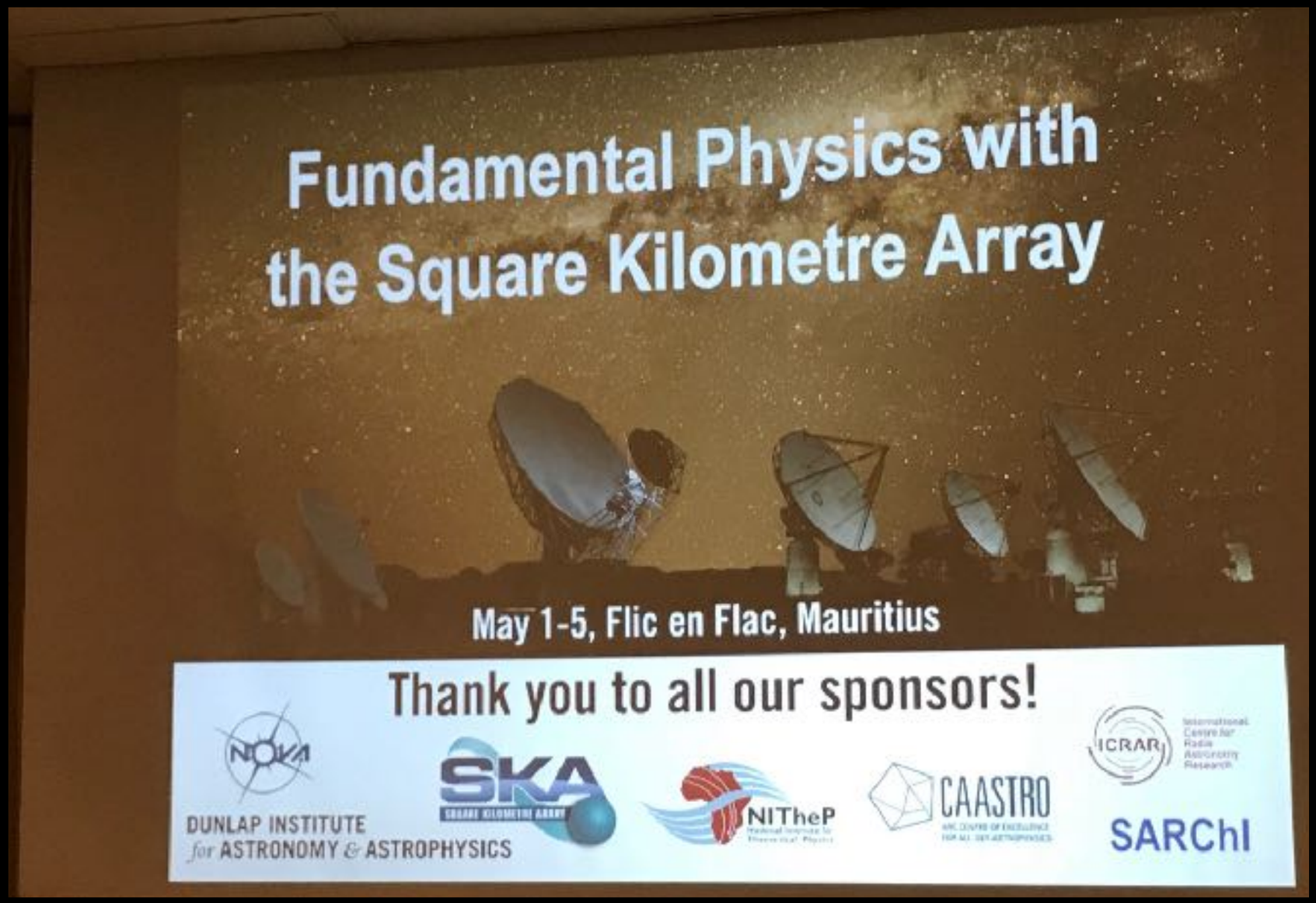
Fundamental Physics & SKA



Invited Speakers
Bernard Asabere (Ghana)
David Bacon (UK)
Rennan Barkana (Israel)
Celine Boehm (UK)
Phillip Bull (USA)
Tamara Davis (Australia)
Nadir Hashim (Kenya)
Nalini Heeralall-Issur (Mauritius)
Gemma Janssen (Netherlands)
Julien Larena (South Africa)
Samaya Nissanke (Netherlands)
Frans Pretorius (USA)
Jonathan Pritchard (UK)
Signe Riemer-Sørensen (Norway)
Joe Silk (UK)
Kurt Van Der Heyden (South Africa)

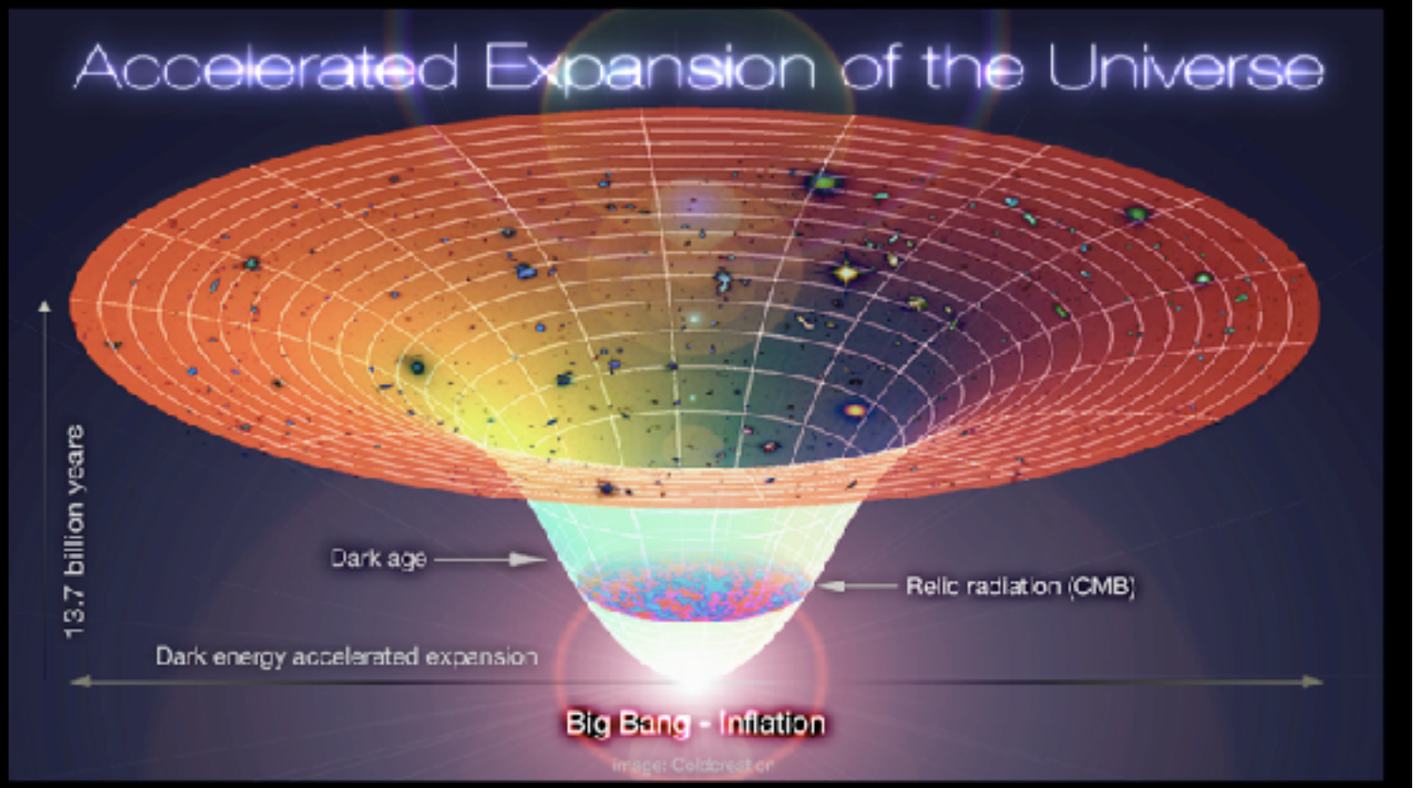
- **Cosmology and Dark Energy**
- **Cosmic Dawn and Reionisation**
- **Dark Matter and Astroparticle Physics**
- **Gravity and gravitational radiation**

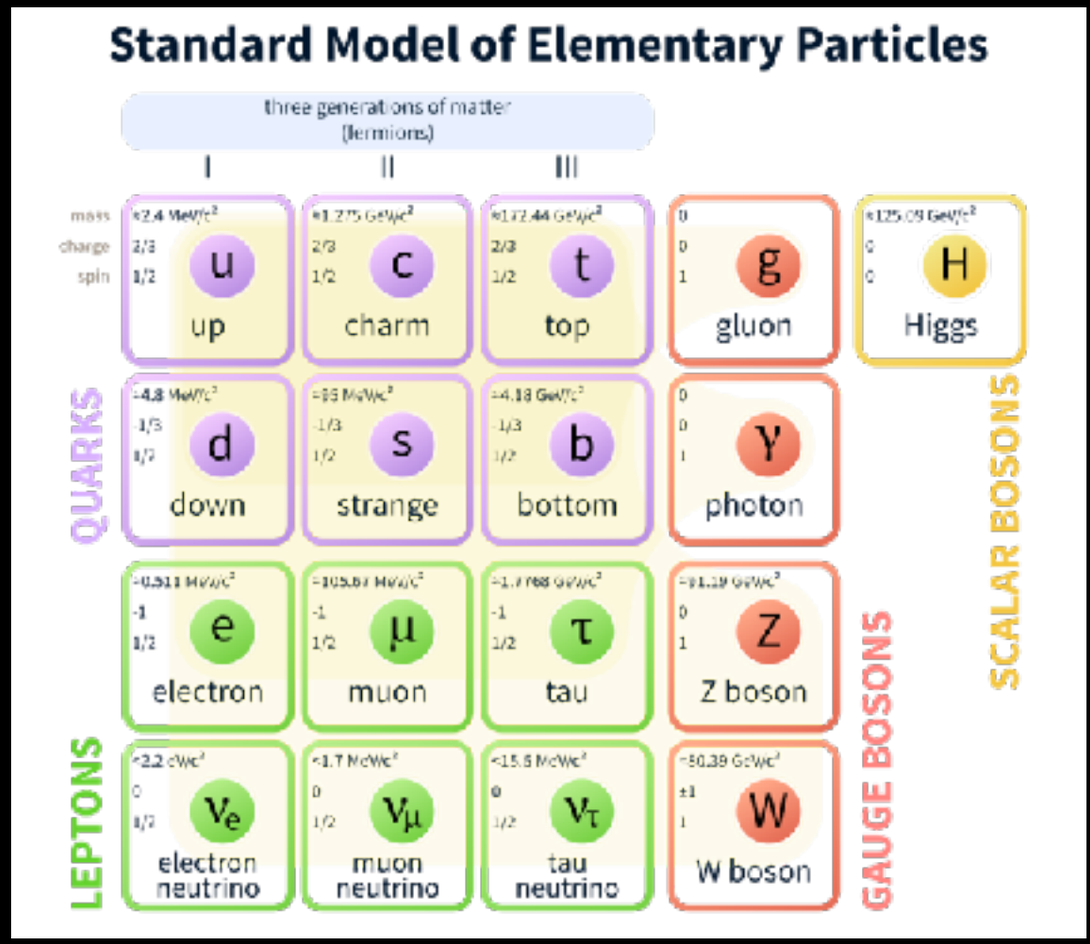
Product Disclosure Statement

Fundamental Physics with the SKA - a summary

- This is presented by someone who does not fully understand, or is working on, most of what is being talked about!
- I am biased
- This is incomplete… mostly..
- It’s brief…

