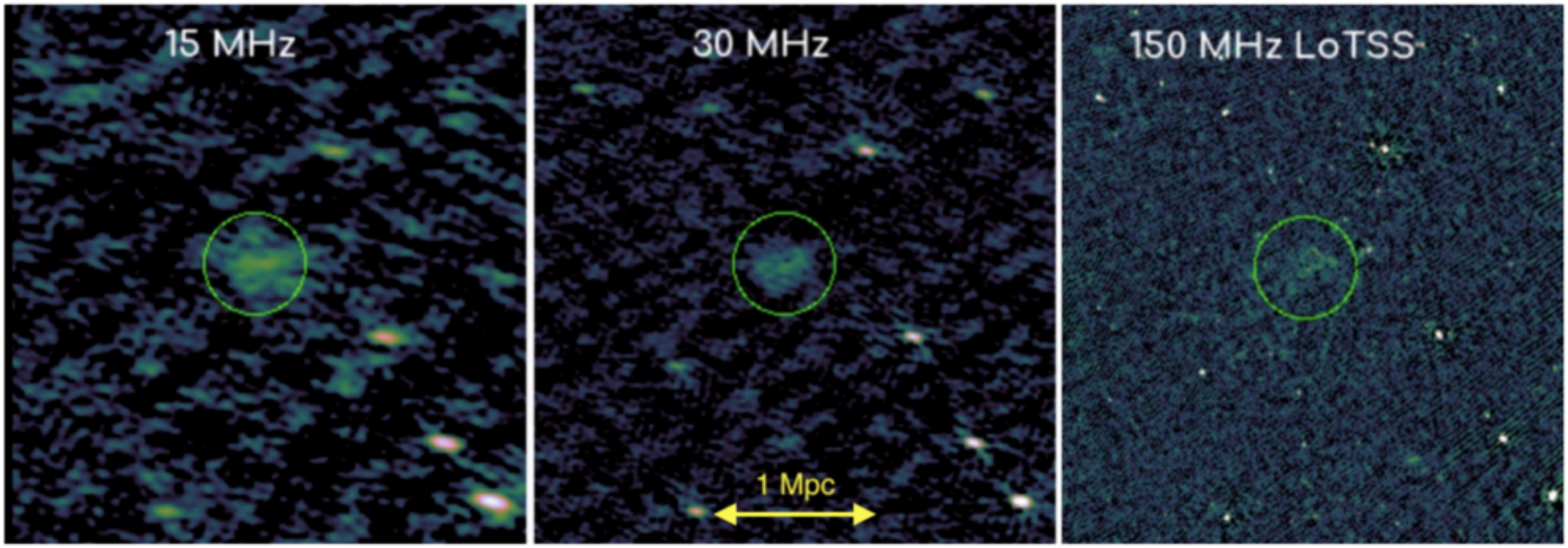
What is our niche for synchrotron sources in 2030s?

Fossil sources!



What is our niche for synchrotron sources in 2030s?

