DARK ENERGY DOWN SOUTH

A CELEBRATION OF IOAV WAGA

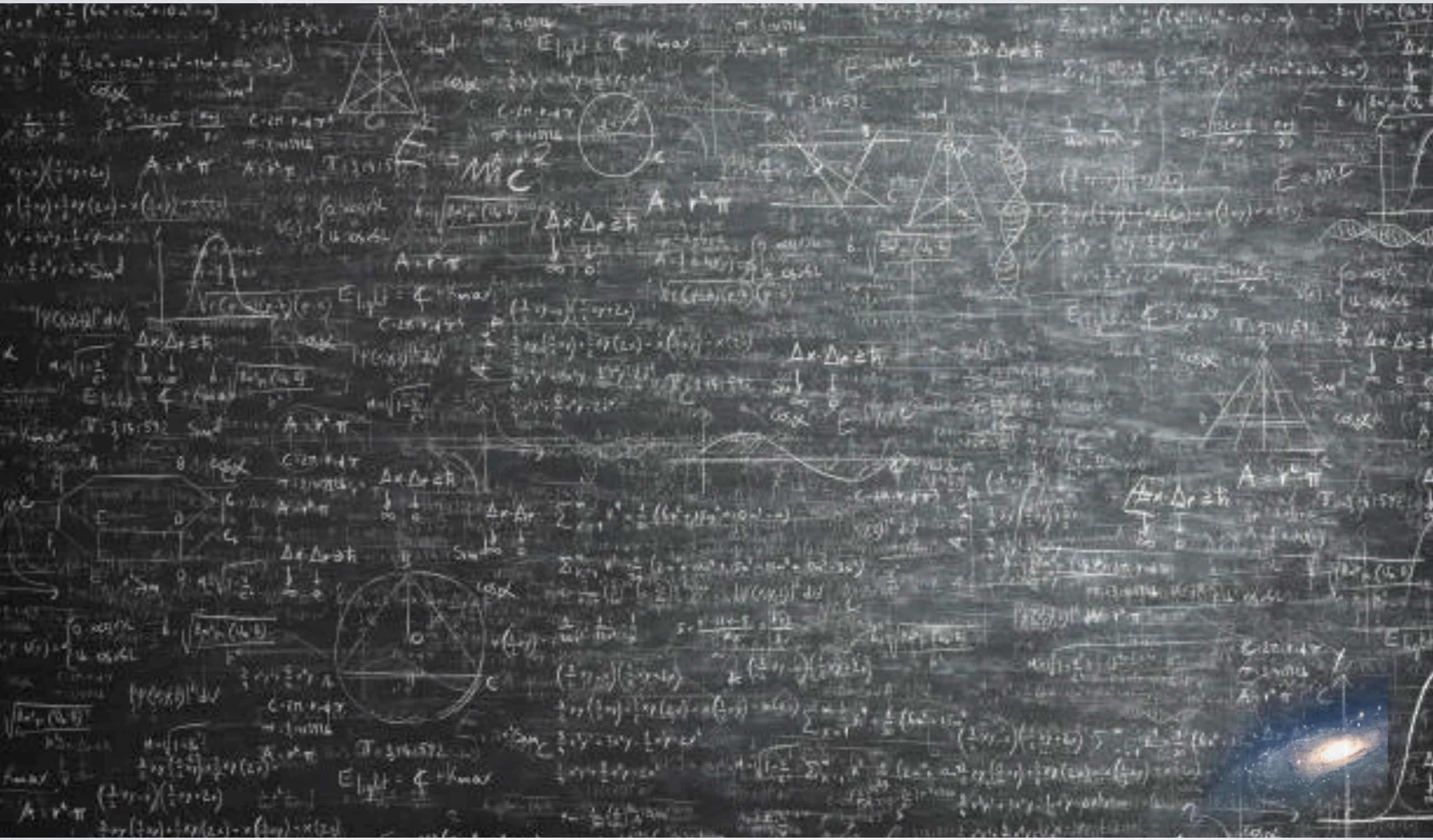


Raul Abramo
Univ. of Sao Paulo

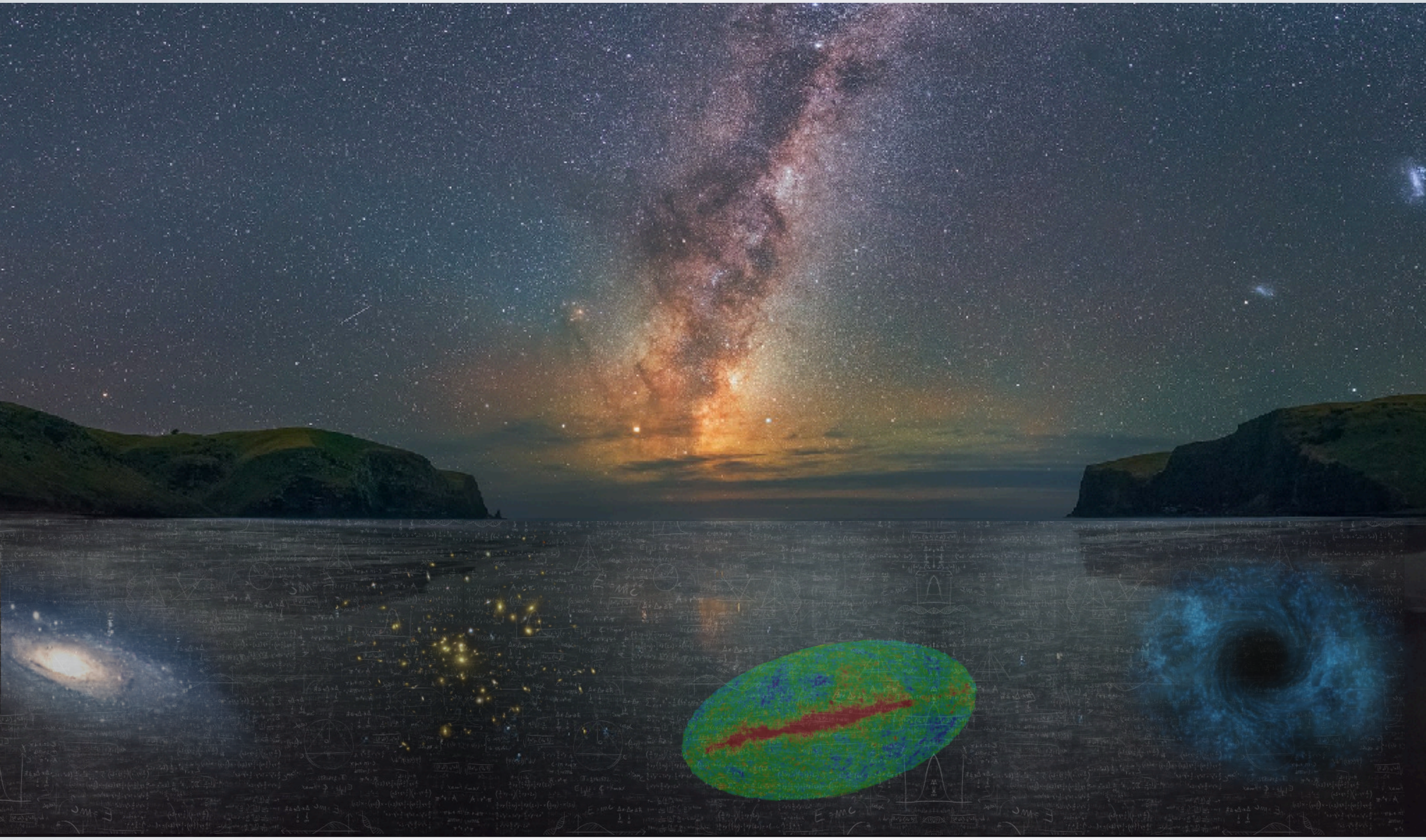
LABCOSMOS
http://www.iag.usp.br/

Physics Institute

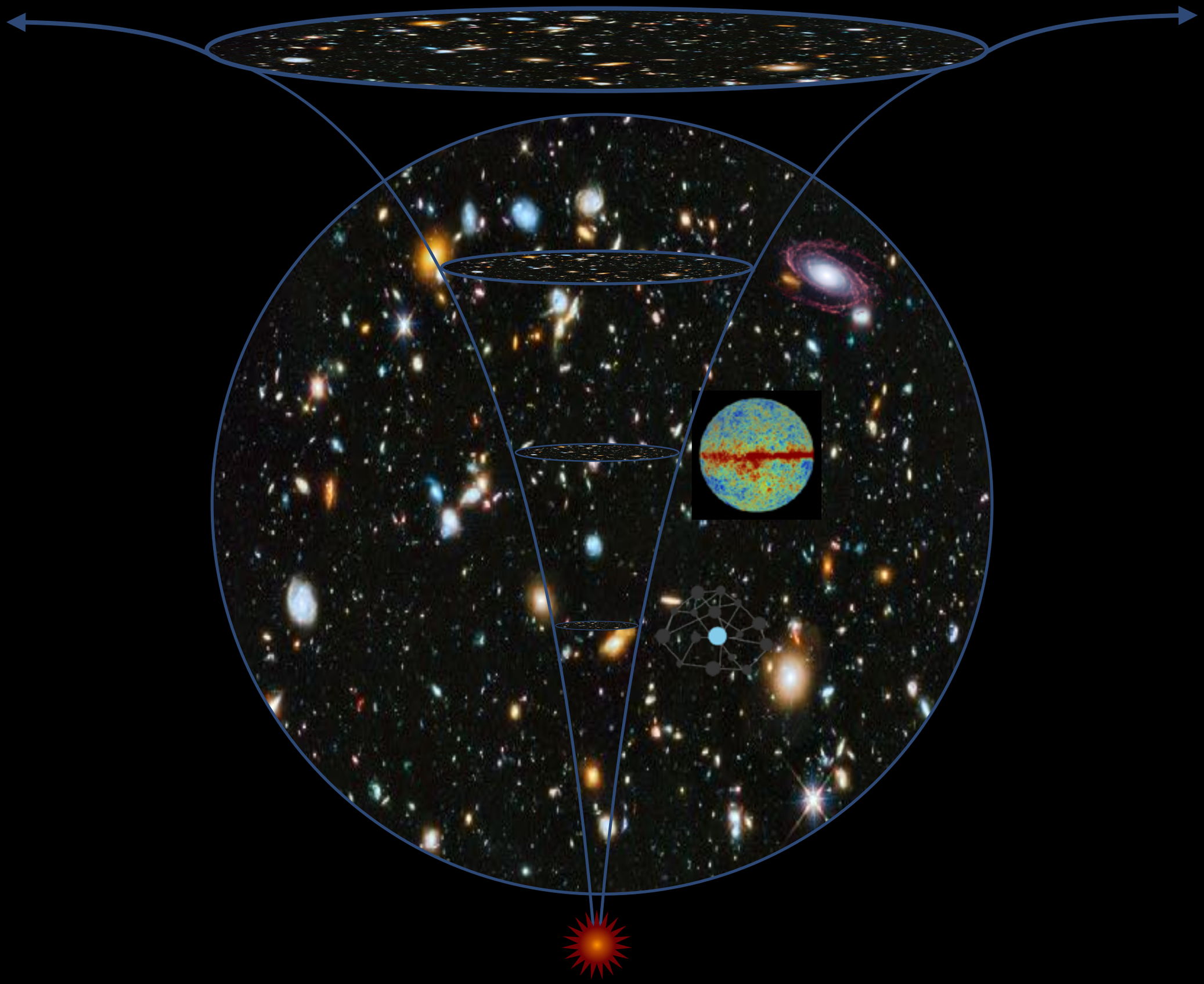
Cosmology in Brazil in the 80's and 90's looked like this:



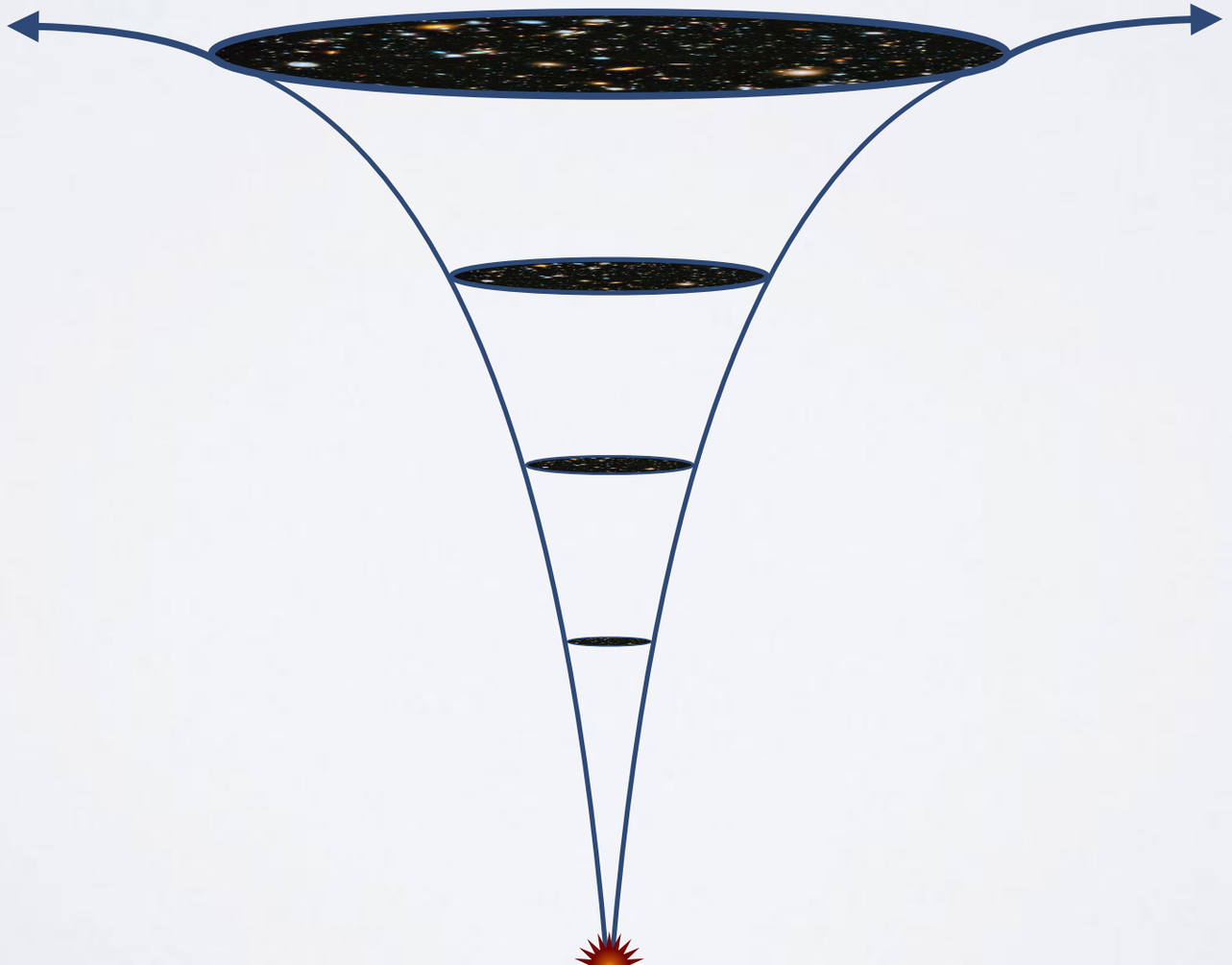
loav, more than anybody, made it look more like this:

