A5 2 Survivability of Andromeda Evolving into a Blazar

D. Booth, A. Friesner and C. Howitt

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

We consider the case that Andromeda evolves into a blazar, an active galaxy with a powerful jet pointing in the direction of the observer. We find that this scenario would pose little threat to life as we know it at the current distance of Andromeda when using lower bounds to calculate the received flux (5.71×10^{-5} erg s^{-1} cm^{-2}) and fluence (14.8 erg cm^{-2}) of the jet. In the case of upper bounds, there is also little threat unless a flare were to last approximately ten days.

Introduction

Current theory dictates that periods of activity are typical in all galaxies, usually due to galactic mergers or the capture and subsequent accretion of cold gas by a central supermassive black hole (SMBH). Most active galaxies that we see today are at high cosmological redshifts, meaning that they are not only very distant but also occurring a long time ago since these redshifts indicate events far in the past [1].

This result is unsurprising as redshifts and luminosities of active galactic nuclei (AGNs) are strongly related because the early universe was more fuel rich and dense, leading to more common and intense galactic mergers, while the more recent universe is fuel poor due to the expenditure of most cold gas into star formation. Younger AGNs are less common and much less luminous than their older counterparts, lacking the strong emission lines we see in the high redshift, high luminosity population.

Since we are considering the present/near future, we assume that the Andromeda Galaxy will become a BL Lacertae object (BL Lac), characterised by a lower luminosity due to lesser accretion rates compared to more energetic, historic blazars. This should help to improve the probability of survival compared to a more energetic blazar such as a flat-spectrum radio quasar (FSRQ).

Theory

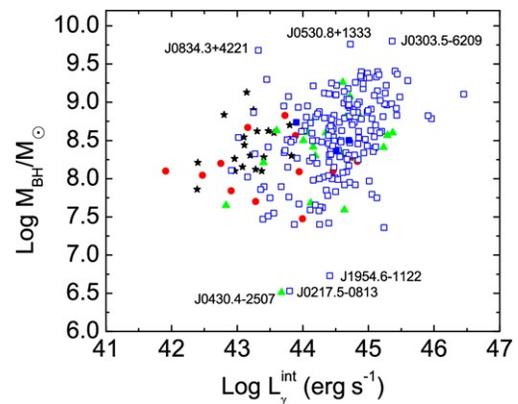We first need to consider a value for the intrinsic unbeamed γ-ray luminosity of the source.

Figure 1: Range of intrinsic unbeamed γ-ray luminosities for a population of blazars [2].

As can be seen in Figure 1 (green filled trian-

gles, red filled circles and black stars represent 3 subclasses of BL Lac), these typically range from $10^{42} \leq L_{\text{int}} \leq 10^{45.5}$ erg s^{-1}, so we take the lower end of this and assume an intrinsic unbeamed γ-ray luminosity of 10^{42} erg s^{-1}.

We can calculate the amplified observed luminosity, L_{obs}, through the following equation:

$$L_{\text{obs}} = L_{\text{int}} \delta^{m+n} \,, \tag{1}$$

where L_{int} is the intrinsic unbeamed γ-ray luminosity; δ is the Doppler Boosting Factor with an average value of 7.97 for BL Lacs [3]; $m = 2$ for continuous jets and $m = 3$ for discrete jets and $n = \alpha_\gamma$ for emissions due to synchrotron self-Comptonisation (SSC)[1] processes or $n = 2\alpha_\gamma + 1$ for external Comptonisation (EC)[2] processes, where α_γ is the spectral energy index and $\alpha_\gamma > 0.5$ for blazars, with BL Lacs at the lower end [4].

To simplify the model, we assume a discrete jet with emissions due to SSC processes and a spectral energy index of $\alpha_\gamma = 1$, returning $m + n \approx 4$. This yields a value of $L_{\text{obs}} = 4.03 \times 10^{45}$ erg s^{-1}.

We can use this value of L_{obs} to calculate the received flux in erg s^{-1} cm^{-2}:

$$F_{\text{obs}} = \frac{L_{\text{obs}}}{4\pi D^2} \,, \tag{2}$$

where F_{obs} is the observed flux received at earth and D is the distance between Earth and Andromeda, $\sim 2.37 \times 10^{24}$ cm [5]. This returns $F_{\text{obs}} = 5.71 \times 10^{-5}$ erg s^{-1} cm^{-2}.

This flux is time dependent and we therefore need to consider the duration of the γ-ray flare that powers the jet, so we assume a duration of 3 days in order to maximise damage without considering a case that is too unrealistic.

This quantity is known as the fluence and is calculated as follows:

$$S_\gamma = F_{\text{obs}} \Delta t \,, \tag{3}$$

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[1] "where ultrarelativistic particles in the jet upscatter the low energy synchrotron photons via inverse Compton processes" [4].

[2] "The low energy photons from external sources are upscattered by ultrarelativistic particles present in the jet and produce γ-ray photons."[4].

where S_γ is the γ-ray fluence and Δt is the duration of the flare. Using the previously assigned values, we find $S_\gamma = 14.8$ erg cm^{-2}.

Discussion

It is estimated that the γ-ray fluence required for an extinction event is 100 kJ m^{-2} [6], or in our units, 10^8 erg cm^{-2}. This means that a low energy blazar as close as Andromeda would not pose a serious threat to life on Earth. The required flare duration for extinction (obtained by rearranging Equation 3 for Δt) would be approximately 55,500 years which is highly improbable. If we instead find the minimum observed lethal flux and then rearrange Equation 2 for each variable, we obtain $F_{\text{obs,min}} = 386$ erg s^{-1} cm^{-2} and therefore a requirement that either $D_{\text{max}} = 9.11 \times 10^{20}$ cm (962 ly) or $L_{\text{obs,min}} = 2.72 \times 10^{52}$ erg s^{-1}. Given that this distance is within the Milky Way (diameter $\sim 10^5$ ly [7]), this is highly unlikely and the required observed luminosity is also far higher than can be expected. If we feed the upper limits from the references ($L_{\text{int}} = 10^{45.5}$ erg s^{-1}, $\delta \approx 40$) into Equations 1, 2 and 3, we find $S_\gamma = 0.297 \times 10^8$ erg cm^{-2} which remains insufficient for extinction unless we increase the flare duration to approximately 10 days. Not impossible but still very unlikely unless Andromeda emitted very-high-energy (VHE) γ-rays [8, 9].

Conclusion

We conclude that there would be no significant threat to life on Earth if the Andromeda Galaxy suddenly evolved into a BL Lac. We also showed that even in the unlikely case of upper limits to key values there would not be an extinction level event. Instead, a gamma-ray burst (GRB) within the Milky Way from an event such as a supernova is far more likely to be problematic for mankind and this has been shown previously in the Journal of Physics Special Topics [10]. A possible extension of this work could be to investigate the case of Andromeda becoming an FSRQ which would be more likely to pose a threat.

References

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