在KM2A上研究”Pulsar Halos”

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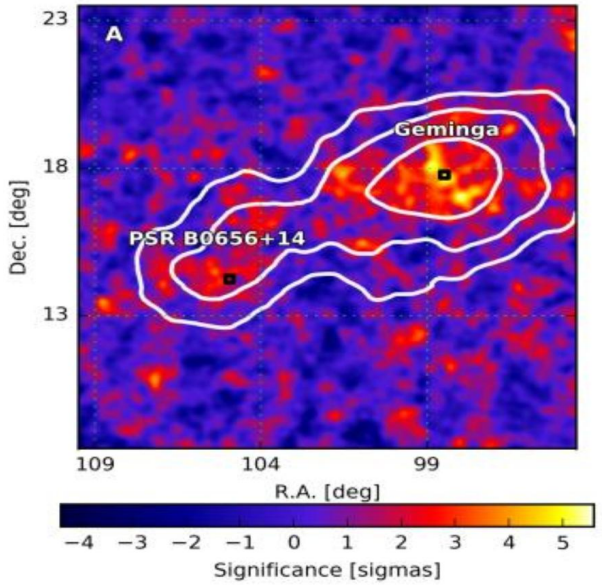
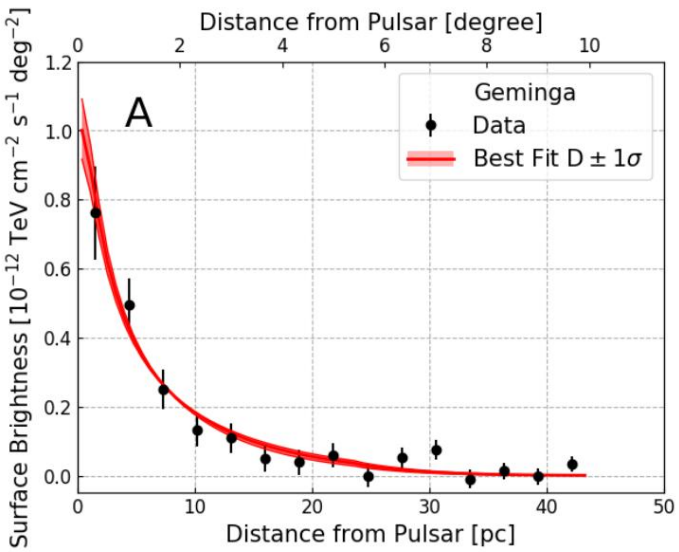
上海 2021年10月13日

