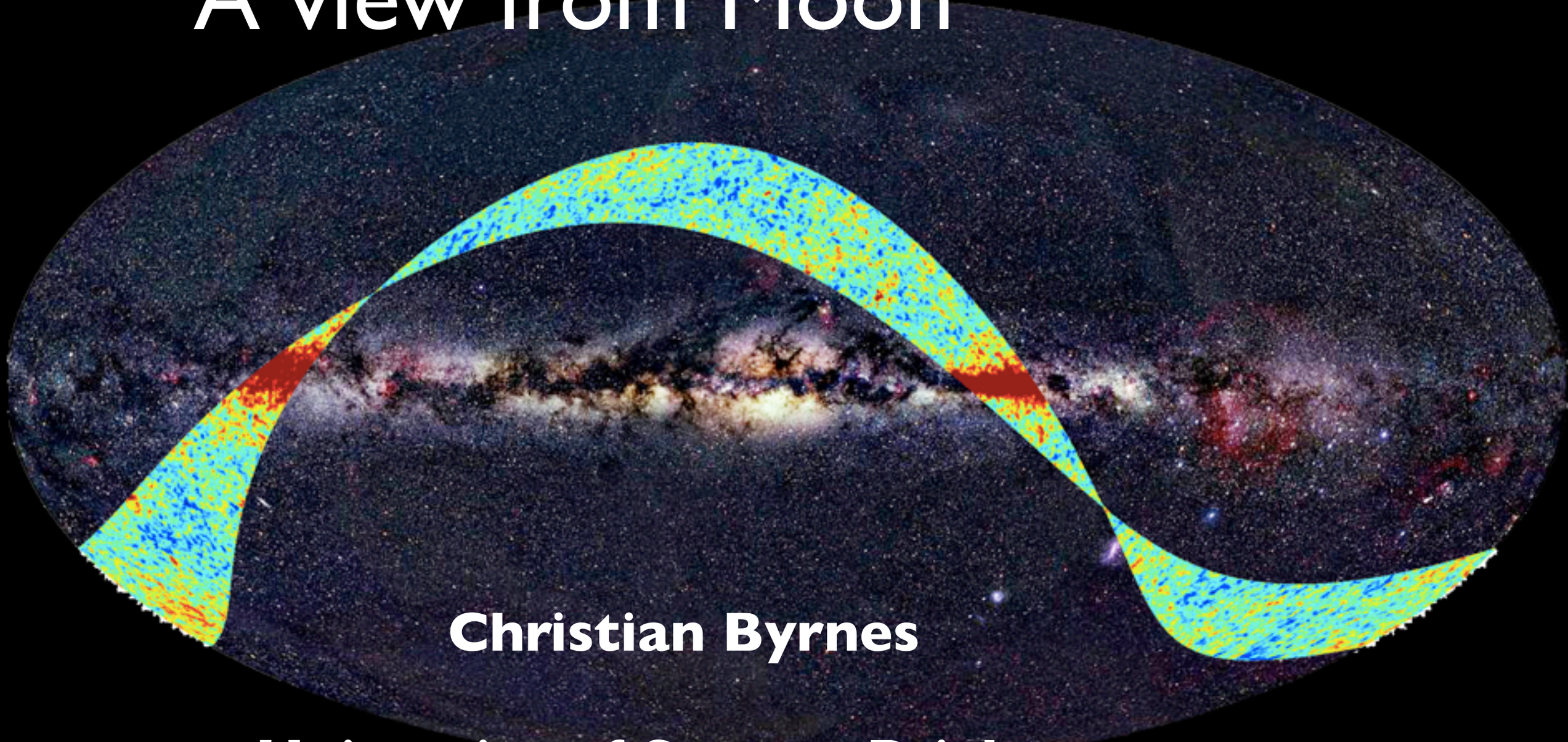
Inflation and dark matter: A view from Moon



