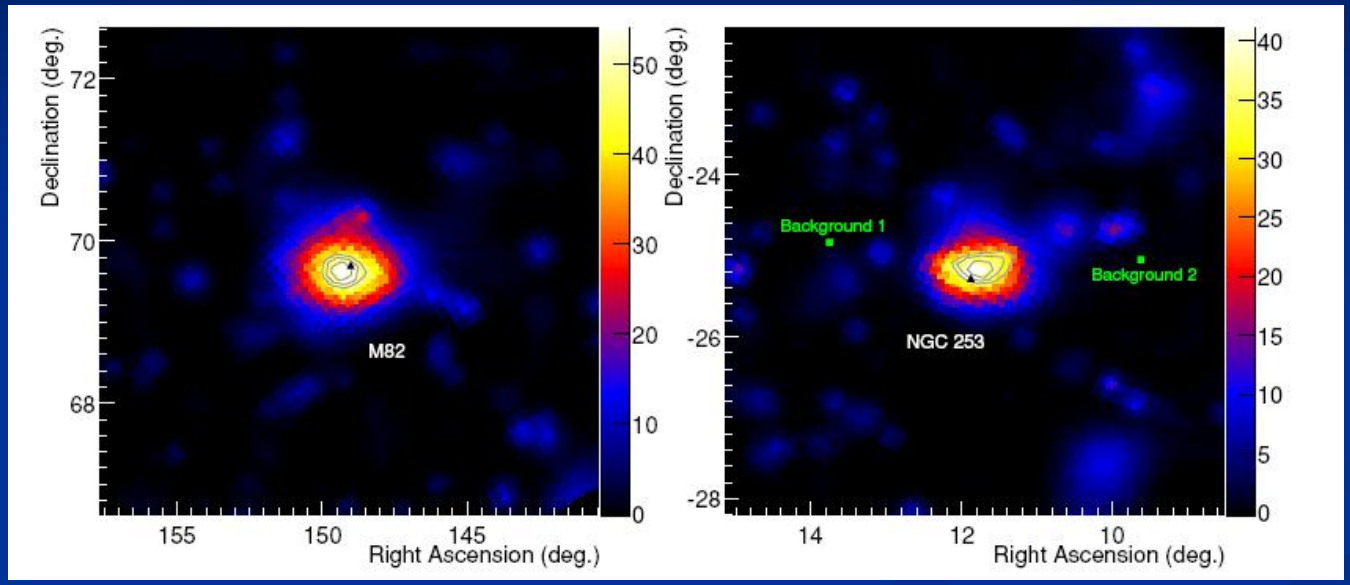
LHAASO合作组会议
2017年1月18-19日，云南大学

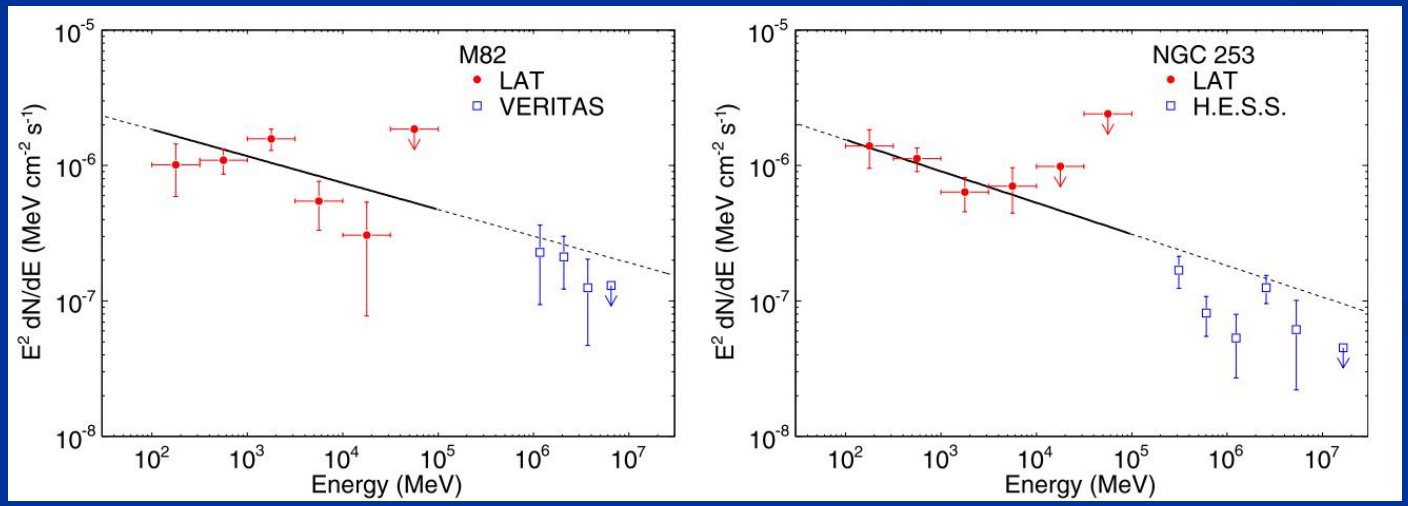
LHAASO对与星暴星系观测

王祥玉
南京大学

II. 星暴星系与LHAASO

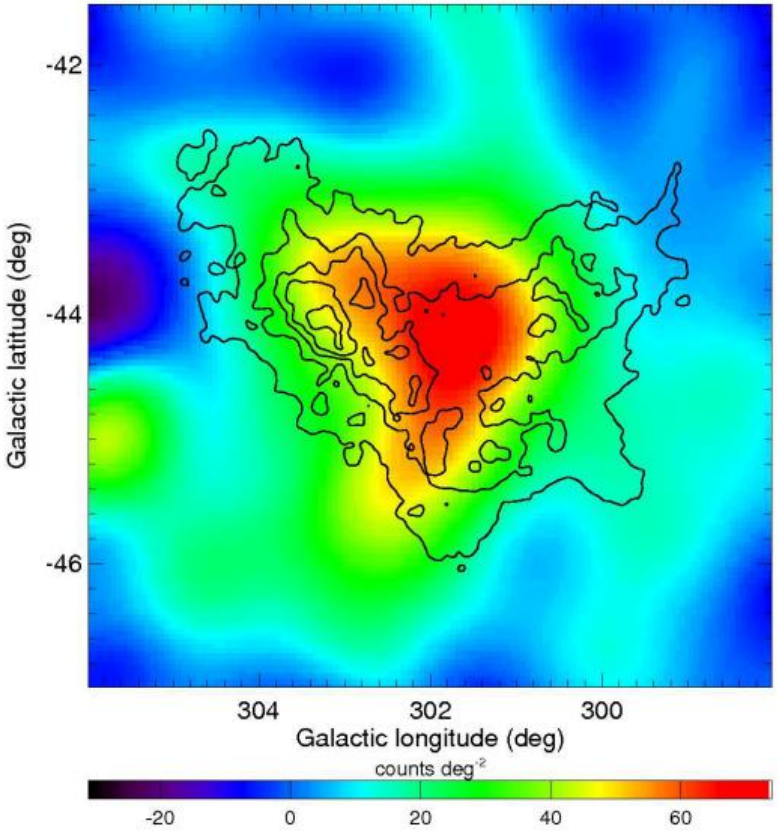
