PROCEEDINGS OF SCIENCE

Dust collisional heating and small grain destruction in NGC 4438

PoS(LCDU 2013)071

M. Bocchio*, **A. P. Jones, A. Abergel**
Institut d'Astrophysique Spatiale (IAS), UMR 8617, CNRS / Université Paris-Sud, 91405 Orsay, France
E-mail: marco.bocchio@ias.u-psud.fr

and HeViCS collaboration

We present a preliminary analysis of the *Herschel* PACS and SPIRE data around the galaxy NGC 4438. Combining the *Spitzer* and *Herschel* data we obtain the full dust spectral energy distribution and explore the heating source and dust survival time in the hot intergalactic medium close to the boundaries of the galaxy. We model the evolution of the dust size distribution and its emission due to collisions with gas ions and electrons and find that the predicted dust spectral energy distribution is consistent with the observations. We therefore conclude that dust in the hot X-ray emitting gas close to NGC 4438 ($T \sim 5 \times 10^6$ K, $n_{\rm H} = 0.02\,{\rm cm}^{-3}$) undergoes both heating and destruction by hot electrons. This highlights the interaction between the cool interstellar medium and the hot intergalactic medium that gives rise to an enhancement of the X-ray luminosity of the galaxy. However, the predicted dust lifetime is shorter than the dynamical timescale and so the hot gas seemingly entrain evaporating dense clumps of the interstellar medium stripped from the galaxy.

The Life Cycle of Dust in the Universe: Observations, Theory, and Laboratory Experiments - LCDU 2013, 18-22 November 2013
Taipei, Taiwan

*Speaker.

1. Introduction

The region around the galaxies NGC 4438 and M86 has a particular astrophysical interest. The Hα + [NII] image (see Fig. 1) shows hot gas filaments linking the two galaxies, providing the evidence for an interaction between them $\sim$ 100 Myr ago [1]. This interaction is responsible for the perturbation of the stellar disk in NGC 4438.

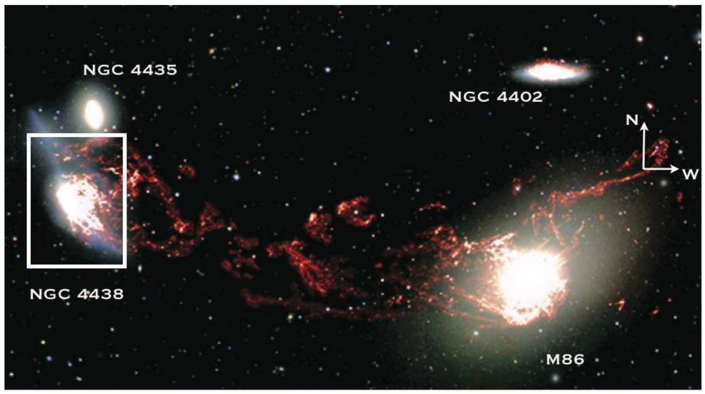


Figure 1: Kenney et al. (2008). Hα + NII (colored red) superimposed on a color SDSS gri image of the region around M86.

From a Chandra survey of nearby galaxies it has been shown that NGC 4438 is an unusual X-ray bright galaxy. It has been proposed that this X-ray emission results from the interaction of the cool interstellar medium (ISM) of the galaxy with the hot intergalactic medium (IGM) [2].

The region around NGC 4438 was observed by *Herschel* SPIRE and PACS as part of the *Herschel* Virgo Cluster Survey (HeViCS, [3]). The Herschel SPIRE data reveal the presence of extra-planar dust up to 4-5 kpc from the galactic disk [4].

Using *Herschel* PACS/SPIRE data we have the unique possibility to achieve the sensitivity and the spatial resolution to measure the temperature of dust embedded in a hot gas. Furthermore, combining *Herschel* data and *Spitzer* data, we are able to derive the full dust spectral energy distribution (SED), which allows us for the first time to quantify the effects of dust heating and erosion in a hot gas.

2. *Herschel* data analysis

The region around NGC 4438 was observed by *Herschel* in parallel mode (i.e. using both SPIRE and PACS instruments) as part of the *Herschel* Virgo Cluster Survey (HeViCS, [3]). The data were reduced as part of the *Herschel* Reference Survey (HRS), the PACS data were reduced following the procedure described by Cortese et al. [5] while the SPIRE data as described by Ciesla et al. [6].