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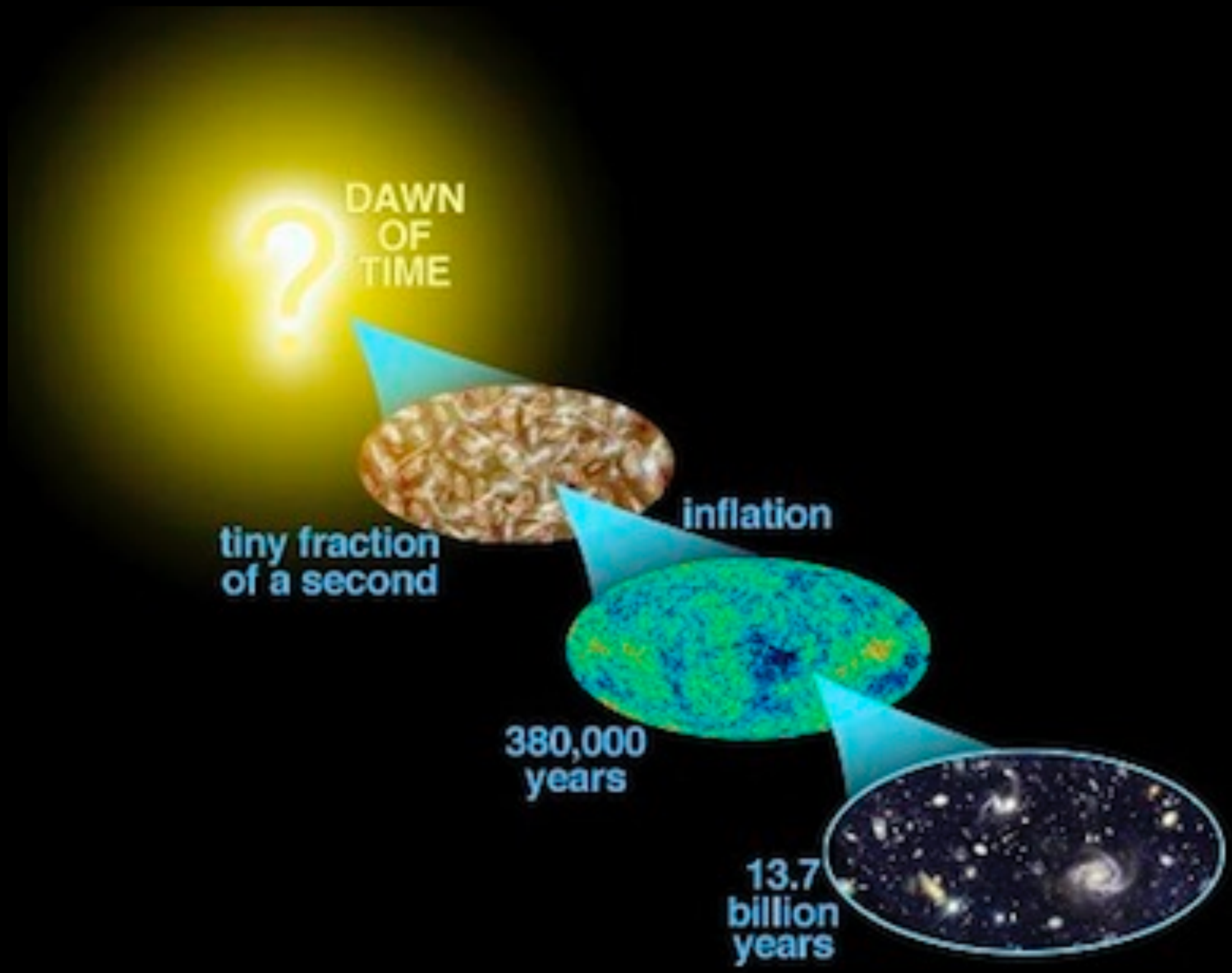
IAP, Astronomy from the Moon, 22 June 2017

