Cosmology on ultra-large scales with the Square Kilometre Array

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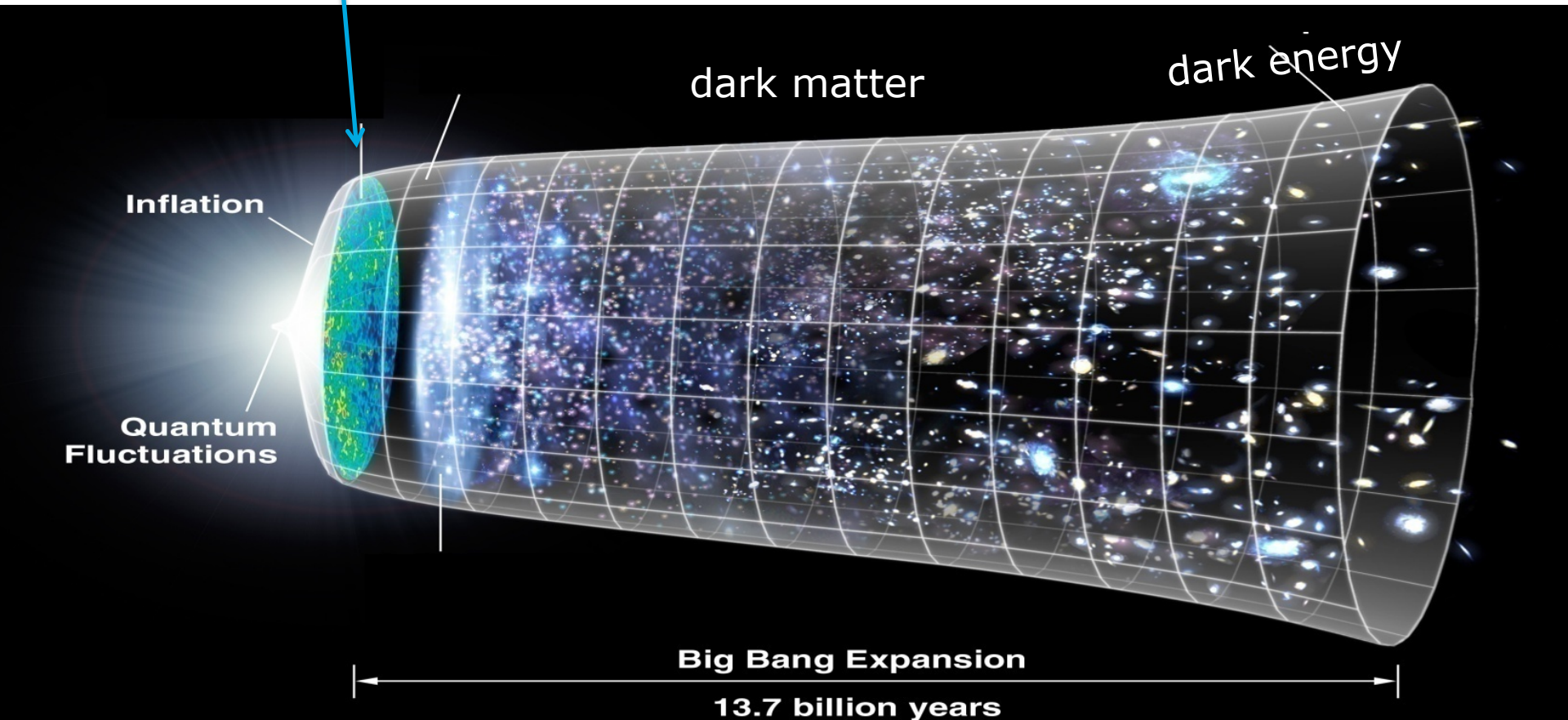
(with many thanks to Roy Maartens, Mario Santos and the SKA cosmology WG)

