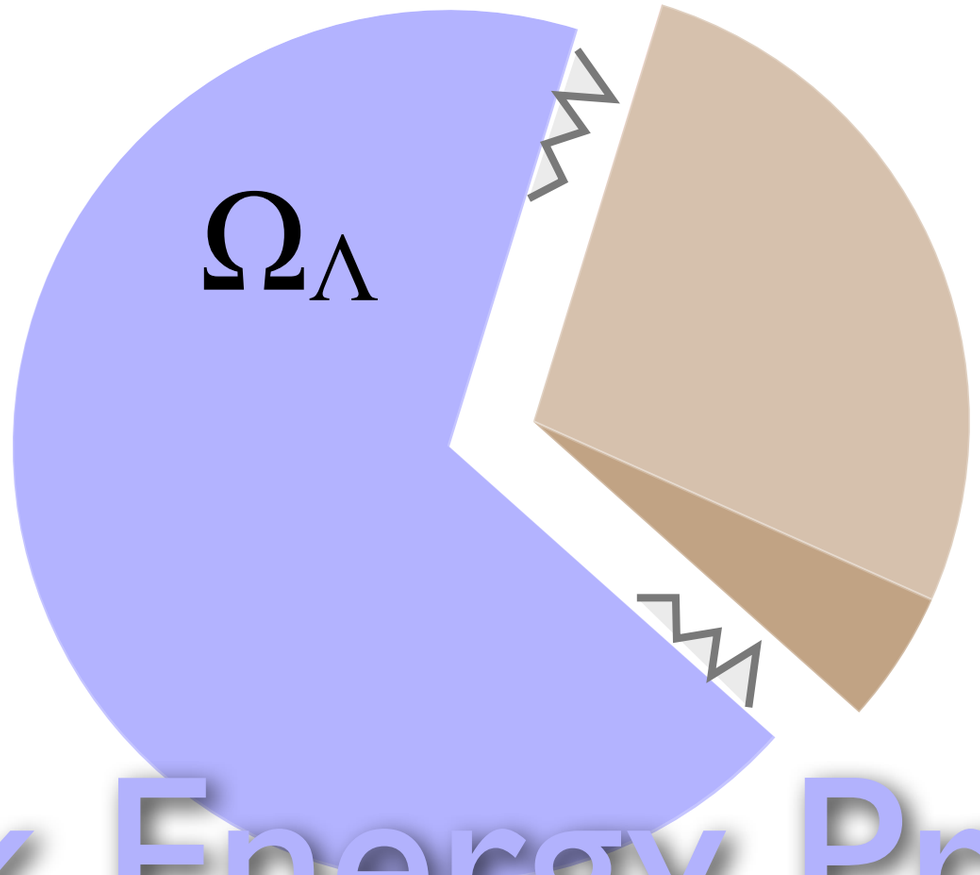
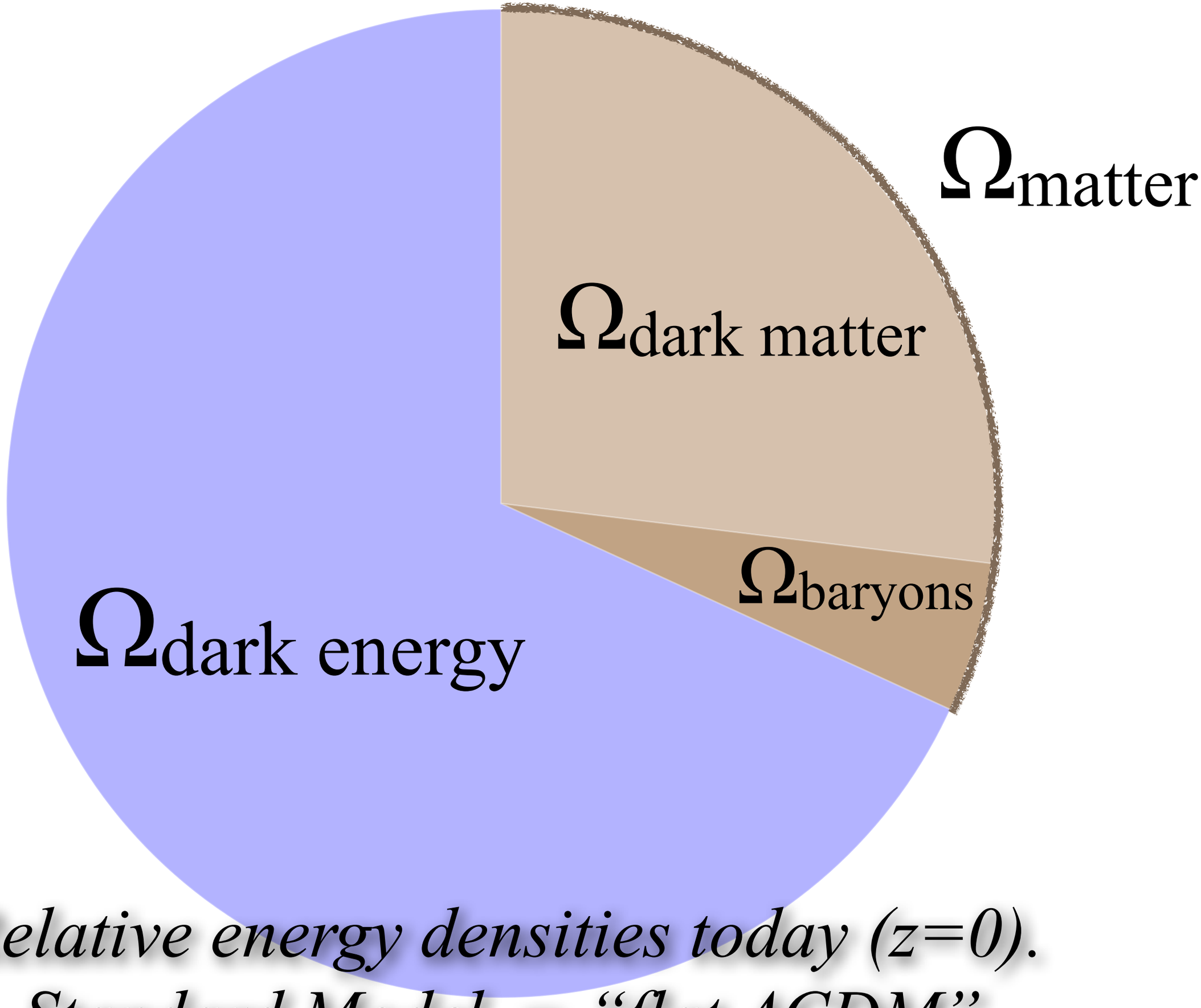