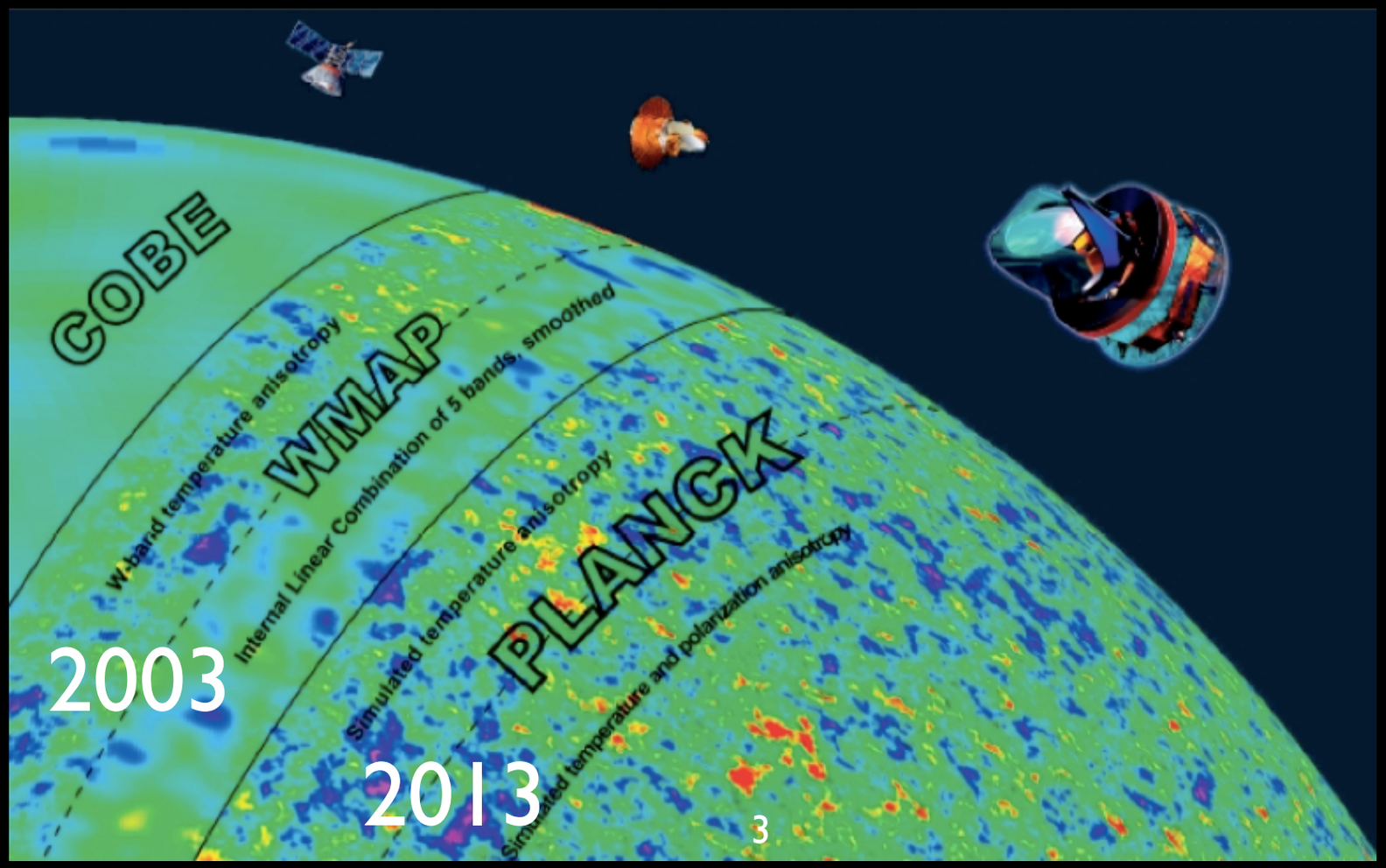


By design, inflationary models produce the same flat background

Only the perturbations can discriminate between them

What's left to learn?

- Planck completes a trilogy of CMB experiments

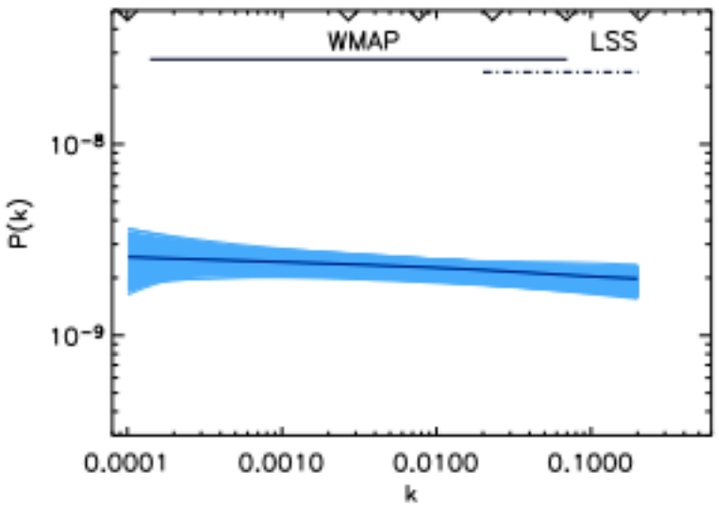


We observe so much yet see so little…

- It is remarkable and disappointing that we can explain the statistical property of 10^7 CMB pixels with just two primordial numbers (+ background parameters)
- We have only measured the amplitude and spectral index of the power spectrum
- Is this evidence that inflation was simple?