planck
inside

cosmological context

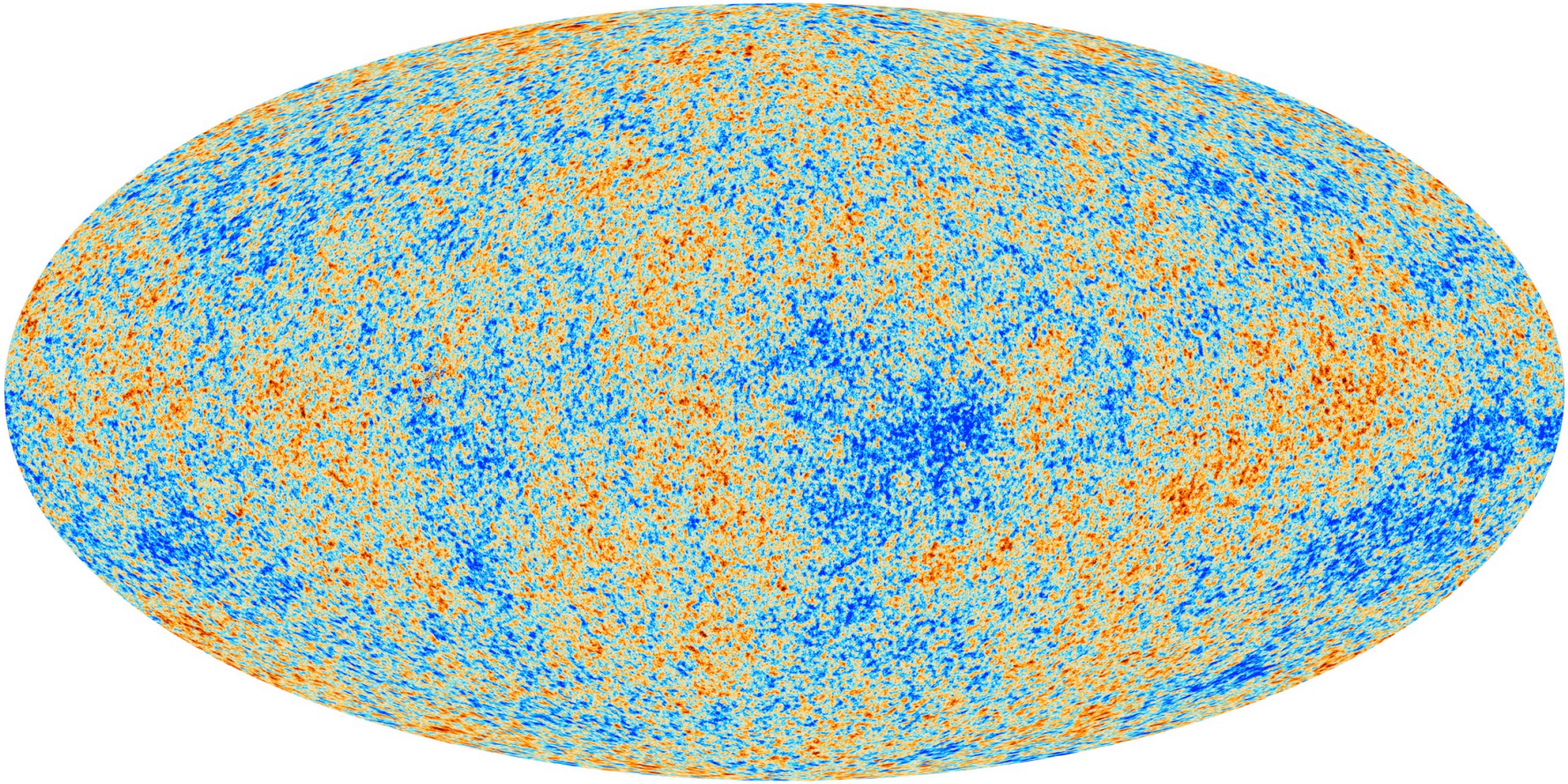
cosmic microwave background (CMB)