We have already started on this path

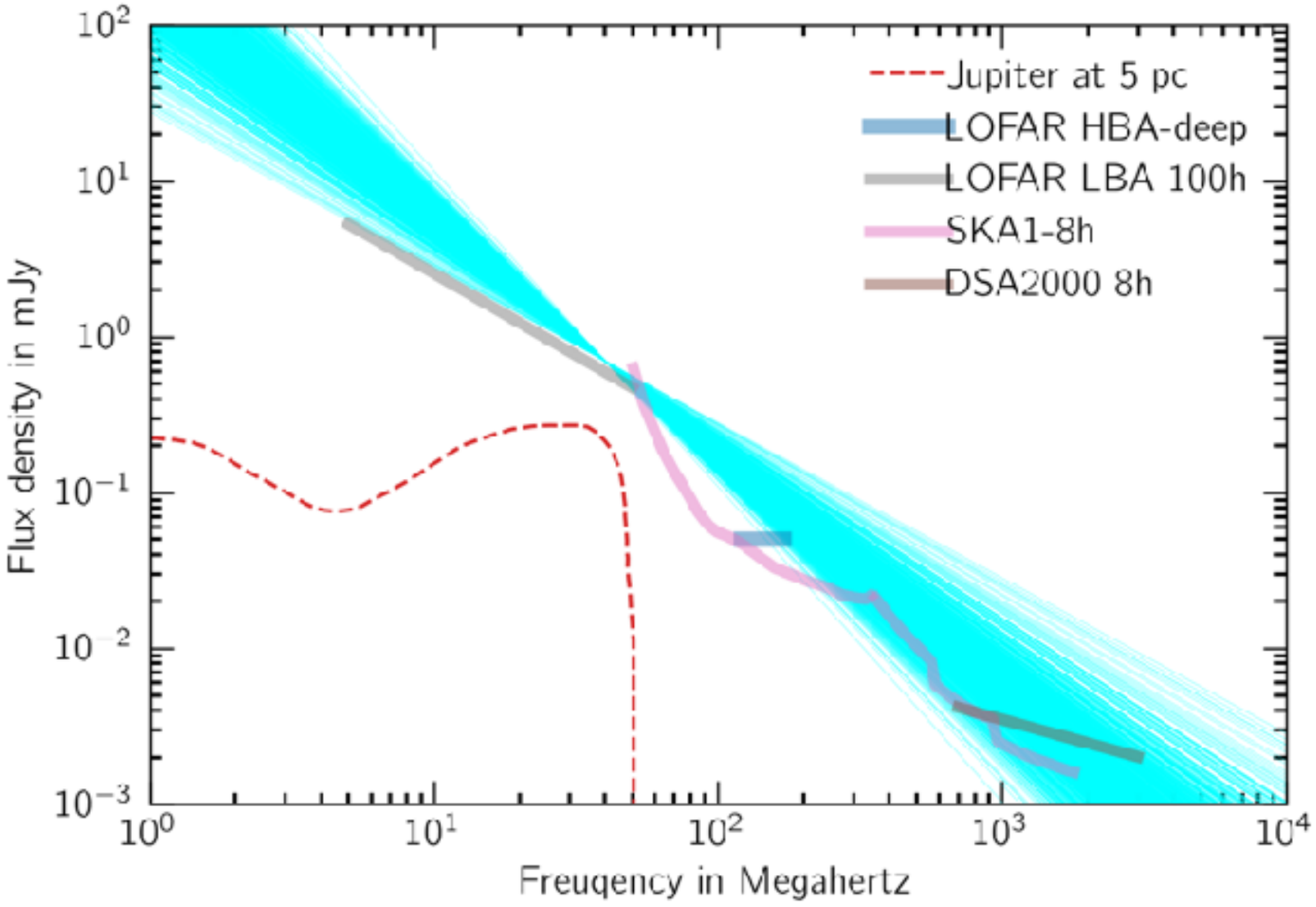


Credit: Reinout van Weeren

Spectral index $\alpha = -1.7$

See Christian's talk later today

What is our niche for pulsars at (very) low frequencies?