Inflation predicts a simple spectrum

Inflation



400,000 years evolution

Cosmic microwave background

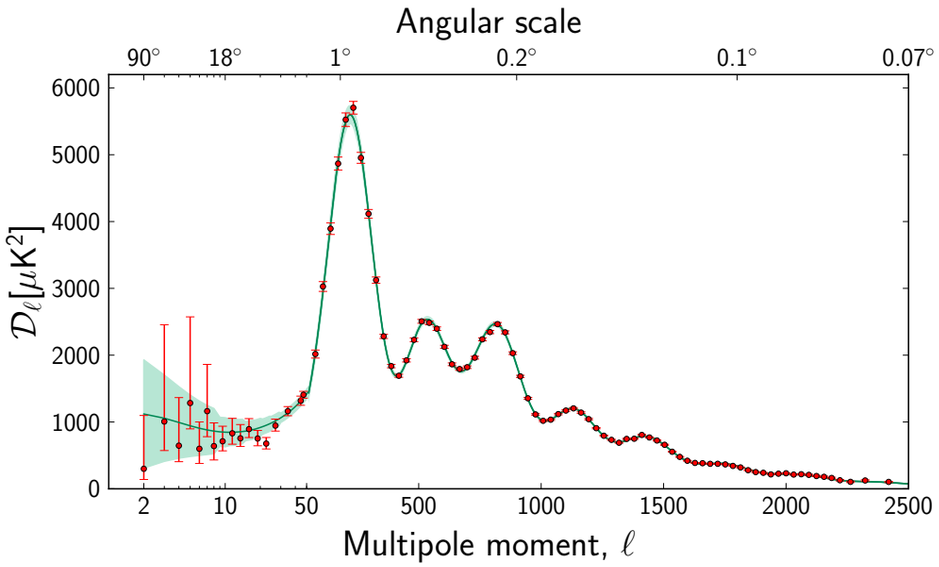
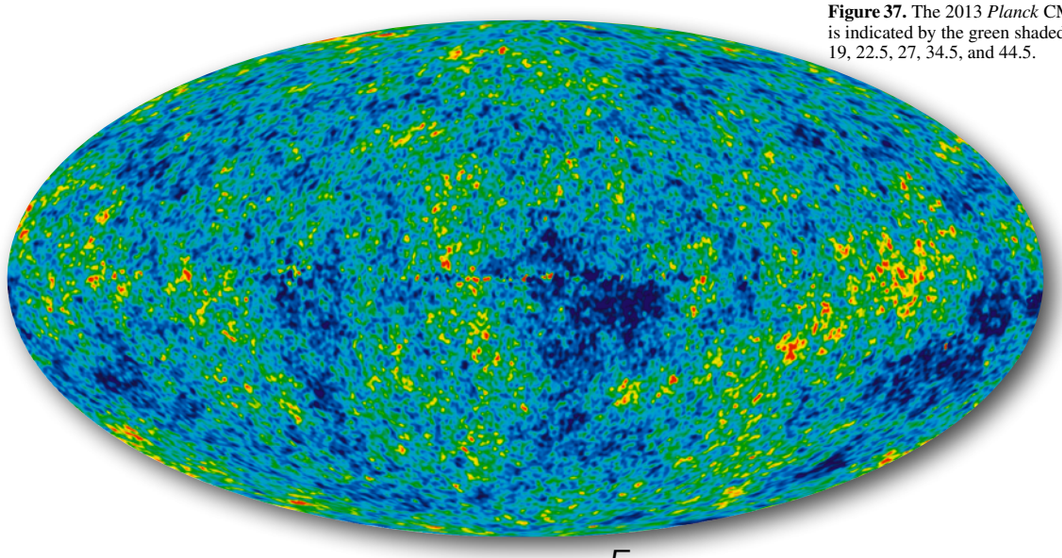


Figure 37. The 2013 *Planck* CMB temperature angular power spectrum. The error bars include cosmic variance, whose magnitude is indicated by the green shaded area around the best fit model. The low-ℓ values are plotted at 2, 3, 4, 5, 6, 7, 8, 9.5, 11.5, 13.5, 16, 19, 22.5, 27, 34.5, and 44.5.



