

KAIROS : KID Array Instrument to Reveal the Origin of Structures

Proposal for a French SAT observing at high frequencies

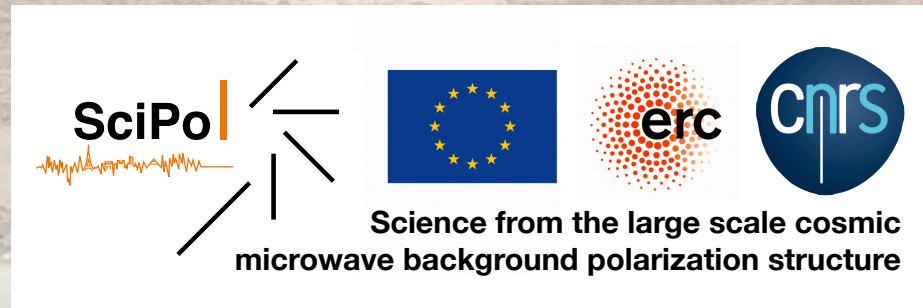


Benjamin Beringue

on behalf of the KAIROS collaboration

AstroParticule et Cosmologie (APC) - CNRS

beringue@apc.in2p3.fr



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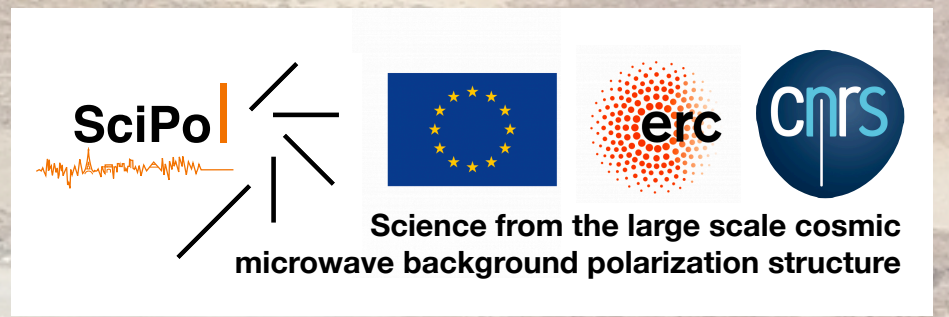
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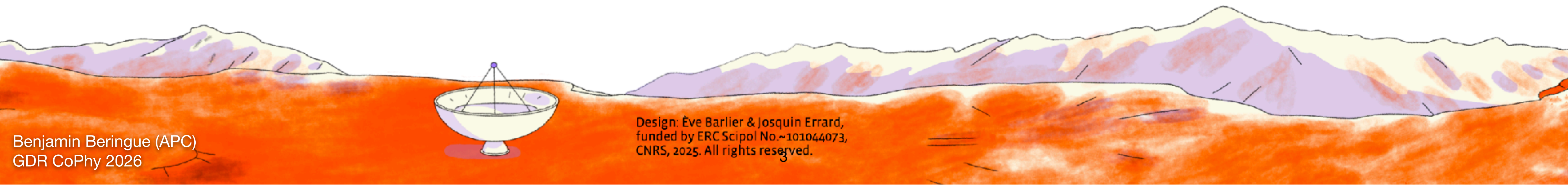


Many slides adapted from previous presentations by J. Errard, A. Catalano, ...



OUTLINE

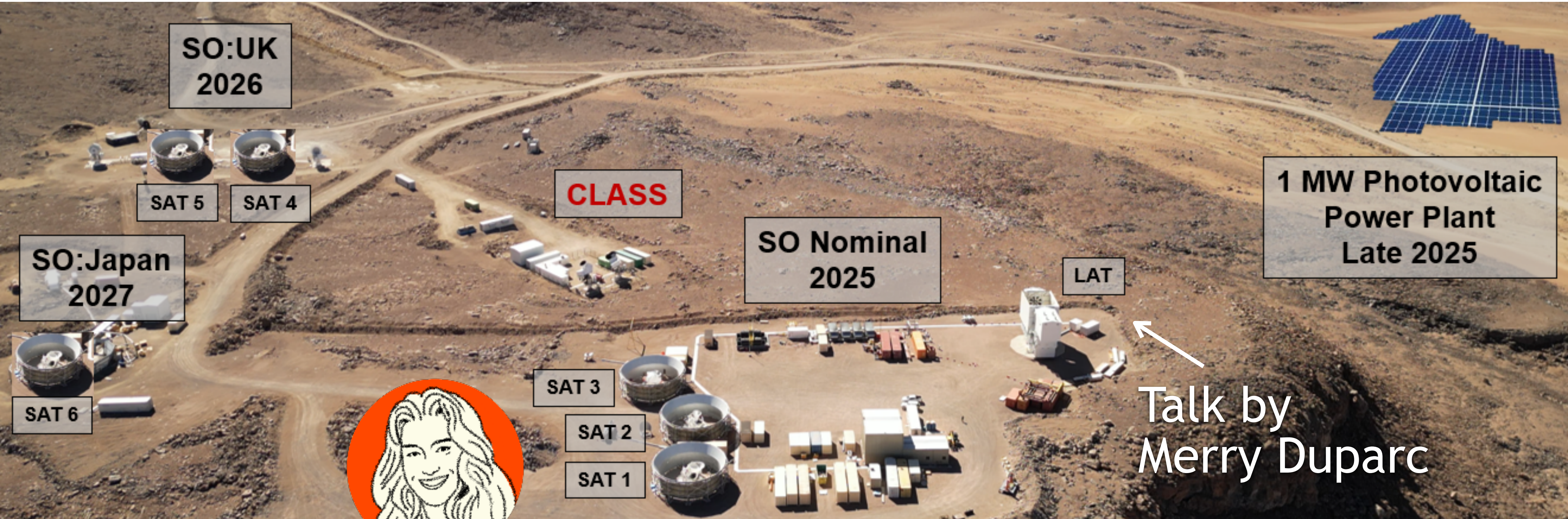
- Short term evolution of Simons Observatory
- Observing frequencies, the higher the better ?
- Technology readiness in France
- Status and future steps



Short term evolution of Simons Observatory



Short term evolution of Simons Observatory

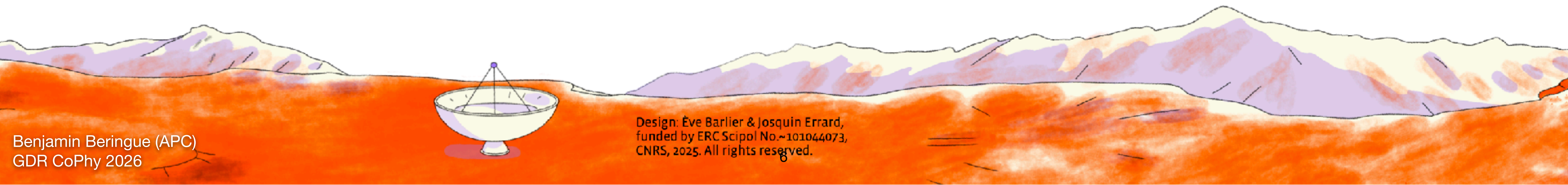
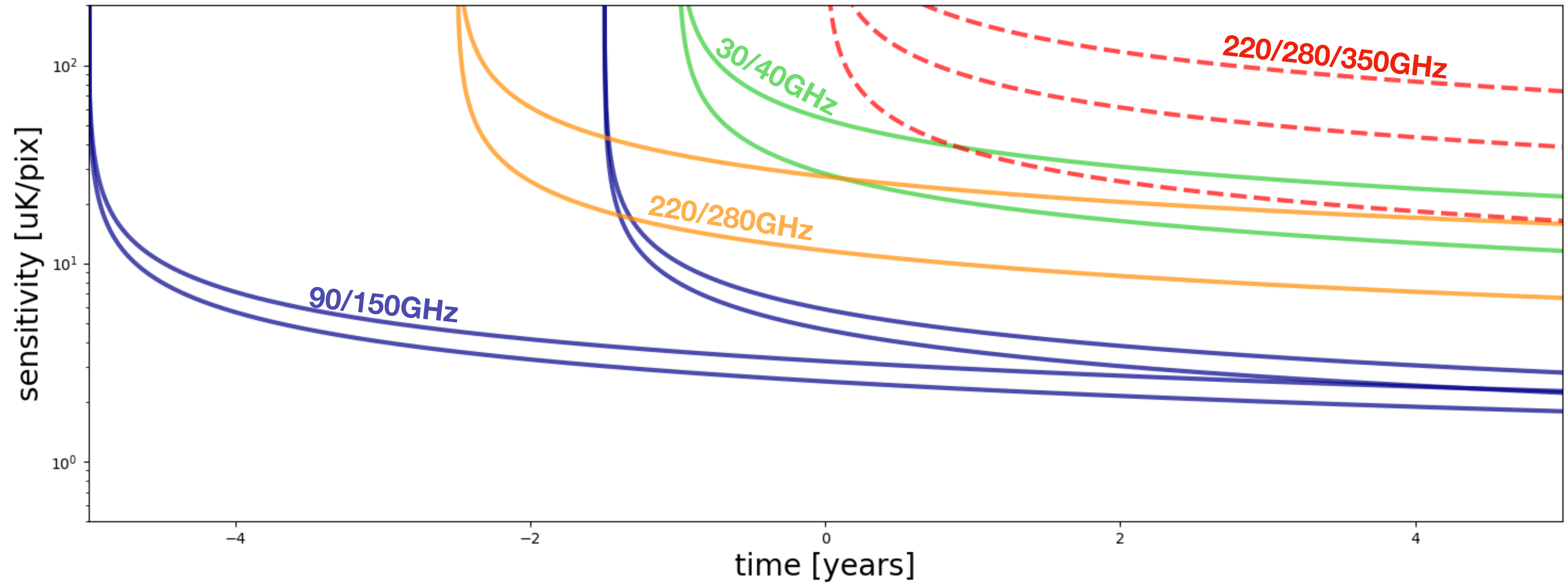


Amalia Villarrubia Aguilar

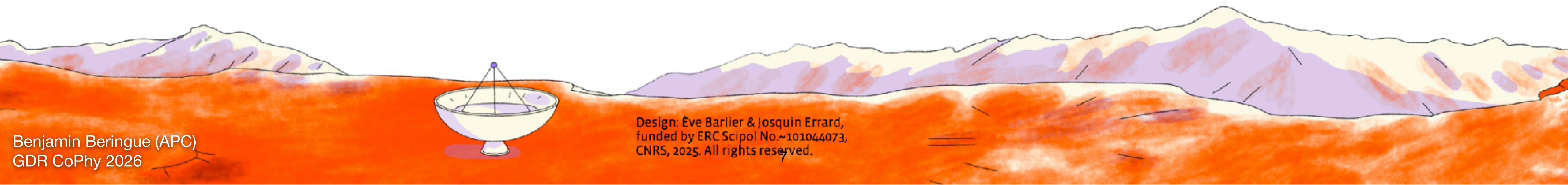
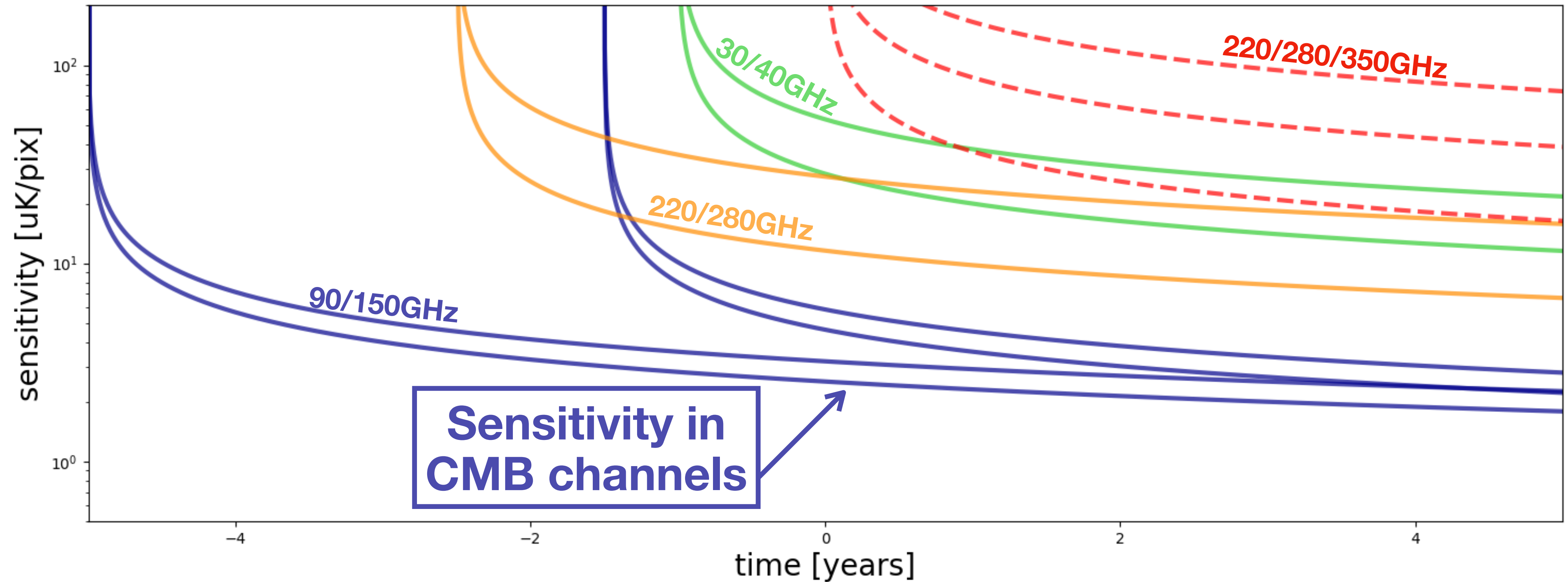


Design: Ève Barlier & Josquin Errard, funded by ERC Scipol No.~101044073, CNRS, 2025. All rights reserved.

