The Milky Way Panorama Credit: ESO / S. Brunier

Newsletter of ***A Cosmology Group*** - November 2021

ACG Editorial

$\mathcal{I}$ learned about a new type of fallacy: the *Motte-and-Bailey*. It describes the kind of arguments put forward by many cosmologists when defending ΛCDM.

In their argumentation, cosmologists conflate two positions: the easy-to-defend BB model (the "Motte") and the controversial ΛCDM model (the "Bailey").[1] When the ΛCDM-bailey is challenged, cosmologists insist that they are only advancing the BB position. Upon retreating to the BB-motte, cosmologists claim that the ΛCDM-bailey has not been refuted (because the critic refused to attack the BB) or that the critic is unreasonable (by equating an attack on ΛCDM with an attack on the BB).

$\mathcal{I}$n this Newsletter: galaxy evolution puzzles, a quasar and a protocluster 770 Myr after the Big Bang, and a massive blow for the very challenged standard model: ΛCDM is ruled out at $> \mathbf{6}\sigma$.

Louis Marmet, November 10, 2021
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ACG - Leading Science into a New Cosmological Paradigm

Reviewed Publications[2]

- Galaxy and Large-Scale Structure Formation

"A massive stellar bulge in a regularly rotating galaxy 1.2 billion years after the Big Bang"
F. Lelli, E. M. Di Teodoro, F. Fraternali, *et al.*, Science **371(6530)** 713 (2021)
doi: 10.1126/science.abc1893 and arXiv:2102.05957

Cosmological models predict that galaxies forming in the early Universe experience a chaotic phase of gas accretion and star formation, followed by gas ejection due to feedback processes. Here we present submillimeter observations of ALESS 073.1, a starburst galaxy at redshift $z \sim 5$, when the Universe was 1.2 billion years old. This galaxy's cold gas forms a regularly rotating disk with negligible noncircular motions. The galaxy rotation curve requires the presence of a central bulge in addition to a star-forming disk. We conclude that massive bulges and regularly <u>rotating disks can form more rapidly in the early Universe than predicted by models of galaxy formation</u>.

Challenged ΛCDM inference J deduced from: G and H.

"Constraints on the star formation histories of galaxies in the Local Cosmological Volume"
P. Kroupa, M. Haslbauer, I. Banik (Bonn), *et al.*, MNRAS **497(1)** 37 (September 2020)
doi: 10.1093/mnras/staa1851 and arXiv:2007.07905

The majority of galaxies with current star-formation rates (SFRs), $\mathrm{SFR}_o \geq 10^{-3}\ \mathrm{M}_\odot/\mathrm{yr}$, in the Local Cosmological Volume where observations should be reliable, have the property that their observed SFR_o is larger than their av-

[1] Adapted from Wikipedia's Motte-and-bailey_fallacy page.
[2] Quoted text is adapted from the original articles: <u>underlined text is my emphasis</u>, *italicized text are my comments.*

erage star formation rate. This is in tension with the evolution of galaxies described by delayed-τ models, according to which the opposite would be expected. The tension is apparent in that local galaxies imply the star formation timescale τ approx 6.7 Gyr, much longer than the 3.5–4.5 Gyr obtained using an empirically determined main sequence at several redshifts. This suggested near-constancy of a galaxy's SFR over time raises non-trivial problems for the evolution and formation time of galaxies, but is broadly consistent with the observed decreasing main sequence with increasing age of the Universe.

Challenged ΛCDM inference J deduced from: G and H.

"On the origin of surprisingly cold gas discs in galaxies at high redshift"
M. Kretschmer, A. Dekel, R. Teyssier, arXiv:2103.06882 (2021)
arXiv:2103.06882

We address the puzzling observational indications for very "cold" galactic discs at redshifts $z \geq 3$, an epoch when discs are expected to be highly perturbed. Using a high-resolution cosmological zoom-in simulation, we identify such a cold disc at $z \sim 3.5$. The confinement of molecular gas to cold, dense clouds reside near the disc mid-plane, while the atomic gas is spread into a turbulent and more extended thicker disc. Although rotation-supported discs are expected at high redshift, these findings of extremely cold gas discs are surprising.

Challenged ΛCDM inference J deduced from: G and H.

