Reflections

1. Intuition is not enough. Need data!

STAR PRODUCTION IN AN EXPANDING UNIVERSE

INTERPRETING THE COSMIC MICROWAVE BACKGROUND

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THE observation by Penzias and Wilson[1] of an isotropic microwave background, later confirmed by Roll and Wilkinson[2], has received two conflicting interpretations. Dicke, Peebles, Roll and Wilkinson[3] postulate a universe of the type considered by Gamow[4], in which the energy density of radiation exceeds that of matter near the beginning of the expansion, and interpret the observed radiation field as a remnant of the initial 'flash'. According to the second interpretation, the observed radiation was emitted between 10 and 10^5 years after the beginning of the expansion by ionized hydrogen at a nearly constant temperature in the range 10^4–10^6 °K. Miss Kaufman[6] has shown that this model[5] is consistent with the observations of Penzias and Wilson and of Roll and Wilkinson as well as with measurement of the radio-noise background between 10 and 400 Mc/s. At millimetre wave-lengths, where no measurements have as yet been made, the constant-temperature model predicts a much lower value

$$\mathbf{v} = S(t)\,\frac{d\bar{\mathbf{x}}}{dt} \qquad (4)$$

where the components of $\bar{\mathbf{x}}$ are 'co-moving' spatial co-ordinates. Energy exchange between the radiation field and the matter is described by the equation:

$$\frac{d}{dt}(\varepsilon_r S^3) + p_r \frac{dS^3}{dt} = (q-r)S^3$$

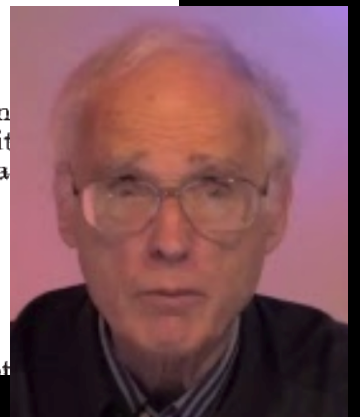
where q and r represent, respectively, the mean emission and absorption of radiant energy per unit On inserting equations (2) and (5) in (1), we obta

$$\frac{d}{dt}(\varepsilon' S^3) + p' \frac{dS^3}{dt} = (-q + r)S^3$$

where

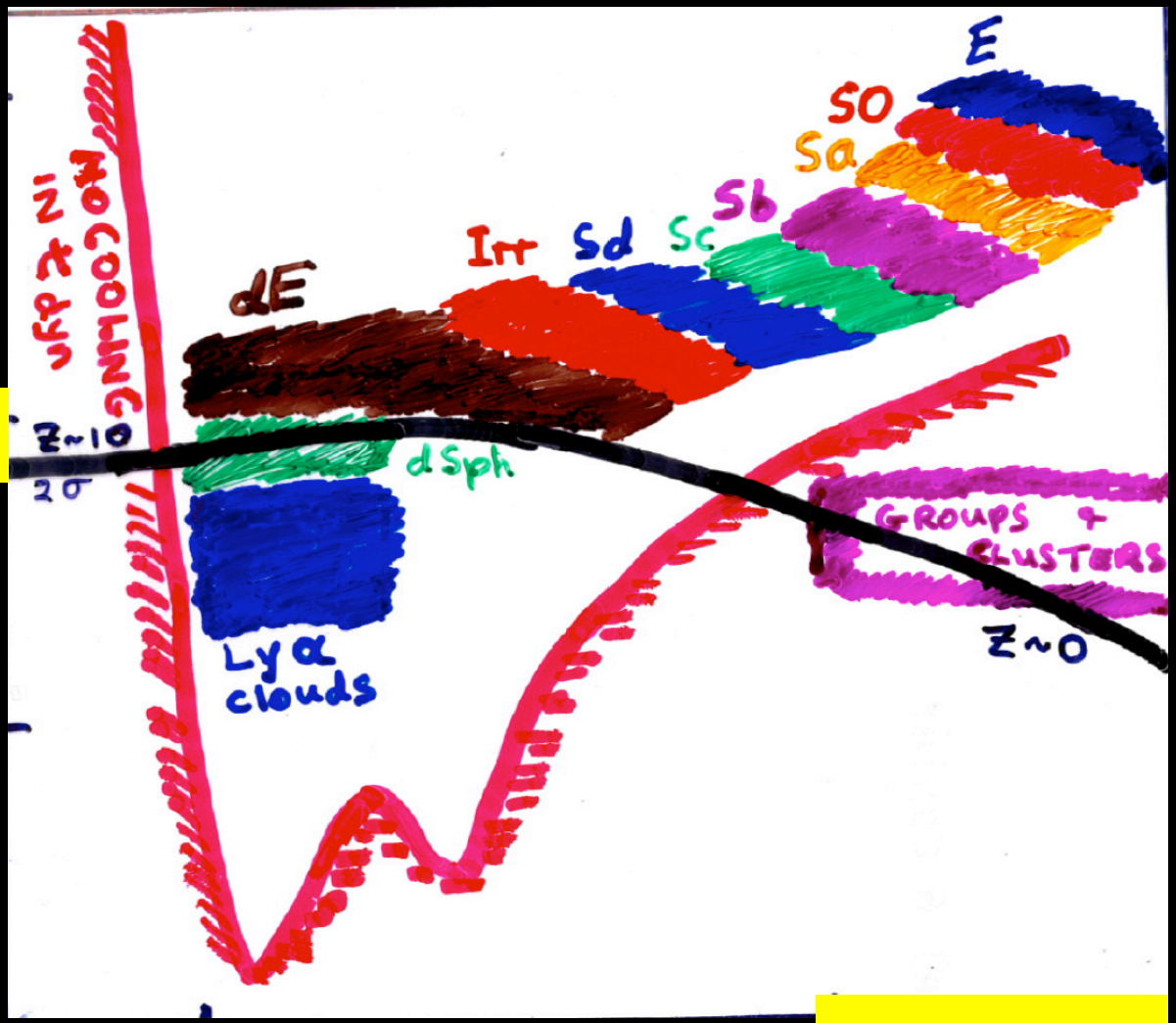
$$\varepsilon' = \varepsilon_k + \varepsilon_g, \quad p' = p_k + p_g$$

