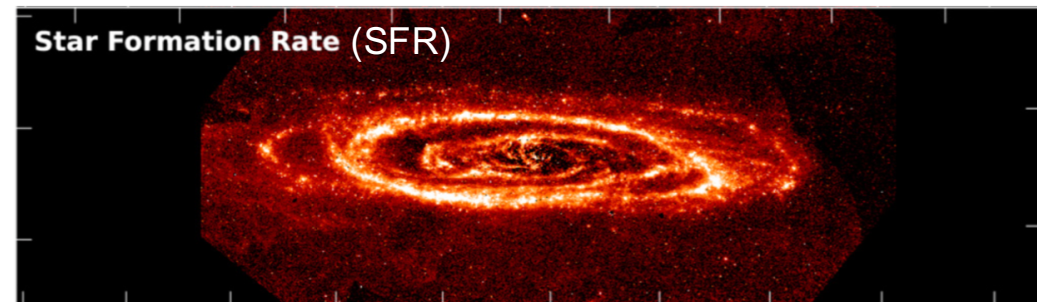
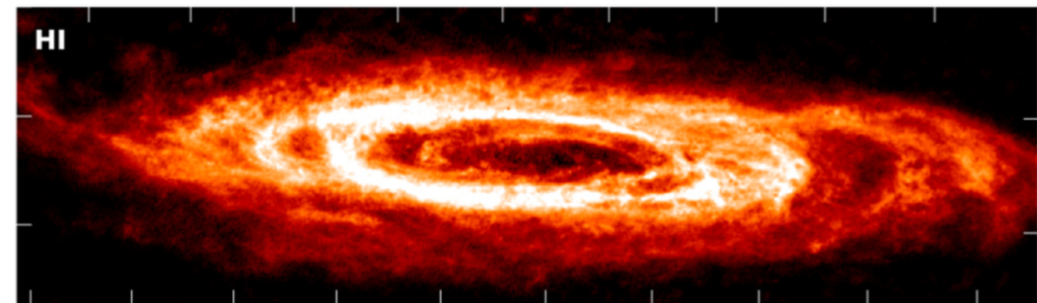
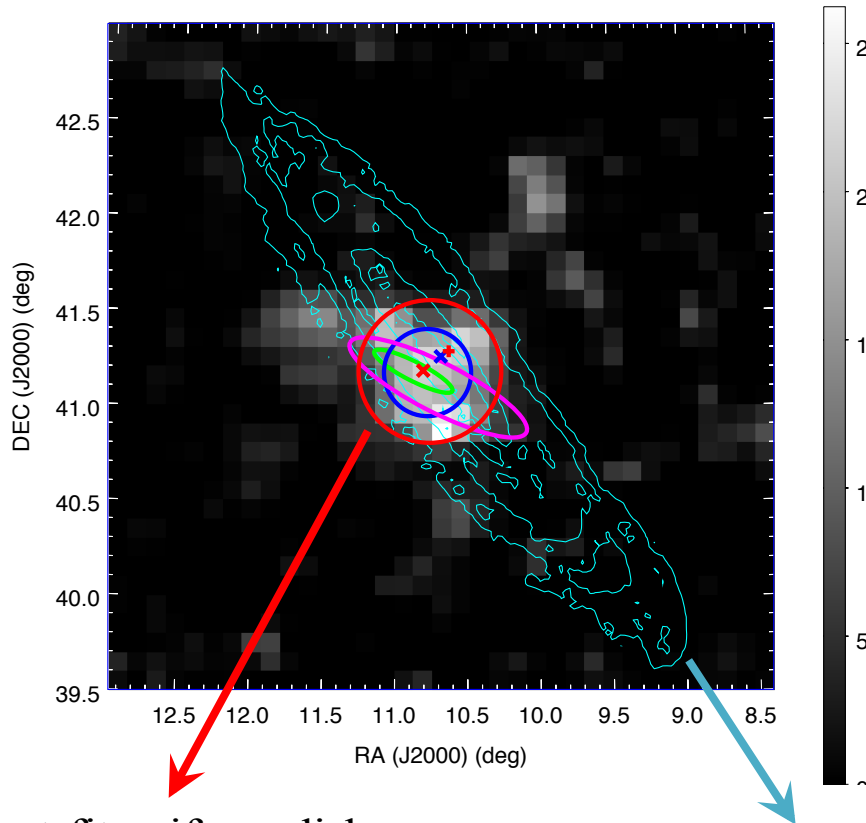




- ✓ How galaxies shine in gamma rays?
 - Interactions of cosmic rays (CR) with interstellar medium (π^0 decay, inverse-Compton, bremsstrahlung)
 - astrophysical sources (supernova remnants, pulsars and pulsar wind nebulae, binaries...)
 - dark matter
- ✓ LAT detected 7 extragalactic star-forming or starburst galaxies and performed systematic studies of more than 60 galaxies.
- ✓ **M31**: only other large spiral local galaxy, close => best target for resolved analysis



Spatial analysis (>1 GeV)

