New Constrains on Dark Energy Models from the Abundance of Massive High Redshift Galaxies

In a recent article published in the last issue september 2020 of The Astrophysical Journal, an international research team from the INAF-Rome and Padova Astronomical Observatories, Japan National Observatory at Tokyo, Paris-Saclay University, Paris University, and CNRS at PSL Paris Observatory and Sorbonne University, combined for the first time the astronomical data of three different and independent probes on the abundance of the most massive galaxies at high redshifts to obtain new robust constraints on dark energy models of high current interest under close scrutiny. The combined probes and results allow to strongly constraint (and even exclude) models which were presently unconstrained or even favoured by single probes. They also open the possibility to alleviate or even explain the present tension on the values of the Hubble constant H_0.

As is well known, the Universe at the present time is in a phase of accelerated expansion. The present content is largely dominated (almost the 75%) by some form of dark energy, responsible of the accelerated expansion. Although the nature of dark energy remains unknown, the simplest models assume to be connected with the vacuum energy and that such energy can be evolving, a particular case being the well known cosmological constant.

The general dark energy parameterization allowing for its evolution across cosmic time is in terms of two parameters (w_0, wa): the local parameter w_0 and of the lookback time derivative of the equation of state wa. (In particular, the values w_0 = -1, wa = 0 yield the dark energy without evolution, that is the cosmological constant case).

The aim of the team is to derive precision constraints for the evolution of the dark energy equation-of-state that are complementary to and go beyond the existing probes. The team proposes to probe the nature and evolution of dark energy through the evolution of the galaxy population over cosmic time.

The team computed the abundances of massive systems predicted in different dynamical dark energy models at high redshifts z in a range of redshifts between z = 4 and z = 7, and compared such predictions with the measured abundances of the most massive galaxies observed at such redshifts.

The team obtained robust constraints on the combinations of the dark energy parameters (w_0, wa) in the different dynamical dark energy models by using three independent probes:

(i) the observed stellar mass function of massive objects at redshifts $z \geq 6$ obtained from the CANDELS survey.

(ii) the estimated volume density of massive galactic halos derived from the observation of massive, star-forming galaxies detected in the submillimeter range at redshift $z \approx 4$.

(iii) the rareness of the most massive system (with an estimated gas mass exceeding $3 \times 10^{11} M_{\odot}$) observed to be in place at the redshift $z \approx 7$: the far-infrared–hyperluminous galaxy SPT0311–58 recently detected in the South Pole Telescope survey (SPT).

For each observable, the most conservative assumption for the relation between the observed baryonic component and the dark matter mass M has been considered.

(iv) Finally, the team shows that the combination of the obtained constraints from the above three probes *excludes a sizable fraction* of the parameter space (w_0, wa) of the dark energy models and obtained a simple analytic equation for it:

$$wa \gtrsim -3/4 - (w_0 + 3/2),$$

that is to say: models that are presently allowed (or even favored) by existing single probes are tightly constrained or even excluded. As an example, the Figure below illustrates some of these results.

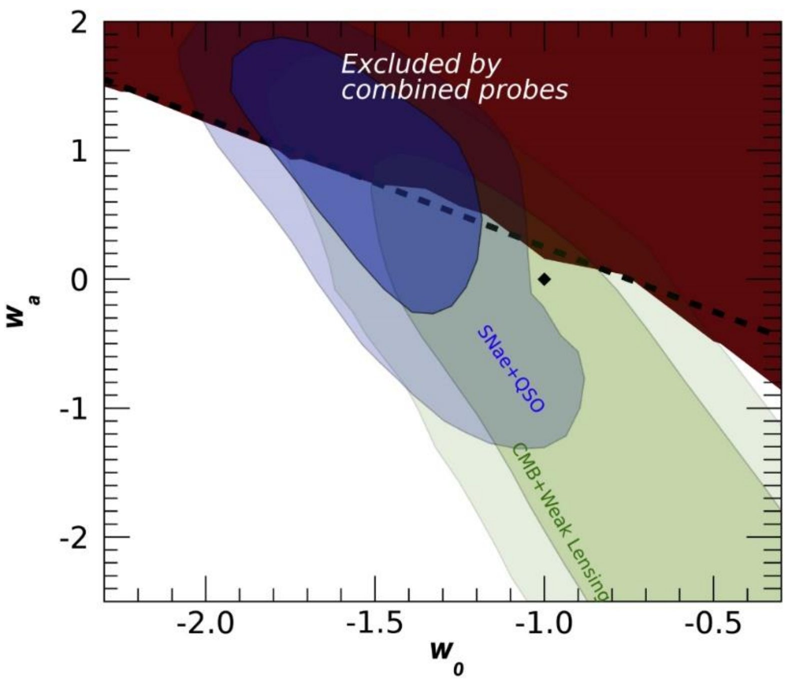

Figure 1. Exclusion regions (2σ confidence level) in the (w_0−wa) plane derived from the combination of three different probes: for the CANDELS field at $z \geq 6$, for submillimeter galaxies at $z \approx 4$ and for the far-infrared galaxy SPT0311–58 at $z \approx 7$. For each observable, the most conservative case has been considered for the conversion of stellar mass to dark matter mass. The dashed black line shows the analytical expression obtained for the boundary of the excluded region: $wa = -3/4 - (w_0 + 3/2)$. Among the results, the figure implies that a major fraction of the parameter space favored by distant quasars, combined with the CMB and weak lensing, is excluded at the 2σ confidence level.

The results do not depend on the details of the baryon physics involved in the galaxy formation. They neither depend on the nature (warm or cold) of the dark matter component taking into account the present limit on the mass of the dark matter (thermal relic) candidates $m_X \geq 3$ keV. For dark matter particle masses in the keV range (warm dark matter), the power spectrum on the massive galaxy scales as those investigated in this work $M \geq 10^{10}\ M_\odot$ is identical to the cold dark matter power spectrum and therefore, the results are the same.

These results also open the possibility that the present Hubble constant H_0 tension (up to 5σ) between the values derived from the early universe (CMB) and those obtained from the local universe measurements may be alleviated or even explained in this context, because the combinations of the parameters (w_0, wa) allowing for the reconciliation of the different H_0 values are allowed too by the present results.

Reference: *Constraints on Dynamical Dark Energy Models from the Abundance of Massive Galaxies at High Redshifts*, N. Menci et al.
The Astrophysical Journal, Volume 900, Number 2, p 108 September 2020

Link to the article:
https://iopscience.iop.org/article/10.3847/1538-4357/aba9d2

Link to the e-Print : https://arxiv.org/abs/2007.12453

Contact : Norma Sanchez, CNRS PSL-Paris Observatory Sorbonne University LERMA UMR 8112

Norma.Sanchez@obspm.fr

https://lerma.obspm.fr/~sanchez/