Abdo et al. 2010

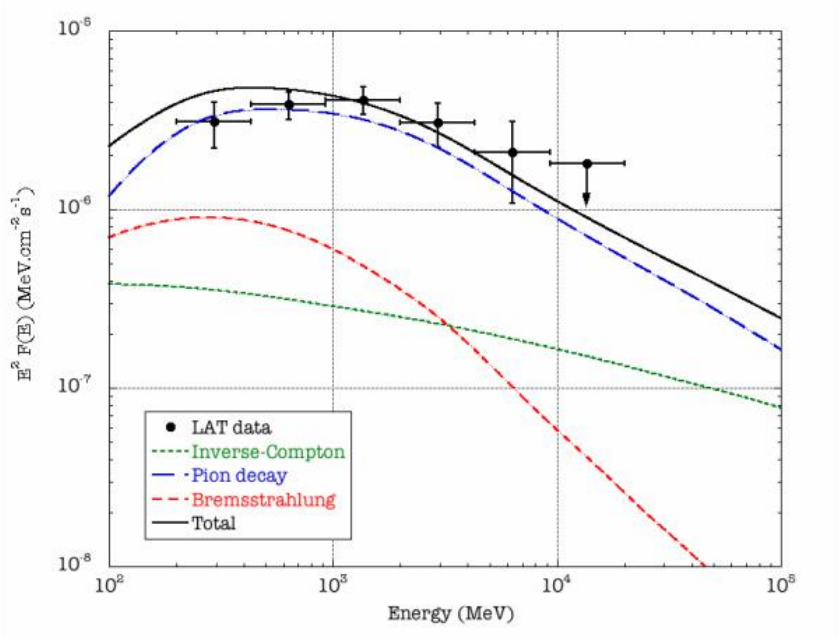




SMC-LAT observations

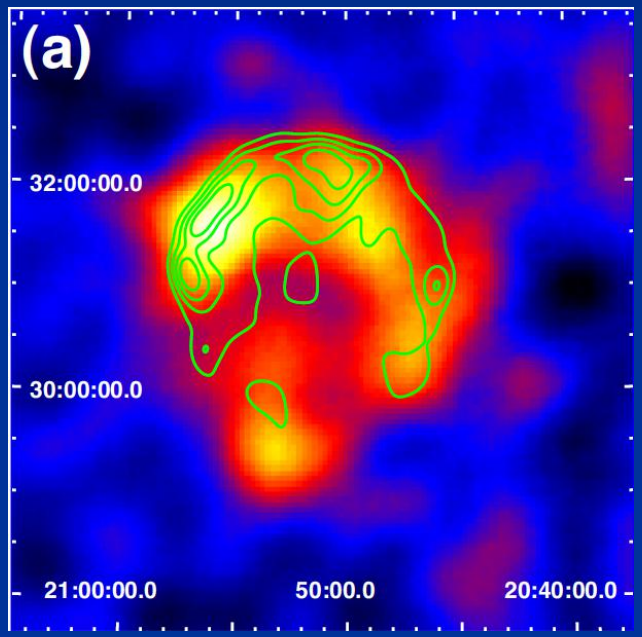
Abdo et al. 2010





Cosmic rays accelerated by SNRs

Cygnus Loop (0.5-10 GeV)

