中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

双区扩散模型下脉冲星对宇宙线正电子超出的解释

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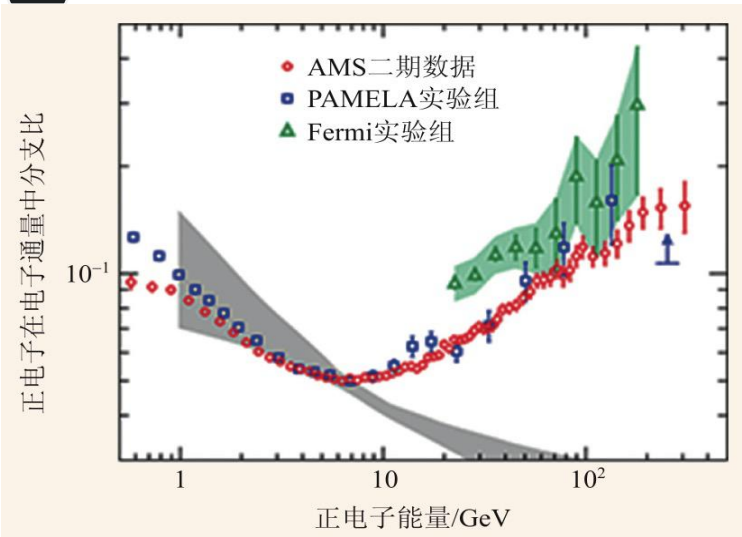
2021.08.16，青岛

ApJ 884,124 (2019)