"EMPRESS. II. Highly Fe-Enriched Metal-poor Galaxies with ~ 1.0 (Fe/O)$_\odot$ and 0.02 (O/H)$_\odot$: Possible Traces of Super Massive (> 300M$_\odot$) Stars in Early Galaxies"
T. Kojima, M. Ouchi, M. Rauch, *et al.*, The Astrophysical Journal **913(1)** (2021)
doi: 10.3847/1538-4357/abec3d and arXiv:2006.03831

We present element abundance ratios and ionizing radiation of local young low-mass extremely metal poor galaxies (EMPGs) with a 2% solar oxygen abundance (N/O)$_\odot$ and a high specific star-formation rate, and other (extremely) metal poor galaxies. The iron-to-oxygen abundance ratios (Fe/O) of the EMPGs are generally high; the EMPGs with the 2%-solar oxygen abundance show high Fe/O ratios of $\sim$ 90–140% (Fe/O)$_\odot$, which are unlikely explained by suggested scenarios of Type Ia supernova iron productions, iron's dust depletion, and metal-poor gas inflow onto previously metal-riched galaxies with solar abundances. Moreover, these EMPGs have very high HeII4686/Hβ ratios of $\sim 1/40$, which are not reproduced by existing models of high-mass X-ray binaries whose progenitor stellar masses are less than 120 M$_\odot$. We propose that both the high Fe/O ratios and the high HeII4686/Hβ ratios are explained by the past existence of super massive ($>$ 300 M$_\odot$) stars, which may evolve into intermediate-mass black holes ($\geq$ 100 M$_\odot$). *The most massive known stars have a mass* < 250 $M_\odot$.

Challenged ΛCDM inference J deduced from: G and H.

"Spiral morphology in an intensely star-forming disk galaxy more than 12 billion years ago"
T. Tsukui, S. Iguchi, Science **372(6547)**, 1201 (11 Jun 2021)
doi: 10.1126/science.abe9680 and arXiv:2108.02206

Spiral galaxies have distinct internal structures including a stellar bulge, disk and spiral arms. It is unknown when in cosmic history these structures formed. We analyze observations of BRI 1335-0417, an intensely star-forming galaxy in the distant Universe, at redshift 4.41. The [C II] gas kinematics show a steep velocity rise near the galaxy center and have a two-armed spiral morphology that extends from about 2 to 5 kiloparsecs in radius. We interpret these features as due to a central compact structure, such as a bulge, a rotating gas disk and either spiral arms or tidal tails. These features had been formed within 1.4 billion years after the Big Bang, long before the peak of cosmic star formation.

Challenged ΛCDM inference J deduced from: G and H.

- Old Systems

"In pursuit of giants I. The evolution of the dust-to-stellar mass ratio in distant dusty galaxies"
D. Donevski, A. Lapi, *et al.*, A&A **644**, A144 (2020)
doi: 10.1051/0004-6361/202038405 and arXiv:2008.09995

Since their initial discovery 20 years ago, very distant and massive galaxies that form a prodigious amount of young stars – so-called 'dusty' (star-forming) galaxies – represent a serious challenge for astronomers... many of these dusty 'giants' have been formed when the Universe was very young, sometimes even less than 1 billion years old, and scientists have been wondering how could such large amount of dust have been produced so early in time. Our estimates showed that supernovae explosions could not be responsible for all of it and a part had to be produced through particle collisions in the gaseous metal-rich environment around massive stars, as previously supposed by theoretical models.

"Interestingly, we also showed that irrespective of their distance, stellar mass or size, compact 'starburst' galaxies always have dust-to-stellar mass ratio higher than the normal galaxies" said Lara Pantoni, Ph.D. student.
... an argument against the evolution of galaxies? (From "Unveiling the double origin of cosmic dust in the distant Universe" https://phys.org/news/2021-01-unveiling-cosmic-distant-universe.html)

Challenged ΛCDM inference J deduced from: G and H.

"A Luminous Quasar at Redshift 7.642"
Feige Wang, Jinyi Yang, *et al.*, ApJL **907** L1 (2021)
doi: 10.3847/2041-8213/abd8c6 and arXiv:2101.03179

We report the discovery of a luminous quasar at $z = 7.642$, the most distant quasar yet known. The existence of such a massive SMBH just ~ 670 million years after the big bang challenges significantly theoretical models of supermassive black holes growth. In addition, the quasar spectrum exhibits strong broad absorption line with a maximum velocity close to 20% of the speed of light. The relativistic broad absorption line features indicate that there is a strong active galactic nucleus-driven outflow in this system.

Challenged ΛCDM inferences G and H.

