Search for high energy γ-ray emission from galaxies of the Local Group with Fermi/LAT

J.-P. Lenain & R. Walter

ISDC Data Centre for Astrophysics, Observatoire de Genève, Université de Genève, Chemin d'Ecogia 16, CH-1290 Versoix, Switzerland

Send requests to: jean-philippe.lenain@unige.ch

Abstract

Normal galaxies begin to arise from the shadows at high energies, as can be seen with the discovery of high energy γ-ray emission from the Andromeda galaxy (M 31) by the *Fermi*/LAT collaboration.

We present a study on the search for high energy emission around galaxies of the Local Group. Several false alarms, significant detections are found, which could be associated to quasars in the regions of interest. Upper limits on the high energy emission of nearby normal galaxies are derived, and we discuss them in the context of γ-ray emission from cosmic ray interactions with the local interstellar medium in these galaxies.

The sample

We search for **high energy γ-ray emission** from all the **major galaxies** pertaining to the **Local Group** (e.g. Karachentsev 2005), which are not detected so far: M 81, M 83, IC 342, Maffei 1, Maffei 2, M 94. Other galaxies from the Local Group for which high energy emission has been reported are: the SMC (Abdo et al. 2010a), the LMC (Abdo et al. 2010b), M 31 (the Andromeda galaxy Abdo et al. 2010c), M 82 (Abdo et al. 2010d), Cen A (Abdo et al. 2010e,f), and NGC 253 (Abdo et al. 2010d).

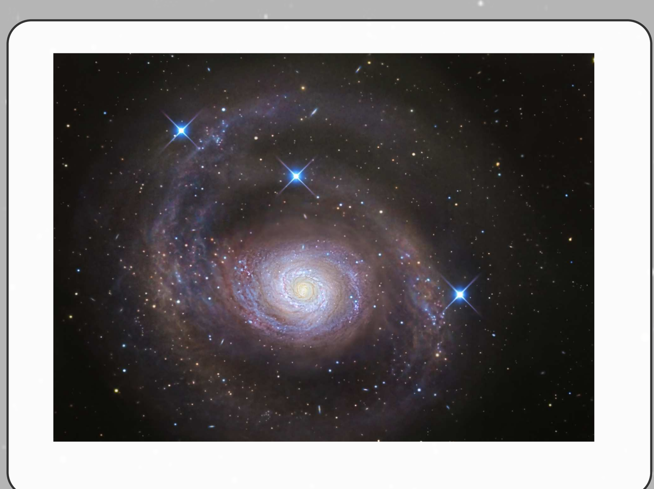

Figure 1: Optical image of M 94, distant by 4.7 Mpc.

Credits: R. Jay GaBany (Blackbird Obs.). Collaboration: I. Trujillo, I. Martinez-Valpuesta, D. Martinez-Delgado (IAC); J. Penarrubia (IoA Cambridge); M. Pohlen (Cardiff).

Seyfert 2 galaxies as NGC 1068 and NGC 4945, encompassing starburst regions in their centre, also begin to reveal themselves as being high energy γ-ray emitters (Lenain et al. 2010).

Results

Source	L_γ (10^{43} ph s^{-1})	R_{SN} (yr^{-1})	M_{gas} ($10^9 M_\odot$)
M 81	< 1.5	0.008 ± 0.002	5.2 ± 1.7
M 83	< 1.4	0.05 ± 0.03	5.5 ± 1.1
IC 342	< 11.5	0.18 ± 0.10	4.0 ± 0.8
Maffei 1	< 3.0	?	?
Maffei 2	< 1.7	?	?
M 94	< 3.3	0.04 ± 0.02	0.6 ± 0.1

The emission of the core of Cen A being dominated by the central active galactic nucleus, we exclude this source from our sample. The galaxies from the Maffei group lie at low Galactic latitudes, and therefore their supernova rate and gas mass are hardly derived from observations.

In the case of M 83, a positive signal (TS>25) was found in the vicinity of the source of interest, but turned out to be more compatible with a blazar in the region of interest: 2E 3100 (z = 0.513), which lies 0.33° away from M 83 (see Fig. 2).

For the search of γ-ray emission from M 81, the strong starburst emitter M 82 (Abdo et al. 2010d) is 0.62° away from M 81, only allowing loose upper limits to be derived on the emission of the latter.