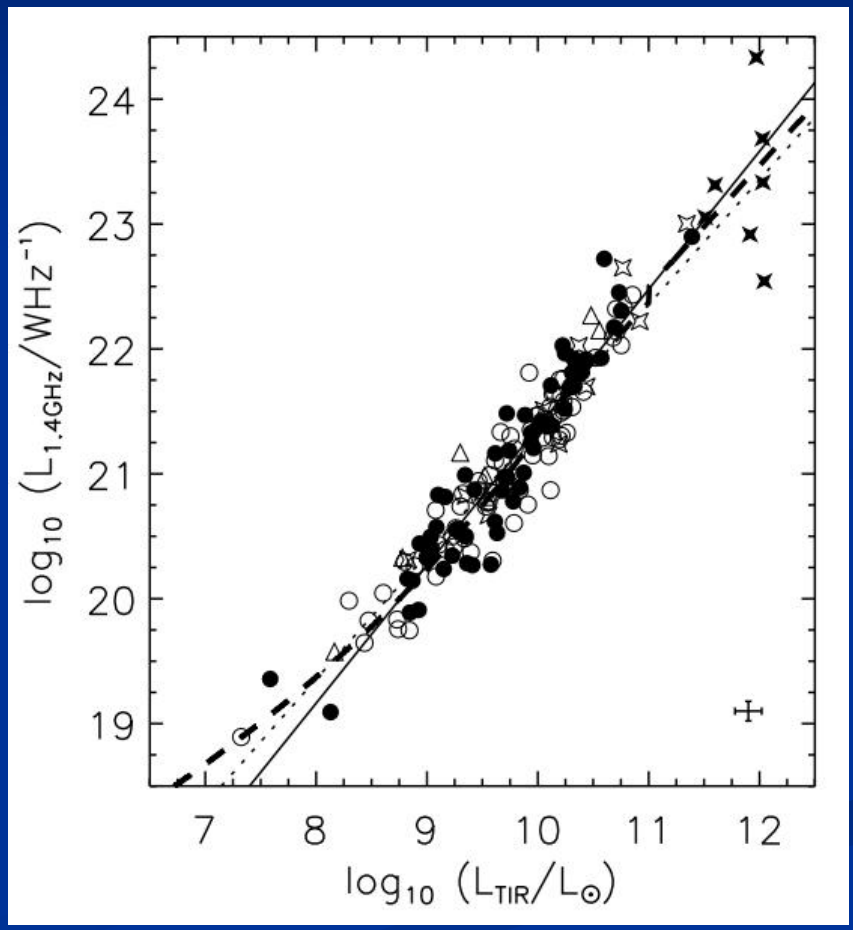


- Supernova explosions induce shocks (SNRs)
- Cosmic rays are accelerated across these shock fronts
- GeV Gamma-rays are produced by Cosmic rays

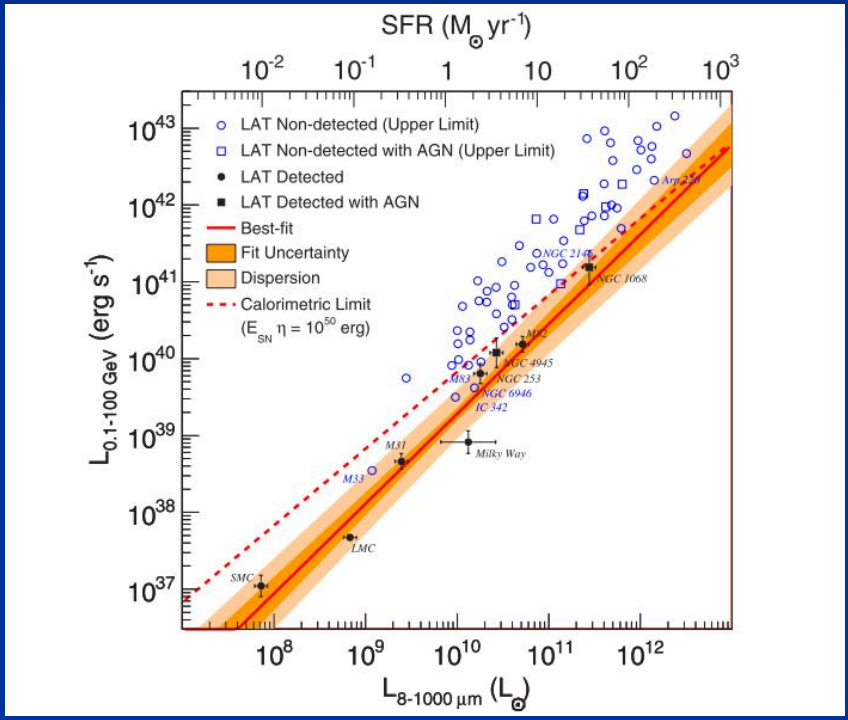
$$p^{+}_{CR} + p^{+}_{ISM} \rightarrow p^{+} + p^{+} + \pi^{0},\ \pi^{0} \rightarrow \gamma + \gamma$$

宇宙线在星系中的作用

- a rough equipartition of the magnetic and cosmic ray (CR) energy densities
- Only relatively recently have the effects of CRs have been considered in the context of galaxy formation
- CR –star formation connection



Correlation between gamma-ray and infrared luminosities



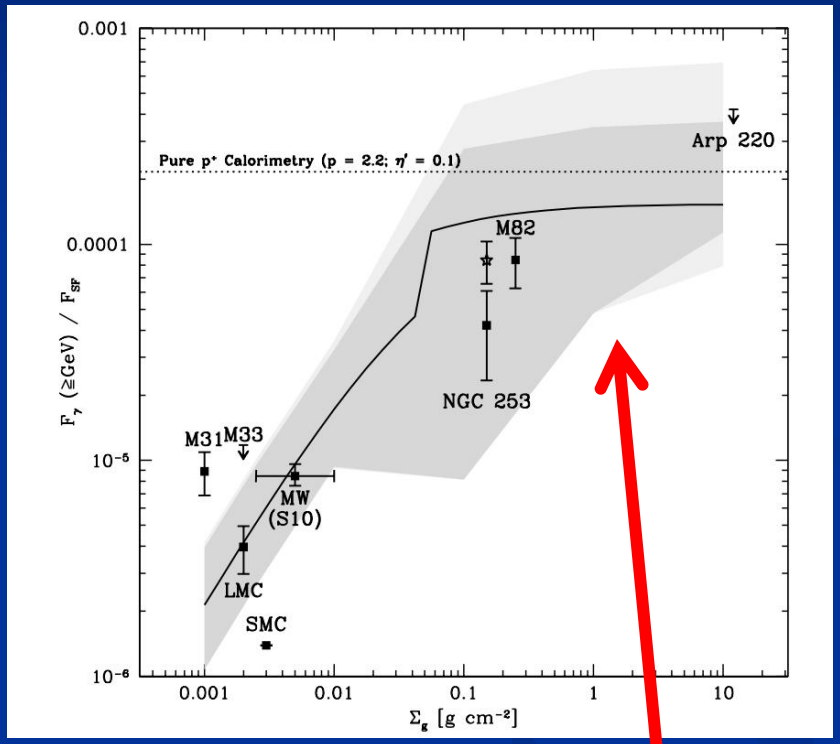
Ackermann et al. 2012

- Several nearby star-forming galaxies detected
- Gamma-ray and infrared luminosity well correlated
- Naturally expected if more CR energy is converted into gamma-rays in more luminous galaxies

CR calorimeter?

