Observing M 31 with VERITAS

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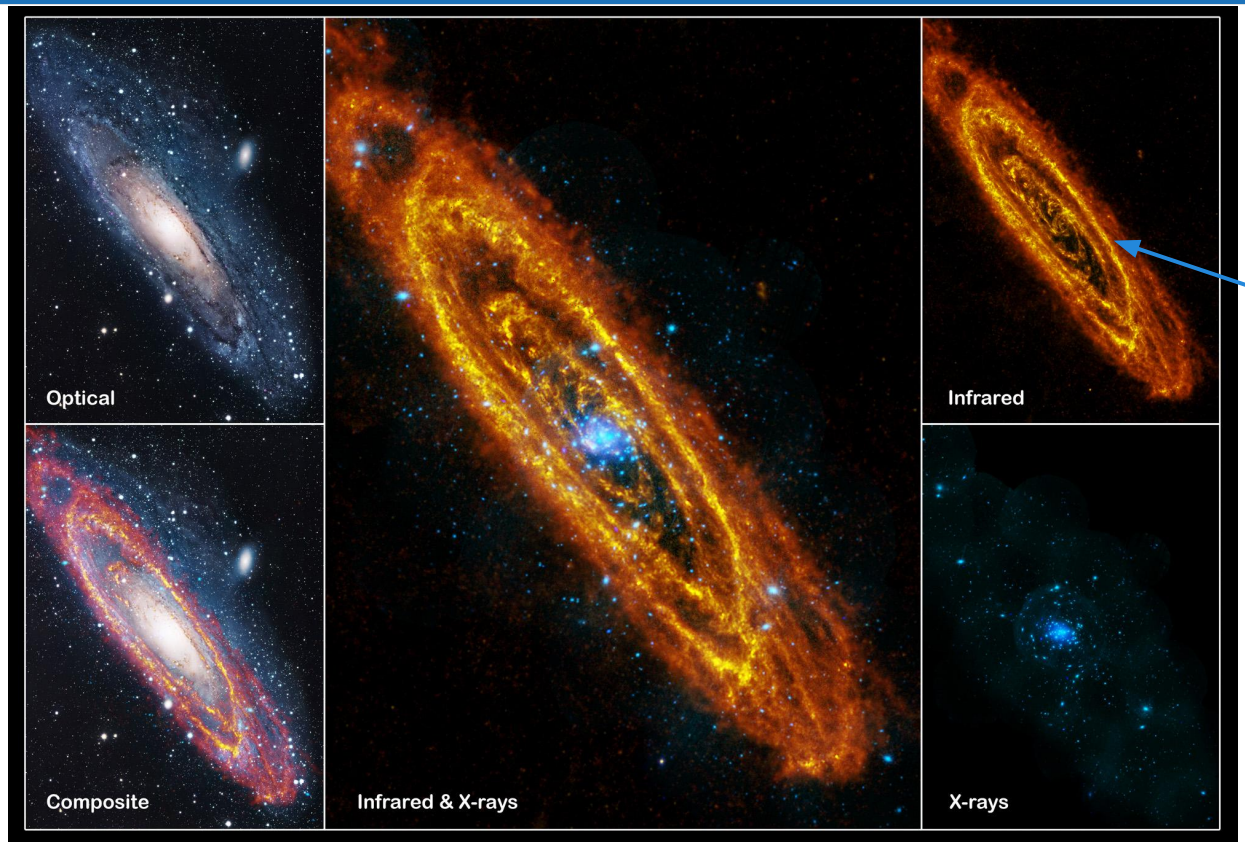
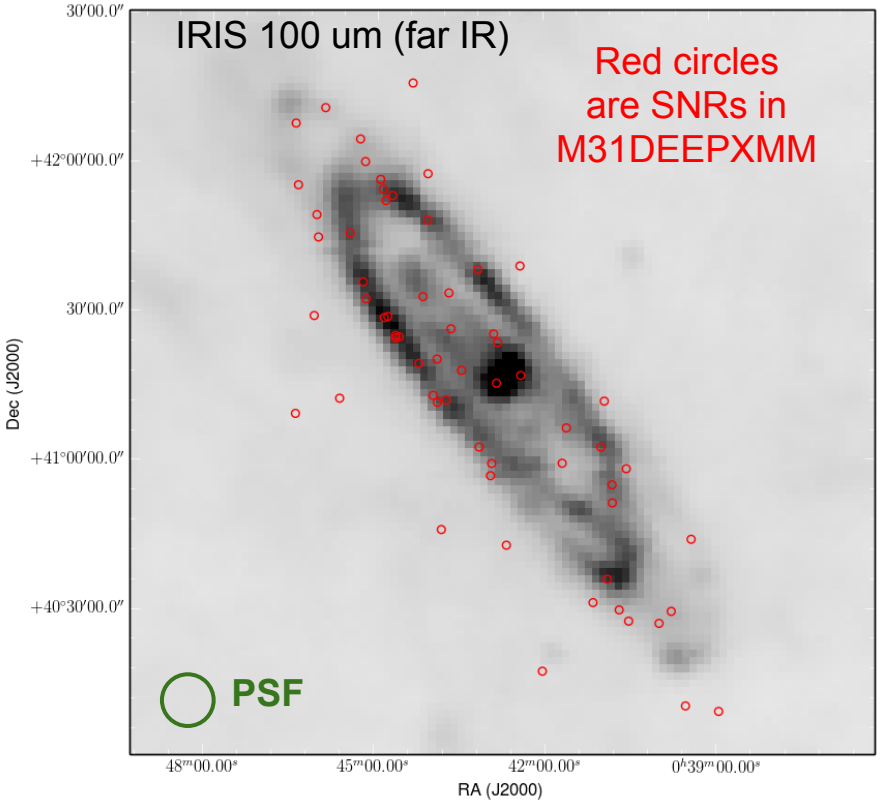
M 31 - a well-studied object