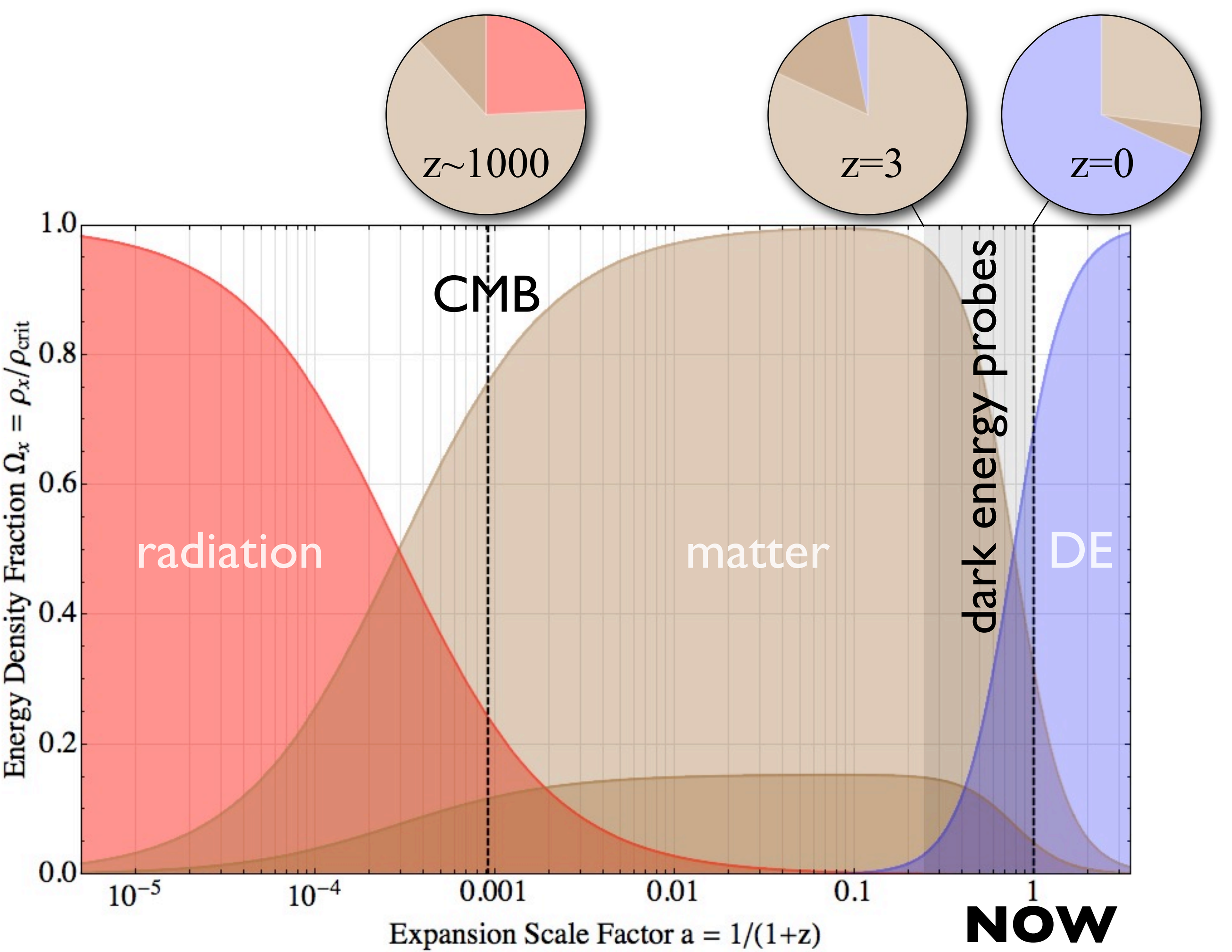
Dark Energy Probes

David Kirkby, UC Irvine

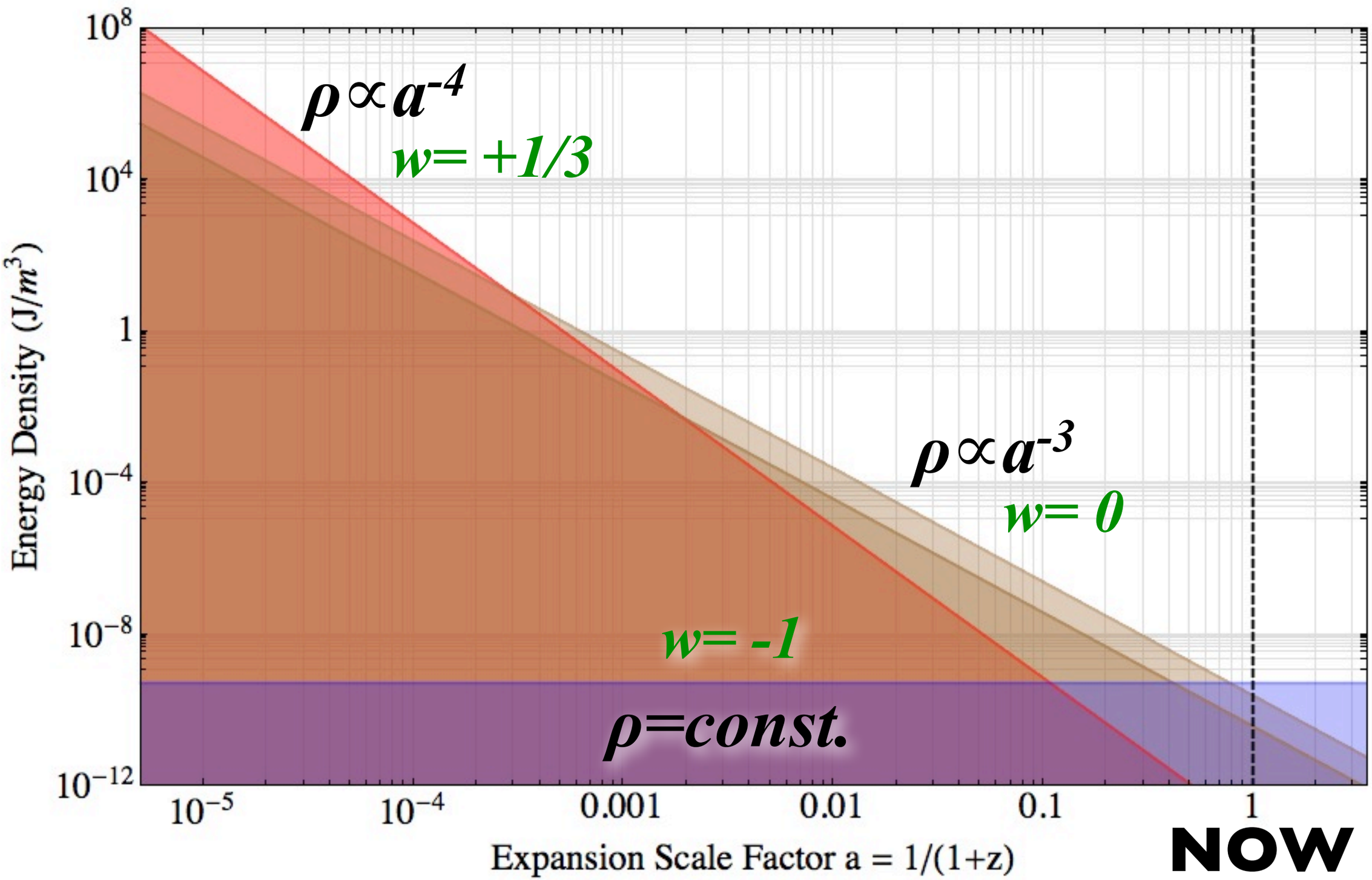
TAUP 2013 — Asilomar CA
9 Sep 2013

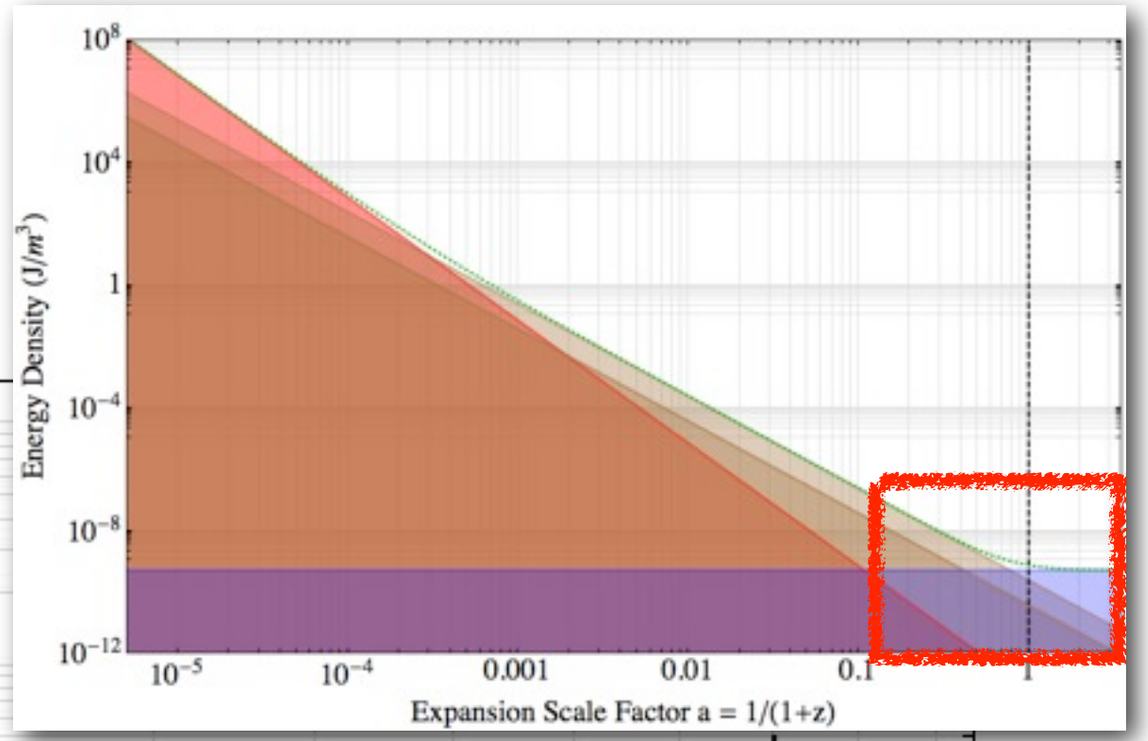


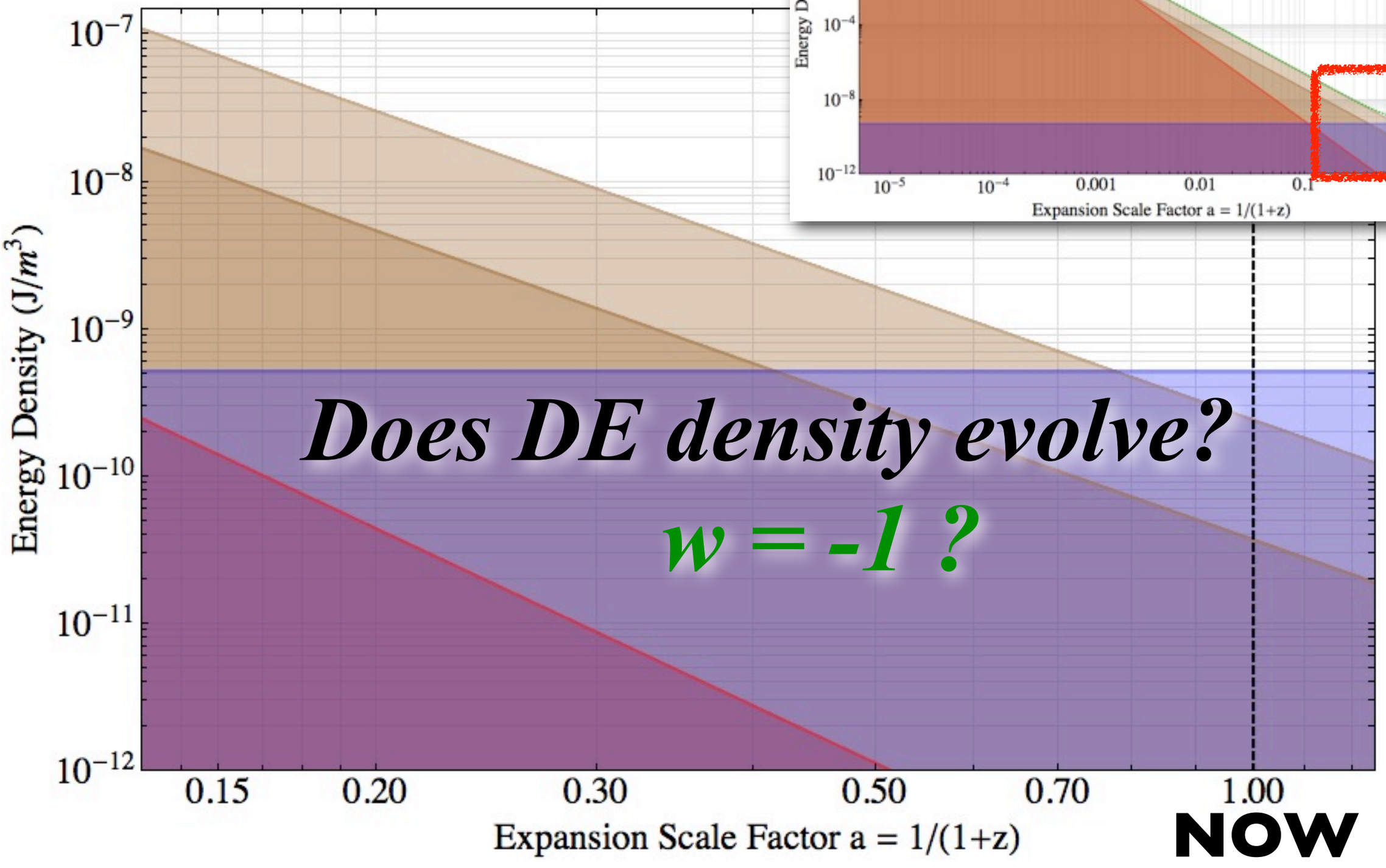
Relative energy densities today (z=0).
Standard Model = "flat ΛCDM"


z~1000
z=3
z=0
CMB
radiation
matter
DE
dark energy probes
NOW
Energy Density Fraction $\Omega_x = \rho_x/\rho_{crit}$
1.0
0.8
0.6
0.4
0.2
0.0
10^{-5}
10^{-4}
0.001
0.01
0.1
1
Expansion Scale Factor a = 1/(1+z)

Equation of state: $\rho \propto a^{-3(1+w)}$







Does DE density evolve?

w = -1 ?

Does DE density evolve?

YES

NO

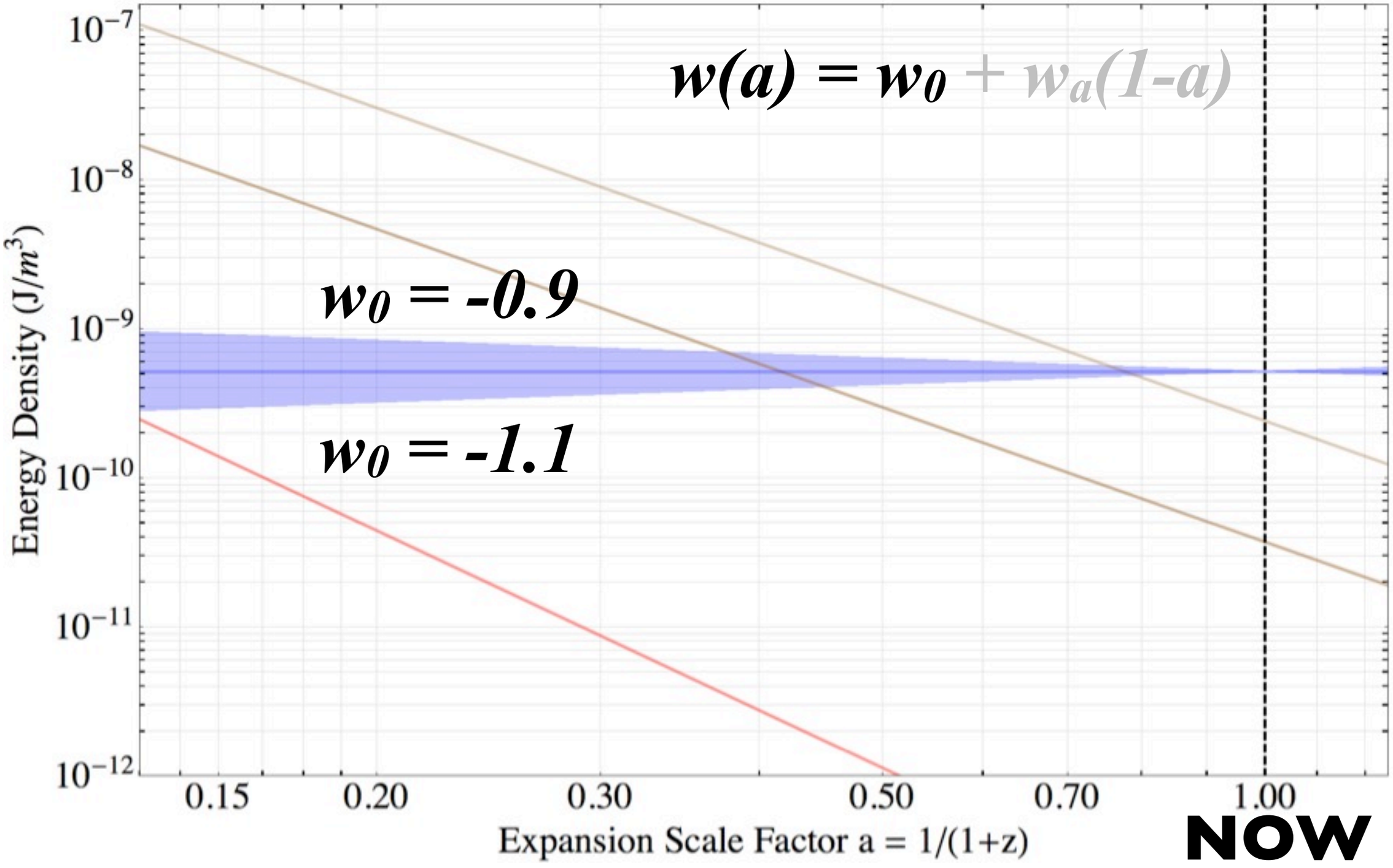
Are DE observations self-consistent within general relativity?

New form of energy

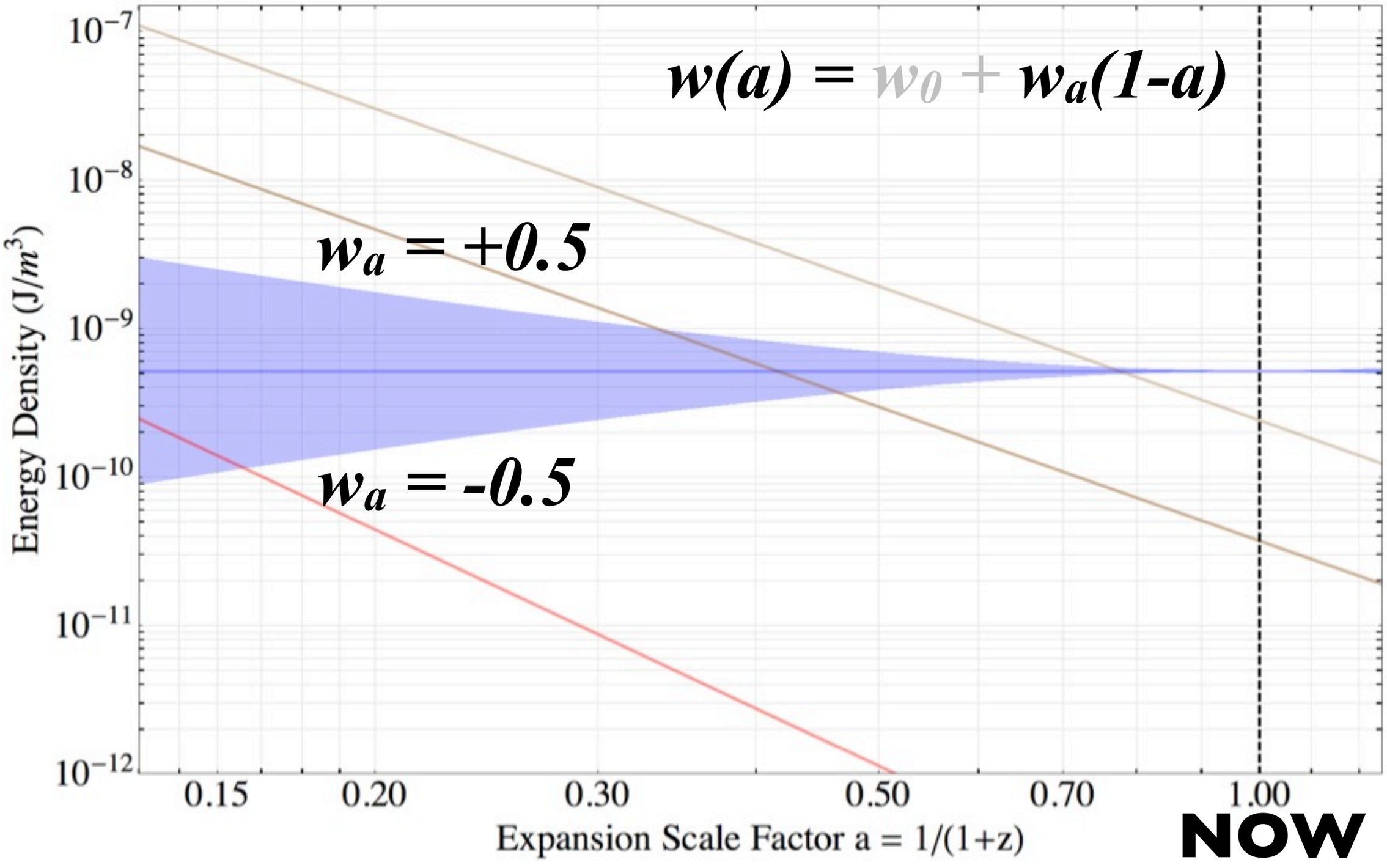
New theory of gravity

Cosmological constant

Dark energy equation of state parameters:



Dark energy equation of state parameters:



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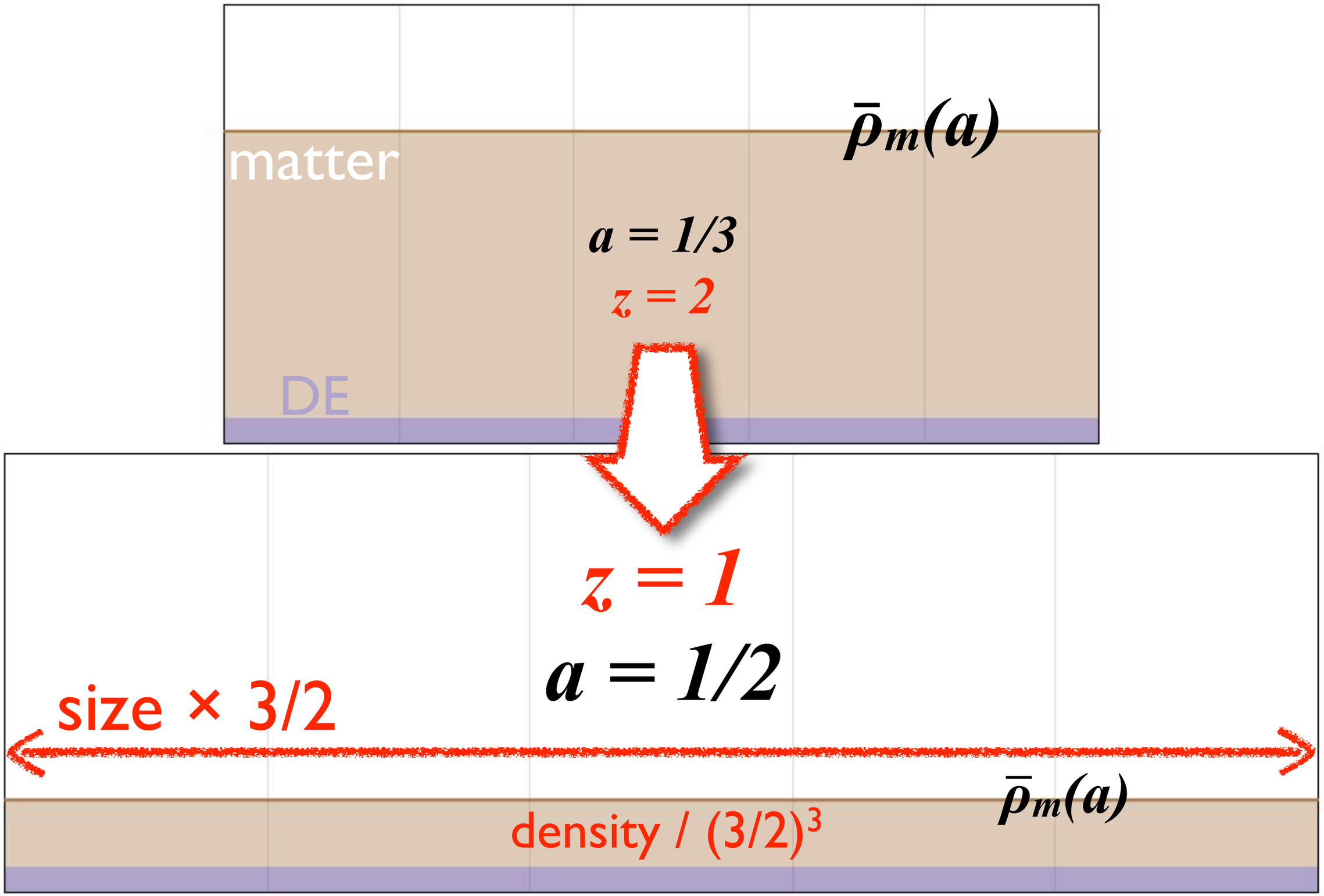
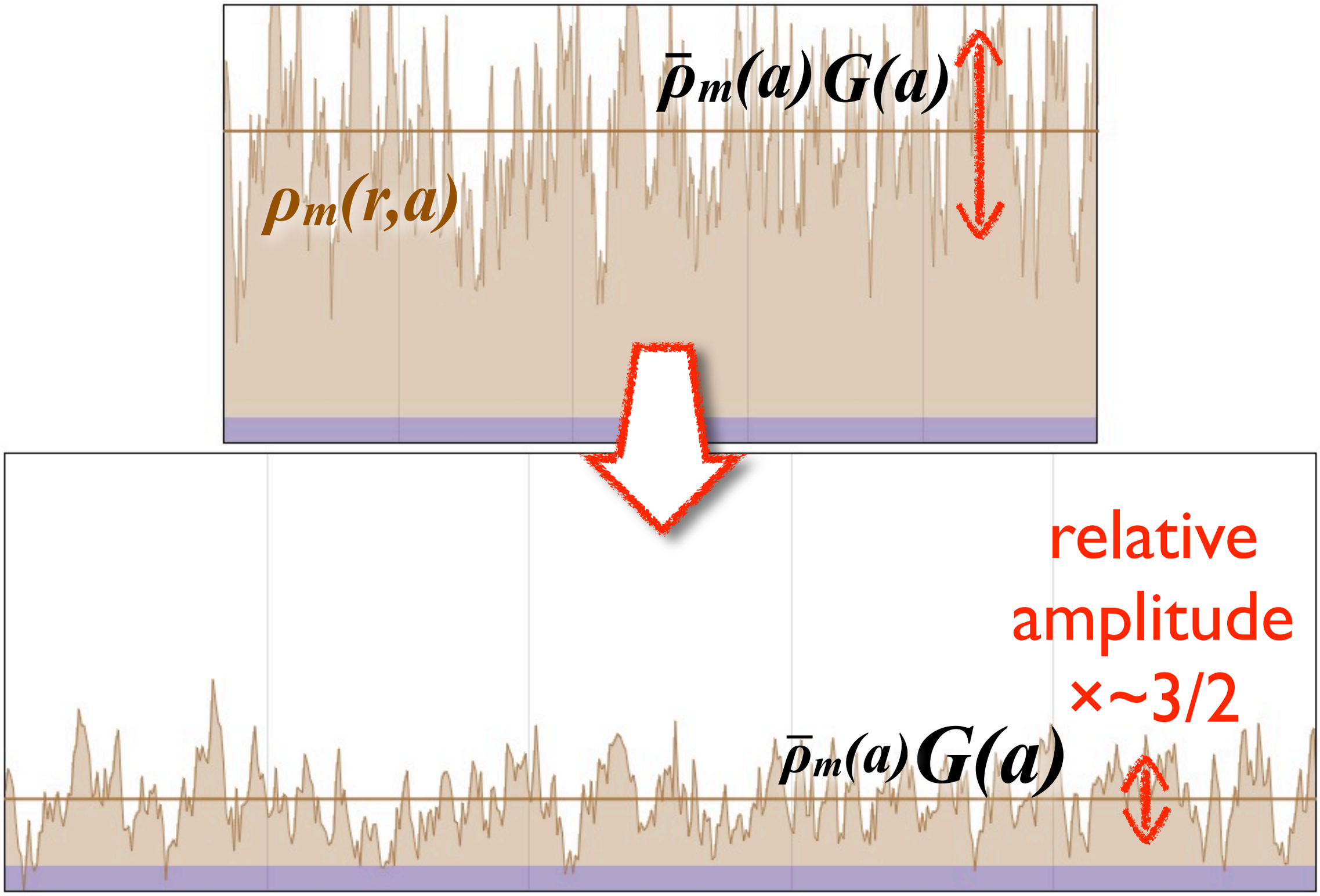
Cosmological constant

Dark energy observables:
smooth expansion + growth of structure



Dark energy observables:

smooth expansion + growth of structure



Dark energy observables:
smooth expansion + growth of structure

cosmic microwave background (CMB)

type-Ia supernovae (SN)

baryon acoustic oscillations (BAO)

weak lensing (WL)

redshift space distortion,
cluster abundances, ...

Dark Energy Probes

Dark Energy Probes

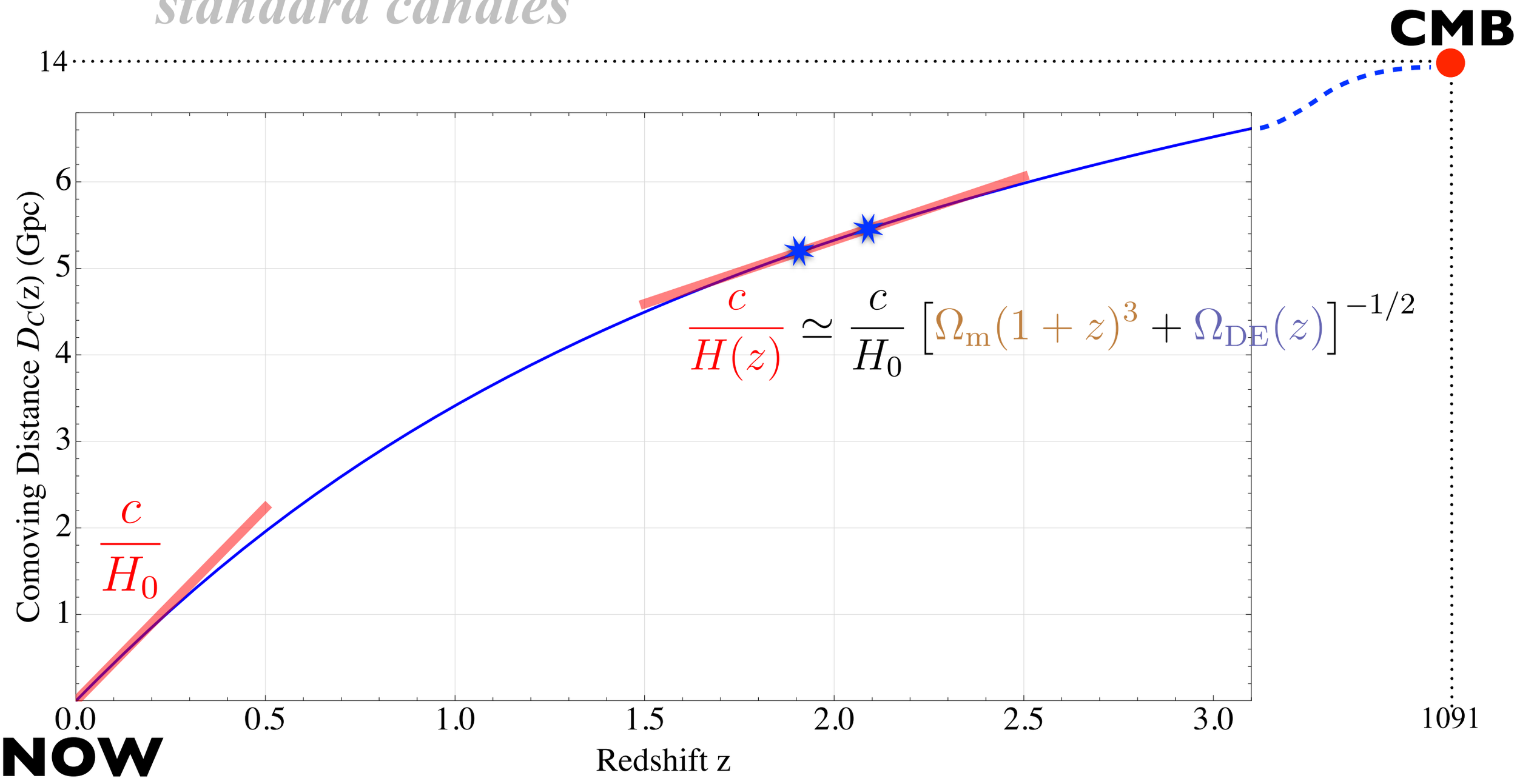
smooth expansion + growth of structure

Hubble function

distance vs redshift

standard rulers

standard candles



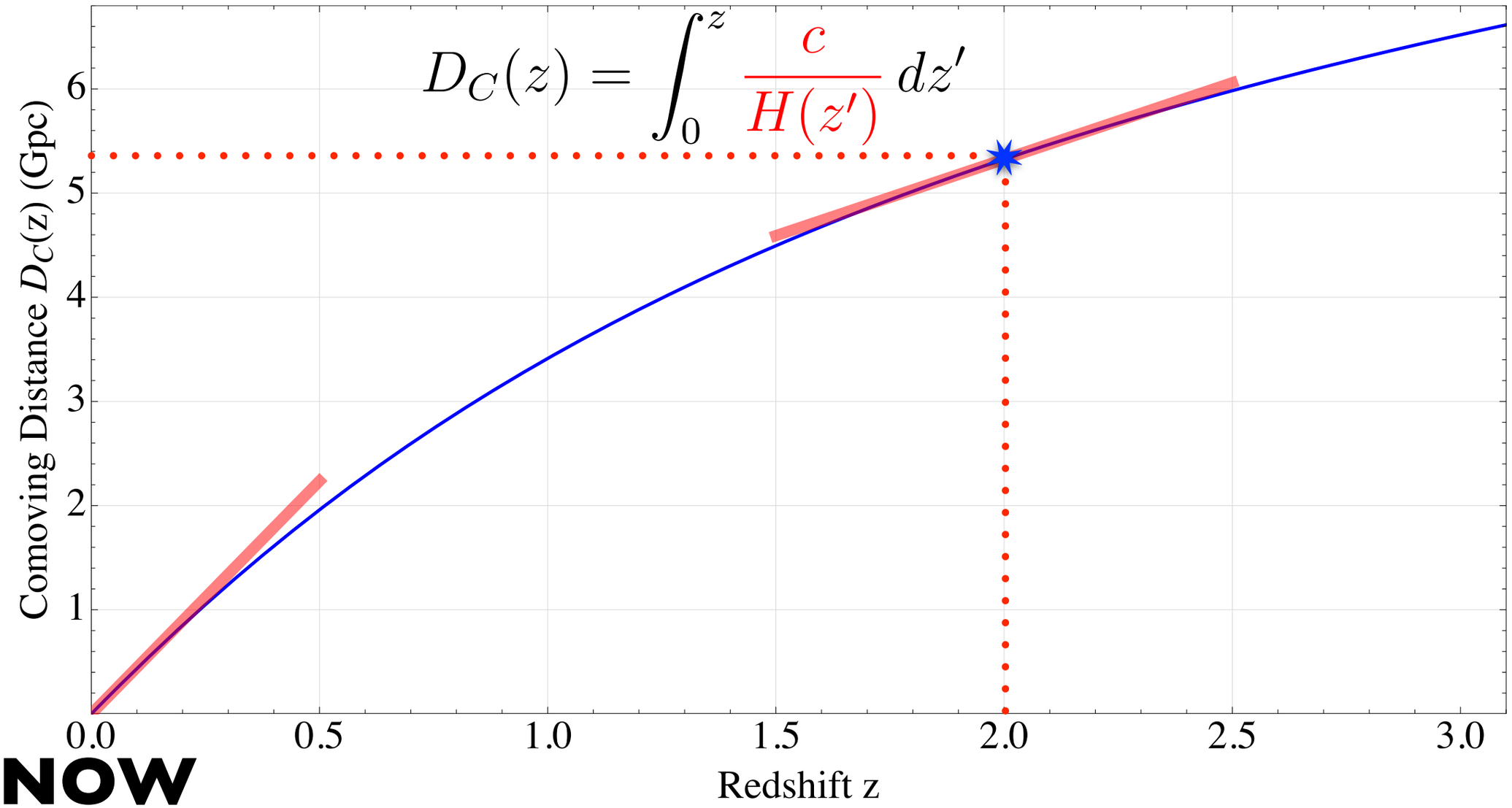
smooth expansion + growth of structure

Hubble function

distance vs redshift

standard rulers

standard candles



smooth expansion + growth of structure

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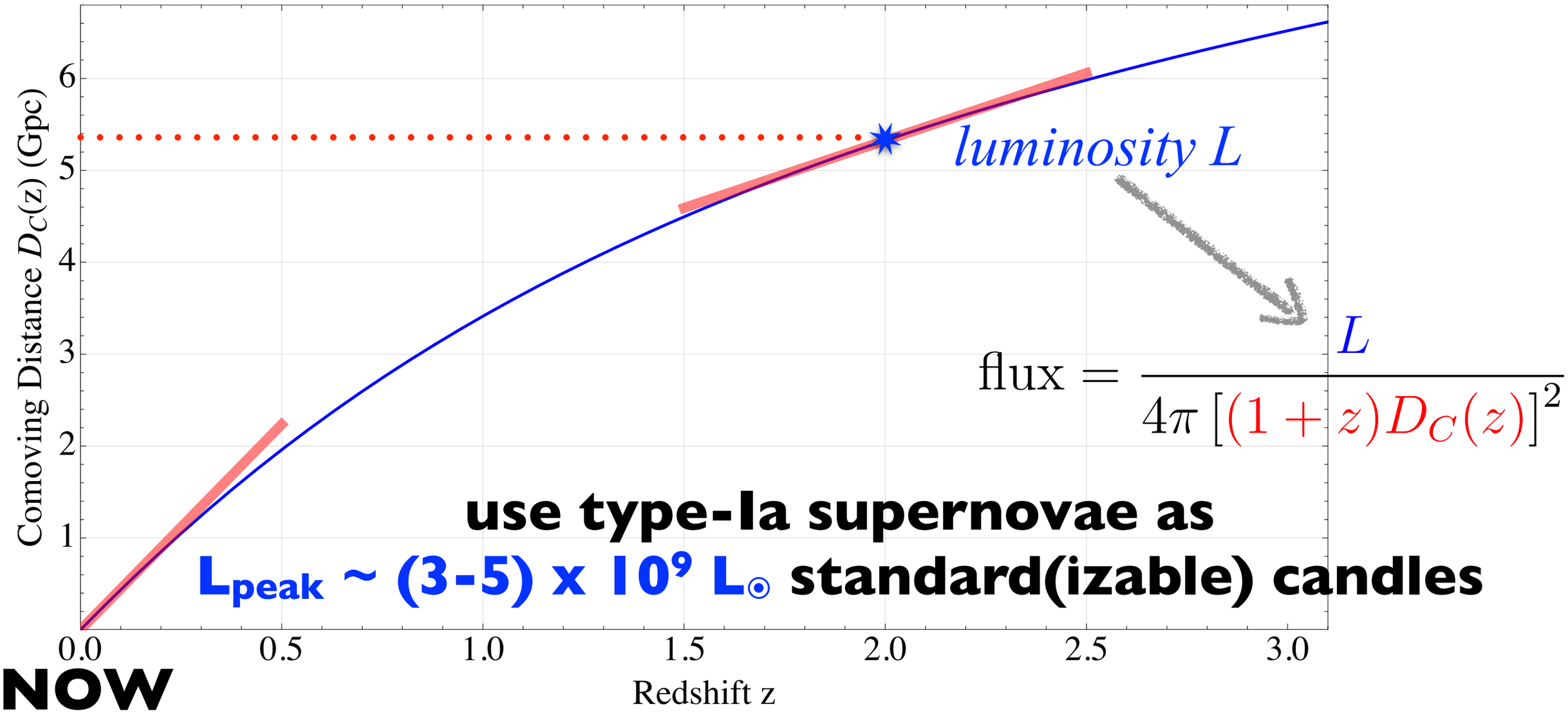