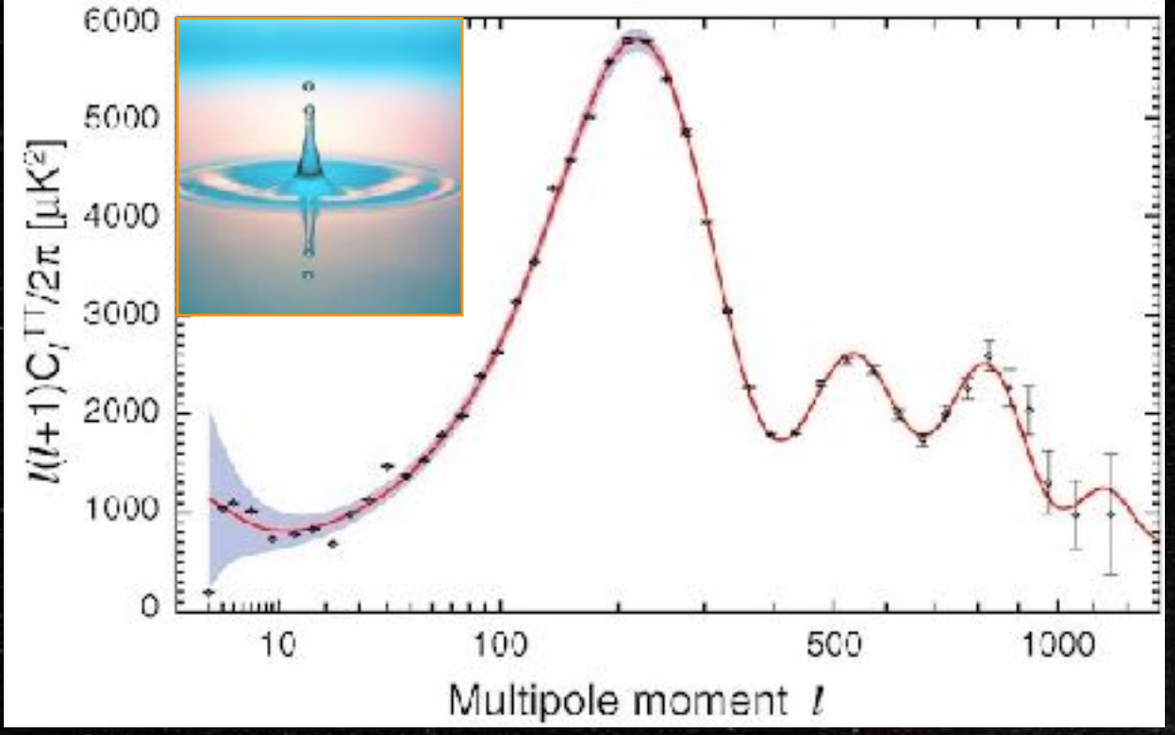


THE MYSTERIES OF OUR UNIVERSE



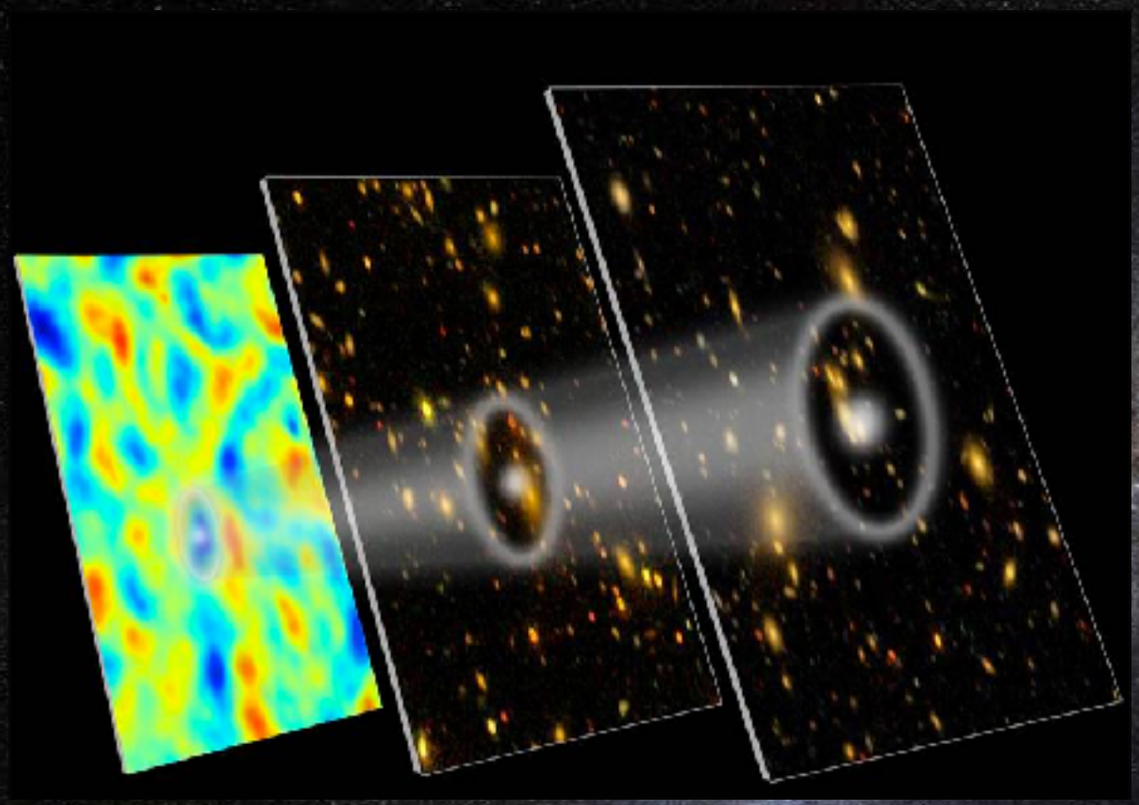
COSMIC ACCELERATION
DARK ENERGY
GRAVITY





Baryon acoustic oscillations (BAOs)

Up until ~300.000 years after the Big Bang, the photon/baryon fluid was driven by **gravity** and by **radiation pressure**, which led to the formation of **acoustic waves** in that fluid - waves which became imprinted the distribution of matter

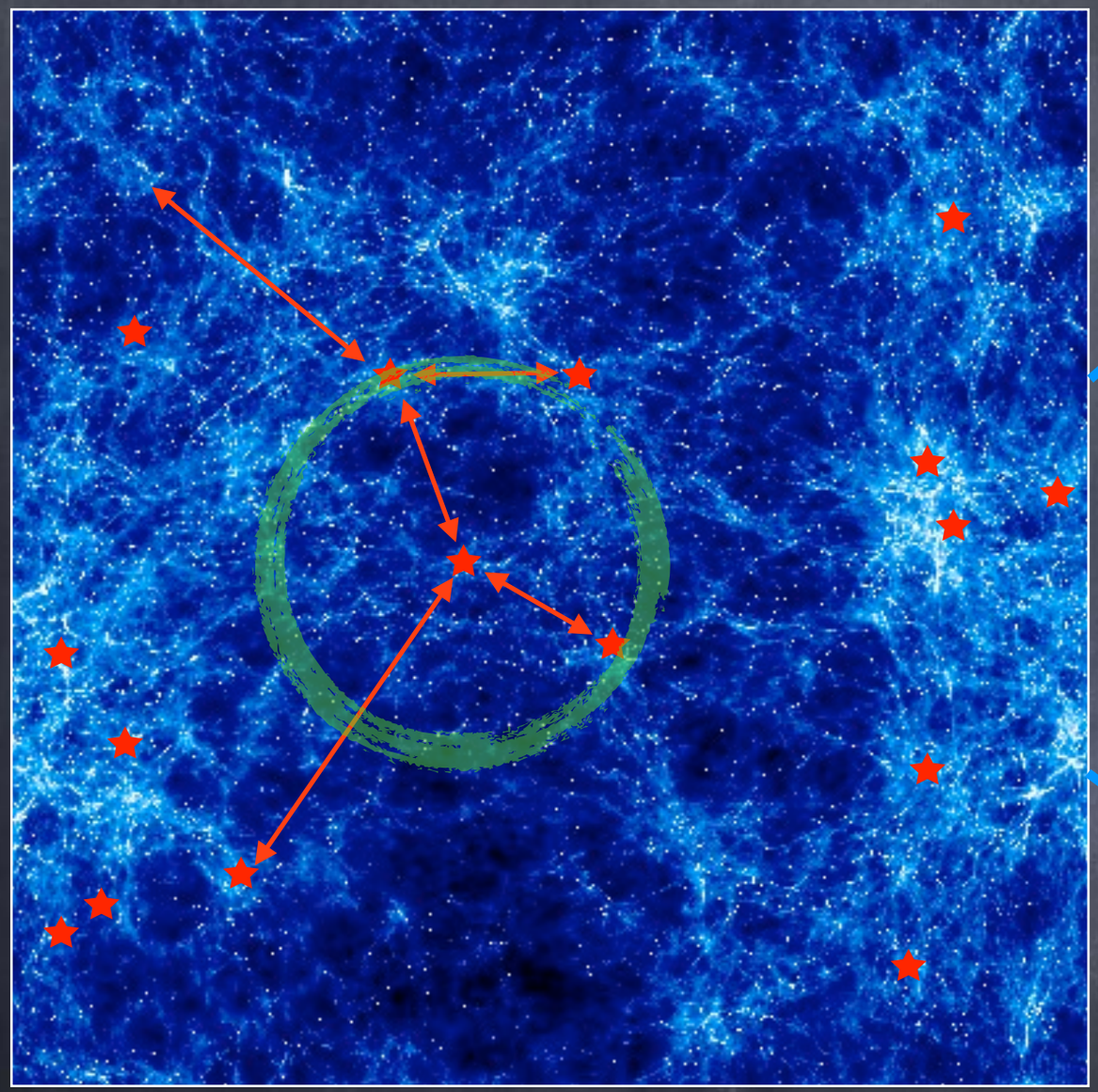


The matter (and galaxy) distribution bears the imprint of those acoustic waves — the **baryon acoustic oscillations (BAOs)**