- "calorimetry fraction limit"

$$F_{\rm cal} \equiv \frac{L_\pi}{L_{\rm CR}(K \geqslant K_{\rm th})}$$

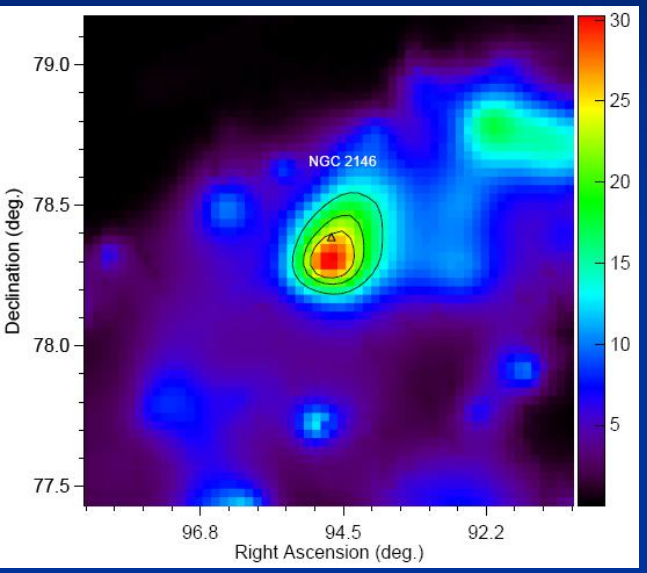


Best target: (ultra) luminous infrared galaxies

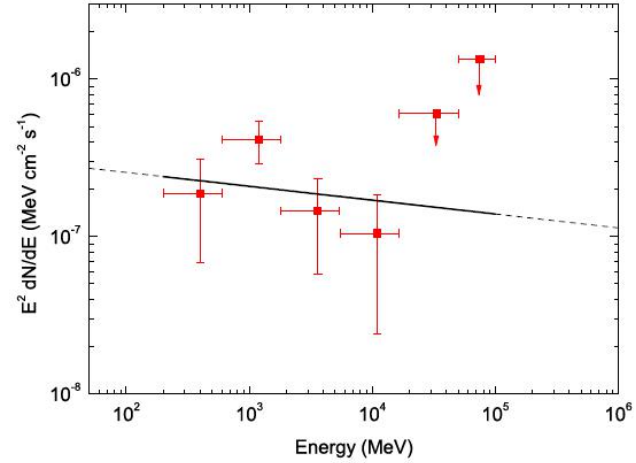
Lacki et al. 2011

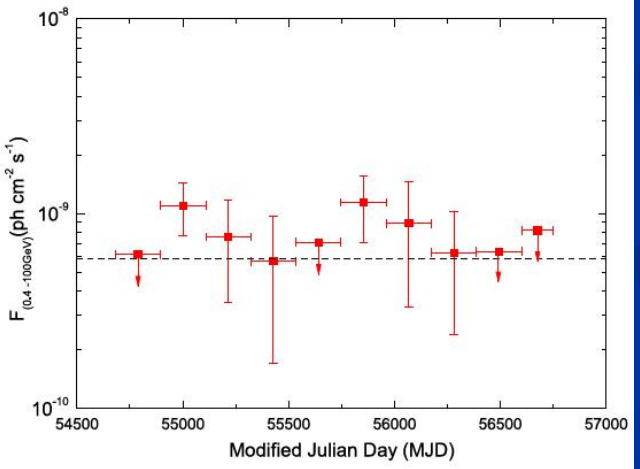
GeV emission from LIRG NGC 2146

Tang, Wang & Tam 2014



- A luminous infrared galaxy – CR calorimeter ?
- using the 68 month Fermi data
- 5.5 σ detection of gamma-ray emission above 200 MeV



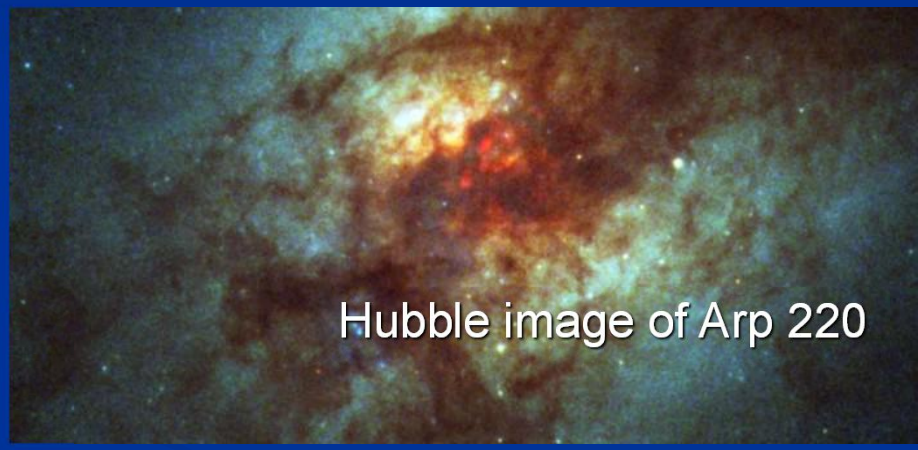


Arp 220- the nearest ULIRG: must be calorimeter!