NOW

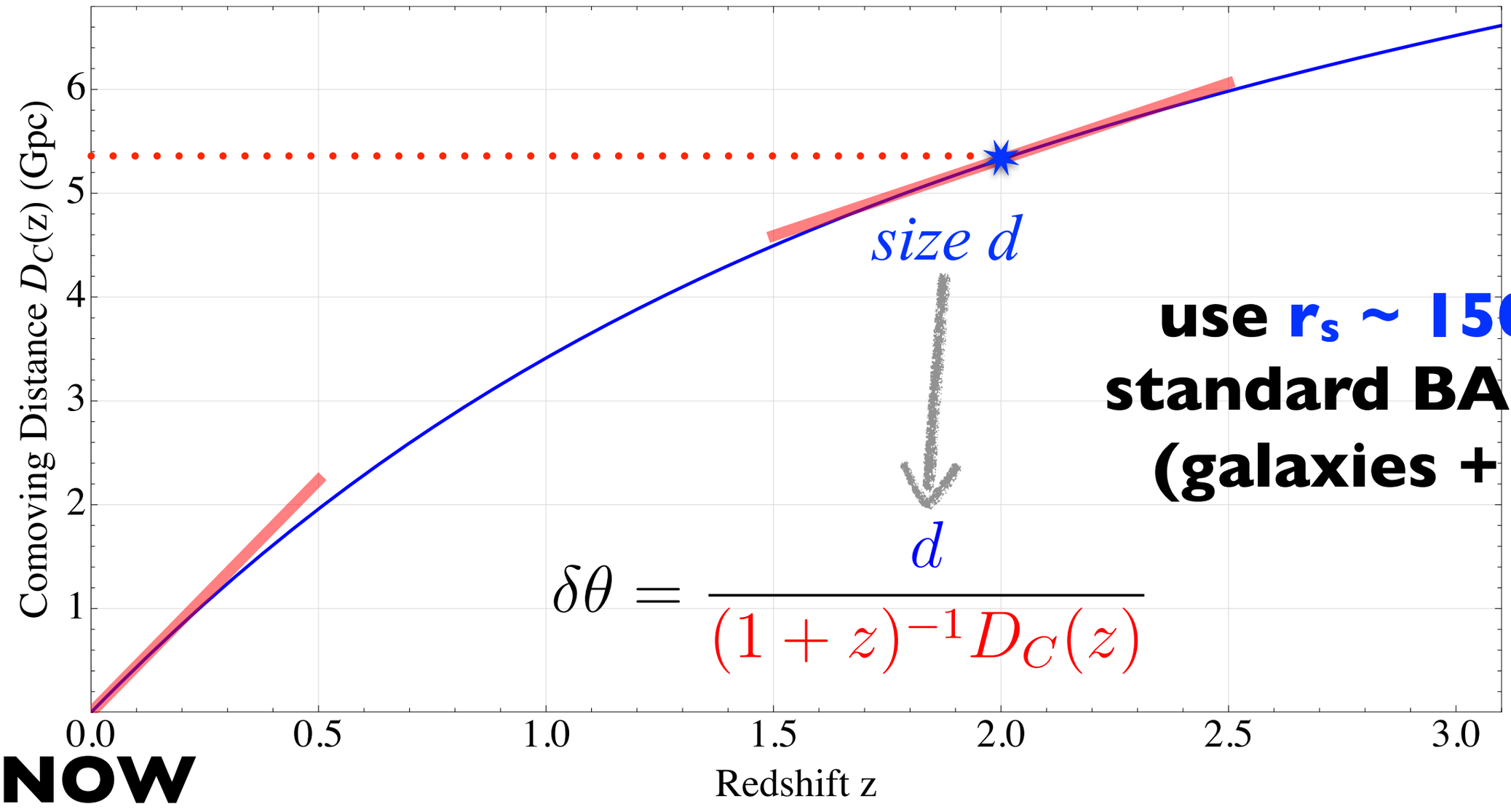
smooth expansion + growth of structure

Hubble function

distance vs redshift

standard candles

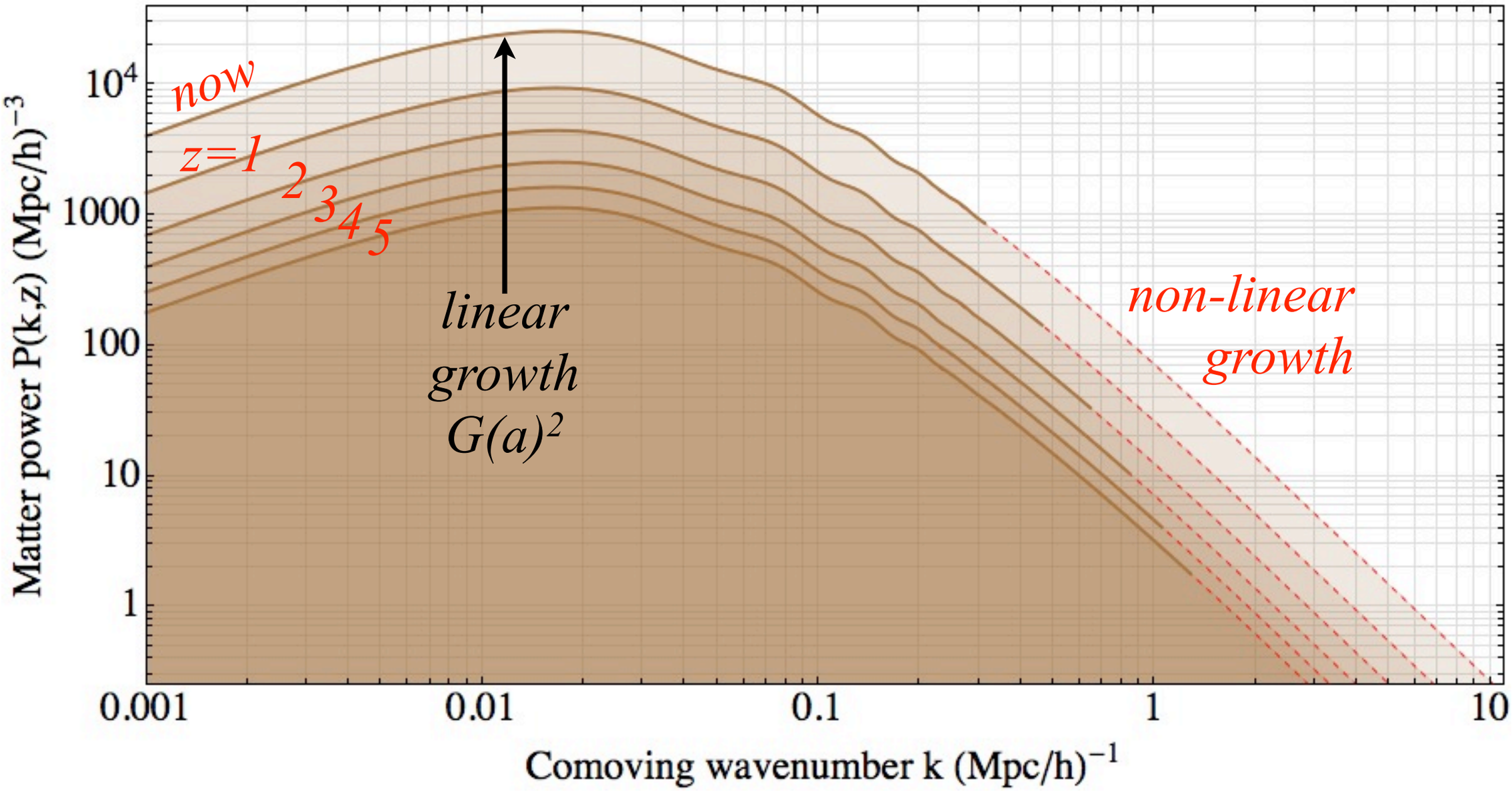
standard rulers



smooth expansion + growth of structure

Hubble function
distance vs redshift
standard rulers
standard candles

growth function
power spectrum
non-linearity
correlation function



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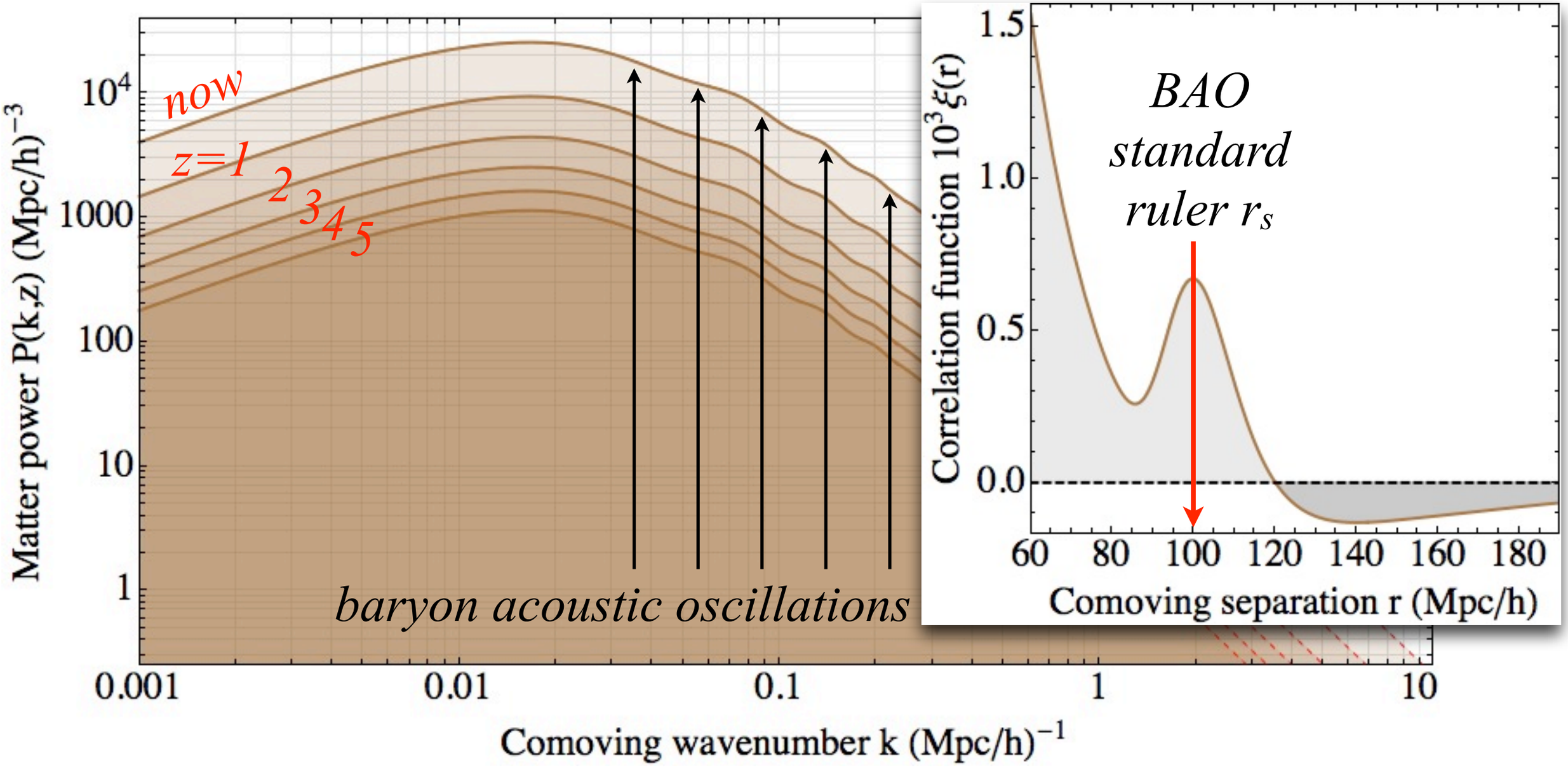
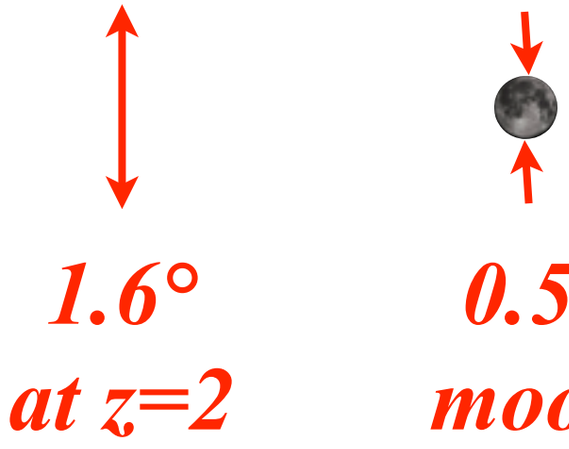