BAOs: characteristic length scale

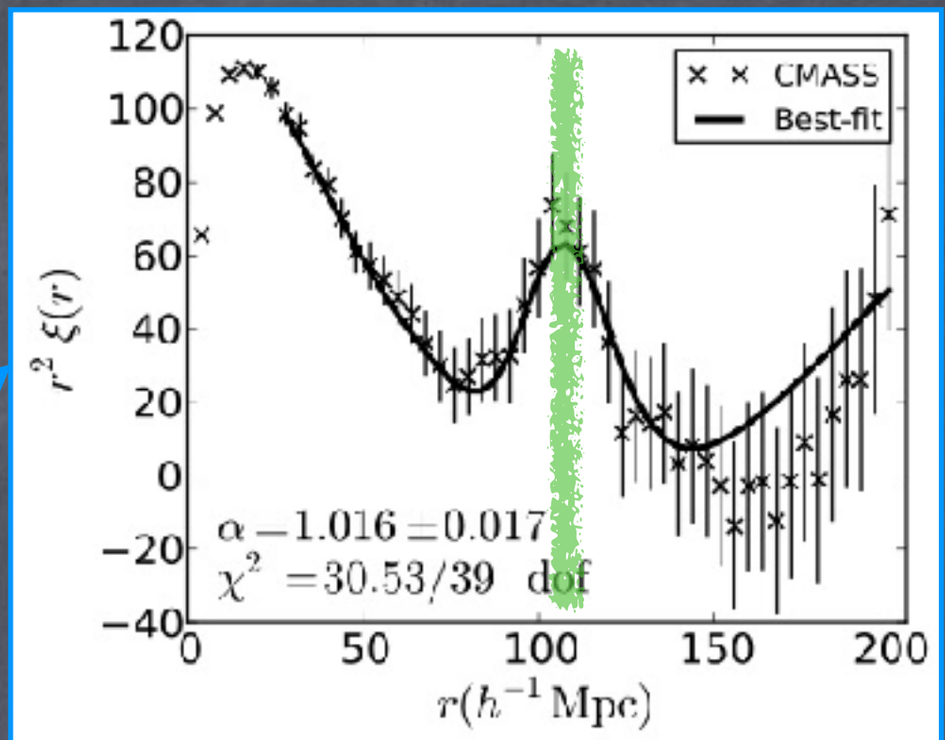
$L_{BAO} \sim 149$ Mpc

Galaxy clustering

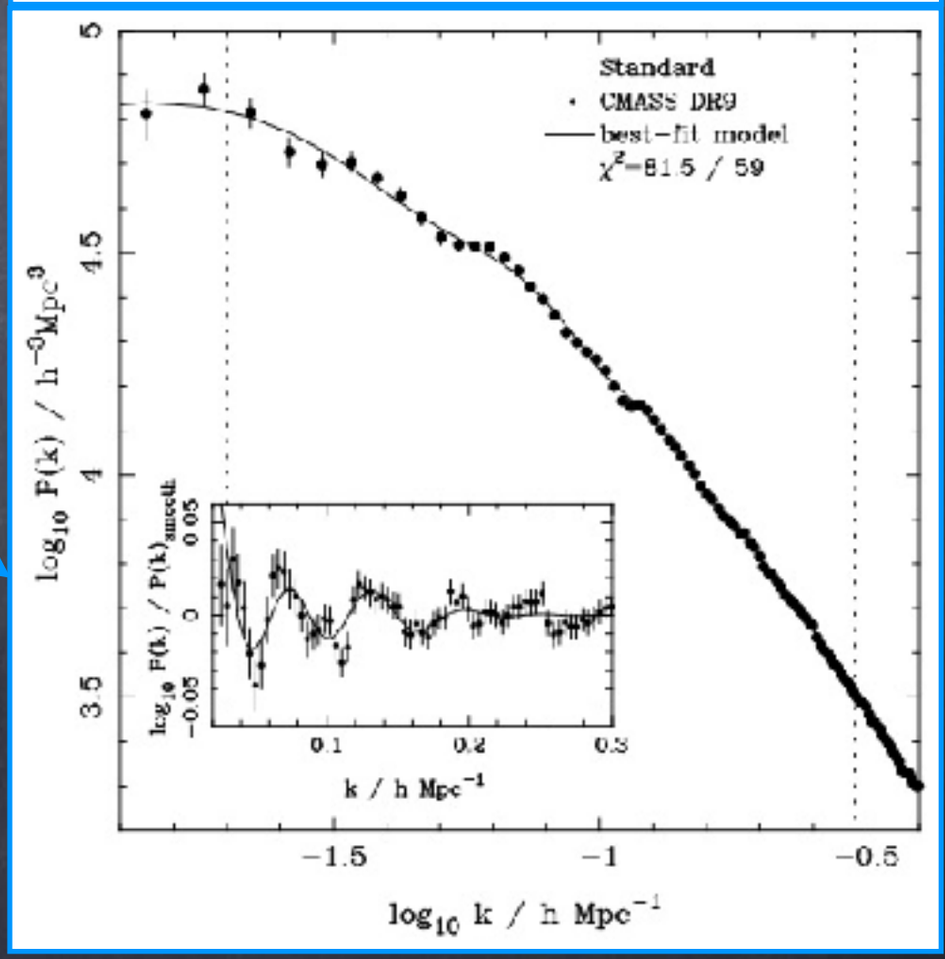


Galaxies trace dark matter

Clustering in position space

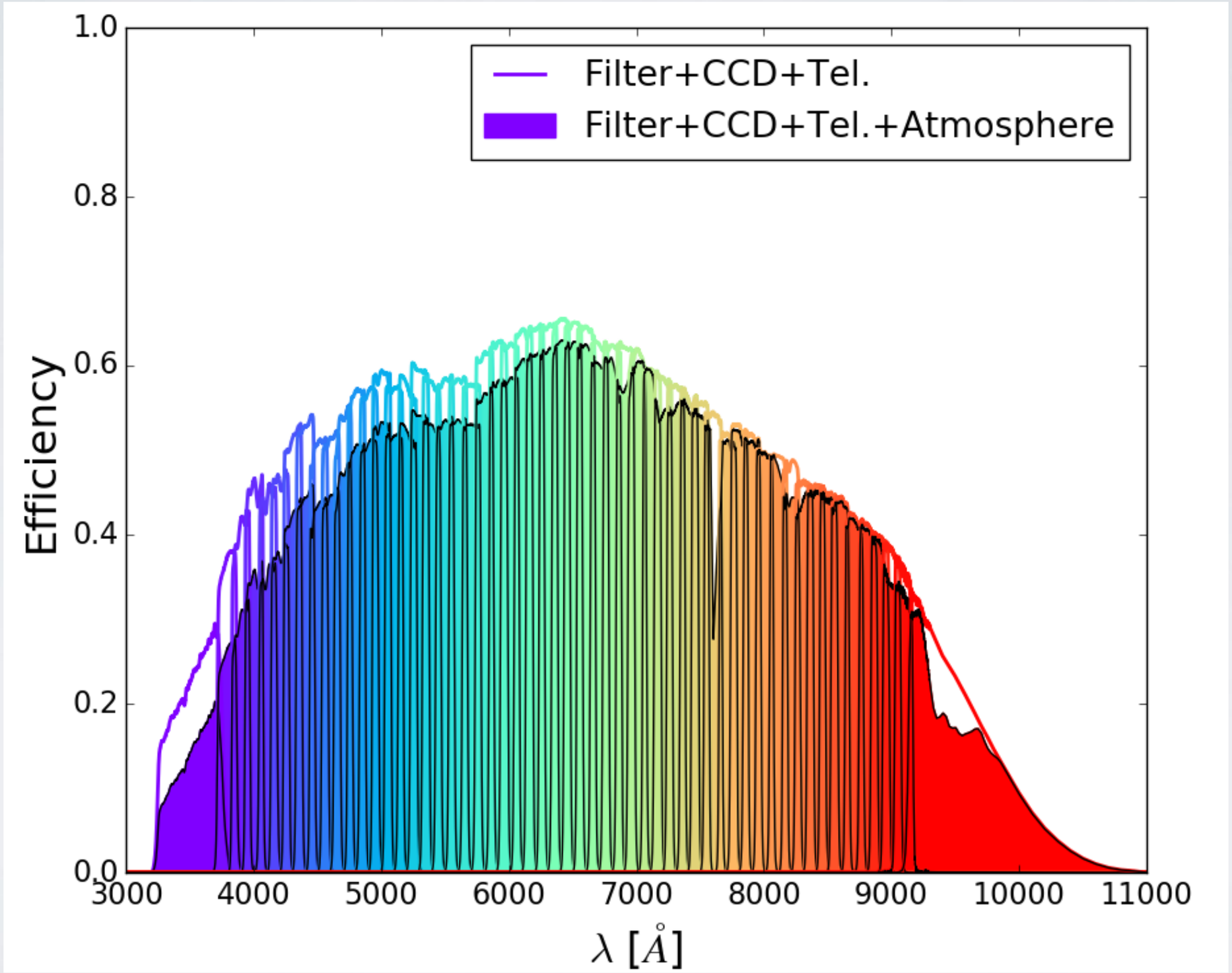


Clustering in Fourier space



⇨ **Statistical measure** - we must map **millions of galaxies in 3D**, through distances of billions of light-years ⇨ **immense challenge!!!**

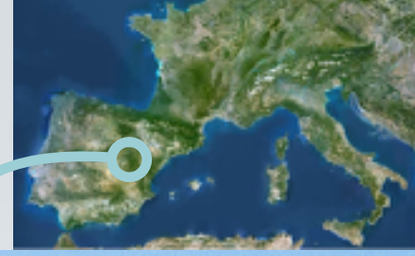
J-PAS



Benítez et al. 2009
Benítez et al. 2014

CEFCA

FONDO DE INVERSIONES DE TERUEL · GOBIERNO DE ARAGON · GOBIERNO DE ESPANA · MINISTERIO DE ECONOMIA Y COMPETITIVIDAD · UNIÓN EUROPEA · CSIC · araid · Ministério da Ciência e Tecnologia · FAPESP · FAPERJ · FINEP



@ Spain

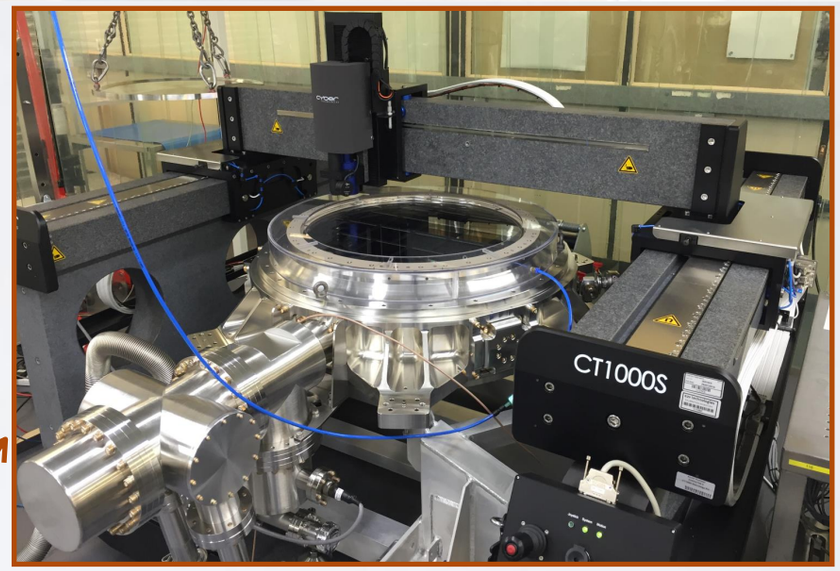
OAJ

Observatorio Astronomico de Javalambre

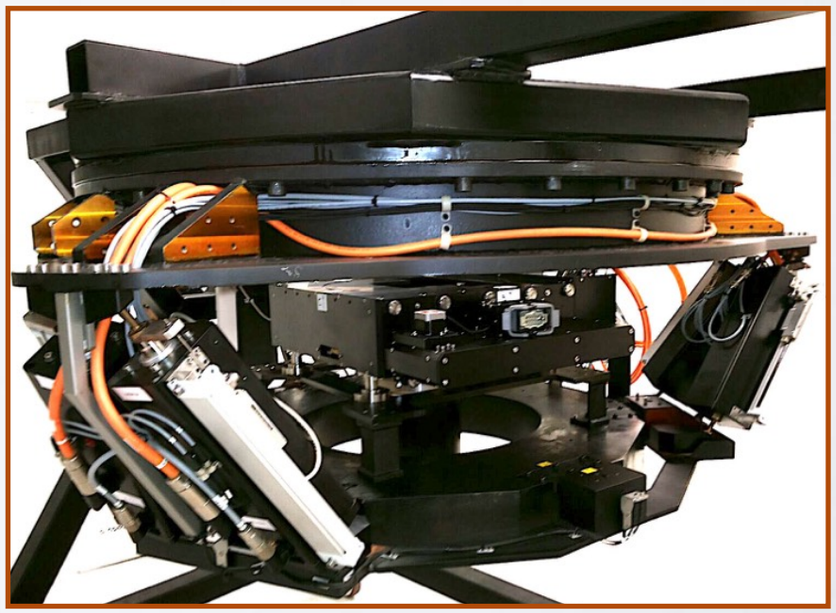


T250 / JST





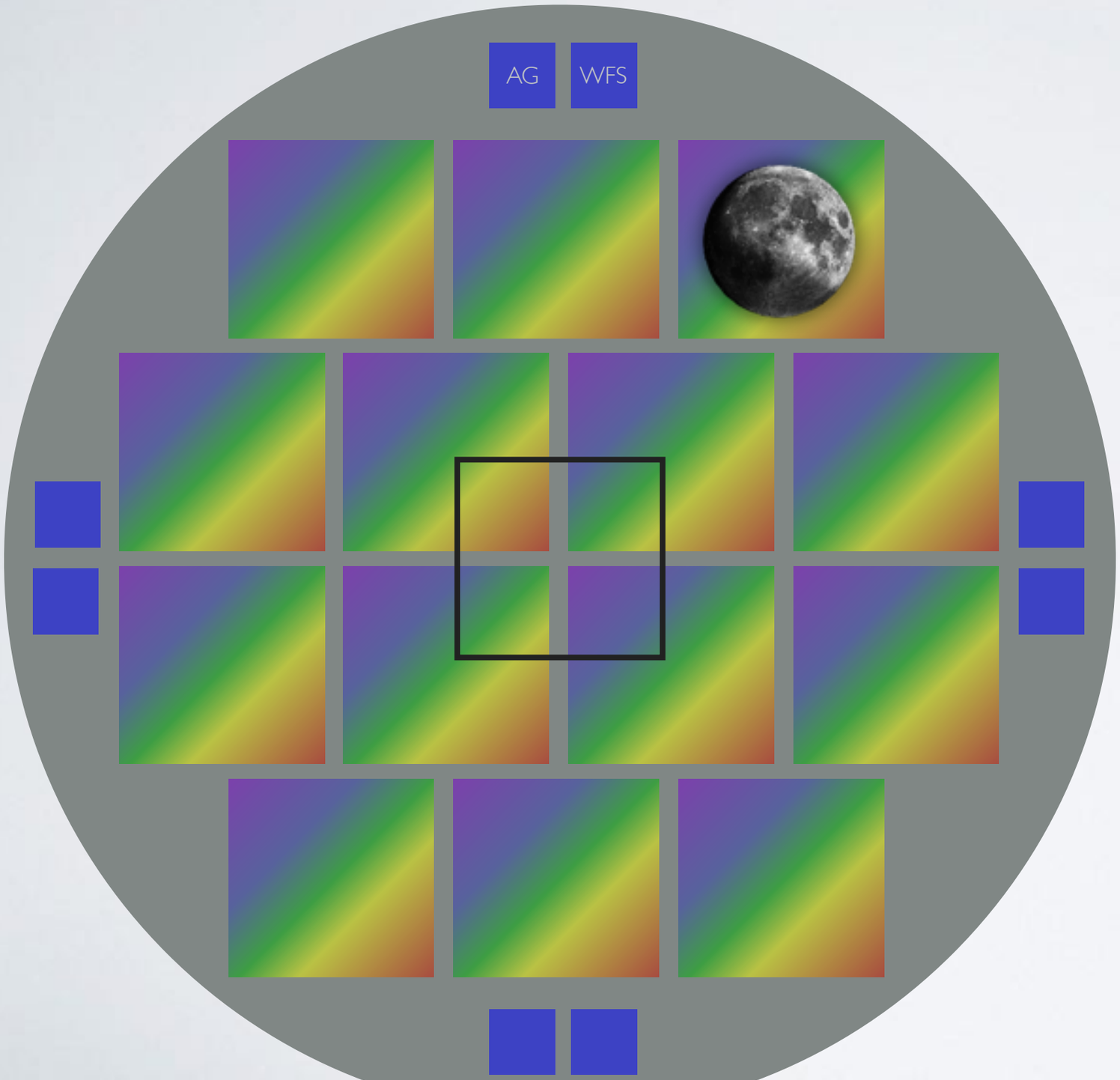
JPCam
commissioning
Q4/2018



PathFinder camera
observing now

Javalambre Survey Telescope
T250

FoV ø : 3 deg



JPCam

14 e2V CCDs (1.2 Gpix)