"A Lyman-α protocluster at redshift 6.9"
W. Hu, J. Wang, L. Infante,, *et al.*, Nature Astronomy **5** 485 (2021)
doi: 10.1038/s41550-020-01291-y and arXiv:2101.10204

We report the discovery of the protocluster LAGER-z7OD1 at a redshift of 6.93, when the Universe was only 770 million years old and could be experiencing rapid evolution of the neutral hydrogen fraction in the intergalactic medium. The protocluster is identified by an overdensity of 6 times the average galaxy density. This is the largest protogroup at this redshift. The total volume of the ionized bubbles generated by its member galaxies is found to be comparable to the volume of the protocluster itself, indicating that we are witnessing the merging of the individual bubbles and that the intergalactic medium within the protocluster is almost fully ionized.

Sky and Telescope: skyandtelescope.org/astronomy-news/astronomers-spot-galaxies-clustering-in-early-universe

Challenged ΛCDM inference J deduced from: G and H.

- Cosmology

"A massive blow for ΛCDM – the high redshift, mass, and collision velocity of the interacting galaxy cluster El Gordo contradicts concordance cosmology"
E. Asencio, I. Banik, P. Kroupa, MNRAS **500(4)** 5249 (2021)
doi: 10.1093/mnras/staa3441 and arXiv:2012.03950

El Gordo (ACT-CL J0102-4915) is an extremely massive galaxy cluster ($M_{200} \approx 3\times10^{15}$ $M_\odot$) at redshift $z = 0.87$ composed of two subclusters with a mass ratio of 3.6 merging at speed 2500 km/s. Such a fast collision between individually rare massive clusters is unexpected in Lambda cold dark matter (ΛCDM) cosmology at such high z. However, this is required for non-cosmological hydrodynamical simulations of the merger to match its observed properties. Here, we determine the probability of finding a similar object in a ΛCDM context. We search for galaxy cluster pairs that have turned around from the cosmic expansion with properties similar to El Gordo in terms of total mass, mass ratio, redshift, and collision velocity relative to virial velocity. We fit the distribution of pair total mass quite accurately, with the fits used in two methods to infer the probability of observing El Gordo in the surveyed region. Detecting one pair with its mass and redshift rules out ΛCDM cosmology at $\mathbf{6.16}\sigma$.

Challenged ΛCDM inference G deduced from: F.

"**Challenges for ΛCDM: An update**"
L. Perivolaropoulos, F. Skara, arXiv:2105.05208 [astro-ph.CO] (2021)
arXiv:2105.05208

A number of challenges of ΛCDM has been emerging during the past few years as the accuracy of cosmological observations improves. We discuss in a unified manner many existing signals in cosmological and astrophysical data that appear to be in some tension ($> 2\sigma$) with the standard model: the well studied 5σ challenge of ΛCDM (the Hubble H_0 crisis), other well known tensions (the growth tension and the lensing amplitude AL anomaly), and a wide range of other less discussed less-standard signals which may also constitute hints towards new physics... *or hints that ΛCDM is seriously flawed...* such as cosmic dipoles (the fine structure constant α, velocity and quasar dipoles), CMB asymmetries, BAO Lyα tension, age of the Universe issues, the Lithium problem, the core-cusp and missing satellite problems, quasars Hubble diagram, oscillating short range gravity signals, etc.

Challenged ΛCDM inferences: all of them.

Number of challenges to ΛCDM inferences (see Nov. 2020 Newsletter):

43×G: "Big Bang Cosmology", 36×H: "GR applied to the universe", 32×F: "Hubble law",
28×J: "Galaxy & structure formation", 22×E: "Galactic recession", 5×I: "CMB from hot state",
from the publications reviewed in Newsletters from May 2020 to November 2021.

This shows how the 'Big Bang' is at the source of most of the tensions between theory and observations.

A Cosmology Group

A Cosmology Group draws its mandate from the *Open Letter to the Scientific Community* to engage scientists in an open exchange of ideas beyond the framework of Standard Cosmology through a critical examination[3] of the methods and investigations of cosmology. The *ACG Newsletter* highlights observational results that are anomalous in terms of the Big Bang paradigm.

The *Newsletter* is published irregularly, editor's schedule permitting, and when interesting papers are available. ACG subscribers[4] receive notifications of *Newsletter* publications and a few additional announcements. You can subscribe to *ACG* by sending a request to `redshift@cosmology.info`.

If you would like to suggest a paper for review, please send a direct reference to `redshift@cosmology.info`. Published work in a refereed journal and with open access (e.g. a preprint on `arXiv` or `HAL`) is preferred.

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[3]When the thesis is supported by empirical evidence.
[4]ACG currently has 71 members.