Ministério da Ciência, Tecnologia e Inovações

Centro Brasileiro de Pesquisas Físicas

Cosmologia com python

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clearnightsrthebest.com

How structures form?

$\bar{\rho}(1+\delta)$, with $\delta \ll 1$.

$$\delta(\vec{r},t) \equiv \frac{\varepsilon(\vec{r},t) - \bar{\varepsilon}(t)}{\bar{\varepsilon}(t)}$$

$$\ddot{R} = -\frac{G(\Delta M)}{R^2} = -\frac{G}{R^2}\left(\frac{4\pi}{3}R^3\bar{\rho}\delta\right)$$

$$\frac{\ddot{R}}{R} = -\frac{4\pi G\bar{\rho}}{3}\delta(t)$$

Mass Remain constant during the colapse....

$$M = \frac{4\pi}{3}\bar{\rho}[1+\delta(t)]R(t)^3$$

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$$\frac{\ddot{R}}{R} = -\frac{4\pi G\bar{\rho}}{3}\delta(t)$$

$$M = \frac{4\pi}{3}\bar{\rho}[1+\delta(t)]R(t)^3$$

$$R(t) = R_0[1+\delta(t)]^{-1/3} ,$$

$$R_0 \equiv \left(\frac{3M}{4\pi\bar{\rho}}\right)^{1/3} = \text{constant}$$

$$R(t) \approx R_0[1 - \frac{1}{3}\delta(t)] .$$

$$\delta \ll 1$$

$$\ddot{R} \approx -\frac{1}{3}R_0\ddot{\delta} \approx -\frac{1}{3}R\ddot{\delta}$$

How structures form?

$\bar{\rho}(1+\delta)$, with $\delta \ll 1$.

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$$R(t) \approx R_0[1-\frac{1}{3}\delta(t)] \ .$$

$$\delta \ll 1$$

$$\ddot{R} \approx -\frac{1}{3}R_0\ddot{\delta} \approx -\frac{1}{3}R\ddot{\delta}$$

$$t_{\rm dyn} = \frac{1}{(4\pi G\bar{\rho})^{1/2}} = \left(\frac{c^2}{4\pi G\bar{\varepsilon}}\right)^{1/2}$$

$$\delta(t) = A_1 e^{t/t_{\rm dyn}} + A_2 e^{-t/t_{\rm dyn}}$$

How structures form?

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$$\delta(t) = A_1 e^{t/t_{\rm dyn}} + A_2 e^{-t/t_{\rm dyn}}$$

$$c_s = c\left(\frac{dP}{d\varepsilon}\right)^{1/2} = \sqrt{w}c$$

$$w \approx \frac{kT}{\mu c^2}$$

For hydrostatic equilibrium to be attained, the pressure gradient must build up before the overdense region collapses:

$$t_{\rm pre} < t_{\rm dyn} .$$

$$\lambda_J \sim c_s t_{\rm dyn} \sim c_s \left(\frac{c^2}{G\bar{\varepsilon}}\right)^{1/2}$$

Overdense regions larger than the Jeans length collapse under their own gravity

$$\lambda_J = c_s \left(\frac{\pi c^2}{G\bar{\varepsilon}}\right)^{1/2} = 2\pi c_s t_{\rm dyn} .$$

How structures form?

$\bar{\rho}(1+\delta)$, with $\delta \ll 1$.

$$t_{\text{pre}} < t_{\text{dyn}} \ .$$

$$\delta(\vec{r},t) \equiv \frac{\varepsilon(\vec{r},t) - \bar{\varepsilon}(t)}{\bar{\varepsilon}(t)}$$

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$$\lambda_J = c_s \left(\frac{\pi c^2}{G\bar{\varepsilon}}\right)^{1/2} = 2\pi c_s t_{\text{dyn}} \ .$$

$$t_{\text{dyn}} = \frac{1}{(4\pi G\bar{\rho})^{1/2}} = \left(\frac{c^2}{4\pi G\bar{\varepsilon}}\right)^{1/2}$$

$$H^{-1} = \left(\frac{3c^2}{8\pi G\bar{\varepsilon}}\right)^{1/2}$$

$$\lambda_J = 2\pi c_s t_{\text{dyn}} = 2\pi \left(\frac{3}{2}\right)^{1/2} \frac{c_s}{H}$$

$$\lambda_J = 2\pi \left(\frac{2}{3}\right)^{1/2} \sqrt{w}\frac{c}{H} \ .$$

How structures form?

$\bar{\rho}(1+\delta)$, with $\delta \ll 1$.

$$t_{\rm pre} < t_{\rm dyn} \ .$$

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$$\lambda_J = 2\pi c_s t_{\rm dyn} = 2\pi \left(\frac{3}{2}\right)^{1/2} \frac{c_s}{H}$$

$$\lambda_J = 2\pi \left(\frac{2}{3}\right)^{1/2} \sqrt{w}\frac{c}{H} \ .$$

$$c_s(\text{photon}) = c/\sqrt{3} \approx 0.58c$$

$$c_s(\text{baryon}) = \left(\frac{kT}{mc^2}\right)^{1/2} c$$

Power Spectrum

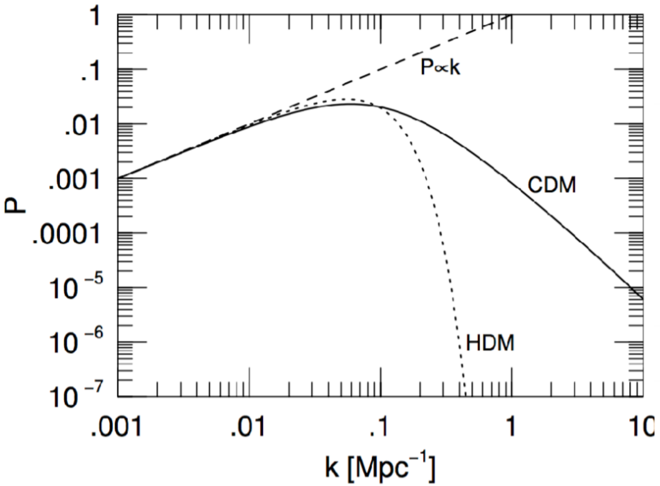
$$\delta(\vec{r}, t) \equiv \frac{\varepsilon(\vec{r}, t) - \bar{\varepsilon}(t)}{\bar{\varepsilon}(t)}$$

$$\delta(\vec{r}) = \frac{V}{(2\pi)^3} \int \delta_{\vec{k}} e^{-i\vec{k}\cdot\vec{r}} d^3k$$

$$\ddot{\delta}_{\vec{k}} + 2H\dot{\delta}_{\vec{k}} - \frac{3}{2}\Omega_m H^2 \delta_{\vec{k}} = 0$$