Even complex models often look simple

- At least, given the current observational precision

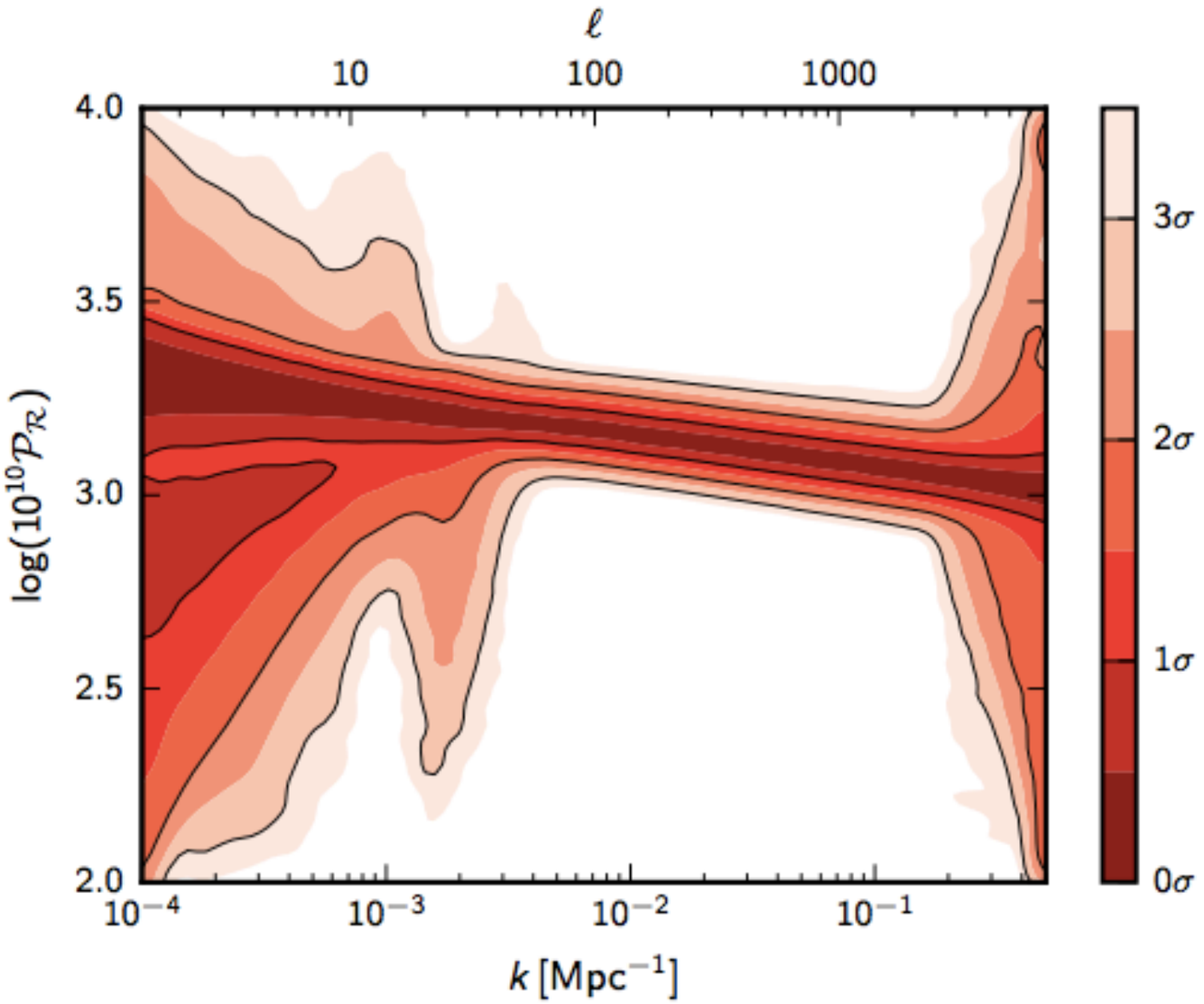
- Despite current “precision era” constraints, ‘complex’ multifield models with non-Gaussianity can provide an equally good fit, even when penalising the extra parameters
  (e.g. Vennin et al ’15 or Dias, Fraser & Marsh ’17)

- Very different models can provide an equally good Bayesian evidence, despite completely different evolution during the early universe

- To improve, we need
  1. More precise measurements
  2. To probe new information on smaller scales (we have to wait Giga years to probe larger scales)

- Why not both!