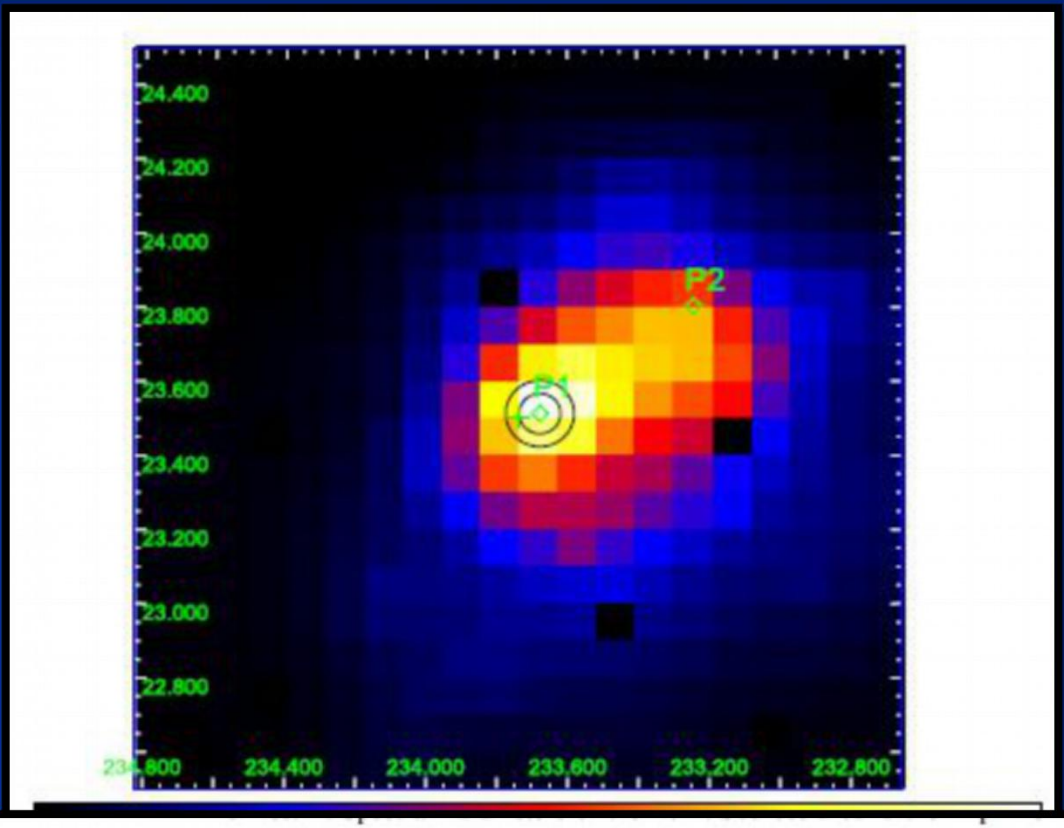
- A prototype of ULIRG: $L_{IR}=1.4*10^{12}L_{sun}$
- D=78Mpc
- $n\sim10^{4}cm^{-3}$

  $t_{pp}<t_{escape}$
- Possible AGN
- SN rate: 4+-2/yr
- Long predicted to be GeV sources

(e.g.,Torres 2004; Lacki+ 2011; Yoast-Hull+2015)