In our analysis we use the PACS 100 μm, 160 μm and SPIRE 250 μm and 350 μm maps. We convolve all the maps to a common resolution (the beam size of the 350 μm SPIRE data, 24.9$''$ / beam) assuming gaussian beams and regrid the images to a common pixel size (the pixel size of the 250 μm SPIRE data, 36 arcsec^2 / pixel).

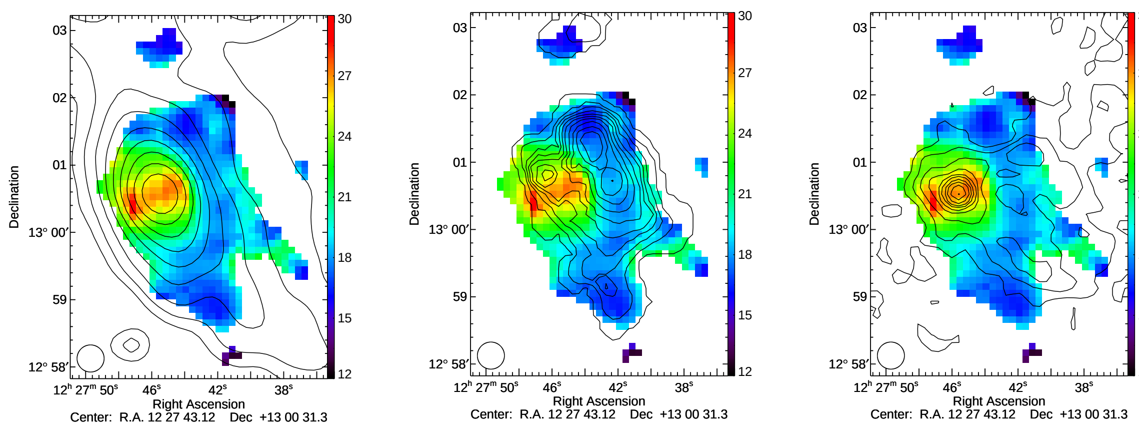
Using a χ^2 minimization technique, we fit the SED on a pixel-by-pixel basis with a modified blackbody:

$$I_\nu = \tau_{\nu_0} B_\nu(T)(\nu/\nu_0)^\beta \,, \tag{2.1}$$

where τ_{ν_0} is the optical depth at the reference frequency $\nu_0 = 3000\,\mathrm{GHz}$ ($100\,\mu$m, τ_{100} hereafter), $B_\nu(T)$ is the Planck blackbody emission for a given temperature T and β is the emissivity spectral index at the frequency ν_0. The value of β is kept fixed ($\beta = 1.8$) as estimated by Planck Collaboration [7].

3. Results

We estimate the radiation field around NGC 4438 from *GALEX*, SDSS and 2MASS data and we calculate its scaling factor with respect to the Mathis et al. [8] radiation field (the U value described by Draine & Li [9]) for each of the pixels (see Fig. 2a). We notice that the temperature



(a) Radiation field (U factor) contours on the temperature map.

(b) HI contours [10] on the temperature map.

(c) X-ray contours [11] on the temperature map.

Figure 2

map is asymmetric with respect to the galaxy centre and that it is not correlated with the radiation field. For a given radiation field, on the east and west side of the galaxy we observe a different dust temperature (i.e. $T \sim 23\,$K east side and $T \sim 15-18\,$K west side). Furthermore, in the east side region where we find the unusually hot dust we do not detect any HI emission (Fig. 2b) but we notice bright X-ray emission (Fig. 2c). This suggests that the dust is embedded in a hot gas.

From theoretical models [12, 13, 14] we would expect that grains embedded in a hot gas undergo collisions with the fast ions and electrons therefore leading to both erosion and collisional heating. We model the time-dependent dust spectral energy distribution that we would observe in the hot gas on the east side of the galaxy ($T \sim 5\times10^6\,$K, $n_\mathrm{H} = 0.02\,\mathrm{cm}^{-3}$, [11]). In Fig. 3 we show the dust SED on the east and west side of the galaxy. We define the time spent in the hot gas as t_hot. We notice that, on the east side, we obtain the best fit to the observational data for $t_\mathrm{hot} = 10^5$ yr. On the other hand, on the west side we are able to reproduce the dust SED assuming the only photon heating.