$$\delta_{\vec{k}} = |\delta_{\vec{k}}| e^{i\phi_{\vec{k}}}$$

$$P(k) = \langle |\delta_{\vec{k}}|^2 \rangle$$



Power Spectrum

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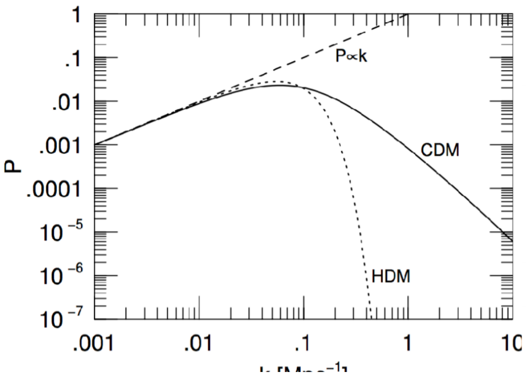
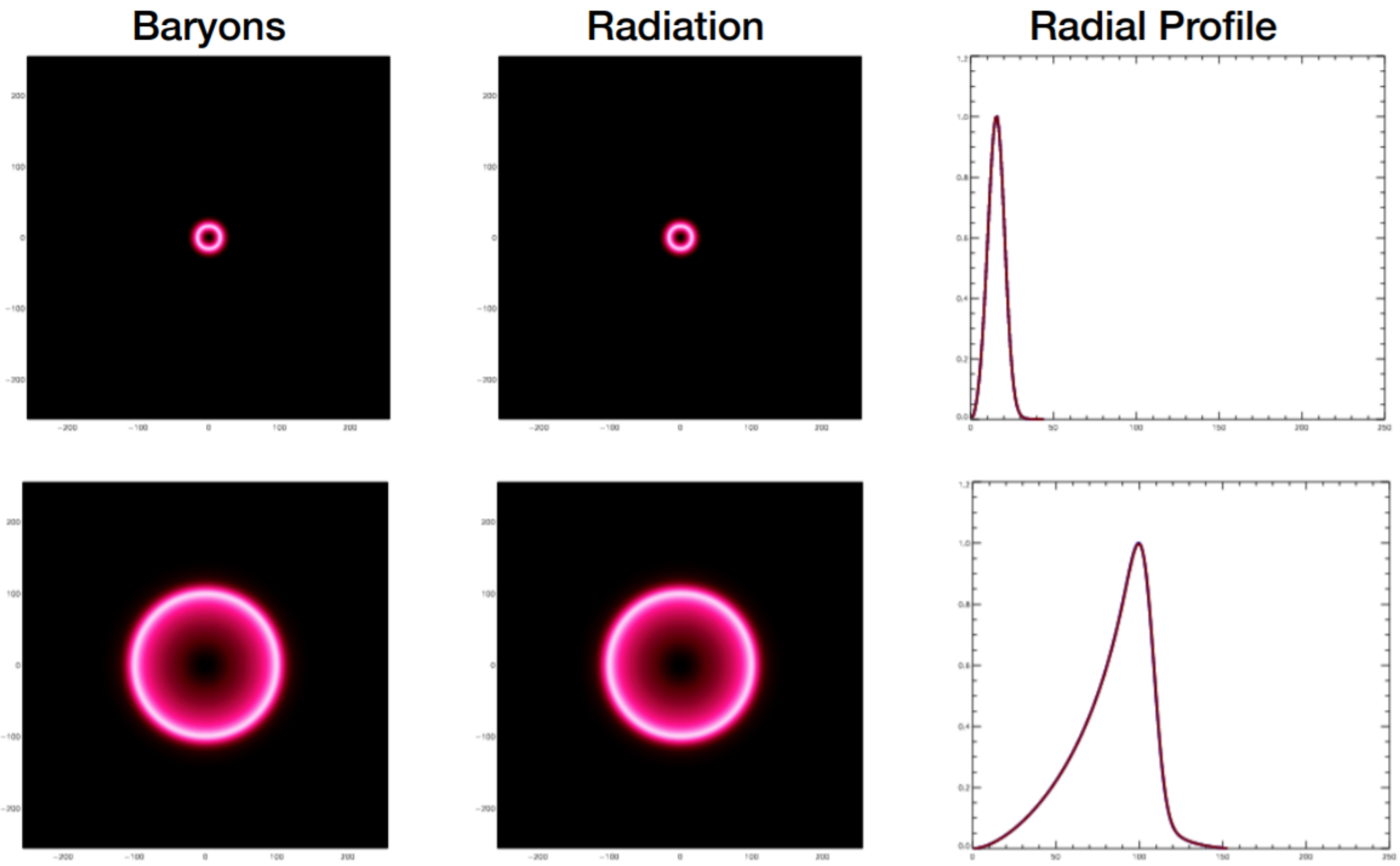


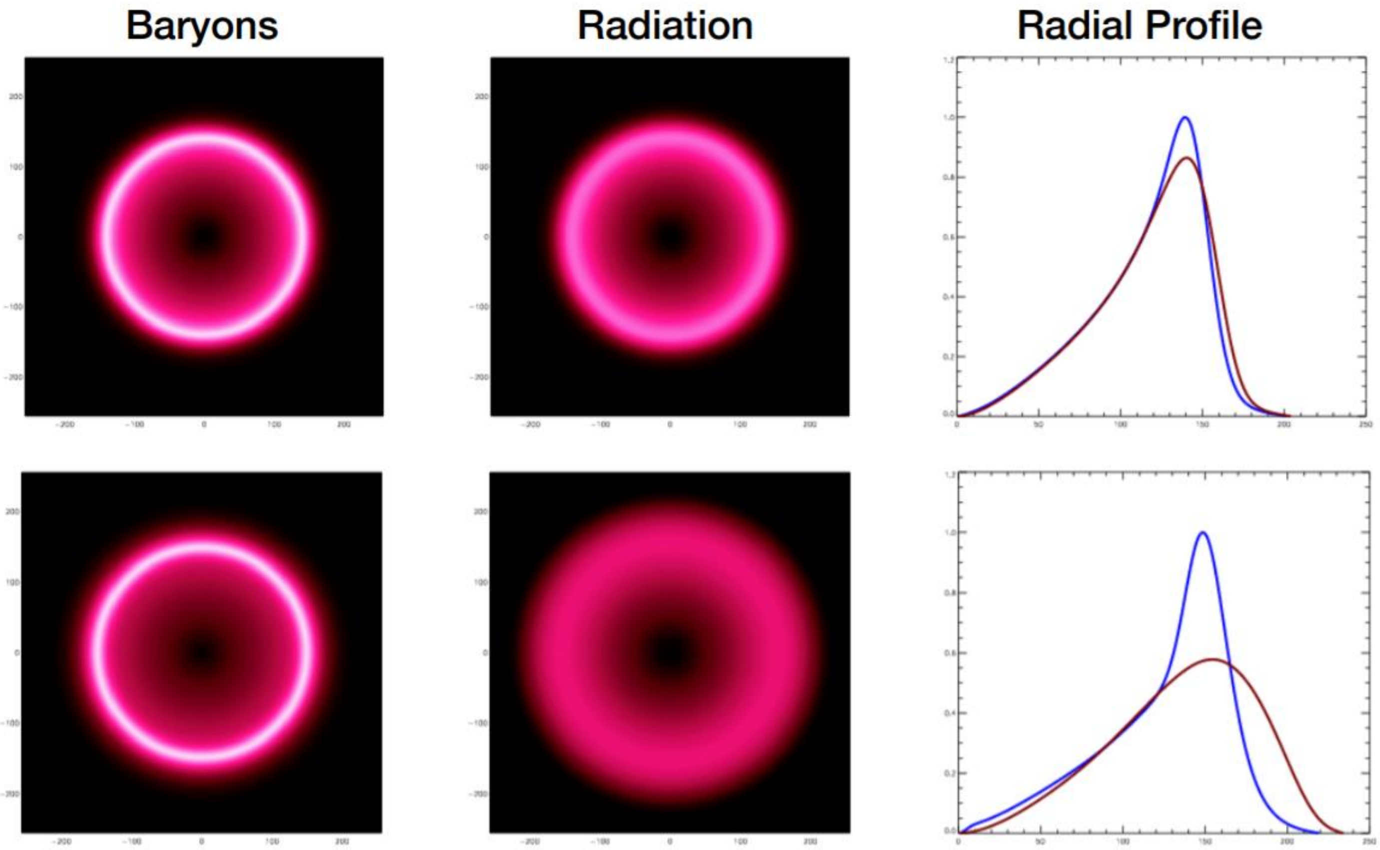
$$\sigma_8^2 = \frac{1}{2\pi^2} \int W_s^2 k^2 P(k) dk$$