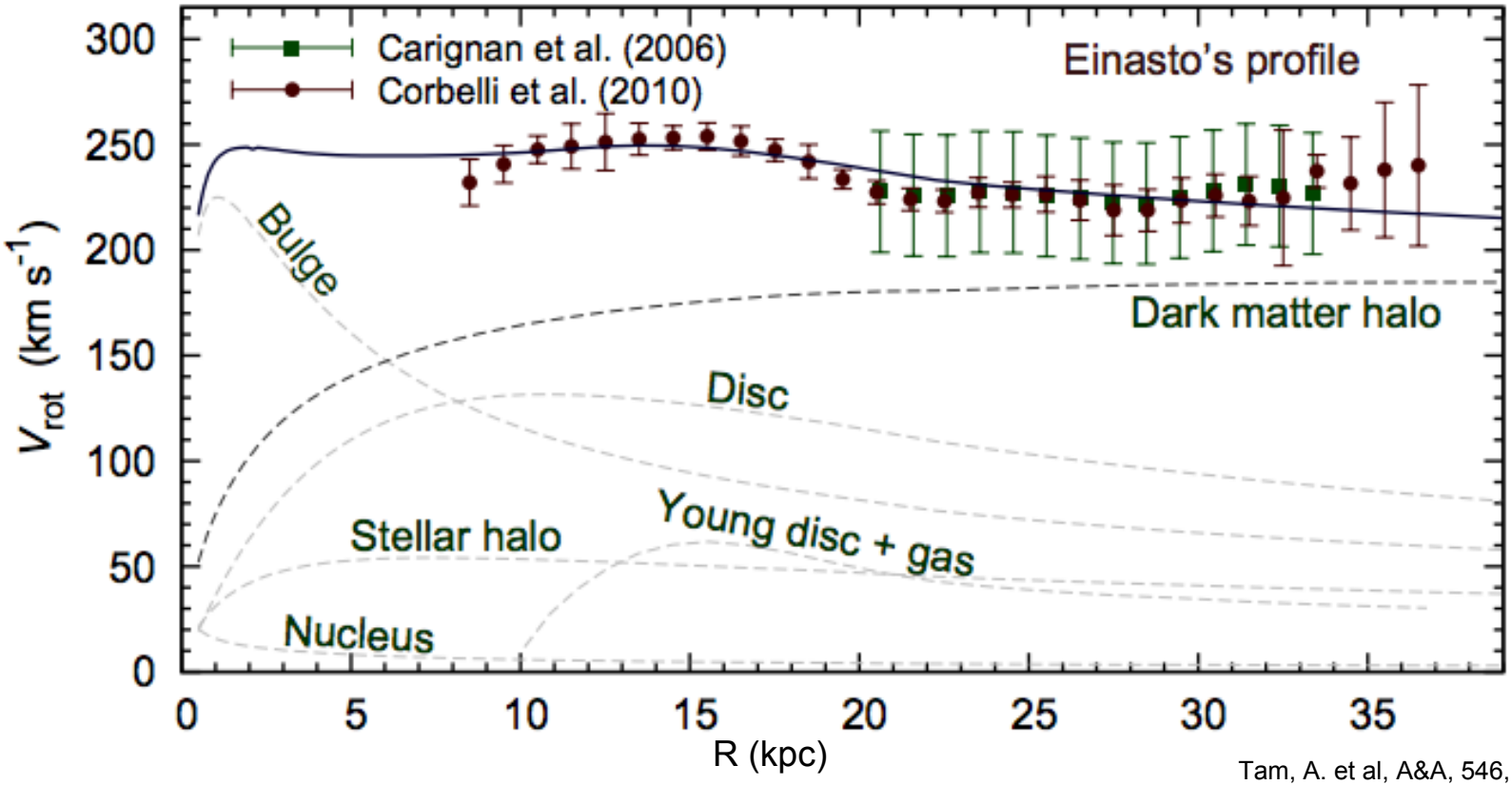
A testbed for diffuse VHE gamma-ray emission

