PRESS RELEASE

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STATISTICS CAST LIGHT ON THE HUBBLE CONSTANT TENSION

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The quest for the true value of the Hubble constant (H_0) tension which gives a measure of the current expansion of the Universe is still on. The fervent debate today is about the discrepancy between the H_0 values obtained from type Ia supernovae (SNe Ia) and from the Cosmic Microwave Background Radiation (CMB), a radiation emitted from the early Universe close to its origin. Because of this debate, an international team led by Dr. Maria Dainotti, assistant professor at the National Astronomical Observatory of Japan (NAOJ) and affiliate research scientist at Space Science Institute, Boulder, CO, opened a new research field of investigation with a series of three papers by investigating if this tension could be alleviated when considering alternative cosmological models (namely when the Universe is not flat as currently assumed, but it is closed for example) with the aid of statistics and supercomputing facilities at NAOJ.

The team included a statistical expert, Prof. Malgorzata Bogdan from Lund University, and theoreticians from the National Autonomous University of Mexico (UNAM), Prof. Nissim Fraija, and University of Nevada Las Vegas, Prof. Bing Zhang. The team was assisted in running the simulations at the supercomputing facilities by Kazunari Iwasaki, Assistant Professor at NAOJ and member of the Center for Computational Astrophysics (CfCA) at NAOJ.

The fate of a flat Universe is that it will only expand at a rate just sufficient to avoid collapse, whereas a closed Universe will expand to a maximum size and after that will then collapse in upon itself. To tackle this issue, the team, in Bargiacchi, Dainotti et al. (2022), investigated different statistical tools from the ones commonly used in the framework of standard cosmological models. They quantified the difference between the theoretical formulation, which includes the shape of the Universe (e.g., flat or closed Universe), of the distance from us to several cosmological objects, such as the SNe Ia, Quasars, Baryon Acoustic Oscillations, and Gamma-Ray Bursts (GRBs) compared with the observed distance obtained by using these objects as distance estimators independently from the shape of the Universe. An illustrative picture is shown in Fig. 1.