SKA



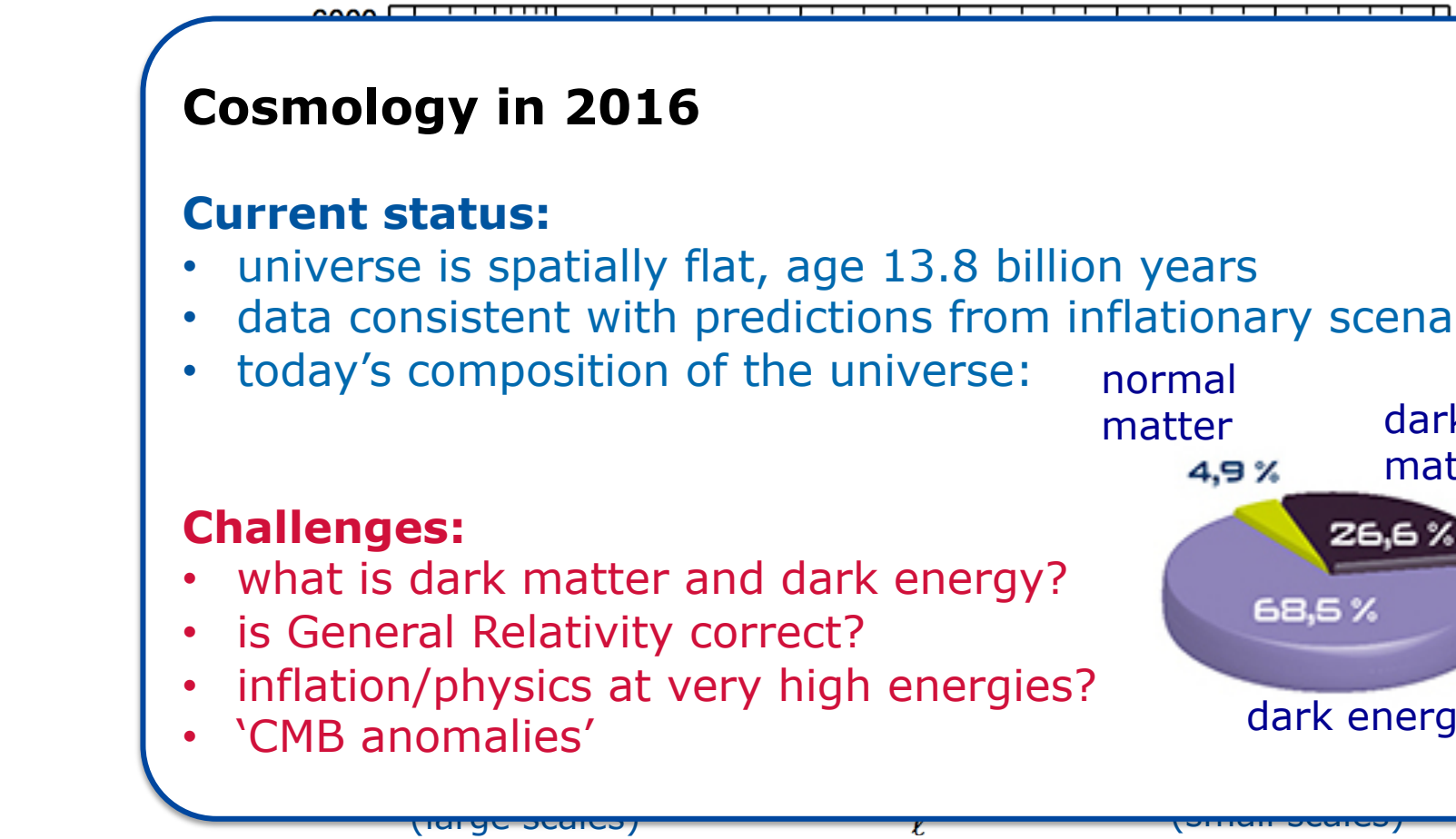
the Planck CMB map

temperature fluctuations → seeds of future clusters, galaxies, and us



redshift z = 1100 → size of universe 1/(1+z) ~ 1/1100
age of universe: 380’000 years (vs 13.8 Gyr today)

the cosmic microwave background



Cosmology in 2016

Current status:

- universe is spatially flat, age 13.8 billion years
- data consistent with predictions from inflationary scenario
- today's composition of the universe:

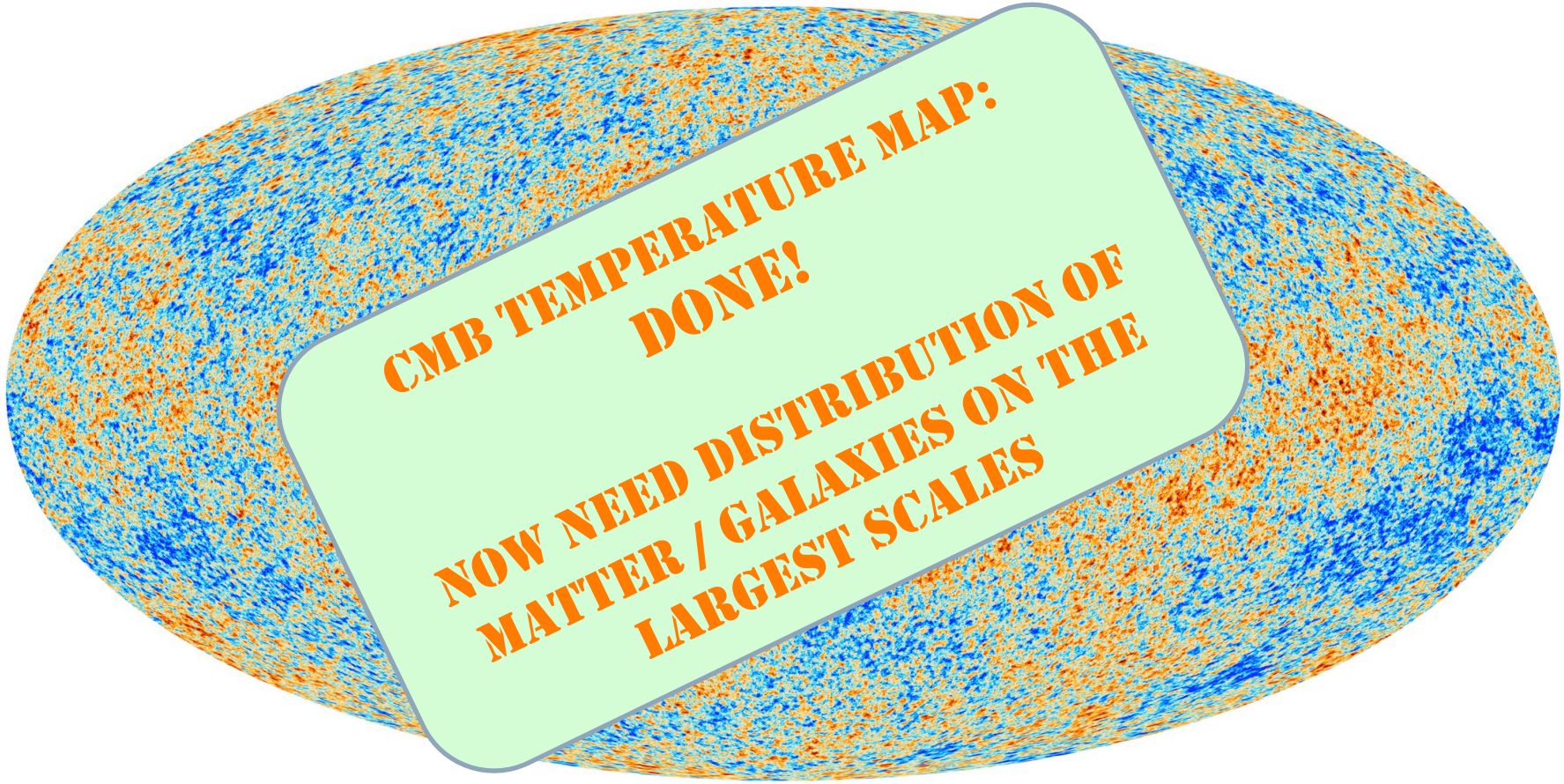
Challenges:

- what is dark matter and dark energy?
- is General Relativity correct?
- inflation/physics at very high energies?
- 'CMB anomalies'

red curve:
best fit 6-parameter ΛCDM ('standard') model
→ fits thousands of C_l / millions of pixels

Planck 2015 TT combined:
ell range 30 – 2508
$X^2 = 2546.67$; $N_{dof} = 2479$
probability 16.8%

the Planck CMB map



temperature fluctuations → seeds of future clusters, galaxies, and us

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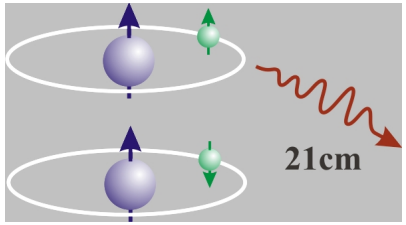
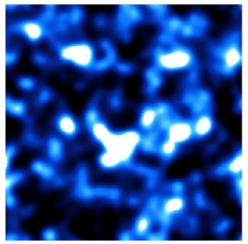
SKA cosmological surveys

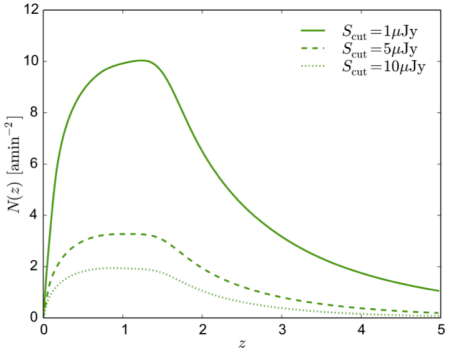
- ***HI galaxy redshift survey***
  - '21cm' radiation from neutral hydrogen spin flip
  - individual galaxies detected
  - precise redshift, radio analogue of optical spectroscopic survey
  - no foregrounds, but needs very high sensitivity



- ***HI intensity mapping survey (IM)***
  - individual galaxies not detected, only integrated emission
  - good for large-scale structure mapping
  - a bit like CMB but with multiple redshifts, can also extract lensing information (similar to CMB)
  - many narrow redshift bins possible
  - foreground a big problem, not yet fully proven technique