Baryon Acoustic Oscillation

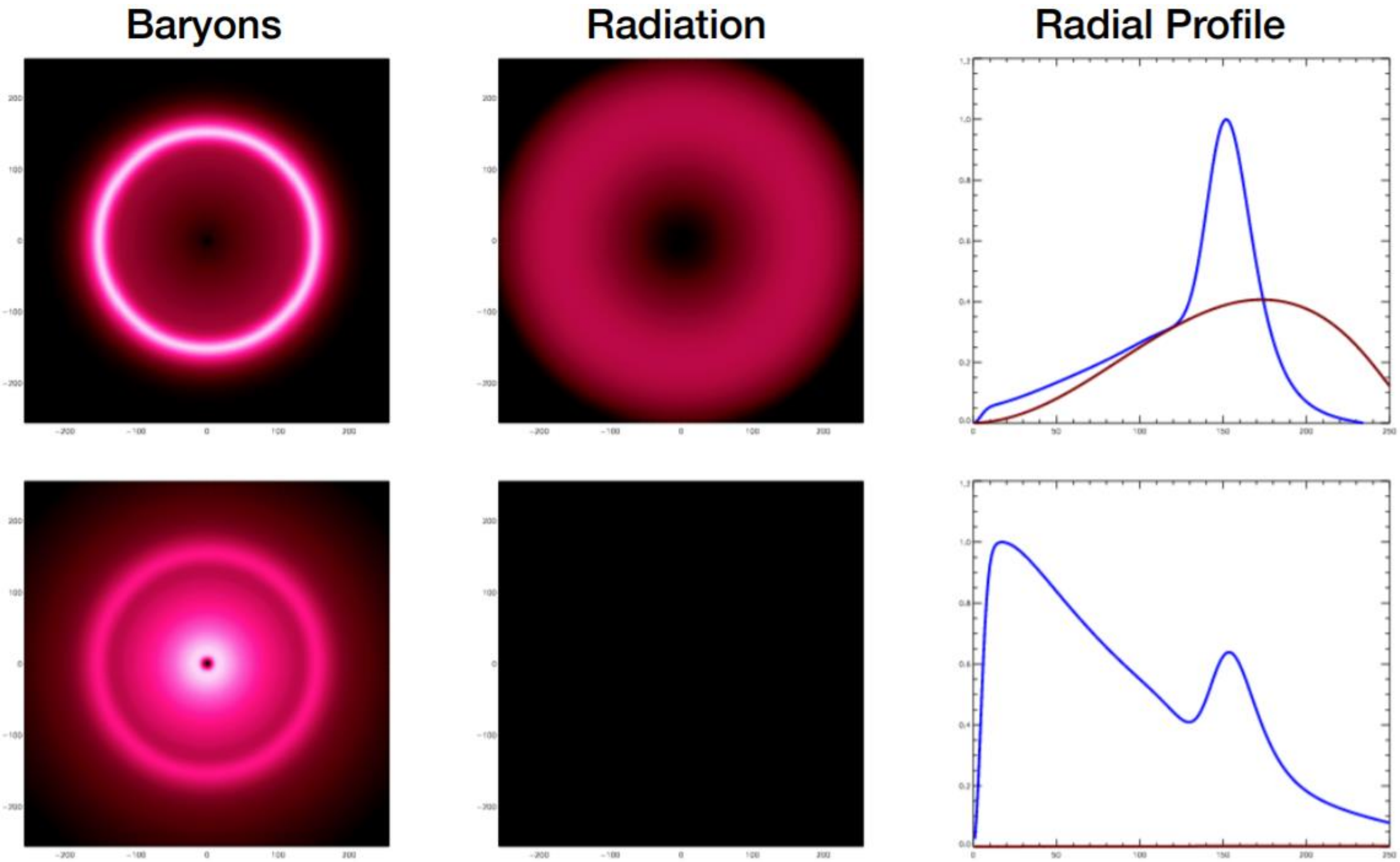


https://w.astro.berkeley.edu/~mwhite/bao/

Baryon Acoustic Oscillation

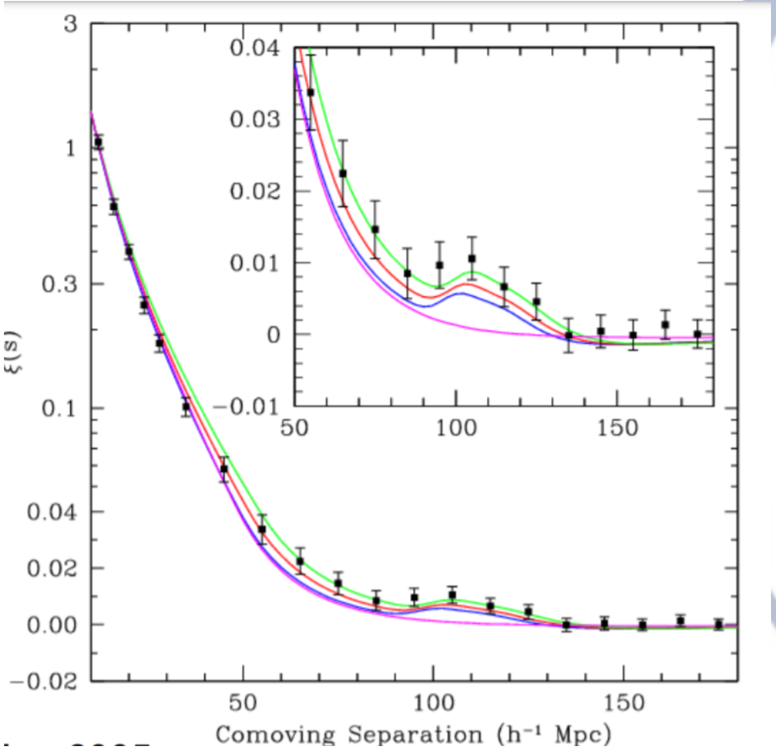


Baryon Acoustic Oscillation

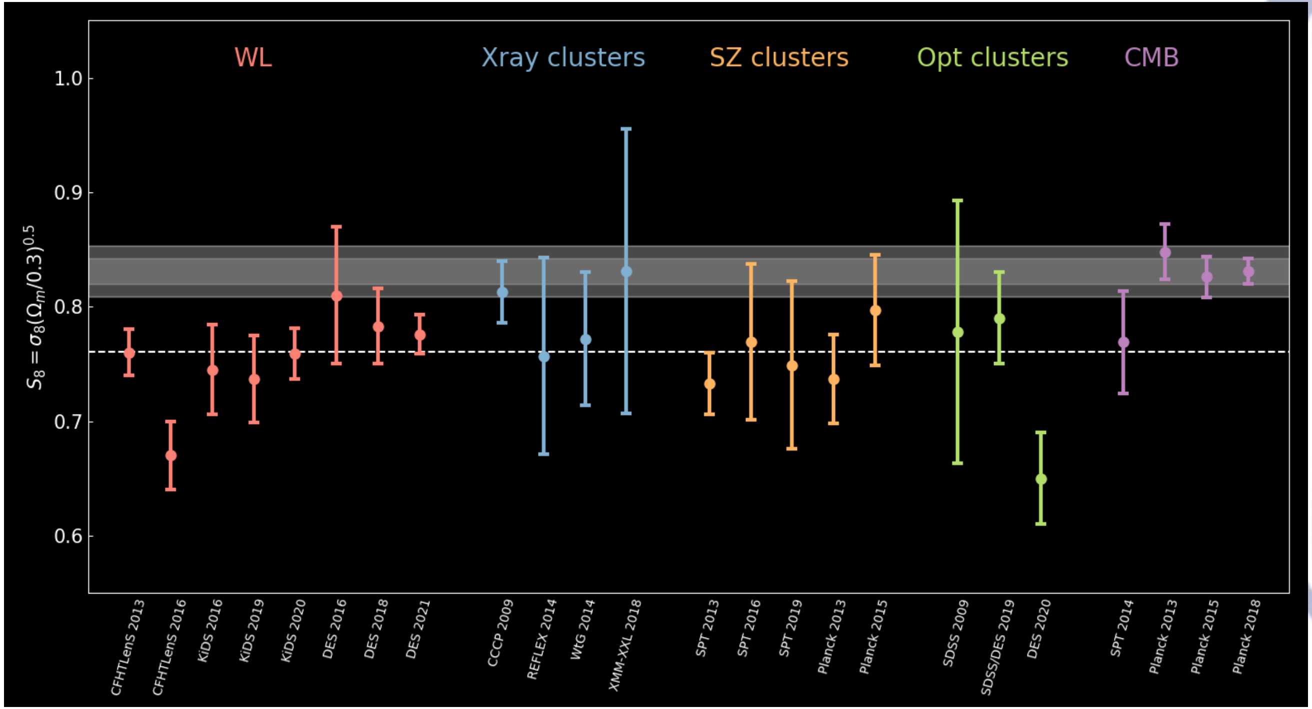


Baryon Acoustic Oscillation