Emission is predicted to occur in gas rich regions due to interaction of CRs with the ISM (primarily HI).

Majority of the gas and SNRs contained in a star forming ring ~ 10 kpc from the galaxy core.



and a potential dark matter candidate



Tam, A. et al, A&A, 546, A4, (2012)

Updated *Fermi*-LAT extended source analysis

Update of published result using a model map from the IRIS 100 um

2FGL sources & 1ES 0037 + 405 from the 1FHL & a point source at (00 48 18.0, 39 3 28.49)

Resultant fit for M 31

TS = 84.65

> 100 MeV integral flux = $(1.06 \pm 0.25) \times 10^{-8}$ ph cm^{-2} s^{-1}

gamma = 2.31 ± 0.08

Extrapolate for > 300 GeV integral flux

$(3.50 \pm 2.35) \times 10^{-13}$ ph cm^{-2} s^{-1} (0.3 ± 0.2% Crab)

Whole source!
- it is fairly weak unless something else is contributing at higher energies

VERITAS

Array of four 12-m diameter Cherenkov telescopes

F.L.Whipple Observatory,
Mt Hopkins, AZ

Energy range: 85 GeV - 30 TeV
Energy resolution: 15% - 25%
Angular resolution: 0.1°

See talk by N. Otte tomorrow

VERITAS Observations

Legacy Dataset

- 13.4 hours targeted on M 31 (pre camera upgrade, post T1 move)
- 15.6 hours targeted on other sources but covering M 31 (all 4 telescope array configurations)

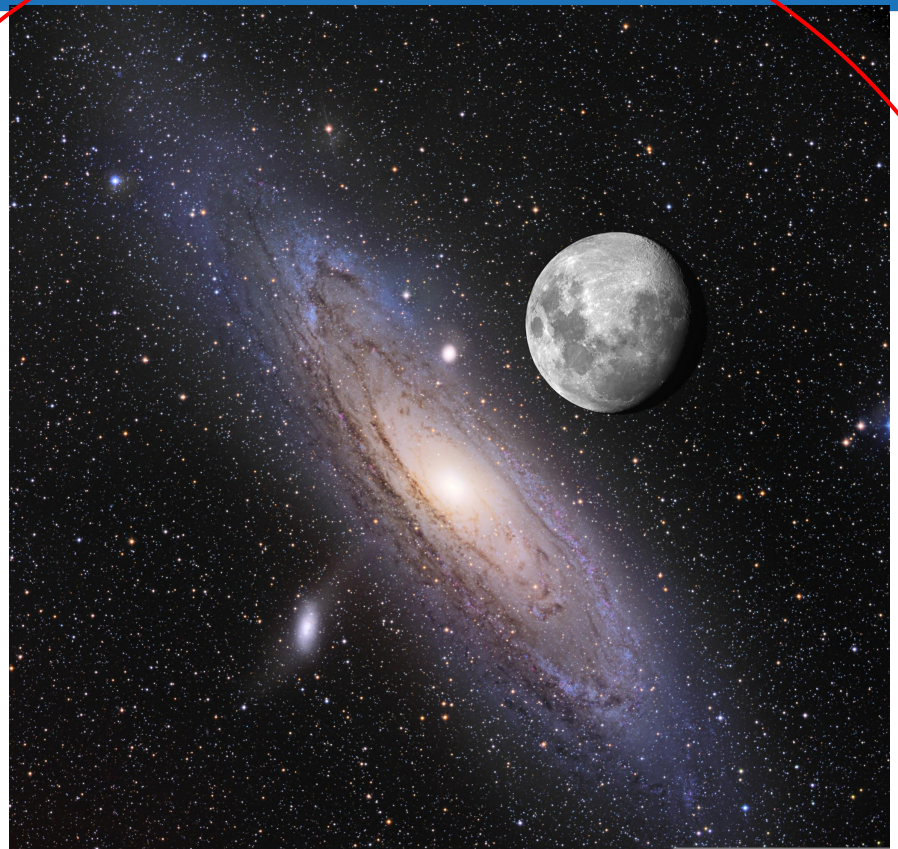
Never fully analysed due to challenges with optical brightness and size.