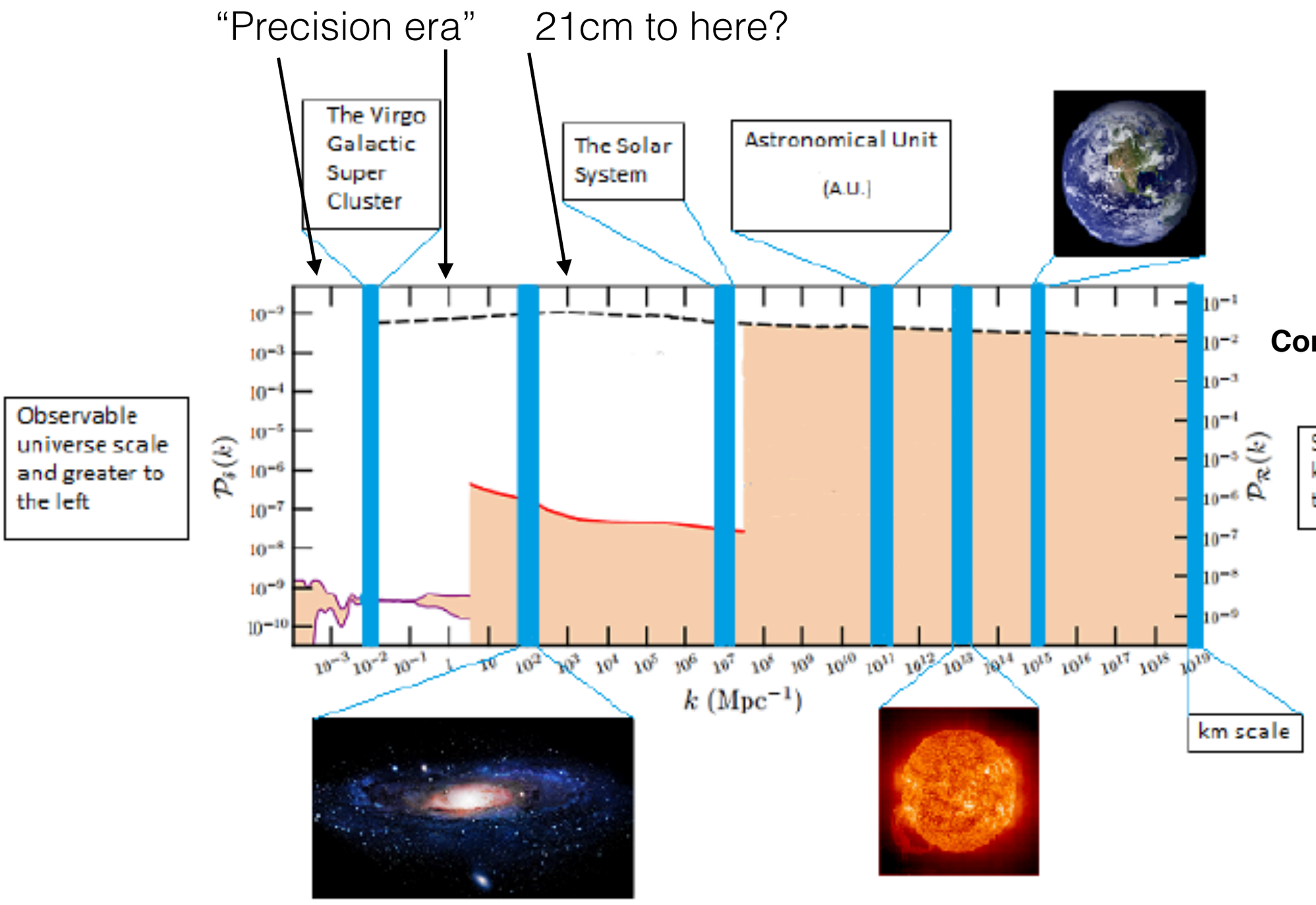
Planck precision



Precise over 2 decades in length scales

From Planck 2015: Constraints on inflation

Planck precision in perspective



Constraint from PBHs

Modified from Bringmann, Scott, Akrami 2011

What about the small scales?

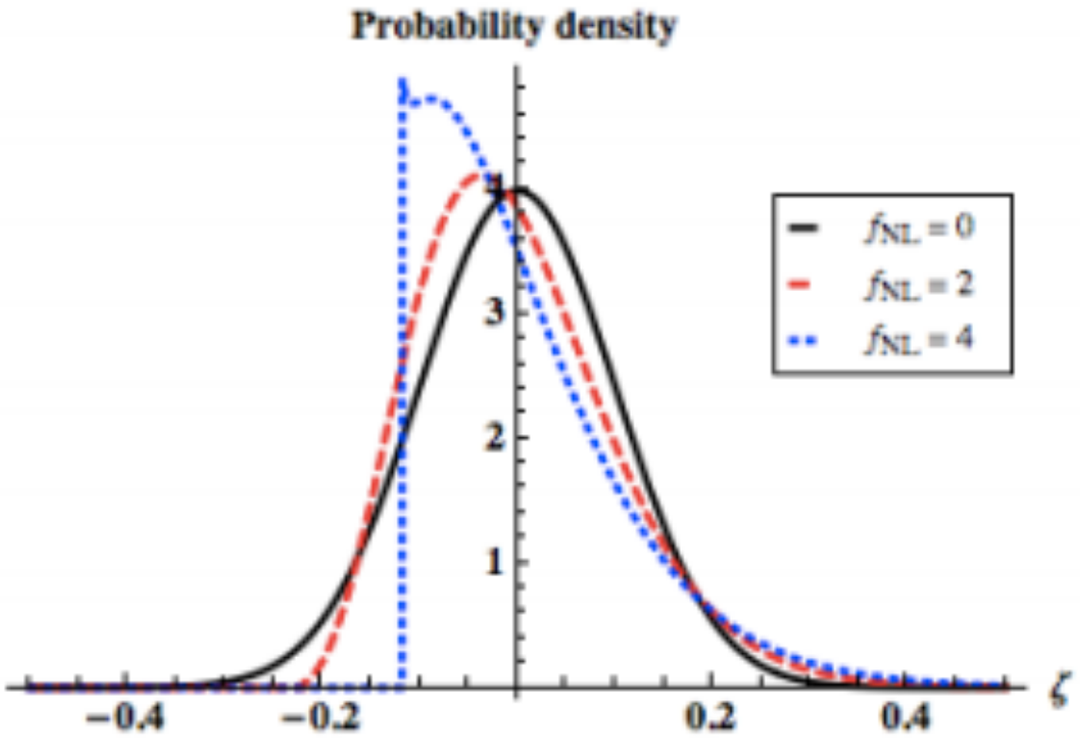
We can’t use the solar system to reconstruct the inflationary potential