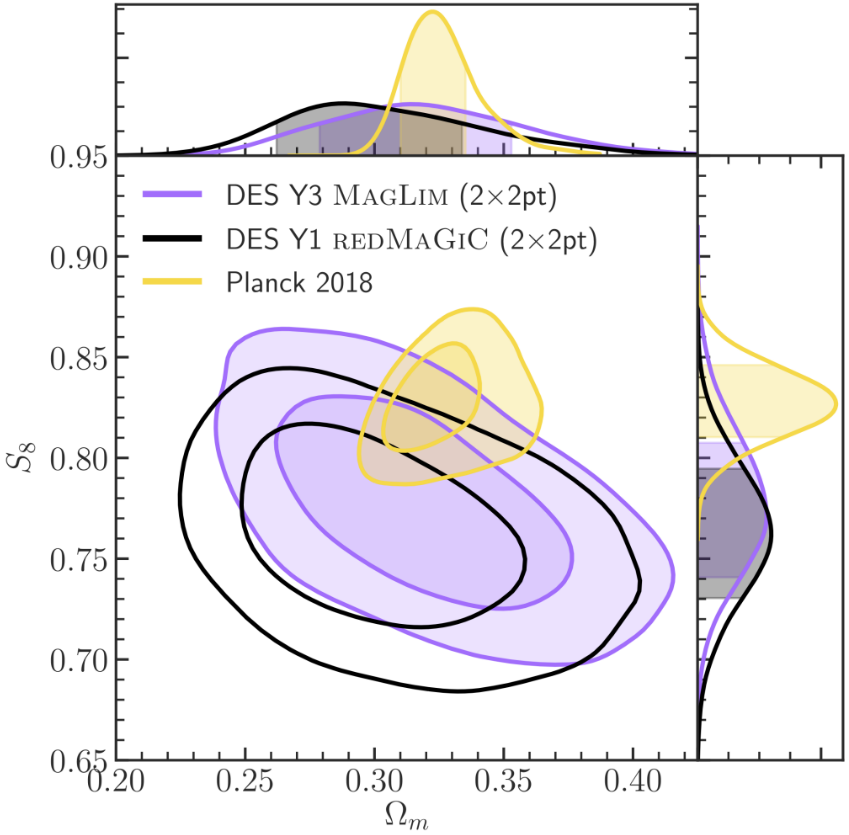
$$dN = n_{\mathrm{gal}}[1 + \xi(r)]dV$$



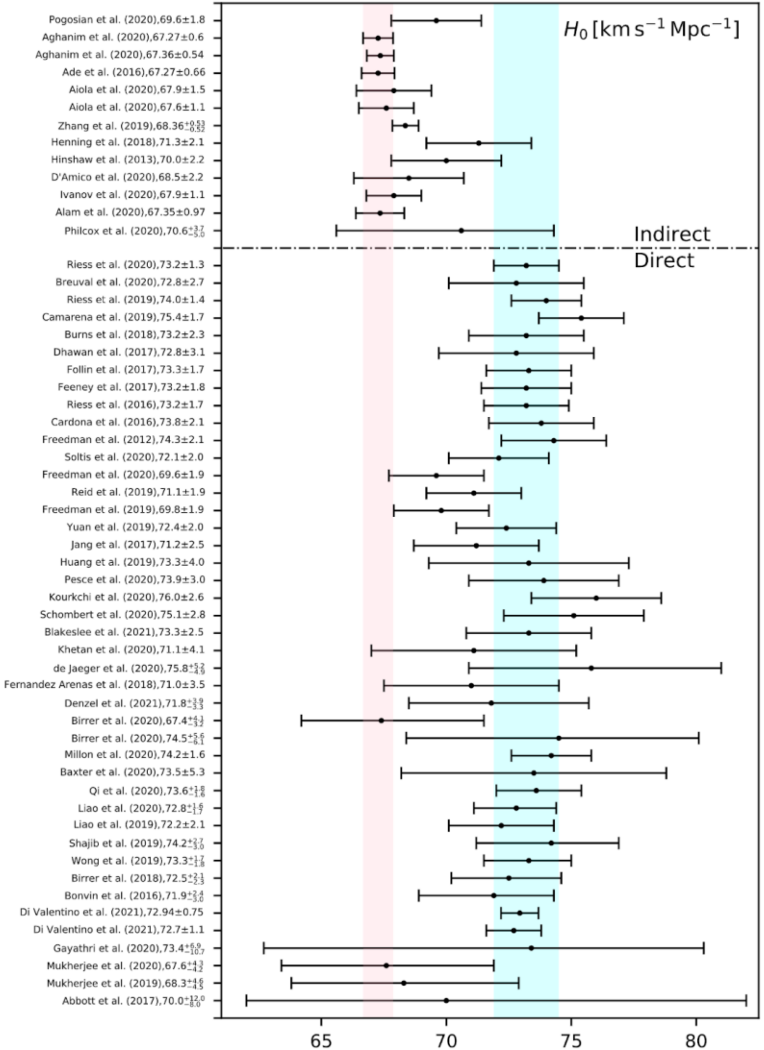
Tension on standard model



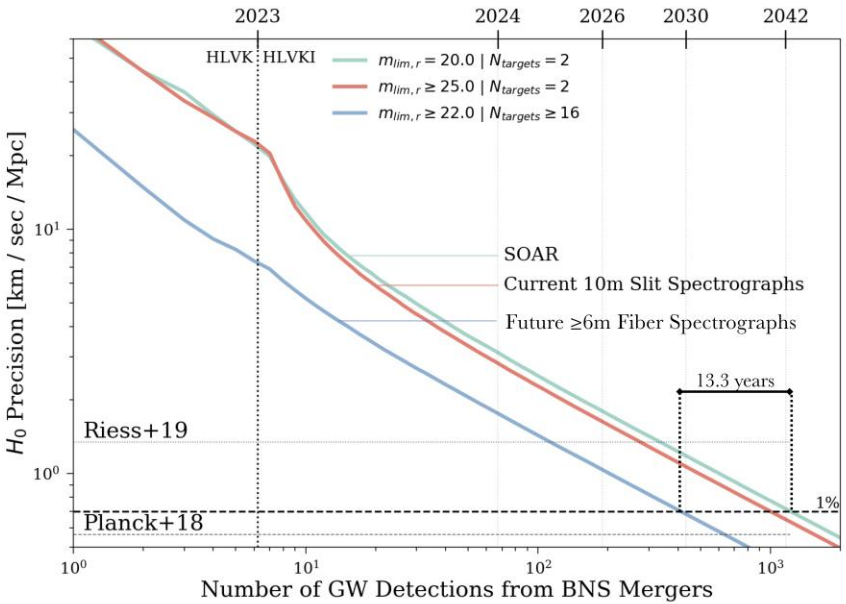
Tensions on the standard model ?



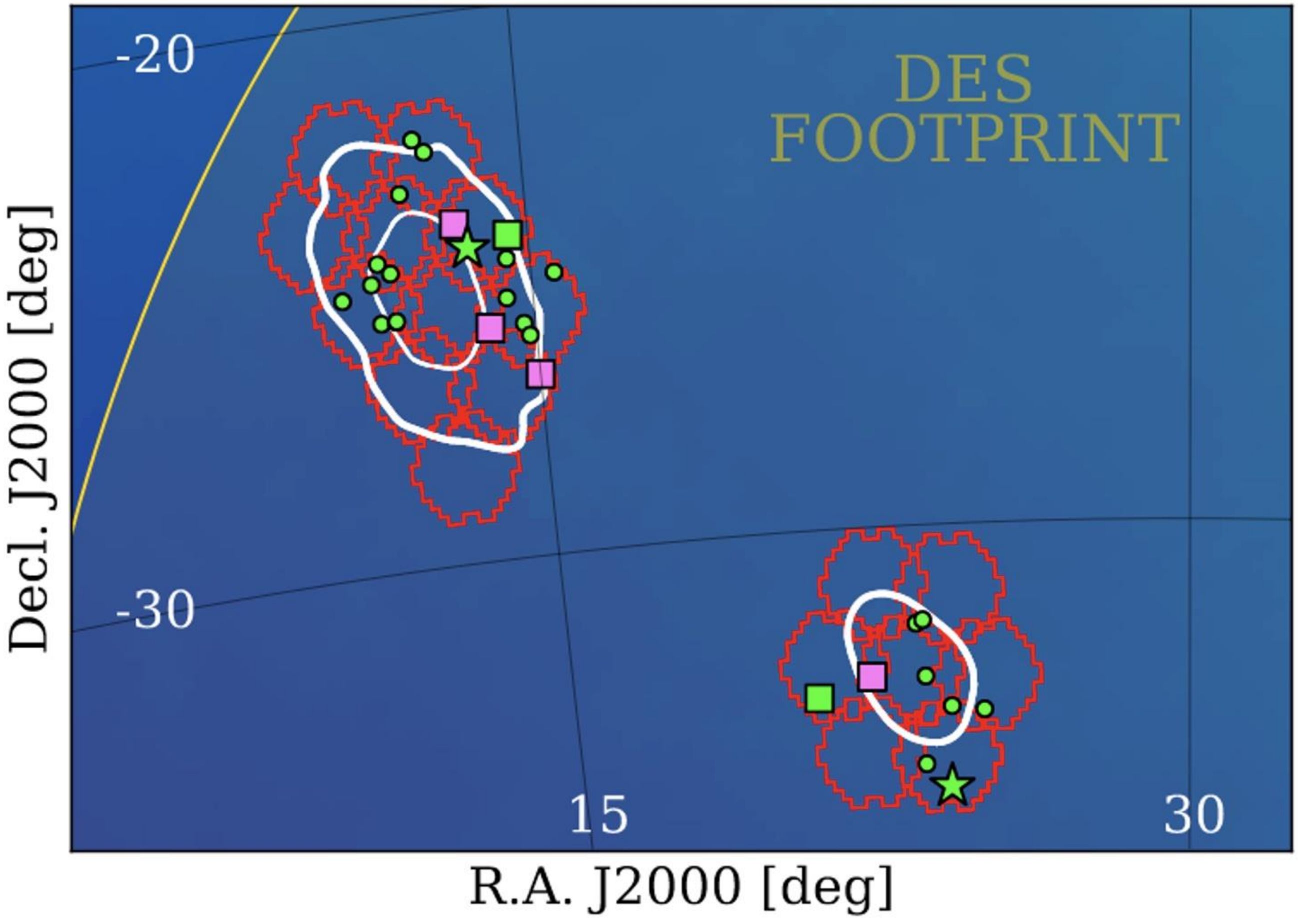
H0 Controversy



Gravitational Waves ?