Not detected at VHE, HEGRA collaboration upper limits (point sources, > 500 GeV, 20.1 hours)

- central region < 3% Crab
- edges < 30% Crab

The Challenge

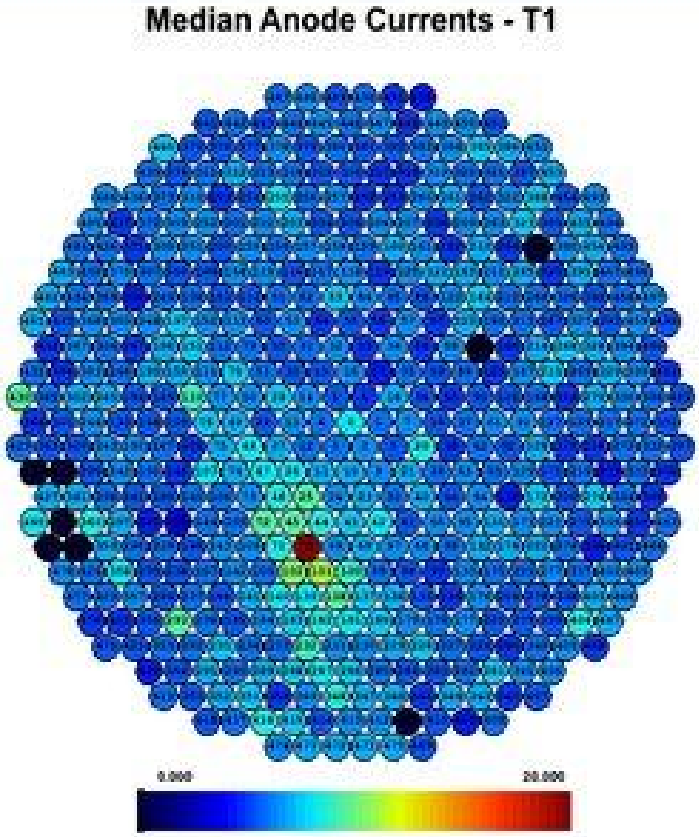
It is big ...