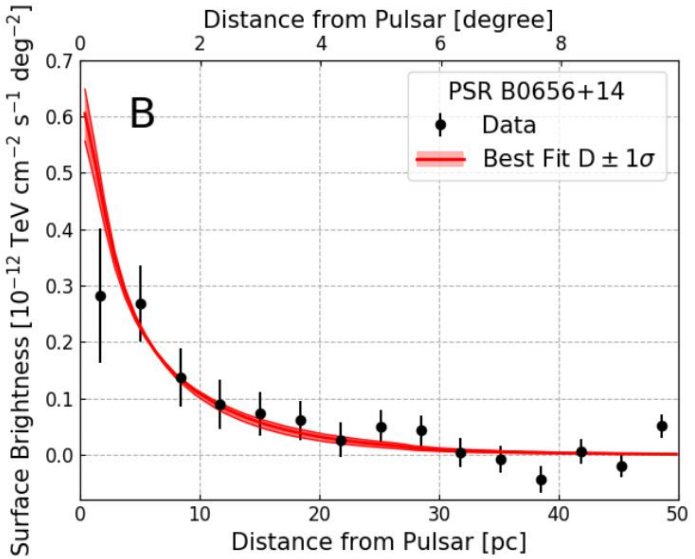
报告内容

- Pulsar halos
- KM2A数据结果
- Pulsar B0540+23 和 Pulsar J1831-0952
- 总结

背景： HAWC(High-Altitude Water Cherenkov Observatory)的观测







age: Geminga 342Kyr

Monogem(B0656+14) 110Kyr

Gamma energy range: 8-40 TeV

Joint fit: $D_{100}=4.5 \pm 1.2 \times 10^{27} cm^2/s$

Low than D_{100} from B/C : 100 times

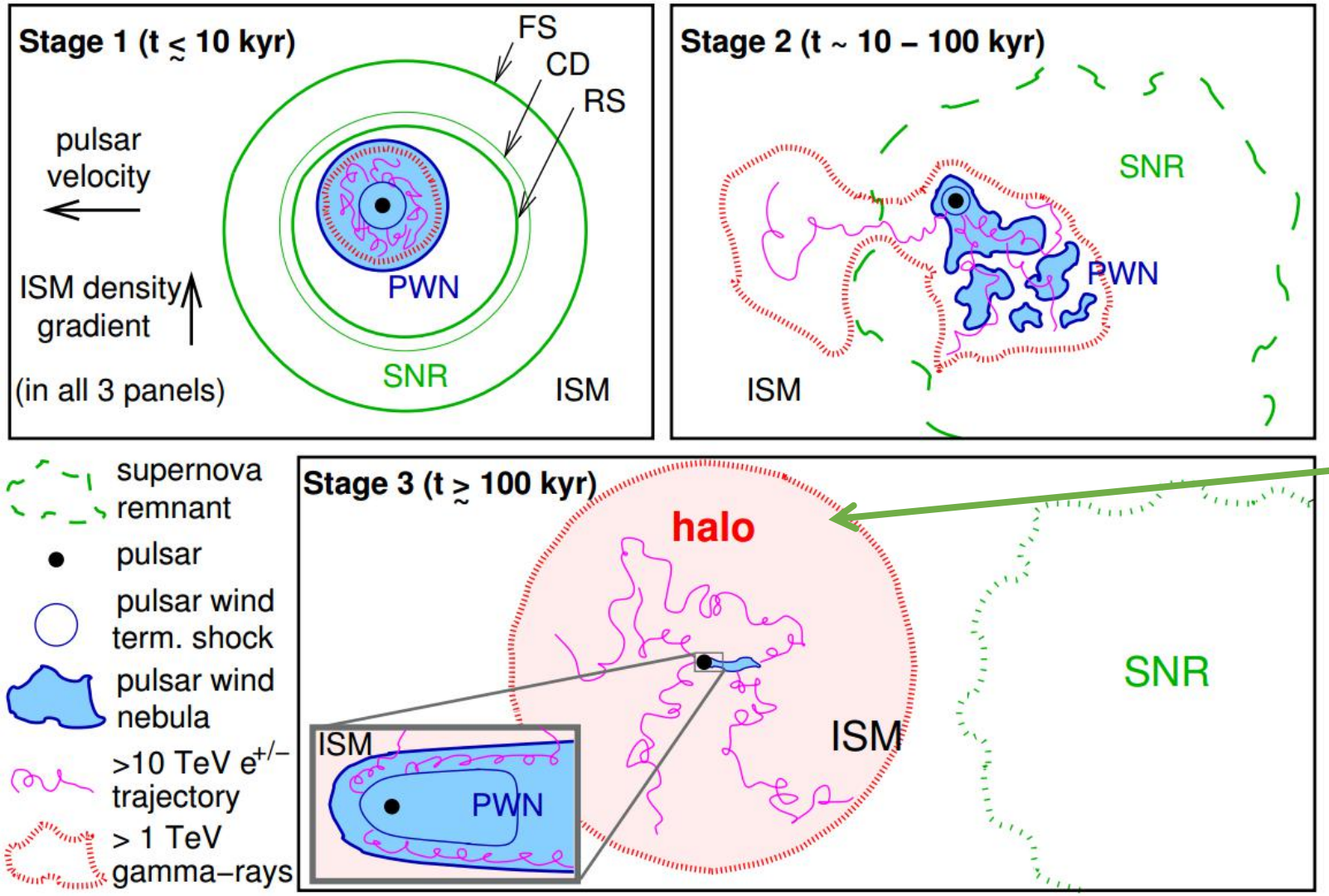
→ **Slow diffusion**

Explain by $e^{\pm}$ from pulsar wind nebula(PWN) inverse Compton scattering(ICS) the background photos

General?