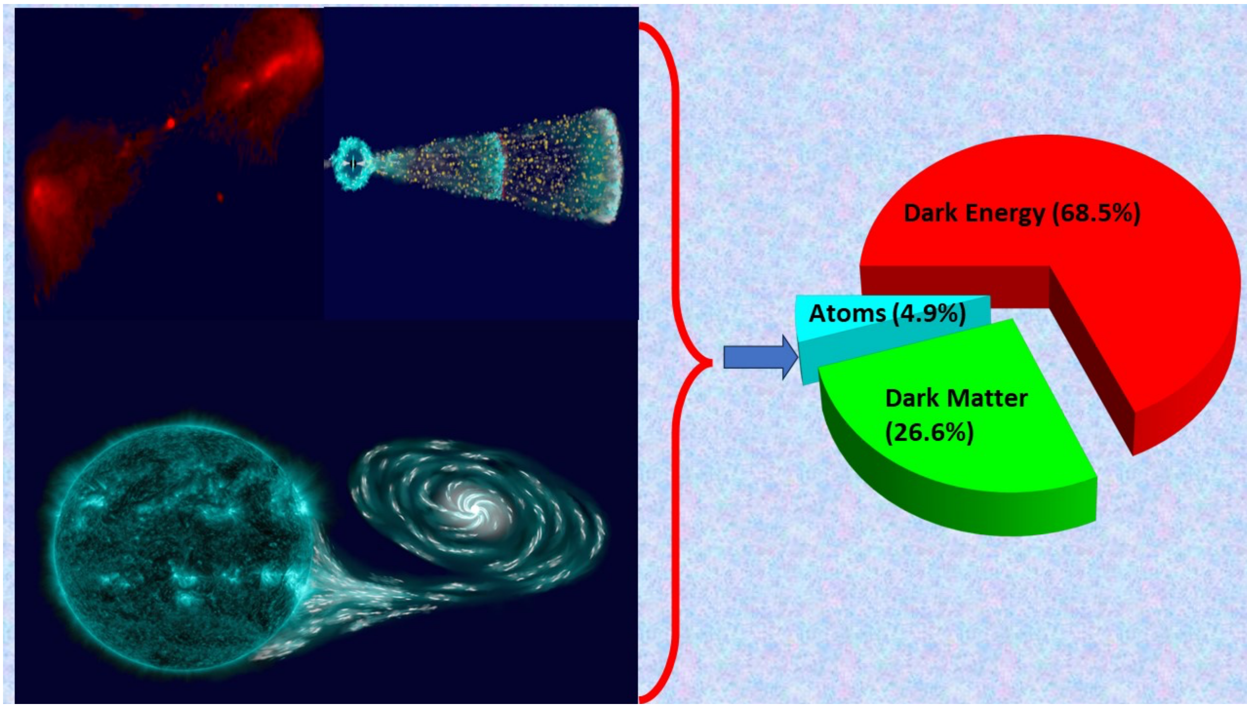

Figure 1: This schematic picture shows that from combined analysis of the explosion of GRBs (upper right), the emission of quasars (upper left), and the explosion of SNe Ia (bottom), astronomers can estimate the amounts of different components of the Universe (pie chart at right). Credit: Aleksander Lenart, Giada Bargiacchi and Maria Giovanna Dainotti.

They pinpointed that this difference is not Gaussian (bell curve shaped) as is commonly assumed, but instead has other statistical shapes. By using these more appropriate statistics, Dainotti et al. (2023a), within the alternative cosmology framework, showed reduced uncertainties of the Hubble constant by 35%. This increased precision leads to values of H_0 which are closer to the values of SNe Ia, but the discrepancy with the early Universe with CMB increases. In addition, although a flat cosmological model is the most suitable one, there is a hint toward a closed Universe.

Computations were carried out at facilities at the Center for Computational Astrophysics (CfCA), National Astronomical Observatory of Japan with the collaboration of the coauthor Iwasaki, Assistant Professor at Division of Science and at the CfCA. One example of the analysis conducted with the aid of the CfCA is shown in Fig. 2.

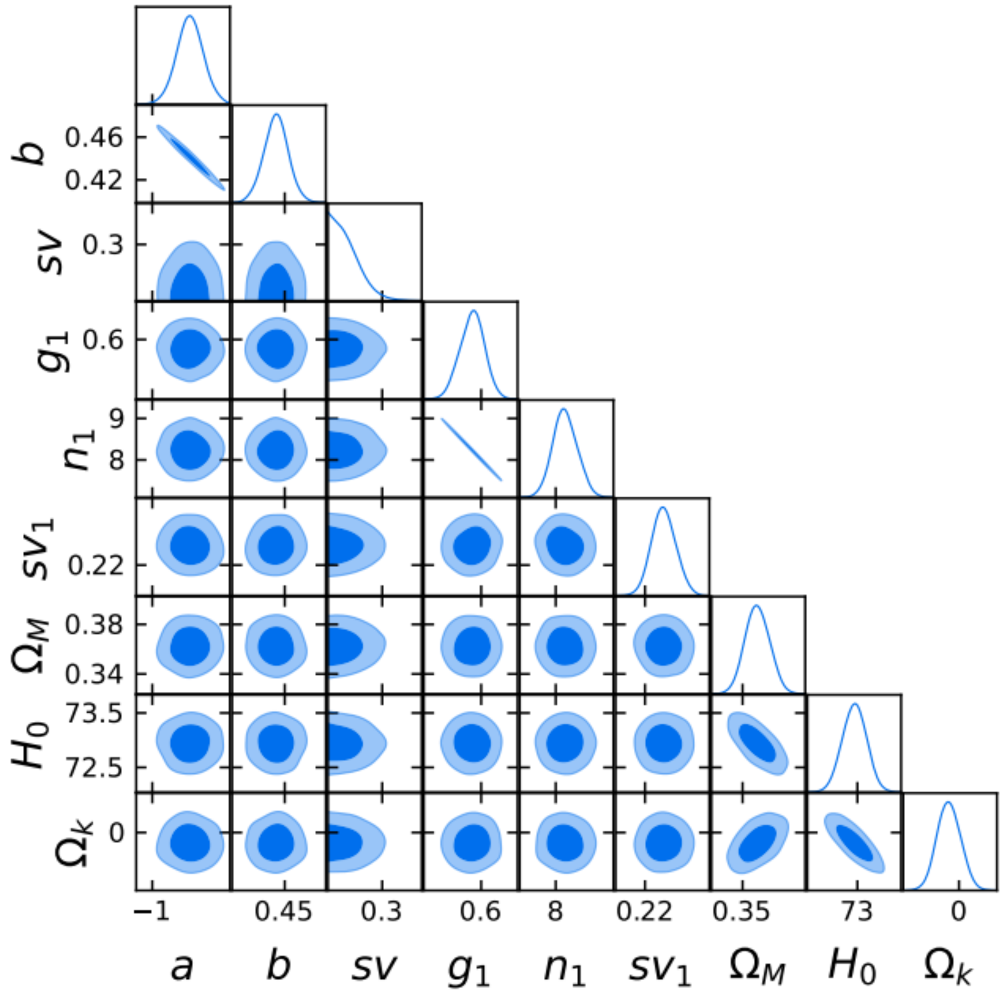

Figure 2: The contour plots for the parameters for GRBs (a, b, sv) and quasars (g1, n1, sv1) together with the values of the Hubble constant, H_0, the dark matter content, ΩM, and the curvature of the universe, Ωk. These computations hint at a closed cosmological model. Credit: Dainotti et al. 2023, ApJ, Volume 951, Issue 1, id.63