Approximate
VERITAS FOV

The Challenge

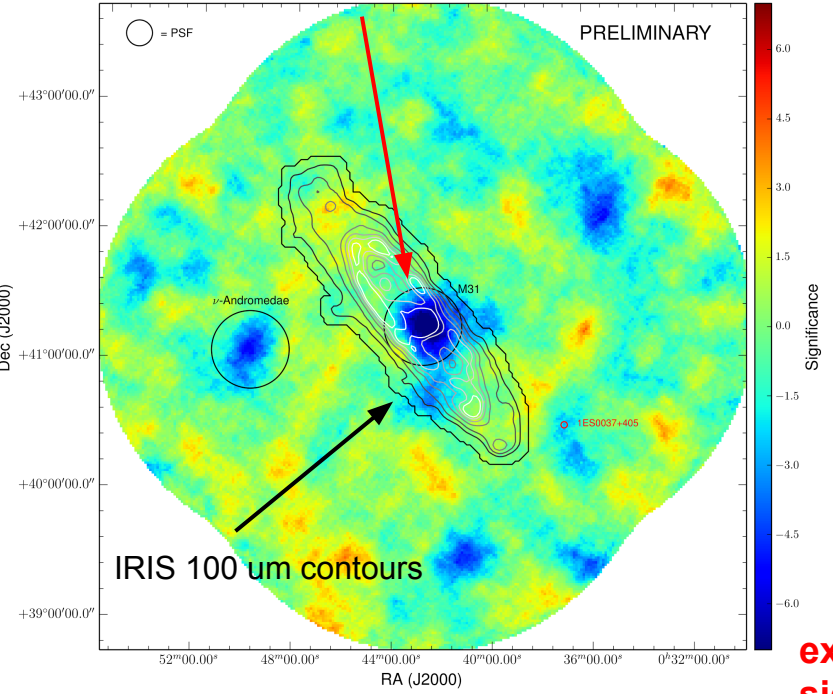
... and optically bright

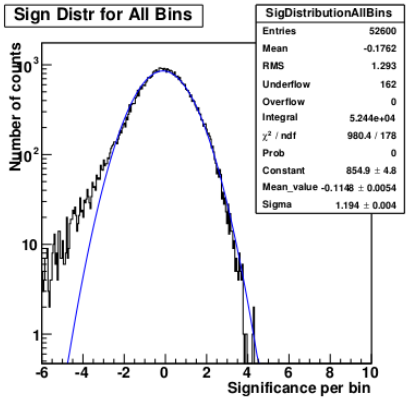


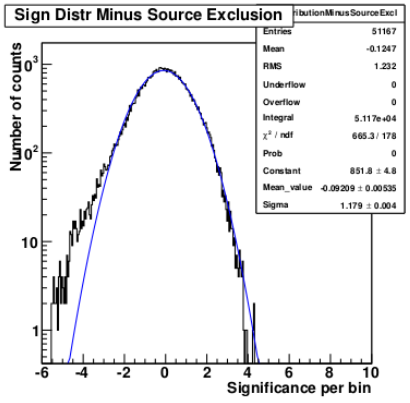
The impact on data

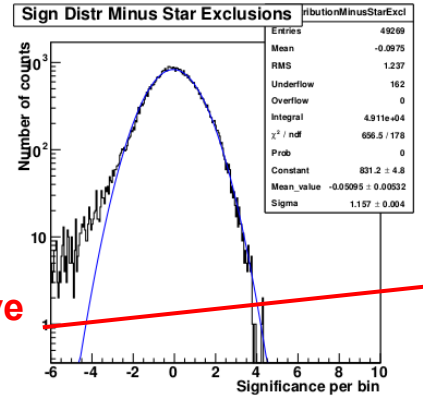
Optically bright > high currents > higher cleaning threshold > central hole

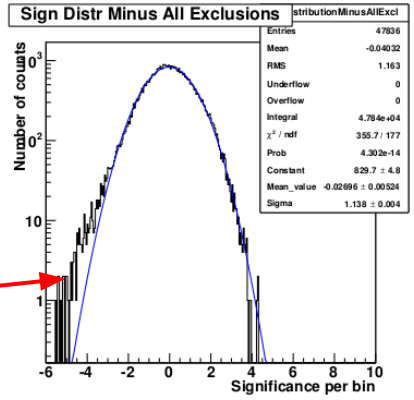
Large central hole











excess negative significance

Possible approaches

Extend central exclusion region

- Excludes the source we want to measure

Increase the size cut

- Needs to be very high to reduce hole sufficiently

Single image cleaning thresholds across the camera

- Approach used in this analysis
- Thresholds fixed to a compromise between affected and “background” pixels