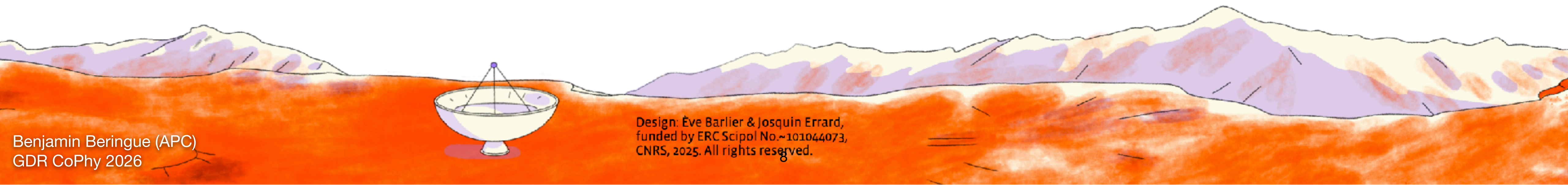
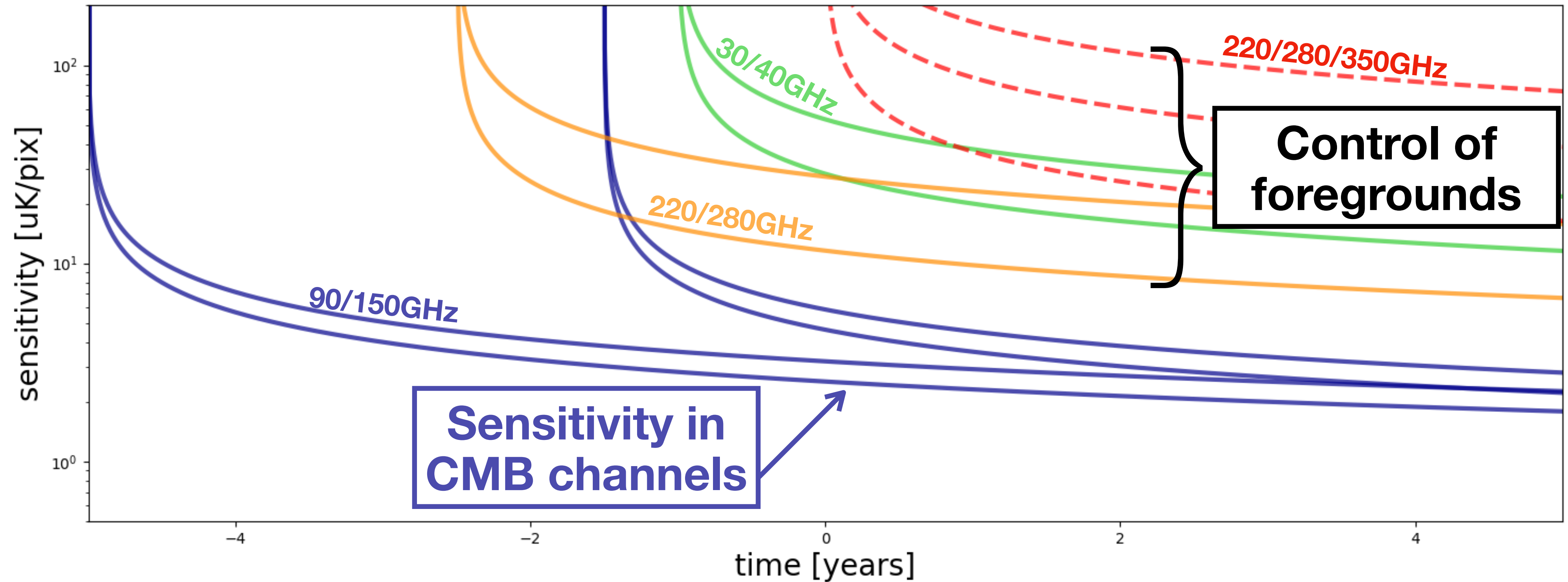
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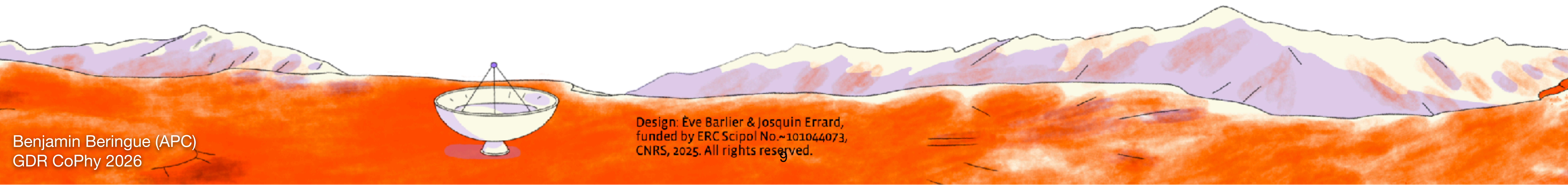
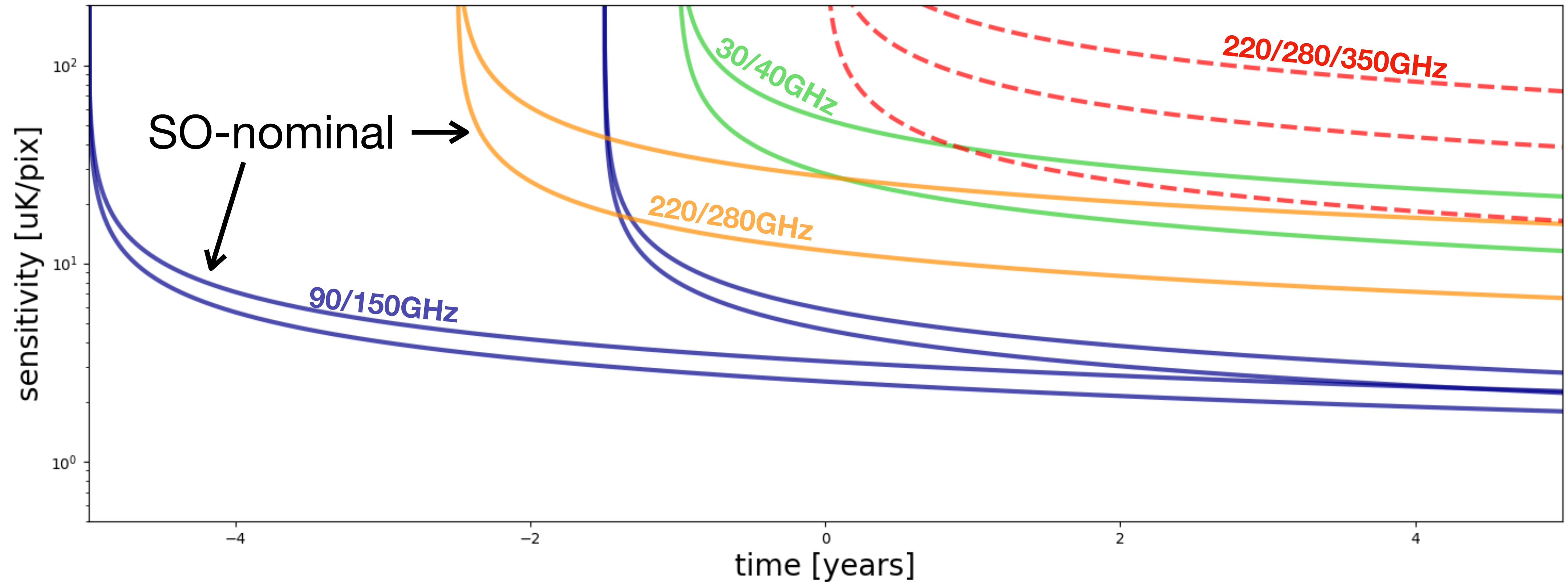
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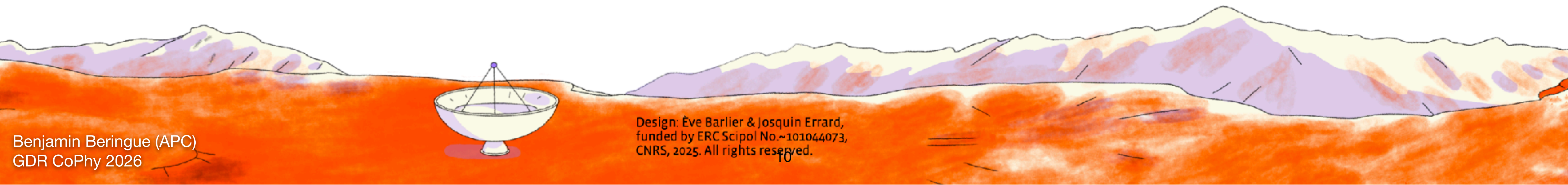
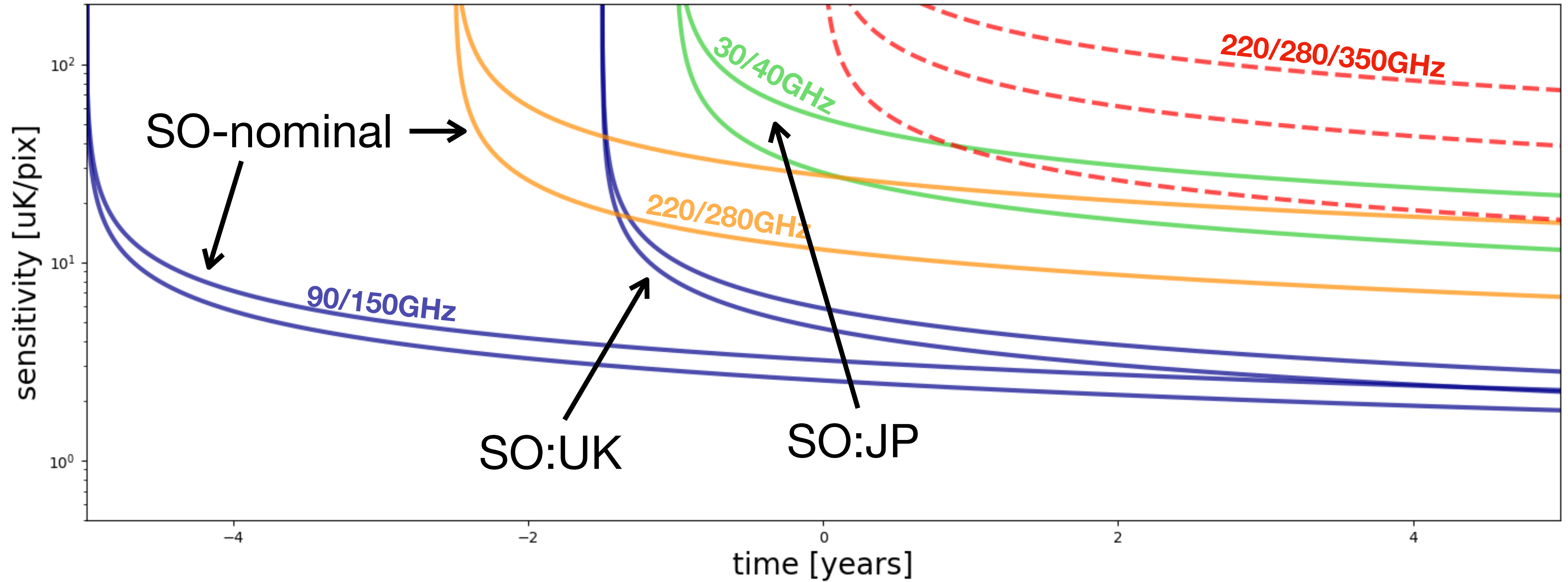
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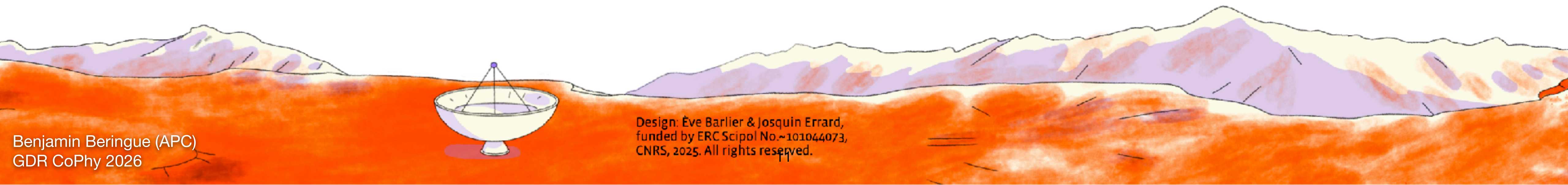
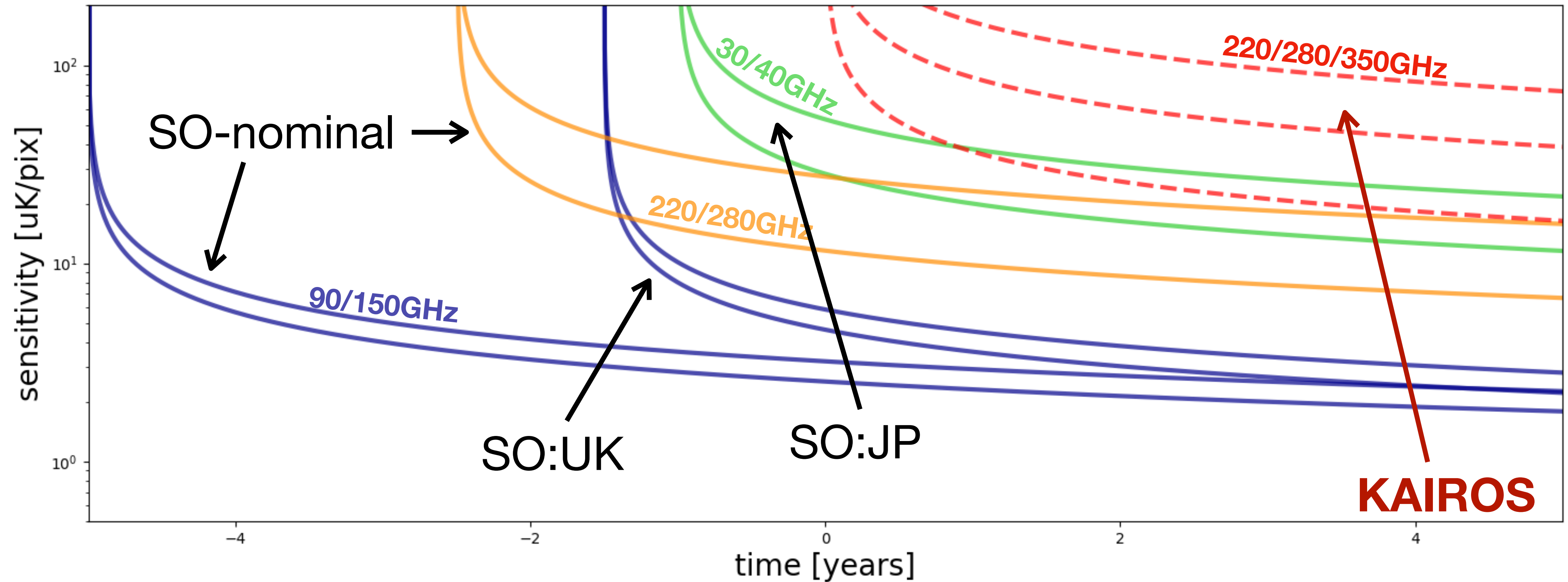
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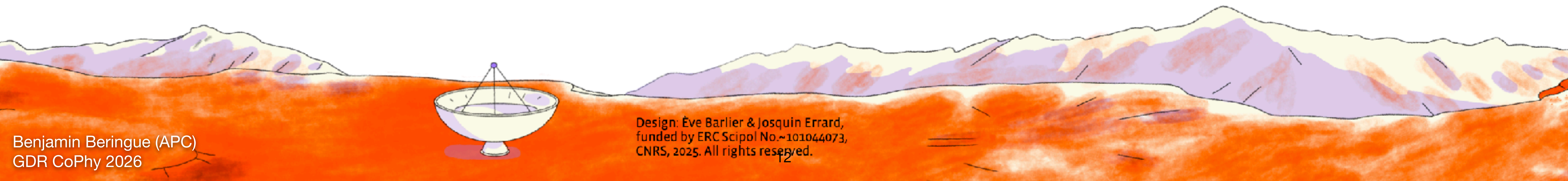
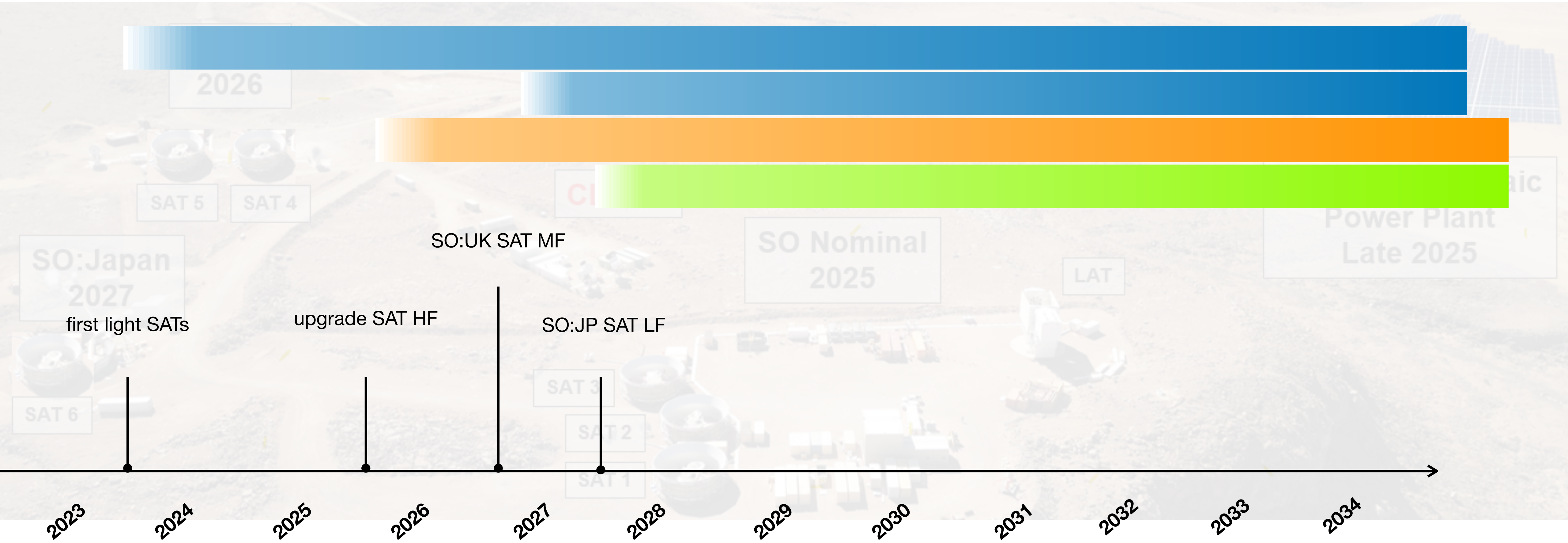
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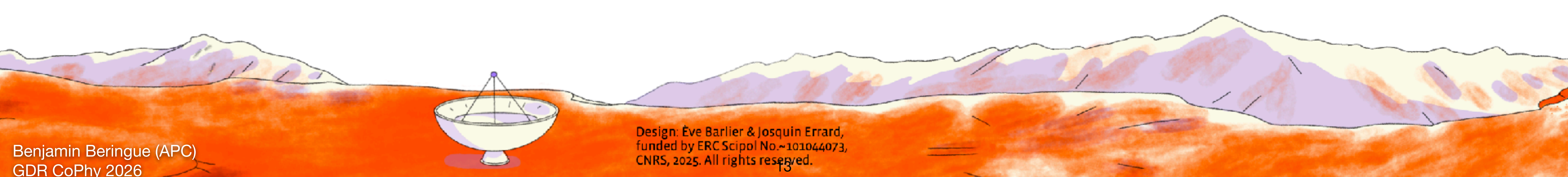
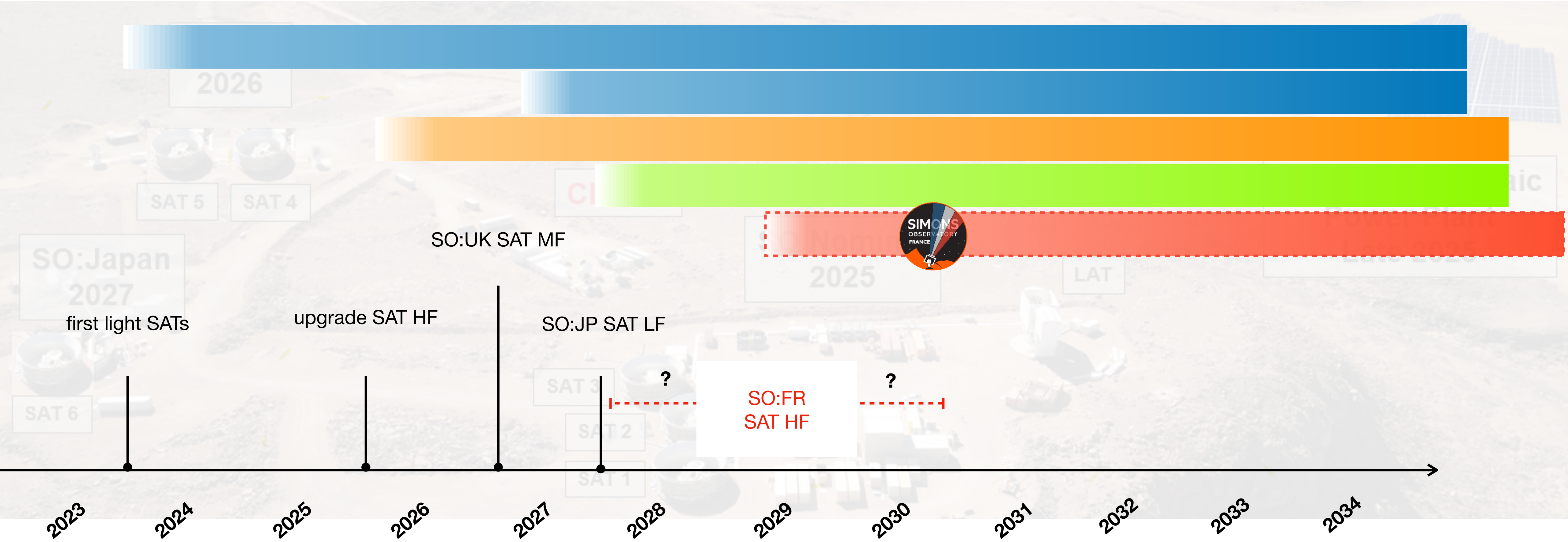
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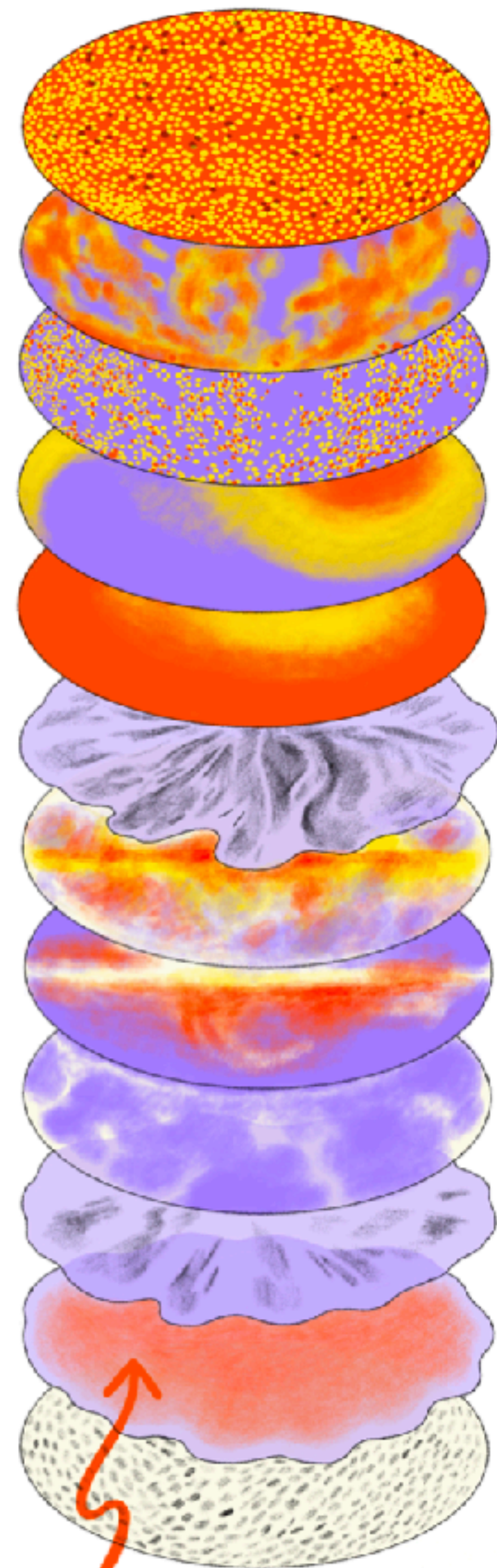


