The Magellanic Clouds
Galactic Science outside the Milky Way

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Introduction

Content
• A tour of the sources now accessible from more/improved LAT data
• Some details on data analysis
• Open questions on the interpretation of some sources
• Many results from LMC
• Interesting comparison with SMC
• Conclusions

Analysis setup
• Most is based on Pass 7 reprocessed data, SOURCE class
• Using 5.5 years of data
• 2FGL catalog
• 200MeV-100GeV
Large Magellanic Cloud (LMC)

30 Doradus

Large Magellanic Cloud (LMC)
LMC: counts maps 800MeV-8GeV and 8-80GeV (smoothing with gaussian of 0.2°)

PKS0601-70

• A bright region, 30 Dor: what lies behind?
• Extended emission not filling the galaxy or following the gas
• A few hard sources
**LMC: model**

### What are the emission components?
- Model-fitting over 200MeV-100GeV
- Iteratively add point sources and gaussians until fit stops improving

#### The global LMC picture
- 4 point sources
  - 1 unid
  - 2 pulsars (J0540 and J0537)
  - 1 SNR (N132D)
- 4/5 extended sources
  - Disk (E0)
  - North (E2)
  - West (E4)
  - Near 30Dor (E1/E3)

[Image of LMC model with point sources and extended sources labeled.]
**LMC: PSR J0540-6919**

First «extragalactic» gamma-ray pulsar!

- Power law with exp. cutoff spectrum
- Pulsation search using photon weighting based on model
- Ephemeris from RXTE over 3.5 yrs
- Pulsations at $6.8\sigma$ (facilitated by Pass 8)

- The Crab twin, giant spin-down power
- Rare extreme case useful to test emission models
- Helpful to understand $\gamma$-ray emission from 30Dor

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**Done in collaboration with Lucas Guillemot and Frank Marshall**

**Preliminary**

Currently checking profile alignment in optical/X/$\gamma$…
LMC: PSR J0540-6919

Thanks to David Smith

Gamma-ray luminosity $6.3 \times 10^{36}$ erg/s
~10 times more luminous than Crab
(also more luminous in pulsed X-rays)

Preliminary
LMC: PSR J0537-6910

The most powerful pulsar known
(5000 yr, spin-down \(\sim 4.9 \times 10^{38}\) erg/s)
- Luminosity 1-100GeV \(\sim 2.4 \times 10^{36}\) erg/s
- Flat spectrum over \(\sim 1-100\)GeV … up to 800GeV?

Unclear origin of the emission
- GeV counterpart to TeV PWN N157B? Too flat?
- Pulsar+PWN? No pulsations detected…
- SNR? Too luminous in GeV range? Interacting? Enough material for pp interactions?

Preliminary
LMC: SNR N132D

The brightest supernova remnant in the LMC
- Luminosity 1-100GeV \( \approx 1.3 \times 10^{36} \) erg/s
- Hard spectrum
- Marginally detected by HESS from 200h observations
- Spectral match? see N. Komin’s talk

- Transition between middle-aged and old SNRs?

Funk, 2011

Preliminary
LMC: cosmic-ray population

Method

• Assumption: extended emission is CR-ISM hadronic interactions
• \( I(E_\gamma, r) = q(E_\gamma, r) \cdot N_H(r) \)
• Iteratively add emissivity Gaussian-like projected regions, each time optimizing position/size
• … multiply by gas column density map, fit as templates with given spectral model
• Direct way to estimate emissivities

Ex: 4 regions with different emissivities
LMC: cosmic-ray population

An inhomogeneous distribution
- CR sea has 1/3 the local CR density
- CR enhancements by factors 2-8
- No CR enhancement in 30 Dor...
- … but >0.5° offset from it
- Correlation with cavities and shells
Small Magellanic Cloud (SMC)

Spitzer

bar

wing

Small Magellanic Cloud (SMC)
SMC: counts maps 800MeV-8GeV and 8-80GeV (smoothing with gaussian of 0.2°)

- Extended emission following the bar of the SMC
- No hard sources within SMC boundaries
SMC: cosmic-ray population

Global picture differs from LMC
- No point-like source in SMC
- CR sea has \(~5\%\) the local CR density
- CR enhancement in the bar by \(~4\)
- No obvious correlation with cavities …or star forming regions
  (but geometry is different)
Conclusions

**Galactic science in the Magellanic Clouds**

- Providing extreme objects to complement studies of Galactic HE and VHE sources
  - Two of the most powerful pulsars known
  - One X-ray bright SNR of the rare O-rich class
- Probing the cosmic-ray population of star-forming galaxies seen from outside/above
  - CR seas with smaller densities than local in SMC and LMC
  - Inhomogenous distributions with enhancements in places by factors 2-8
  - Possible correlation with cavities in LMC, but nothing obvious in SMC
  - Relation of CRs/γ-rays to star-forming regions is not straightforward

- Combined with the latest HESS results: good prospects for CTA!

**Currently writing papers…**