正电子超出



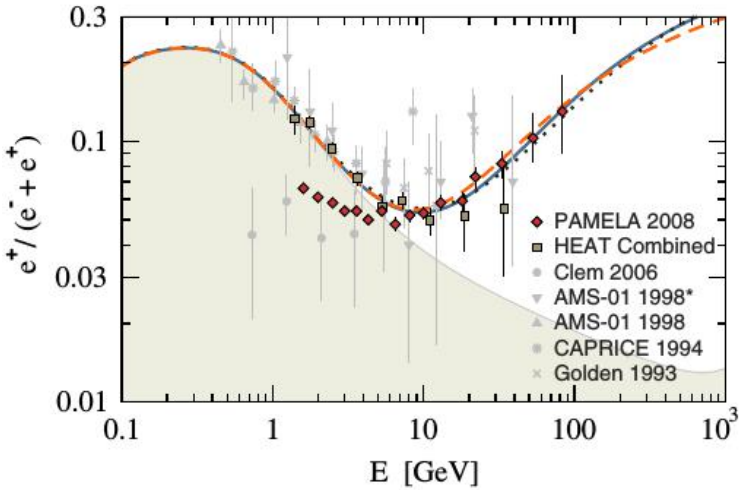
数据点：不同实验测量的宇宙线正电子比

灰色阴影：宇宙线在传播过程中预期产生的次级正电子

正电子超出的可能来源：

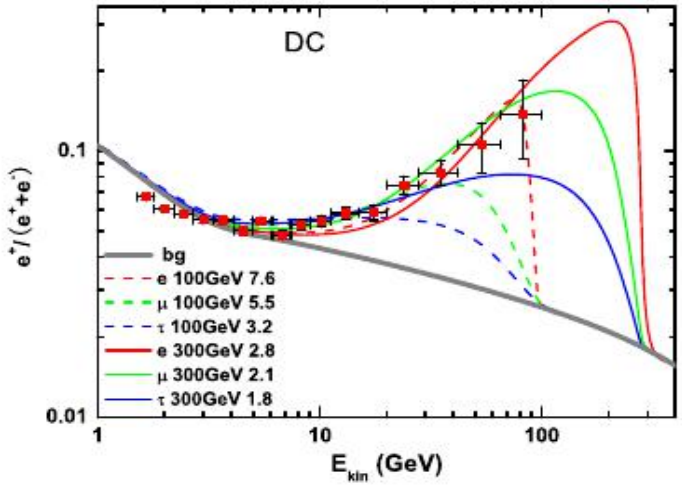
脉冲星，暗物质湮灭/衰变

脉冲星模型



Yuksel H. et al. 2009

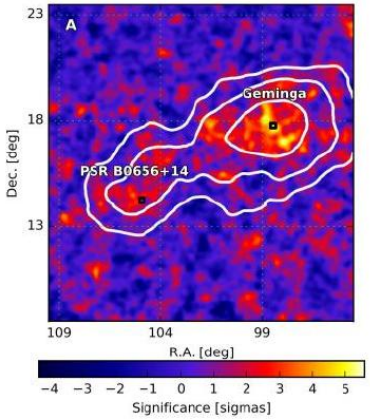
暗物质模型



Yin P. et al. 2009

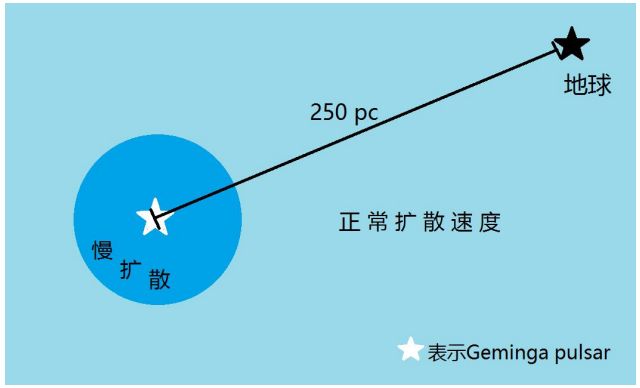
重要进展1

脉冲星周围的异常慢扩散：对电子传播有重要影响

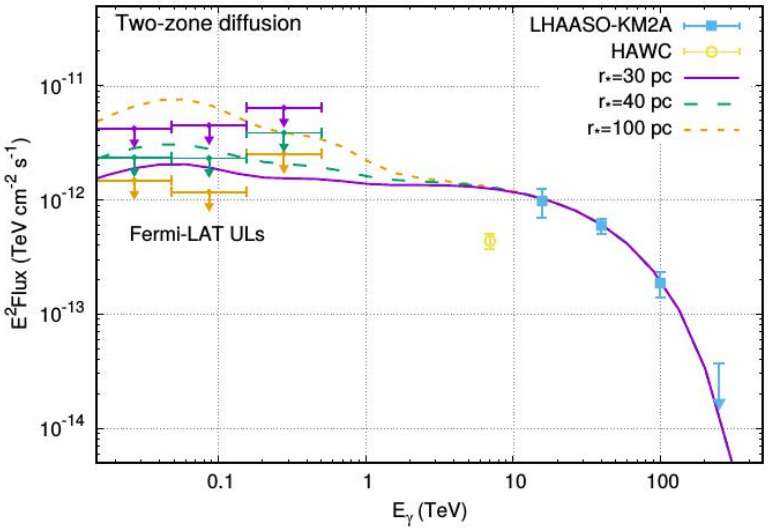


HAWC 2017