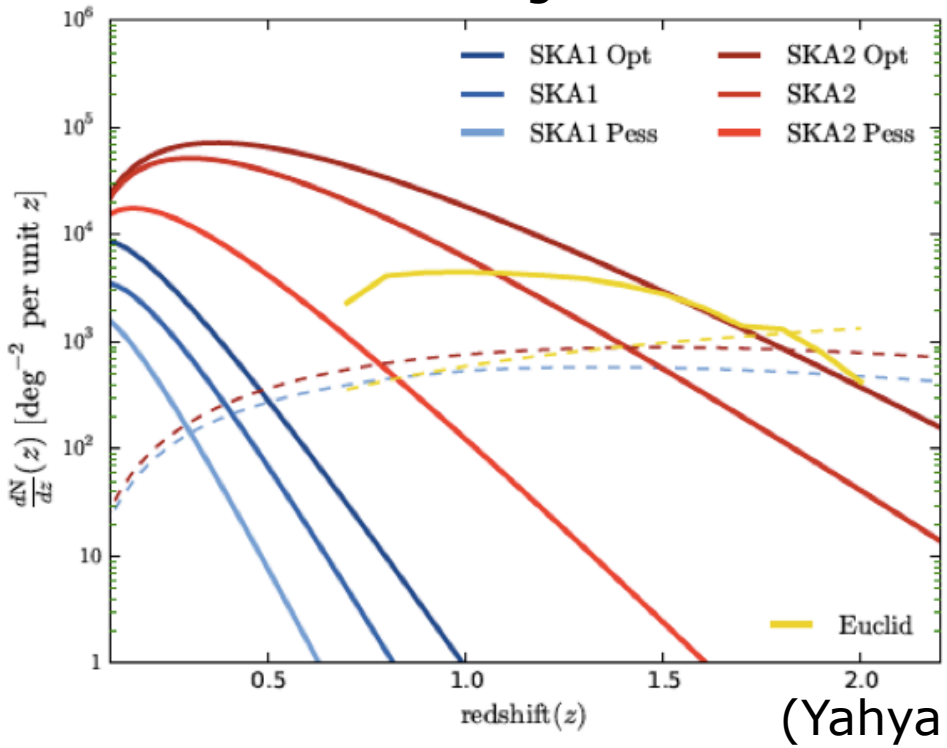


- ***Radio continuum survey***
  - total radio emission from galaxies
  - many galaxies at high redshift, but no redshifts
  - can do weak lensing, needs HI redshift information