Standard models

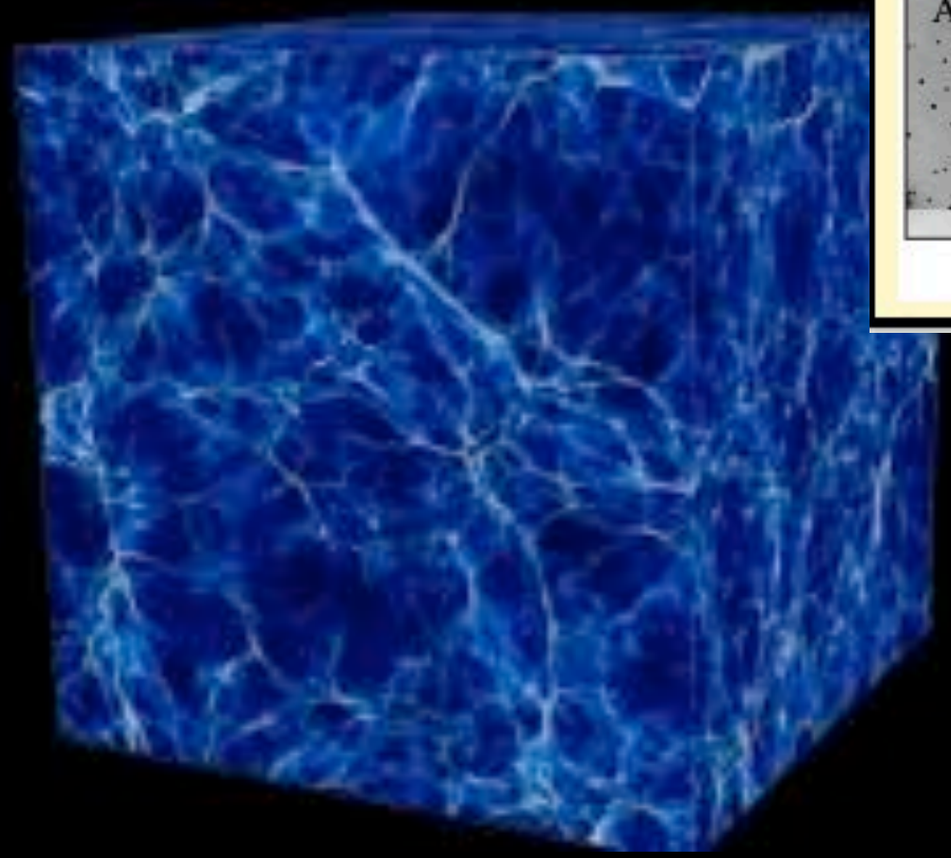


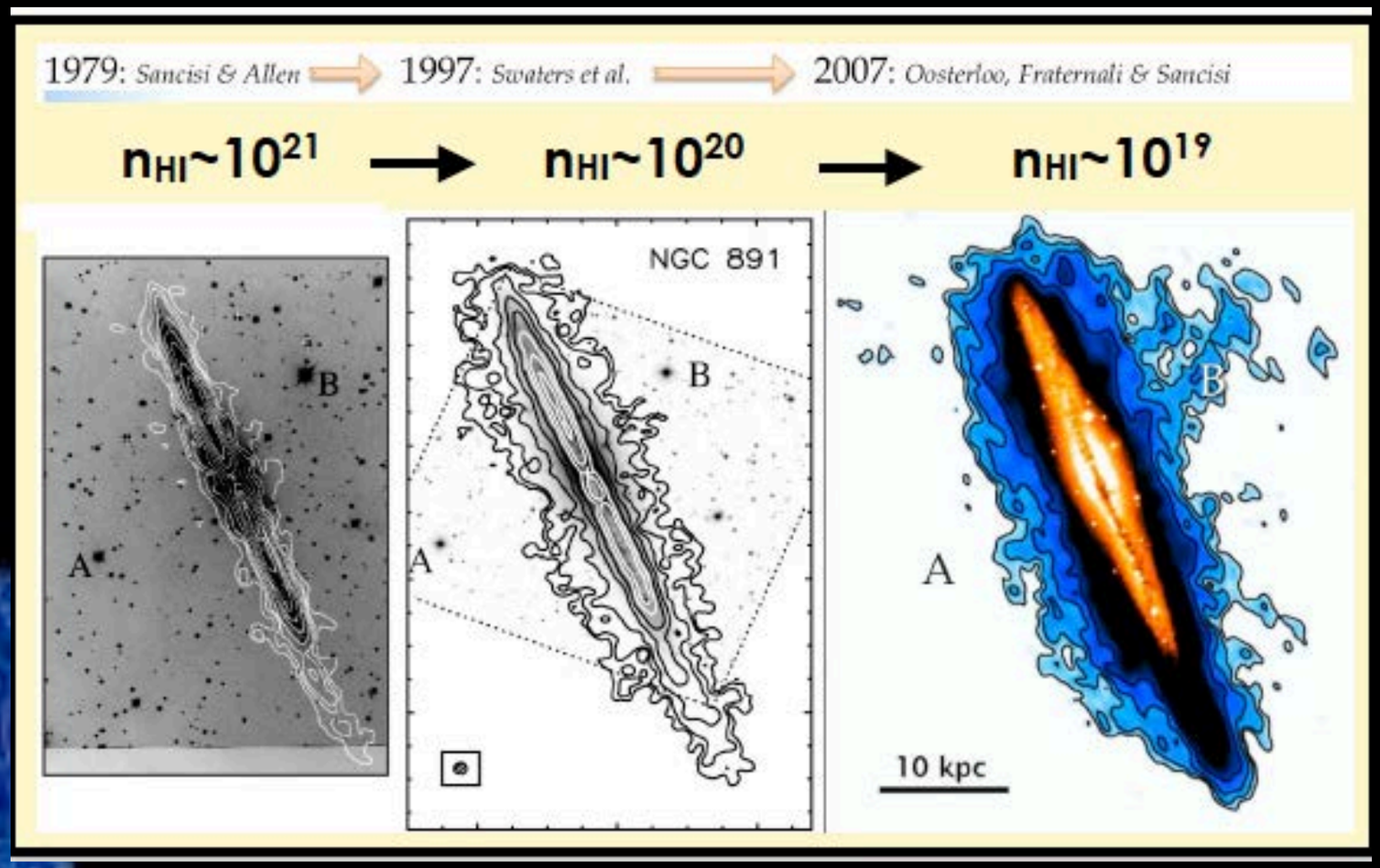


ΛCDM + GR

Both are very successful
Both make testable predictions
Both have parameters determined by experiment and not theory
Both require (maybe the same) new ideas/physics to be complete

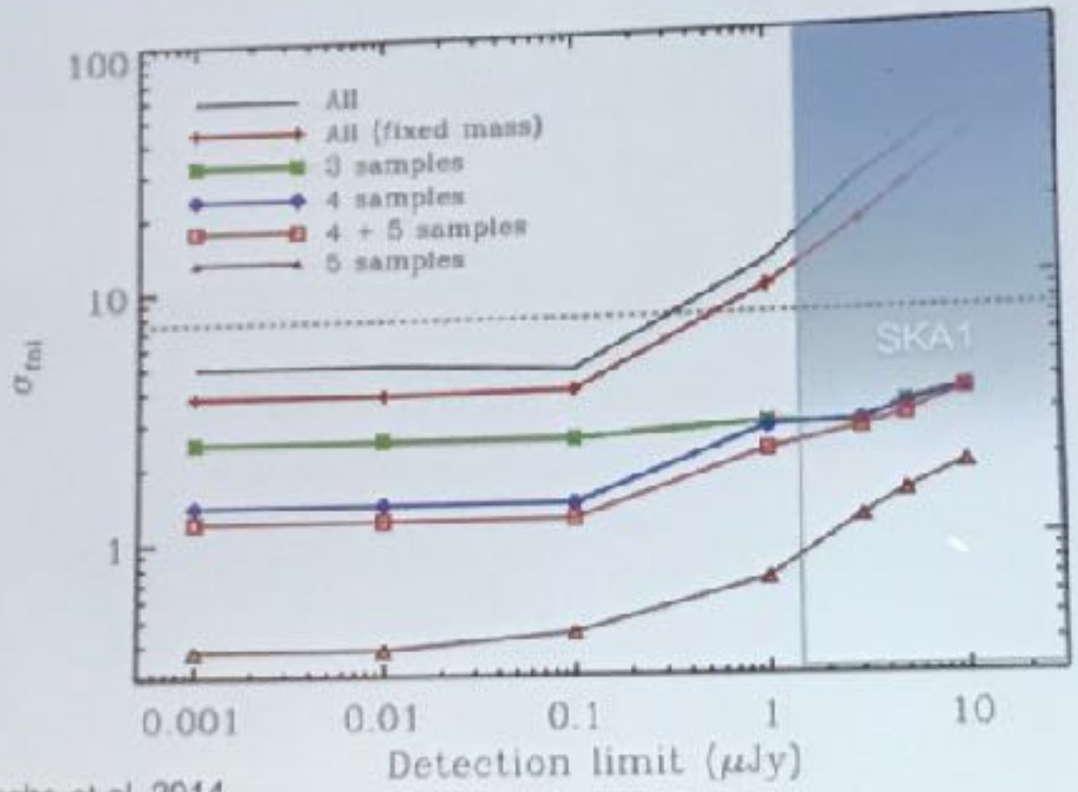
Testing predictions





Testing predictions

Primordial non-Gaussianity



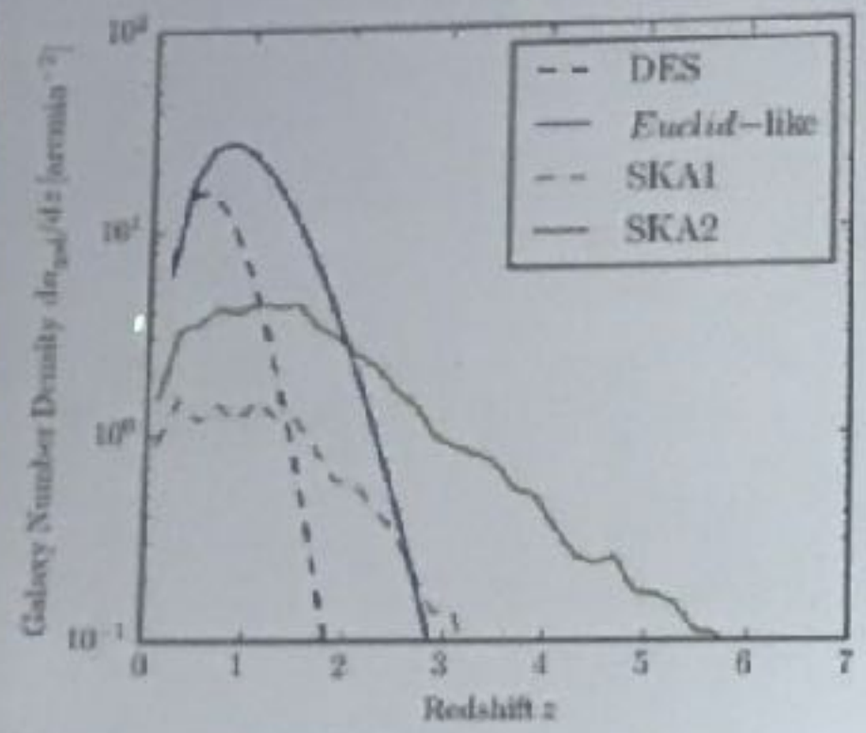
Ferramacho et al. 2014

Exploring the Universe with the world's largest radio telescope

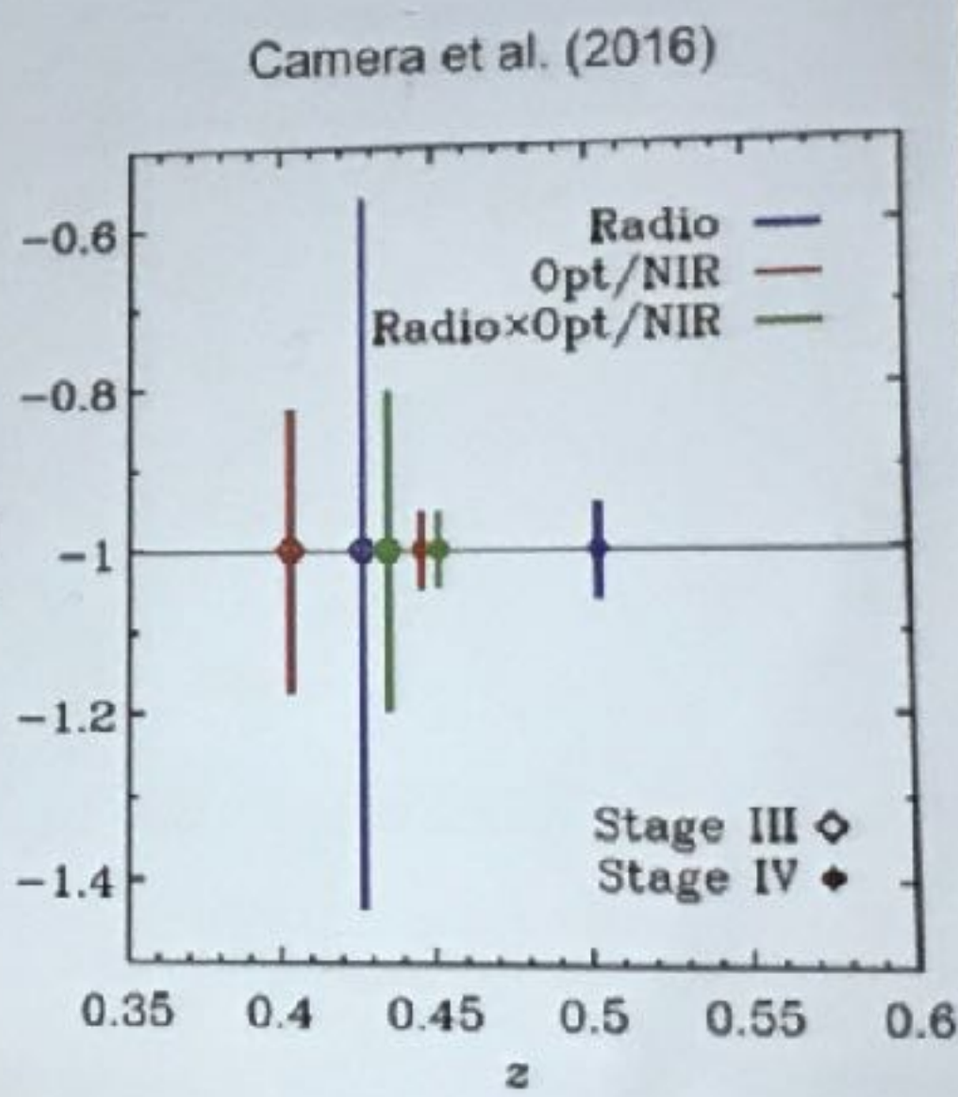
1 May 2017

Testing predictions

Dark Energy



Harrison et al. (2016)