Short term evolution of Simons Observatory



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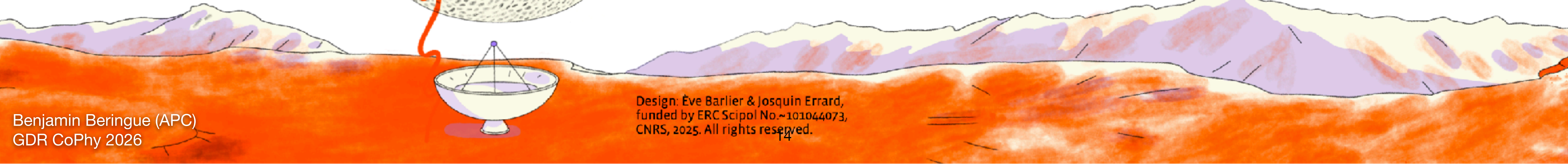




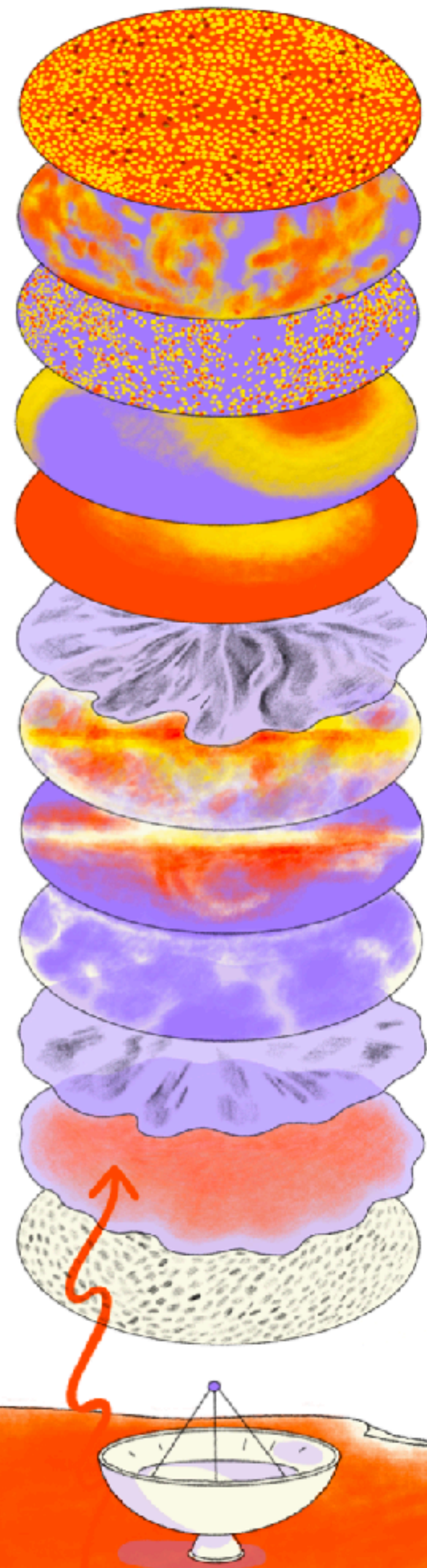
- B-modes
- E-modes
- Intensity anisotropies
- Dipole
- Monopole
- Gravitational lensing
- Galactic and extra-galactic foregrounds
- Atmosphere
- Systematics
- Ground emissions
- Noise



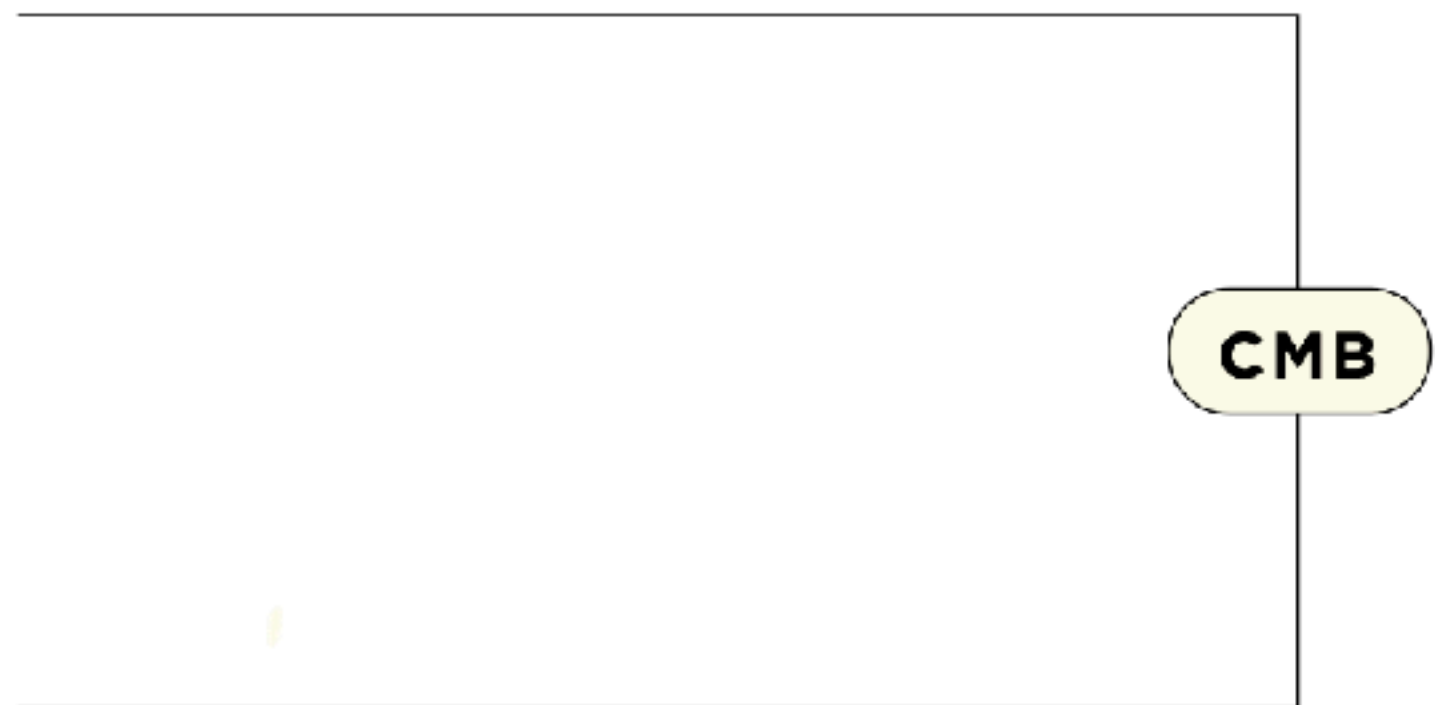
CMB



Design: Ève Barlier & Josquin Errard, funded by ERC Scipol No.~101044073, CNRS, 2025. All rights reserved.