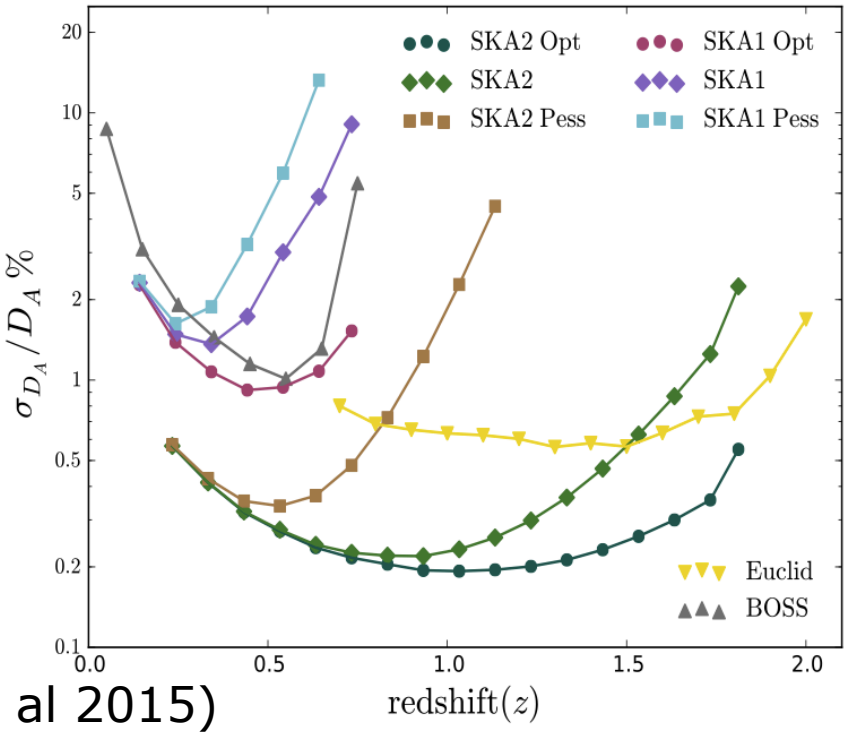


SKA HI galaxy redshift surveys

number of galaxies



precision of distance measurement

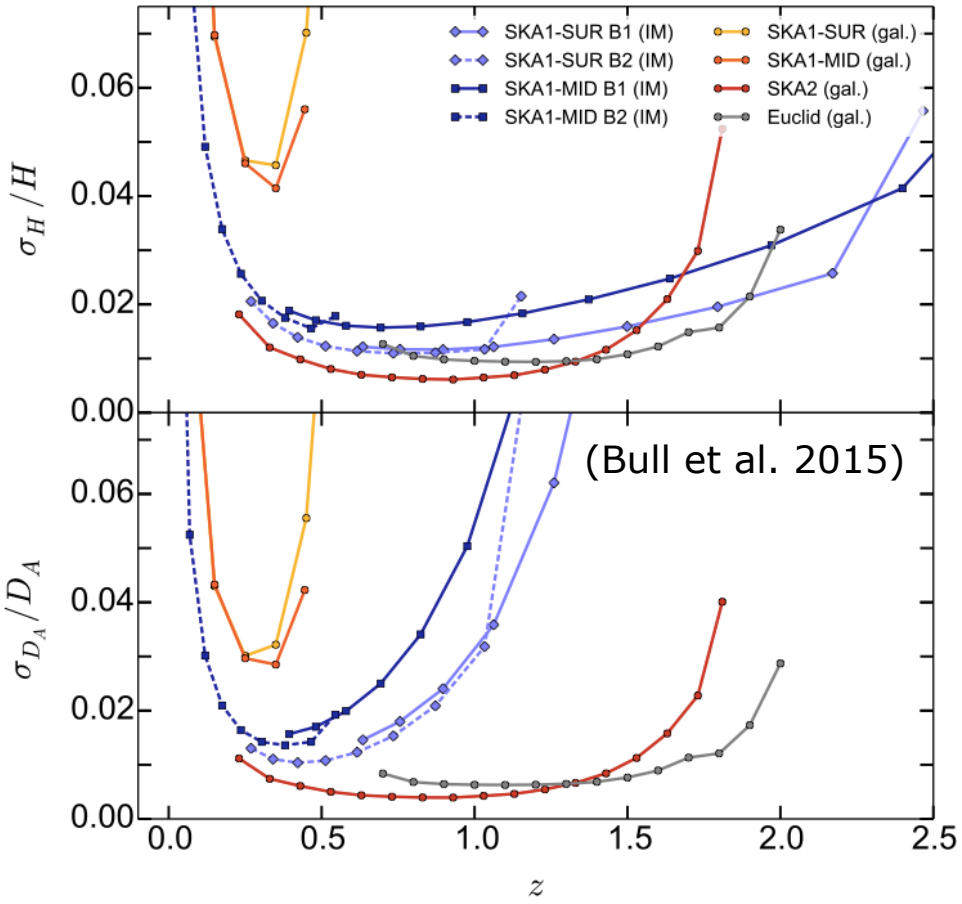


(Yahya et al 2015)

- SKA1: 10 million galaxies, 5000 deg2, z<0.6
- SKA2: 1 billion galaxies, 30000 deg2, z<2

- *SKA1 not a game changer, but complementary to optical surveys*
- *SKA2 will be a game changer*