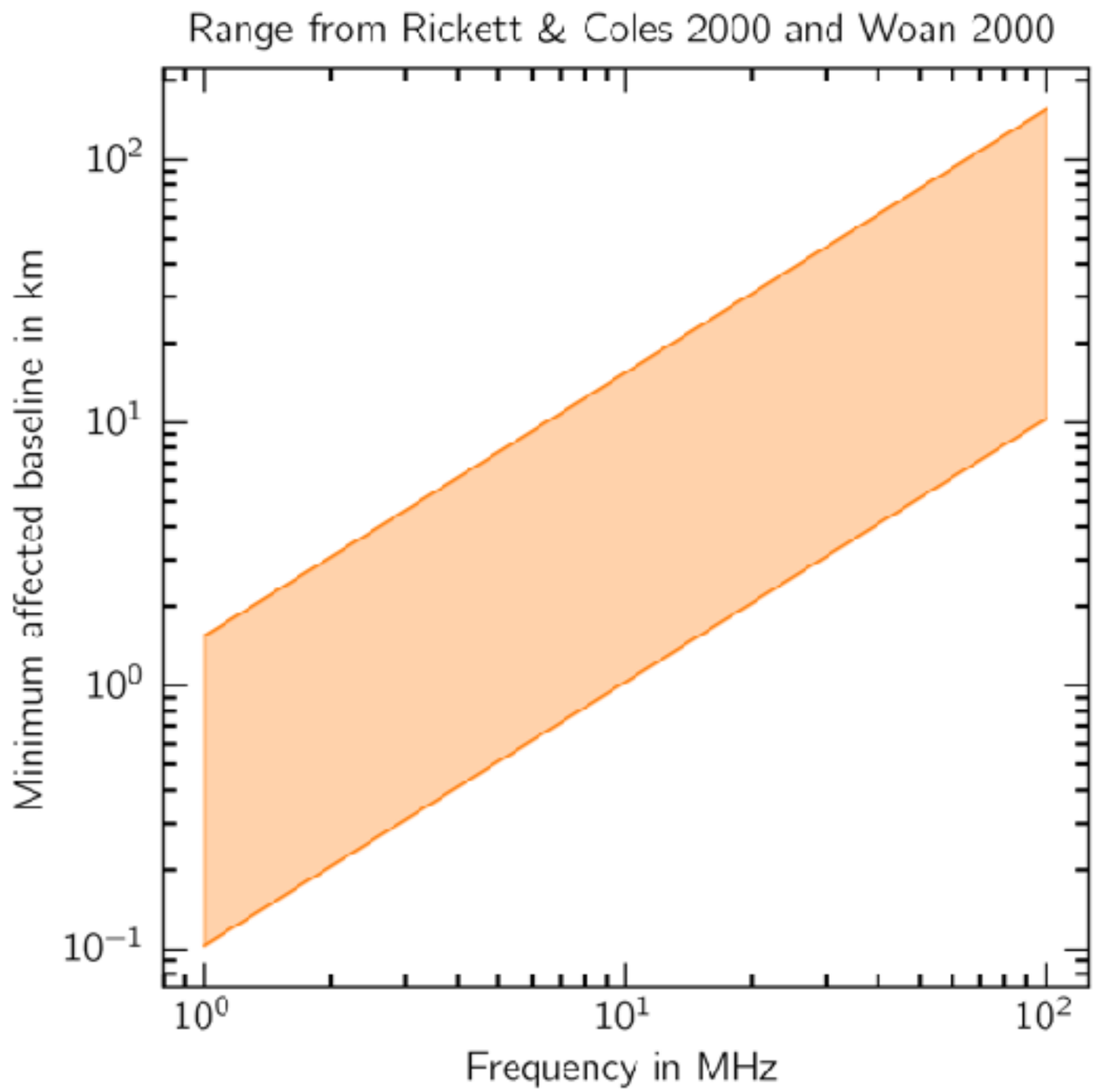


SNR not super competitive -> survey maybe of limited interest
But ….

(1)Propagation effects (RM at milli-radian/m^2 ;
(2)Space weather, IPM
(3)Wider beam at lower freq?

What is our niche for heliophysics / space weather?