Abeysekara et al., Science 358, 911–914 (2017) 17 November 2017

脉冲星风星云的演化



“Puslar halo”

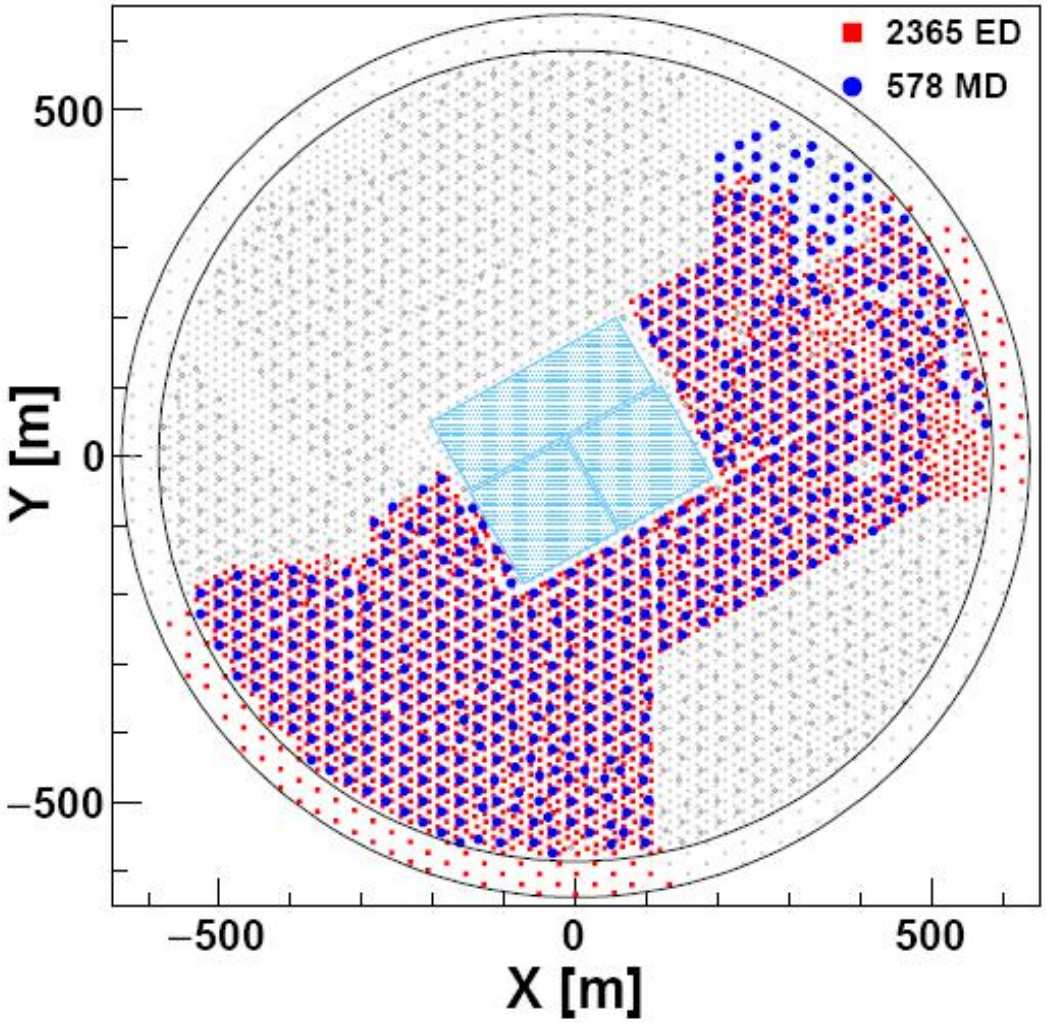
Gaensler, B. M., & Slane, P. O. (2006). The evolution and structure of pulsar wind nebulae. *Annual Review of Astronomy and Astrophysics*, *44*, 17–47.

