Planck Observation of two nearby galaxies: Cen A and M82

F. De Paolis, [1 2] G. Ingrosso, [1 2] A. A. Nucita, [1 2] V. G. Gurzadyan, [3 4] A. L. Kashin, [3 4] H. G. Khachatryan, [3 4] S. Mirzoyan, [3 4] D. Vetrugno, [5] Ph. Jetzer, [6] A. Qadir, [7]

[1]Dipartimento di Matematica e Fisica "E. De Giorgi", Università del Salento, Via per Arnesano, I-73100 Lecce, Italy

[2]Istituto Nazionale di Fisica Nucleare, Sezione di Lecce, Via per Arnesano, I-73100 Lecce, Italy

[3]Yerevan Physics Institute, Yerevan, Armenia

[4]Yerevan State University, Yerevan, Armenia

[5]Dipartimento di Fisica, Università di Trento, Via Sommarive 14, I-38123 Povo (TN), Italy

[6]Institute für Theoretische Physik, Universität Zürich, Winterthurerstrasse 190, 8057 Zürich, Switzerland

[7]Center for Advanced Mathematics and Physics, National University of Science and Technology, Islamabad, Pakistan

Cosmic Microwave Background (CMB) data are mainly used with the primary aim to infer the values of the parameters of the cosmological standard model. In addition, CMB data offer also a unique opportunity to study the large-scale temperature asymmetries far beyond the size typically accessible with other tools toward nearby astronomical systems (see, e.g. [1,2]).

During 2015 we have followed in particular the approach in [2] studying Planck's data toward two nearby galaxies: Centaurus A (Cen A), a radio galaxy that is considered the closest AGN (Active Galactic Nucleus) to us (at a distance of $\simeq 3.8 \pm 0.1$ Mpc) and M82, the largest galaxy in the M81 group in the Ursa Major constellation. To reveal and study the Cen A giant lobes (GLN and GLS towards the northern and southern part of the galaxy, respectively) by Planck's data we have divided the Cen A sky field in two parts and removing the innermost part (about 20 arcmin), which corresponds to the galaxy and the innermost radio lobes. The mean temperature difference T_m in μK between the two LGN and the LGS was then obtained in each Planck band at 70, 100, and 143 GHz, with the corresponding standard error. As one can see (in blue), the GLN region is hotter than the GLS region up to a galactocentric distance of about 5 degrees in all bands (Fig. 1). In brown we also give the temperature excess of 360 control regions equally spaced at one degree distance to each other in Galactic longitude and at the same latitude as Cen A. The excess temperature, most likely, comes from a Doppler-induced effect related to the bulk velocity of the jet powering the Cen A radio lobes

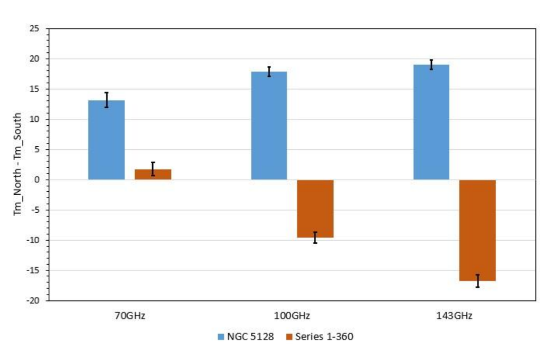

Figure 1. Excess temperature in μK of the northern Cen A lobe with respect to the southern one in the 70, 100 an d143 GHz Planck data. In brown, the temperature excess in 360 control fields is given. The standard errors are also shown.

and/or to their rotation with respect to an axis directed along the east-west direction (see [3] for further details). As far as the M82 galaxy is concerned, the Planck sky field towards M82 has been divided into four quadrants, indicated as A1, A2, A3, and A4, as shown in Fig. 2. It results that the A3+A4 region is systematically hotter than the other in all Planck's bands up to a galactocentric distance of $40 - 50$ arcmin. For example, within 30 arcmin the temperature excess turns out to be 50 ± 10 μK while the 360 control fields give a temperature excess ≤ 12 μK. Thus, the temperature asymmetry is detected with a confidence level of about 3σ. We have also considered the temperature asymmetry with respect to the major axis