伽马射线观测表明一些中年脉冲星附近的星际介质中存在宇宙线异常慢扩散，**远远慢于银河系的平均扩散速度！**



双区扩散模型示意图



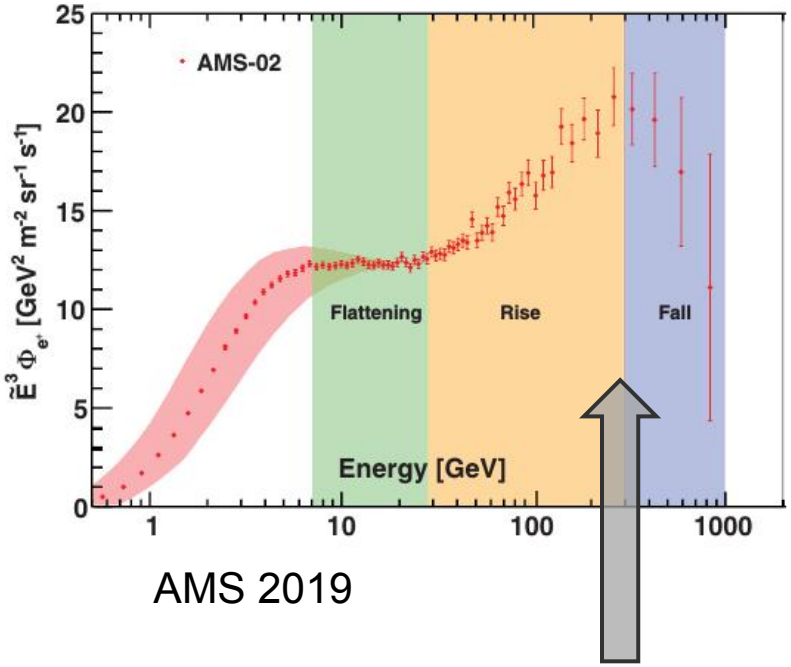
LHAASO J0621+3755

- 单区慢扩散模型无法对伽马射线能谱给出自恰解释
- 双区扩散模型下，**慢扩散区的尺度不能大于 ~ 50 pc**

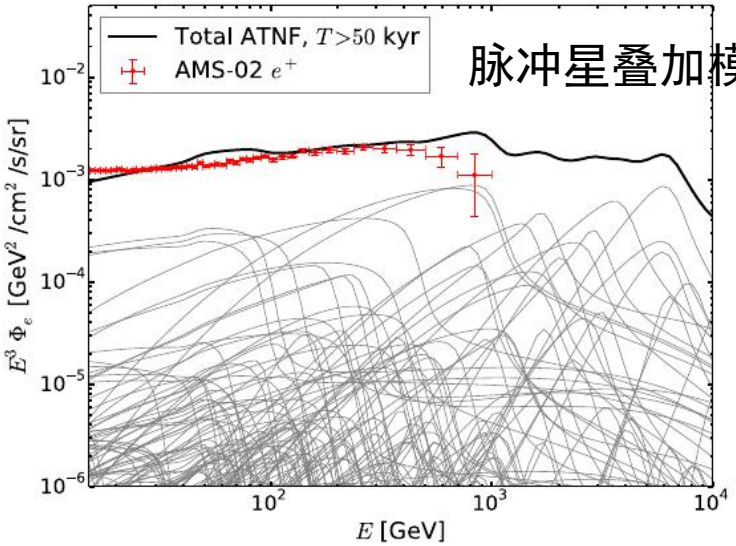
Fang K. et al. 2021

重要进展2

正电子能谱的高能截断：由某个脉冲星主导



AMS 2019



脉冲星叠加模型

Manconi S. et al. 2020

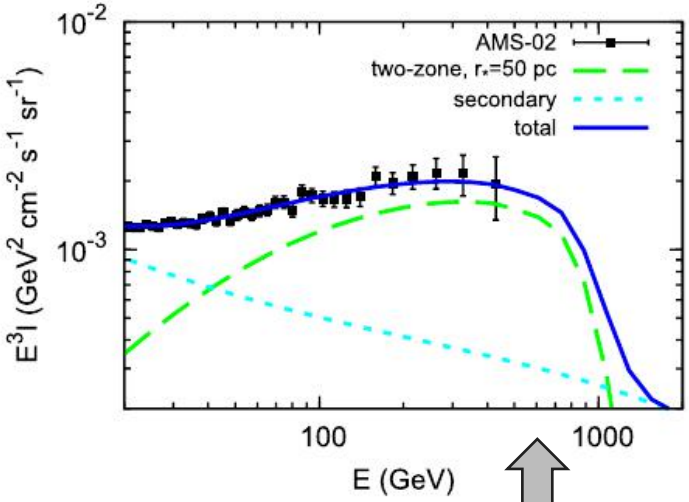
- 以大于4σ的显著性表明高能截断的存在
- 可能对应于某个主导脉冲星的年龄（传播过程的能损）