9216 x 9232 pix

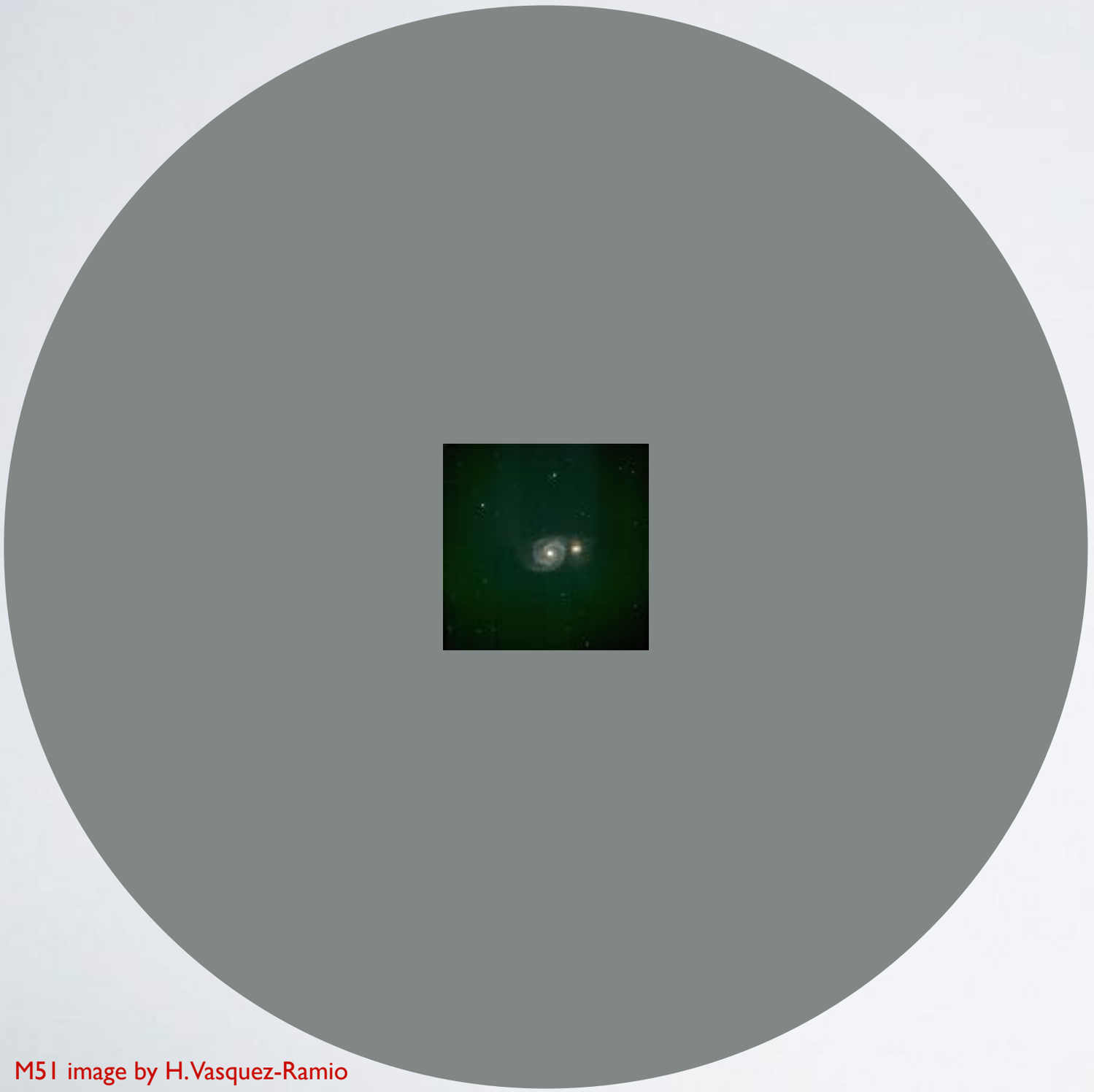
0.5897 deg x 0.5886 deg

Commissioning Q3/2018

1200 deg²/year (all filters, r~22.5)

Javalambre Survey Telescope
T250

FoV ⌀ : 3 deg



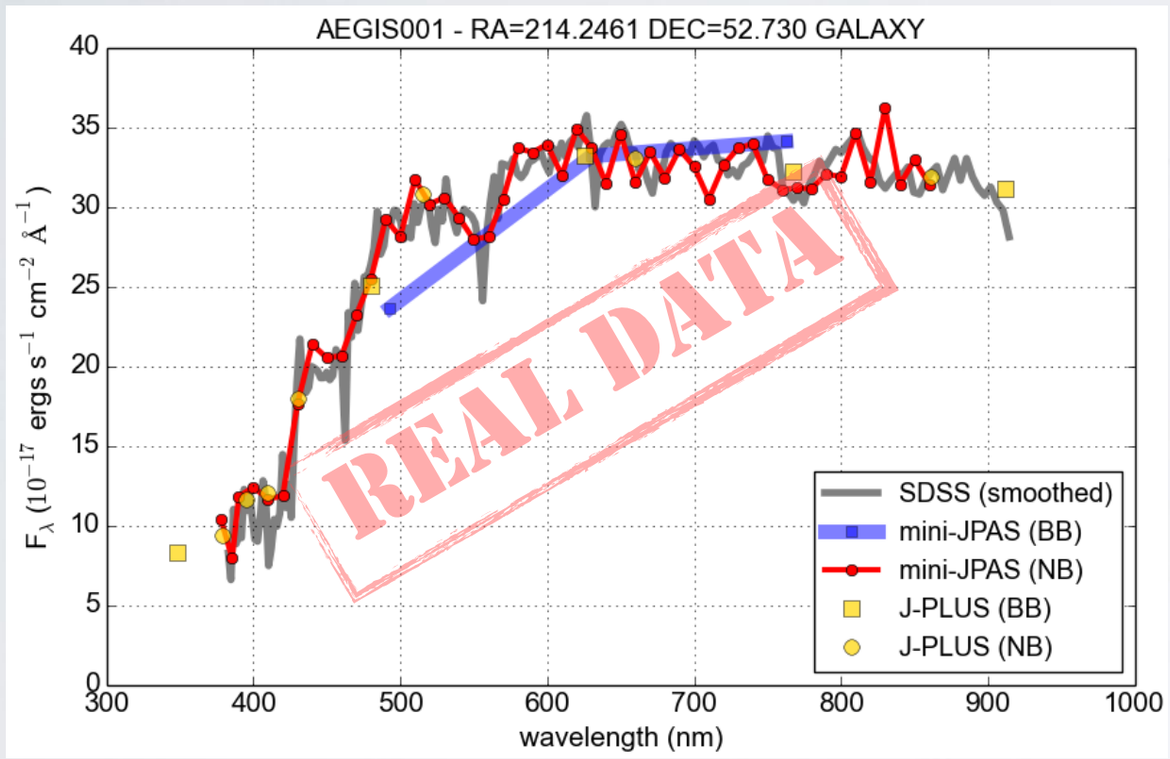
M51 image by H. Vasquez-Ramio

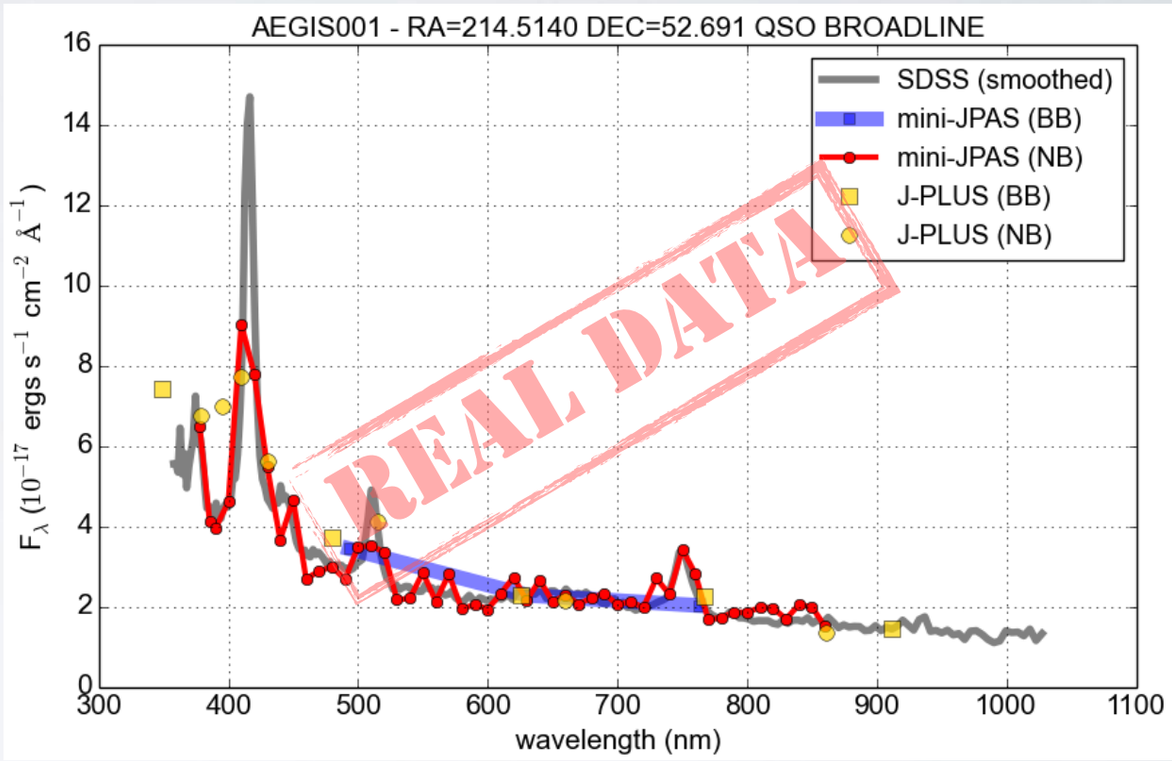
PathFinder camera
1 e2V CCD
9216 x 9232 pix
0.5897 deg x 0.5886 deg

Science Verification:
Mini-JPAS @ AEGIS
(Extended Groth Strip + DEEP2)



MINI J-PAS



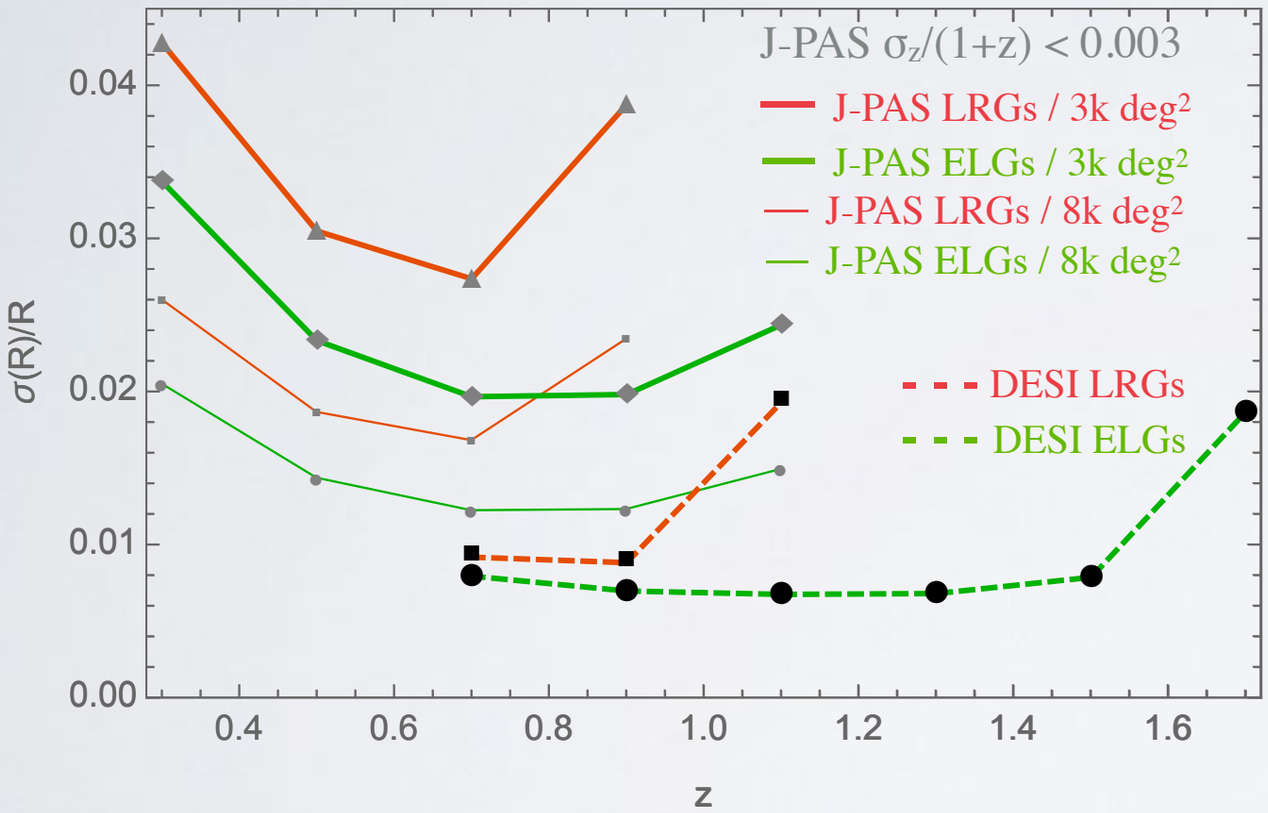


Proof of concept: photometric redshifts accuracies of ~0.3% with narrow-band filters