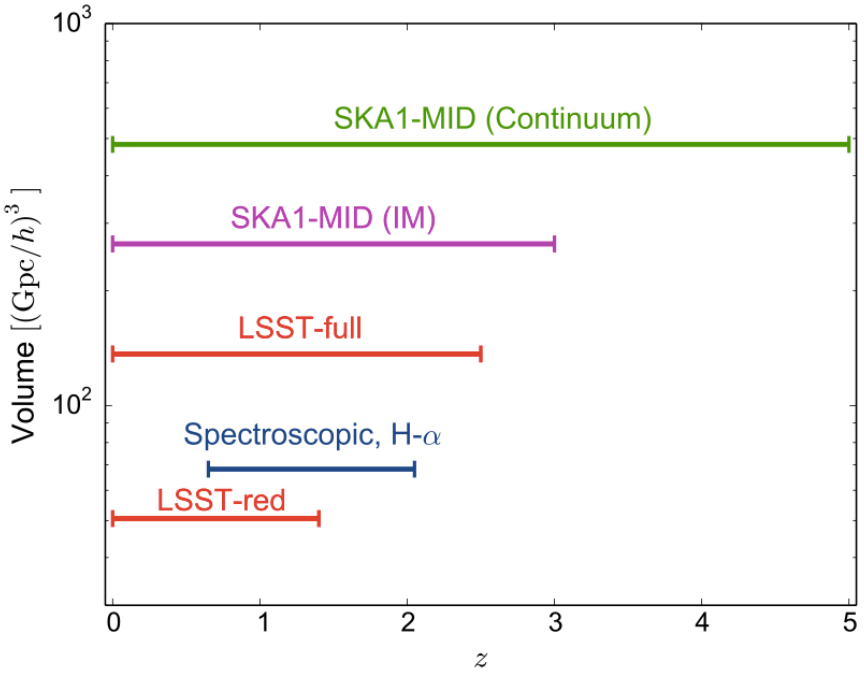
SKA1 intensity mapping



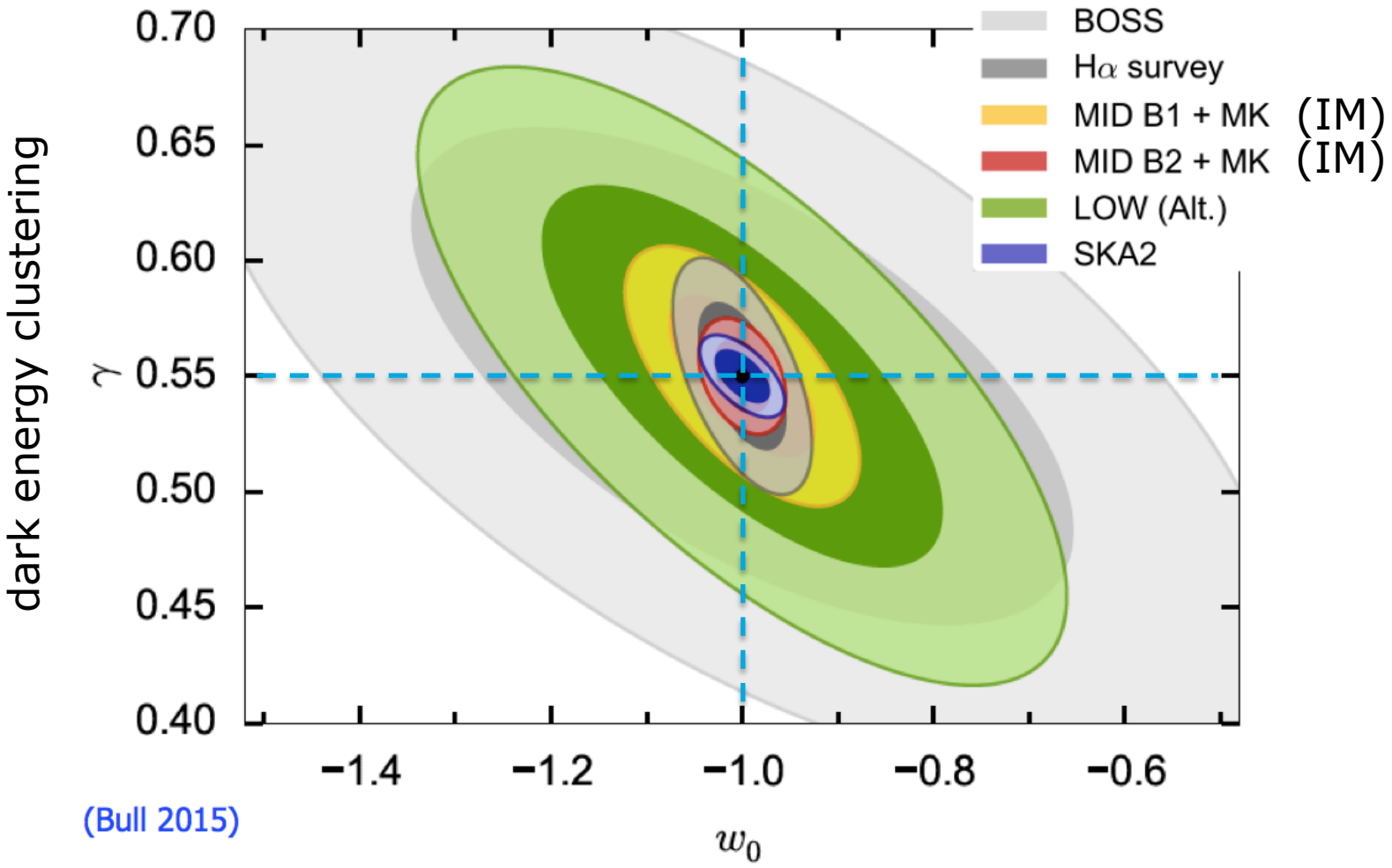
errors on expansion rate H(z) and distance D(z): Intensity mapping with SKA1 performs very well

Intensity mapping:

- good redshift precision
- large volume
- but need to control systematic effects



testing the nature of dark energy



testing isotropy on large scales

Does the matter dipole agree with the CMB dipole?

- current data (NVSS) shows a difference in velocity

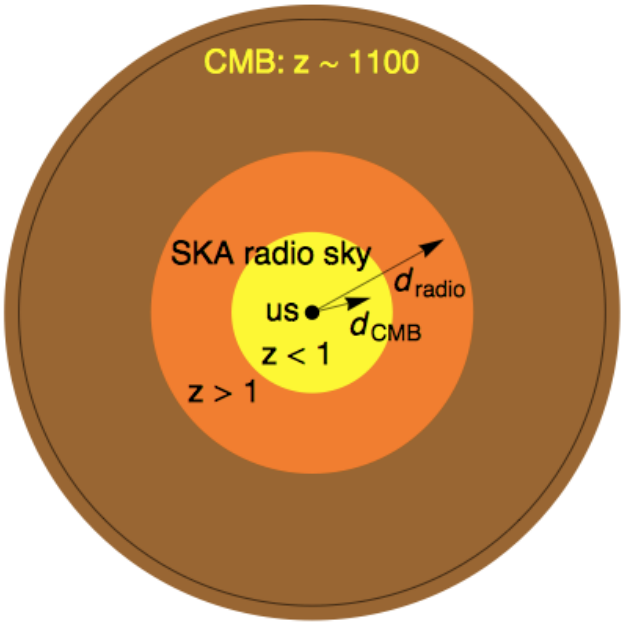
SKA continuum surveys:

- SKA1 will locate dipole within 5°
- SKA2 will locate dipole within 1°

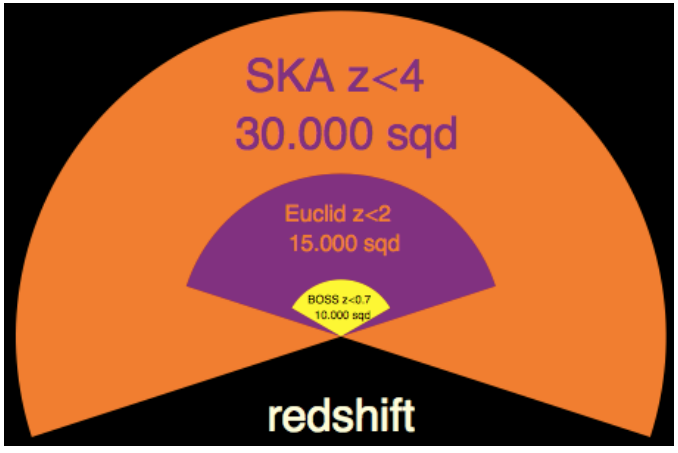
- IM survey can test Copernican Principle to a few per cent

- These are fundamental tests on which all the other cosmological analyses rely!

