# Gamma Rays from Star Formation in Galaxy Clusters

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## Gamma Rays in Galaxy Clusters

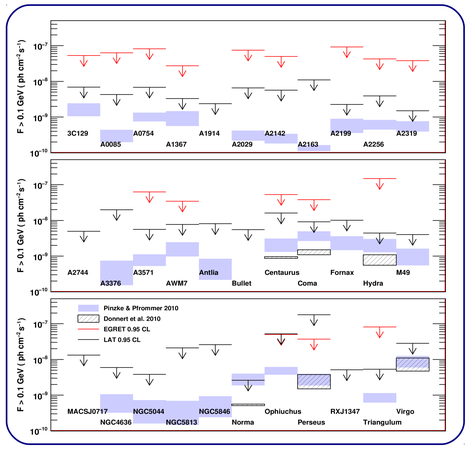
Gamma-ray emission from clusters has not yet been detected.

However, gamma rays are expected from:

*Dark Matter*

*Cosmic Rays*

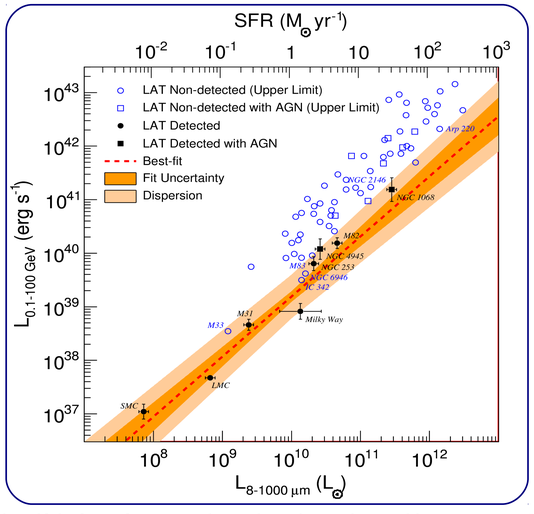
*Cluster Member Galaxies*




*Upper limits* on gamma-ray emission from *Fermi*-LAT [1].

## Gamma Ray – Star Formation Connection

Star Formation → Supernovae → Supernova Remnants as particle accelerators → cosmic rays → gamma rays (via pion decay from hadronic collisions and inverse Compton scattering of electrons)



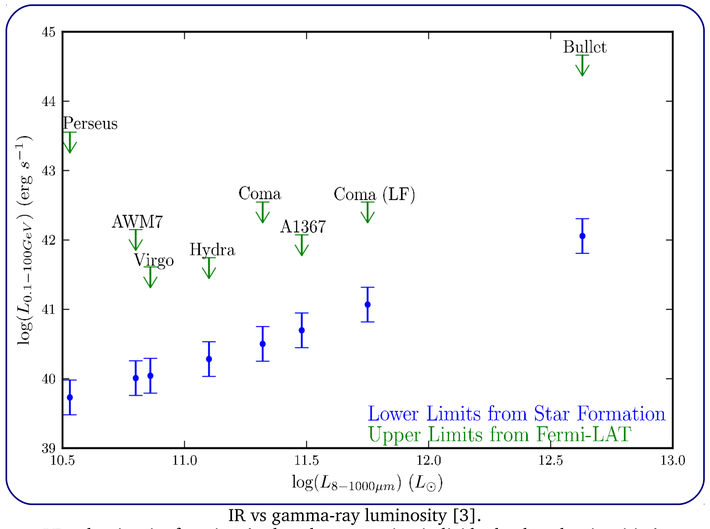

A handful of star-forming galaxies have been observed by Fermi-LAT [2].

Infrared Luminosity (UV radiation from stars processed by dust into IR) and Radio Luminosity (synchrotron radiation from electrons accelerated by supernova remnants) are proxies for Star Formation Rate (SFR).

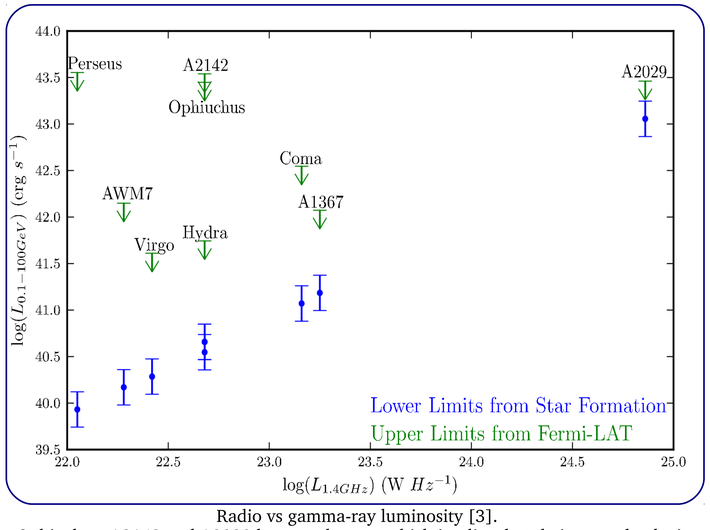
## Lower Limits on Gamma-ray Emission in Galaxy Clusters

We predict gamma-ray luminosities associated with star formation in clusters by searching the literature for IR and radio luminosities (which are proxies for SFR) of cluster member galaxies and applying the relationship between SFR and gamma-ray luminosity.

The sum of the gamma-ray luminosities of the galaxies within a cluster is a *lower limit* on the gamma ray emission from that cluster!




IR vs gamma-ray luminosity [3].
LF = luminosity function (rather than summing individual galaxy luminosities).




Radio vs gamma-ray luminosity [3].
Ophiuchus, A2142 and A2029 have cool cores, which implies that their central galaxies may have elevated SFRs. For these clusters only the luminosity of the central, brightest cluster galaxy is considered. Warning: A2029 may host an AGN.

## Conclusions

Gamma rays have not yet been detected from galaxy clusters. However, gamma-ray emission is expected from clusters.

The lower limit on this emission is gamma rays associated with star formation in cluster member galaxies, unresolved by *Fermi*-LAT.

We predict lower limits on the gamma ray emission for nearby clusters and find:

- Star formation accounts for at least 10% of the total gamma-ray emission from some clusters
- Emission from star formation in clusters is only a factor of a few below the current sensitivity of *Fermi*
- Over its lifetime (~10 years), *Fermi* may be able to detect this emission
- Next-generation ground-based VHE gamma-ray instruments (e.g., CTA) may also be able to detect this emission (assuming no spectral breaks)

## References

[1] Ackermann, M., et al. 2010, ApJ, 717, L71.

[2] Ackermann, M., et. al. 2012, ApJ, 755, 164.

[3] Storm, E., Jeltema, T. E., Profumo, S., 2012, ApJ, 755, 117.

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