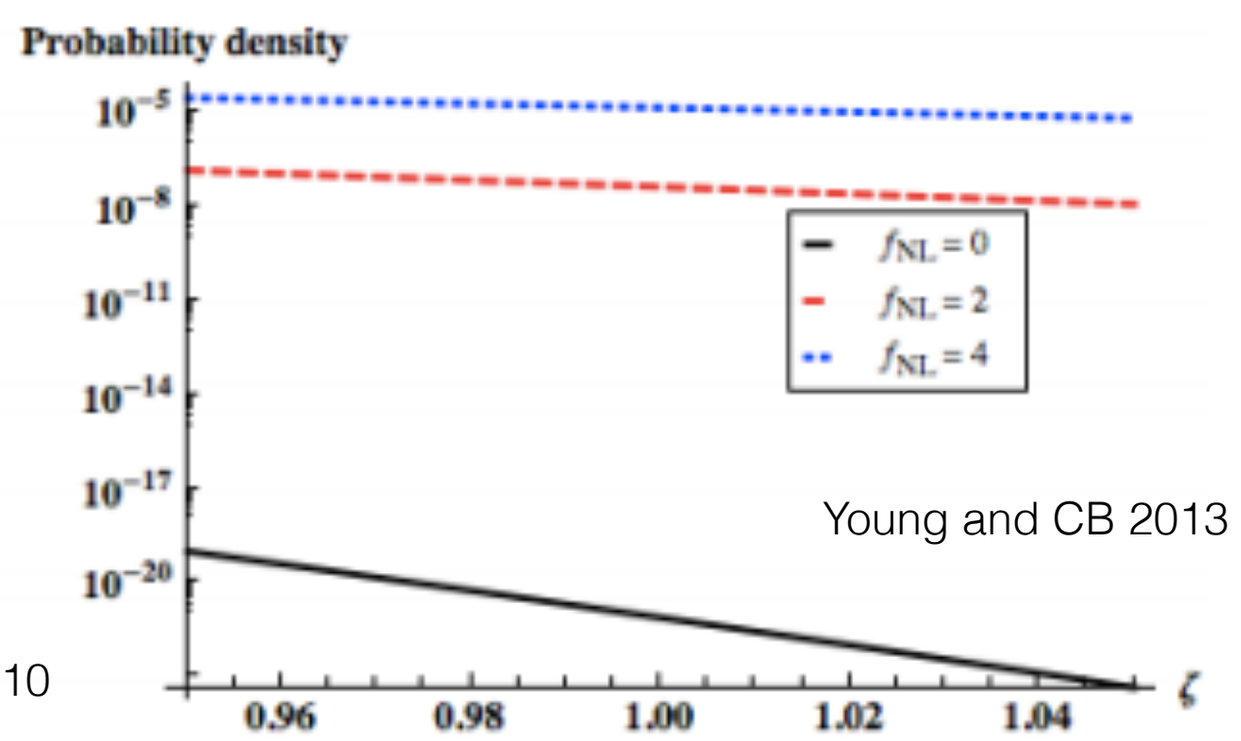
At high redshifts, the small scales are still linear

We can also probe relics such as primordial black holes and primordial gravitational waves

Is dark matter a new particle?

- This is common lore. MOND is having a hard time
- There is one candidate which does not modify gravity or require a new particle - Primordial black holes (PBHs)
- Black holes naturally have all the correct properties (cold, collisionless, neutral)
- To create them, the primordial power spectrum needs to grow from the observed 10^{-9} to ~10^{-2} on small scales
- Possible conflict with gravitational wave constraints, that can be evaded by making the perturbations non-Gaussian. PBHs are extremely rare during formation





Young and CB 2013

PBHs as a DM candidate

- Three possibilities still exist:

1. Asteroid mass M~10^{20} g
2. M~10 solar mass PBHs, very topical since LIGO detected this mass range
3. Planckian mass PBH relics - the nightmare DM scenario!