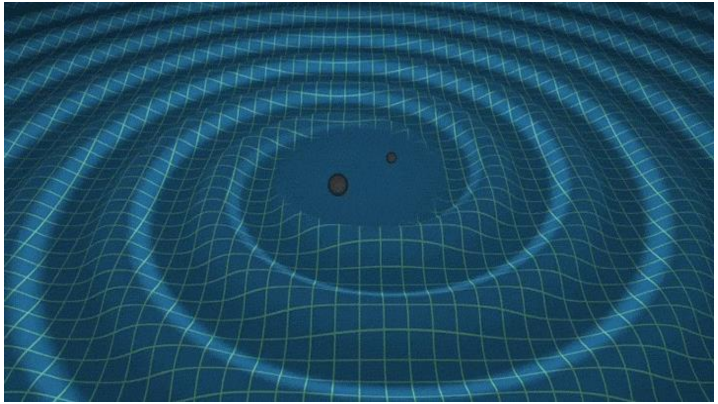


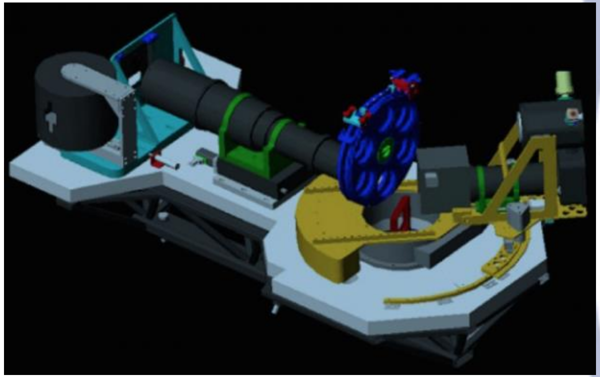
Search for GW counterparts



Gravitational Waves - The Kilonova Hunter

We are currently applying the same kind of model to develop a real-time Spectro Kilonova Classificator

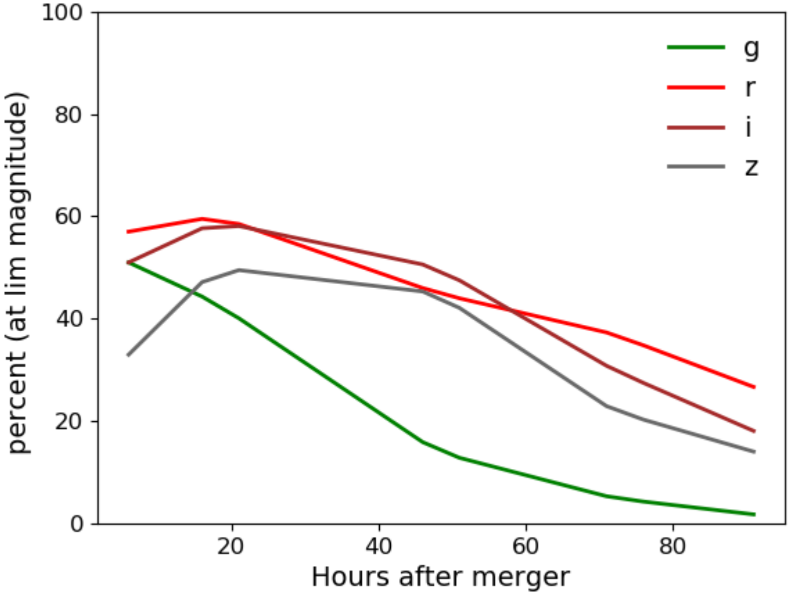


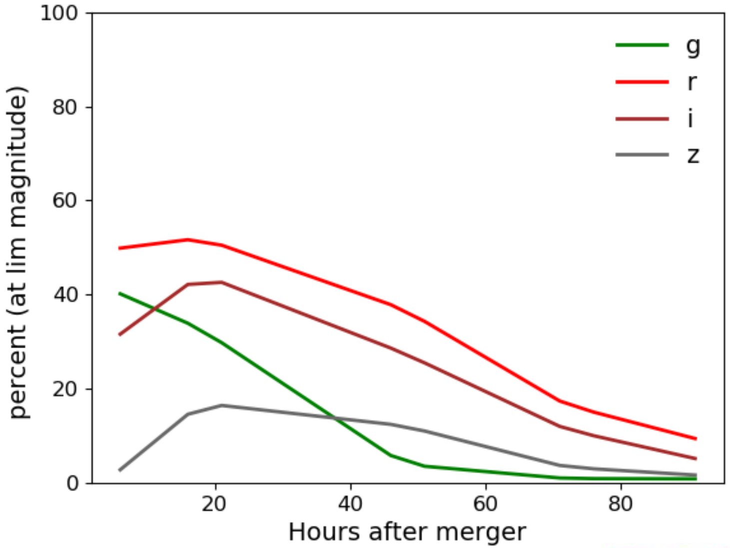


SOAR TELESCOPE

Strategy to find GW events

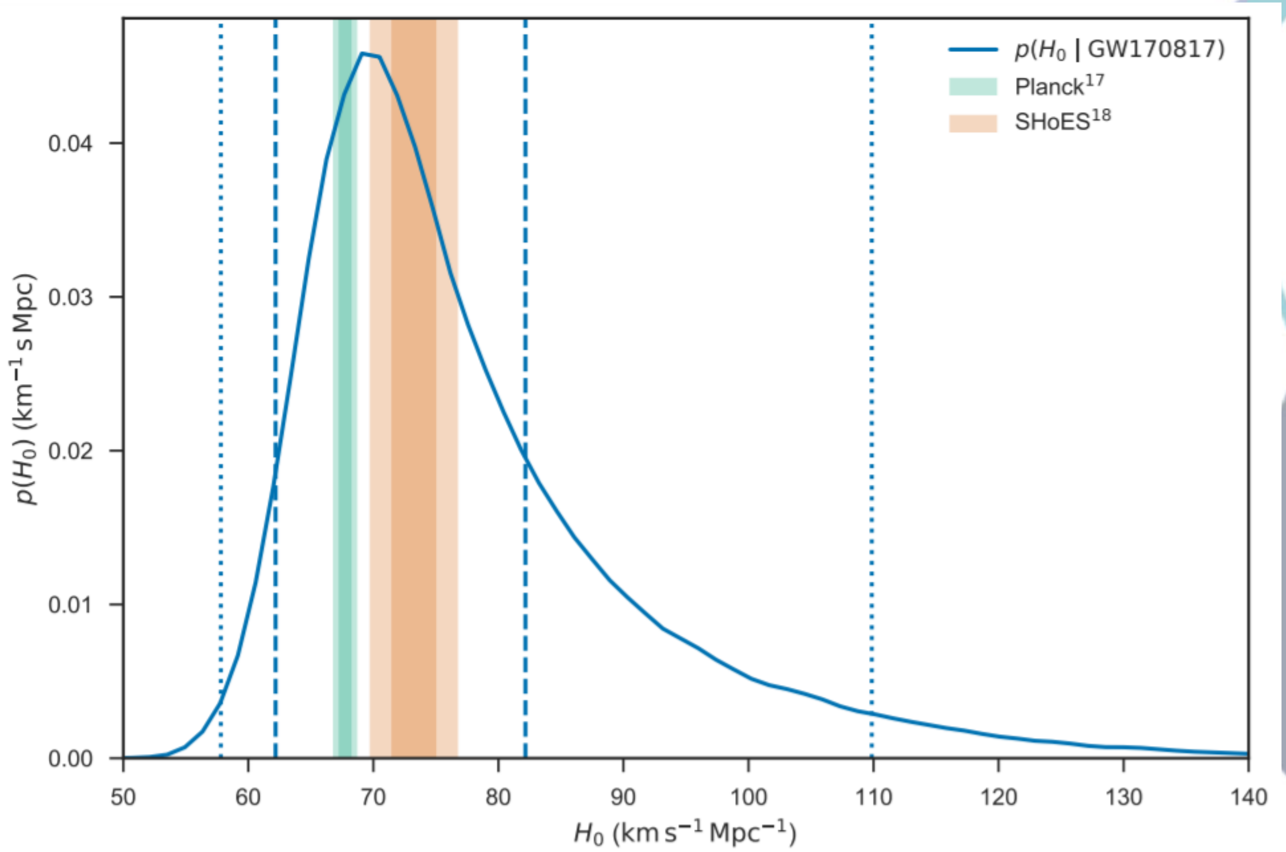
For a given Test Gravitational Wave event   (90 sec vs 600 sec) 90% coverage.