Fermi/LAT data analysis

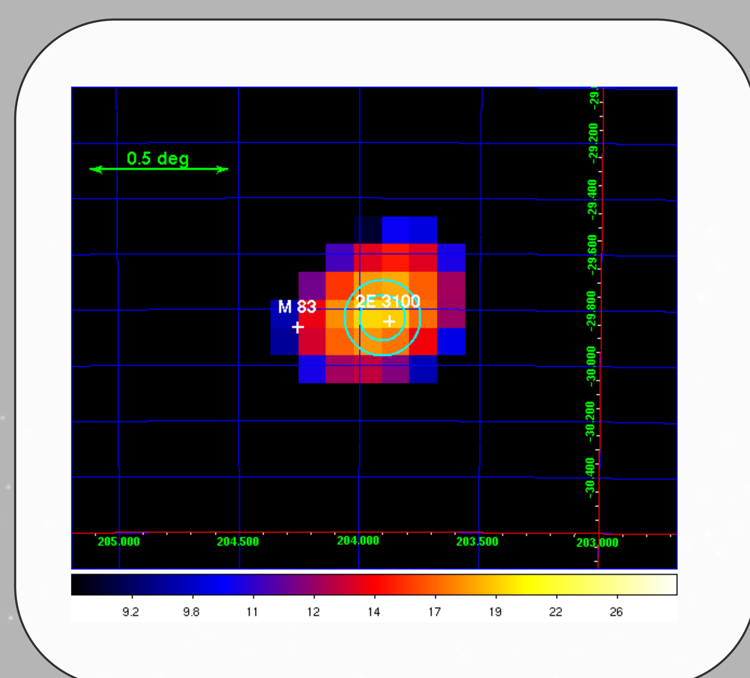

Figure 2: TS map of the region of interest around M 83, between 200 MeV and 200 GeV. The nominal positions of M 83 and the blazar 2E 3100 are shown in white. The best fit position on the *Fermi*/LAT excess is shown in cyan for 68% and 95% CL, and is clearly compatible with 2E 3100, not with M 83.

The *Fermi*/LAT data analysis on the different sources in the sample were performed using the publicly available data, from August 4, 2008 to January 1, 2010. We used the **unbinned likelihood** method (Atwood et al. 2009) from the *Science Tools* (`v9r18p6`) analysis software provided by the *Fermi* collaboration. The data analysis was performed using diffuse class events, with the `P6_V3` instrument response, in the **200 MeV–200 GeV** energy range, and using regions of interest of 10° of radius around the nominal position of the galaxies in the sample.

In the modelled reconstruction of the sources, all the objects included in the first year *Fermi*/LAT catalogue (1FGL Abdo et al. 2010g) were included. Other sources, with Test Statistics (TS, Mattox et al. 1996) above 25 (roughly equivalent to a 5σ detection) and not reported in the 1FGL catalogue, were also included in the source models. For each of such source added to the model, we first ran a likelihood test, using `gtlike`, to assess whether the new introduced source was significant. In case the TS was above 25, the position on this source was then optimised using the tool `gtfindsrc`, before refining the spectral parameters on the best position using `gtlike`.