LHAASO 视场最亮的30个中年脉冲星

NAME	RA (°)	Dec (°)	l (°)	b (°)	r (kpc)	t (100 kyr)	$\dot{E}$ (10^{34}erg s^{-1})	$\dot{E}/r^2$ (10^{34}erg s^{-1}kpc^{-2})	Comments[a]
J0633+1746	98.5	17.8	195.1	4.3	0.19	3.42	3.25	90.03	Geminga, detected by HAWC
B0656+14	105.0	14.2	201.1	8.3	0.29	1.11	3.80	45.18	detected by HAWC
B1951+32	298.2	32.9	68.8	2.8	3.00	1.07	374	41.56	with X-ray PWN, missed in TeV
J1954+2836	298.6	28.6	65.2	0.4	1.96	0.69	105	27.33	detected by Milagro
J1740+1000	265.1	10.0	34.0	20.3	1.23	1.14	23.2	15.33	with X-ray PWN, missed by HAWC
J1913+1011	288.3	10.2	44.5	-0.2	4.61	1.69	287	13.50	detected by HESS,YBJ,HAWC
J1836+5925	279.1	59.4	88.9	25.0	0.30	18.3	1.14	12.67	missed in TeV
J2032+4127	308.1	41.5	80.2	1.0	1.33	2.01	15.2	8.59	detected in X-ray,TeV
J1928+1746	292.2	17.8	52.9	0.1	4.34	0.83	160	8.49	detected by HAWC?
J1831-0952	277.9	-9.9	21.9	-0.1	3.68	1.28	108	7.97	detected by HESS,HAWC
B0114+58	19.4	59.2	126.3	-3.5	1.77	2.75	22.1	7.05	
J0633+0632	98.4	6.5	205.1	-0.9	1.35	0.59	11.9	6.53	detected by HAWC
J0248+6021	42.1	60.4	136.9	0.7	2.00	0.62	21.3	5.33	
B0355+54	59.7	54.2	148.2	0.8	1.00	5.64	4.54	4.54	the Mushroom X-ray PWN
J1938+2213	294.6	22.2	57.9	0.3	3.42	0.62	36.6	3.13	
J0538+2817	84.6	28.3	179.7	-1.7	1.30	6.18	4.94	2.92	with X-ray PWN, missed by HAWC?
B1830-08	278.4	-8.5	23.4	0.1	4.50	1.47	58.4	2.88	with X-ray PWN
J2043+2740	310.9	27.7	70.6	-9.2	1.48	12.0	5.64	2.57	
J2021+4026	305.4	40.4	78.2	2.1	2.15	0.77	11.6	2.51	detected in X-ray,TeV
J1857+0143	284.4	1.7	35.2	-0.6	4.57	0.71	45.1	2.16	detected by HESS,HAWC
B0611+22	93.6	22.5	188.8	2.4	1.74	0.89	6.24	2.06	
J1841-0345	280.4	-3.8	28.4	0.4	3.78	0.56	26.9	1.88	
J1913+0904	288.3	9.1	43.5	-0.7	3.00	1.47	16.0	1.78	
B0540+23	85.8	23.5	184.4	-3.3	1.56	2.53	4.09	1.68	detected by HAWC
J1846+0919	281.6	9.3	40.7	5.3	1.53	3.60	3.41	1.46	
J0611+1436	92.8	14.6	195.4	-2.0	0.89	10.7	0.80	1.01	
J0357+3205	59.5	32.1	162.8	-16.0	0.83	5.40	0.59	0.85	missed by ASgamma
J1838-0549	279.7	-5.8	26.3	0.2	4.06	1.12	10.1	0.61	
B0919+06	140.6	6.6	225.4	36.4	1.10	4.97	0.68	0.56	
J1835-0944	278.9	-9.7	22.5	-1.0	4.22	5.25	5.64	0.32	