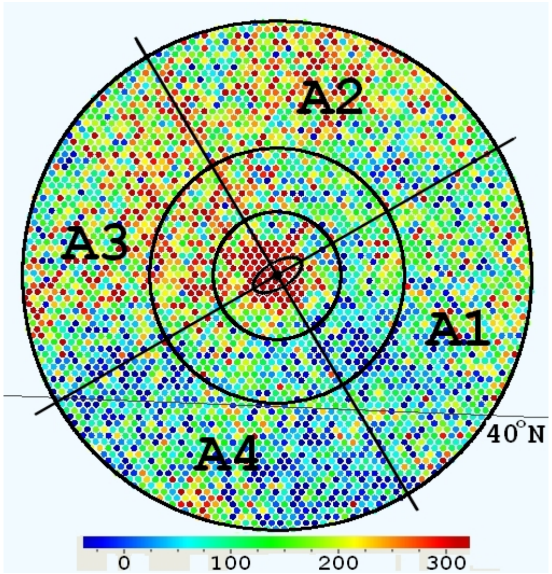

Figure 2. The *Planck* field toward the M82 galaxy in the 70 GHz band. The pixel color gives the temperature excess with respect to the mean CMB temperature in μK. The galactocentric radii of the circles are $15'$, $30'$ and 1^0, respectively. The M82 galaxy is indicated by the inner ellipse with major and minor axes of $10.73'$ and $5.02'$, respectively. The analysis presented in Section 2 is performed within the quadrants indicated as A1, A2, A3, and A4. The line corresponding to Galactic latitude 40^0 North is also shown.

of the M82 galaxy. In this case, the temperature asymmetry of the A2+A3 region with respect to that of the A1+A4 is even larger and remains $\simeq 80$ μK up to 1 degree (about 60 kpc), while the control fields have, in this case, even a negative value of the temperature asymmetry (for further details see [4]). Here we only add that the very fact that the detected temperature asymmetry is almost frequency independent is a clear and strong indication of an effect due to the galaxy halo rotation. We remark that the importance of the methodology proposed, applied to the Cen A and M82 cases, is that, in spite of its simplicity, it may allow to consistently estimate the dynamical mass $M_{\rm dyn}$ (contained within a certain galactocentric distance R) of the considered galaxy once the temperature asymmetry has been quantified. In fact, one has that

$$M_{\rm dyn}(< R) \simeq 700 \left(\frac{\Delta T_{\mu K}}{\tau_{\rm eff} \sin i}\right)^2 R_{\rm kpc} M_{\odot}, \qquad (1)$$

where i is the inclination angle of the galaxy rotation axis with respect to the line of sight and $\tau_{\rm eff}$ is the effective optical depth relevant upon the involved emission mechanisms. This equation directly envisages a lower limit to $M_{\rm dyn}$ (obtained for $\tau_{\rm eff} = 1$) that, in the case of the M82 galaxy, turns out to be ($\Delta T \simeq 80$ μK and $R \simeq 60$ kpc) $M_{\rm dyn} \geq 2.8 \times 10^8$ $M_{\odot}$. This is consistent with the observations and can be further improved by considering the details regarding the emission mechanisms involved (that is estimating $\tau_{\rm eff}$). The contribution to the revealed temperature asymmetries can come from different mechanisms on the different scales, from the matter outflow from the galactic center, to the halo rotation, to the stripped matter due to the interaction with the M81 system, and so on. In general, our method, applied to nearby edge-on spirals, reveals the galactic halo bulk dynamics on a rather large scale in a model-independent way. In this sense it resembles the SZ effect, which on galactic scales cannot work since the e^- temperature is not high enough to produce a substantial effect. The importance of the halo's traced parameters (scale, rotation) by this method is also obvious for dark matter and cosmological reasons, especially if complemented by other dynamical and bulk motion information [5]. Used in synergy with other data, this may provide unique keys to study the bulk dynamics, the outflow ejection processes, and thus the evolution of galactic systems.

REFERENCES

1. F. De Paolis *et al.*, Astronomy and Astrophysics Lett. 534 (2011) id.L8.
2. F. De Paolis *et al.*, Astronomy and Astrophysics Lett. 565 (2014) id.L3.
3. F. De Paolis *et al.*, Astronomy and Astrophysics Lett. 580 (2015) id.L8.
4. V. Gurzadyan *et al.*, Astronomy and Astrophysics 582 (2015) id.A77.
5. S. Rauzy and V.G. Gurzadyan, Monthly Notices of the Royal Astronomical Society 298 (1998) 114.