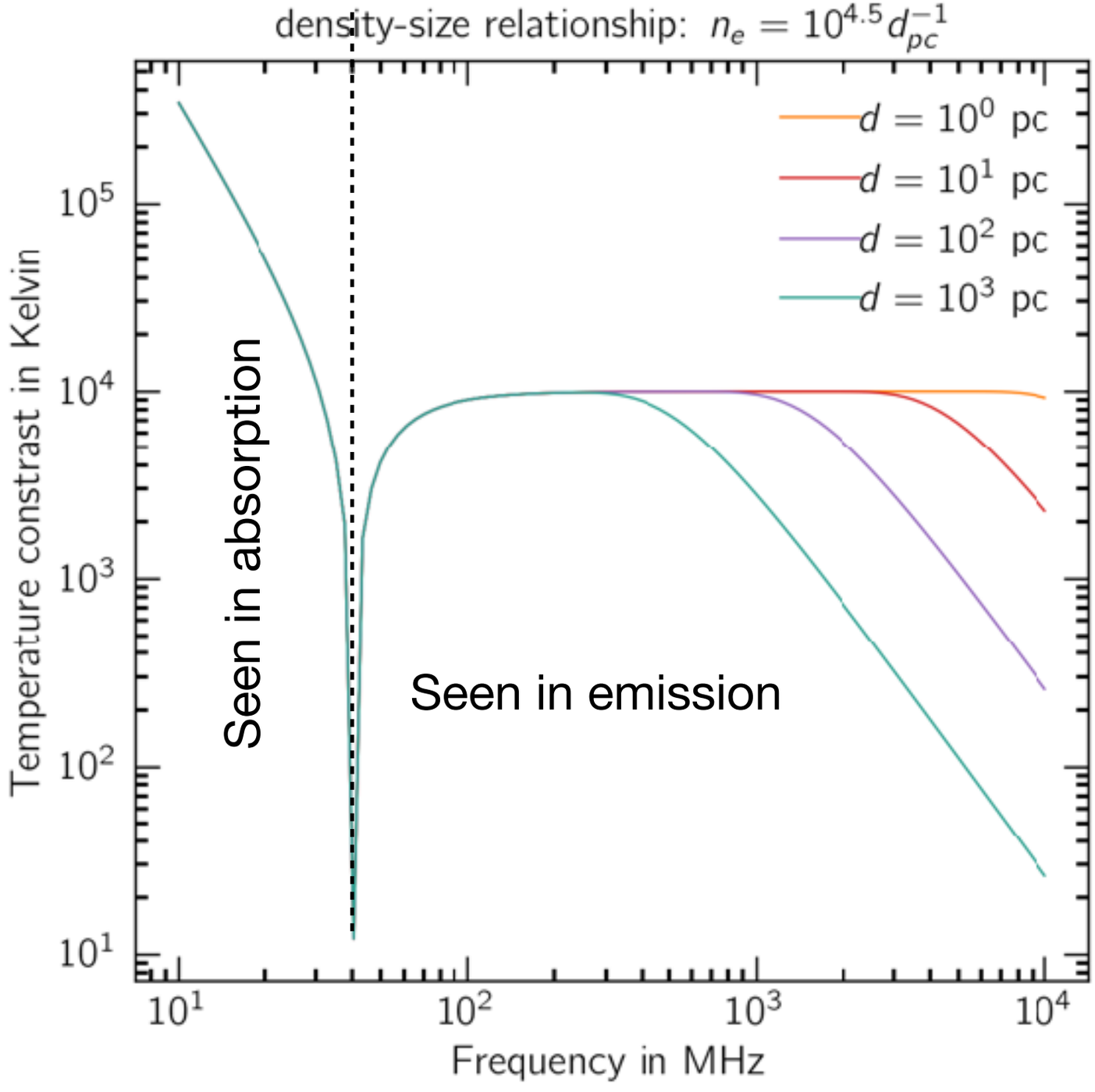
- ~1-10 MHz gap in radio ground based v/s space based observations of Sun
- At ~5 MHz we probe plasma emission at ~ 2 Rsun (wind acceleration region)
- IPM Faraday rotation with pulsars
- IPM scattering with pulsars/quasars



What is the niche for ISM/cosmic ray studies?

Opacity allows for tomography
- obscured HII regions
- Distance from tompgraphy
- Cosmic ray transport models