正电子超出由众多脉冲星贡献？
不！

- 叠加模型无法对截断给出合理的解释
- 截断不可能来自统一的加速上限

重要进展3

Fermi-LAT对Geminga的观测：不利于其对正电子超出的解释？

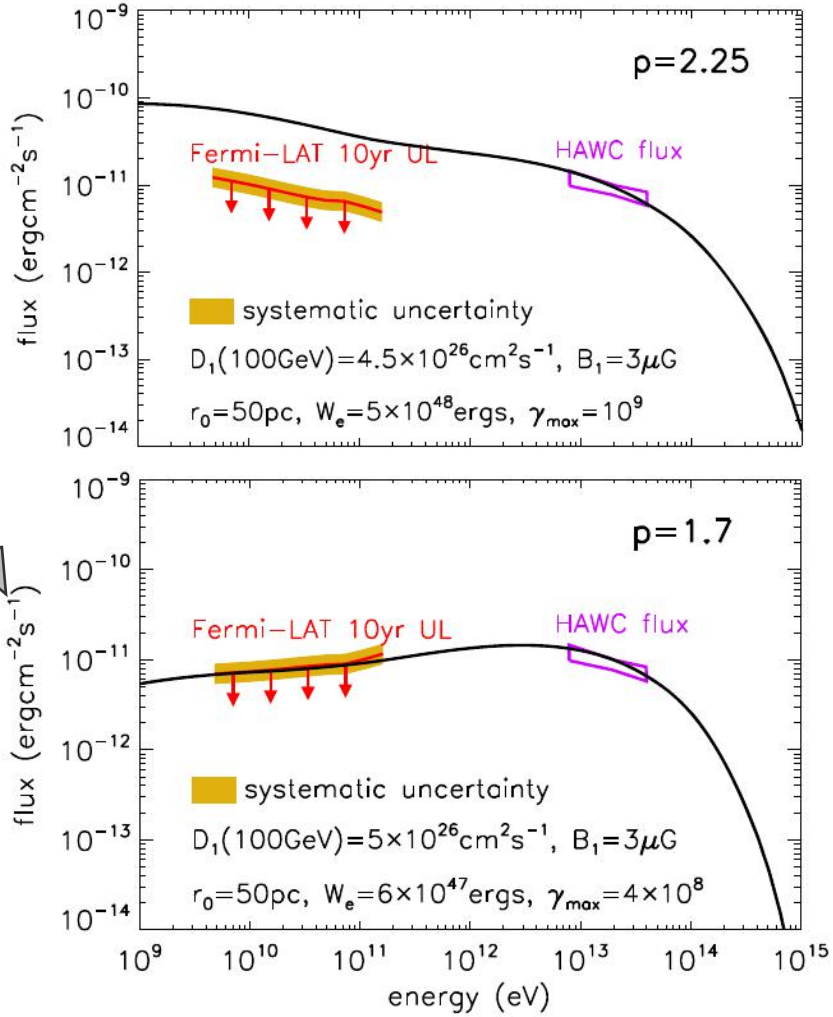


Fang K. et al. 2018

双区扩散下Geminga对正电子能谱的解释

注入谱指数为2.24（HAWC）

- 注入谱指数要显著比HAWC测量的小
- Geminga对正电子的贡献受到限制



Xi S. et al. 2019

目标

在已知的脉冲星（ATNF星表）中寻找解释AMS-02高能正电子能谱的候选脉冲星

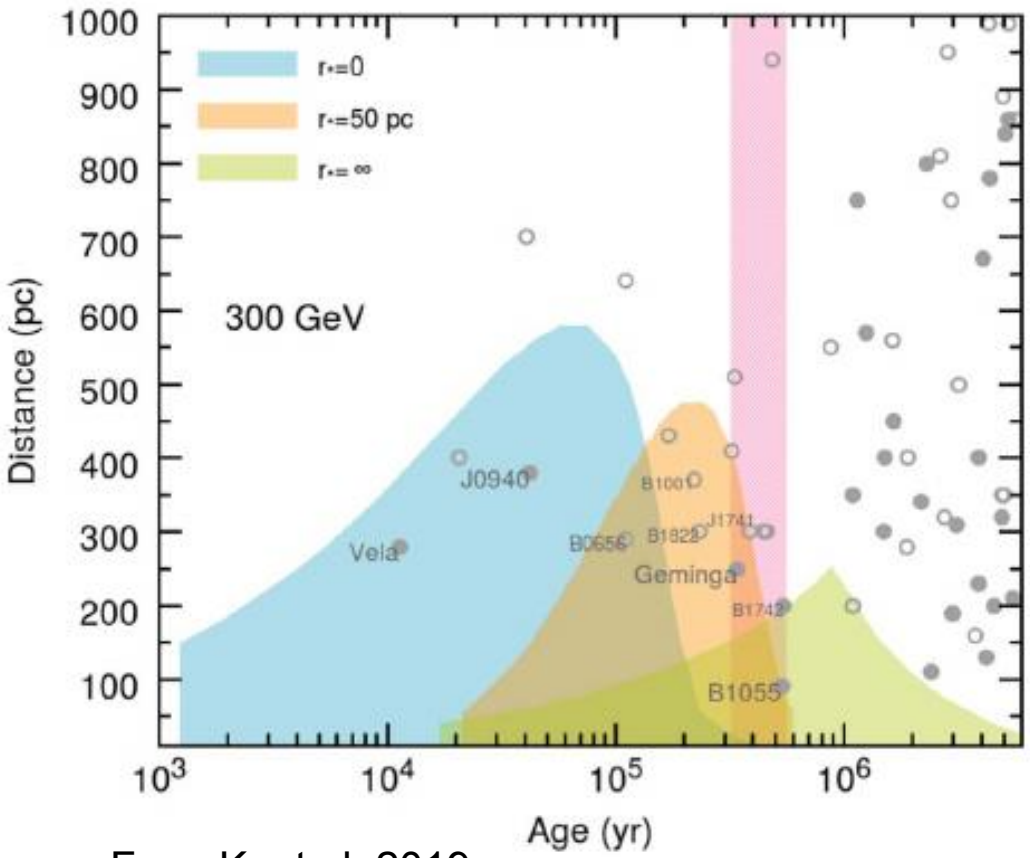