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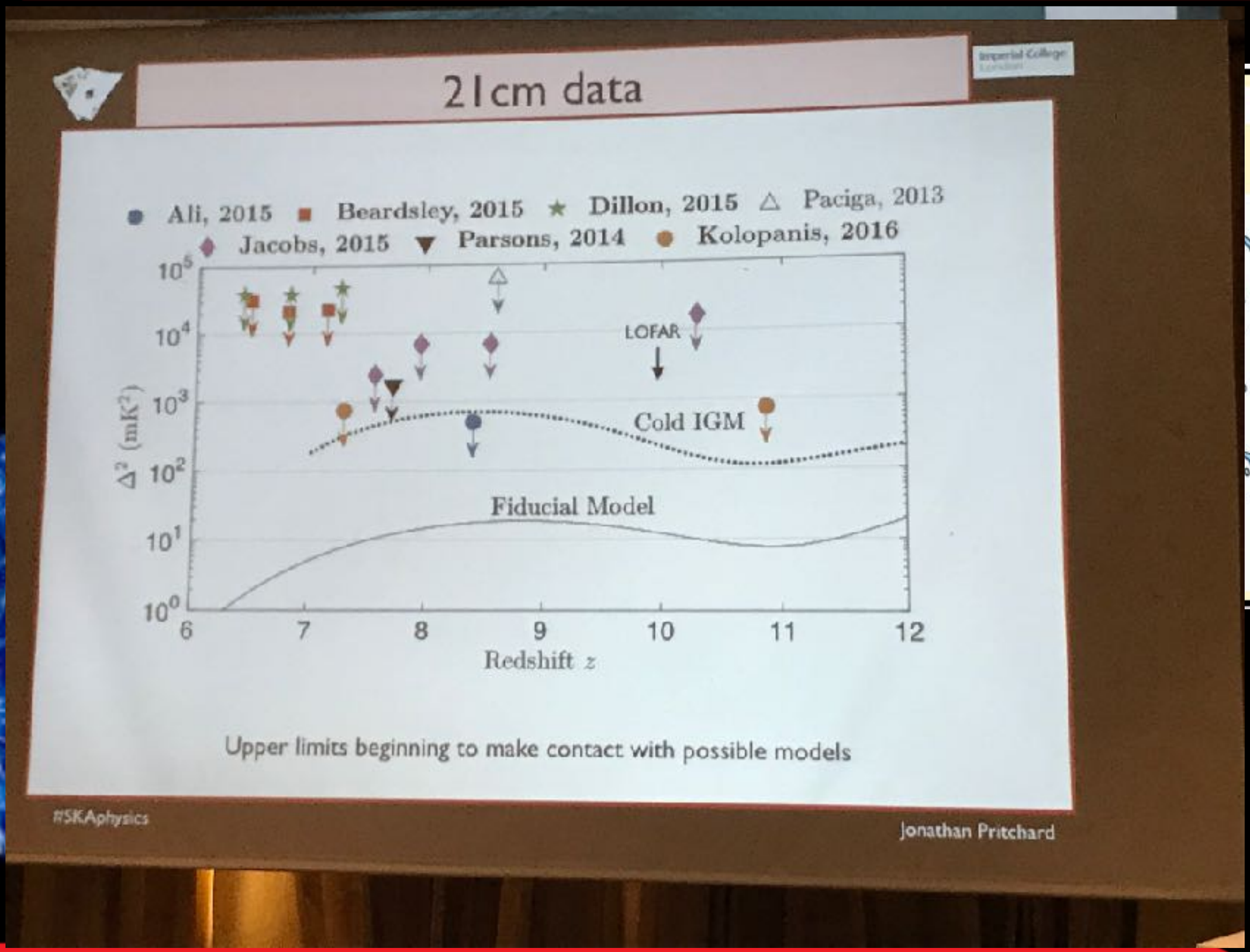
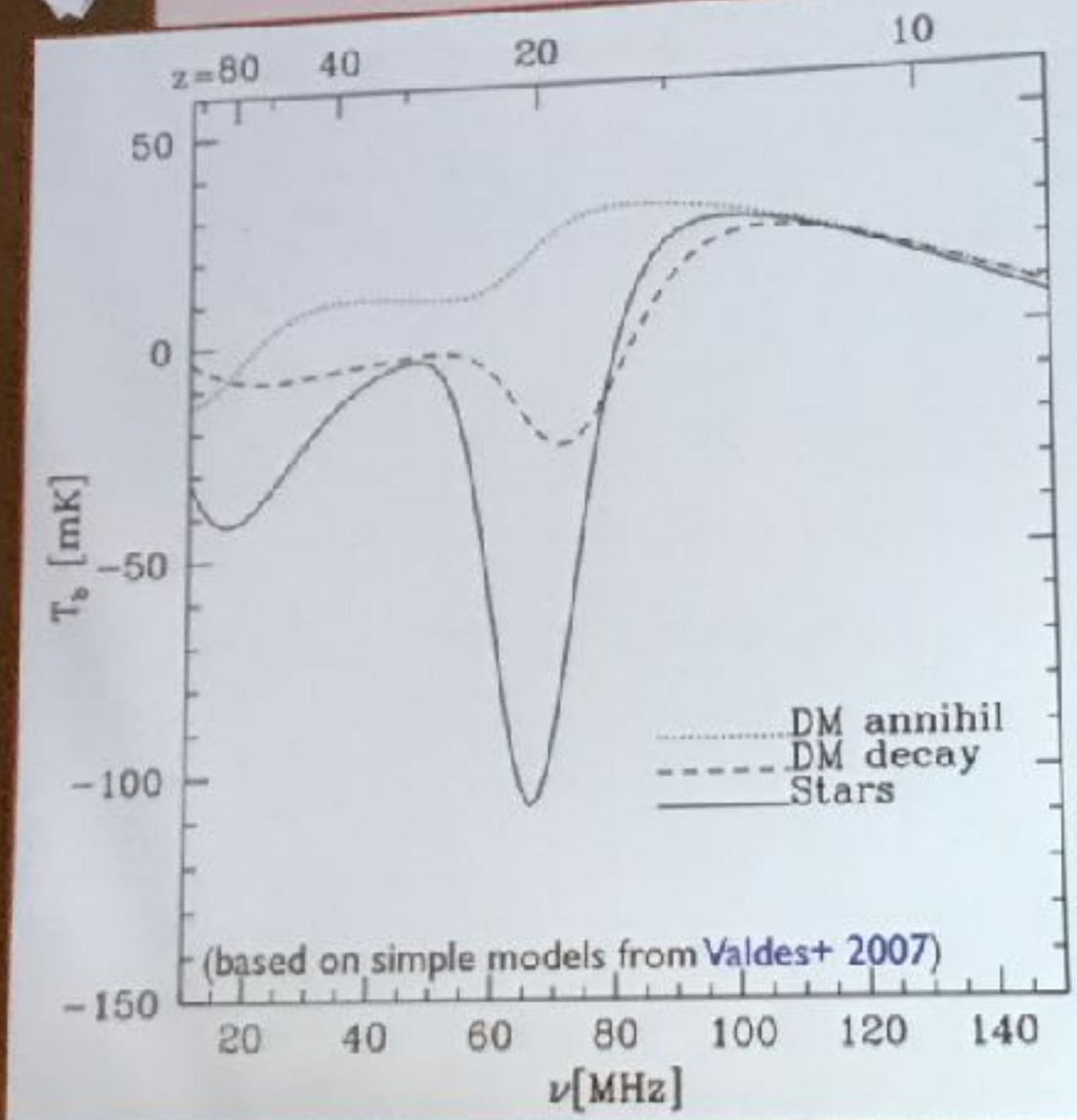
Testing predictions



Testing predictions

Calorimetry and exotic physics



Dark matter decaying after recombination might impact thermal history

Possibilities for exotic energy injection:

DM annihiliation/decay
Furlanetto+ 2006
Valdes+ 2007

Excited DM relaxation
Finkbeiner+ 2008

Evaporating primodial BH
Mack+ 2008

Cosmic string wakes
Brandenburger+ 2010

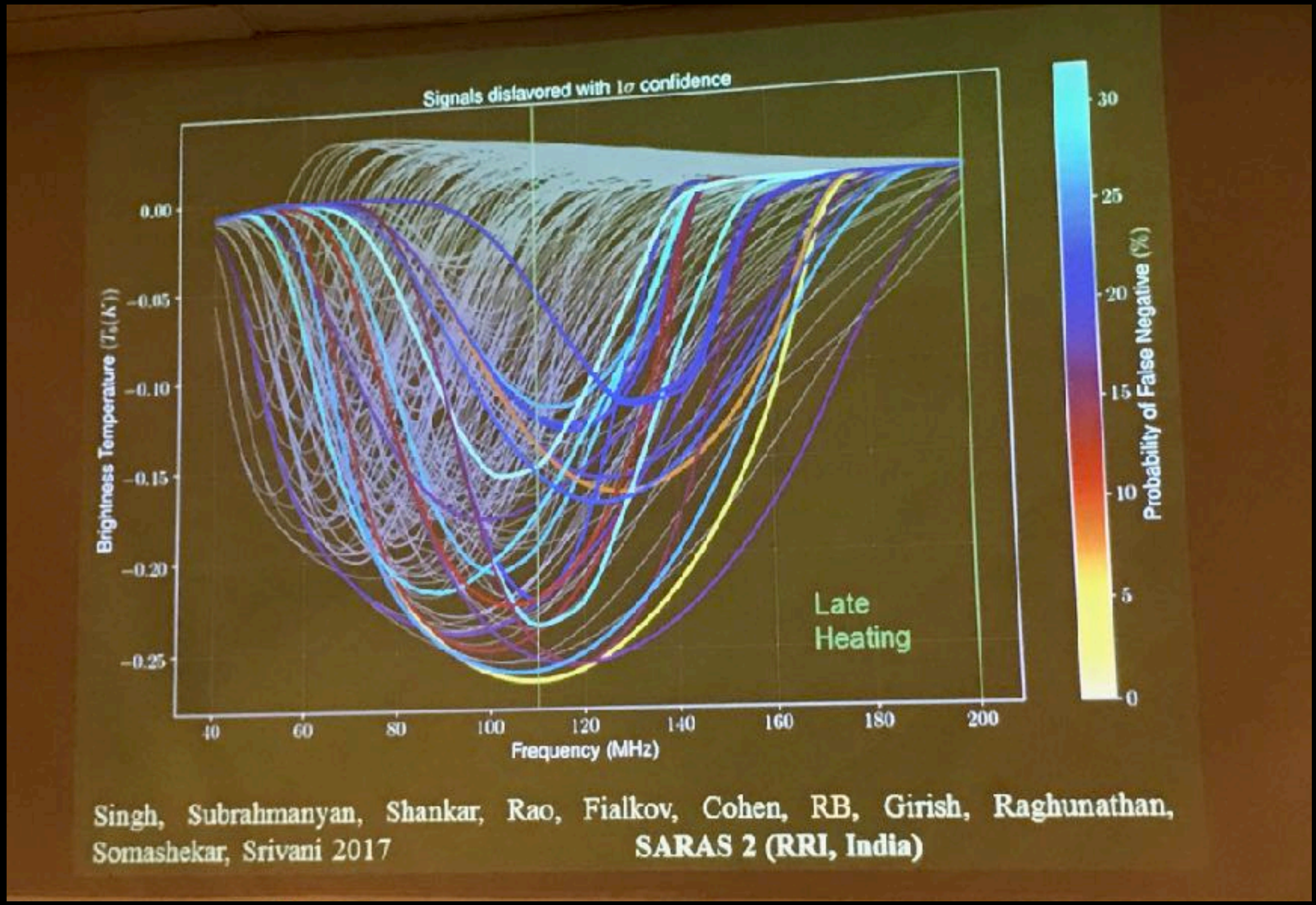
primordial magnetic fields
Shiraishi & Tashiro

...