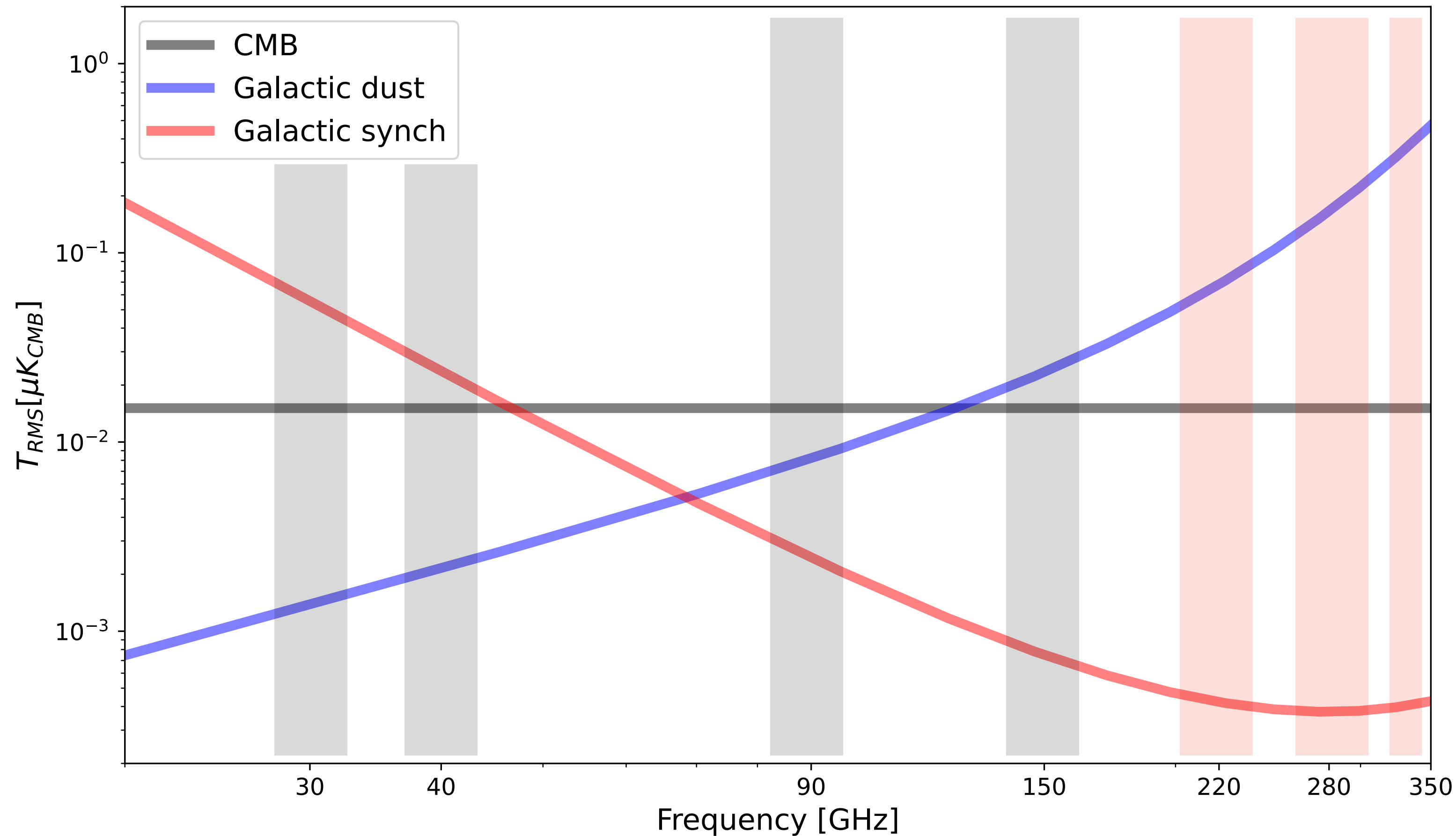


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CMB

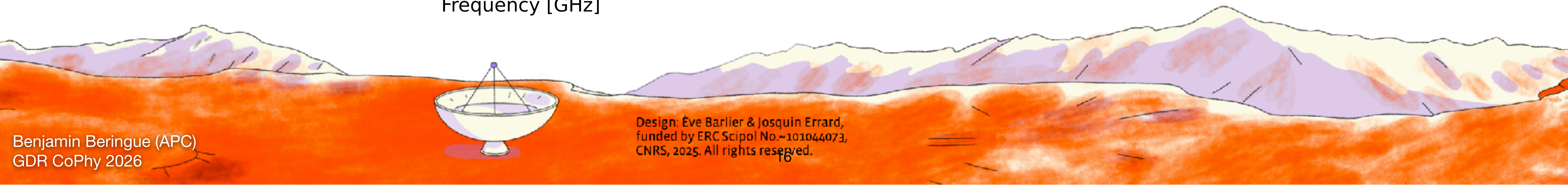
Observing frequencies, the higher the better ?



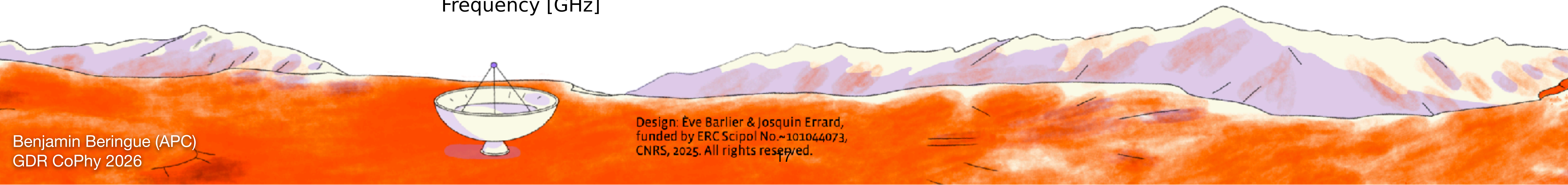
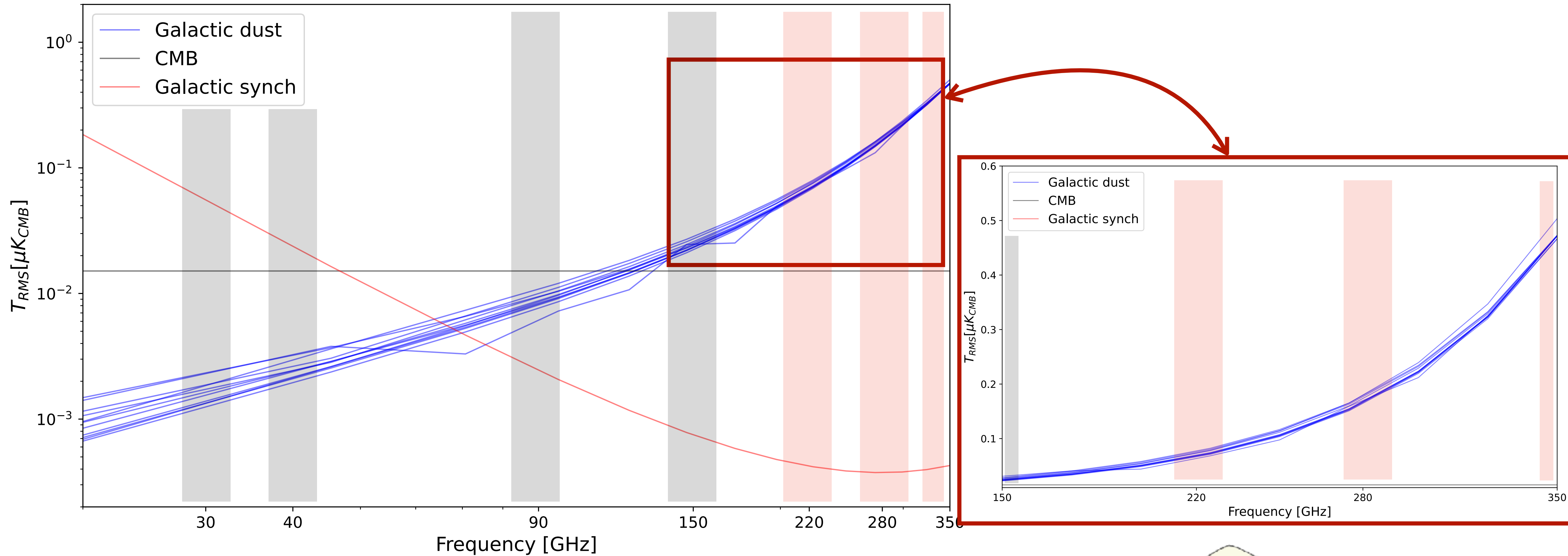
Even with a perfect knowledge of the foregrounds SEDs, the residual in the reconstructed CMB map:

$$\delta s_{CMB} = \delta s_{dust} + \frac{a_{500} n_{150} - a_{150} n_{500}}{a_{500} - a_{150}}$$

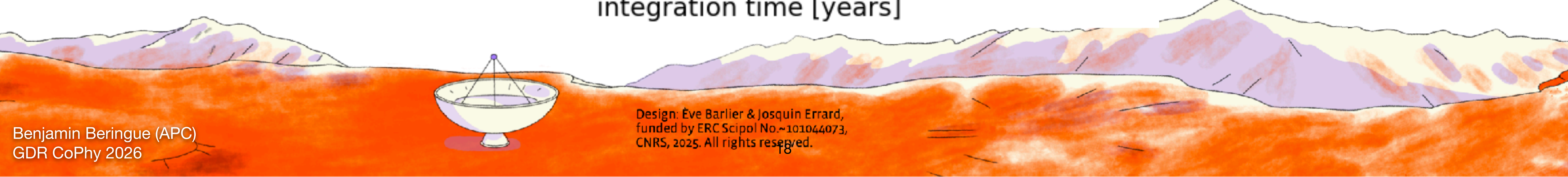
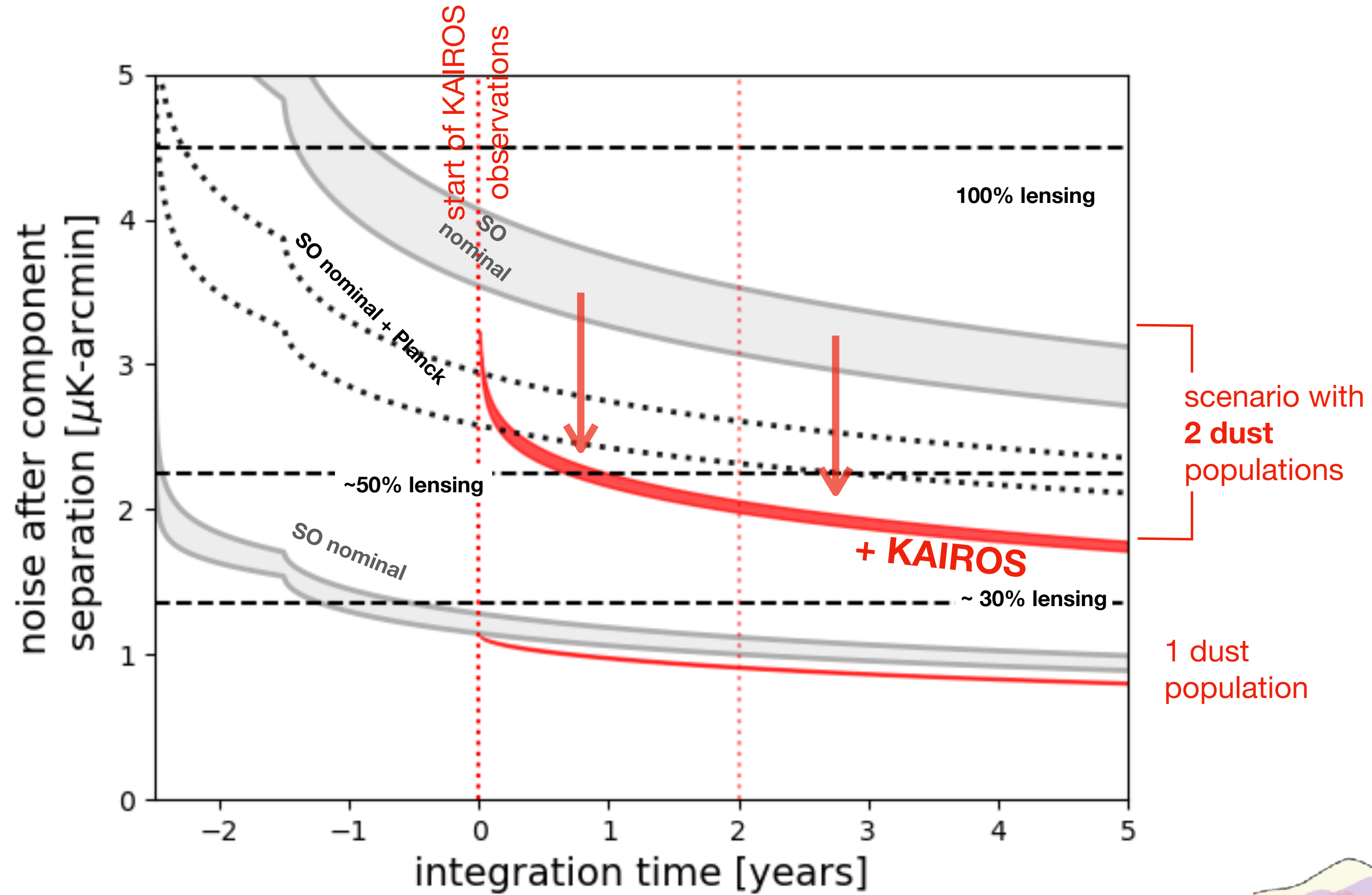
[Krachmalnicoff et al., arXiv:1511.00532]



Observing frequencies, the higher the better ?