from Fang kun

KM2A 数据



Half Array

2019.12.27-2020.12.07

Live time: 320 days

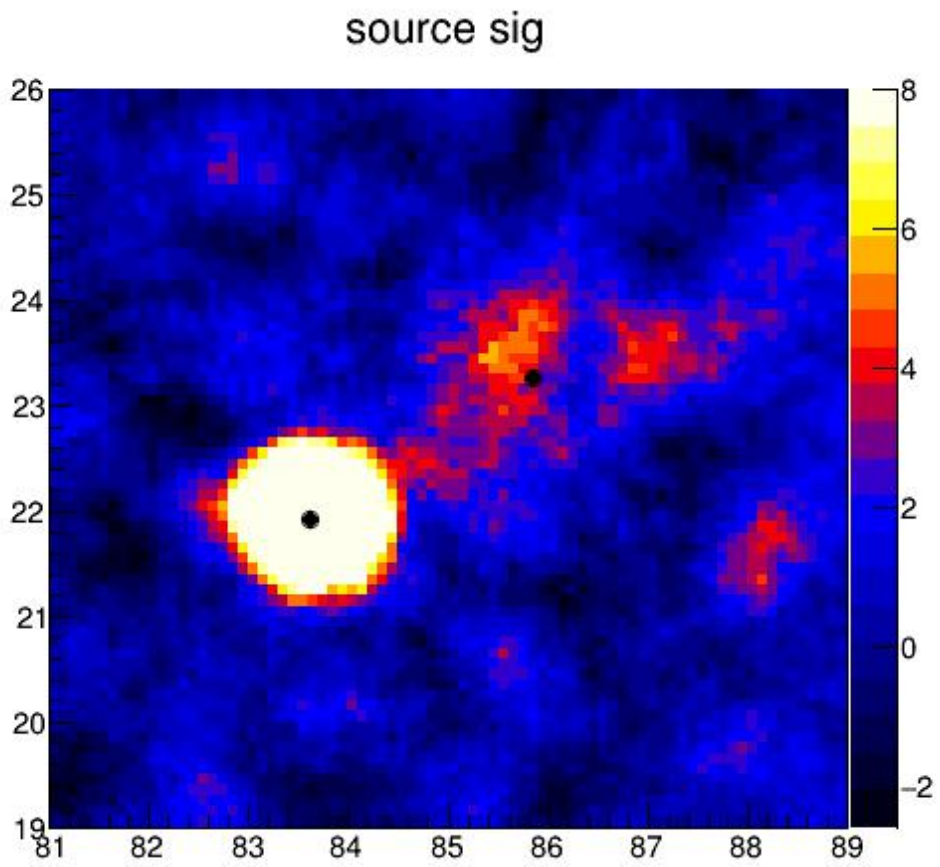
Background:
Equi-zenith angle method

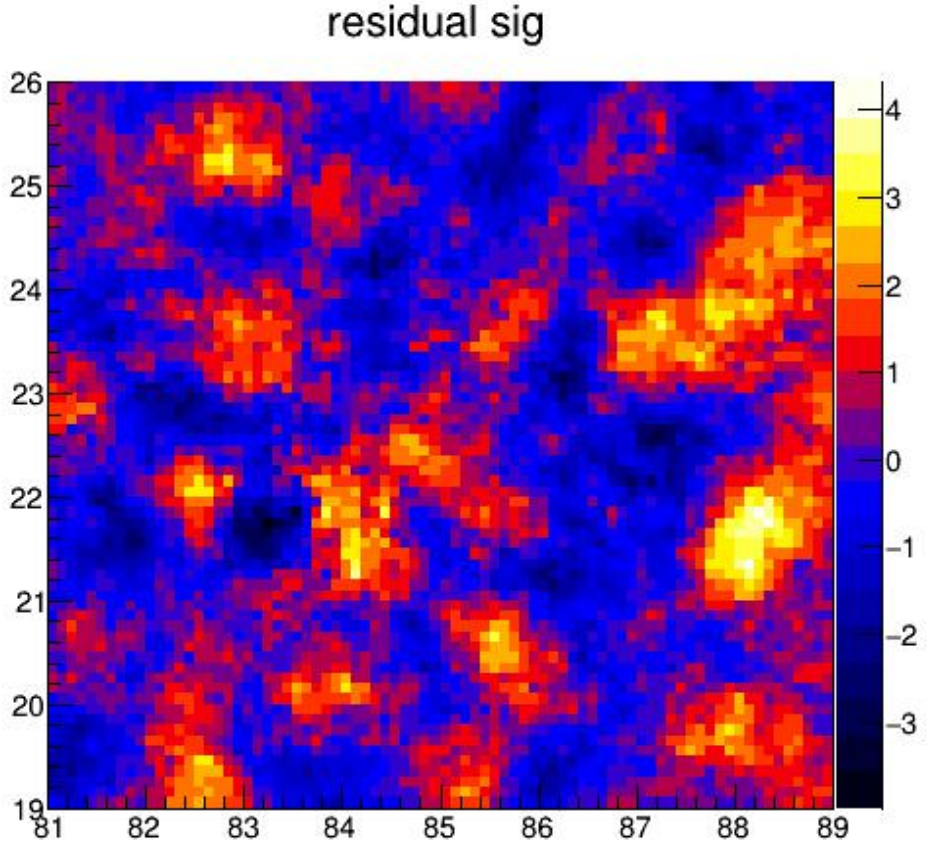
Puslar halos Candidate

Pulsar	(Ra(∘),Dec(∘))	Extension(∘)	TS(Point)	TS(Diffu)	Age(kyr)	Distance(pc)
Geminga	(98.6, 17.5)	6.62 ± 0.66	179.7	668.1	340	250
Monogem	(105.1, 14.5)	6.58 ± 1.58	55.3	213.5	110	288
J0622+3749	(95.6, 37.9)	0.83 ± 0.19	68.3	84.1	207	160
B0540+23	(85.9, 23.5)	1.58 ± 0.41	33.4	48.3	253	1560