#SKAphysics

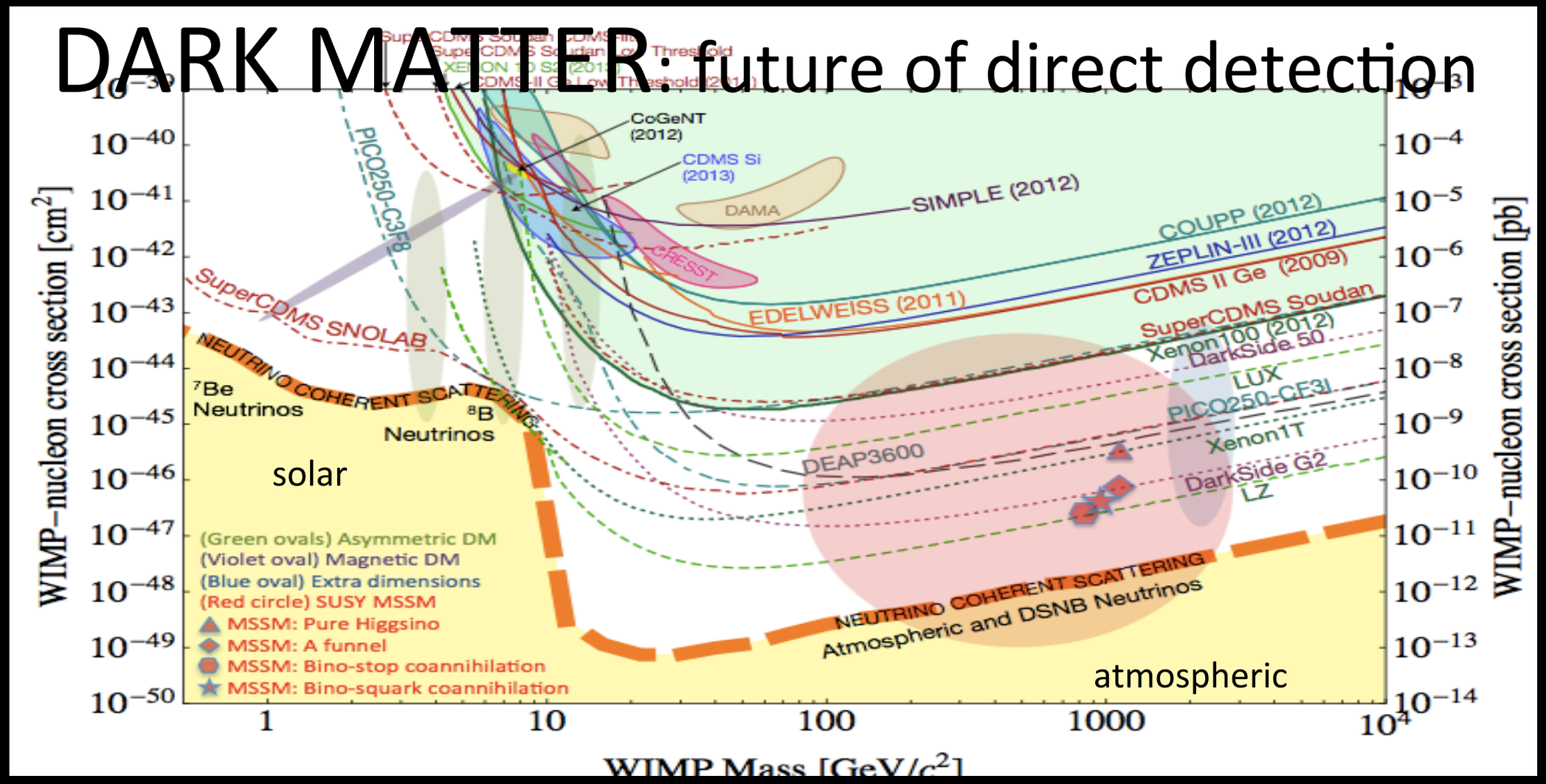
Jonathan Pritchard

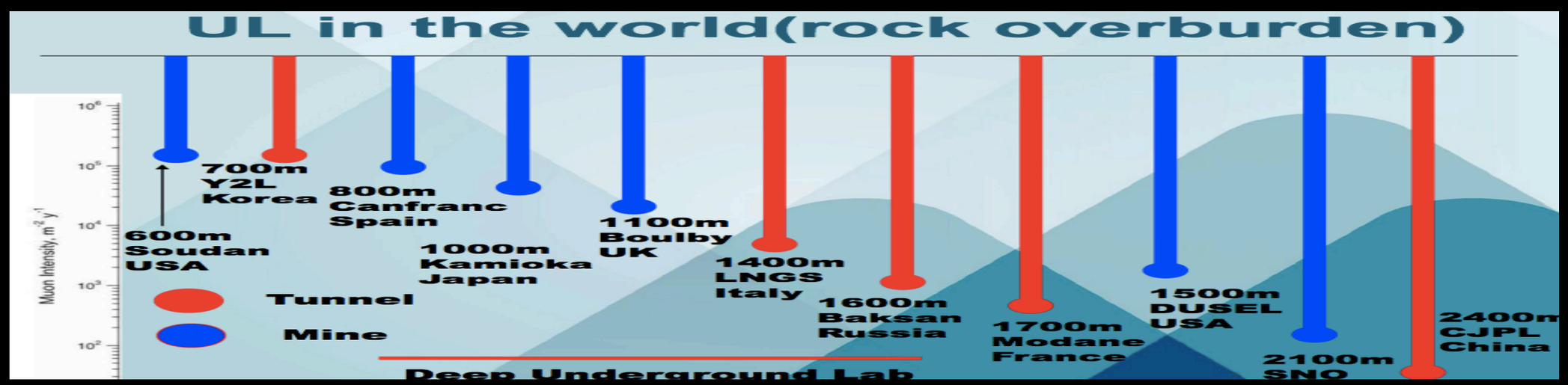
Some parameters required!



BIG Unknowns

DARK MATTER: future of direct detection





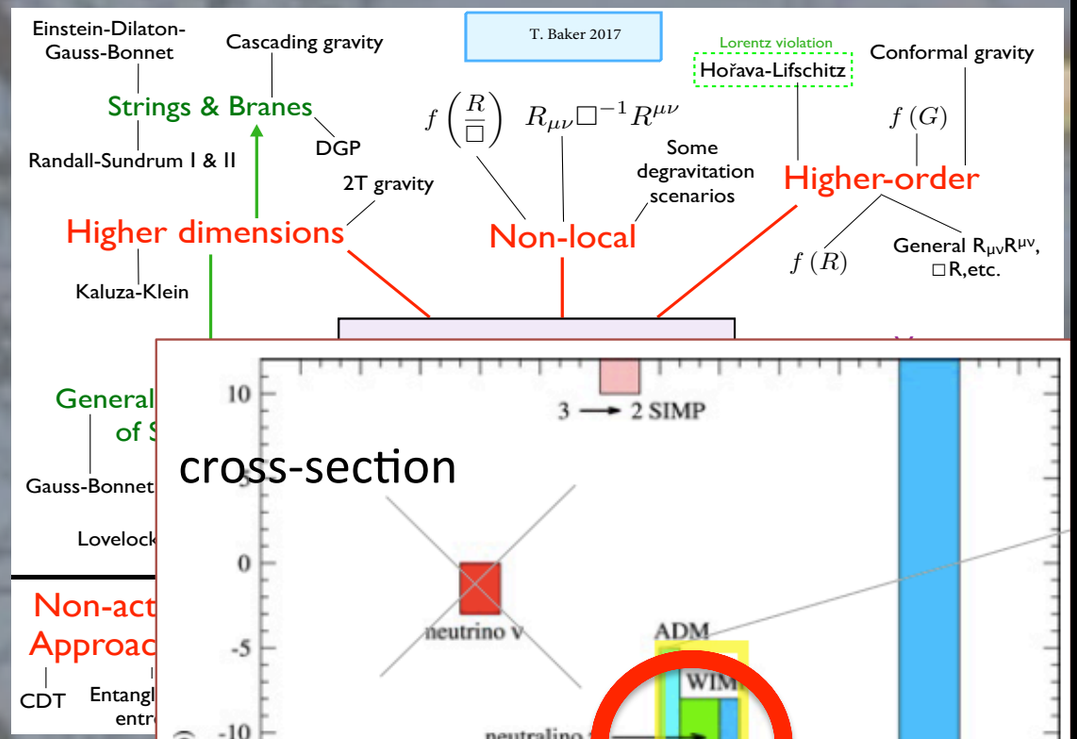
BIG Unknowns

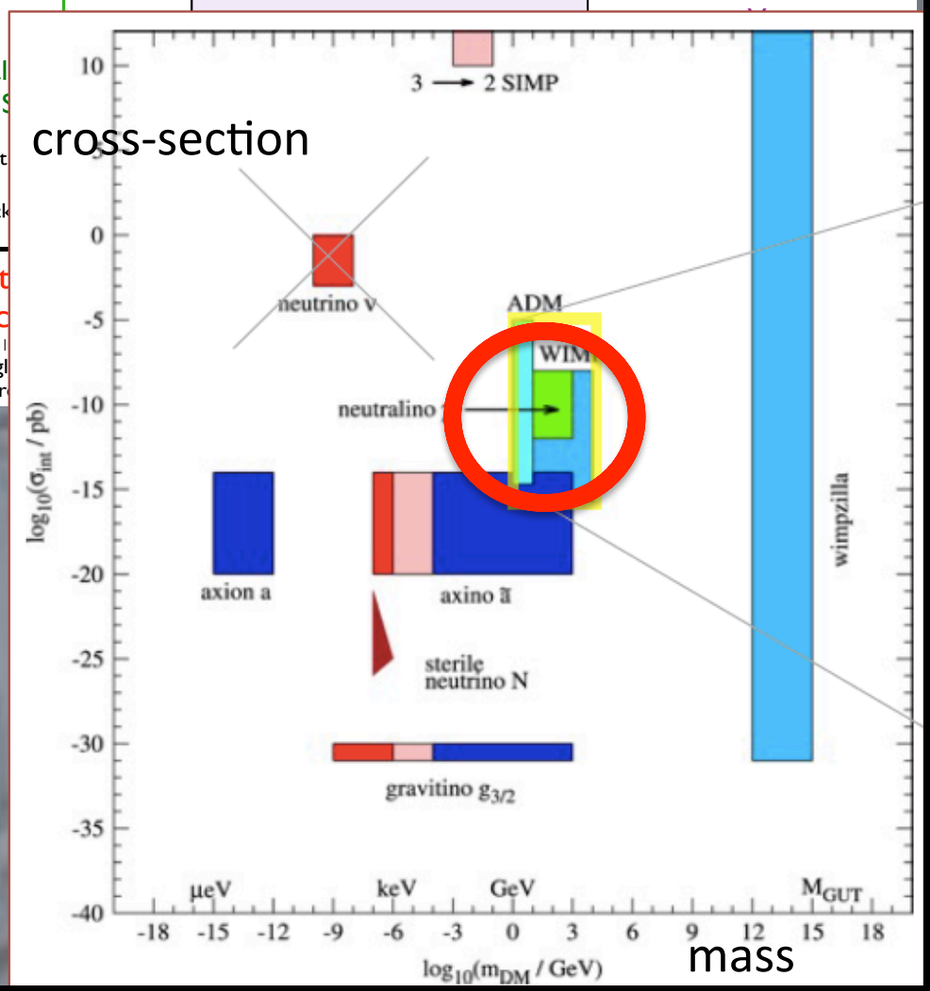
DARK MATTER

What if we don't find dark matter in the next decade(s)?

So far, modifying gravity is ugly and doesn't work!

Look elsewhere!





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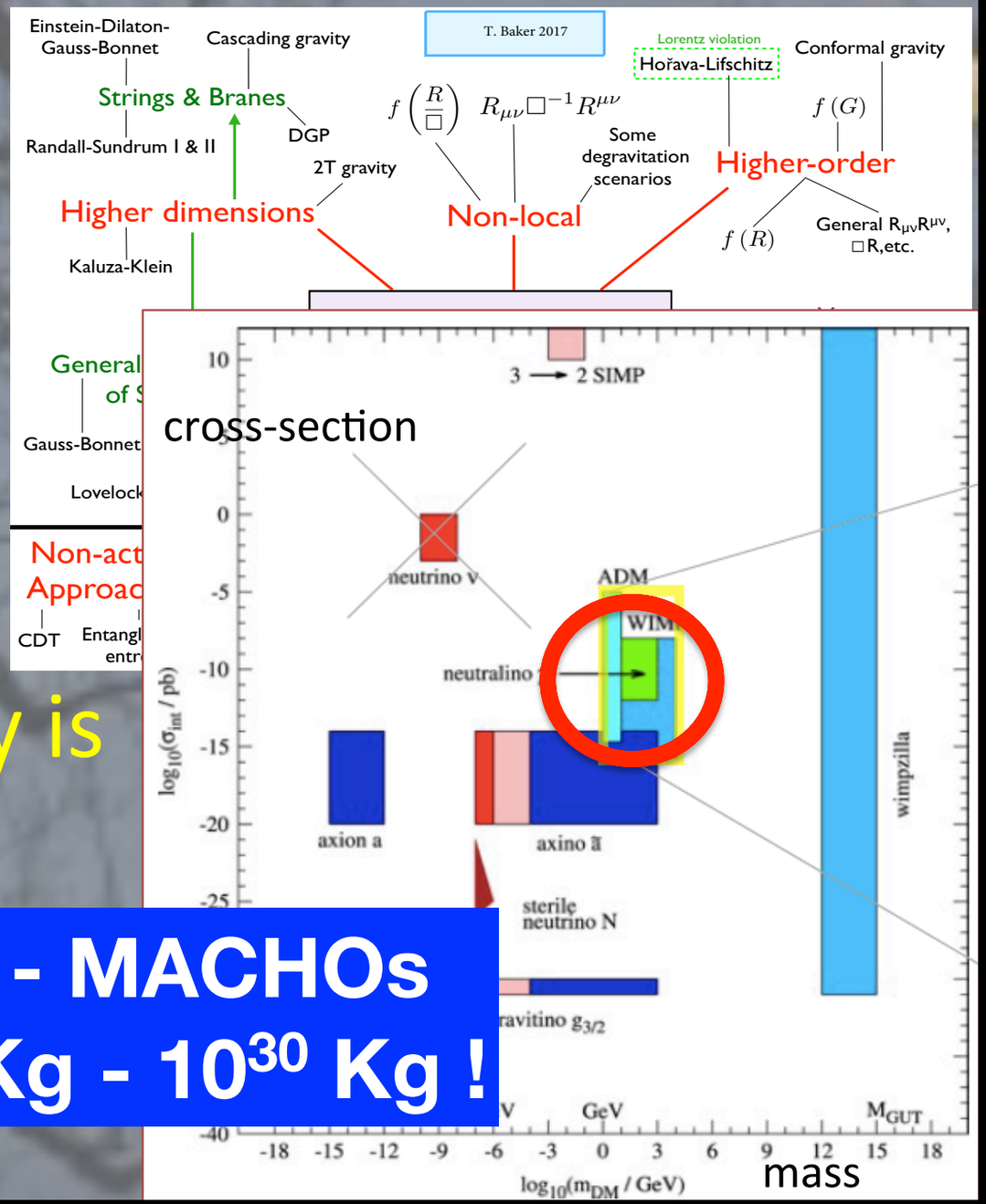


ALP - MACHOs
10^{-55} Kg - 10^{30} Kg !