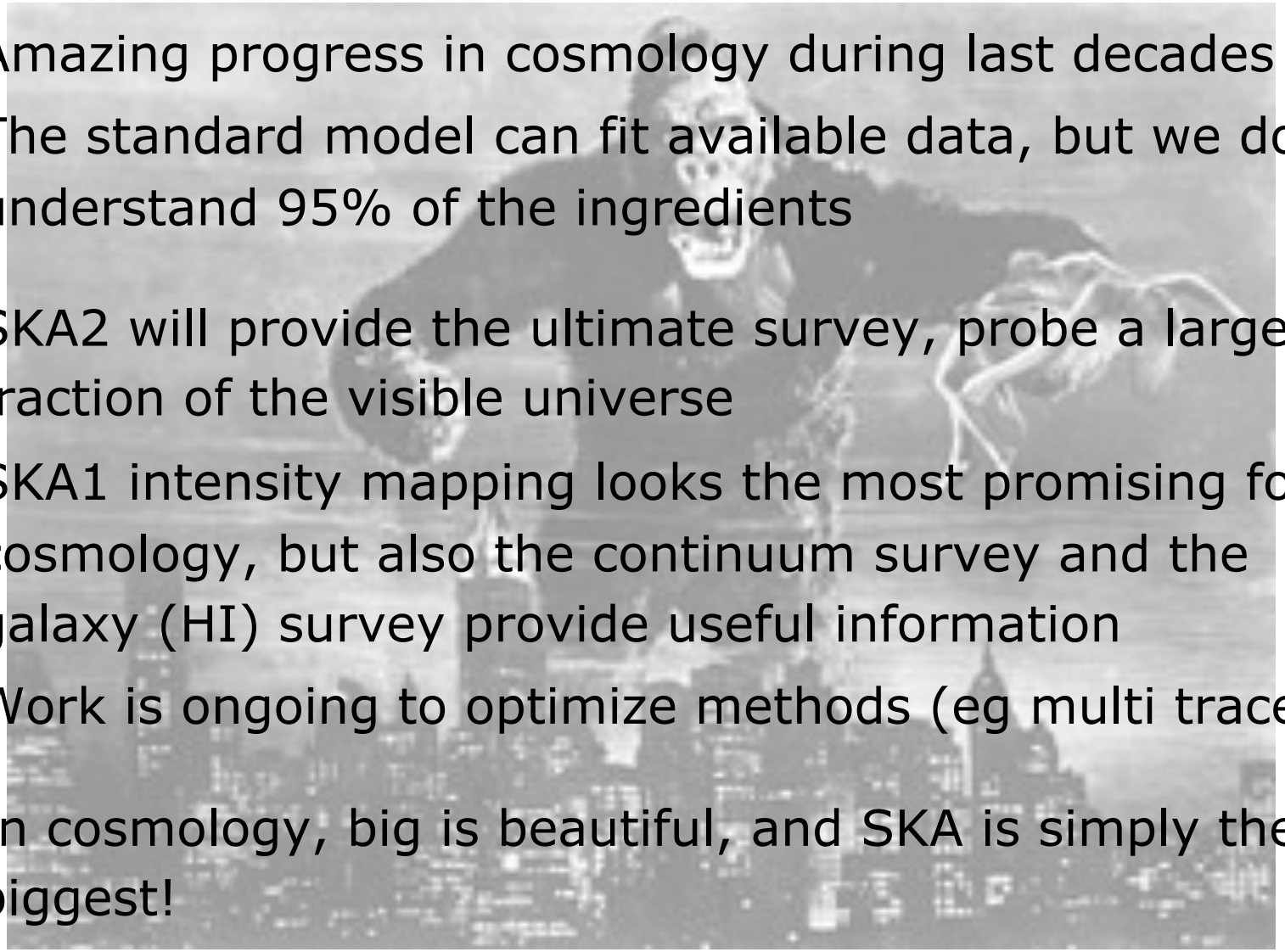
- Surveys probing ultra-large scales are also the best (the only?) hope for testing the Planck large scale anomalies.



Schwarz et al, 2015



Summary



- Amazing progress in cosmology during last decades
- The standard model can fit available data, but we don't understand 95% of the ingredients
- SKA2 will provide the ultimate survey, probe a large fraction of the visible universe
- SKA1 intensity mapping looks the most promising for cosmology, but also the continuum survey and the galaxy (HI) survey provide useful information
- Work is ongoing to optimize methods (eg multi tracer)
- In cosmology, big is beautiful, and SKA is simply the biggest!

thank you