Baryon Acoustic Oscillations

$r_s \sim 150$ Mpc



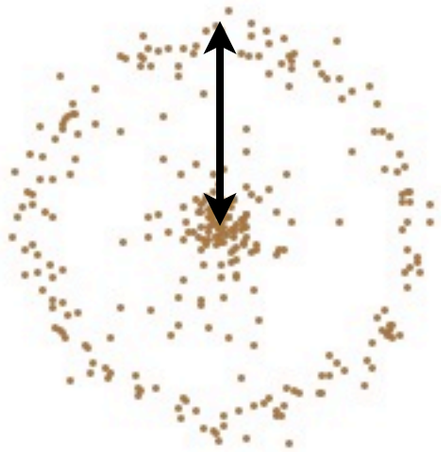
1.6°
at z=2

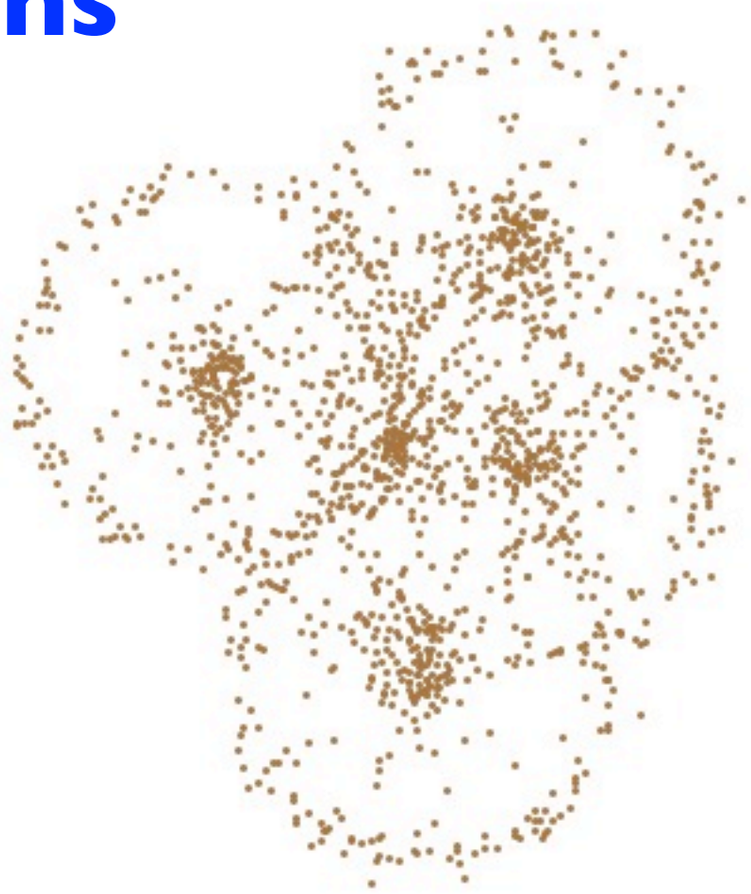
0.5°
moon

movies @ http://darkmatter.ps.uci.edu/baoviz/

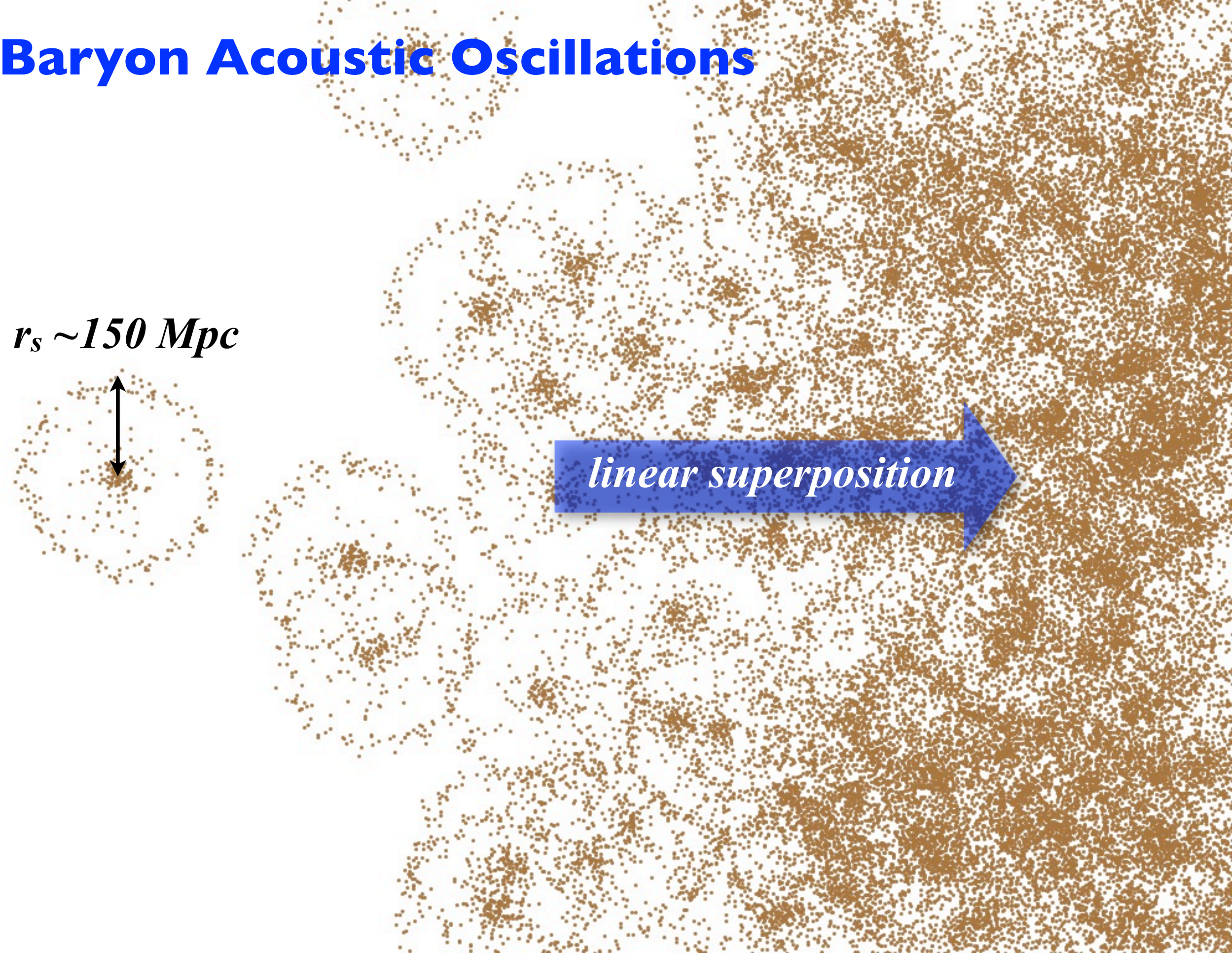
Baryon Acoustic Oscillations

$r_s \sim 150$ Mpc





Baryon Acoustic Oscillations



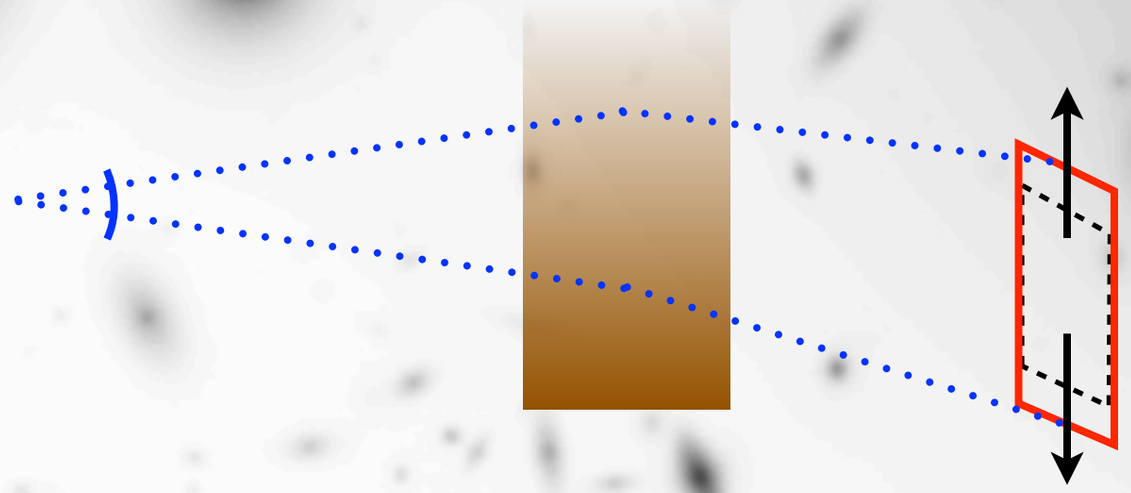
Weak Lensing

1 arcmin.

1/30 moon diameter

(log-intensity scale)

Weak Lensing



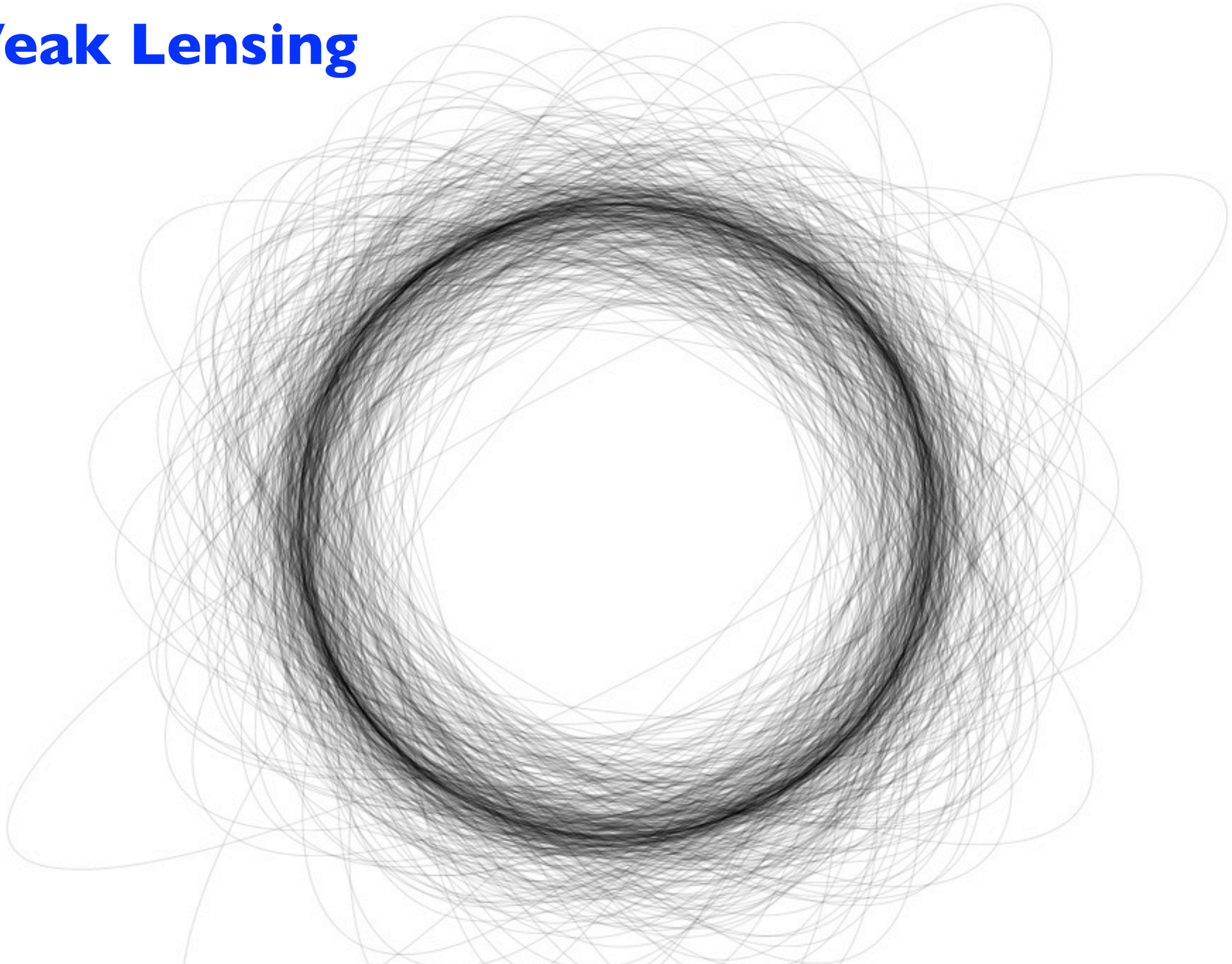
5% constant shear applied

1 arcmin.

1/30 moon diameter

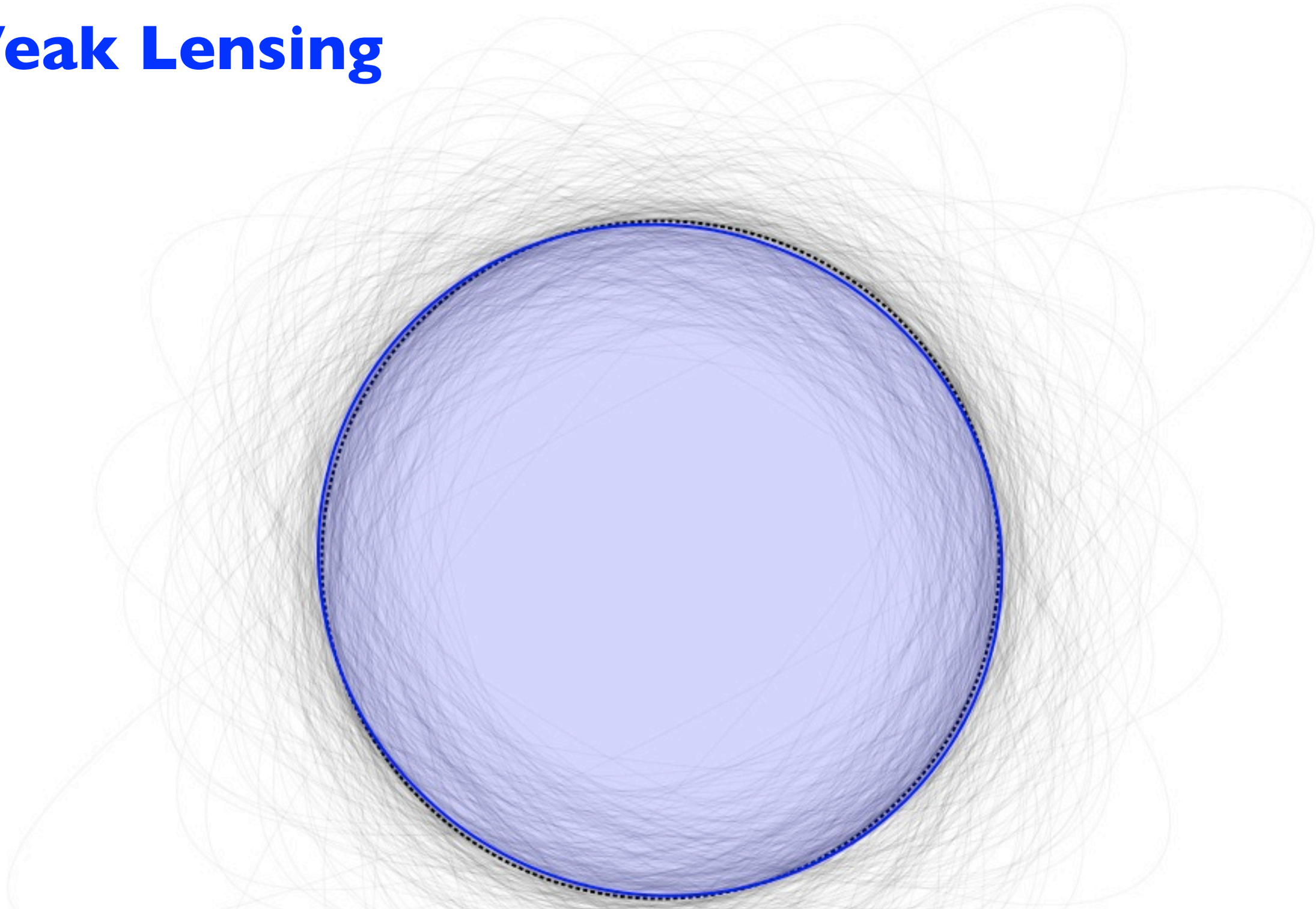
(log-intensity scale)