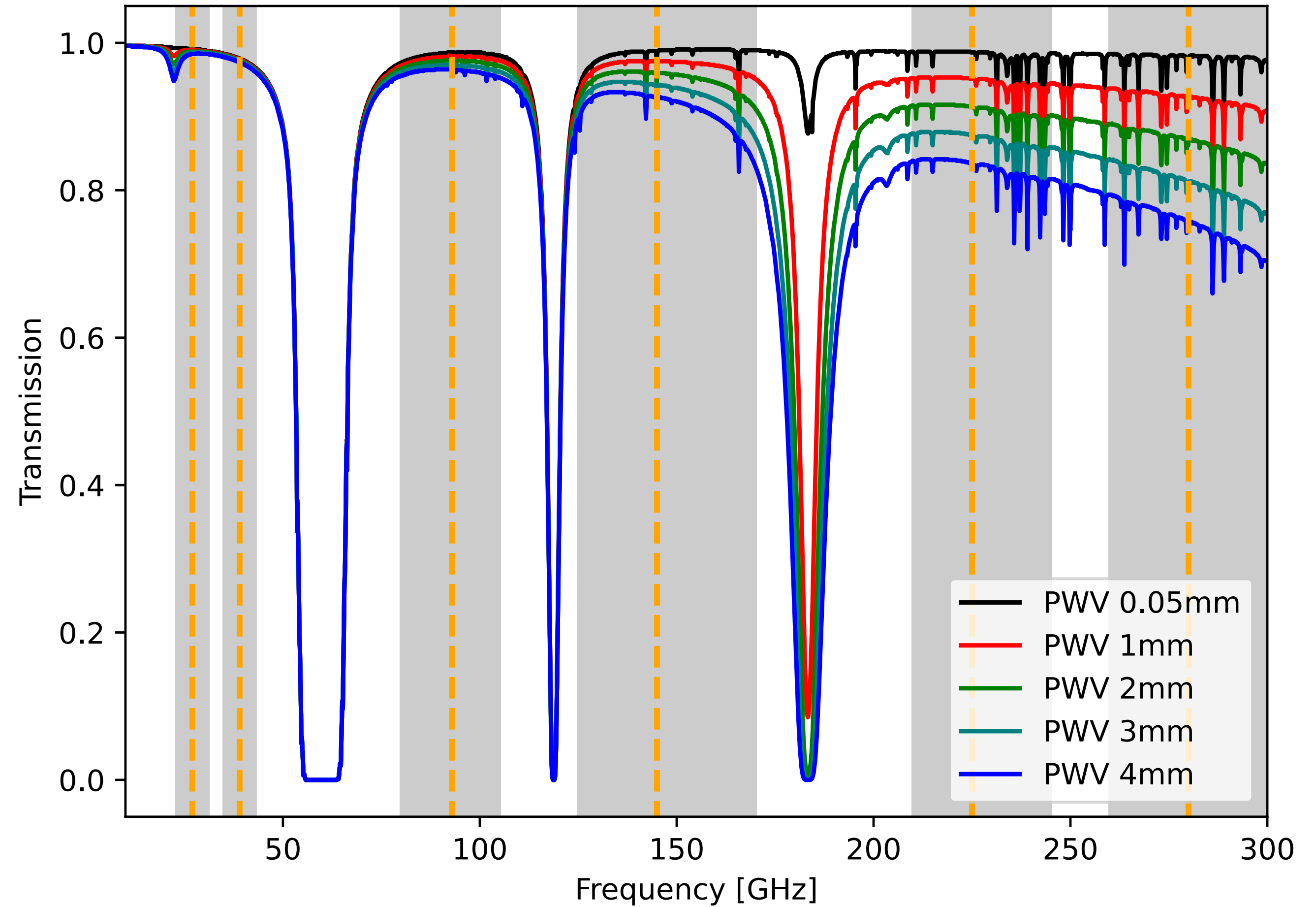
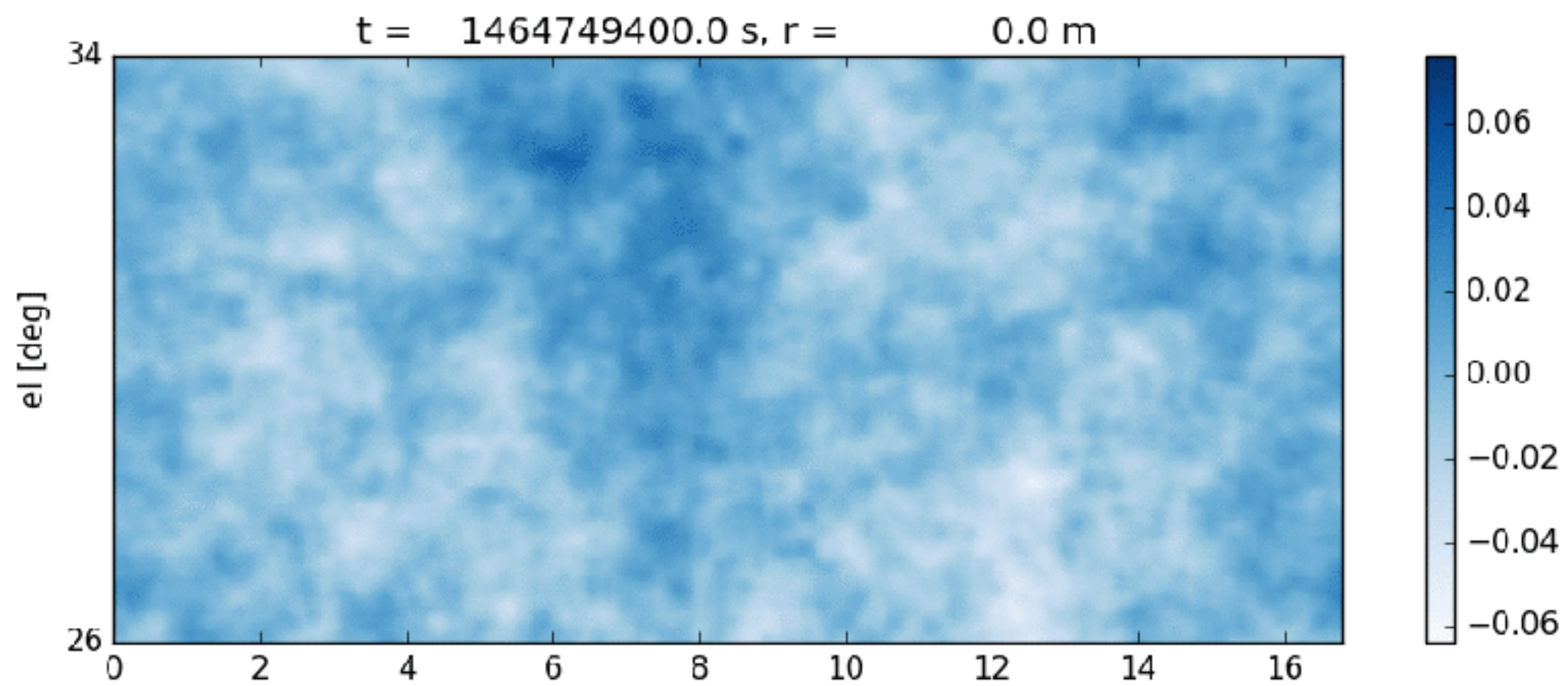


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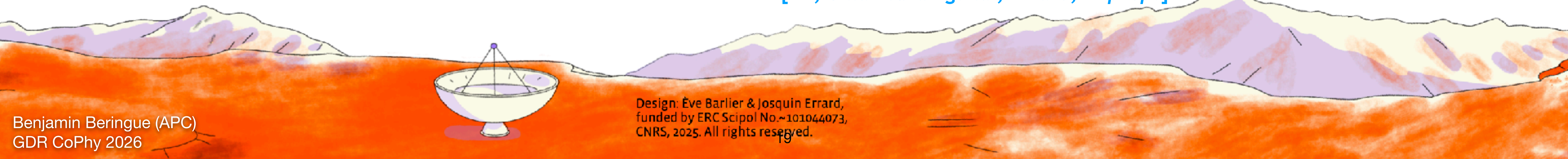


Observing frequencies, the higher the better ?

Access to higher frequencies allows a more precise characterisation (and removal) of atmospheric contamination.



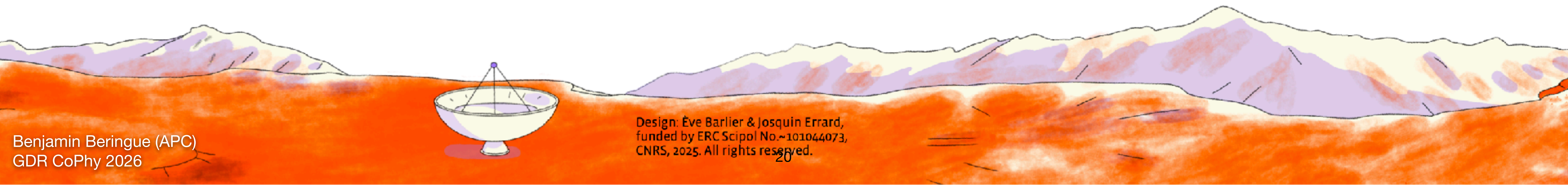
[BB, Villarrubia Aguilar, Errard, *in prep.*]



KAIROS science cases

Galactic science

- is there one or two dust populations?
- map of Bd → impact on our understanding of dust life cycle
- what is the amplitude and properties of the EB correlation for the interstellar dust → potentially a huge impact for the cosmic birefringence



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Impact on component separation and inflation

- improved quality and robustness of component separation → better CMB map depth and stronger control of biases/systematics
- better and more robust constraints on inflation



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Reionization

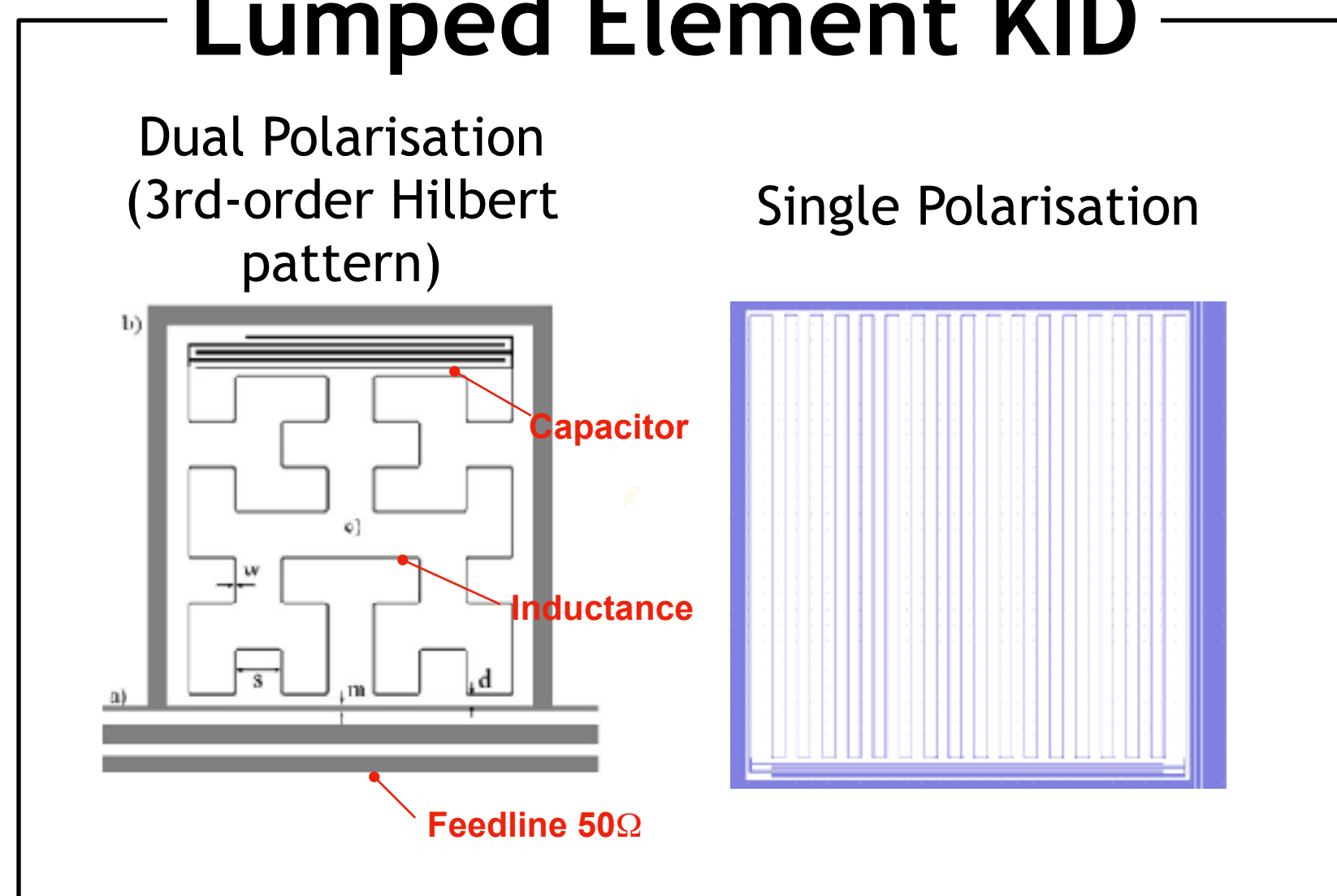
- In an extended version, KAIROS would have potentially a unique access to low ℓ through
- improved calibration and treatment of environmental systematic effects (atmosphere)
 - optimized scanning strategy for large sky area



How to build KAIROS ?

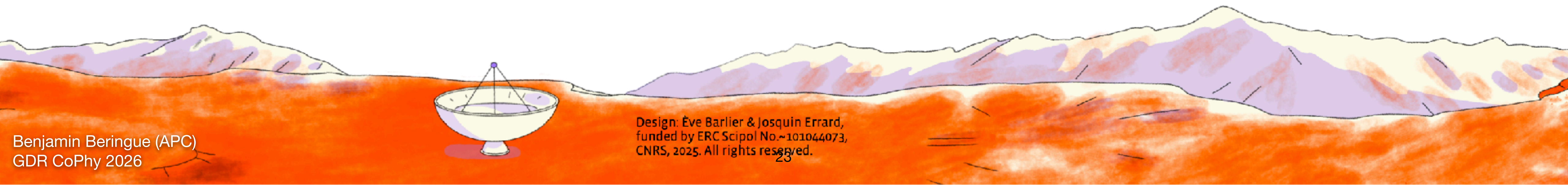
Using Kinetic Inductance Detectors (KIDs) instead of Transition Edge Sensors (TES)

Lumped Element KID



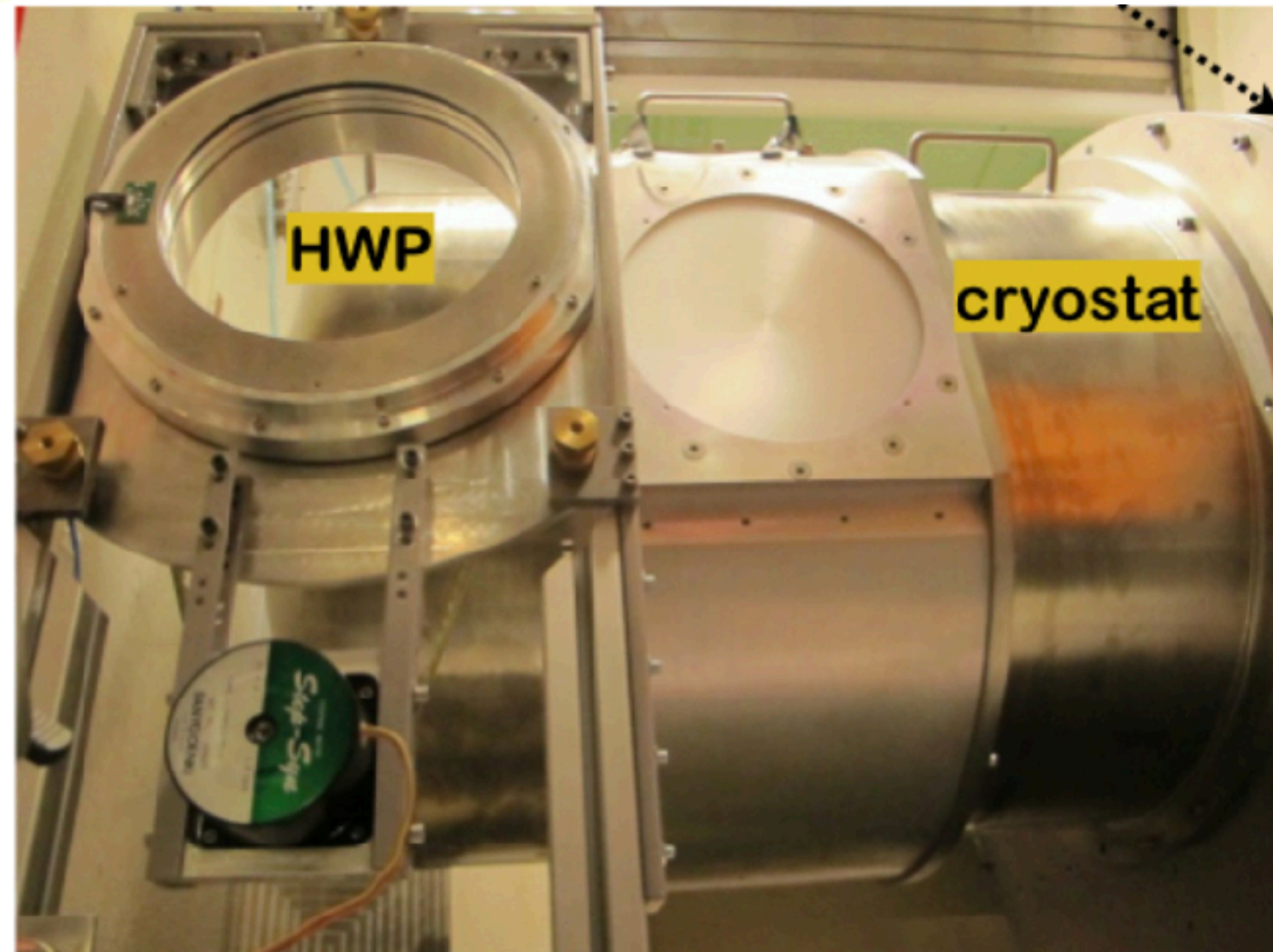
Filled arrays LEKID:

- Large filling factor
- Natural frequency domain multiplexing
- Very high quantum efficiency in a 30% mm-band
- Easy to fabricate



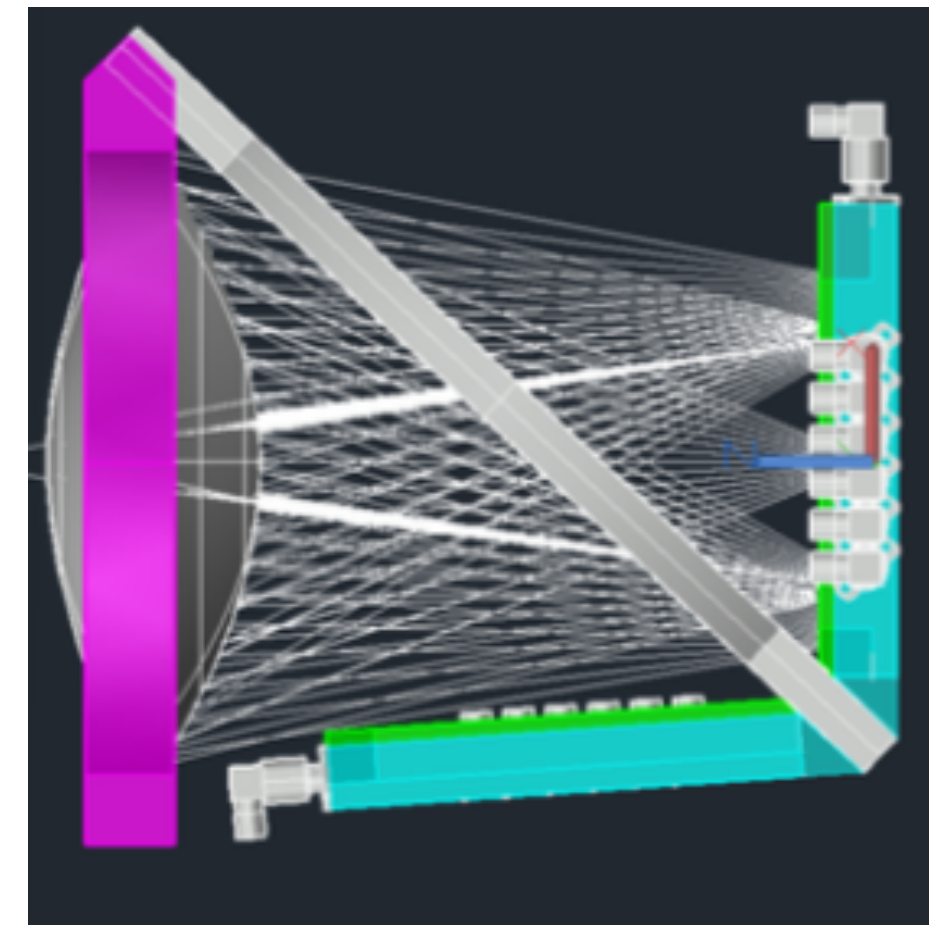
How to build KAIROS ?

Using Half Wave Plate (HWP) to modulate polarised signal



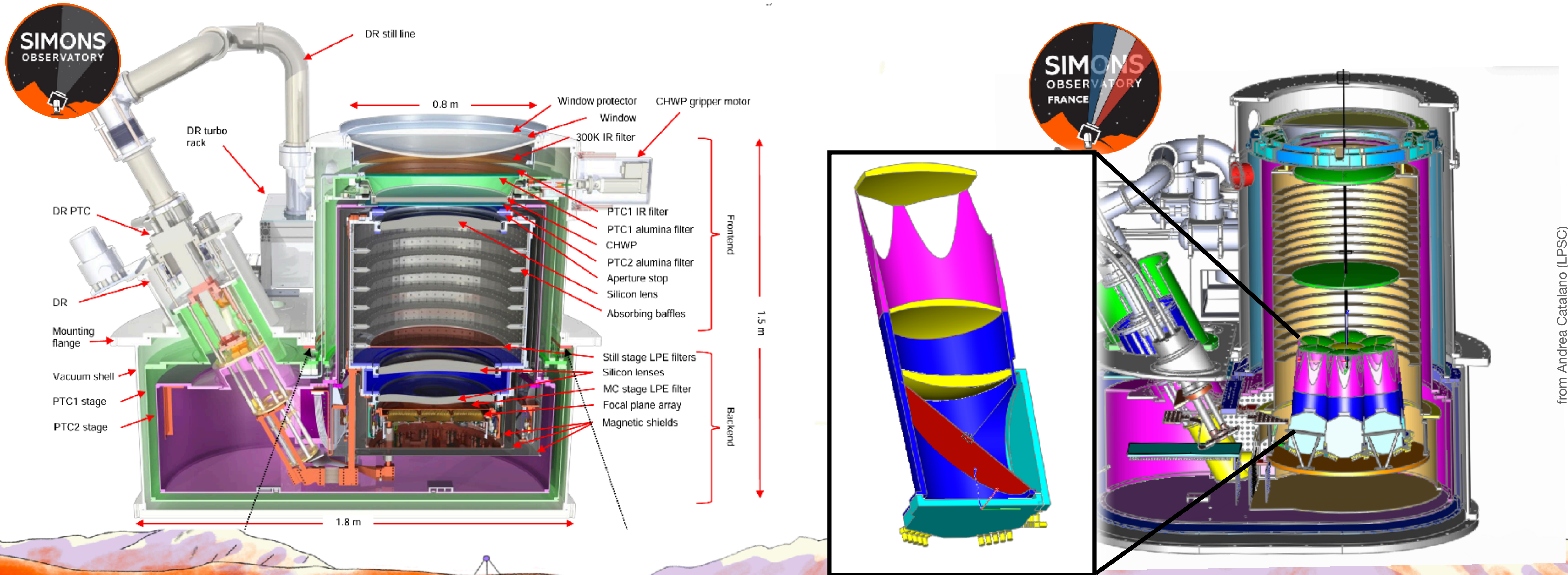
HWP + KIDs

- Higher sampling rate -> faster HWP



How to build KAIROS ?

Reusing cryostat and pointing platform from SO to optimise costs and deployment

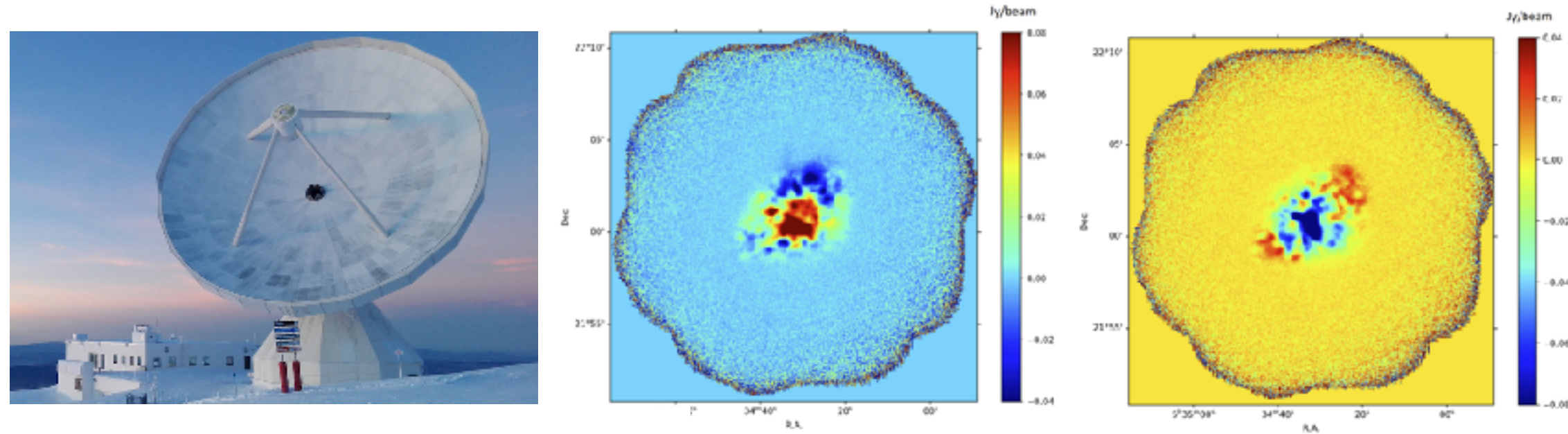


from Andrea Catalano (LPSC)

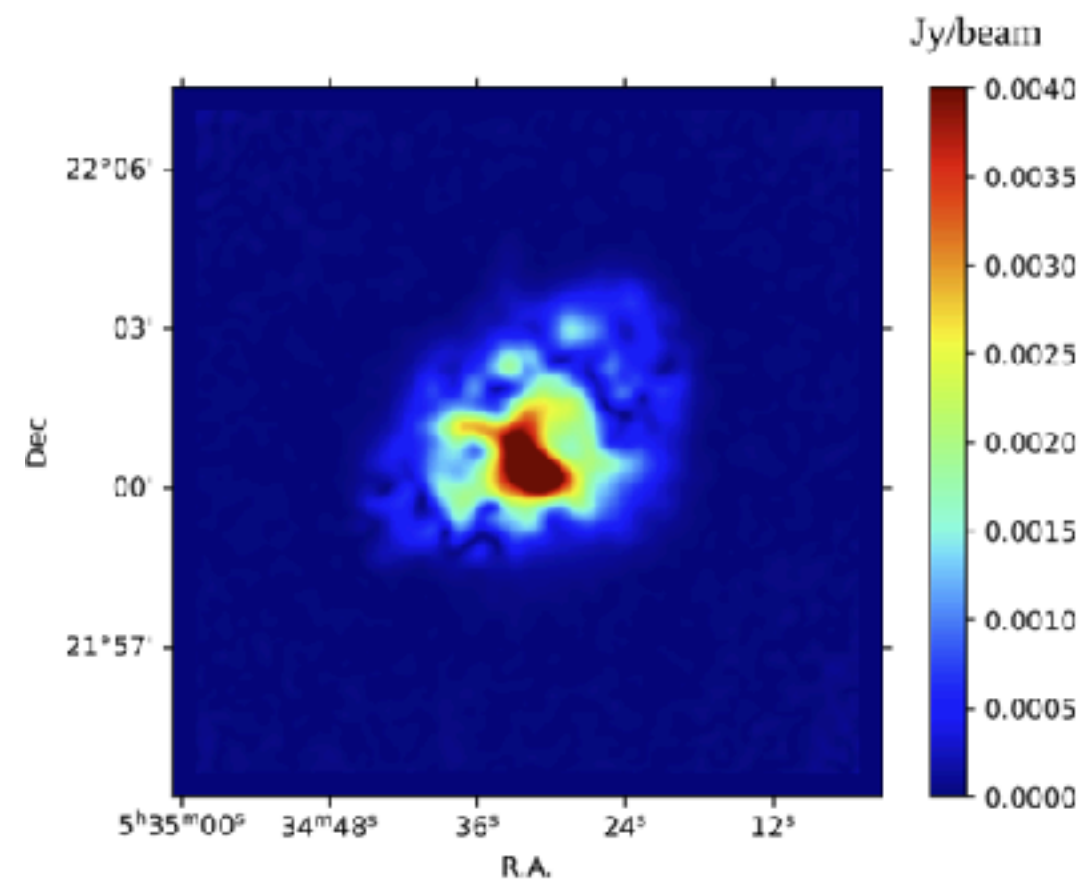
Why build it in France ?

Extensive experience in building and exploiting KIDs millimetre cameras

Stokes Q and U maps of the **Crab nebula** observed by NIKA2 at 260 GHz



Ritacco et al. (2021) - arXiv:2111.02143



NIKA2

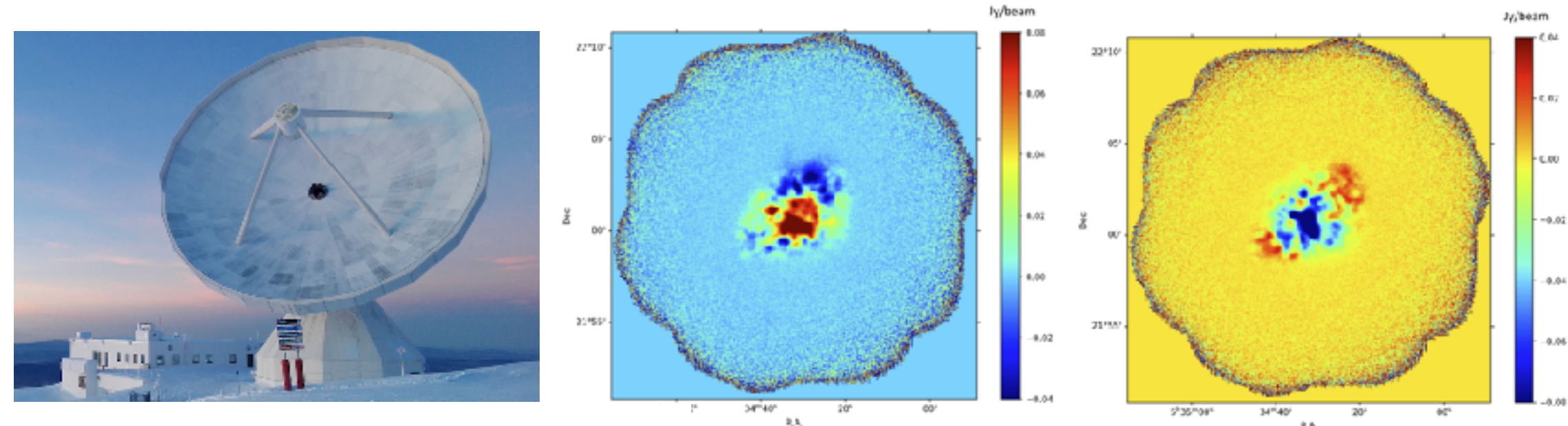
- Polarisation sensitive millimetre camera installed on IRAM 30m telescope
- Final Sensitivity: $\sim 20 \text{ mJy}\cdot\text{s}^{1/2}$
- Polarisation Leakage : $< 1\%$
- Error on the pol. angle reconstruction : $\pm 0.5 \text{ Deg.}$