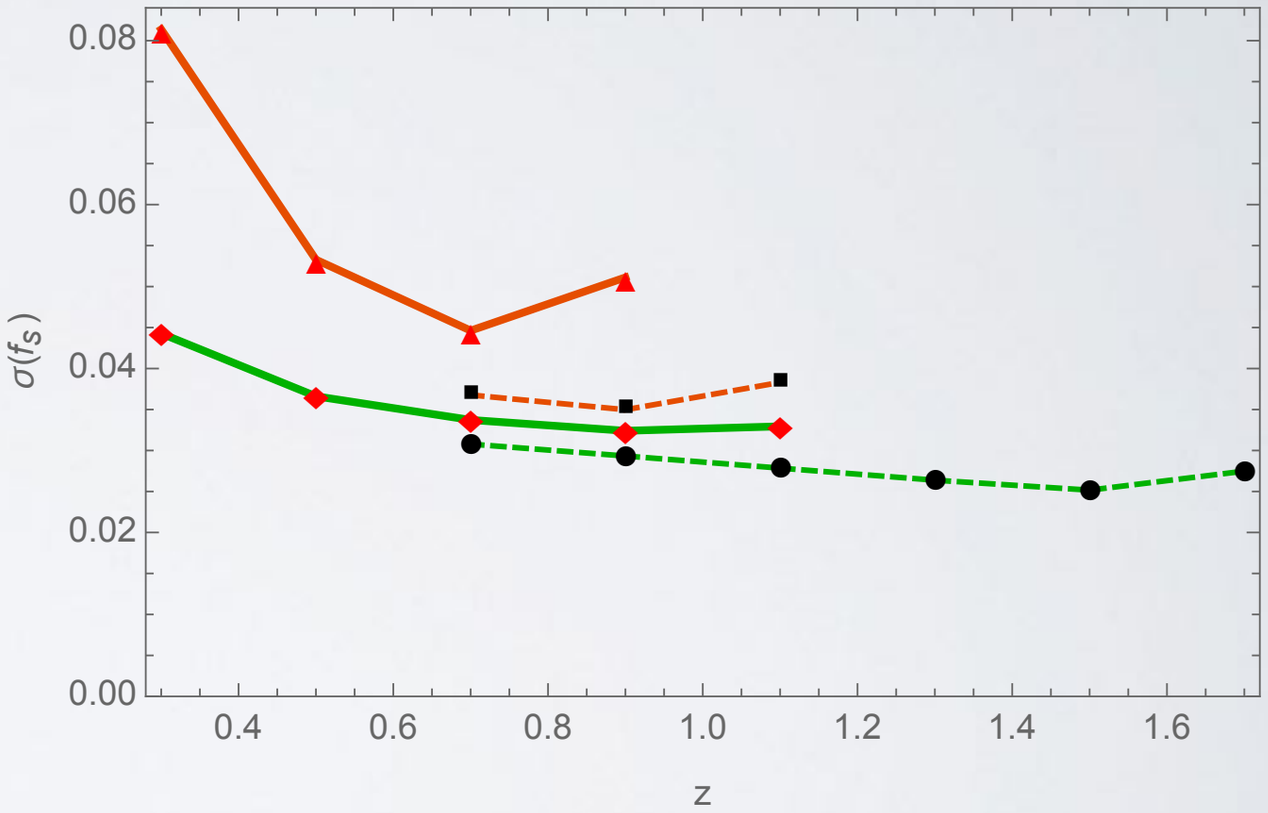
FORECASTS

DARK ENERGY AND GROWTH OF STRUCTURE

$R = R_V = D_a^{2/3} H^{-1/3}$



$f_s = f\,\sigma_8$

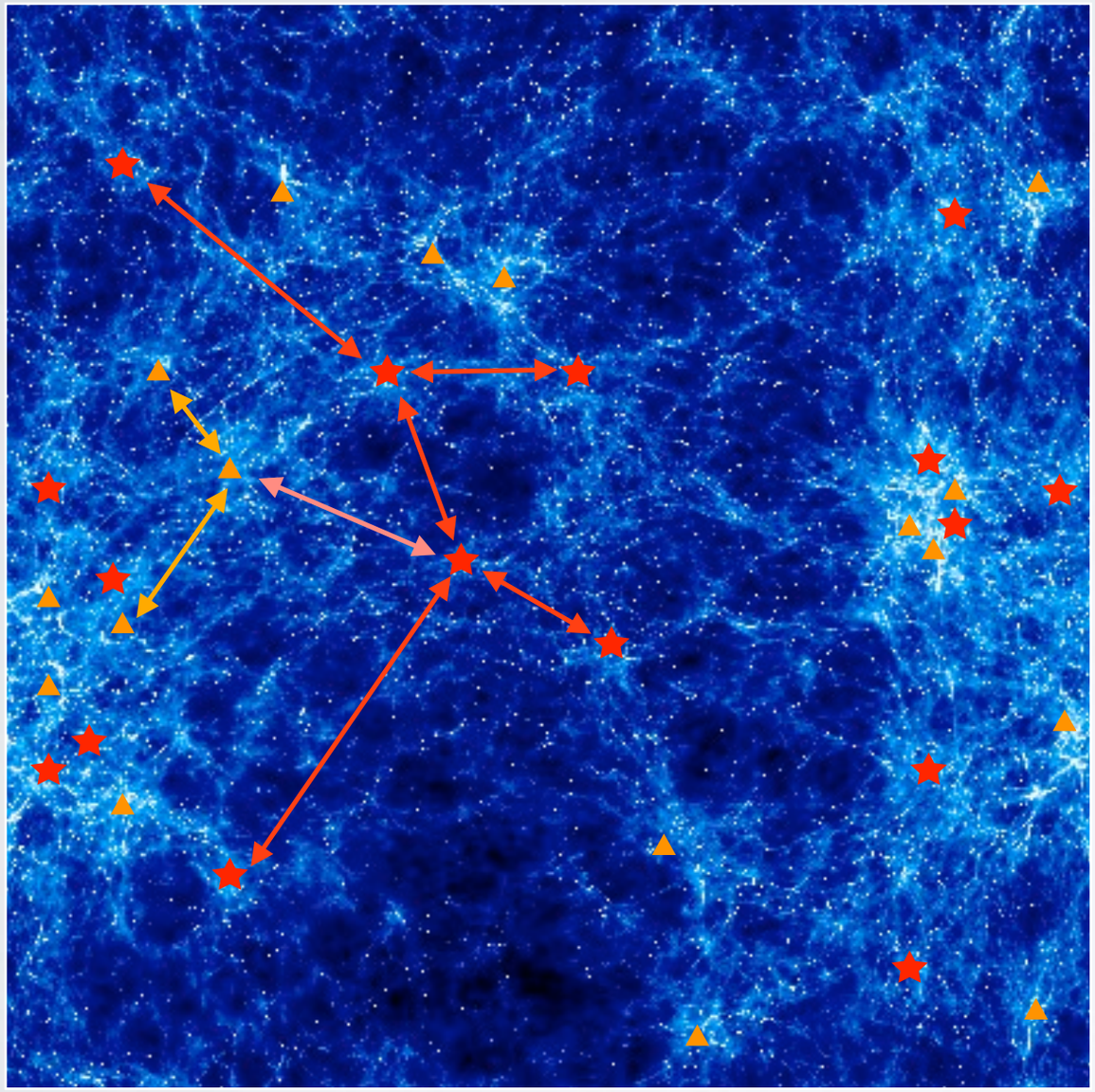


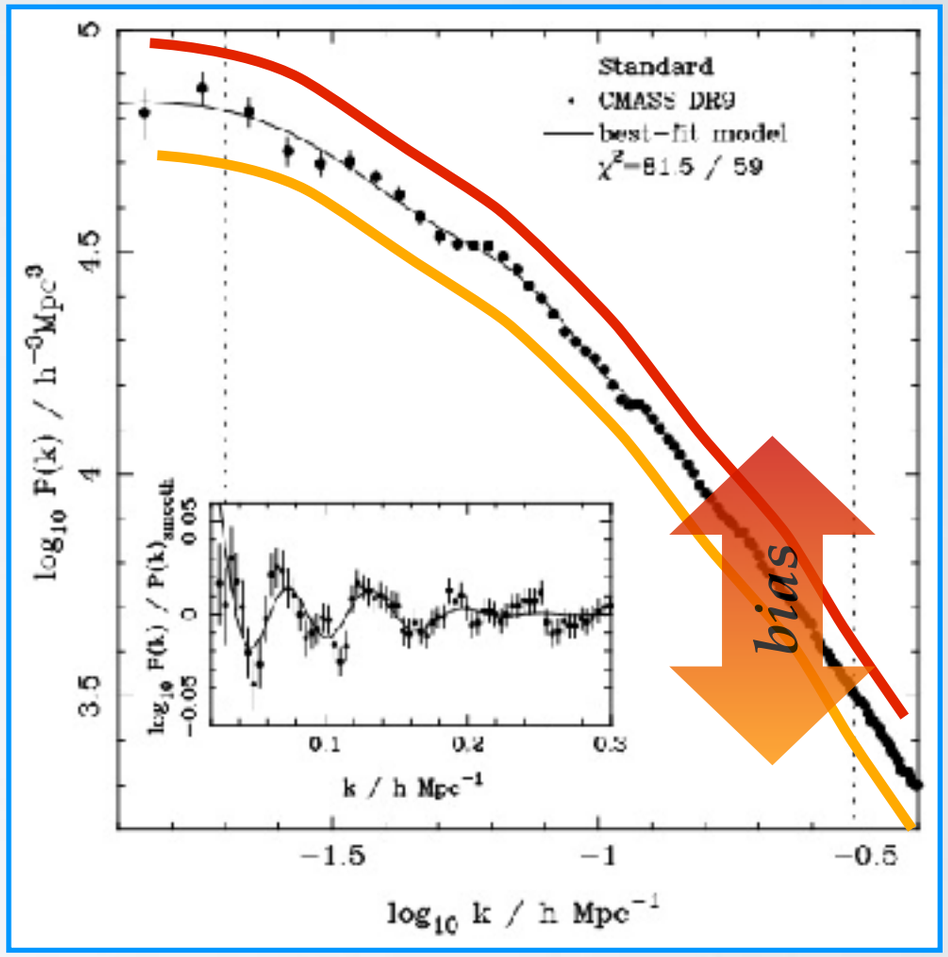
Standard disclaimer/caveat emptor: Fisherology

Matches DESI Final Design Report (March/2016)

LSS BEYOND BAOS

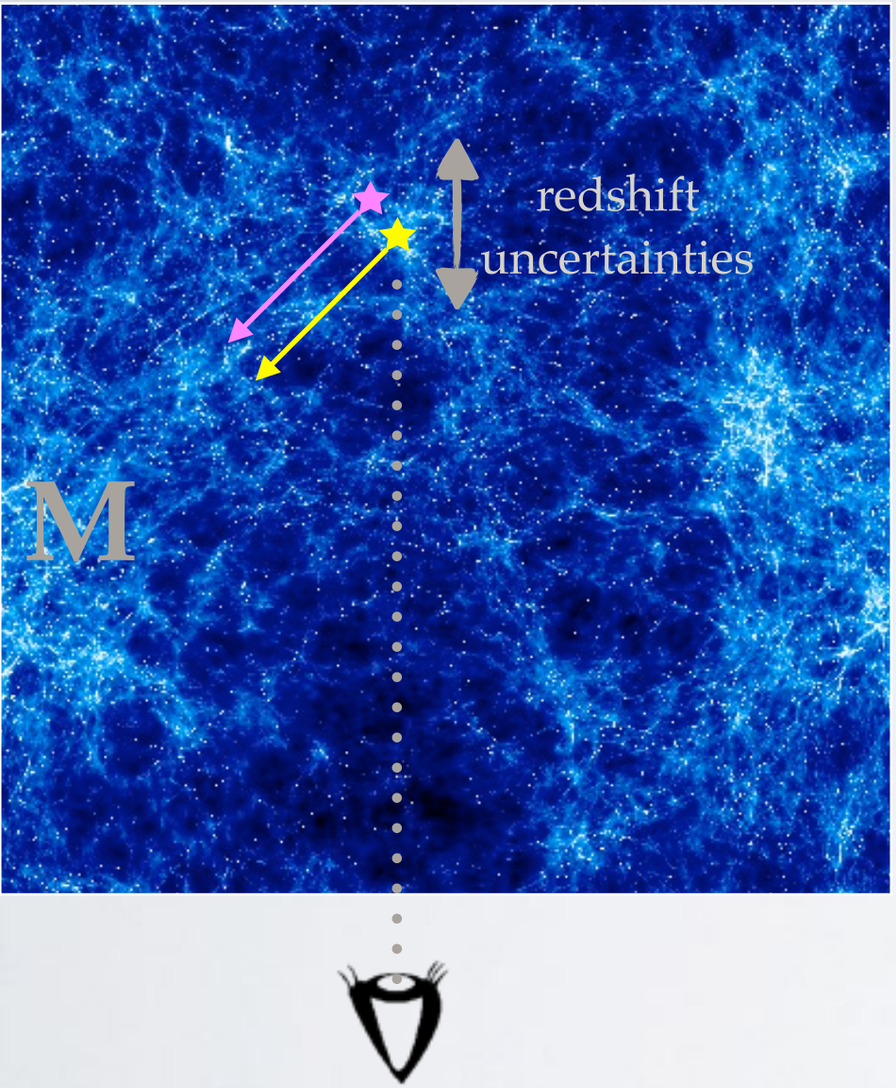
GALAXIES TRACE THE UNDERLYING DENSITY FIELD…