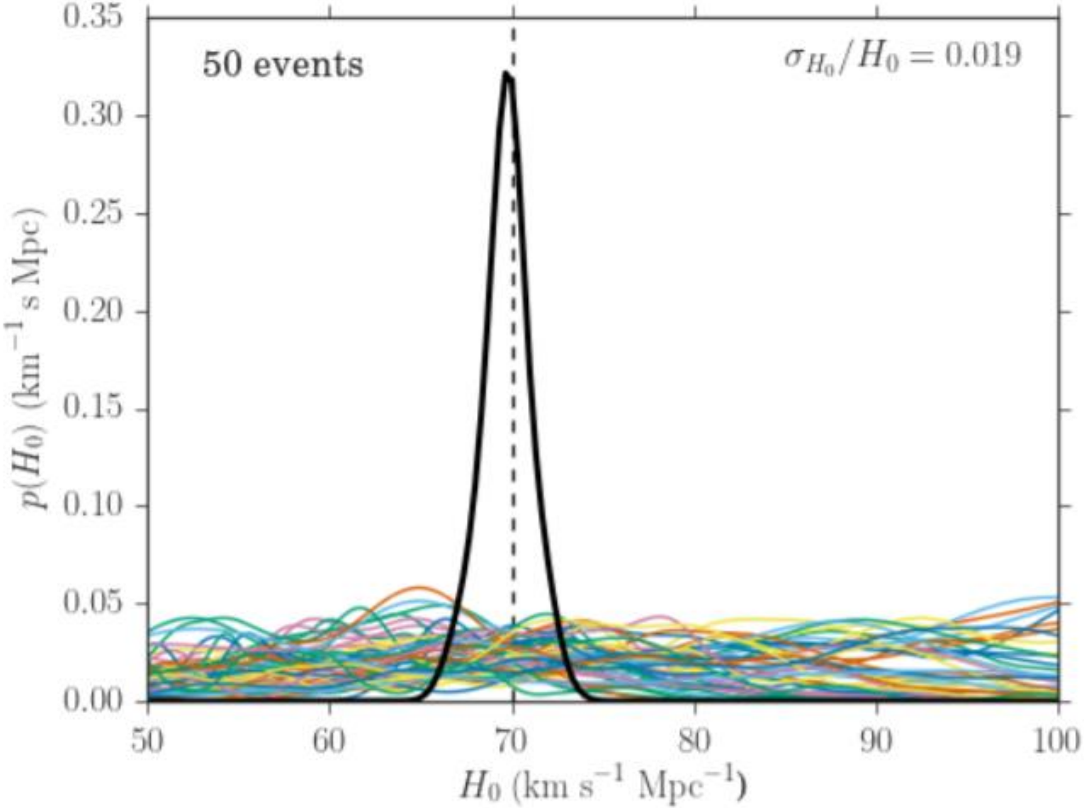


PRELIMINARY

Just a single GW event!