On the origin of GeV emission

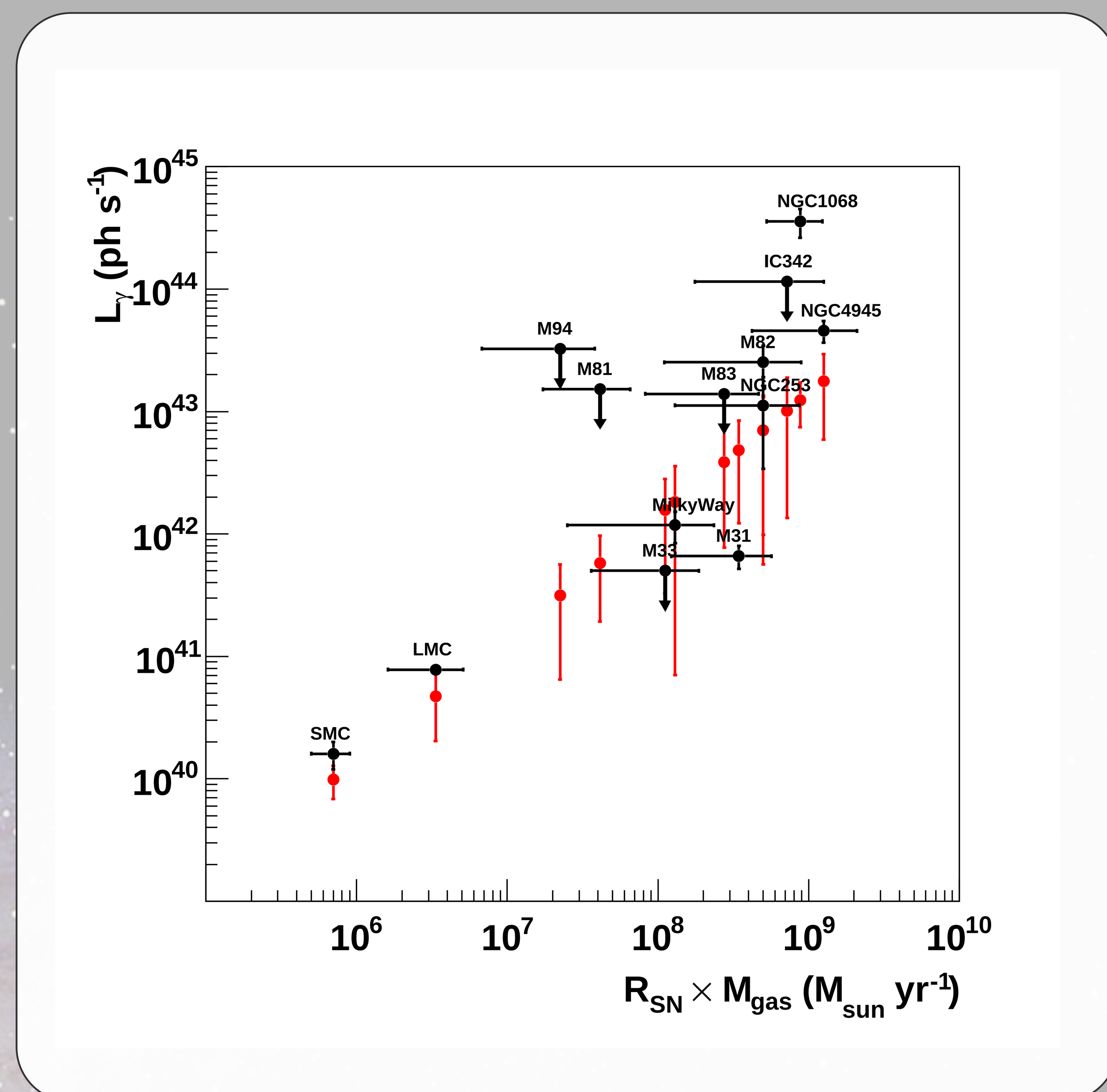

Figure 3: γ-ray luminosity for galaxies detected with *Fermi*/LAT, or 2σ upper limits for undetected objects, against the product of supernova rate time the total gas mass in the host galaxy (black points). Expectations from the model of Pavlidou & Fields (2001) are shown in red points.

Cosmic rays are expelled in the interstellar medium by **supernovæ** within the host galaxy. Propagating through the interstellar medium, they **interact with the gas** through *p*-*p* interactions, resulting in high energy γ-ray emission. Following e.g. Pavlidou & Fields (2001), the high energy γ-ray luminosity is then expected to follow:

$$L_\gamma \propto R_{SN} \times M_{gas}$$

where R_{SN} is the supernova rate in the host galaxy, and M_{gas} the total gas in the interstellar medium (see Fig. 3, and also Abdo et al. 2010c; Persic & Rephaeli 2011).

More data from *Fermi*/LAT are required to possibly discover high energy emission from more starburst and "normal" galaxies, and assess whether such a relation holds, thus helping in constraining the content in cosmic rays of these extragalactic sources.

Acknowledgements & References

This research has made use of NASA's Astrophysics Data System (ADS), of the SIMBAD database, operated at CDS, Strasbourg, France, and of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Abdo, A. A., et al. (*Fermi*/LAT collaboration) 2010a, *A&A*, 523, A46
Abdo, A. A., et al. (*Fermi*/LAT collaboration) 2010b, *A&A*, 512, A7
Abdo, A. A., et al. (*Fermi*/LAT collaboration) 2010c, *A&A*, 523, L2
Abdo, A. A., et al. (*Fermi*/LAT collaboration) 2010d, *ApJ*, 709, L152
Abdo, A. A., et al. (*Fermi*/LAT collaboration) 2010e, *Science*, 328, 725
Abdo, A. A., et al. (*Fermi*/LAT collaboration) 2010f, *ApJ*, 719, 1433
Abdo, A. A., et al. (*Fermi*/LAT collaboration) 2010g, *ApJS*, 188, 405
Atwood, W. B., et al. (*Fermi*/LAT collaboration) 2009, *ApJ*, 697, 1071
Karachentsev, I. D. 2005, *AJ*, 129, 178
Lenain, J.-P., Ricci, C., Türler, M., Dorner, D., & Walter, R. 2010, *A&A*, 524, A72
Mattox, J. R., Bertsch, D. L., Chiang, J., et al. 1996, *ApJ*, 461, 396
Pavlidou, V. & Fields, B. D. 2001, *ApJ*, 558, 63
Persic, M. & Rephaeli, Y. 2011, arXiv:1101.4404

The 2011 Fermi Symposium
Rome, Italy, 9–12 May 2011