Radiative processes always act to diminish the $\varepsilon' S^3$, because in an expanding universe phot

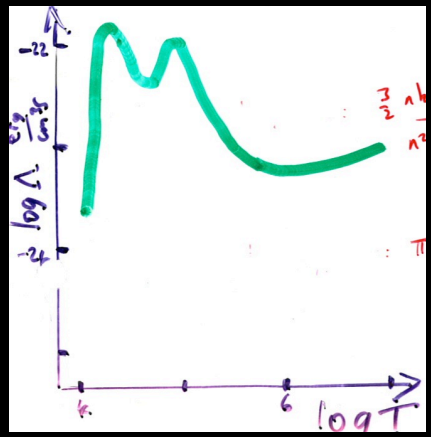



2. Be there at right time, right place
1966

3. Galaxy formation: do analytics but don't forget the data or pretty colours



H, He cooling function



1983Natur.301..574S

4. 1984: choose a new interdisciplinary field where there is a gap to be bridged

experiments to be developed
theory to be defined

DARK MATTER

Where next in cosmology?

1. Dark energy

- experiment

Euclid, DESI, LSST, PFS…

- No end in sight

- theory

Something new needed

Quintessence?

Multiverse ??

Where next in cosmology?

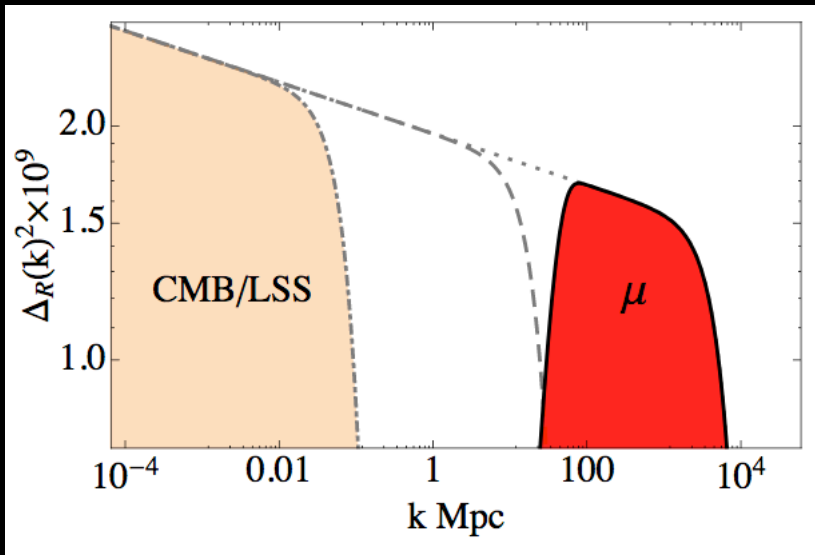
2. the CMB

to B or not to B

no robust prediction

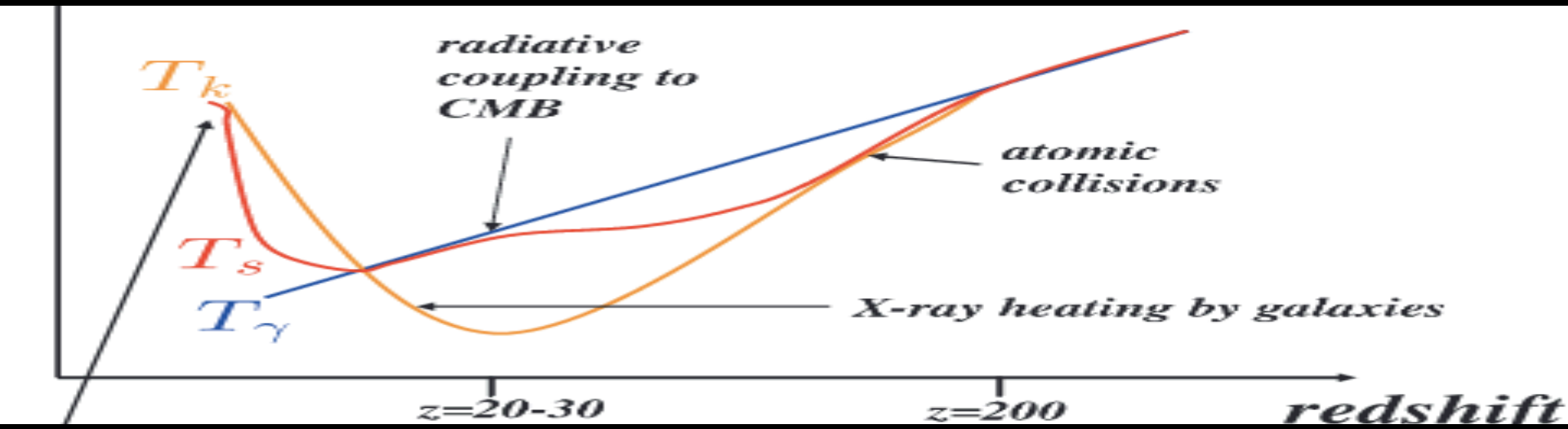
Spectral distortions

Just one number

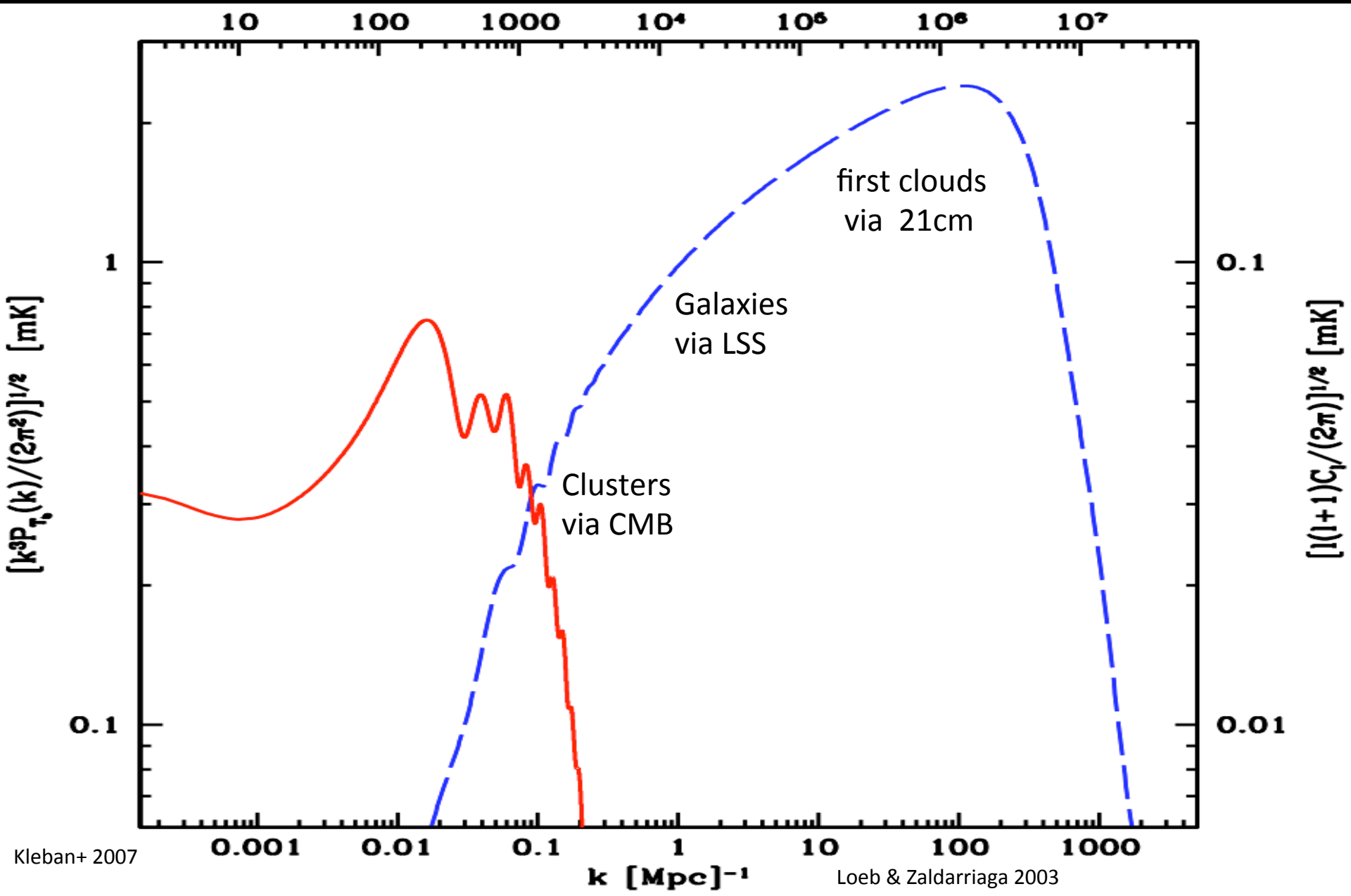


Where next in cosmology?

3. the dark ages



21cm @ z=50 @ 30 MHz @ k~ 100 Mpc^{-1}



Kleban+ 2007

Loeb & Zaldarriaga 2003

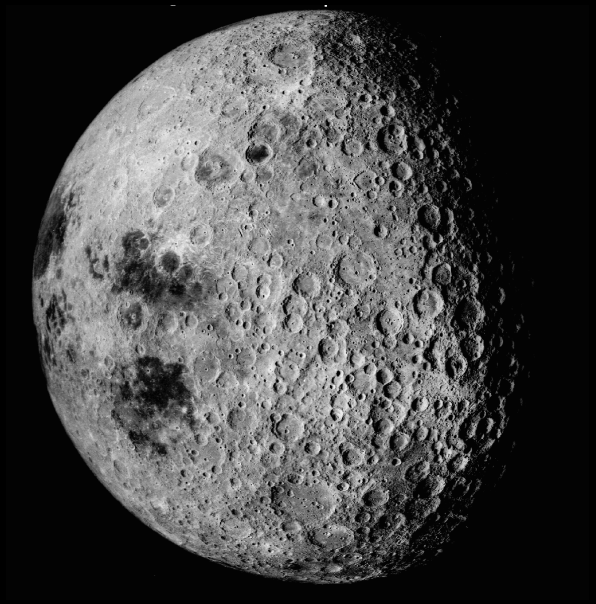
Primordial nongaussianity is predicted generically by inflation but its very low:

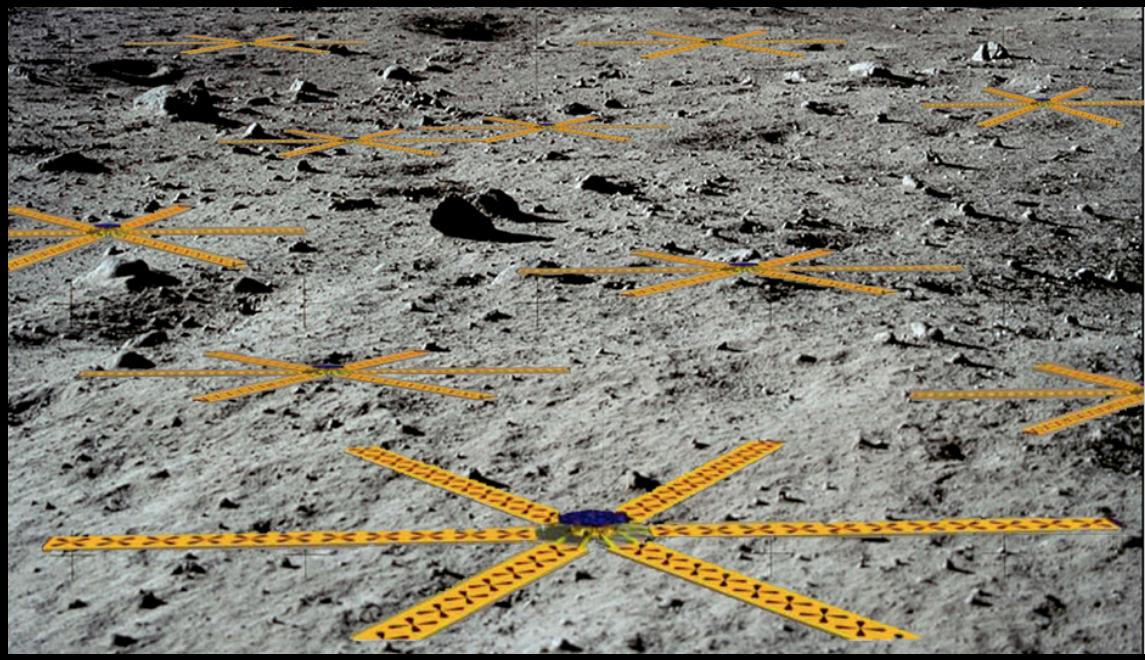
$f_{NL} \sim n_s - 1 \sim 0.03$ $\qquad\qquad$ $\delta T/T\ (1 + f_{NL}\ \delta T/T)$

need to go from $f_{NL} \sim 10$ (CMB) to ~1 (LSS) to ~0.01

- $N \sim 10^6$ modes precision 0.1% CMB
- $N \sim 10^8$ 0.01% LSS
- $N \sim 10^{12}$ (w. x 10^2 from tomography) 0.0001% 21cm@ 30 MHz