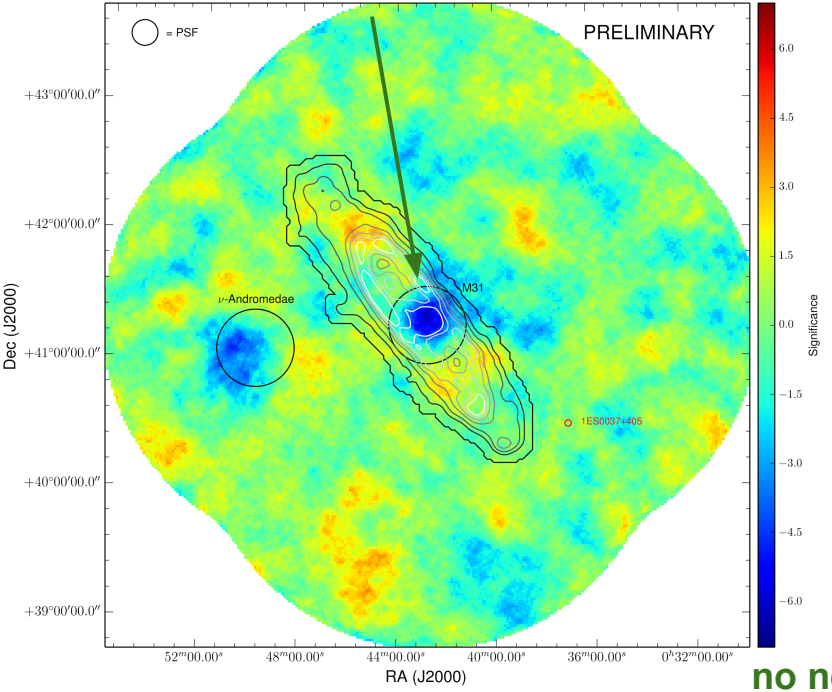
Additional image cleaning parameters

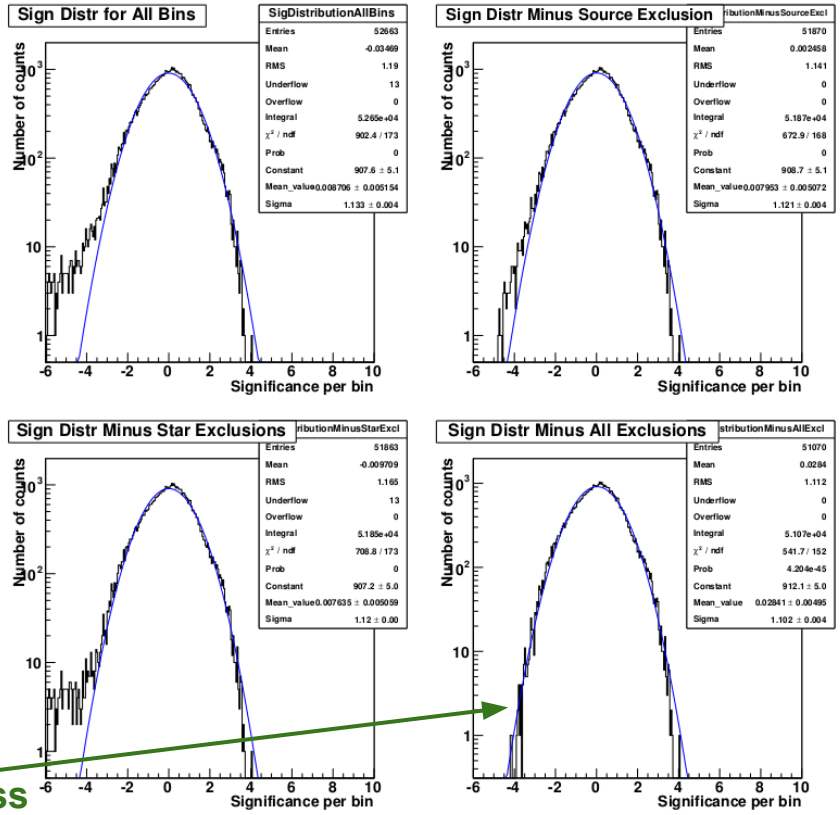
- To be examined in future work

Fixed Threshold Cleaning

The solution? - improvements but not perfect

Central hole smaller





no negative significance excess

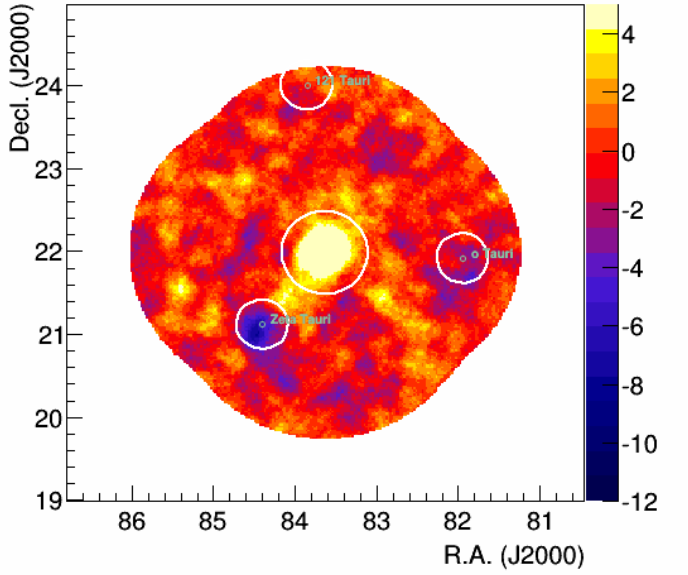
Impact on sensitivity

200 minutes of Crab Data

Standard

E_{thresh} = 120 GeV

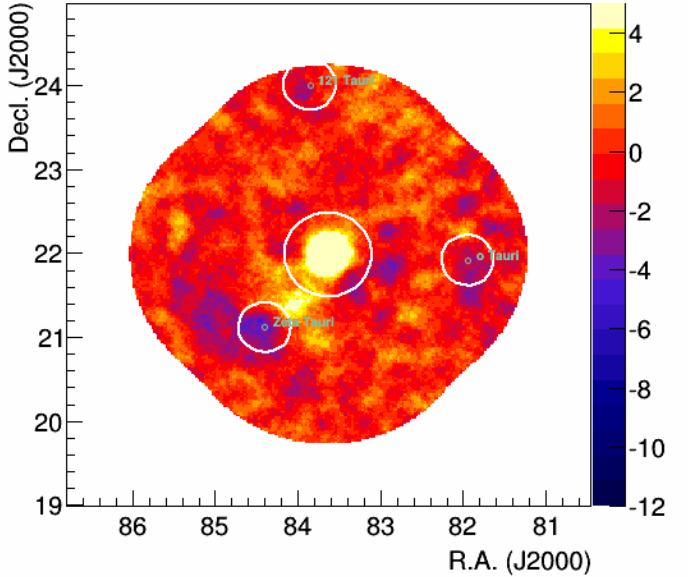
Scaled to 1% Crab, sigma/sqrt hr = 0.539



Threshold

E_{thresh} = 130 GeV

Scaled to 1% Crab, sigma/sqrt hr = 0.511



Preliminary point-source upper limits