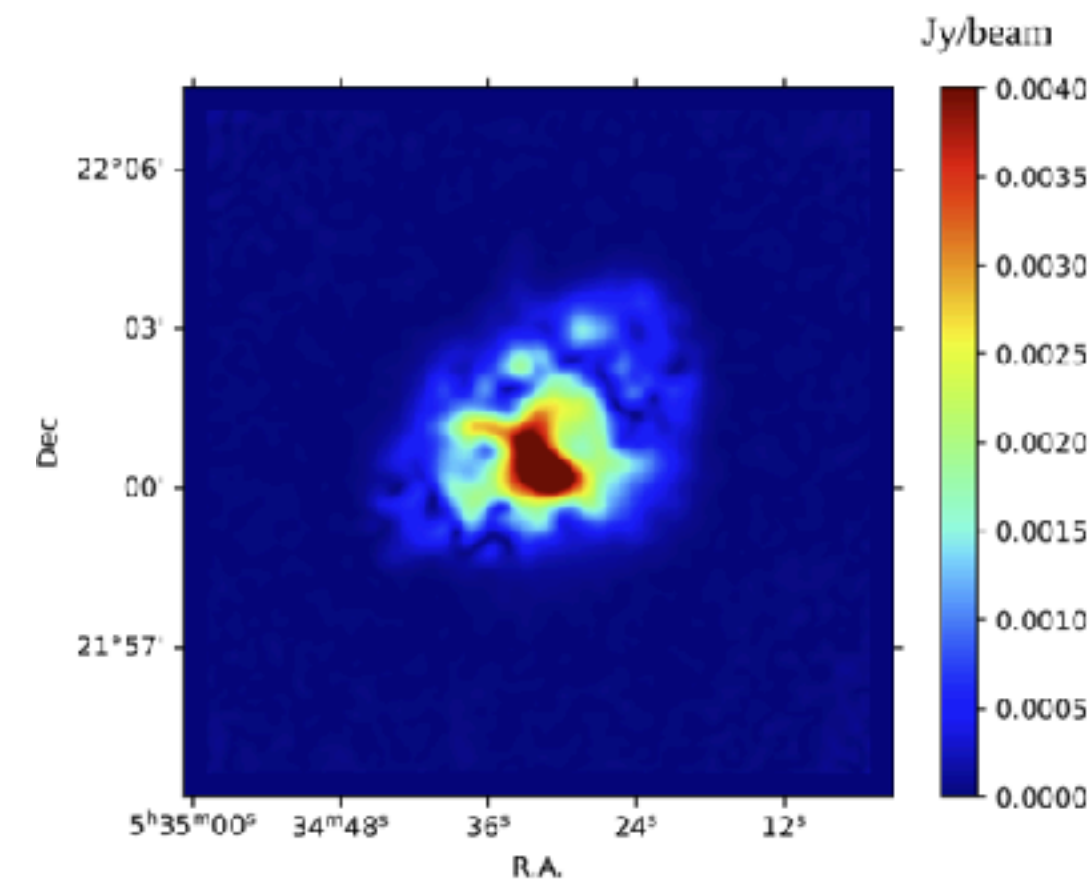
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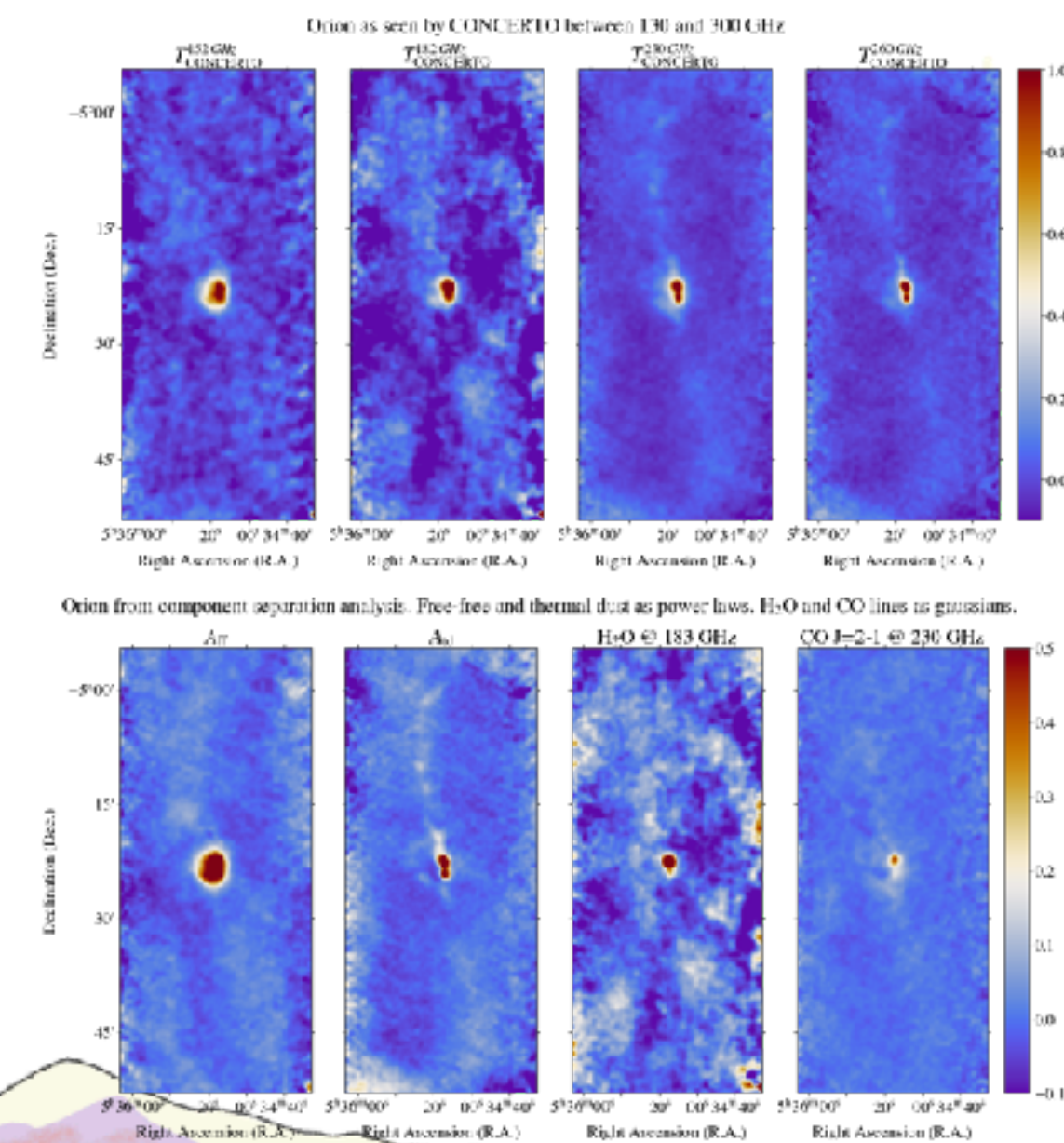
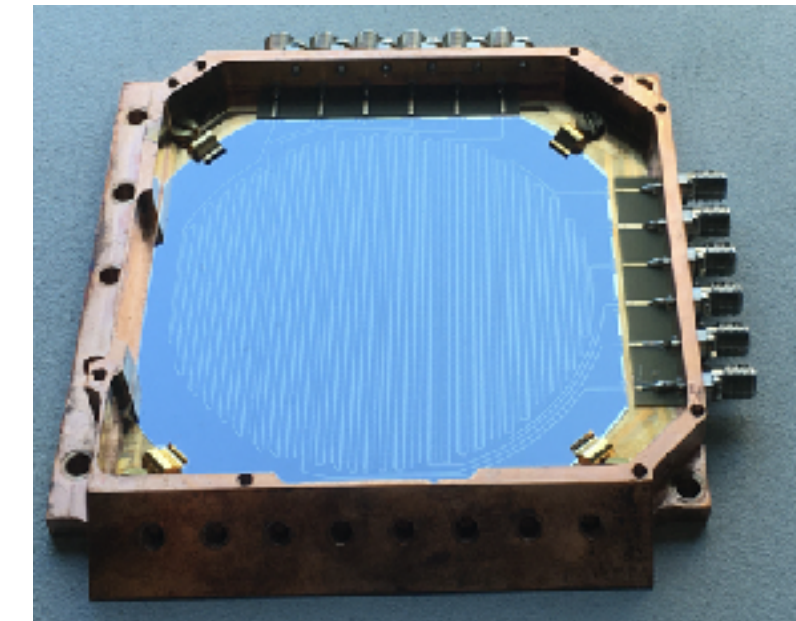


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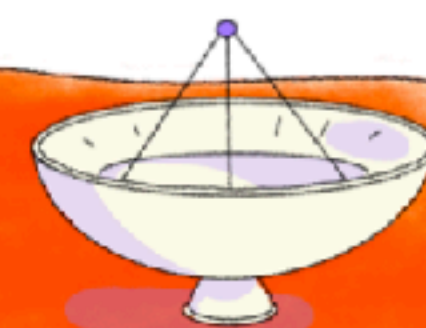


- Spectro-Interferometer (spectral resolution $R > 100$)
- Observing from 120 GHz to 350 GHz at 12 m APEX Tel.
- 2 KID Arrays (4304 pixels)
- High sensitivity ($100 \text{ mJy}\cdot\text{s}^{1/2}$),
- 80% valid KIDs
- 3% calibration error

Preliminary results

Mateo Fernandez Torreiro et al., (in prep)

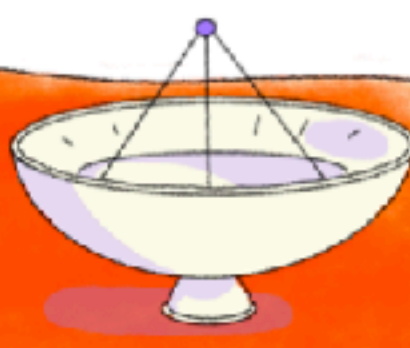
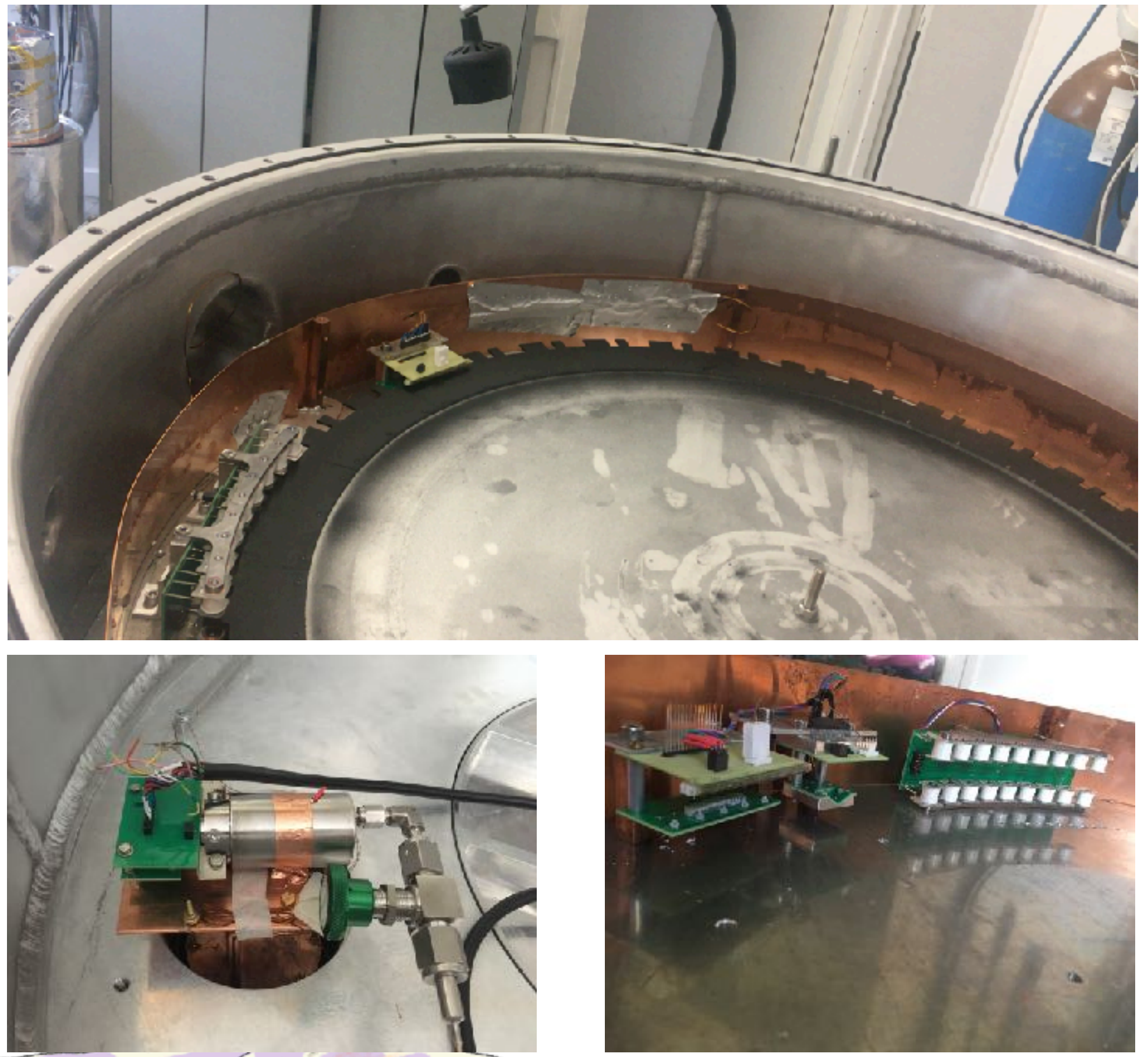
+ see Désert et al. 2504.20487