J1831-0952	(277.8, -9.9)	1.43 ± 0.41	53.7	77.8	128	3680
J2229+6114	(336.9, 60.9)	1.22 ± 0.14	351.1	435.3	10.5	3000
J2238+5903	(338.9, 59.4)	5.08 ± 1.99	94.4	207.3	26	2830
J2021+4026	(305.4, 40.5)	1.08 ± 0.33	40.7	49.6	77	2150
J0633+0632	(42.5, 60.5)	1.60 ± 0.75	18.7	17.7	59	135
J0248+0621	(42.7, 60.4)	1.62 ± 1.06	16.4	20.4	62	2000

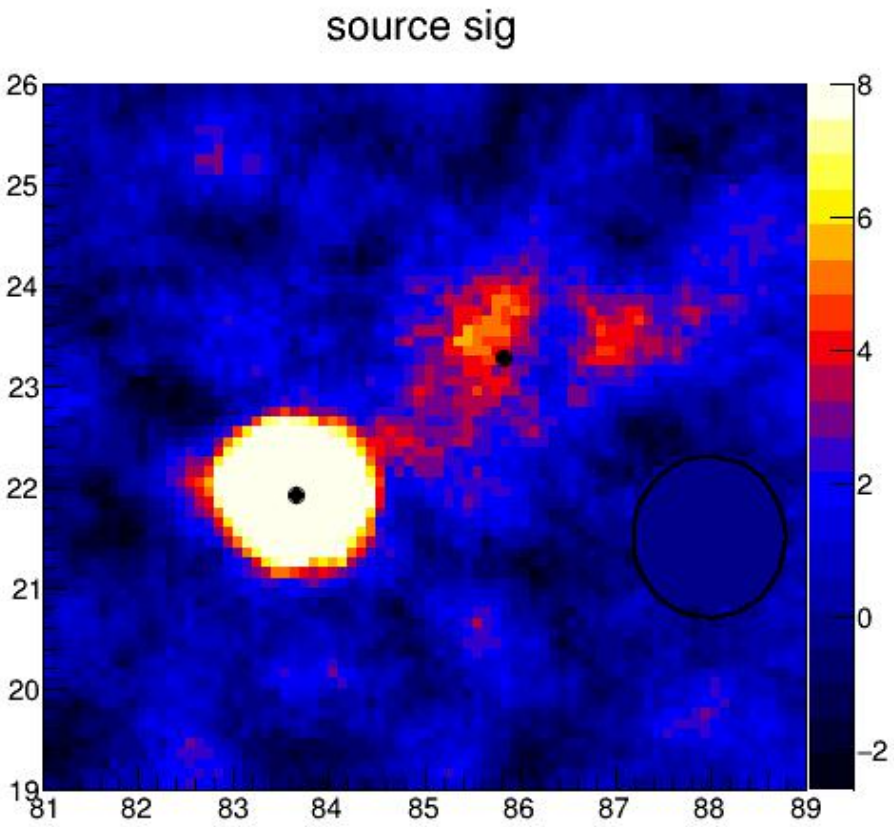
$$\frac{d^2N}{dEd\Omega} = N_0 \left(\frac{E}{20\ \mathrm{TeV}}\right)^{-\alpha} \frac{1.22}{\pi^{3/2}\theta_d(E)(\theta + 0.06\theta_d(E))} \exp(-\theta^2/\theta_d(E)^2)$$