Galaxy core excluded due to optical brightness.

Preliminary, simple approach.

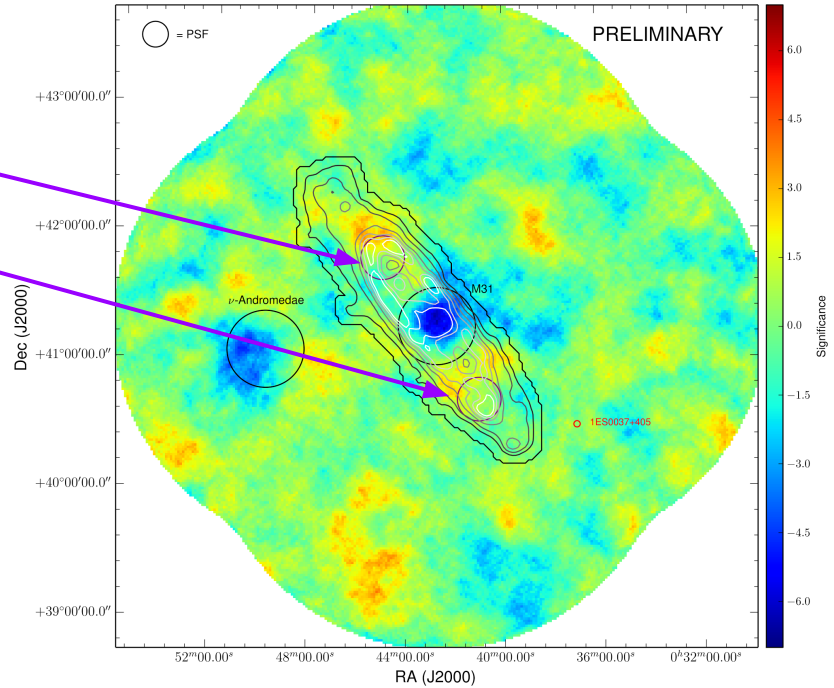
Use two regions (purple).

UL's (99%, Rolke) for M 31 targetted data only

Integral flux > 300 GeV

1: 6.2×10^{-12} ph cm^{-2} s^{-1} (5.3% Crab)

2: 6.9×10^{-12} ph cm^{-2} s^{-1} (5.9% Crab)



Comparison with model

Several diffuse gamma ray emission models exist, e.g. Aharonian & Atoyan (2000), and Kelner, Aharonian and Bugayov (2008).

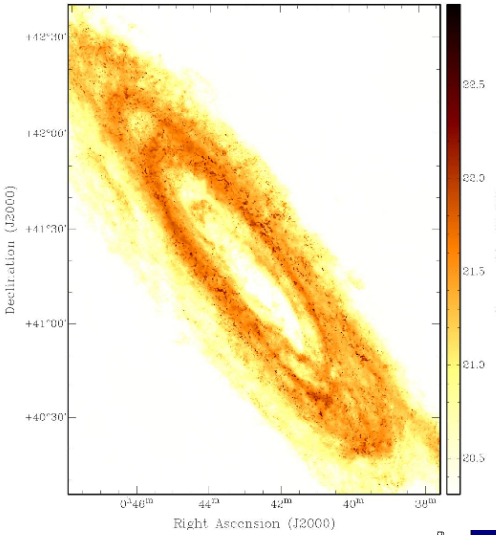
Can use detailed HI map (eg [1]) and compare with gamma ray observations to test models.