BIG Unknowns

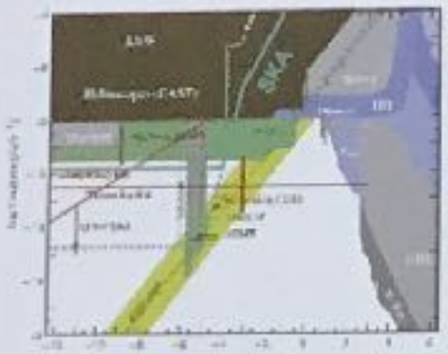
(incomplete) DM candidate list in the SKA perspective

10^{-22} eV

"Fuzzy" Dark Matter
$\lambda_{dB} \sim 1$ kpc ~ size dSph Galaxy

[Hui, Ostriker, Tremaine, Witten 2016]

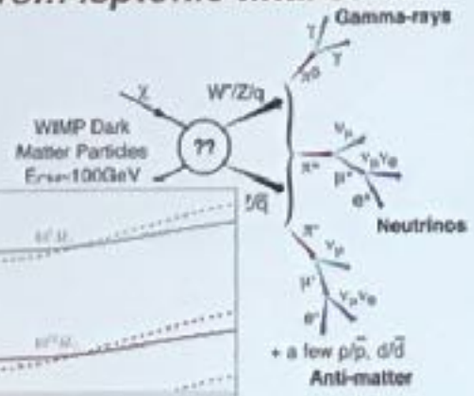
Axion-like particles
*—> **SKA** can constrain the parameter space probing pulsar, magnetars, isolated neutron stars*



1 GeV 1 TeV

Weakly interacting massive particles (WIMPS)
e.g. lightest neutralino state in MSSM

—> SKA will provide strong contraints on radio emission from leptonic final states



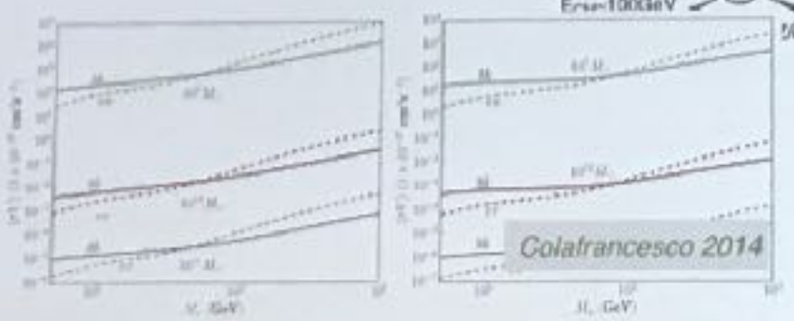


Figure 5: The ⟨σv⟩ upper limits from 30 hour of SKA integration time for $z = 0.01$ at 300 MHz (top) and 1 GHz (bottom) as the neutralino mass M_χ is varied with annihilation channel $b\bar{b}$ in solid lines and $\tau\bar{\tau}$ in dashed lines. A value $\langle B \rangle = 5\ \mu$G was adopted. Black lines correspond to halos with mass $10^{15}\ M_\odot$, red lines to $10^{12}\ M_\odot$ and green lines to $10^9\ M_\odot$ (from Colafrancesco et al. 2014).

10^{19} GeV (10^{-5} g)

Primordial black holes (PBHs)

[Zeld'ovich and Novikov 1966, Hawking 1971]

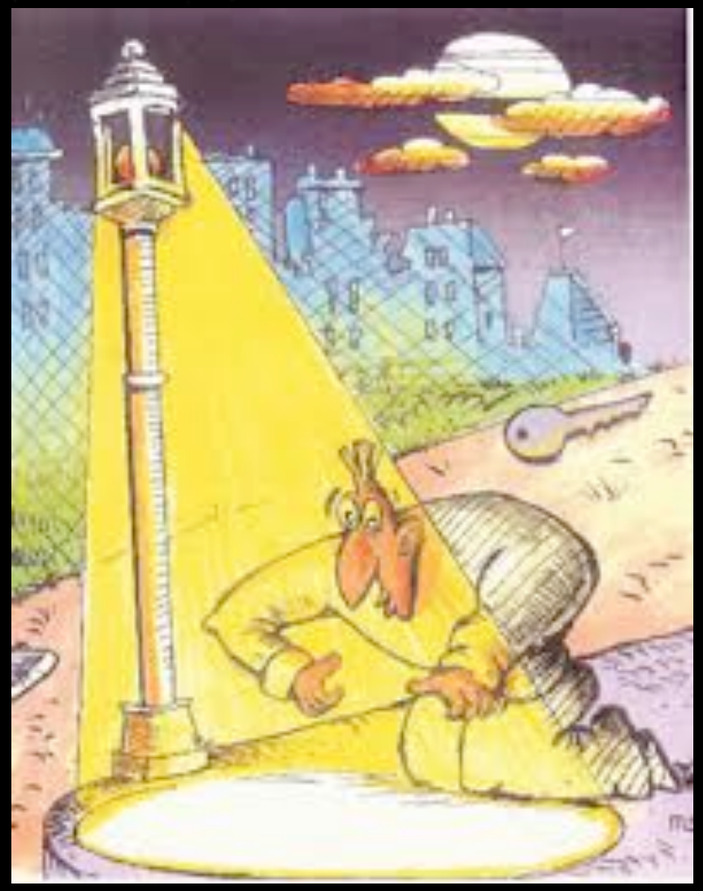
many constraints from lensing, wide binaries, Galactic disk stability; became less popular after MACHO project *[Alcock 2001]*

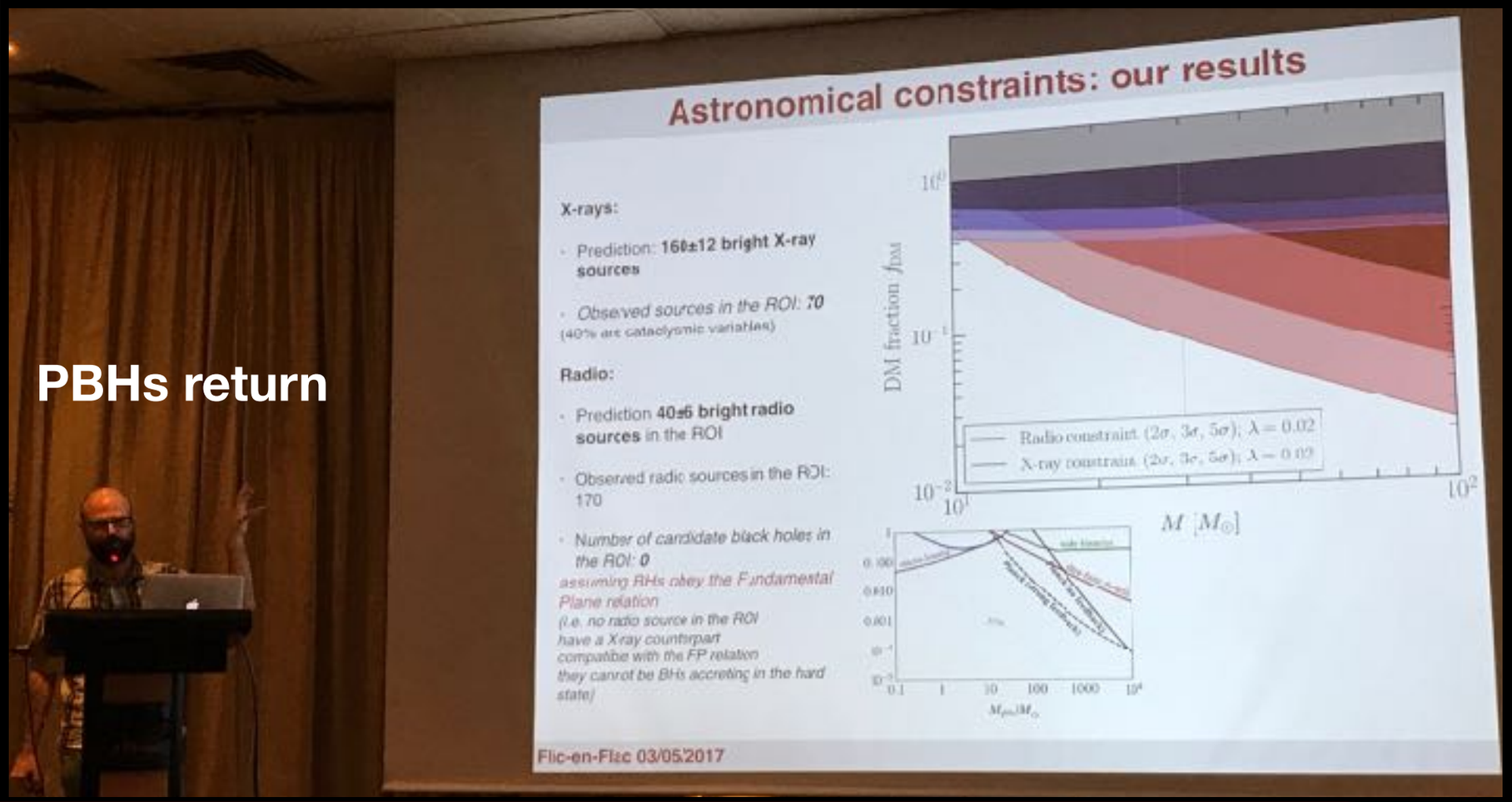
—> SKA can provide strong constraints on the presence of a population of heavy PBHs (GHz radio emission due to accretion of gas in the inner Galaxy)

10^{57} GeV (10^{33} g)