- They would be too rare to detect directly, too light and stable to detect astrophysically and too heavy to produce in any collider
- Probably the best we can do is rule out inflationary models which allow a significant number density of PBHs to form
- Really tight constraints would not only tell us the inflationary potential, but also which part of the potential we are measuring, and hence how much "room" there is for a second field to produce extra inflation

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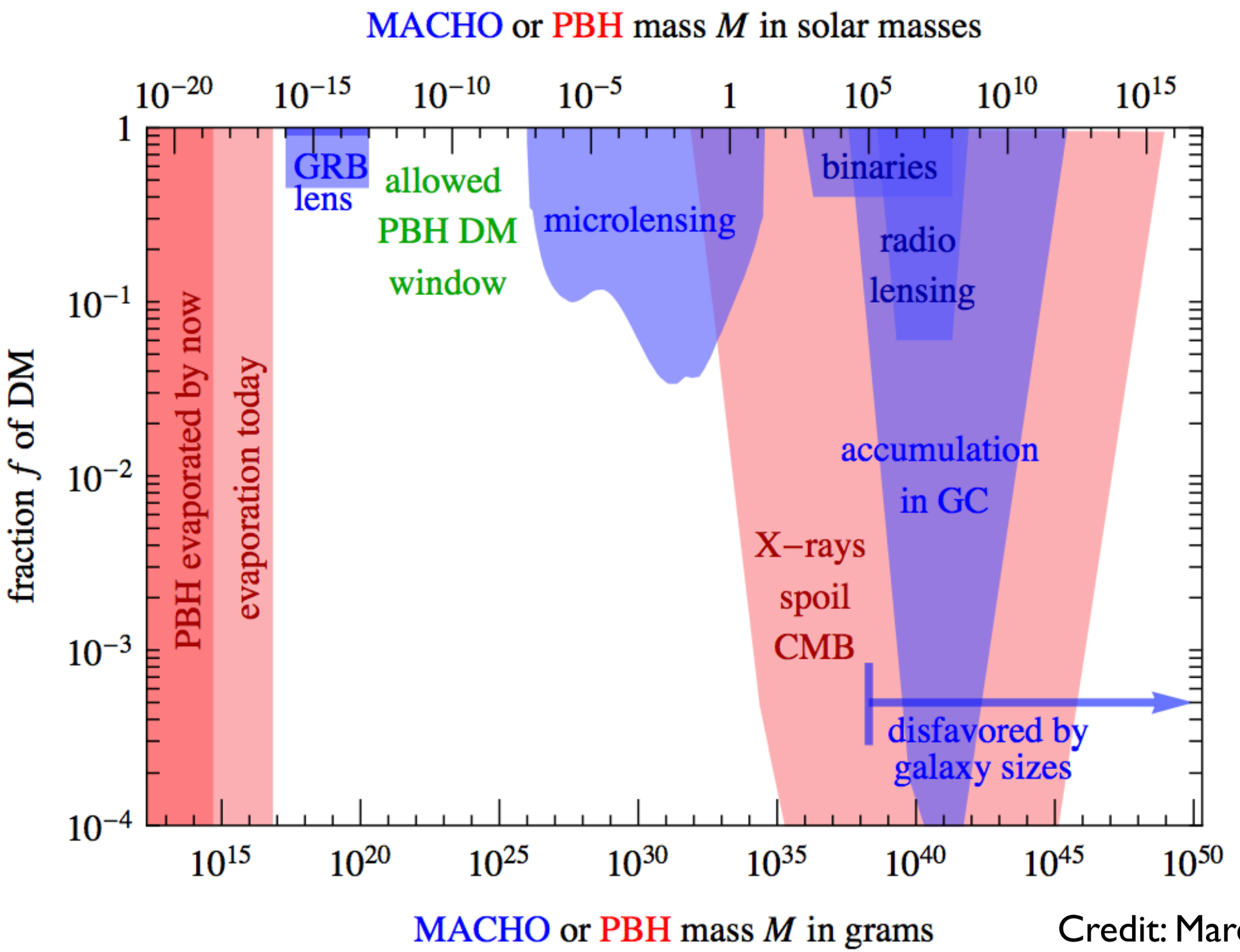
- The dark side of the Moon could provide a bright future for cosmology

Window for heavy PBH as DM



Credit: Marco Cirelli