far side of MOON is most radio-quiet environment in inner solar system



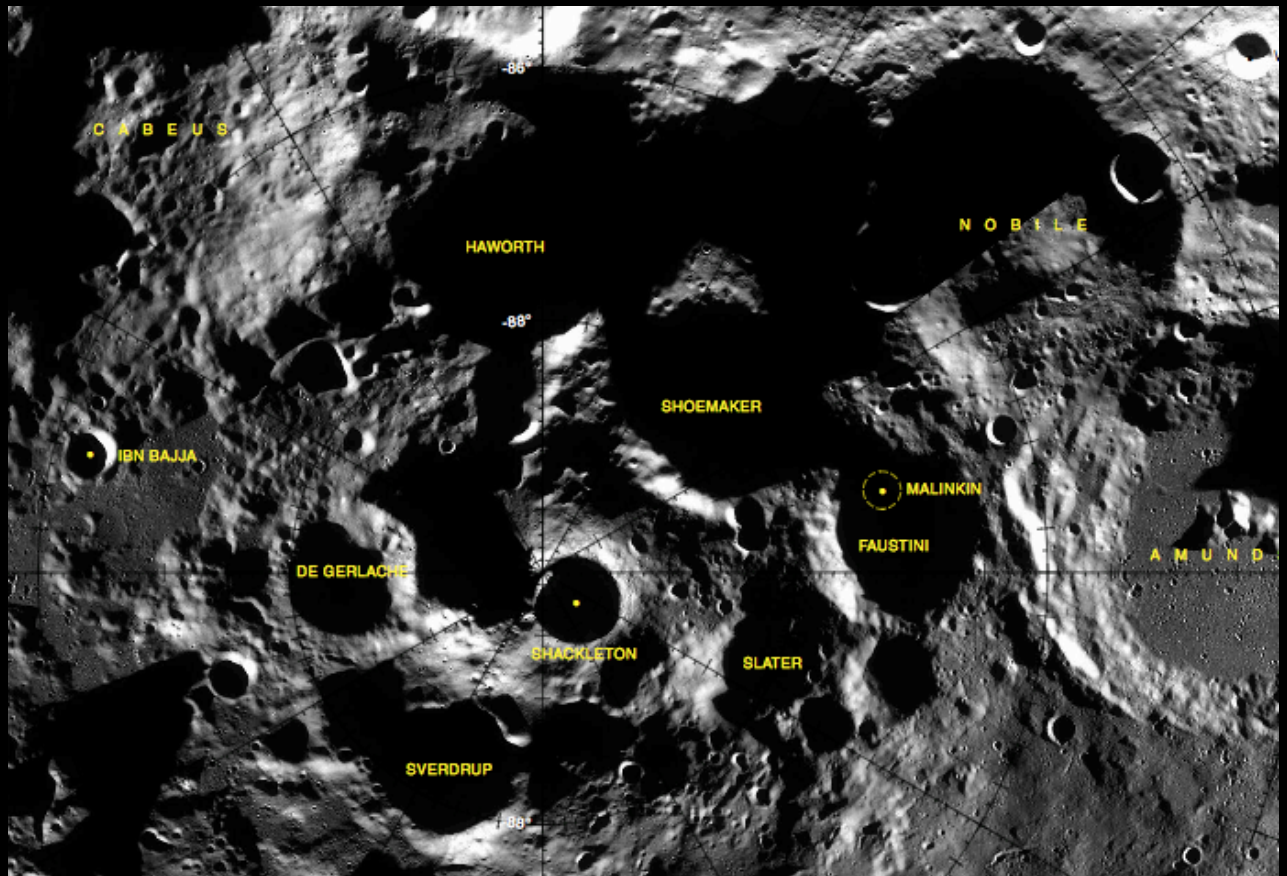


Optimal telescope array is $\ell\lambda/2\pi$ or D ~100 km at λ~ 10 m

need millions of dipoles for weak signal: $\frac{D^2}{4\lambda^2}$ ~10^7

seek ~10mK signal in bright sky foreground T_B~1000K

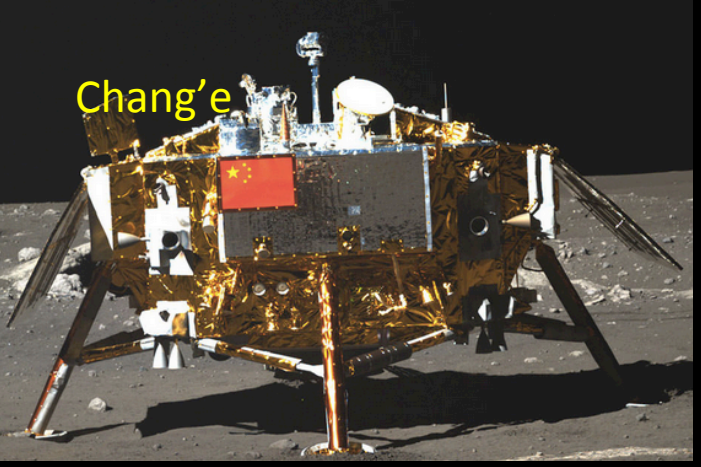
lunar south pole sites for IR astronomy



Shackleton crater

eternal darkness & cold

la lumiere perpetuelle



When?

Europe's space boss says 'now is the time to build a moon village' and pledges permanent lunar base by the end of the next decade

- **ESA said the Moon was the 'right place to be' and Mars is 'ultimate destination'**
- **Said immediate goal was to have a permanent presence on the Moon, even if it was just a robot, by the end of the next decade**

By AFP
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Current US presence

Trump wants to send U.S. astronauts back to moon, someday Mars

WASHINGTON (Reuters) - At a time when China is working on an ambitious lunar program, President Donald Trump vowed on Monday that the United States will remain the leader in space exploration as he began a process to return Americans to the moon.

U.S. President Donald Trump holds a space astronaut toy as he participates in a signing ceremony for Space Policy Directive at the White House in Washington D.C., U.S., December 11, 2017. REUTERS/Carlos Barria

Un grand merci a
Elizabeth,
Gary,
Yohan et
Madeleine!

Thank you all for coming to Paris…its been a wonderful occasion to reflect on Dark Matters!