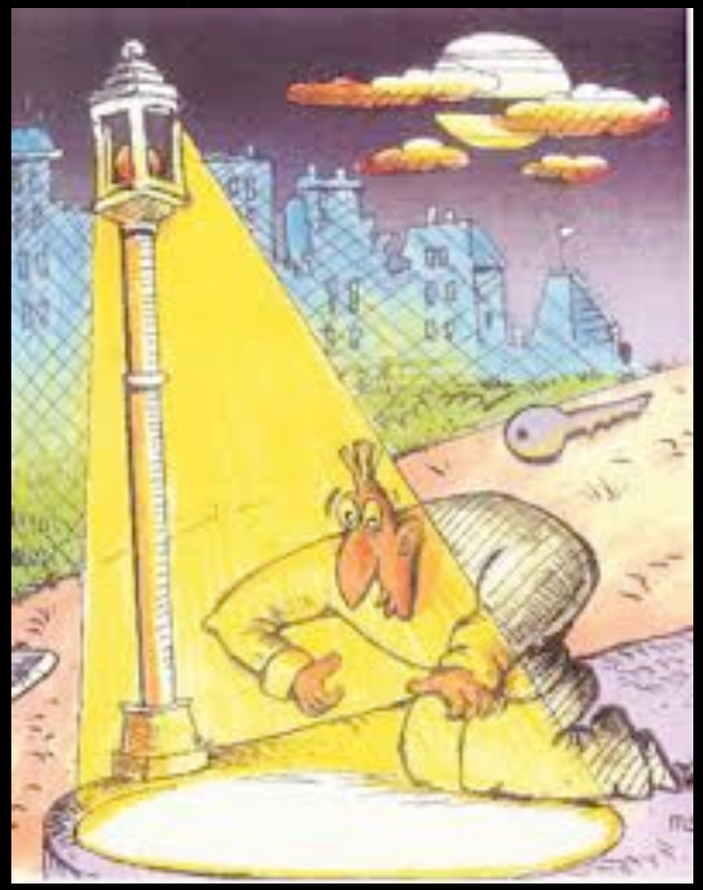
Flic-en-Flac 03/05/2017

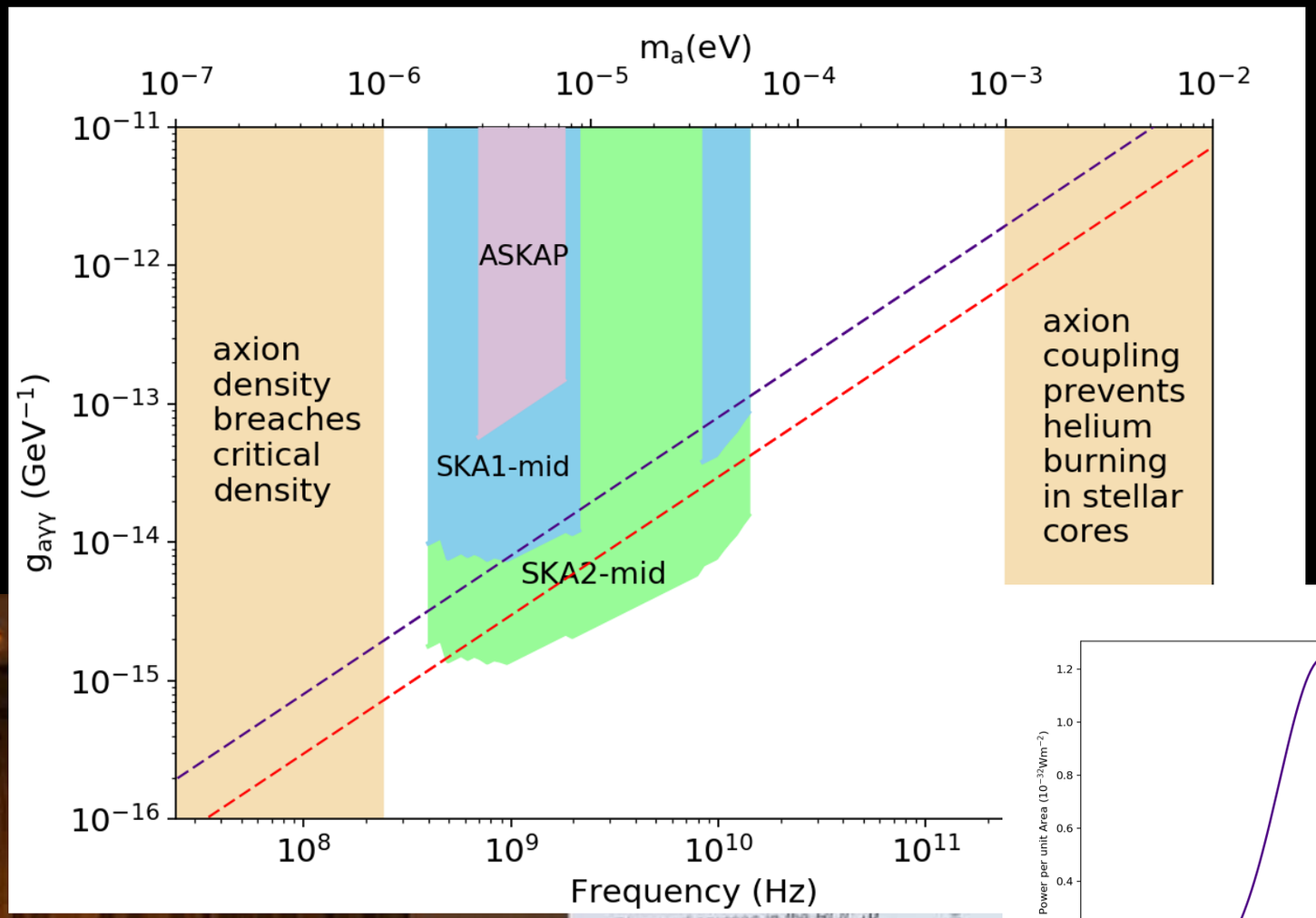
BIG Unknowns

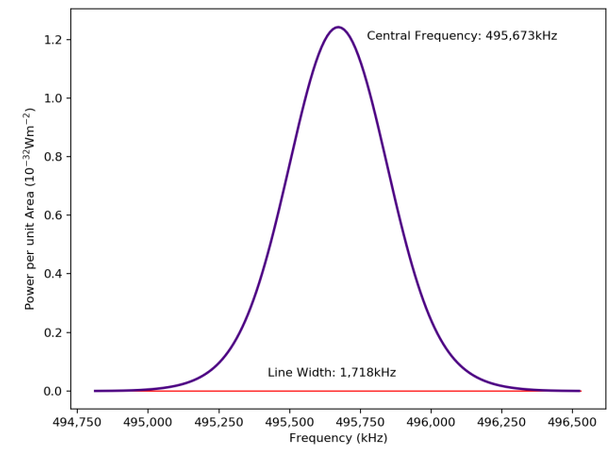


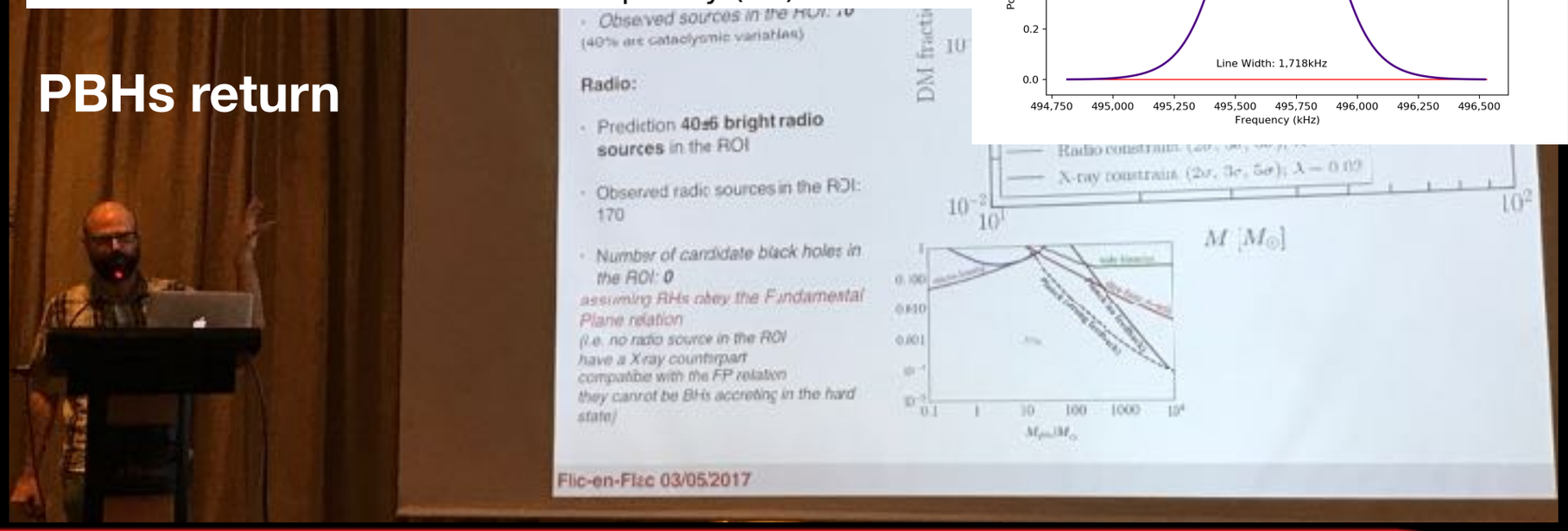


BIG Unknowns

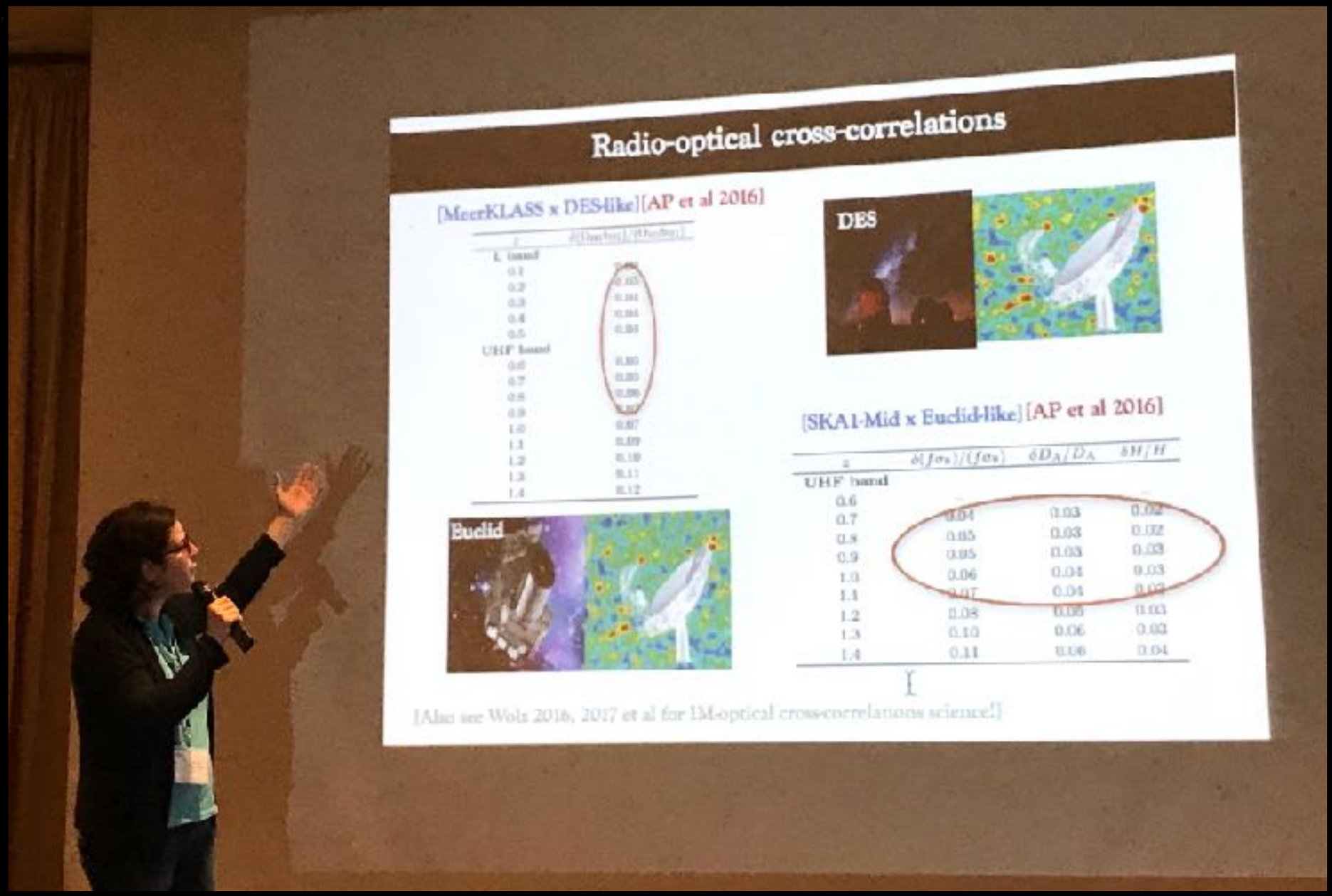




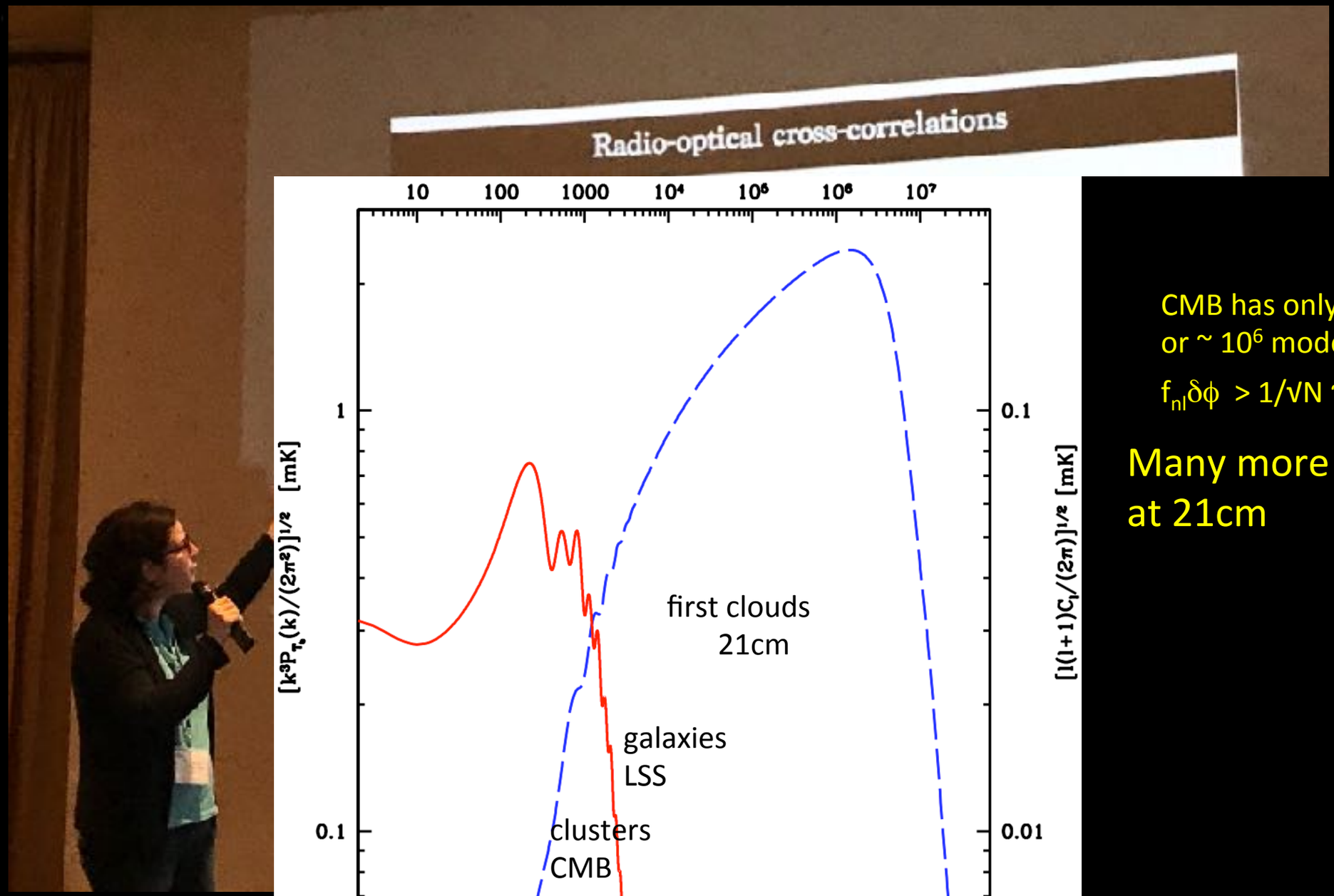




Synergy


Radio-optical cross-correlations
[MeerKLASS x DESlike] [AP et al 2016]
L band
UHF band
DES
Euclid
[SKA1-Mid x Euclid-like] [AP et al 2016]
UHF band
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
0.04
0.05
0.05
0.06
0.08
0.10
0.11
0.03
0.03
0.03
0.04
0.05
0.06
0.06
0.02
0.02
0.03
0.03
0.03
0.03
0.04
[Also see Wolz 2016, 2017 et al for 1M-optical cross-correlations science!]