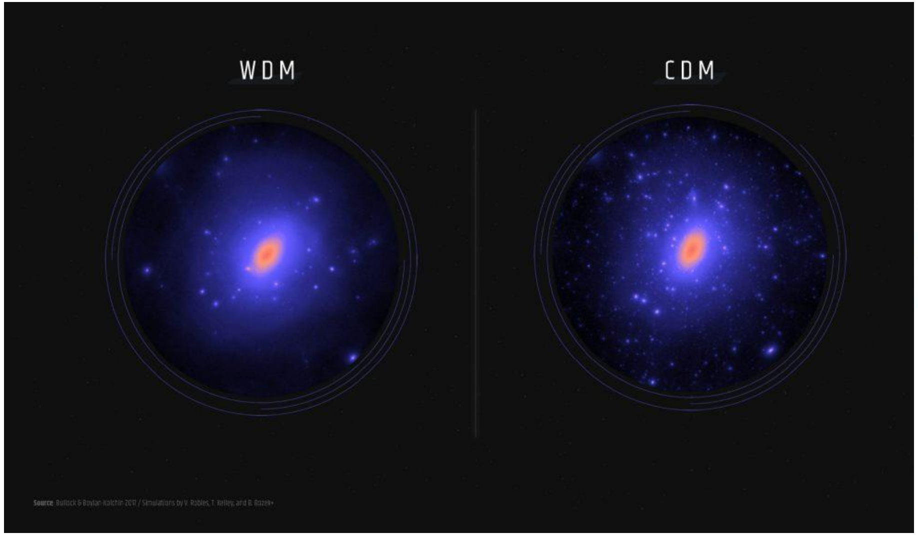


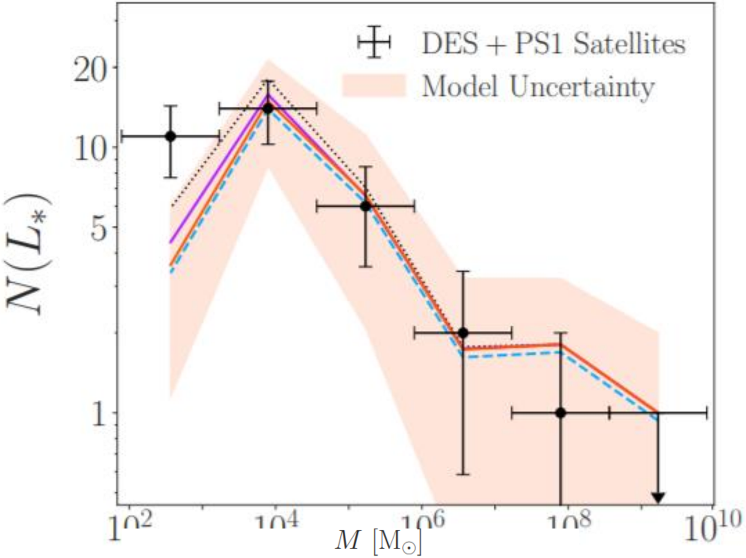
2% H0

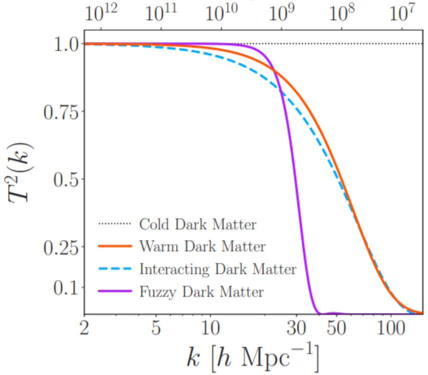


https://arxiv.org/pdf/1907.03578.pdf

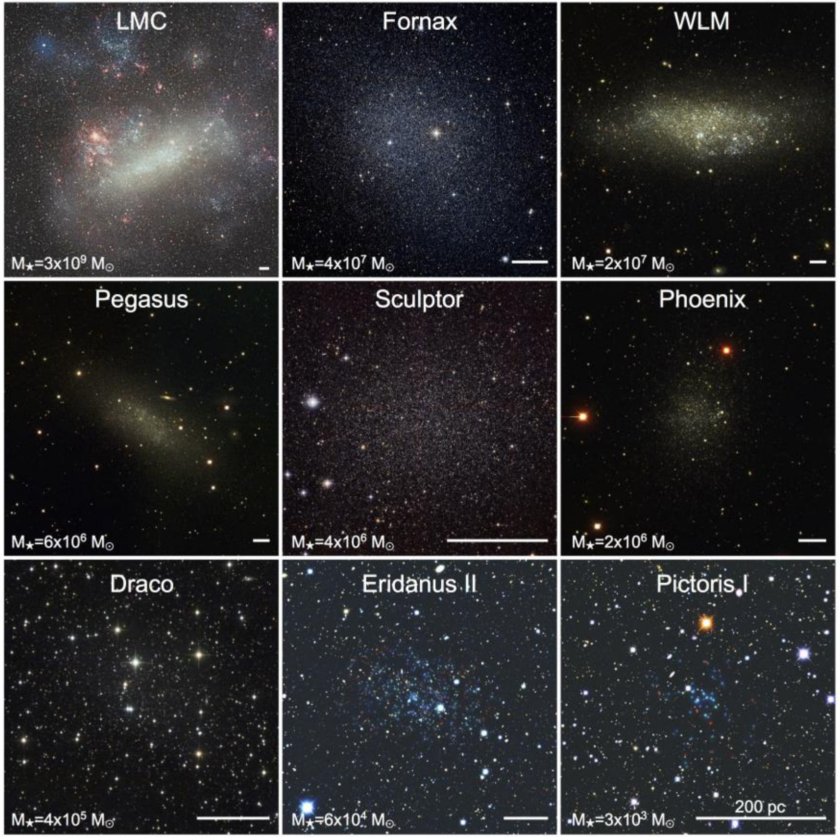
Local Universe Cosmology

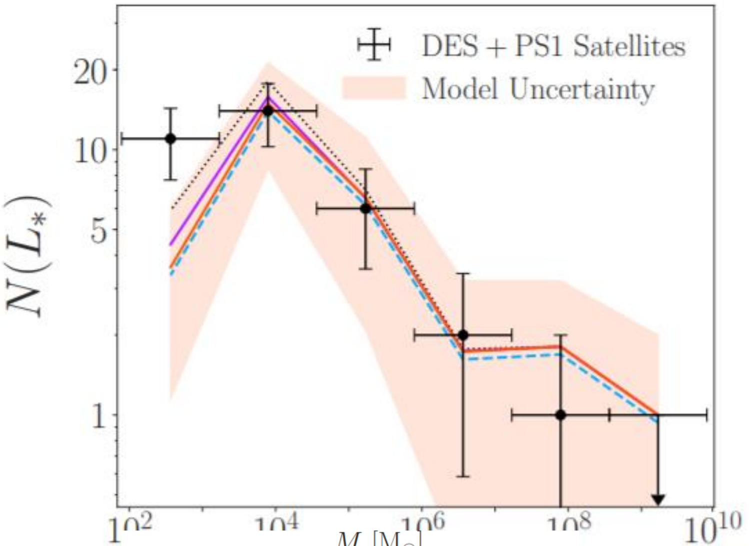


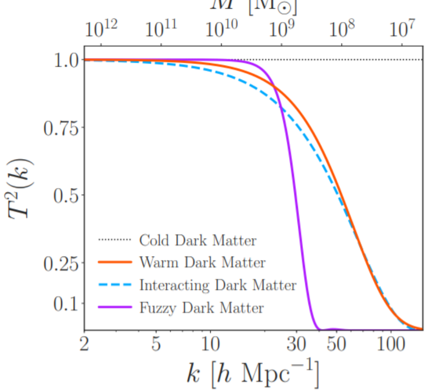




Local Universe Cosmology



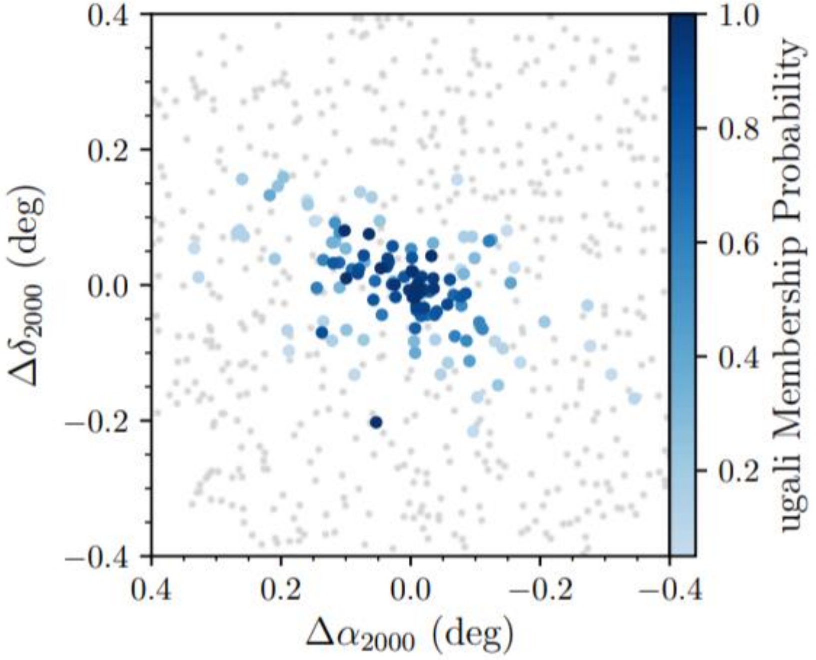


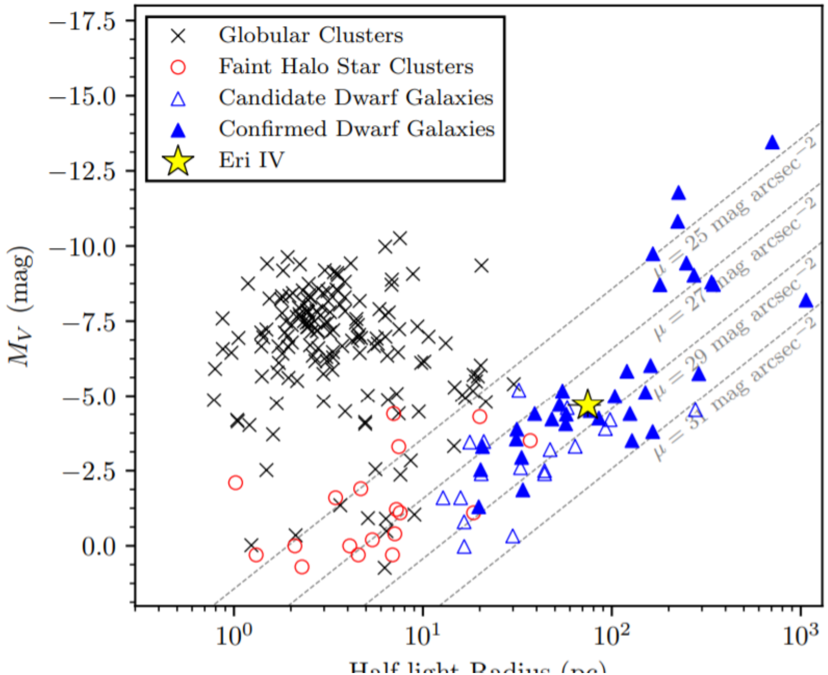


Eridanius IV !

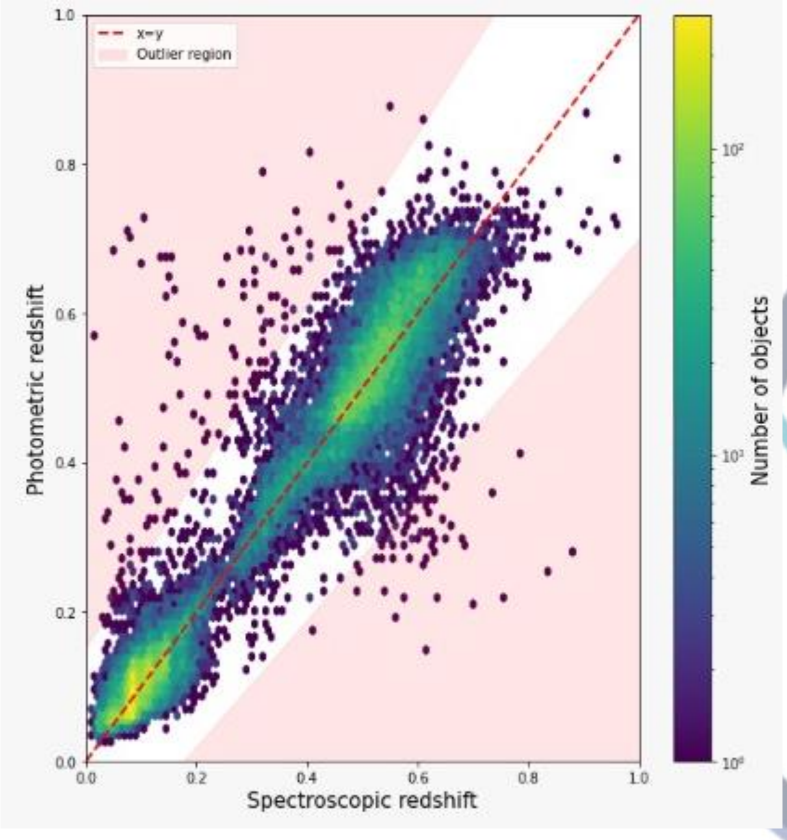
Eridanus IV: an Ultra-Faint Dwarf Galaxy Candidate Discovered in the DECam Local Volume Exploration Survey

W. Cerny,[1,2] A. B. Pace,[3] A. Drlica-Wagner,[4,1,2] S. E. Koposov,[5,6,7] A. K. Vivas,[8] S. Mau,[9,10] A. H. Riley,[11,12] C. R. Bom,[13] J. L. Carlin,[14] Y. Choi,[15] D. Erkal,[16] P. S. Ferguson,[11,12] D. J. James,[17,18] T. S. Li,[19,20] D. Martínez-Delgado,[21] C. E. Martínez-Vázquez,[22] R. R. Munoz,[23] B. Mutlu-Pakdil,[1,2] K. A. G. Olsen,[24] A. Pieres,[25,26] J. D. Sakowska,[16] D. J. Sand,[27] J. D. Simon,[19] A. Smercina,[28] G. S. Stringfellow,[29] E. J. Tollerud,[15] M. Adamów,[30] D. Hernandez-Lang,[31] N. Kuropatkin,[4] L. Santana-Silva,[32] D. L. Tucker,[4] and A. Zenteno[8]
(DELVE Collaboration)