Weak Lensing



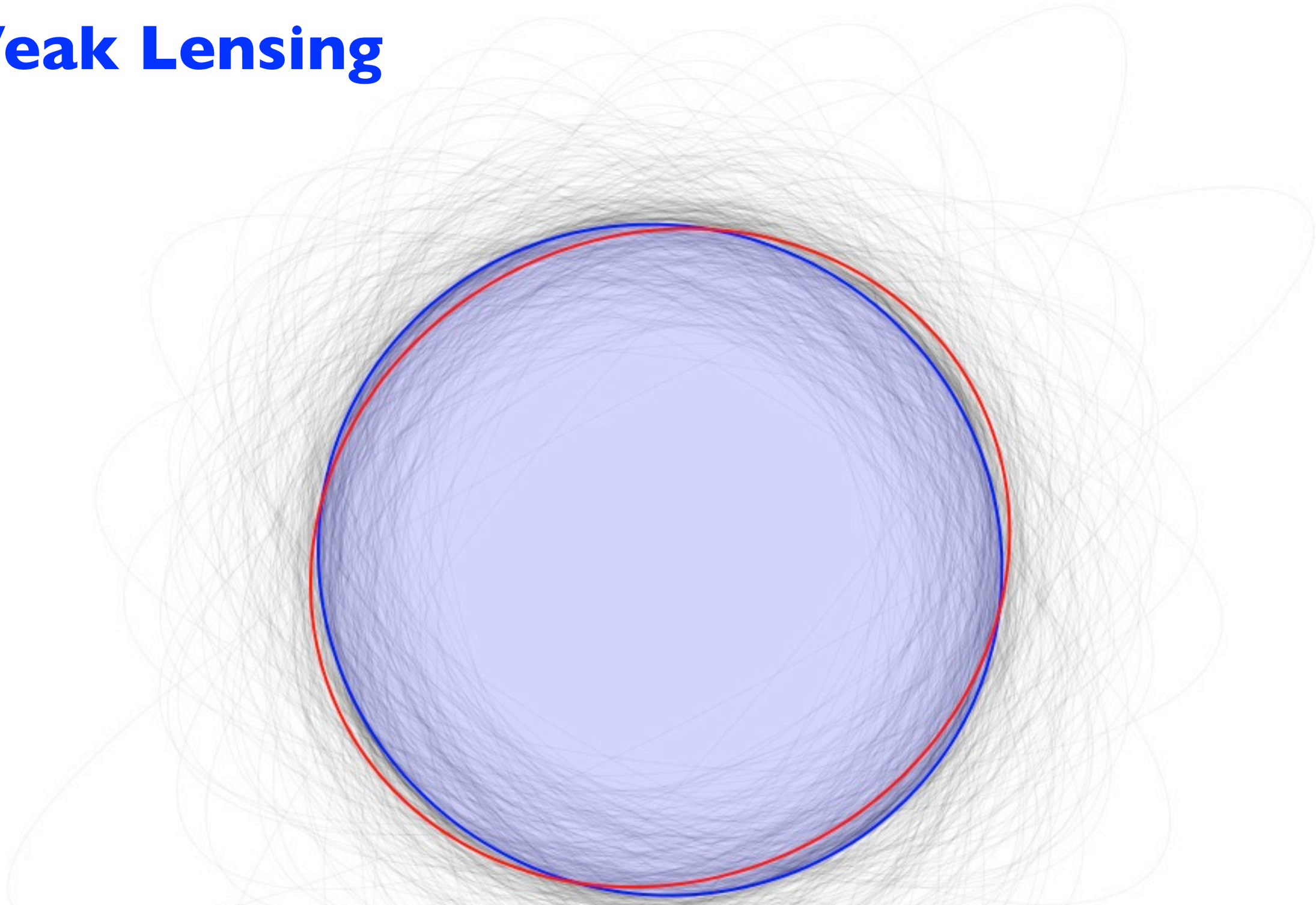
average of 400 galaxy shapes is ~round

Weak Lensing



average of 400 galaxy shapes is ~round

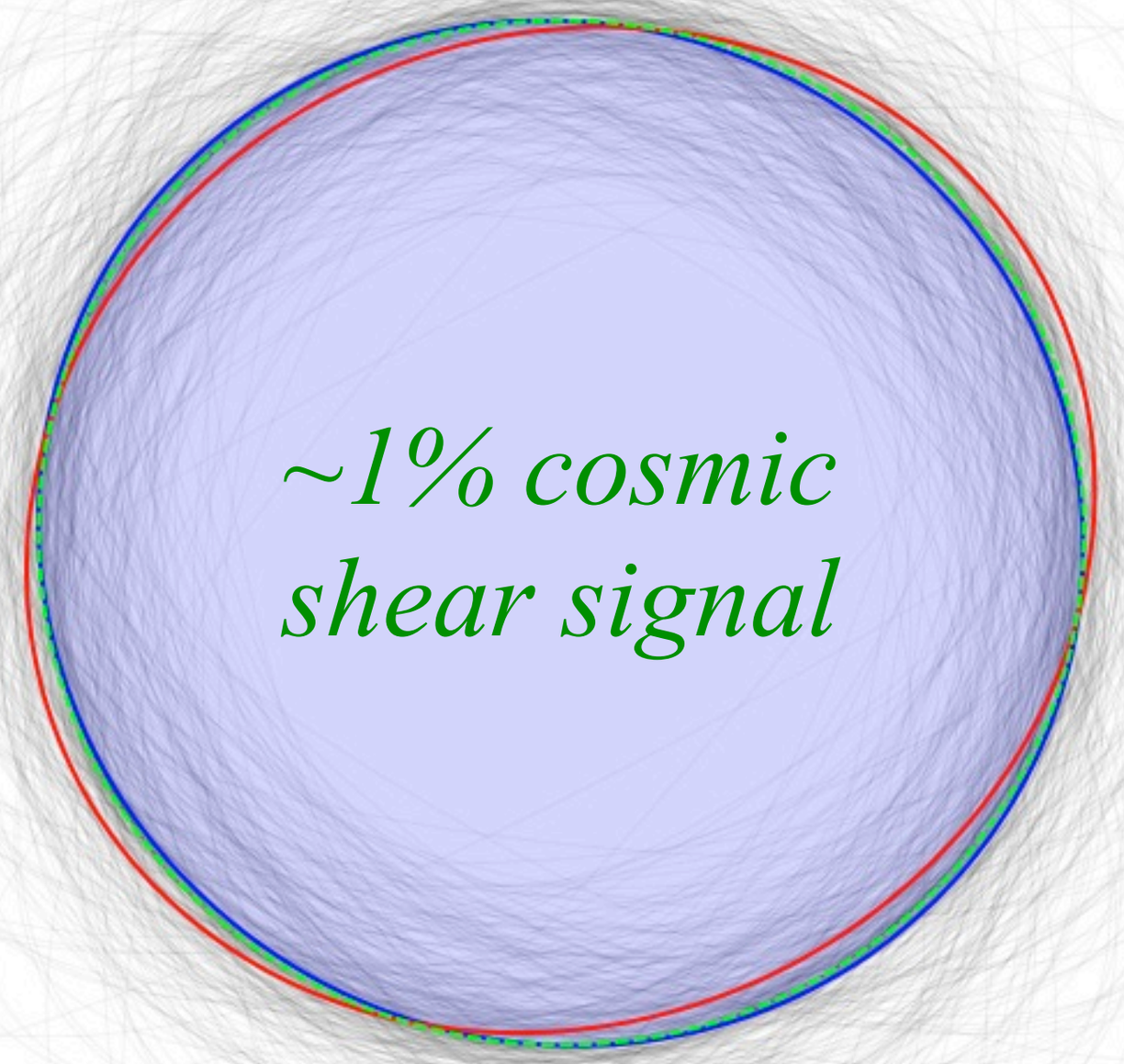
Weak Lensing



5% constant shear applied

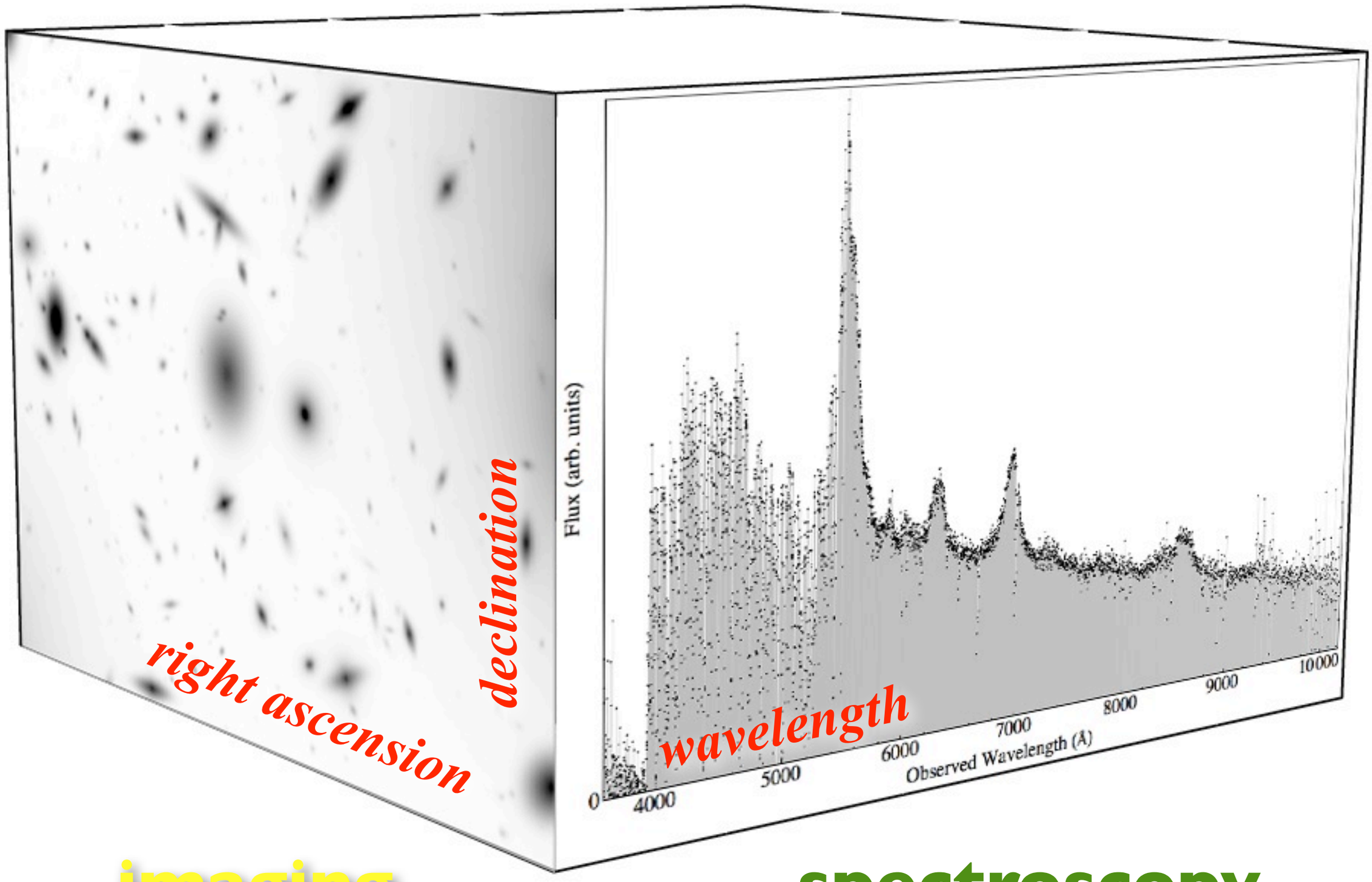
average of 400 galaxy shapes is ~round

Weak Lensing



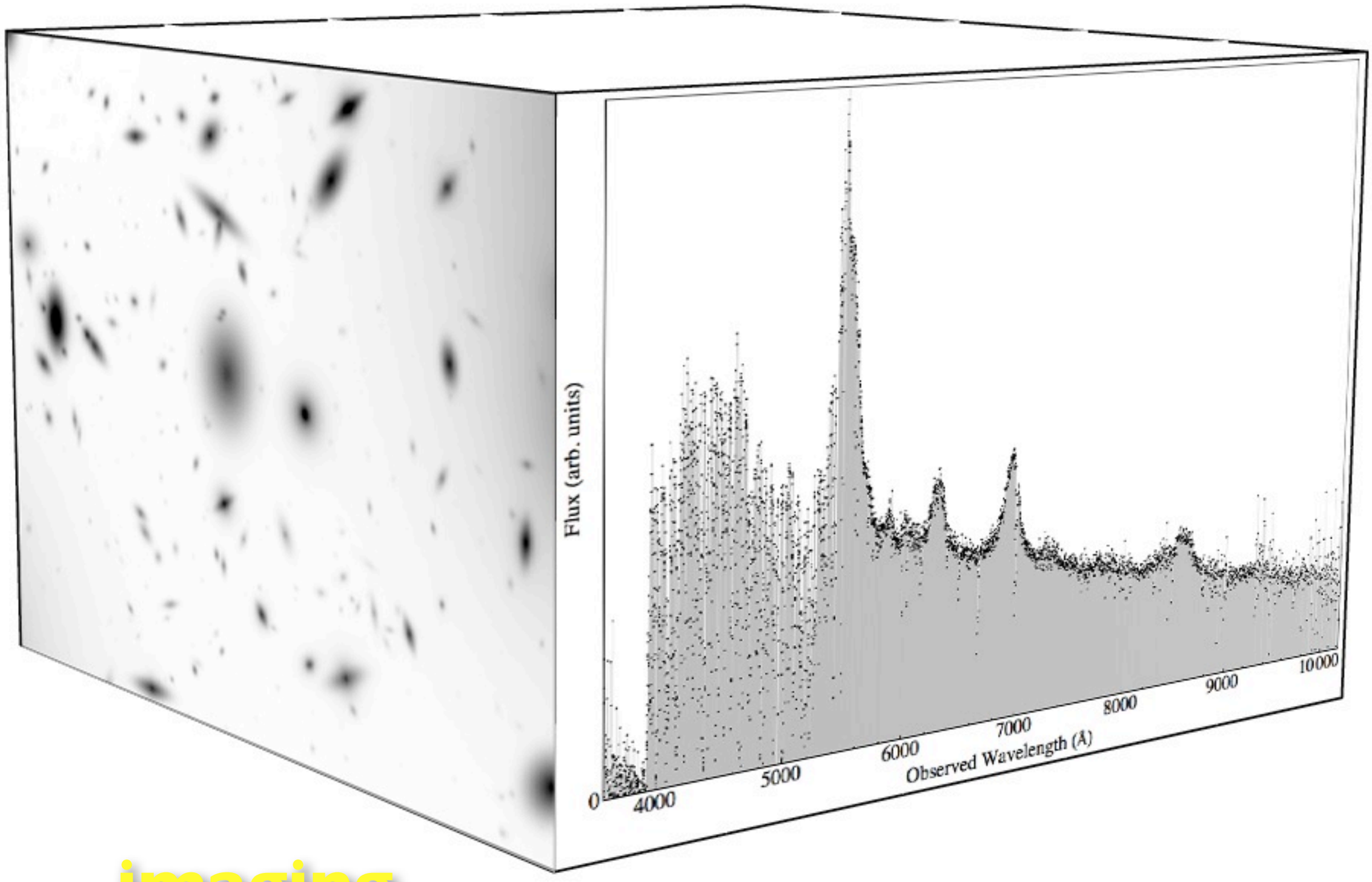
~5% constant shear due to <u>instrument & atmosphere</u>