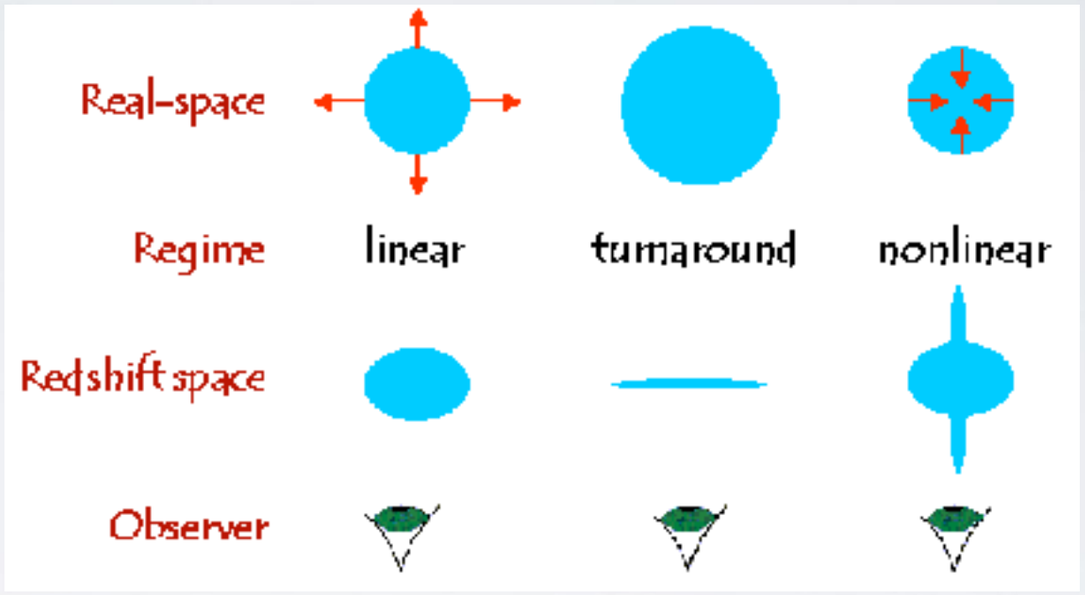




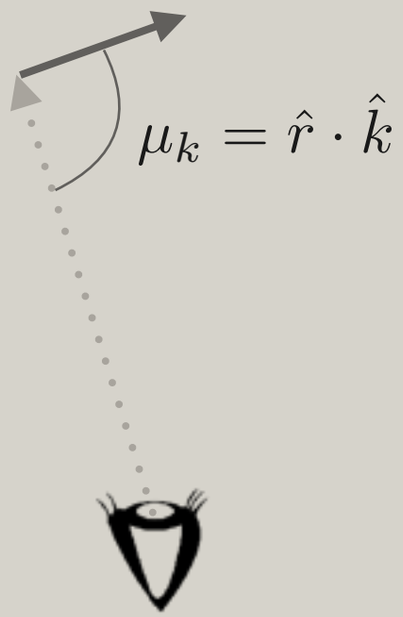
… on large scales; on small scales, intra-halo effects dominate

STRUCTURE FORMATION AND THE EQUIVALENCE PRINCIPLE





Fourier space



redshift ⇌ peculiar velocities

In linear regime, $\nabla v = -\nabla^2 \Phi$

Modified gravity?

⇨ The **velocity field** reflects the gravitational force in an unbiased way

$$P_g(k) \simeq \left(b_g + f\mu_k^2\right)^2 P_m(k)$$ { monopole, quadrupole, ...

Kaiser 1987 | Percival & White 2009 | Raccanelli et al. 2013 etc.

THE MULTI-TRACER TECHNIQUE



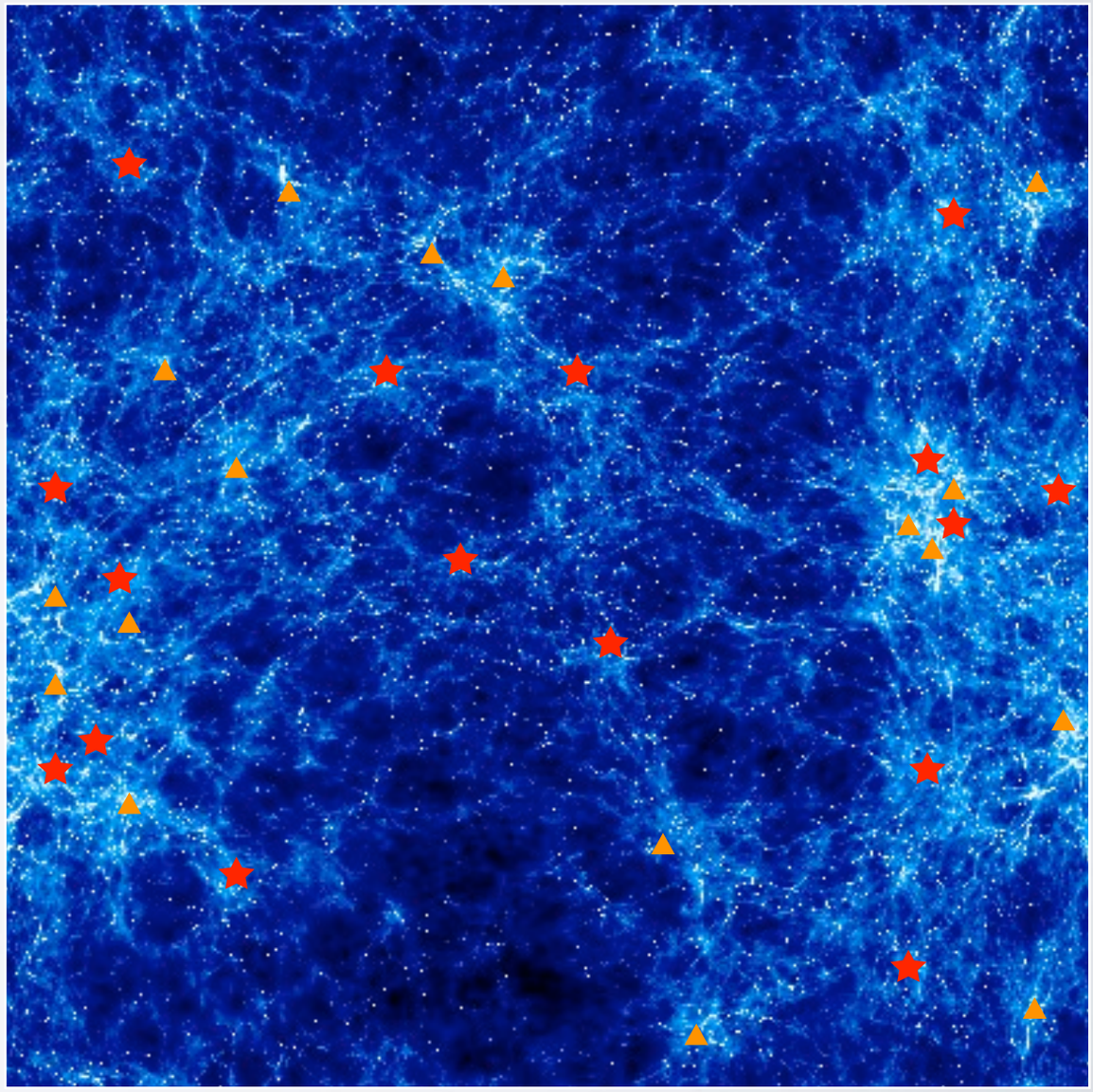
By contrasting the clustering of distinct tracers of large-scale structure, we can measure with "arbitrary" accuracy some physical parameters:

$$\mathcal{P}_1 = n_1 \, (b_1 + f \, \mu_k^2)^2 \, P(k;z)$$

$$\mathcal{P}_2 = n_2 \, (b_2 + f \, \mu_k^2)^2 \, P(k;z)$$

$$\frac{\mathcal{P}_1}{\mathcal{P}_2} = \frac{n_1 \, (b_1 + f \, \mu_k^2)^2}{n_2 \, (b_2 + f \, \mu_k^2)^2}$$

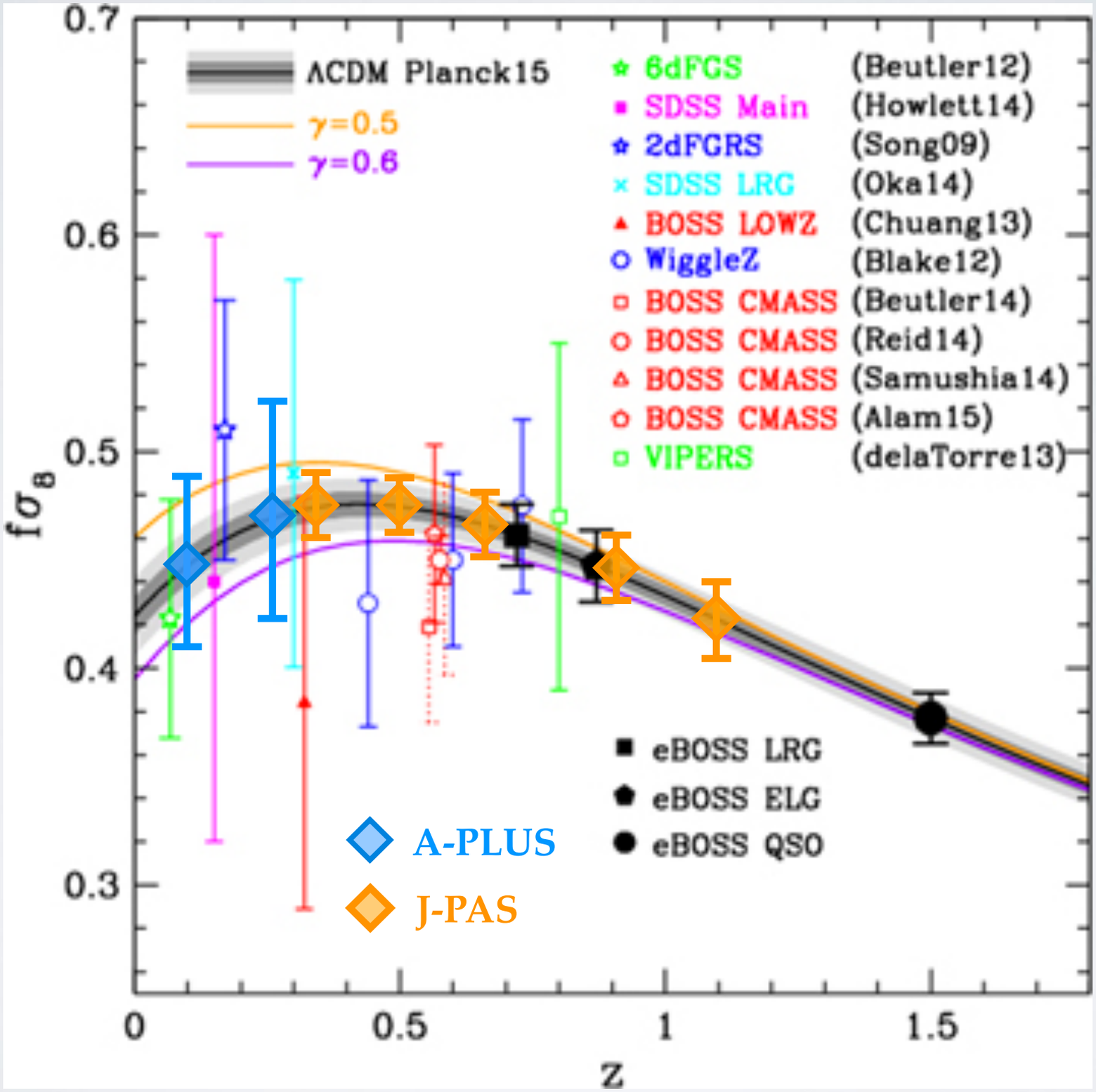
Cosmic variance does not apply:
* bias * RSDs
* NGs * HODs



The key is high numbers of distinct types of tracers: red galaxies, blue galaxies, emission-line galaxies, quasars, neutral H regions (21cm); DM halos; …