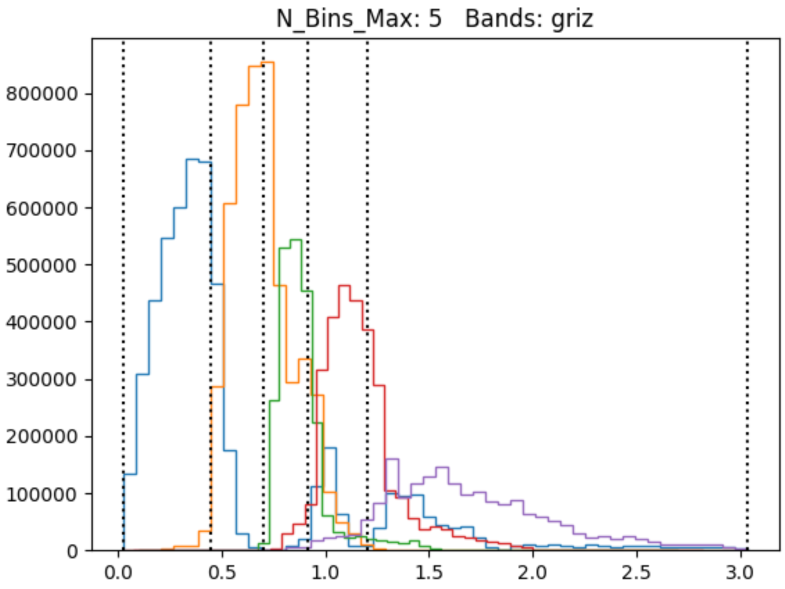


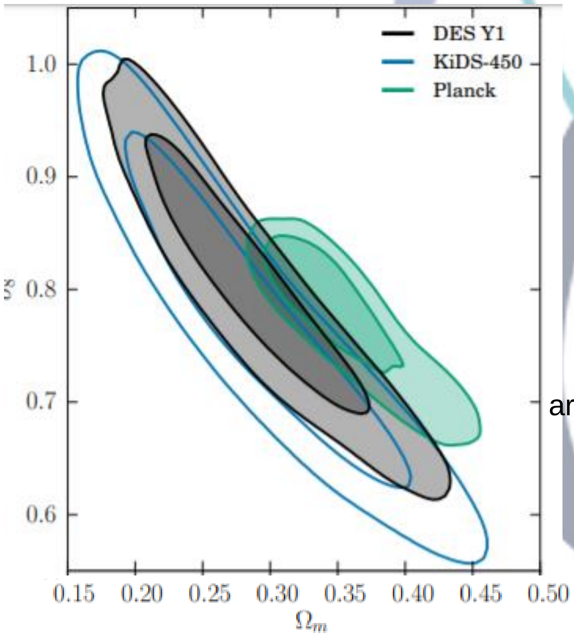
DELVE Survey Cosmology with Deep Learned redshifts



Redshift Bias Challenge

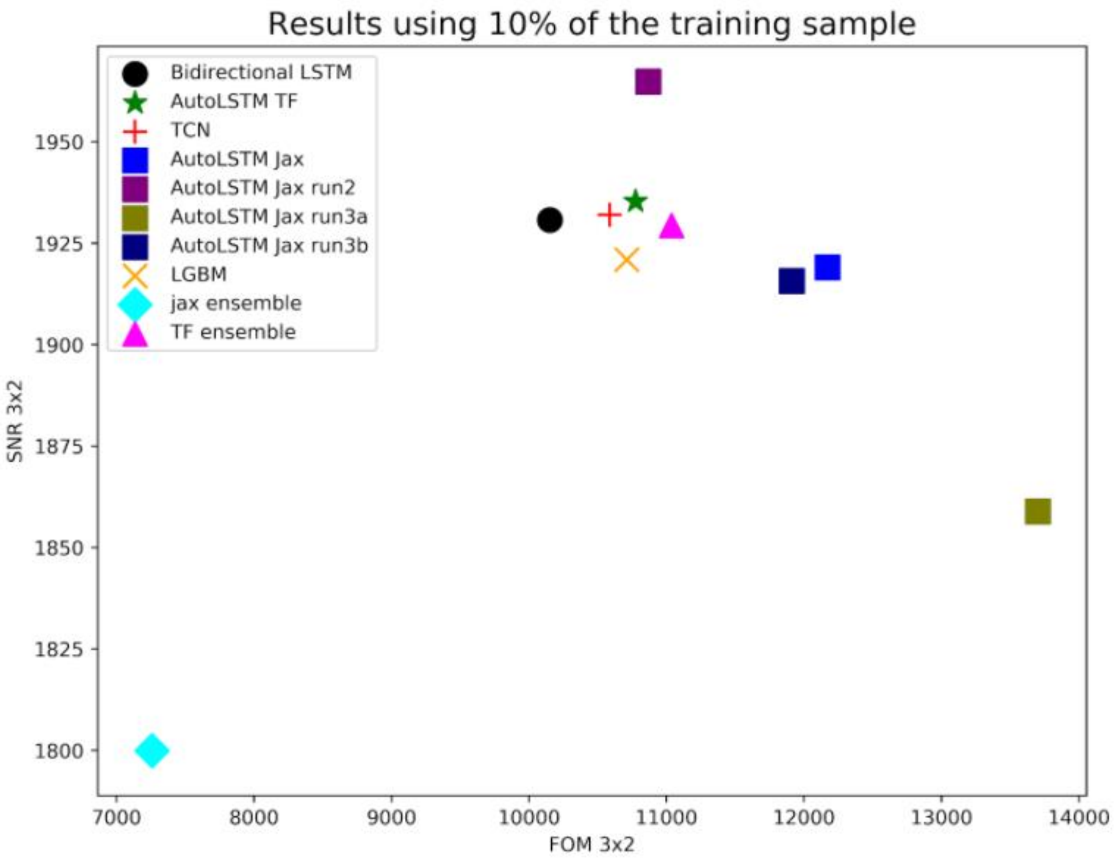
In this challenge you are asked to group galaxies into tomographic bins using only the quantities we generate using the metacalibration method. These quantities are the only ones for which we can compute a shear bias correction associated with the division.





arxiv:1708.01538

DELVE Survey Cosmology with Deep Learned redshifts



Einstein Rings (idealized case)

Singular Isothermal Sphere: $\rho(r) = \frac{\sigma_v^2}{2\pi G r^2}$

slip parameter
$\gamma = \frac{\Phi}{\Psi}$

Einstein Ring in modified gravity $\theta_E = 4\pi\sigma_{\rm obs}^2 \left(\frac{1+\gamma}{2}\right)\frac{D_{LS}}{D_S}$

If $\gamma =$ 1, GR is correct. In our simulated sample we assume GR

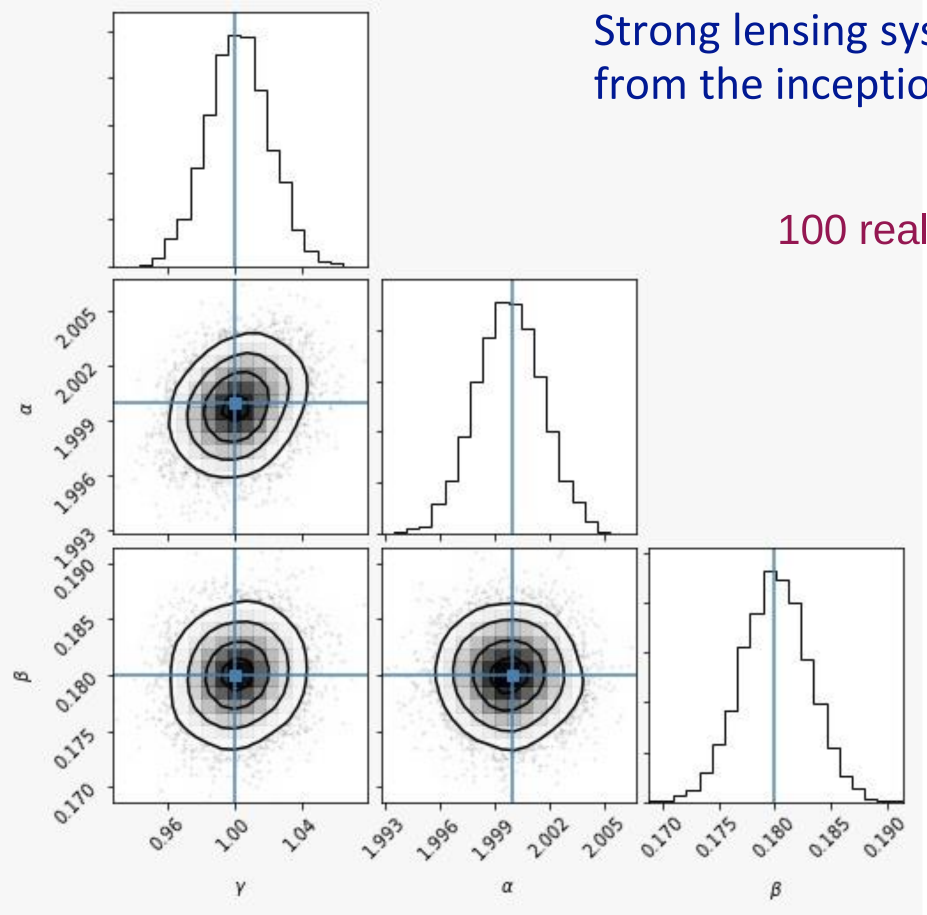
Measure velocity dispersion + Einstein Radius ➔ Test of Einstein General Relativity

Current results need detailed modelling of the lens + z_S, which is hard to obtain

Schwab, Bolton, Rappaport, arXiv:0907.4992

Results

Crisnejo, MM, CB



Strong lensing systems with parameters recovered from the inception neural network

100 realizations of the simulated sample

Mean slip parameter

$$\gamma = 1.003 \pm 0.019$$

A few take aways ....

The Universe is homogeneous and isotrophic in large scales.

Except for the primordial Universe, the GR gives the current (most accepted) description of our Universe.

We mostly agree on the Cosmological model for now, but there are tensions... Who knows what we might find ?

There are exotic things around it, and we just dont know what it is.

Observational Cosmology relays on Big Data now, statistics, Image Processing computational methods. ML is a growing thing.

Main paths to fit the data: 1. Angular Distance, 2. Luminosity Distance. 3. Density perturbations.

There is a lot of other interesting stuff going on ....

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