Synergy

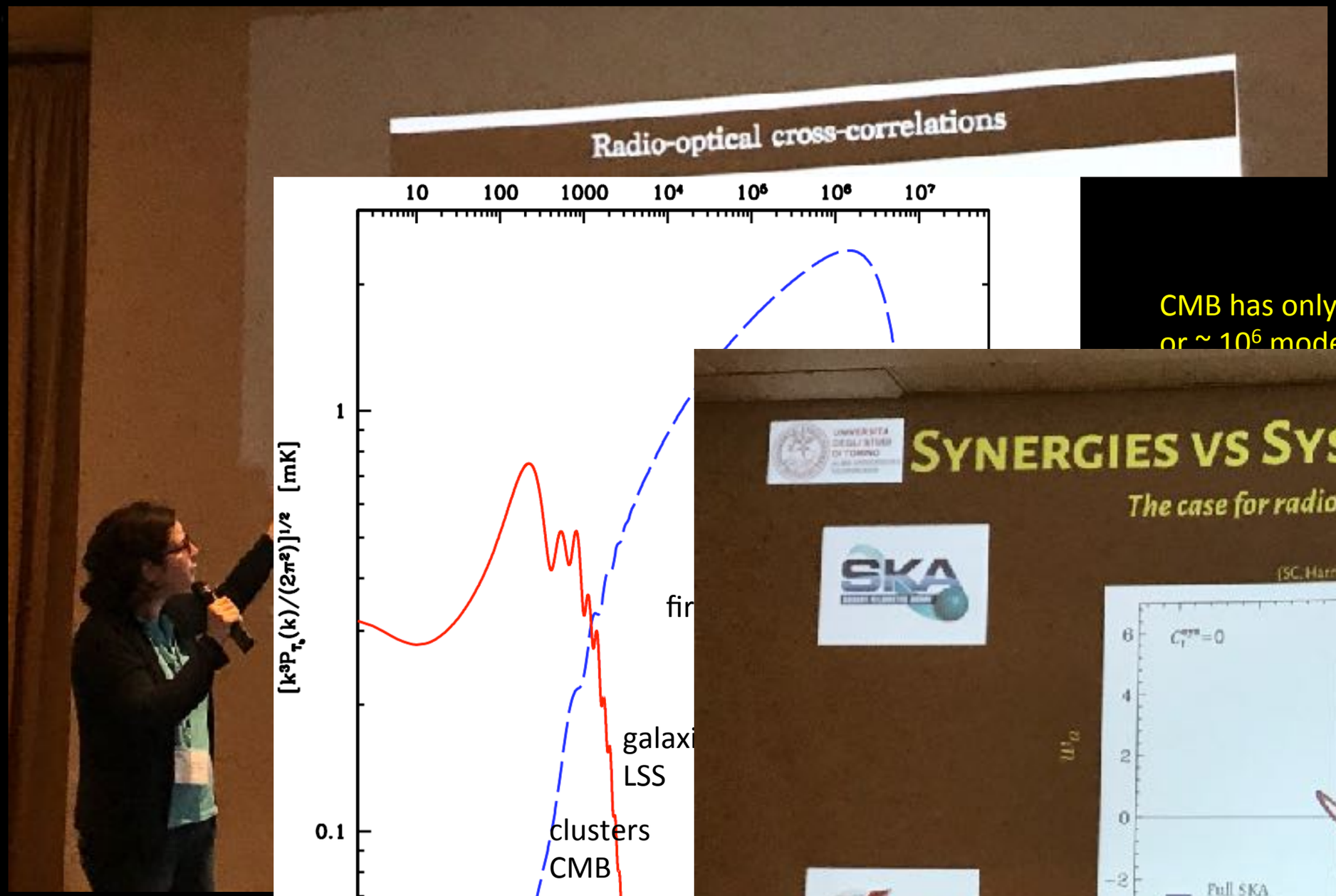


CMB has only $\ell \sim 10^3$ or $\sim 10^6$ modes

$f_{nl}\delta\phi > 1/\sqrt{N} \sim 10^{-3}$

Many more modes at 21cm

Synergy



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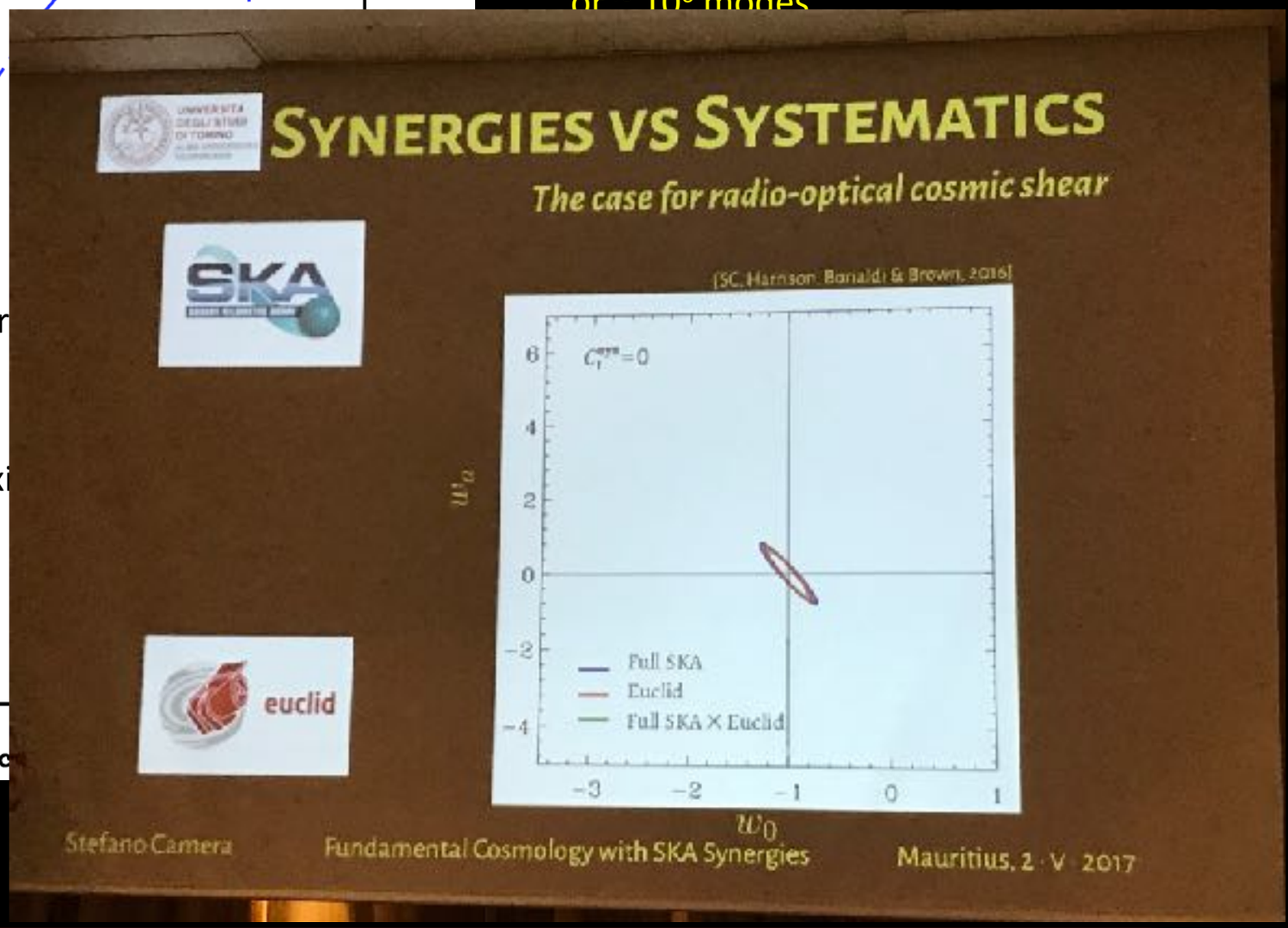
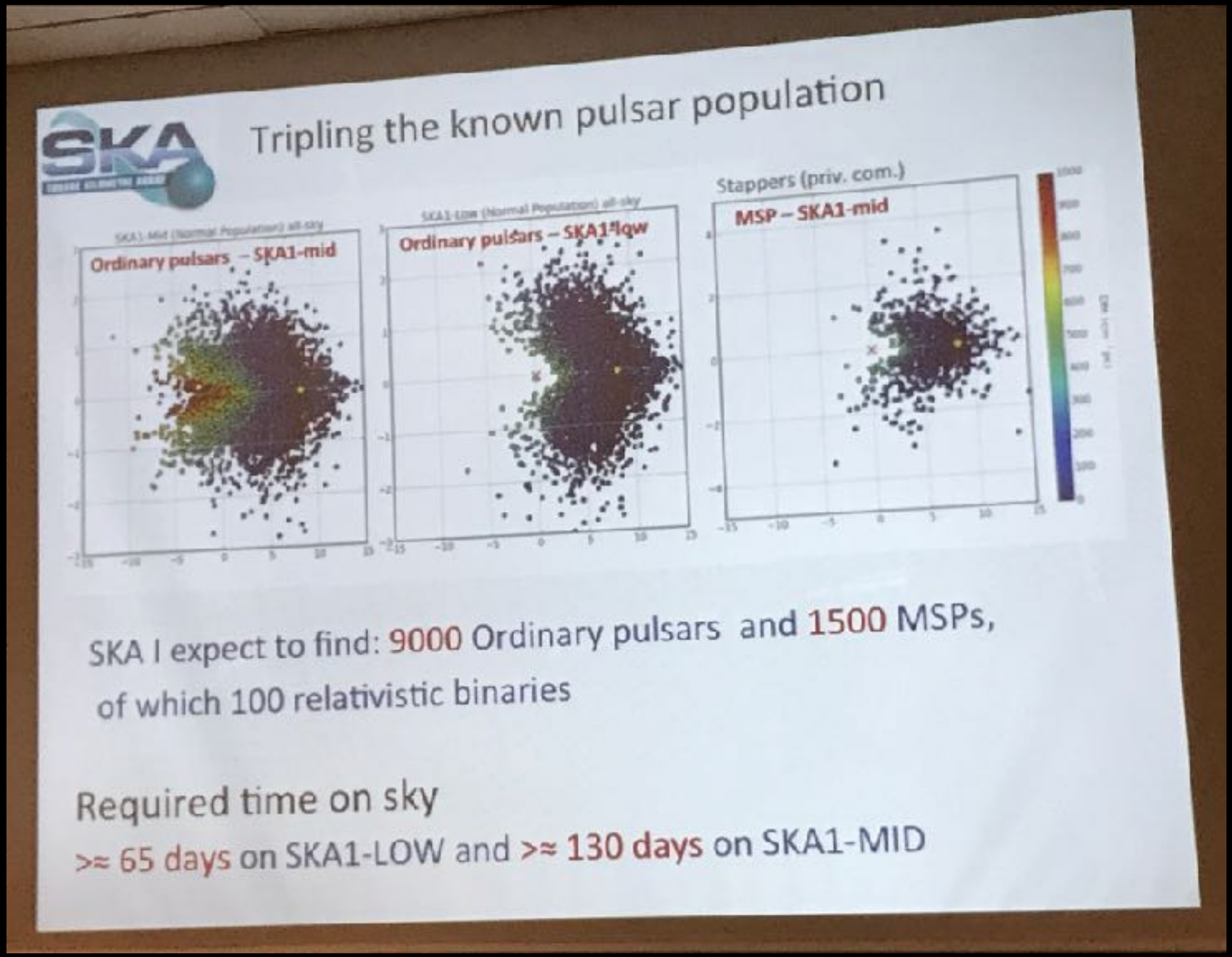