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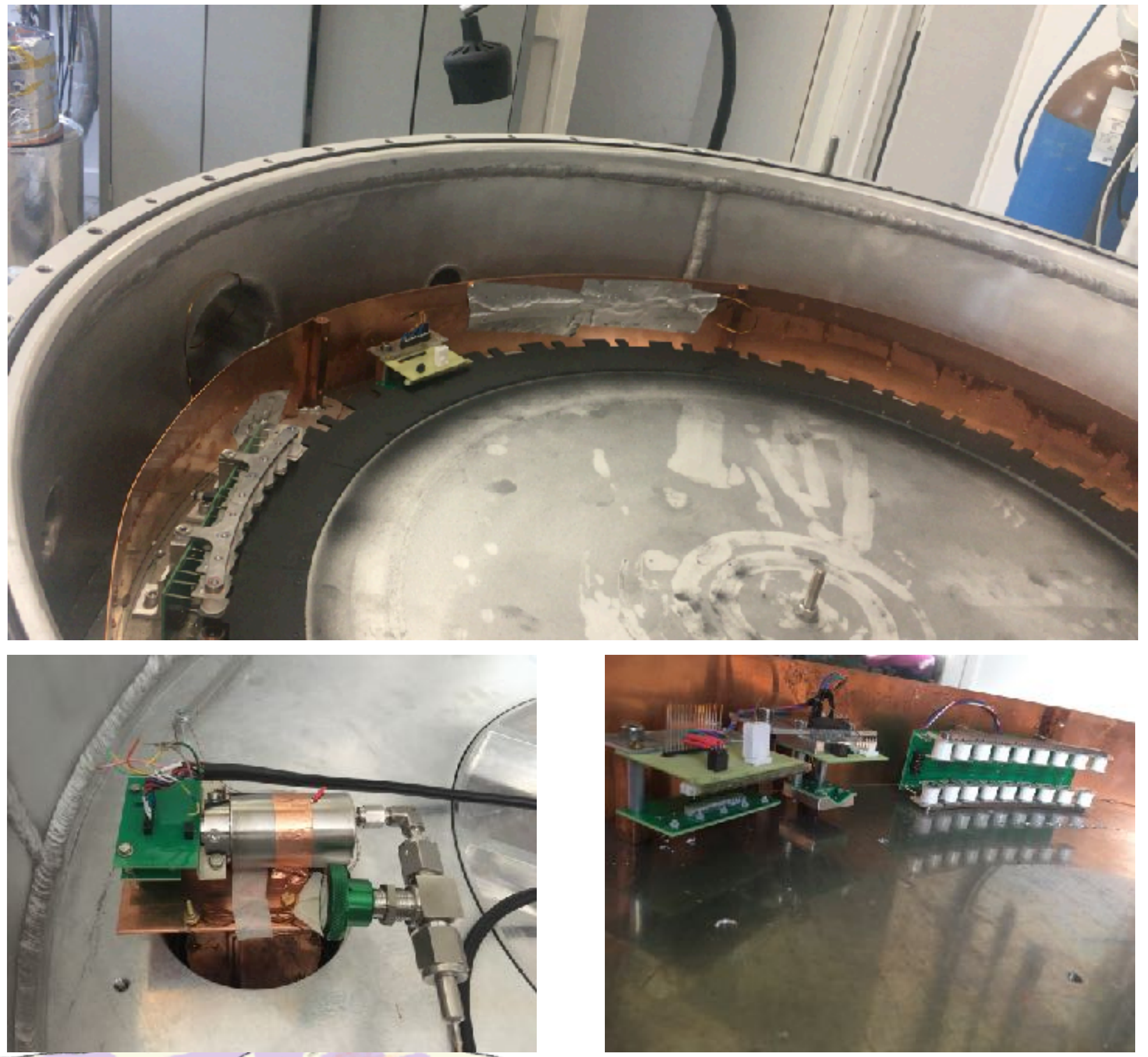
Current status and next steps

On-going fabrication of a test cryostat

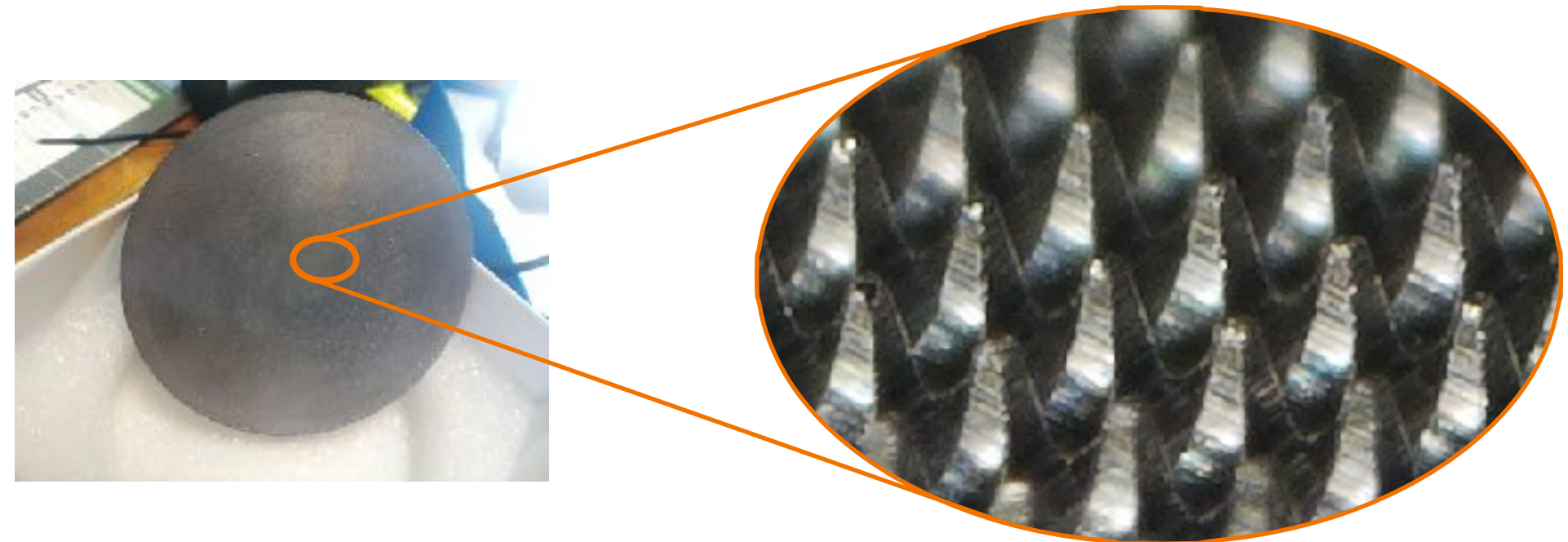
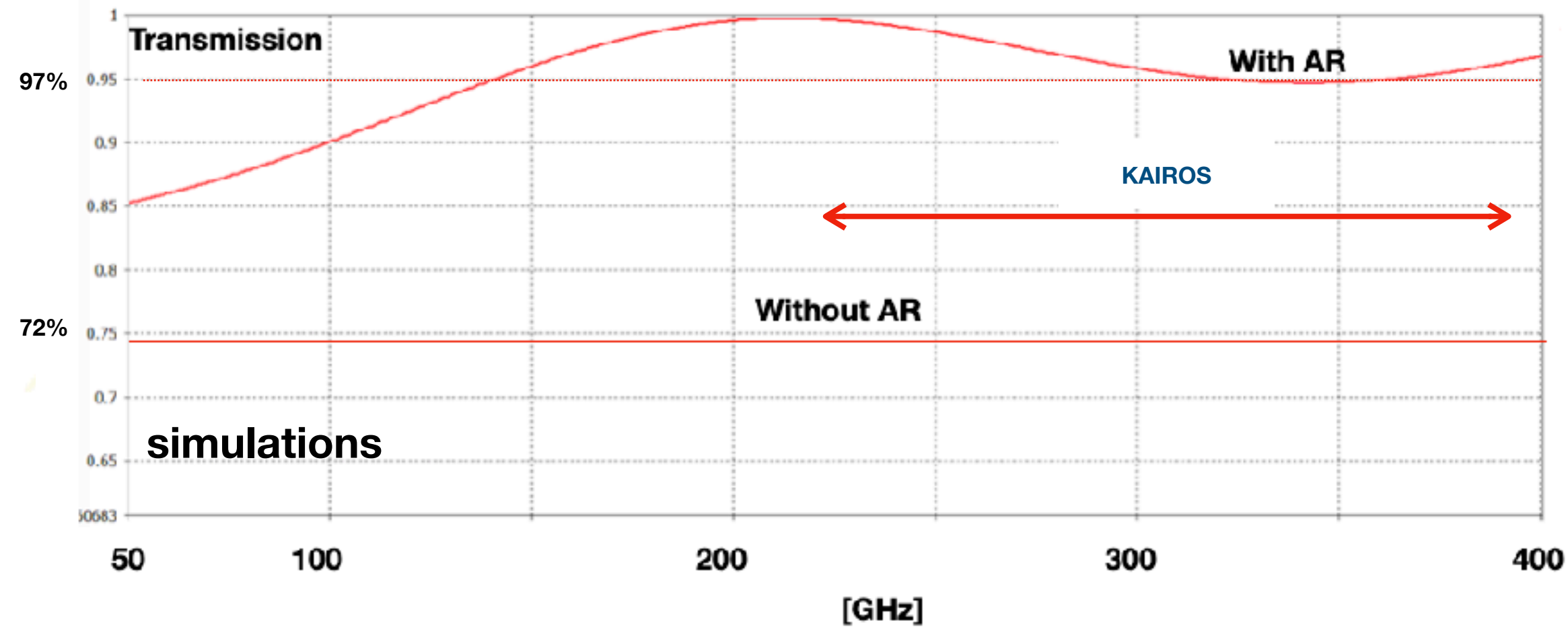


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On-going fabrication of a test cryostat



Tests of anti-reflection coating technologies at LPSC



Current status and next steps

- **Potential Funding**

- Participation to the CNRS (*RI2*) program to design, install and commissioning the KID French SAT. Support of the three CNRS institutes (IN2P3, INSU and INP).
- ERC Synergy in preparation (4 PIs: Catalano, Ponthieu, Calvo, Ganga)
- Started discussions with DOE / LBNL / UCB

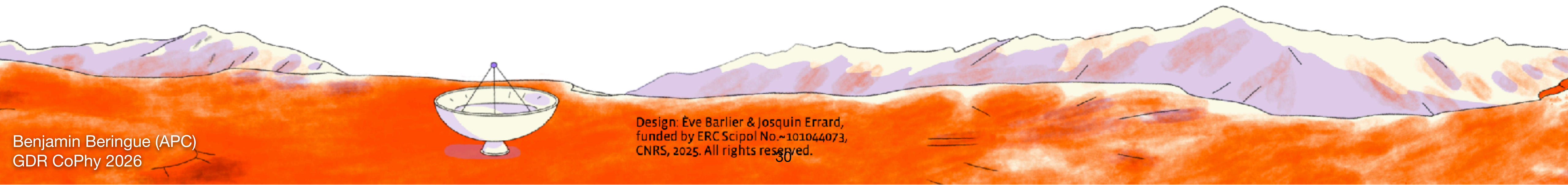
- **Interface with the SO Observatory Execution Office.**

Close contact with S. Staggs, M. Devlin and A. Lee. Preparation of a first Collaboration agreement between OEO and Kairos Consortium. Once funded, the OEO will discuss directly with CNRS institutions.

- **Planning is very hard to keep, KAIROS should start now!**

- **Eventually, France and Europe could have a CMB platform in Chile**

→ strategic investment for future instrumental steps, tests (e.g. LiteBIRD)?



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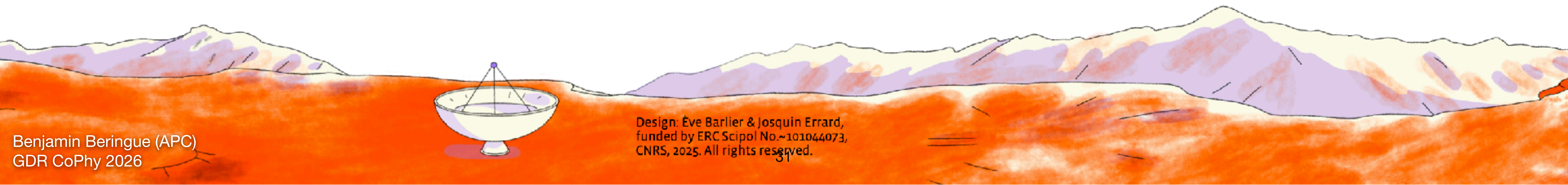
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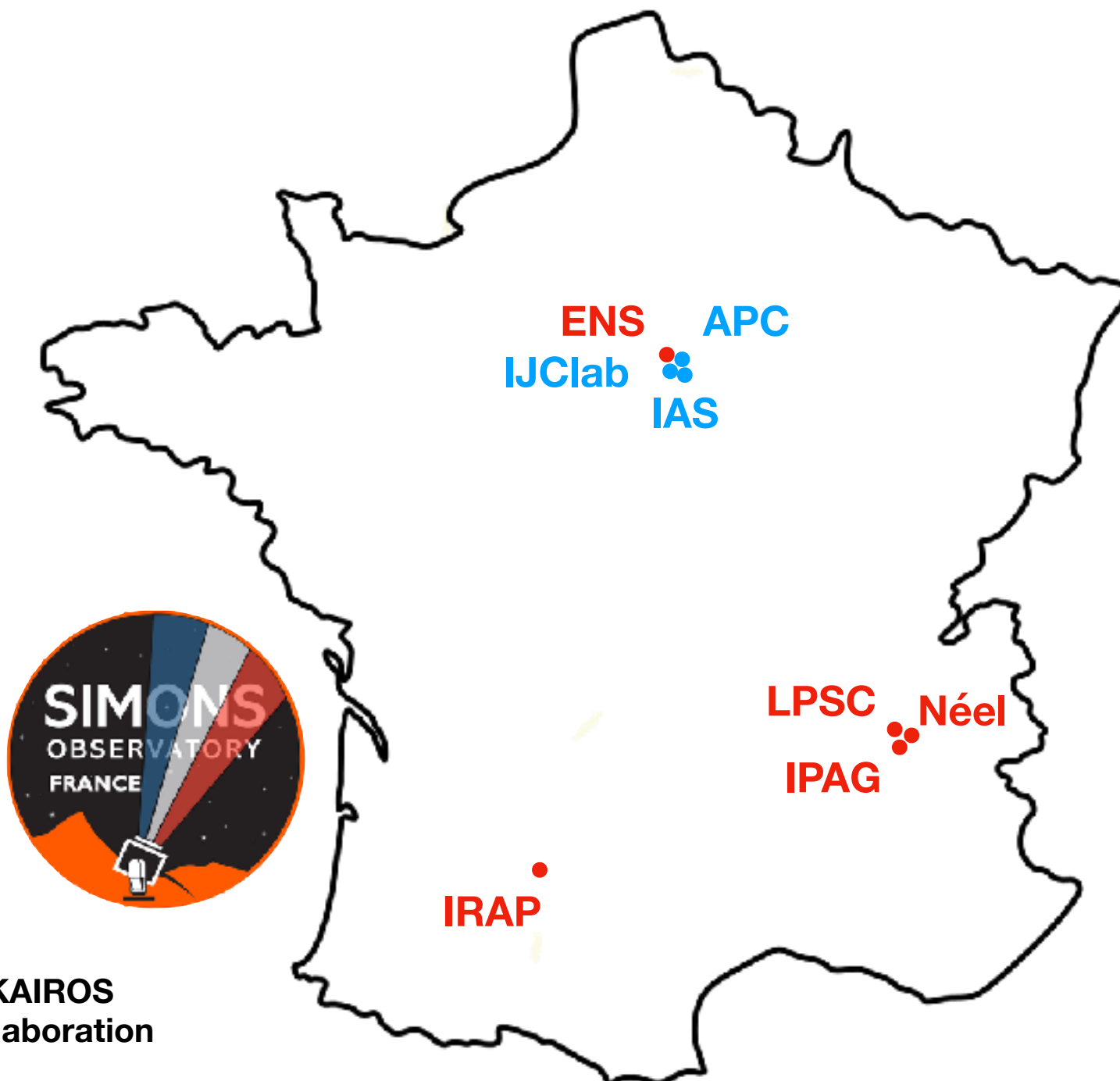
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Current status and next steps



technology is ready, the scientific cases are clear

participation/possible access to SO

strategic investment for future CMB observations

strong synergies with ongoing French efforts (ERC SciPol, Cosmolidar, CosmoCal, etc.)

good training for the next generation