Fermi observation- PASS 8

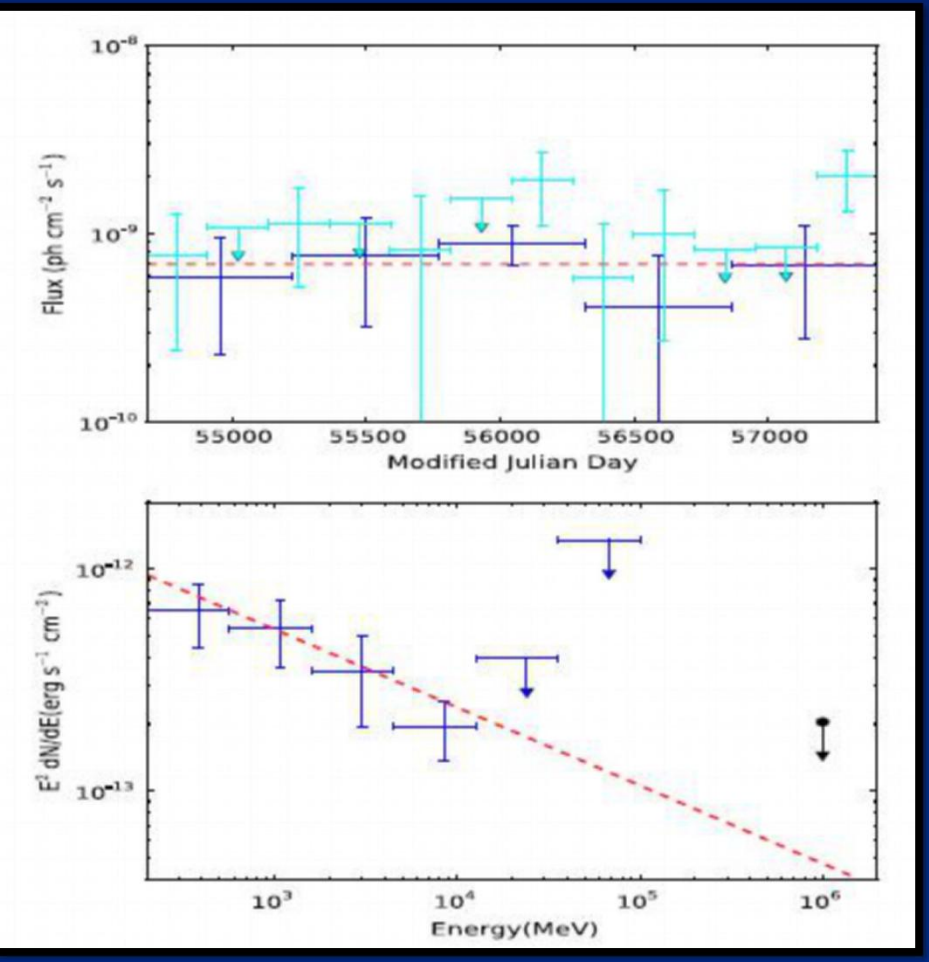


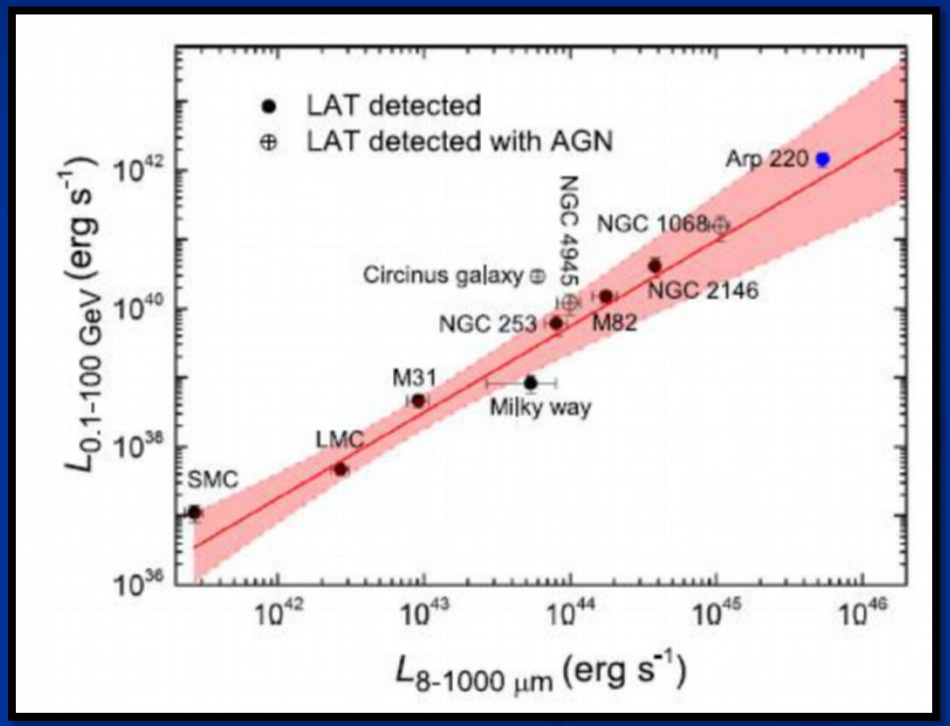
Peng, Wang et al. 2016, ApJL

Point	Position (degree)	r_{95} (degree)	Separation (degree)	Photon Flux (10^{-9} ph cm^{-2} s^{-1})	Energy Flux (10^{-12} erg cm^{-2} s^{-1})	Γ	TS	Association
P1	(233.677, 23.5163)	0.090	0.058	1.76 ± 0.52	1.92 ± 0.43	2.35 ± 0.16	40	Arp 220
P2	(233.239, 23.8049)	0.279	0.547	1.45 ± 0.52	1.39 ± 0.40	2.45 ± 0.19	22	···

LC and SED of Arp 220

Peng, Wang et al. 2016, ApJL





Favor cosmic Rays origin

Implication: the efficiency of powering CRs

Peng, Wang et al. 2016, ApJL

- GeV emission luminosity from CRs

$$L_{\rm CR}(>1\ {\rm GeV}) = 3L_{\gamma}(>1\ {\rm GeV})(\Gamma - 1)\beta_{\pi}^{-1}$$

- Cosmic Rays injection power (SN rate is known)

$$L_{\rm CR}(>1\ {\rm GeV}) = 1.3 \times 10^{44}\ {\rm erg\ s^{-1}} E_{51}\eta\left(\frac{\Gamma_{\rm SN}}{4\ {\rm yr^{-1}}}\right)$$

Γ_{SN}=4+-2 SN/yr

- Efficiency of powering CRs of SNRs

$$\eta \simeq (4.2 \pm 2.6)\% E_{51}^{-1}\left(\frac{\beta_{\pi}}{0.6}\right)^{-1}\left(\frac{\Gamma_{\rm SN}}{4\ {\rm yr^{-1}}}\right)^{-1}$$

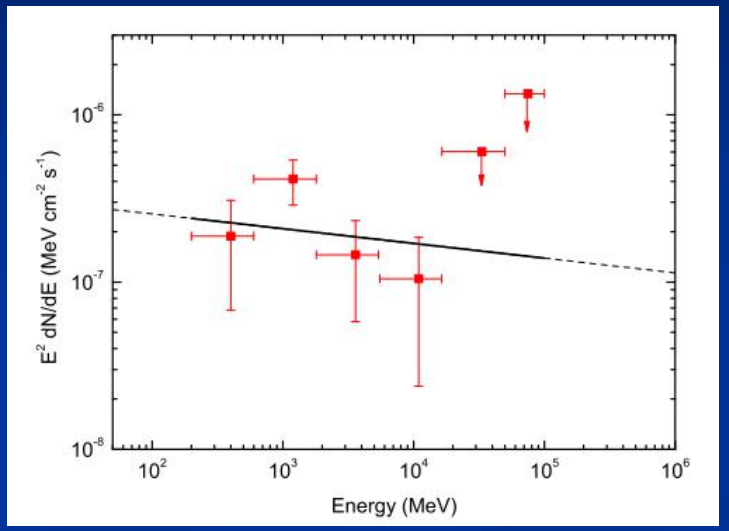
LHAASO proposal: VHE observations of star-forming/starburst galaxies

LHAASO Science: VHE observations of star-forming/starburst galaxies

Xiang-Yu Wang[1], Ruo-Yu Liu[1], Qing-Wen Tang[2], Thomas Tam[3]

[1] *Department of Astronomy, Nanjing University, Nanjing 210093, China*
[2] *School of Science, Nanchang University, Nanchang 330031, China*
[3] *Institute of Astronomy and Space Science, Sun Yat-Sen University, Guangzhou 510275, China*