average of 400 galaxy shapes is ~round



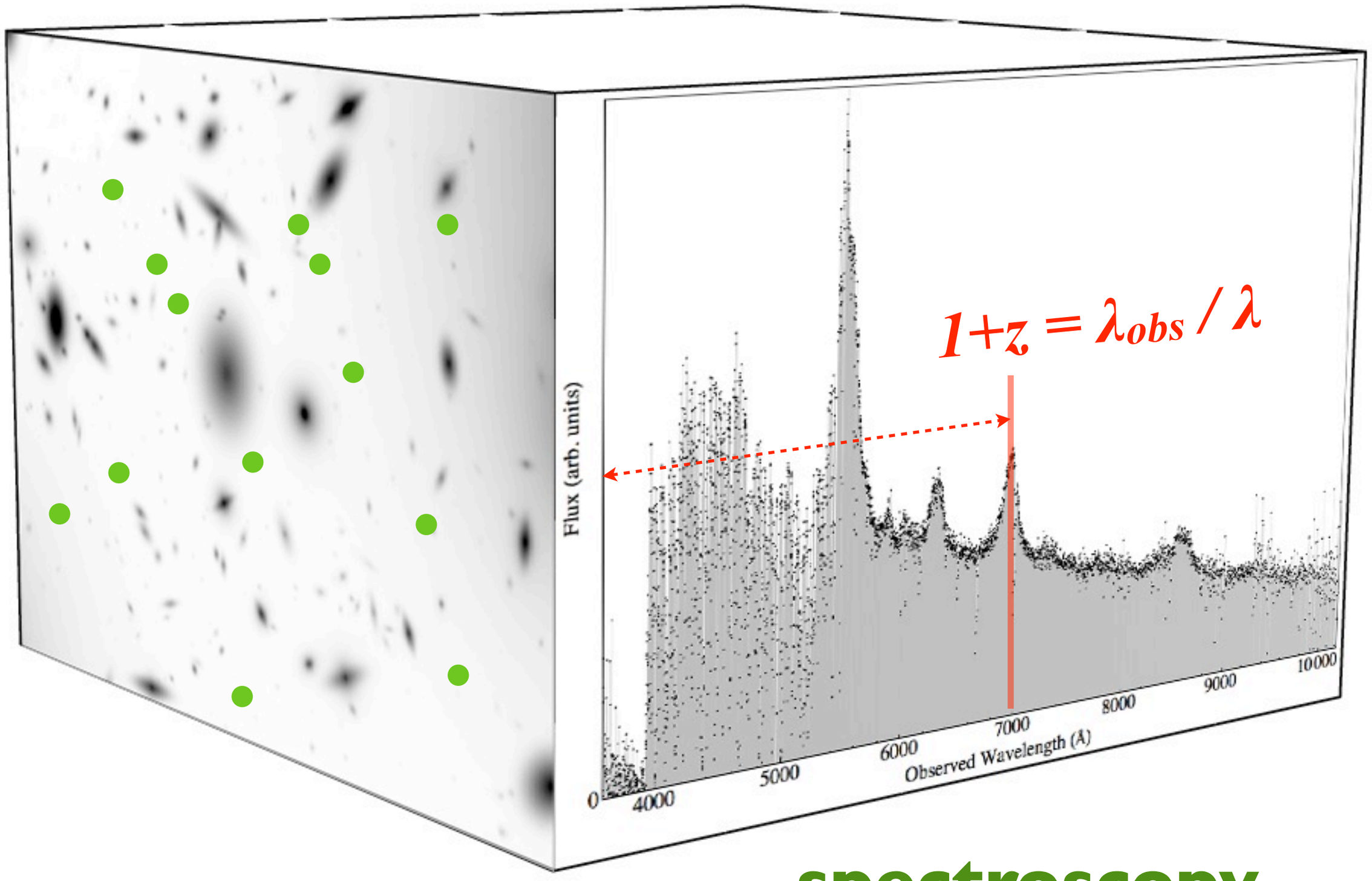
imaging

spectroscopy



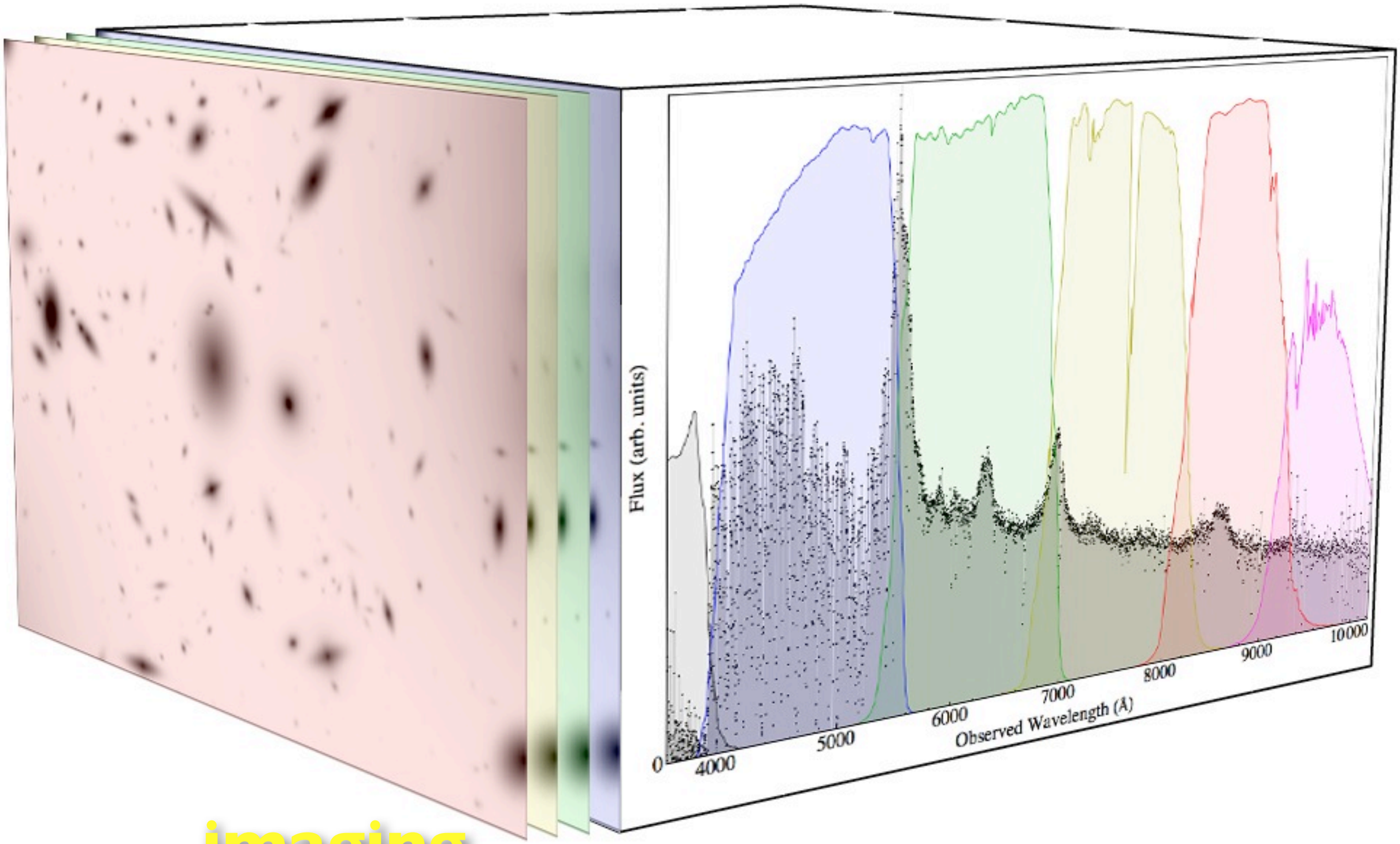
imaging

LSST: 3Gpixels covering 10 sq.deg. with 30 sec. exposures



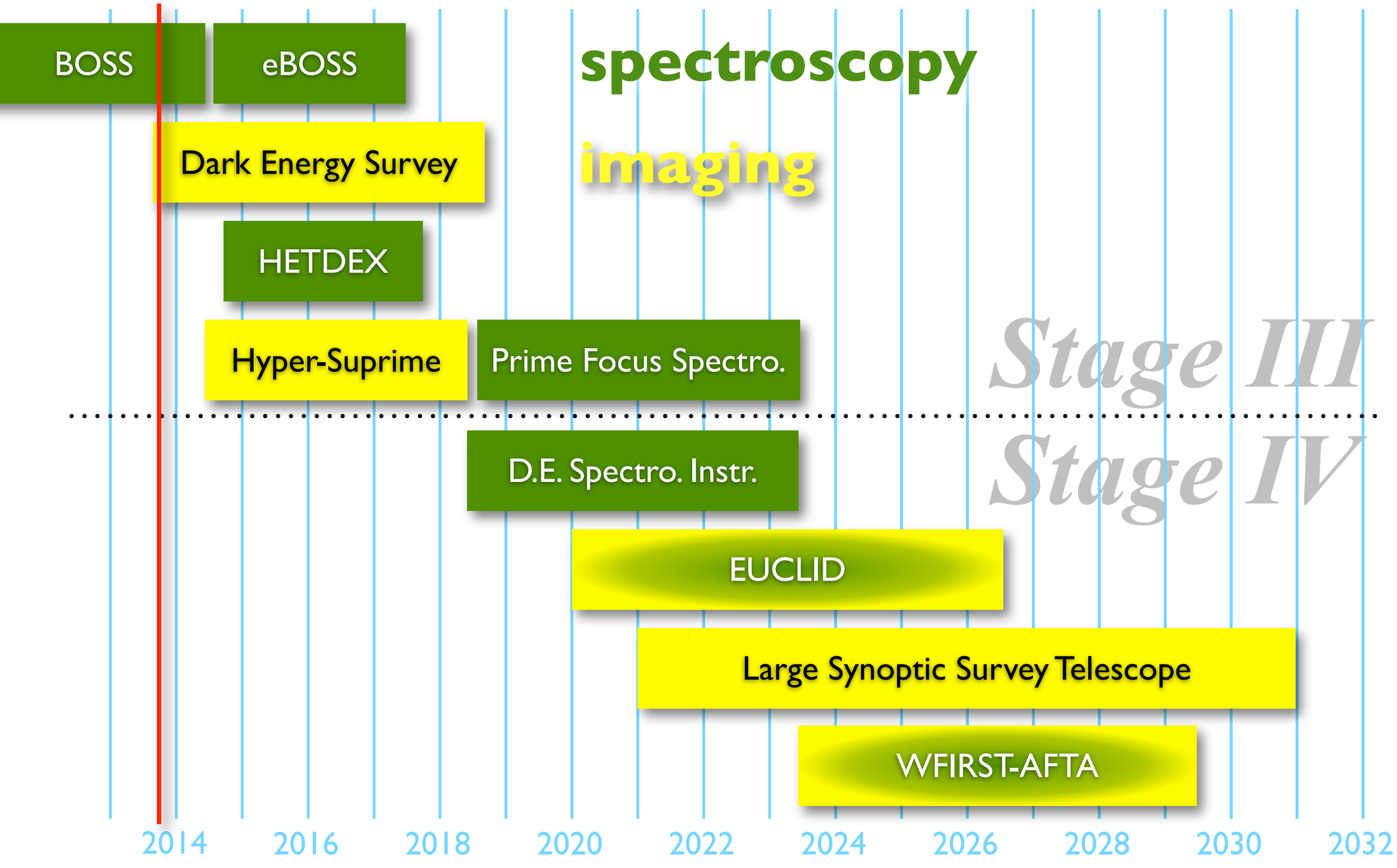
spectroscopy

DESI: 5000 fibers covering 3 sq. deg. with ~30min. exposures



LSST: "photo-z" redshift estimates using 6 filter bands

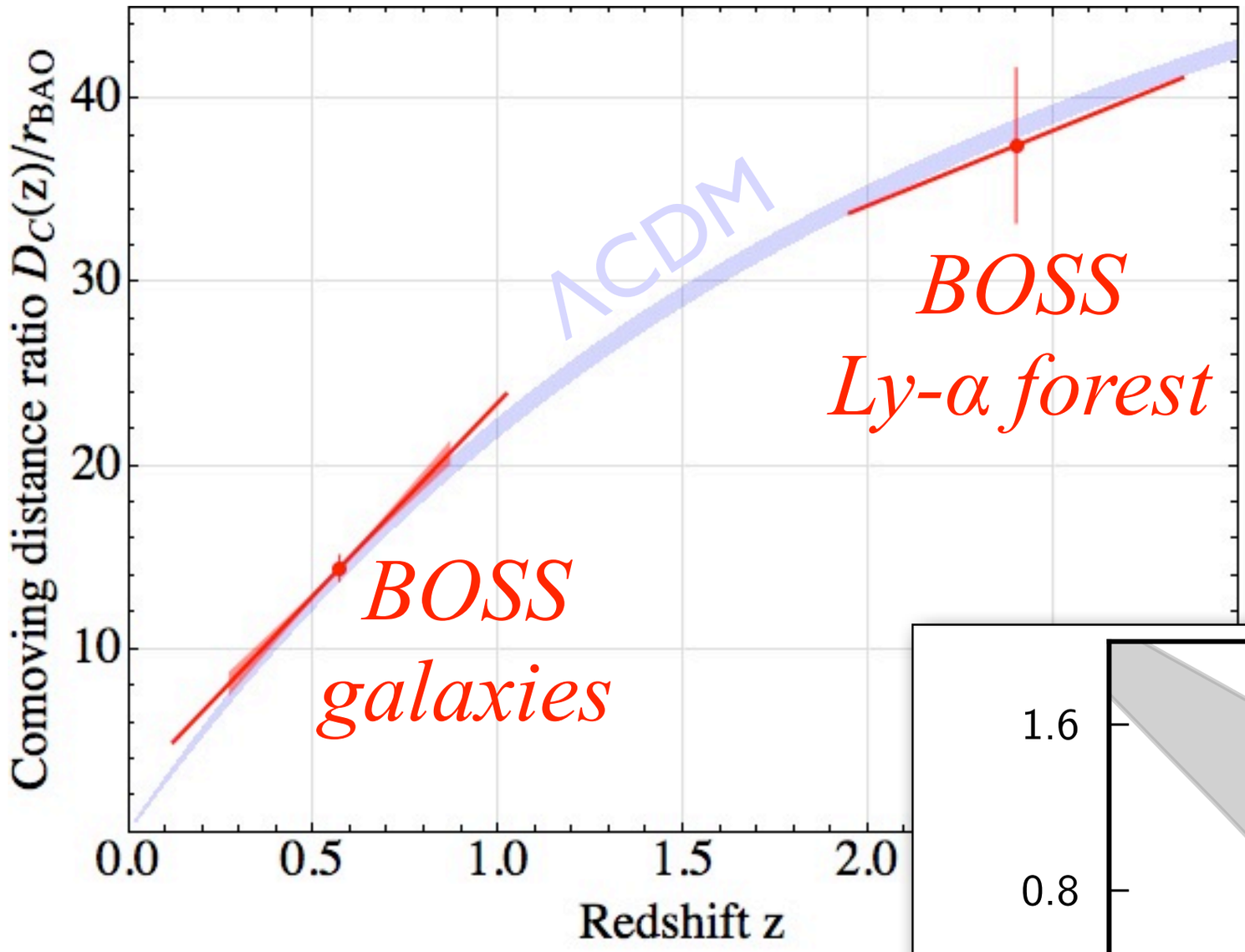
The dark energy facilities roadmap



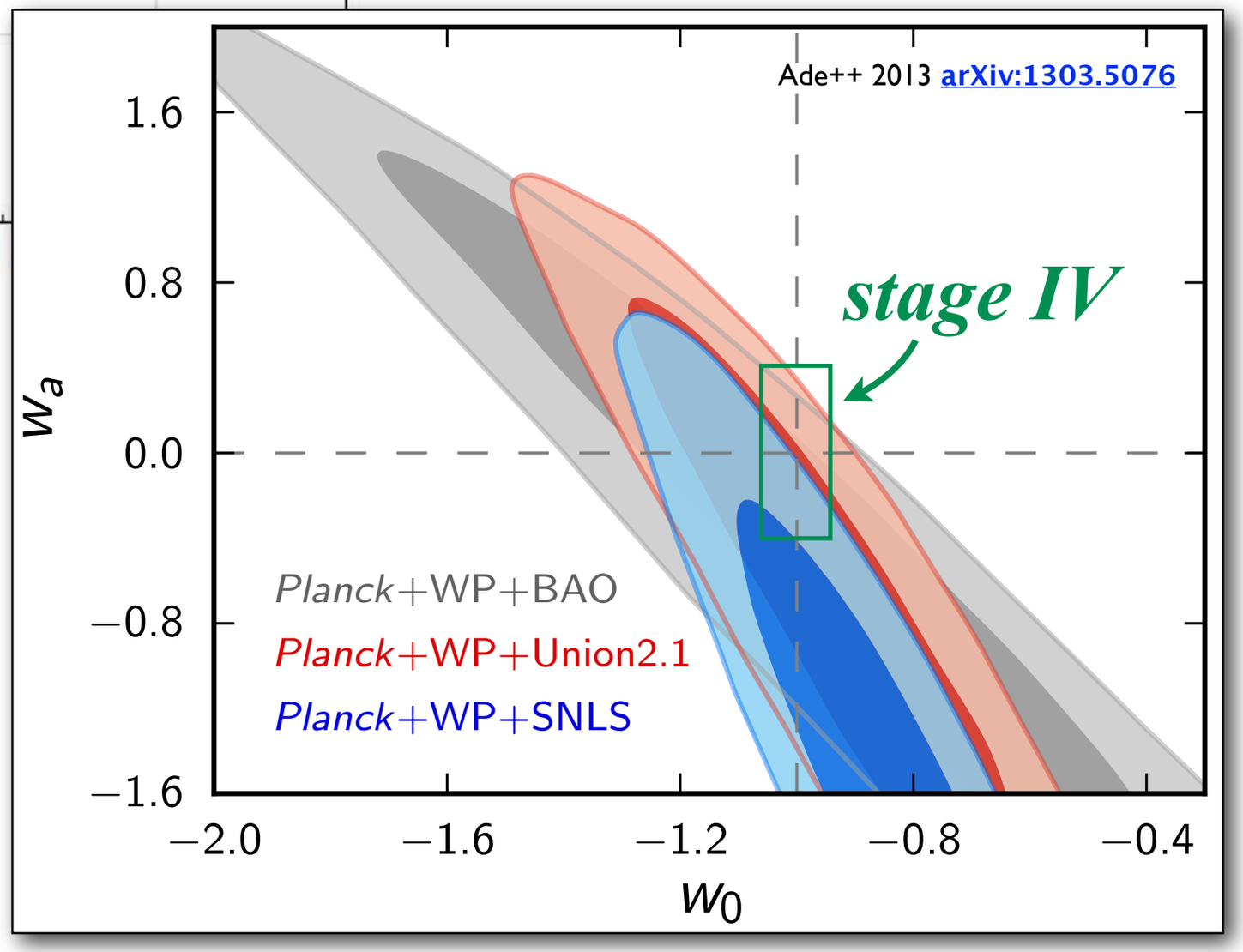
Anderson++ 2013 arXiv:1303.4666

Slosar++ 2013 arXiv:1301.3459

Kirkby++ 2013 arXiv:1301.3456



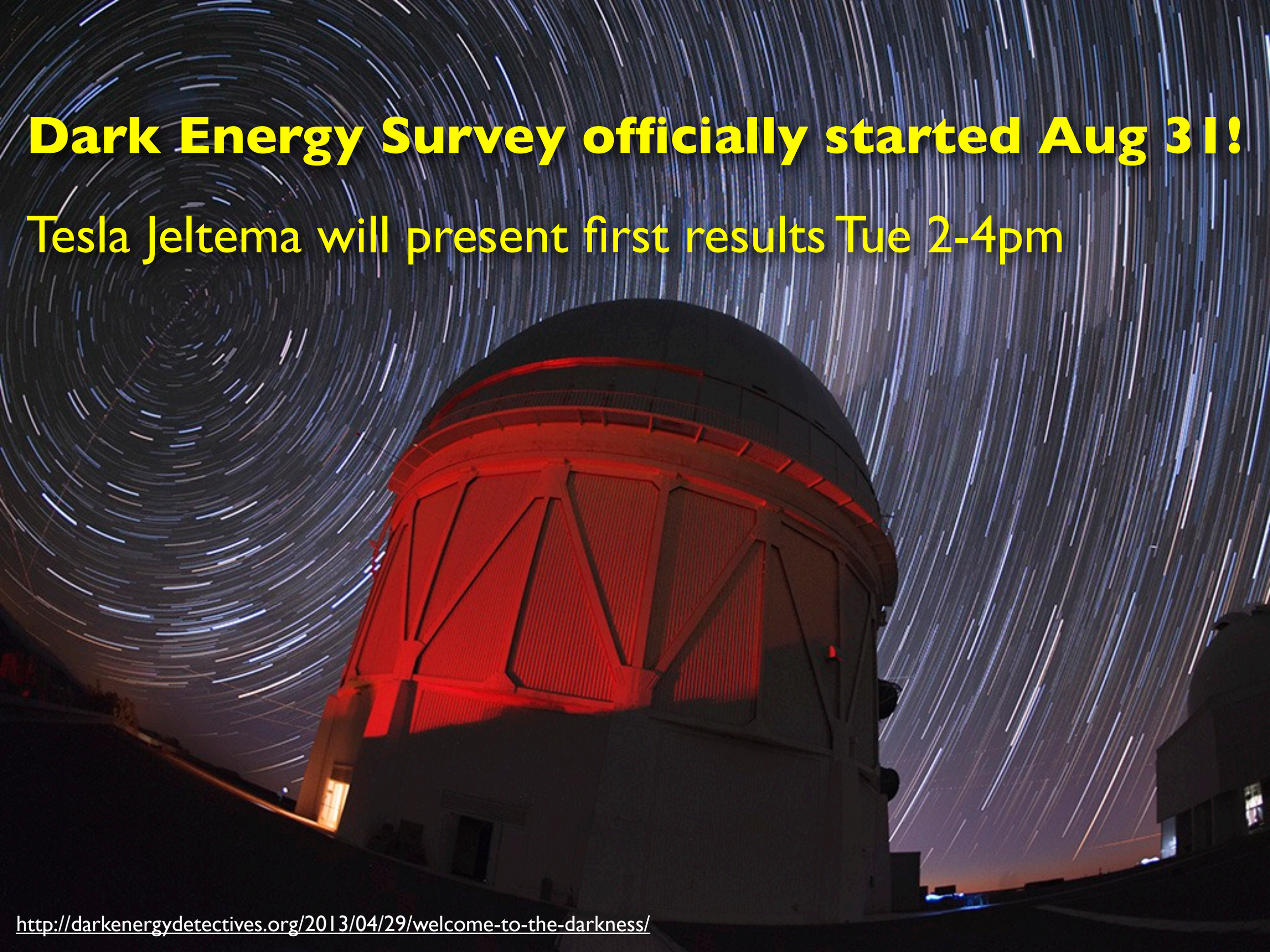
$$w(a) = w_0 + w_a(1\text{-}a)$$



Early stage III results

Dark Energy Survey officially started Aug 31!