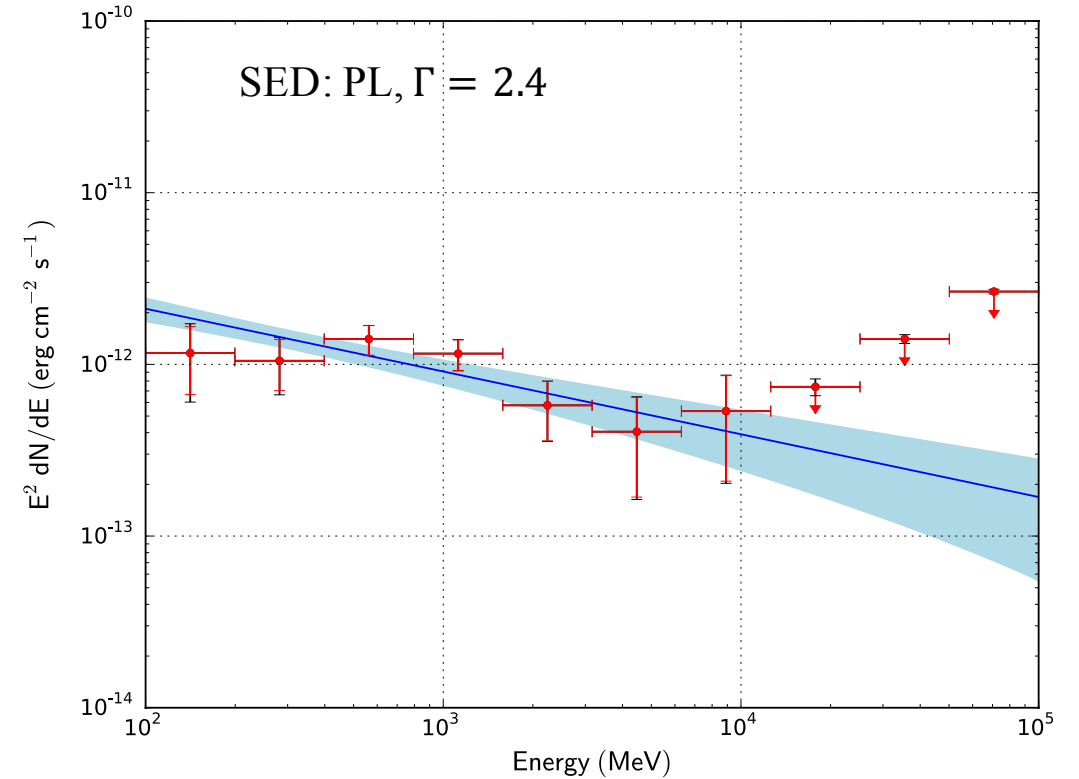


best-fit uniform disk

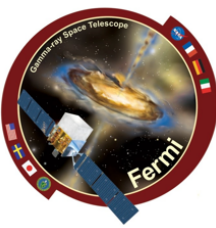
M31 gas column density (N_H) map

- Gamma-ray emission is confined to **inner regions** ($R \sim 5$ kpc)
- **Not correlated** with **interstellar gas and star-formation sites**
- **Disk** (plane) of the galaxy is **not detected**

Spectral analysis (>100 MeV)



- ✓ Adding cutoff: no significant improvement
- ✓ Consistent with the total interstellar emission or pion decay of the MW
- ✓ Less consistent with IC component of the MW
- ✓ Model difference: not significant



I. Interstellar emission

- π^0 decay
 - Low gas content to be compensated by high CR density at the galaxy center (similar to some regions in LMC)
 - But far from typical gas and star-formation regions (not detected in gamma rays)
- inverse-Compton (IC)
 - IC dominates the emission of M31: π^0 decay < 50% IC
 - Opposite to what is inferred for the MW: IC = 45% π^0 decay

III. Dark matter (DM) annihilation/decay

- Smooth halo : Navarro–Frenk–White (NFW) profile
- Take GCE as reference
- J-factors
 - MW: $2 \times 10^{22} \text{ GeV}^2/\text{cm}^5$
 - M31: $8 \times 10^{18} \text{ GeV}^2/\text{cm}^5$
- Expected DM signal from M31: ~ 5 x below observed value
 - But uncertainties on J-factor of M31...
 - And uncertainties on the GCE flux ...

II. Population of millisecond pulsars (MSPs)

- ◆ Related to old star populations in the disk and bulge of galaxies
- ◆ Suggested to be the origin of the Galactic Center Excess (GCE) (e.g. Brandt & Kocsis 15)
- ◆ Case of M31
 - Center: many old stars and X-ray binaries (Barmby+06, Voss & Gilfanov 07, Stiele+10)
 - Possible large population of MSPs at the center
 - Spatial distribution consistent with old stars (IRAC map)
 - $\text{SFR}_{\text{M31}} \sim 0.1 \times \text{SFR}_{\text{MW}}$ — decrease the disk emission
 - $\text{Bulge mass}_{\text{M31}} \sim (5-6) \times \text{MW}$ — increase the center emission
 - Gamma-ray luminosity of M31 $\sim (4-5) \times \text{GCE}$