Sensitivity sufficient for nearby (<10 Mpc) galaxies

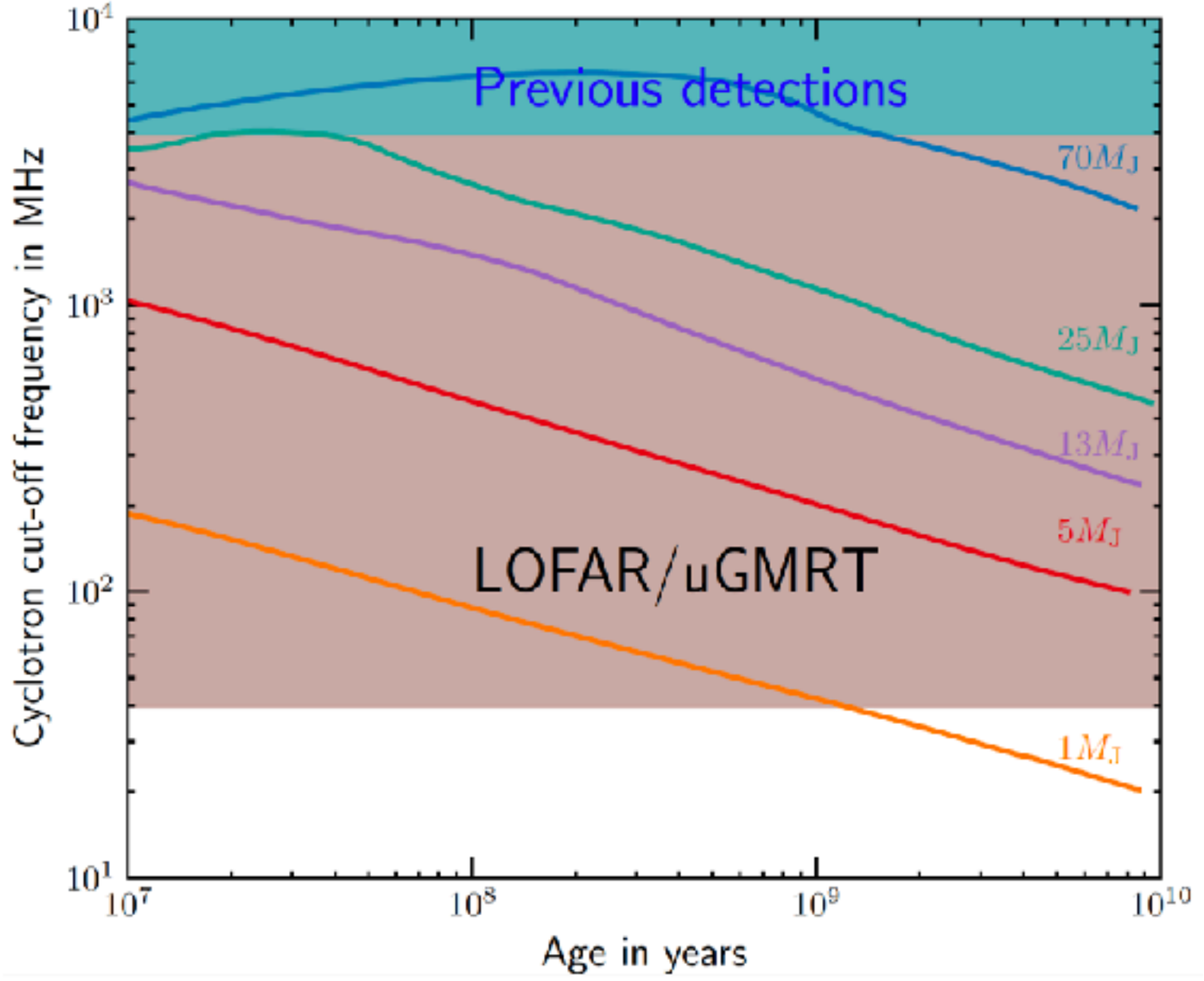


What is the niche for exoplanets?