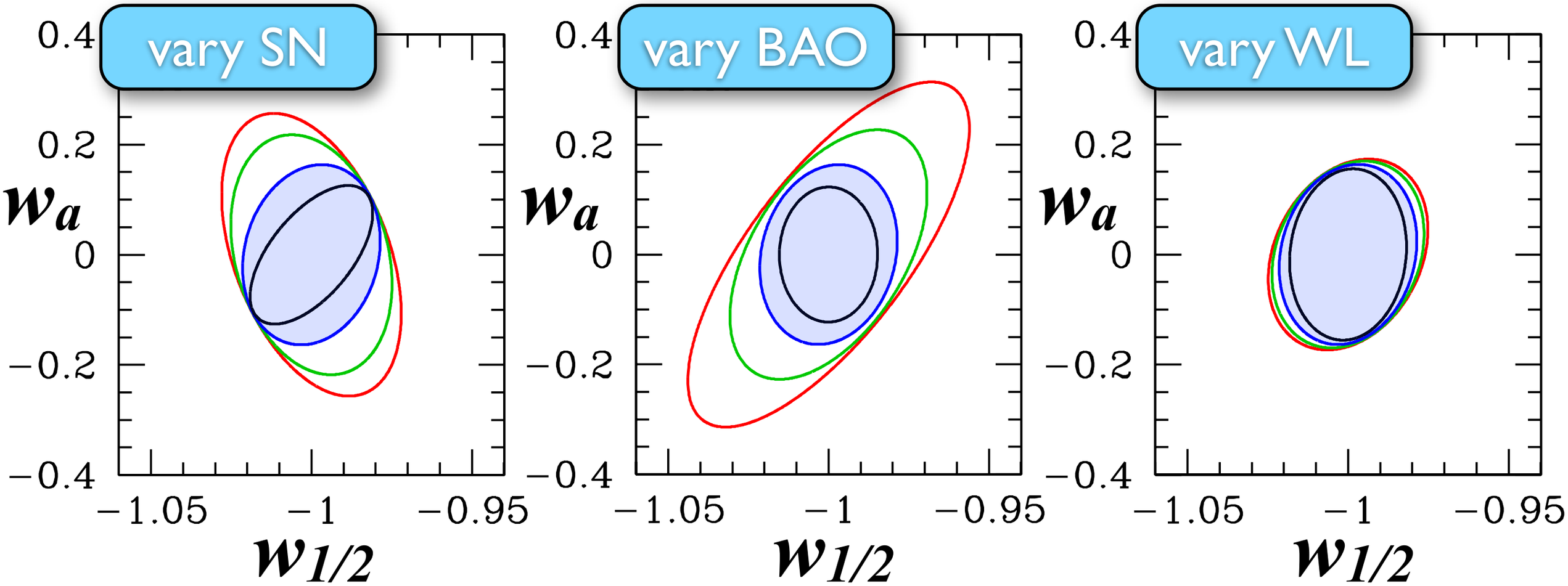
Tesla Jeltema will present first results Tue 2-4pm



http://darkenergydetectives.org/2013/04/29/welcome-to-the-darkness/

Stage IV projected dark energy constraints

combined results: SN+BAO+WL+CMB



/2, nominal errors, x2, x4

Weinberg++ 2013 arXiv:1201.2434

Is dark energy w(a) ≠ -1?

YES

NO

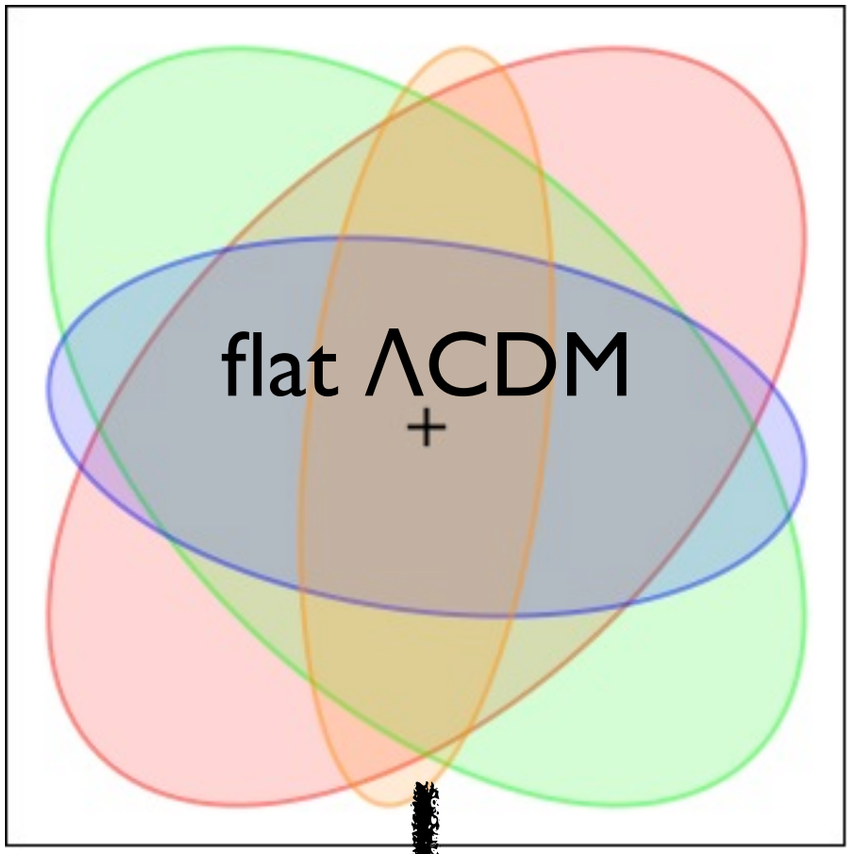
Are distances (BAO,SN) & growth of structure (WL,...) consistent within general relativity?

New form of energy

New theory of gravity

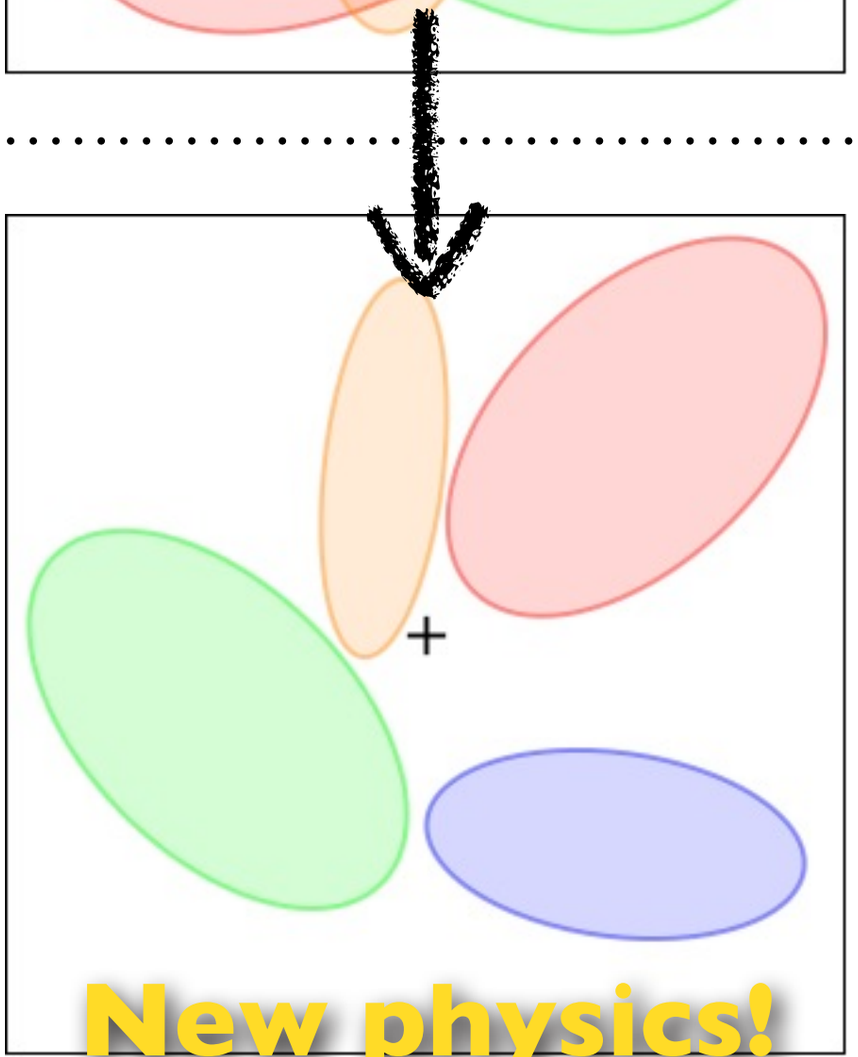
Cosmological constant

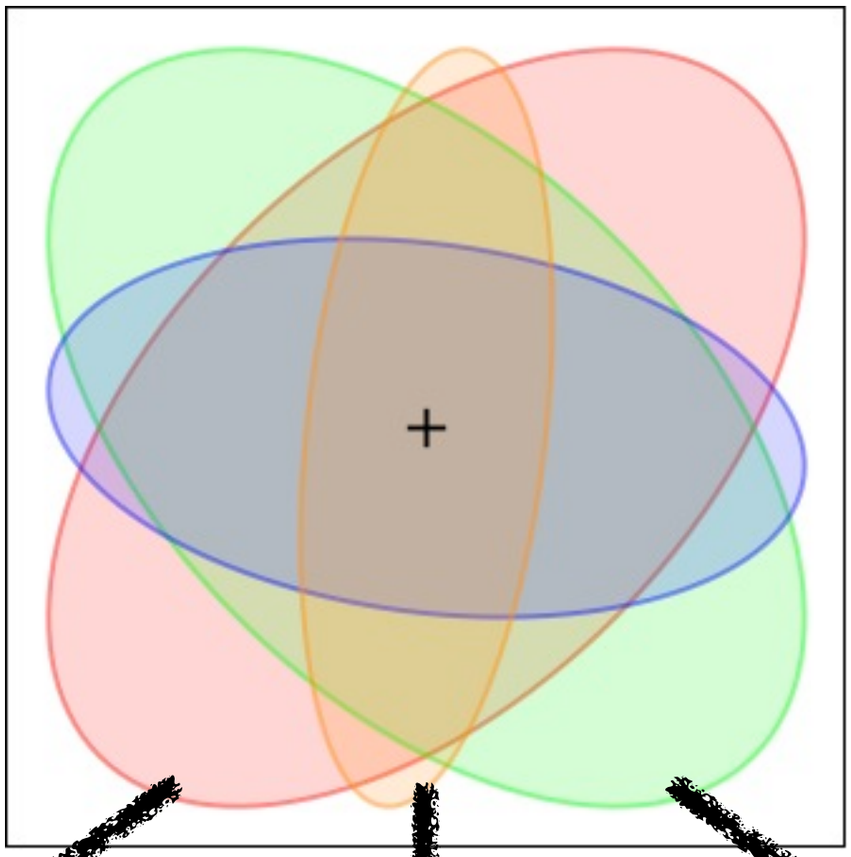
ΛCDM

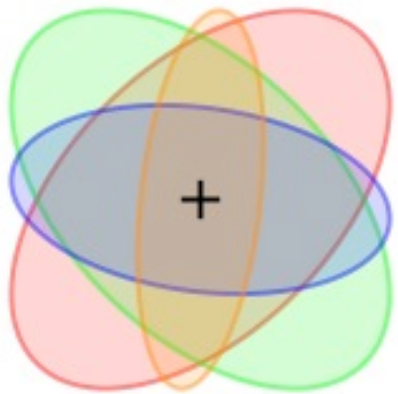


Stage III

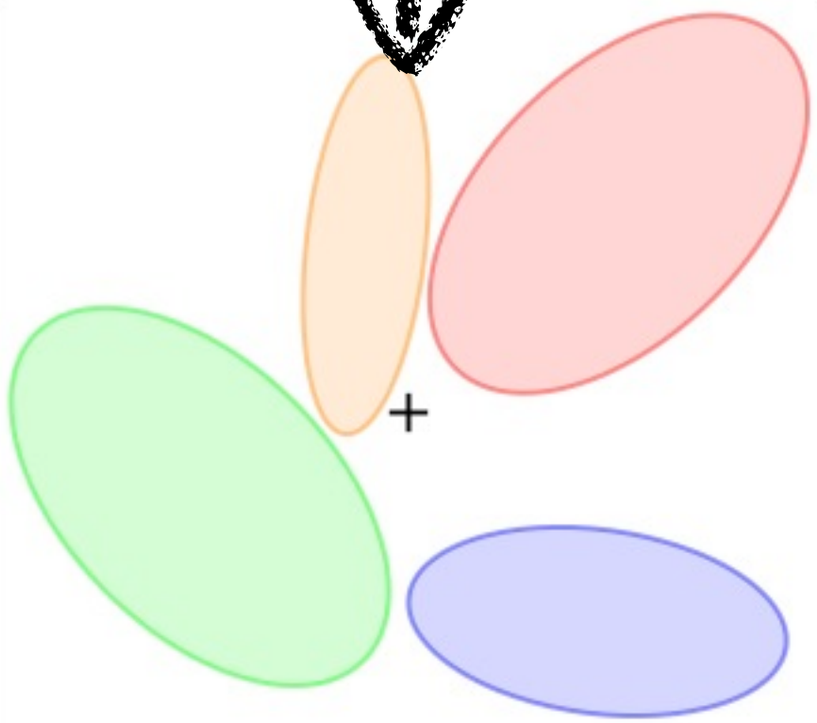
Stage IV



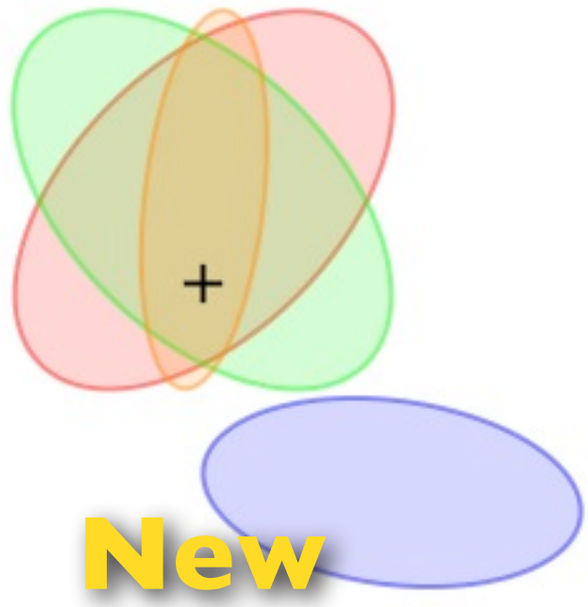




Standard Model?



New physics!



New systematics?