Excited by the possibility of further investigating this tension with distant probes, the researchers strived to use quasars to increase the precision of the dark matter density, ΩM. Because quasars are observed at high distances, they are appealing probes for the early phases of the Universe. However, so far, precision on the evaluation of the cosmological parameters (e.g., ΩM) is possible only with SNe Ia. Dainotti et al. (2023b) have developed a method to determine a sample of quasars that constrain ΩM with the same precision as SNe Ia but reaching much higher distances.

To apply quasars in cosmology, they measured their distance through a physical relation between their X-ray and ultraviolet luminosities. This relation is reliable as a cosmological tool because it does not suffer from observational selection effects. However, its intrinsic dispersion was still too large to constrain cosmological parameters within a precision comparable to the one of SNe Ia. To overcome this issue, a statistical technique was applied to select from the original sample only the sources that present a small dispersion from the studied relation. This new sample of quasars constitutes the "Gold sample". Figure 3 shows the number of sources (N), the ΩM derived, and its probability (PDF). The Gold Quasars sample yields a precision on ΩM unprecedentedly reached with only quasars, even greater than the current SNe Ia precision. This analysis also shows a trend toward ΩM =0.1 (see Fig. 3).

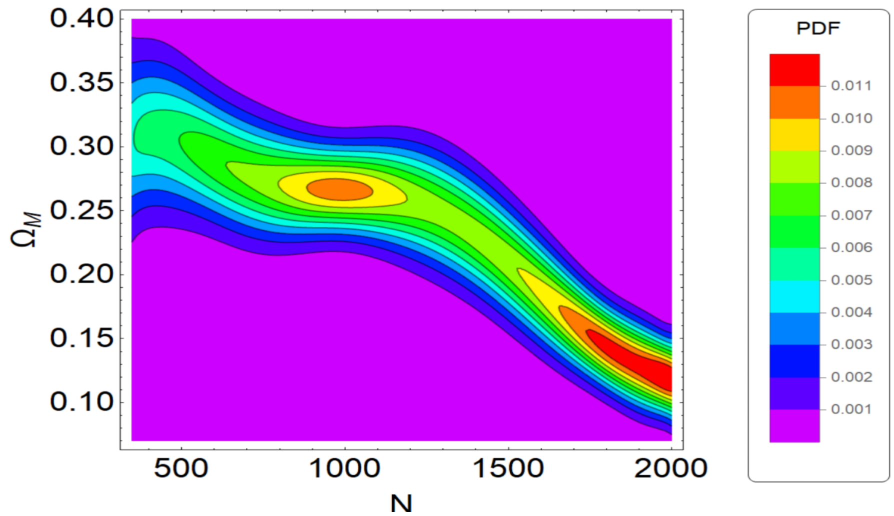

Figure 3: ΩM and its uncertainty vs. the number of quasars (N). The color bar shows the probability density function (PDF), indicating the most probable value of ΩM, thus the smallest uncertainty on ΩM. Credit: Dainotti et al. 2023, ApJ Volume 950, Issue 1, id. 45

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Dainotti et al. 2023a, Reducing the uncertainty on the Hubble constant up to 35\% with an improved statistical analysis: different best-fit likelihoods for Supernovae Ia, Baryon Acoustic Oscillations, Quasars, and Gamma-Ray Bursts - NASA/ADS (harvard.edu).

Dainotti et al. 2023b, Quasars: Standard Candles up to z = 7.5 with the Precision of Supernovae Ia - NASA/ADS (harvard.edu)

Bargiacchi, Dainotti et al. 2022, Gamma-ray bursts, quasars, baryonic acoustic oscillations, and supernovae Ia: new statistical insights and cosmological constraints - NASA/ADS (harvard.edu)

This press release is part of a Coordinated Release from the following organizations: National Astronomical Observatory of Japan, NINS, Space Science Institute, Lund University and National Autonomous University of Mexico (UNAM). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s).

Press release from NAOJ
Japanese: https://www.nao.ac.jp/news/science/2023/20230821-dos.html
English: https://www.nao.ac.jp/en/news/science/2023/20230821-dos.html