Abstract



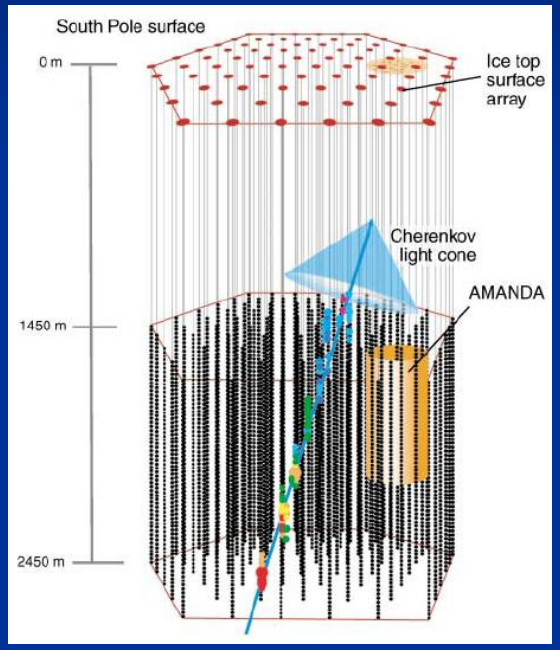
- Using NGC 2146 as a template (d=15Mpc), we estimate the VHE flux assuming a simple power-law extrapolation:

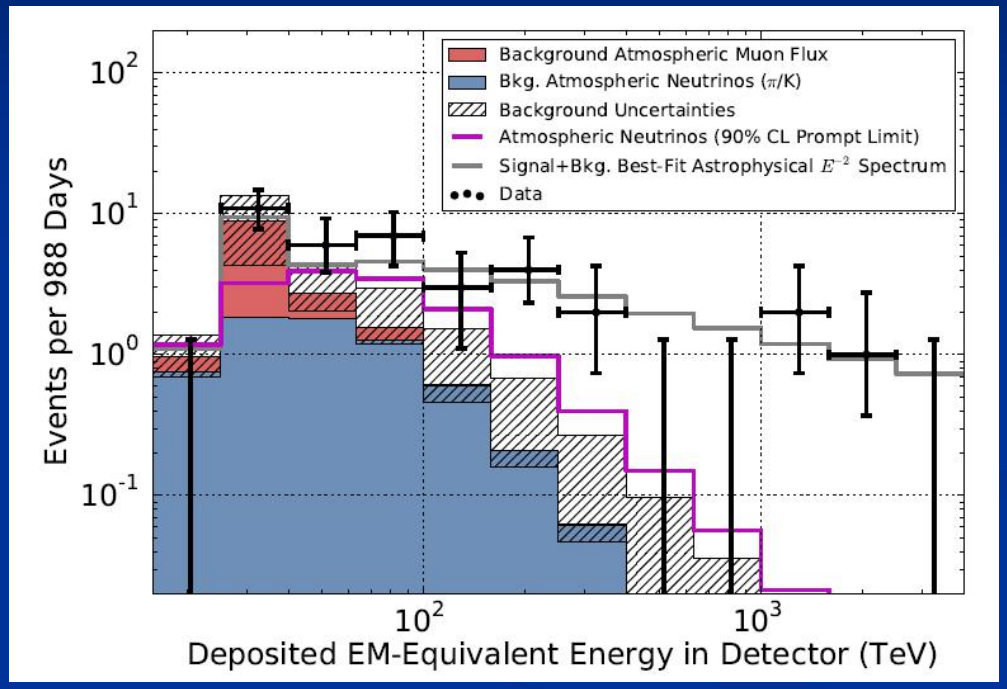
  E^2 dN/dE =10^-13 TeV cm^-2 s^-1 (E/1TeV)^-0.1

- **Observe nearby star-forming and starburst galaxies within 20 Mpc (up to 100 TeV energies).**