BUT need sufficiently detailed VHE observations.

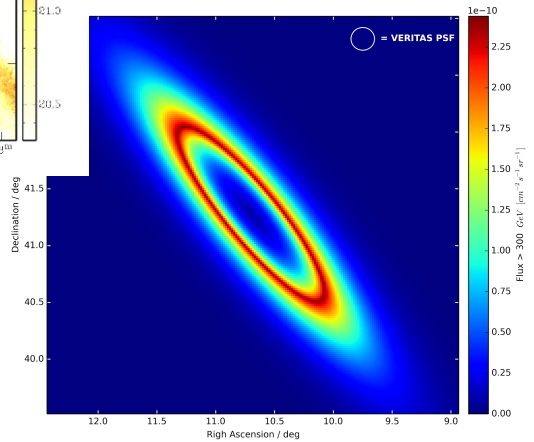
Total predicted flux (> 300 GeV)

= 7.7 x 10^{-14} ph cm^{-2} s^{-1}

~= 0.05% Crab



Predicted > 300 GeV flux



Tiny, but very much a lower limit

[1] Braun, R., et al., ApJ, 695,2,937-953 (2009).

Predicted fluxes

The measured flux from diffuse emission is expected to scale as

$(1/\text{distance})^2 \times M_{\text{hydrogen}} \times$ Star Formation Rate

Prediction	$\text{Distance}_{\text{Galaxy}} / \text{Distance}_{\text{M31}}$	$\text{SFR}_{\text{Galaxy}} / \text{SFR}_{\text{M31}}$	$(\text{Mass Hydrogen})_{\text{Galaxy}} / (\text{Mass Hydrogen})_{\text{M3}}$	Threshold / GeV	Predicted Flux / 10^{-13} ph cm^{-2} s^{-1}	% Crab
Extrapolated Fermi-LAT Result				300	3.50 ± 2.3	0.3
Theoretical Model				300	0.77	0.05
M 82 Scaled	4.65	30.8	0.18	700	14.5	3.5
NGC 253 Scaled	5.05	10.8	1.35	250	9.78	0.37

Conclusions

Predicted VHE flux 0.05 - 3.5% Crab, observations have potential to provide useful insights into the origin of diffuse gamma rays

VHE observations challenging due to size and optical brightness

Fixing cleaning thresholds reduces impact of optical brightness for small loss of sensitivity and increase in energy threshold

Preliminary point-source upper limits from a subset of the data < 5.9% Crab

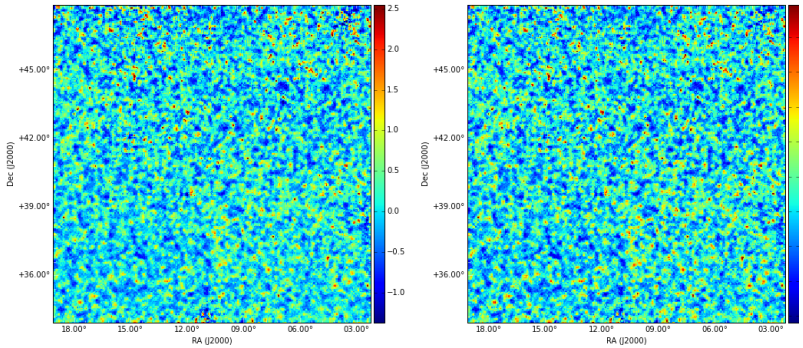
Analysis of additional data, an extended-source analysis and an improved upper-limit calculation are ongoing

This presentation was produced as part of the output of the DGGP, funded under the Programme for Research in Third Level Institutions (PRTLI) Cycle 5 and co-funded by the European Regional Development Fund.

Backup Slides

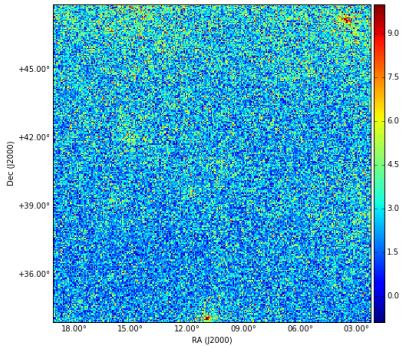
Fermi-LAT sky maps

Residuals Map (counts)



Residuals Map (significance)

Counts Map



Model Map