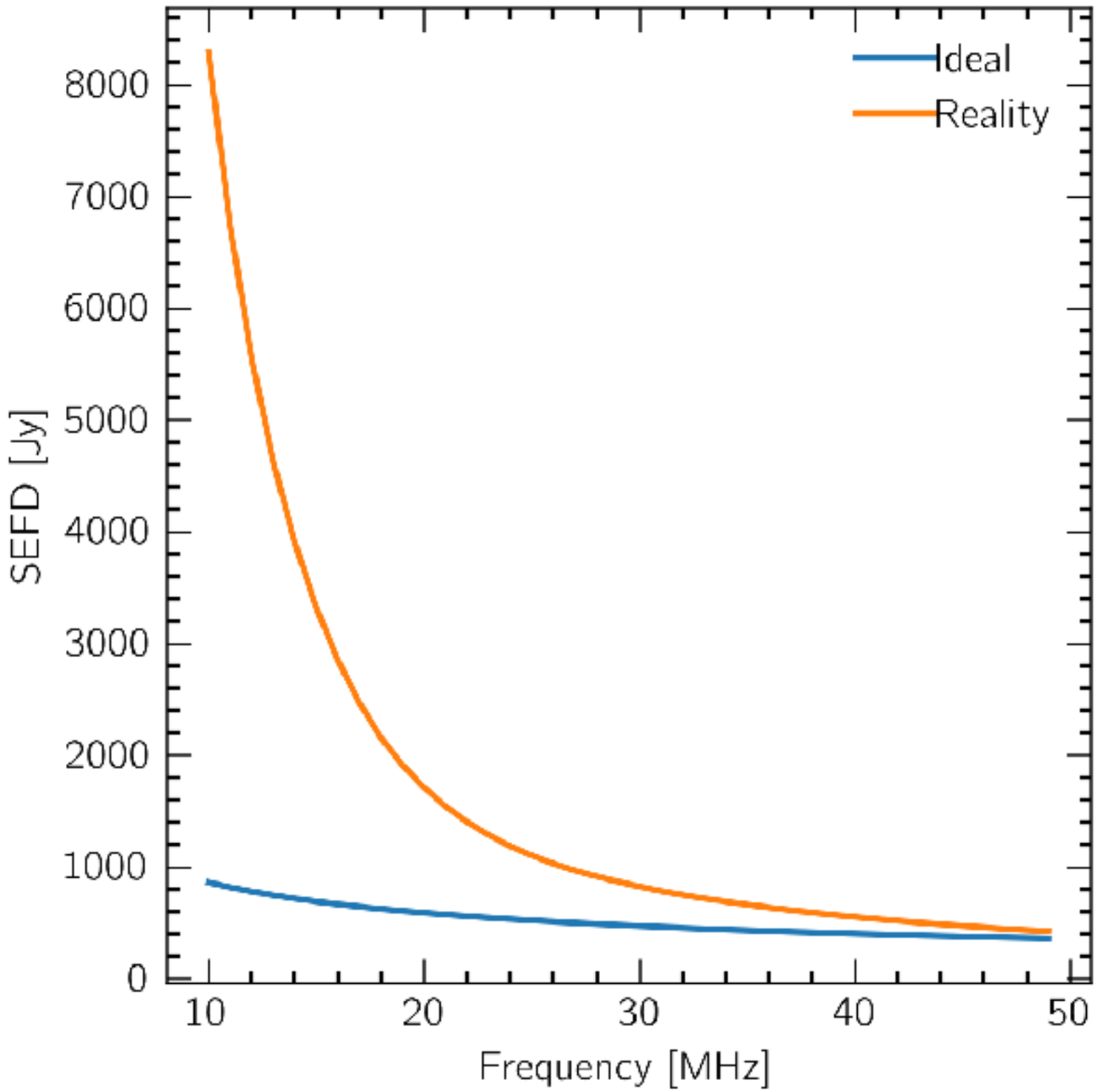
- Radio only viable way to measure magnetic fields of exoplanets

- LOFAR already detects cold brown dwarfs (T ~ 600 K) at HBA
- Proves that magnetospheric engines @ Jupiter x 10^5 exist in nature

- Going down to exoplanet mass may need (sub-) mJy level sensitivity at the lower end of LBA band (challenging but doable)



Non-ideal spacing of LBA dipoles for < 30 MHz



Some pathways - increasing order of financial exuberance

10^5 €

- RFI and linearity studies < 30 MHz
- Spread the LBA dipoles out
- Increase digital bandwidth —> aim for ~100 beams
- X10 LBA sensitivity improvement (30k dipoles)
- LUNAR low-band interferometer

10^9 €

Main conclusions

- Stiff competition around the corner for synchrotron sources and pulsars
- Niche opportunities at low frequency long baselines: fossil electrons, exoplanets, ISM tomography, space weather, Heliophsysics

Let us work out some ideas in detail!