IceCube: diffuse PeV neutrinos detected

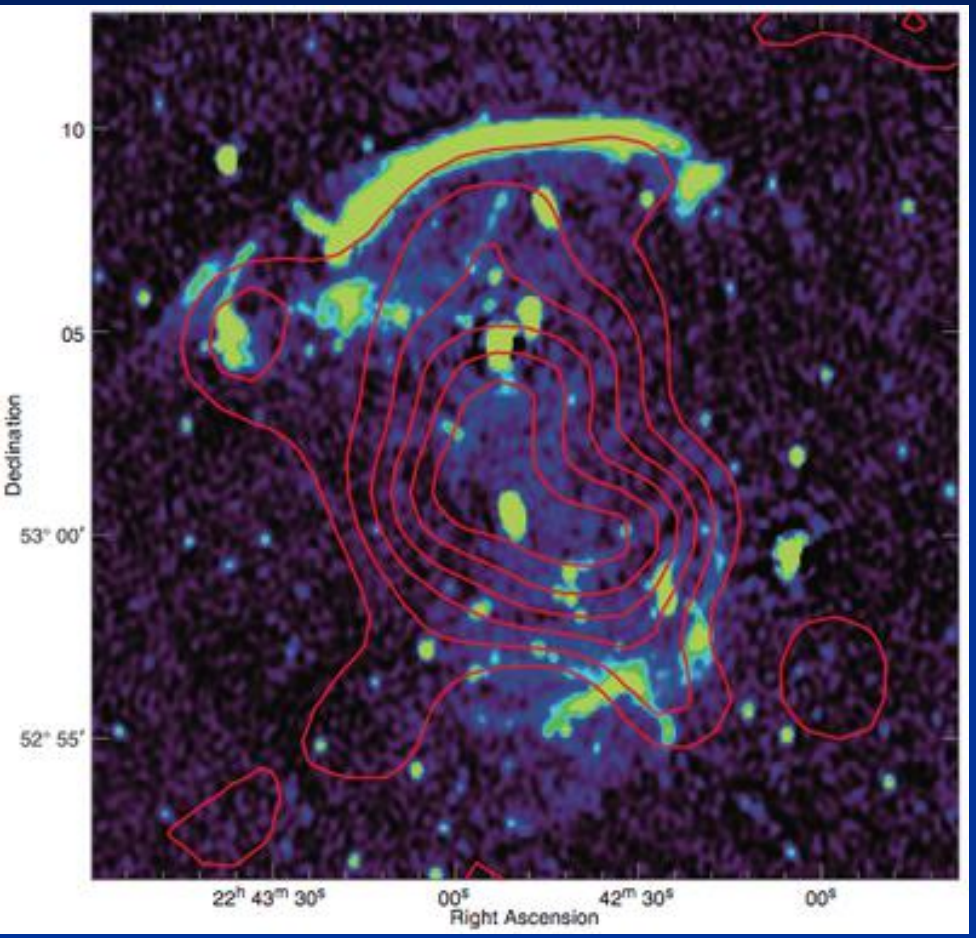
IceCube collaboration , 2014, 2015





- **LHAASO 如能探测到星暴星系100TeV光子，对中微子起源有重要意义。**

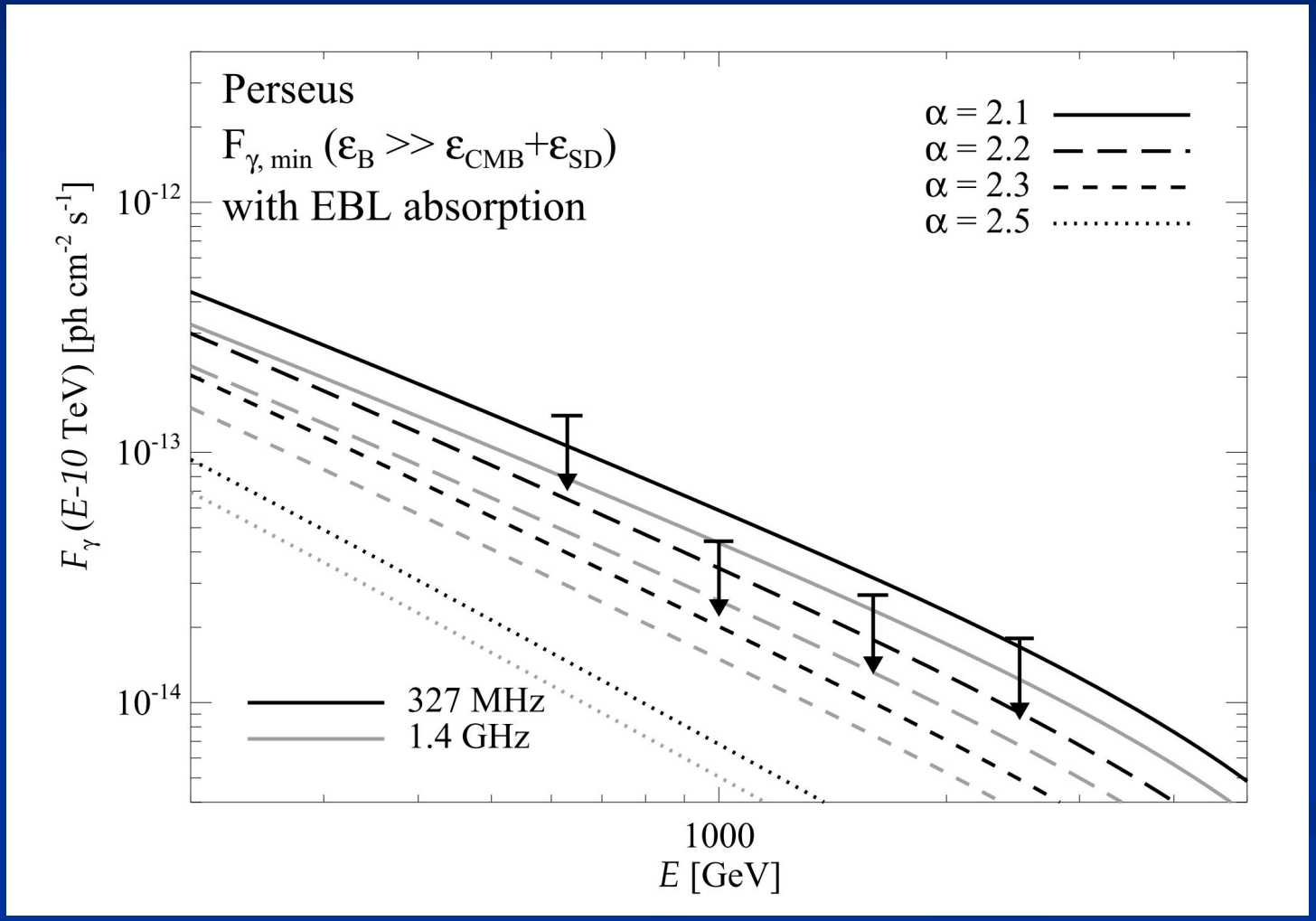
Galaxy cluster- radio relic



WSRT at 1.4 GHz image showing the north and south radio relics. ROSAT X-ray emission is shown by the red contours. (van Weeren et al. 2010)

- Do accretion or merger shocks produce CRs?
  - Radio observations have shown that galaxy clusters are giant reservoirs of CR electrons
  - Gamma-ray limit from Fermi on the average CR-to-thermal energy ratio of 4.6% for a photon index of 2.4 (Huber et al. 13).

MAGIC observation of the Perseus cluster



D=78Mpc

Conclusions

- IACT以及Fermi/LAT已探测到数个星系的伽马辐射
- LHAASO对邻近星系、星暴星系的研究有重要意义(>10 TeV)。
- 星系团的伽玛射线搜寻对研究宇宙结构形成的cosmological shocks有重要意义。