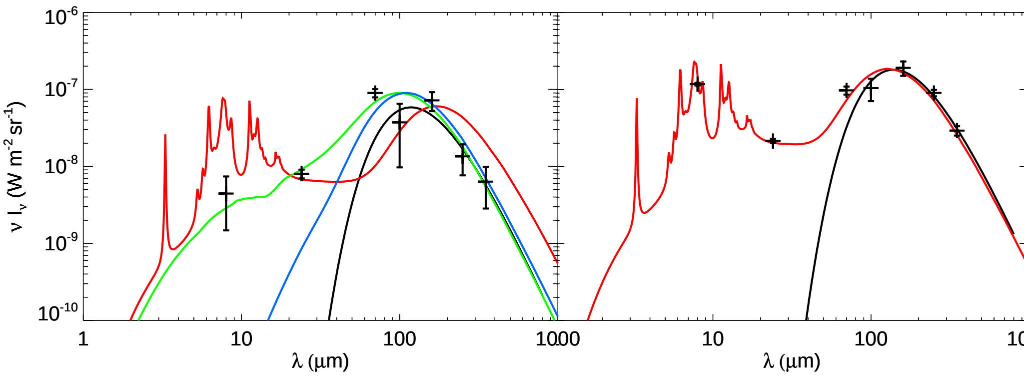


Figure 3: Dust SED of a representative pixel on the east (left panel) and west (right panel) side of the galaxy. Data points represent the *Spitzer* and *Herschel* data. Red, green and blues lines are for $t_{\rm hot} = 0, 10^5, 10^6$ yr respectively. Black lines are the blackbody fit to the *Herschel* data.

4. Conclusions

From this preliminary study we can conclude that the dust on the east side of the galaxy is embedded in a hot gas. The collisions of the grains with the fast ions and electrons are responsible for the dust elevated temperature and the destruction of the smallest grains [13].

This highlights an interaction between the hot IGM and the cool ISM confirming the hypothesis by Li & Wang [2] and explaining the bright X-ray emission of this galaxy.

References

[1] Kenney, J. D. P. et al., 2008, *A spectacular Hα complex in Virgo*, ApJ, 687, L69

[2] Li & Wang, 2013, *Chandra survey of nearby highly inclined disc galaxies - I*, MNRAS, 428, 2085

[3] Davies, J. I. et al., 2010, *The Herschel Virgo Cluster Survey. I*, A&A, 518, L48

[4] Cortese, L. et al., 2010, *Herschel-SPIRE observations of the disturbed galaxy NGC 4438*, A&A, 518, L63

[5] Cortese, L. et al., 2014, *PACS photometry of the Herschel Reference Survey*, A&A, subm.

[6] Ciesla, L. et al., 2012, *Submillimetre photometry of 323 nearby galaxies from the Herschel Reference Survey*, A&A, 543,A161

[7] Planck Collaboration, 2011, *Planck early results. XXIV*, A&A, 536, A24

[8] Mathis, J. S. et al., 1983, *Interstellar radiation field and dust temperatures in the diffuse interstellar matter and in giant molecular clouds*, A&A, 128, 212

[9] Draine, B. T. & Li, A., 2007, *Infrared emission from interstellar dust. IV*, ApJ, 657, 810

[10] Hota, A. et al., 2007, *NGC 4438 and its environment at radio wavelengths*, MNRAS, 380, 1009

[11] Machacek, M. E. et al., 2004, *Chandra observations of NGC 4438*, ApJ, 610, 183

[12] Micelotta, E. R. et al. 2010, *Polycyclic aromatic hydrocarbon processing in a hot gas*, A&A, 510, A37

[13] Bocchio, M. et al., 2012, *Small hydrocarbon particle erosion in a hot gas*, A&A, 545, A124

[14] Bocchio, M. et al., 2013, *Dust heating*, A&A, 556, A6