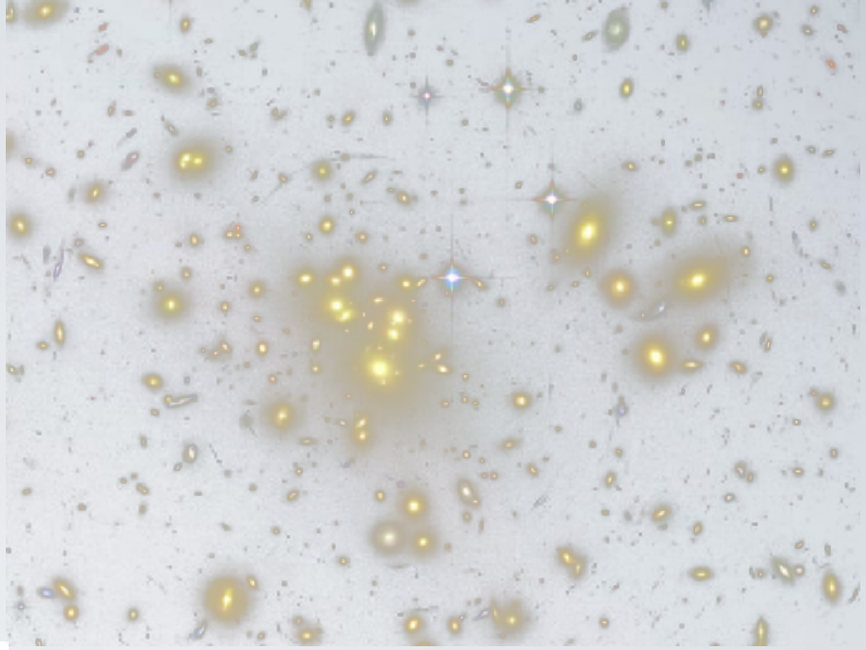
Seljak 2008 ∘ McDonald & Seljak 2008 ∘ Gil-Marín et al. 2011 ∘ Hamaus et al. 2011, 2012 ∘ Cai & Bernstein 2011
R.A. 2012 ∘ R.A. & K. Leonard 2013 ∘ R.A., L. Secco & A. Loureiro 2016

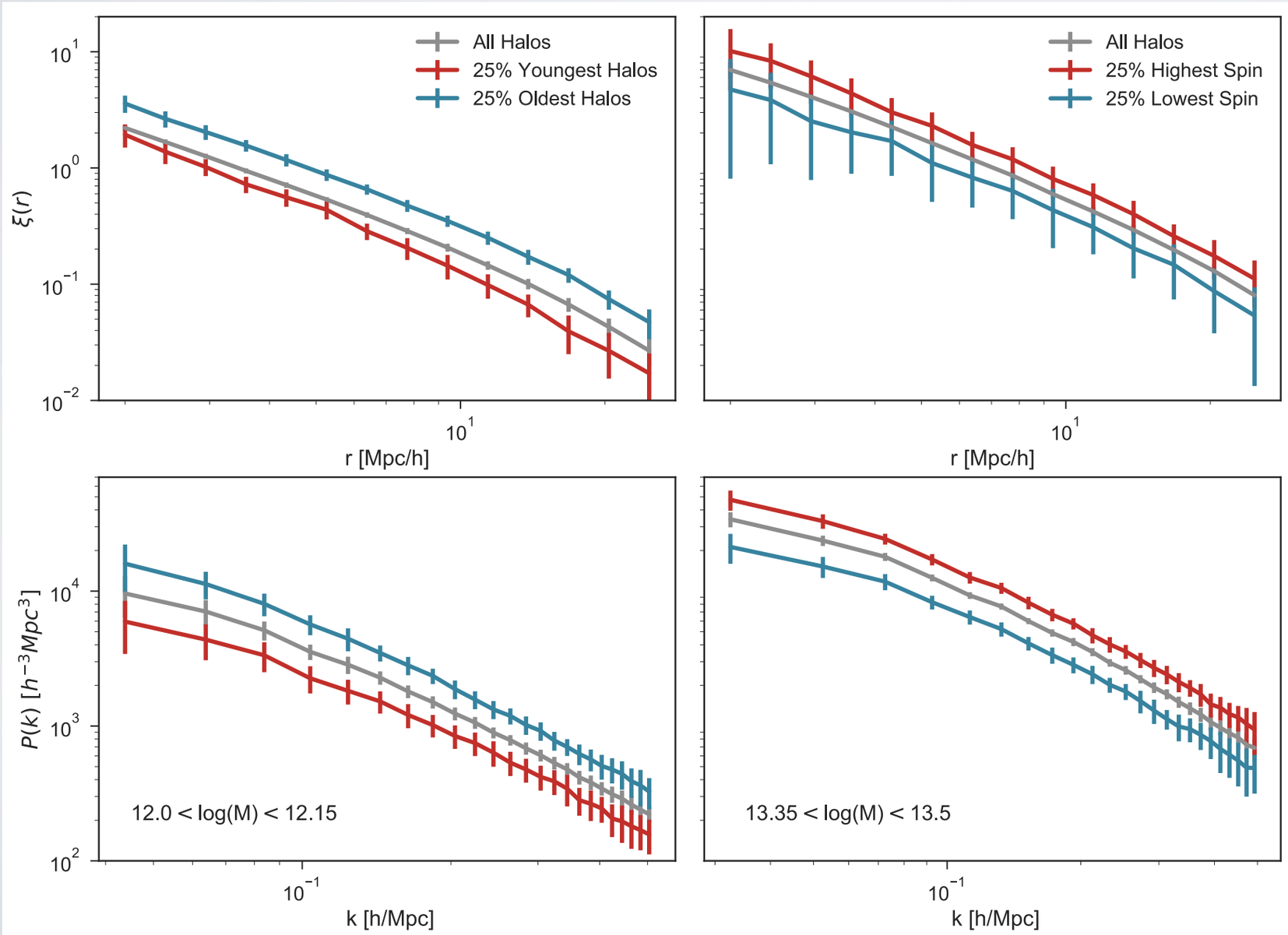
RSD/MODIFIED GRAVITY WITH J-PAS



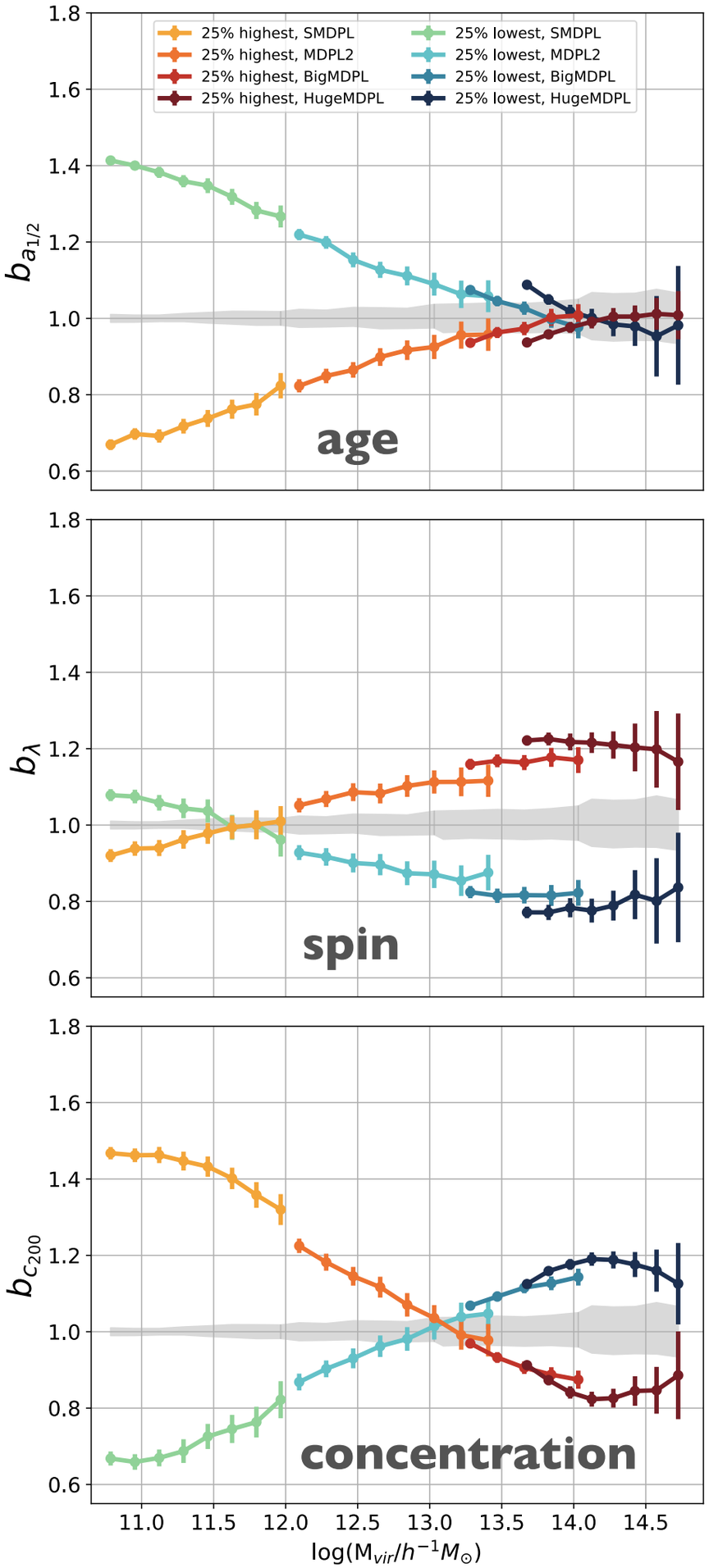
GALAXIES OR HALOS?

- **Halo mass** is the **primary bias** factor
- Other halo properties can also be important:
  age, spin, concentration, …?
- MultiDARK N-body simulations:
  4 boxes: (400 h^{-1} Mpc)^3 , (1 h^{-1} Gpc)^3 , (2.5 h^{-1} Gpc)^3 , (4 h^{-1} Gpc)^3





G. Sato-Polito, A. Montero-Dorta, R.A., F. Prada, A. Klypin + 2018 (to appear)



HALOS MATTER!

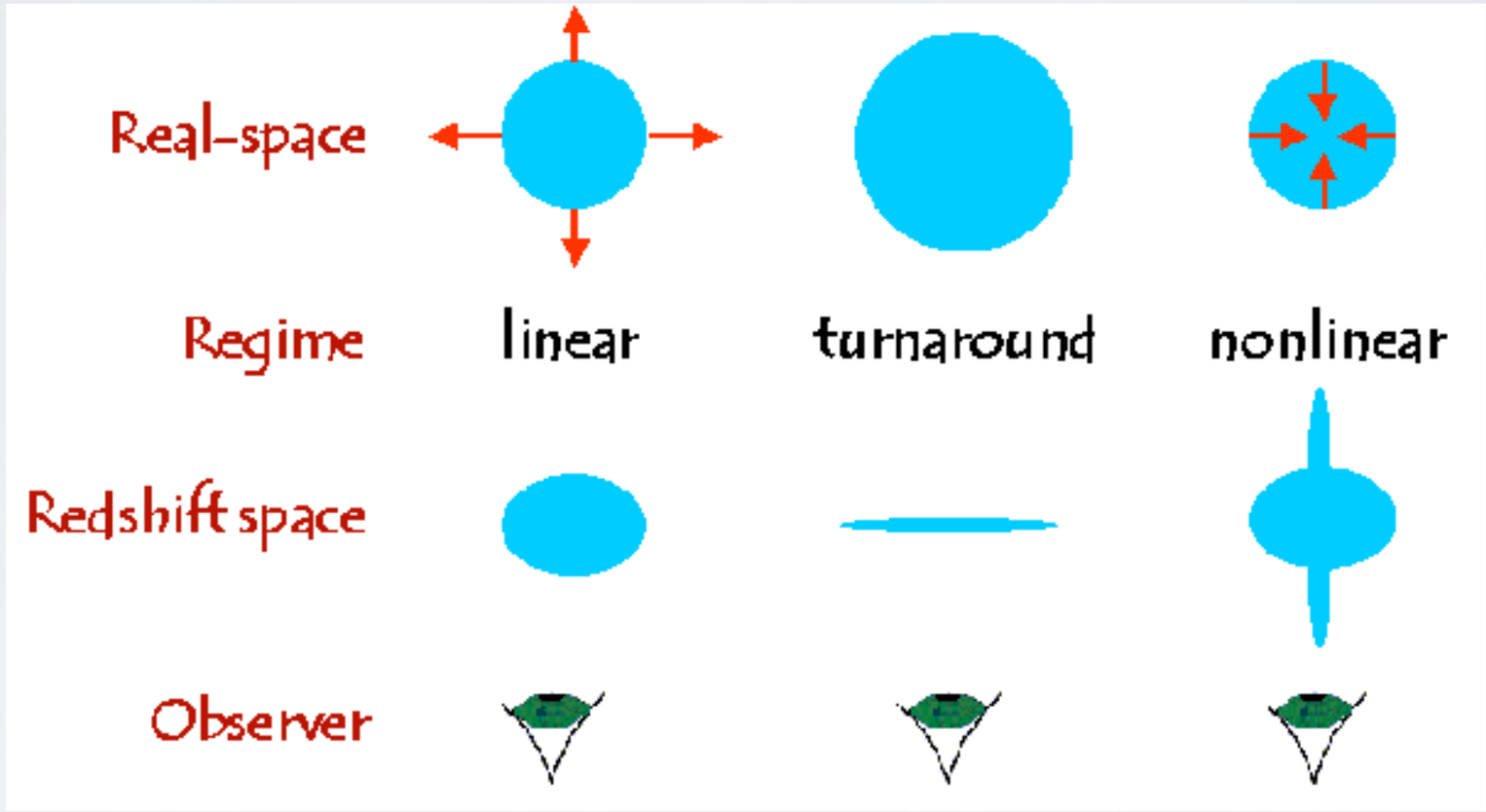
- Bias can change by up to 50% for the same halo mass
- There is no halo mass range which is preserved
- At low ($<10^{12}$ $M_\odot$) masses, age and concentration are main drivers
- At intermediate (10^{12} $M_\odot$<M<$10^{13.5}$ $M_\odot$) masses, spin is important
- At high (M>$10^{13.5}$ $M_\odot$) masses, spin and concentration dominate

Precision cosmology with galaxies & groups & clusters must cope with a deeper understanding of the physics of halos, their environments, and the galaxies that inhabit these structures