☆基于双区扩散模型计算电子传播

- 对正电子的绝对流量有影响
- 对正电子能谱的谱形有影响

☆考虑AMS-02正电子谱高能截断的约束

- 高能截断与该脉冲星的年龄对应

脉冲星的筛选



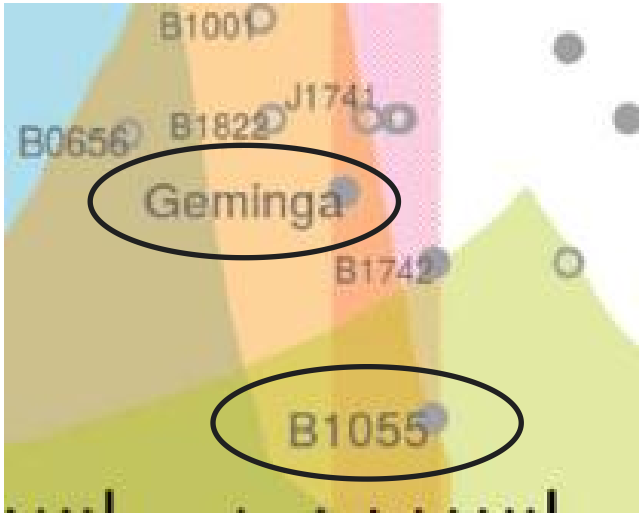
Fang K. et al. 2019

阴影区域：能够对300GeV正电子流量有一半贡献的源

实心点：转动减慢光度较强的脉冲星

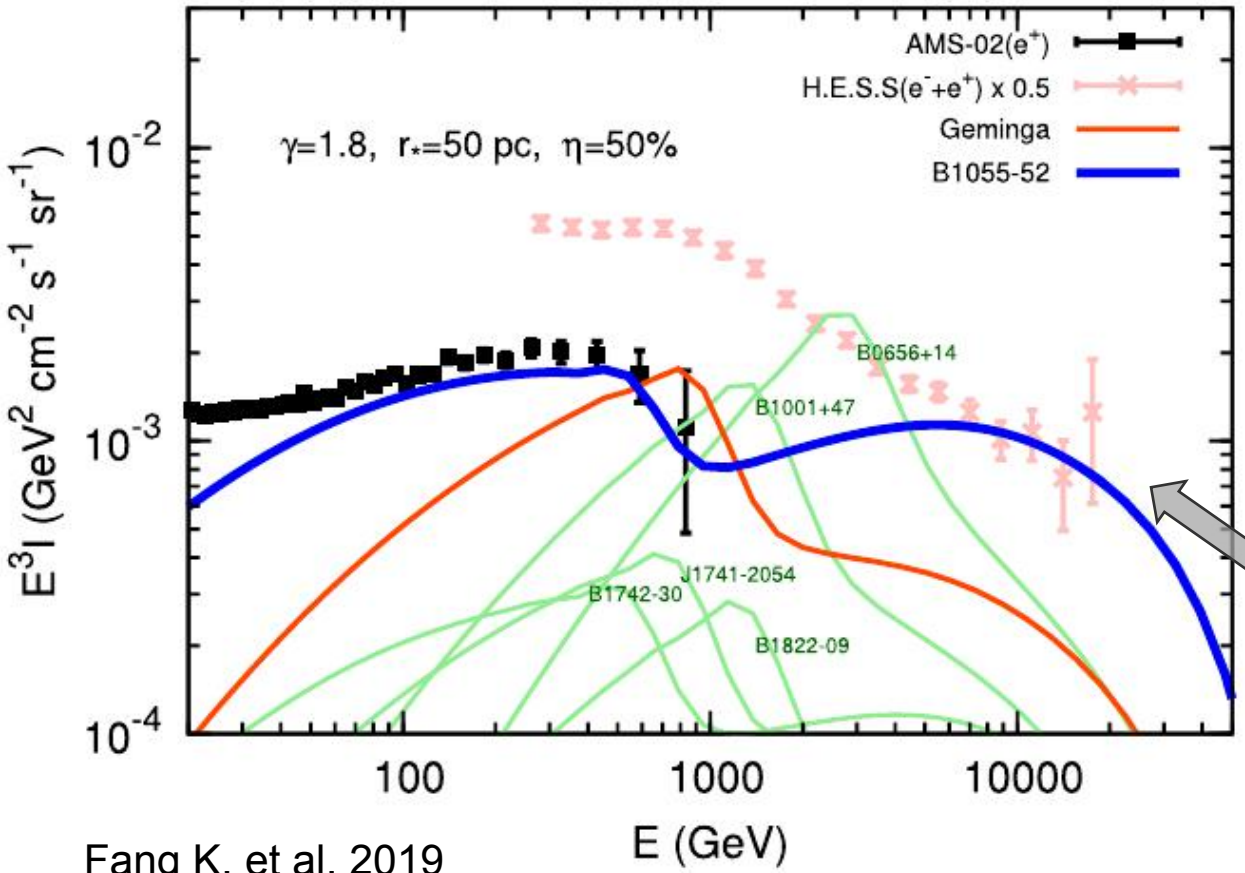
空心点：转动减慢光度较弱的脉冲星

红色带：截断对应的年龄



- 候选脉冲星的范围受到了较好的约束
- PSR B1055-52 与 Geminga

候选脉冲星与正电子能谱



Fang K. et al. 2019

蓝色线：
来自PSR B1055-52的
正电子能谱

图中所有脉冲星采用
了统一的能量转化率

对HESS高能能谱的
可能解释

- PSR B1055-52可以对高能正电子能谱有很好的解释
- 所需要的能量转化率在合理范围内

PSR B1055-52的特征

Monogem B1055-52 Geminga

Geminga，Monogem，B1055-52:

- 年龄相似（~10^2 kyr）
- 转动减慢光度相似（~3×10^{34} erg s-1）
- 磁场相似（~10^{12} G）
- X射线辐射机制相同（BB+PL）
- 都是伽马射线脉冲星
- 都拥有较弱的X射线PWN