Known Unknowns - rare stuff



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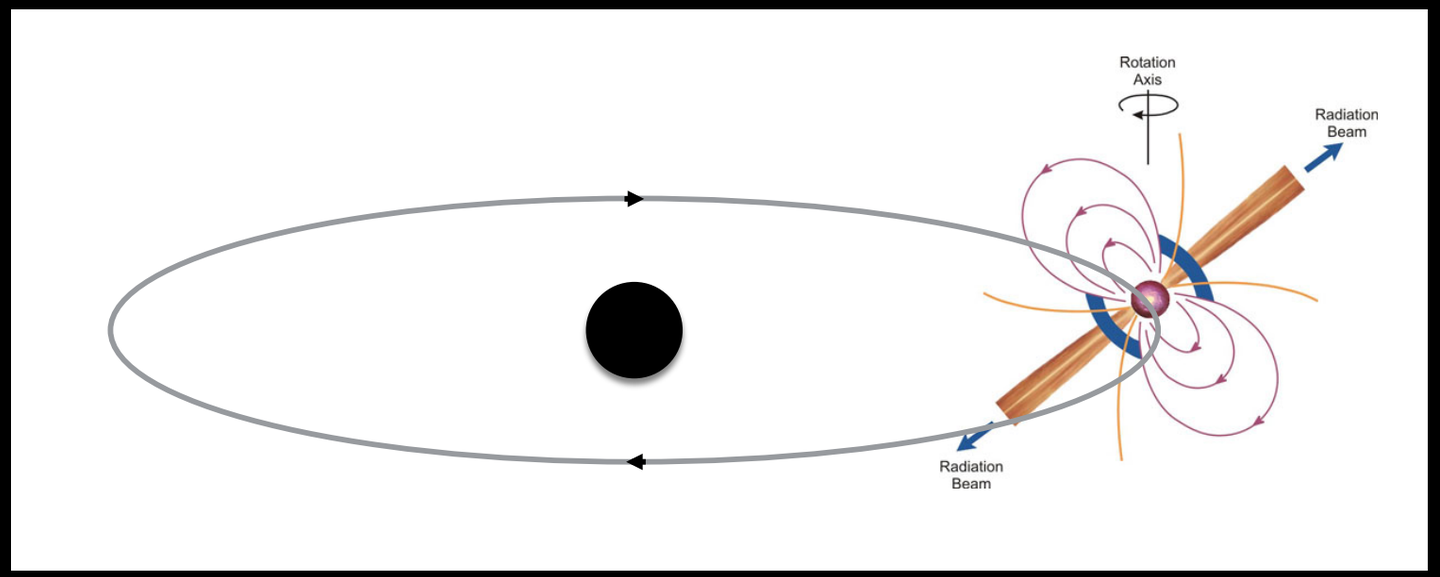
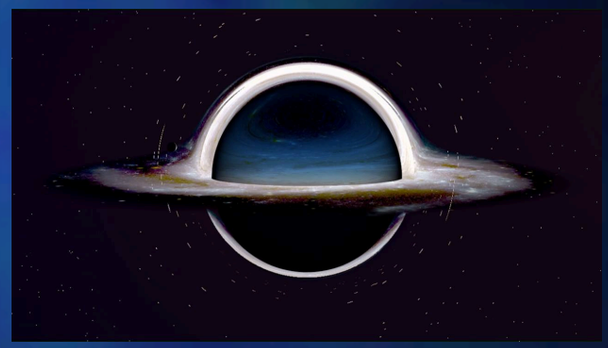
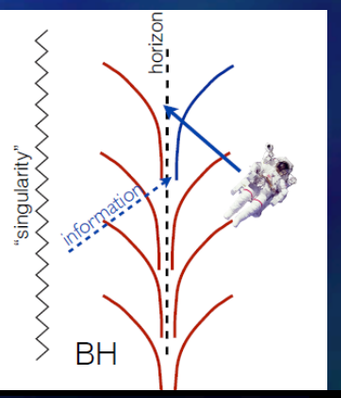
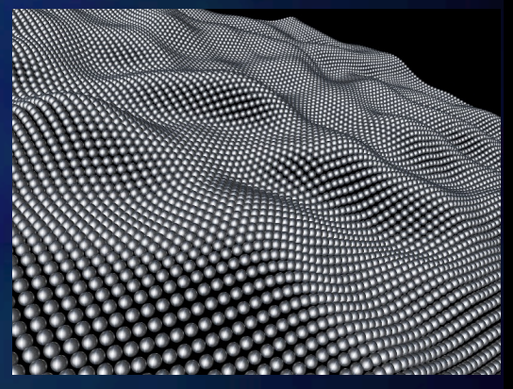
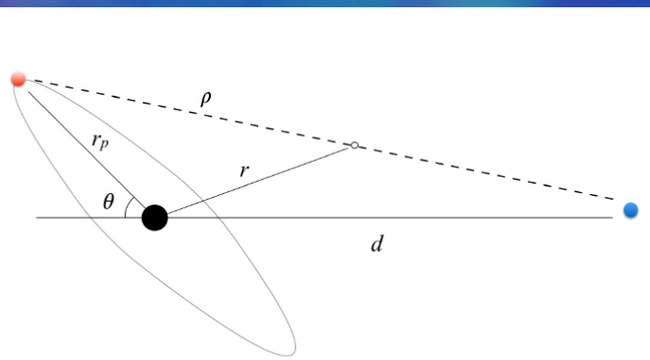








Observing non-violent non-locality in a binary system

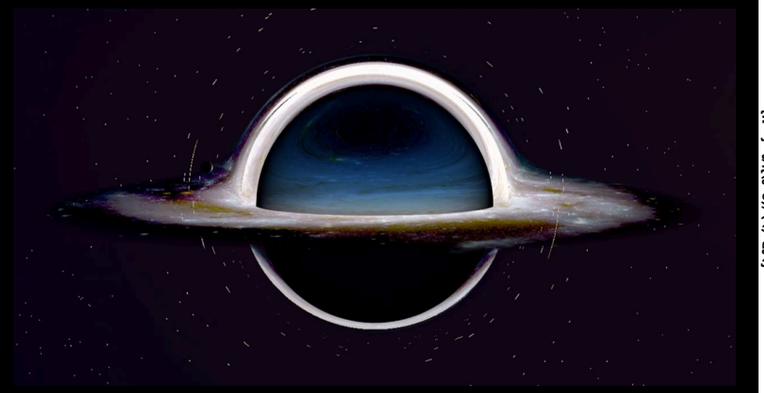


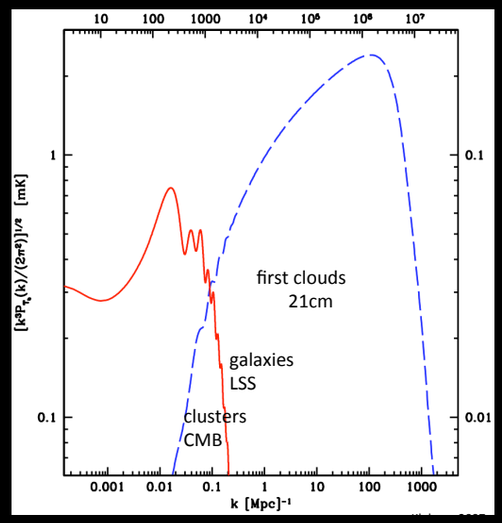
$$M_{BH} = 3M_\odot : \qquad \sigma_\Delta \simeq 3 \times 10^{-5}\,\mathrm{s}$$
$$M_{BH} = 30M_\odot : \qquad \sigma_\Delta \simeq 3 \times 10^{-4}\,\mathrm{s}$$
$$M_{BH} = M_{SgrA*} \simeq 4 \times 10^6 M_\odot : \qquad \sigma_\Delta \simeq 40\,\mathrm{s}\,.$$

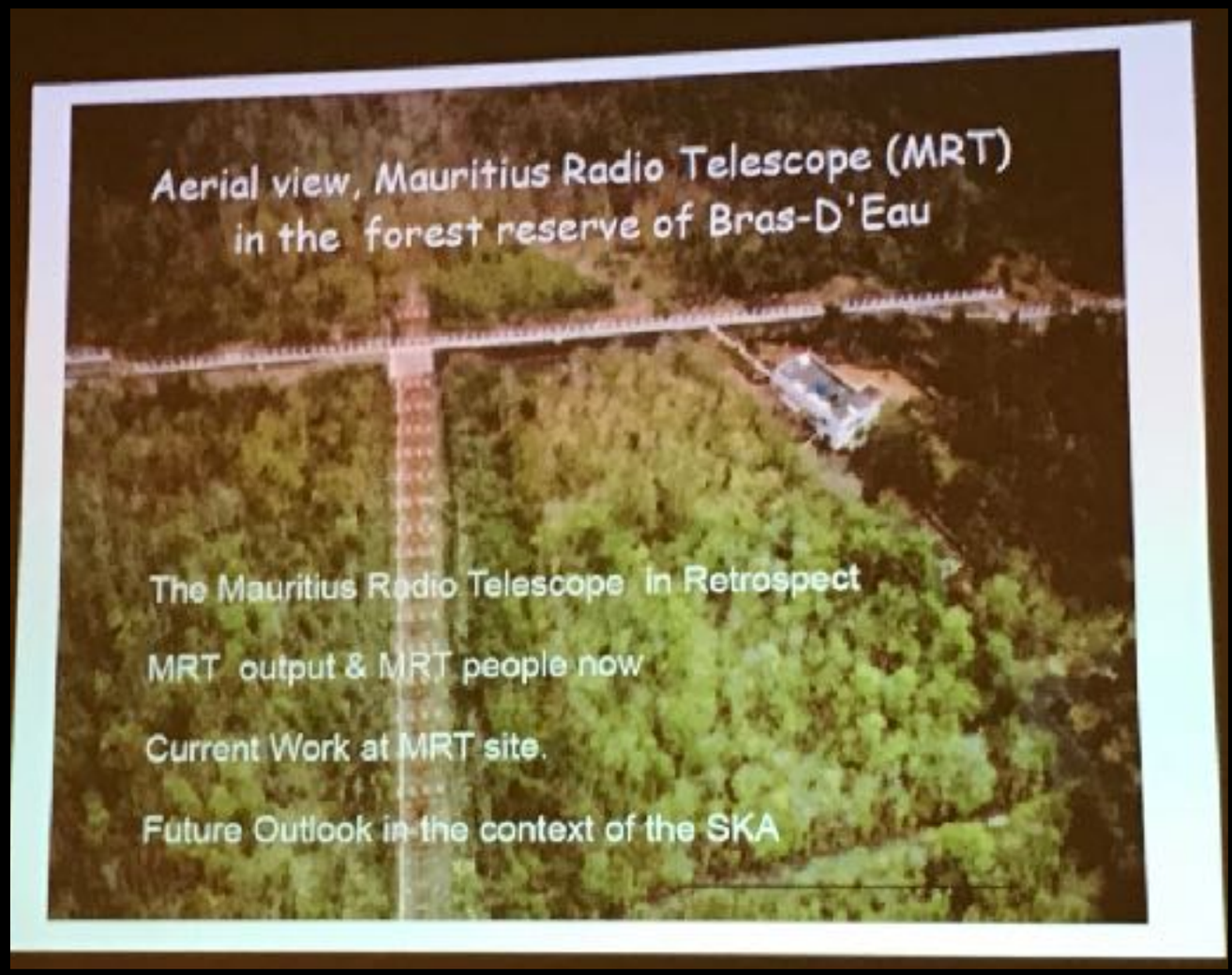
$$\sigma_\Delta \sim \kappa \frac{R_s}{c}$$

Things learned

- The return of the Primordial BHs as a TESTABLE DM candidate
- The possibility of macro quantum gravity physics and TEST
- The need for, and value of, synergetic approaches
- The worth of cross-community meetings
  - More theory - not telescopes?
- Mauritius has/had a radio telescope and a radio astronomy heritage

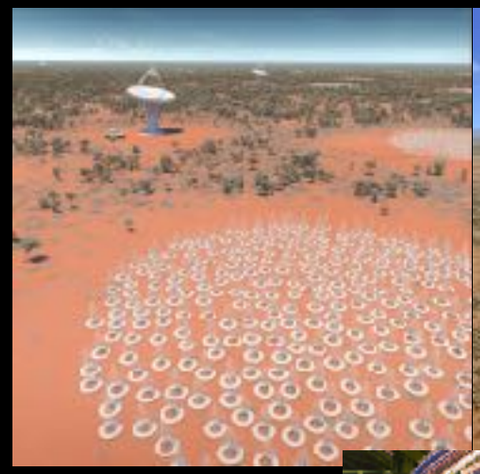


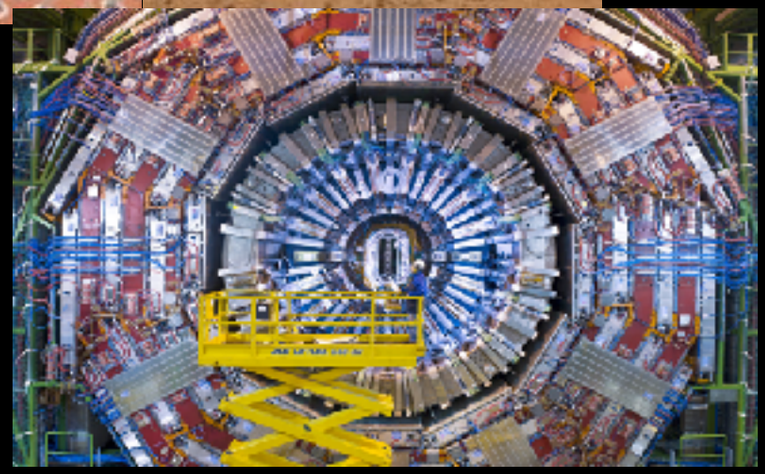




The SKA and us

- Project vs Facility
  - transients vs statistics





The SKA and us

- Project vs Facility
  - transients vs statistics
- The need for cross-community engagement
  - SKA construction shortfall
  - the LHC model

ERIDANUS

Exascale Research Infrastructure for Data in Asian-Pacific astroNonomy Using the SKA

AENEAS

Advanced European Network of E-infrastructures for Astronomy with the SKA

The SKA and us

- Project vs Facility
  - transients vs statistics
- The need for cross-community engagement
  - SKA construction shortfall
  - the LHC model
- Do we need to wait 20 years?
  - the strength of the pathfinders and precursors

The SKA and us

- Project vs Facility
  - transients vs statistics
- The need for cross-community engagement
  - SKA construction shortfall
  - the LHC model
- Do we need to wait 20 years?
  - the strength of the pathfinders and precursors
- We need to be designers and builders - not just users - and that goes for all players!

Mauritius - Flic-en-Flac

Mauritius - Flic-en-Flac

Mauritius - Flic-en-Flac