G. Sato-Polito, A. Montero-Dorta, R.A., F. Prada, A. Klypin 2018 (to appear)

STRUCTURE FORMATION: ORIGINS

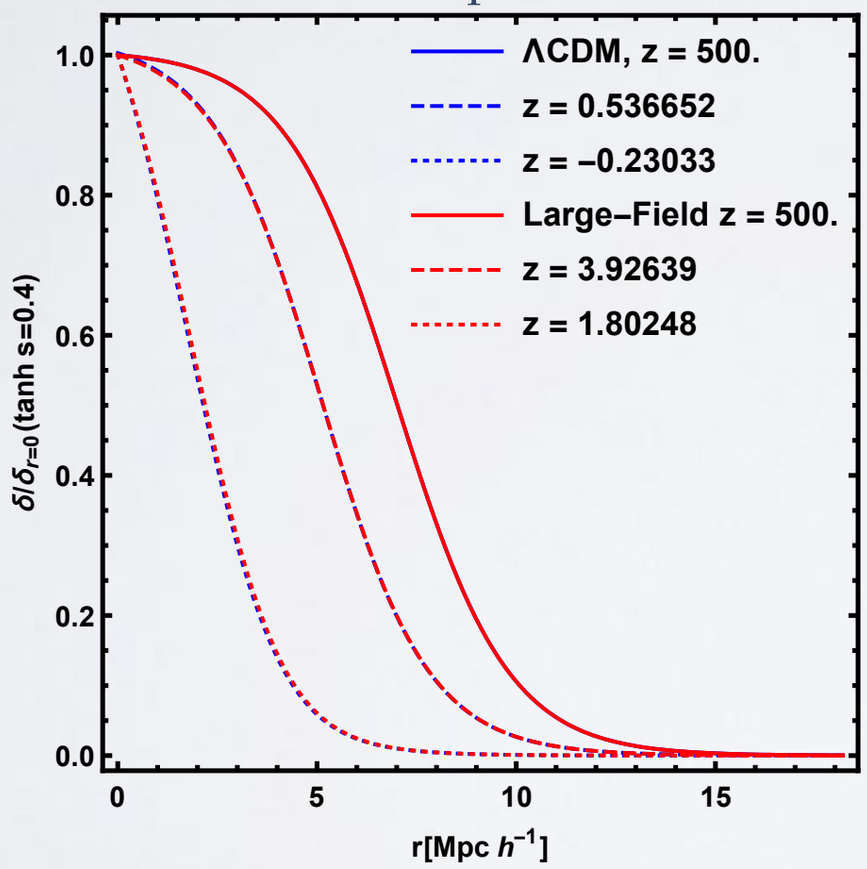
- The first step towards gravitational collapse is when an overdense region splits off from the Hubble flow. This is called **turnaround**



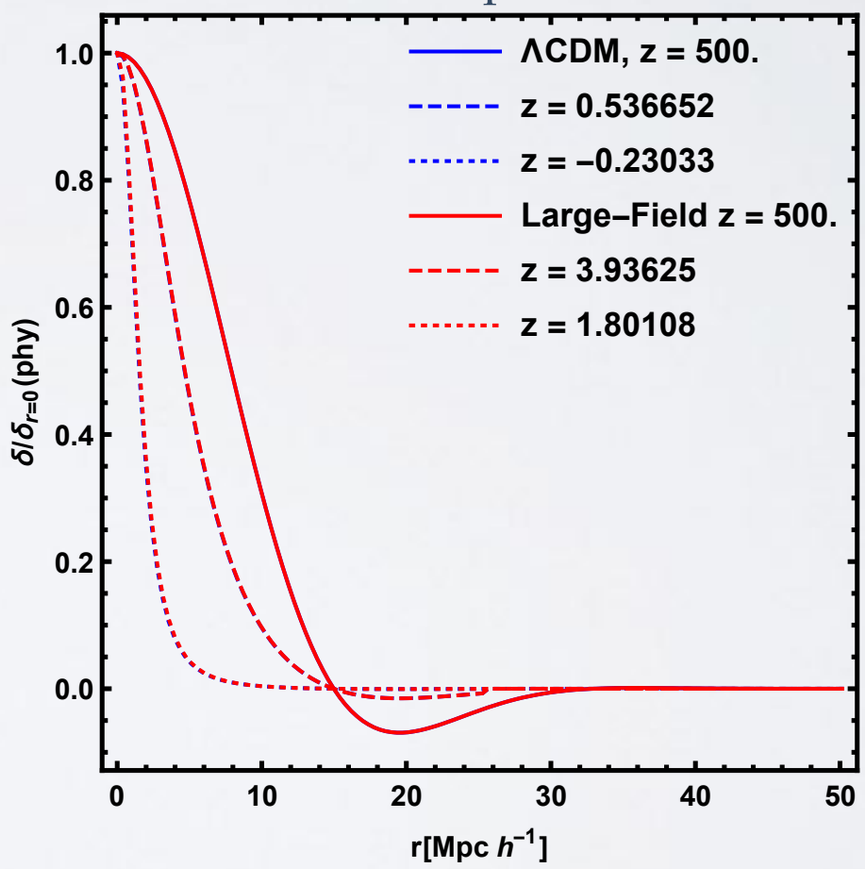
STRUCTURE FORMATION: TURNAROUND

- Turnaround happens in low-density, larger-scale environments compared to groups and clusters
- It is a test of gravity on intermediate scales (of mass and length)
- We computed the evolution of structures in LCDM and in f(R) Modified Gravity

Tanh profile



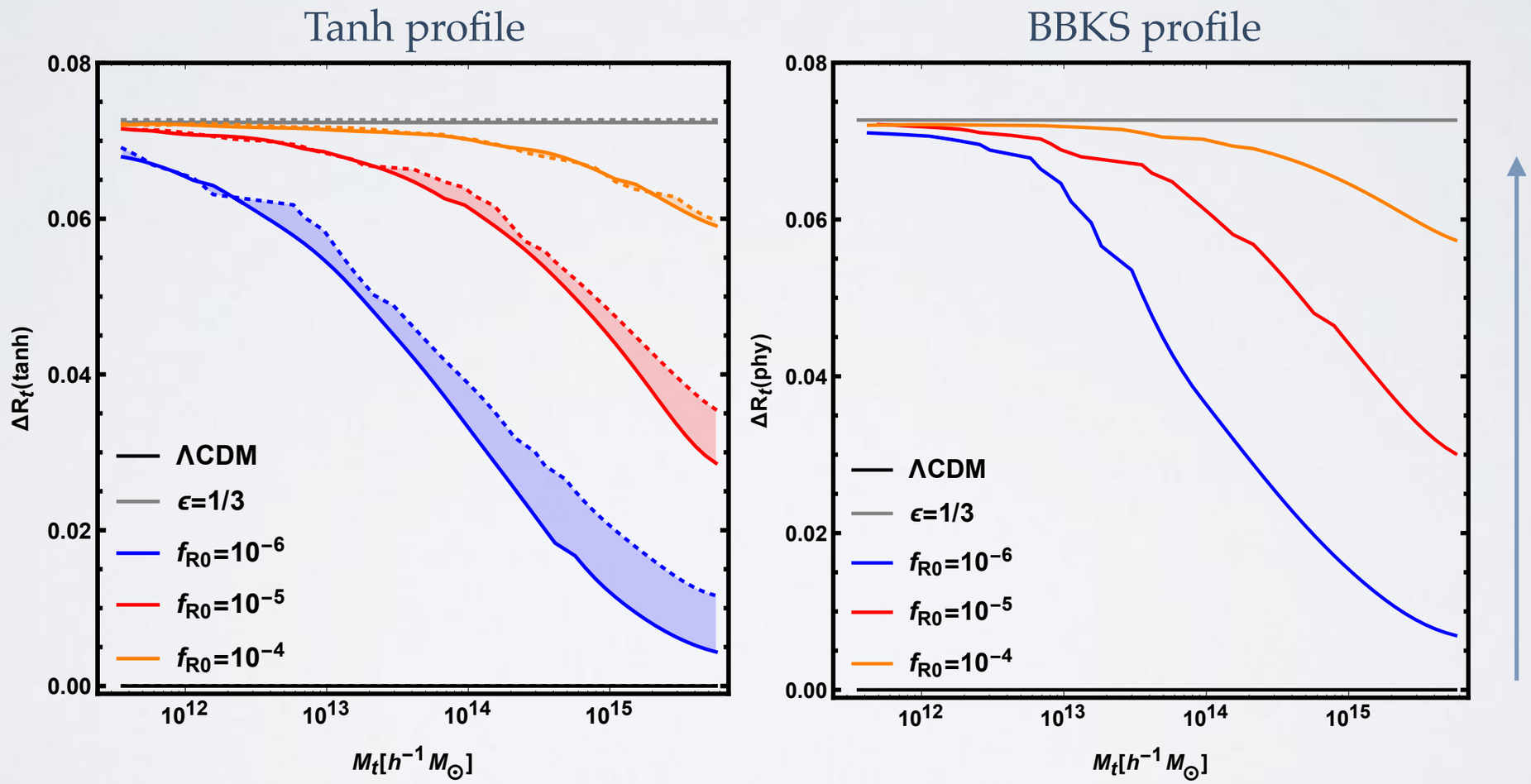
BBKS profile



Rafael C. Lopes, Rodrigo Voivodic, R.A. & L. Sodré Jr.
JCAP 2018, arXiv: 1805.09918
arXiv: 1809.10321

TURNAROUND AND MODIFIED GRAVITY

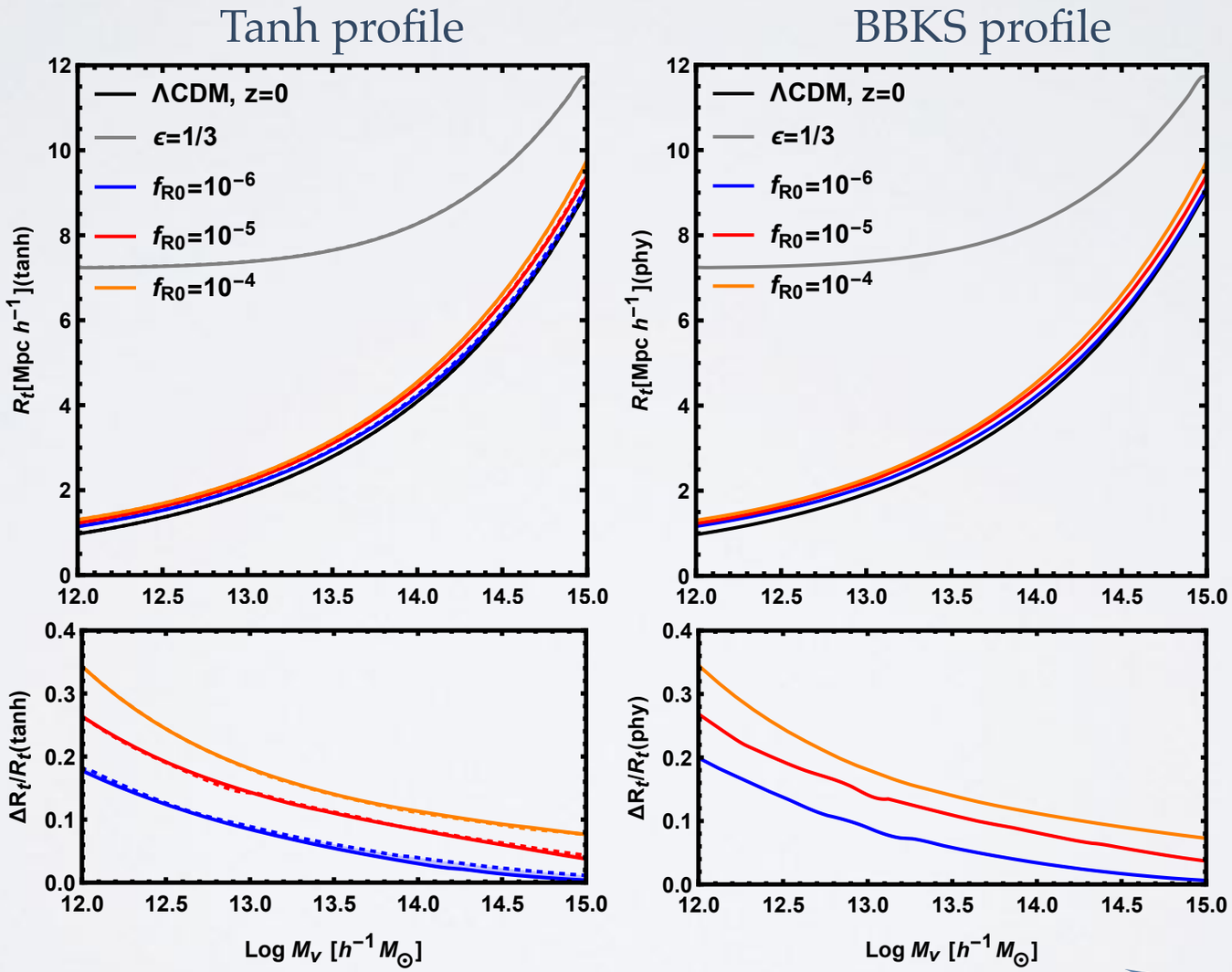
- In the strong field regime of MoG, the turnaround radius at z=0 is up to ~7% larger than in LCDM
- For small masses even small parameters of the f(R) models imply ~7% enhancement of the turnaround radius



Rafael C. Lopes, Rodrigo Voivodic, R.A. & L. Sodré Jr.
JCAP 2018, arXiv: 1805.09918
arXiv: 1809.10321

TURNAROUND AND VIRIAL MASS

- Using the Halo Model (2-halo + 1-halo description) we were able to link the turnaround radius of the outermost shell with the mass of the virialized central regions of systems
- Huge advantage from observational viewpoint



Rafael C. Lopes, Rodrigo Voivodic, R.A. & L. Sodré Jr.
JCAP 2018, arXiv: 1805.09918
arXiv: 1809.10321

virial mass





THANK YOU, IOAV!

sendo terra, querendo ser água III
Sandra Felzen, 2015