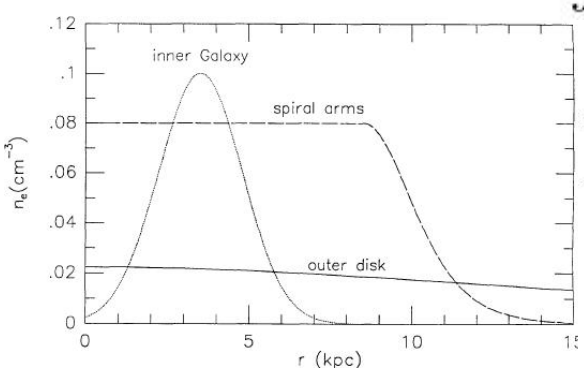
距离：1530 (or 730) pc
DM

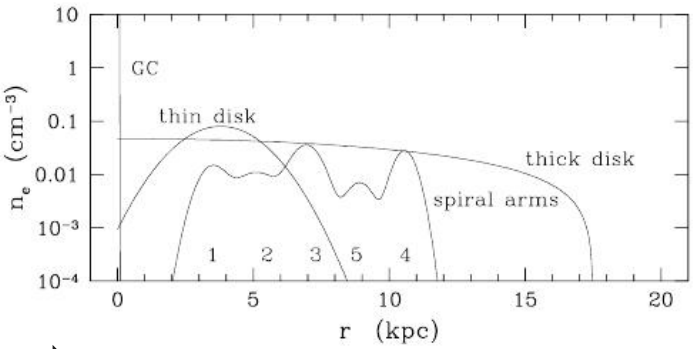
距离：250 pc
PX

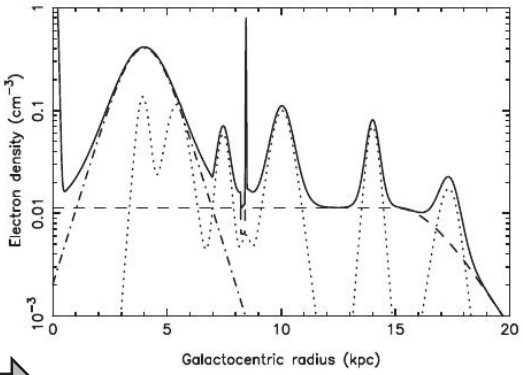
距离：288 pc
PX

PSR B1055-52的距离

色散测量（DM）： $\mathrm{DM} = \int_0^D n_e dl$

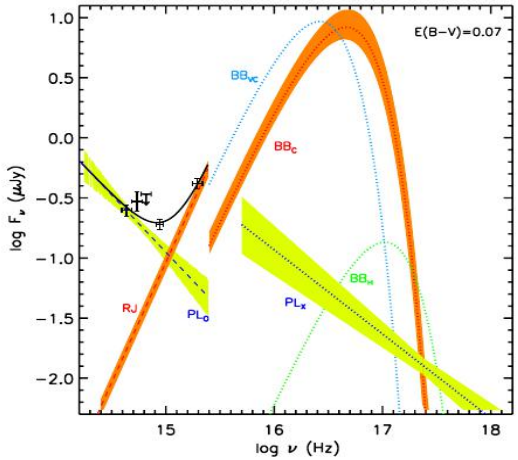




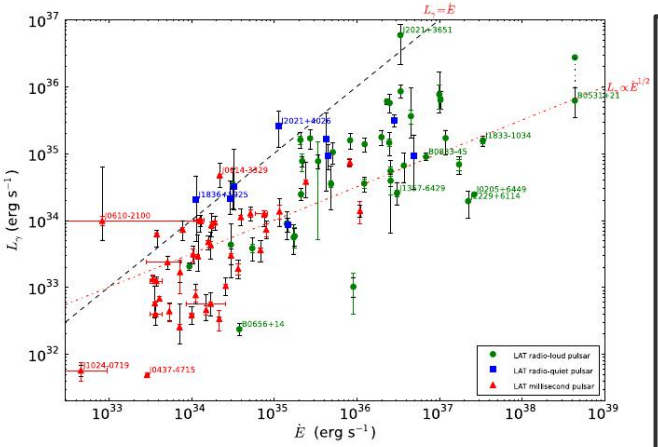


TC93——1530 pc → NE2001——730 pc → YMW16——90 pc

其它观测证据：



Mignani R. et al. 2010



Abdo A. et al. 2013

- 脉冲星的光学和X射线观测表明其距离应比早期测量显著更近
- 伽马射线转化率表明其距离比早期测量显著更近

PSR B1055-52的展望

- 更准确的距离测量：三角视差法

Determining the distance to the gamma-ray pulsar PSR B1055-52 with VLBI

Show affiliations

Hohle, Markus Matthias ; Kargaltsev, Oleg ; Pavlov, George ; Neuhaeuser, Ralph ; Marka, Claudia ; Posselt, Bettina ; Schreyer, Katharina

PSRB1055-52 is one of the rare Neutron stars (NSs) that are detected in radio, near infrared, optical, X-ray and gamma-ray energies that provides enough information to determine the size of its emitting area and to measure the NS radius. However, the radius can only be measured with an accurately known distance. The size of the emitting area can be determined for several other X-ray emitting NSs too, but they are radio-quiet and have only very rough distance estimations (from optical). Only PSRB1055-52 offers us the opportunity to measure the distance precisely (from radio) to determine the radius. With known radius from VLBI distance measurements we are able to find important constrains for the Equation of State.

- 脉冲星周围伽马射线晕的观测：**Fermi-LAT**

B1055的赤经、赤纬：

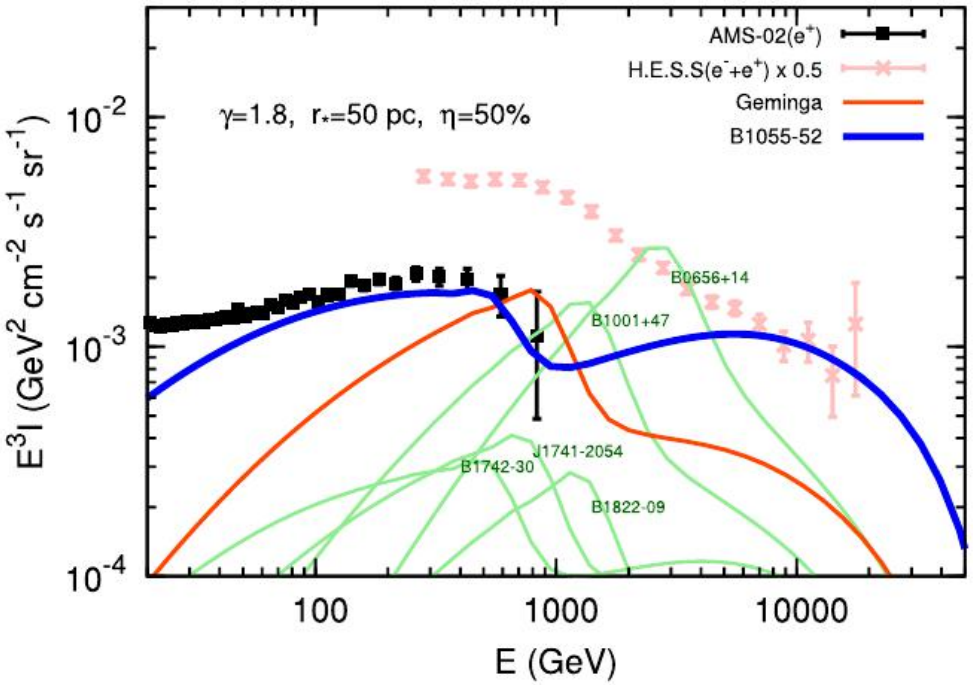
RAJ	10:57:59.045
DECJ	-52:26:56.33

→ 在LHAASO、HAWC天区之外

HESS望远镜：视场太小

总结

- AMS-02测量的高能正电子能谱很可能由某个脉冲星主导
- 在双区扩散模型下遍历了目前已观测到的脉冲星，最有可能的候选者是 **PSR B1055-52**



总结

- AMS-02测量的高能正电子能谱很可能由某个脉冲星主导
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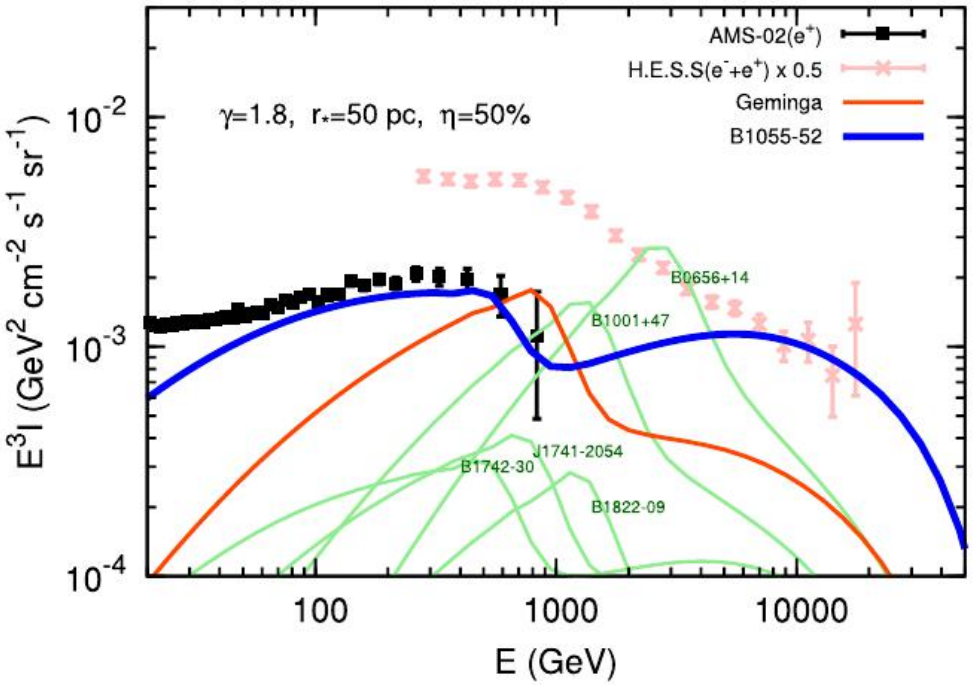

谢谢！