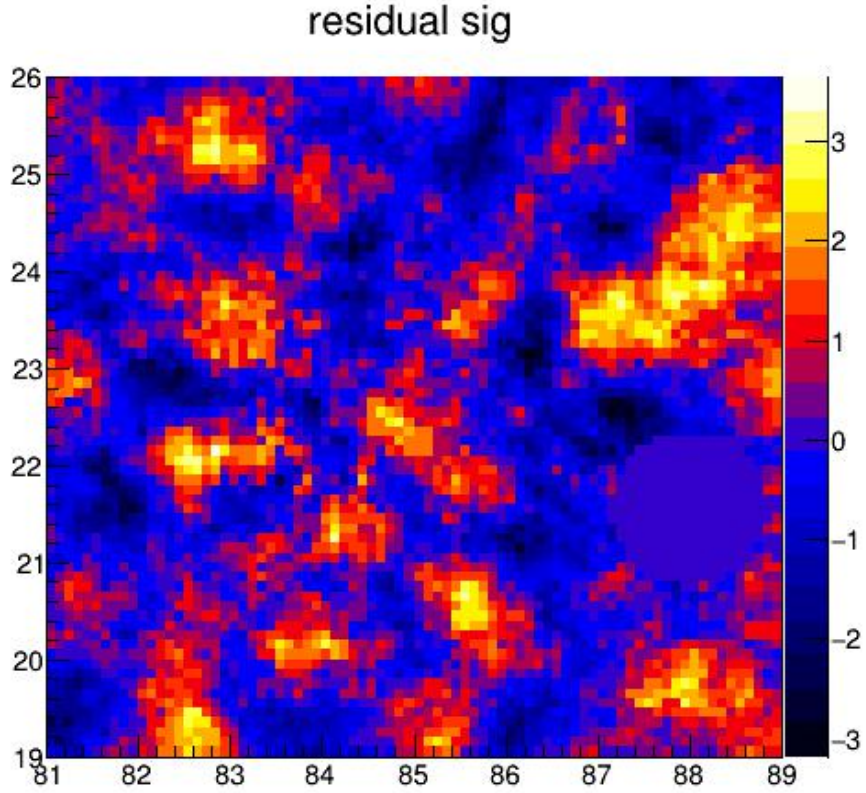
B0540+23





Energy	Model	Ra(°)	Dec(°)	RA(°)	dec(°)	Extension(°)	Np	TS
>25TeV	Point+Point	83.6±0.01	21.9±0.01	85.7±0.05	23.5±0.03	-	6	1624.7
	Point+Gauss	83.6±0.01	21.9±0.01	85.8±0.11	23.3±0.11	0.81±0.13	7	1658.1





Energy	Model	Ra(°)	Dec(°)	RA(°)	dec(°)	Extension(°)	Np	TS
>25TeV	Point+Point	83.6±0.01	21.9±0.01	85.7±0.05	23.5±0.03	-	6	1624.68
	Point+Gauss	83.6±0.01	21.9±0.01	85.8±0.18	23.3±0.15	0.79±0.12	7	1657.85
	Point+HAWC	83.6±0.01	21.9±0.01	85.7±0.12	23.3±0.12	2.27±0.66	7	1657.83

Diffusion Model

$$\frac{dN}{dt} - \nabla(D\nabla N) - \frac{\partial}{\partial E}(bN) = Q$$

$$N_e(E,t,r) = \frac{1}{(4\pi\lambda^2)^{3/2}} \frac{b(E_0)}{b(E)} e^{-r^2/\lambda^2} Q(t,E_0)$$

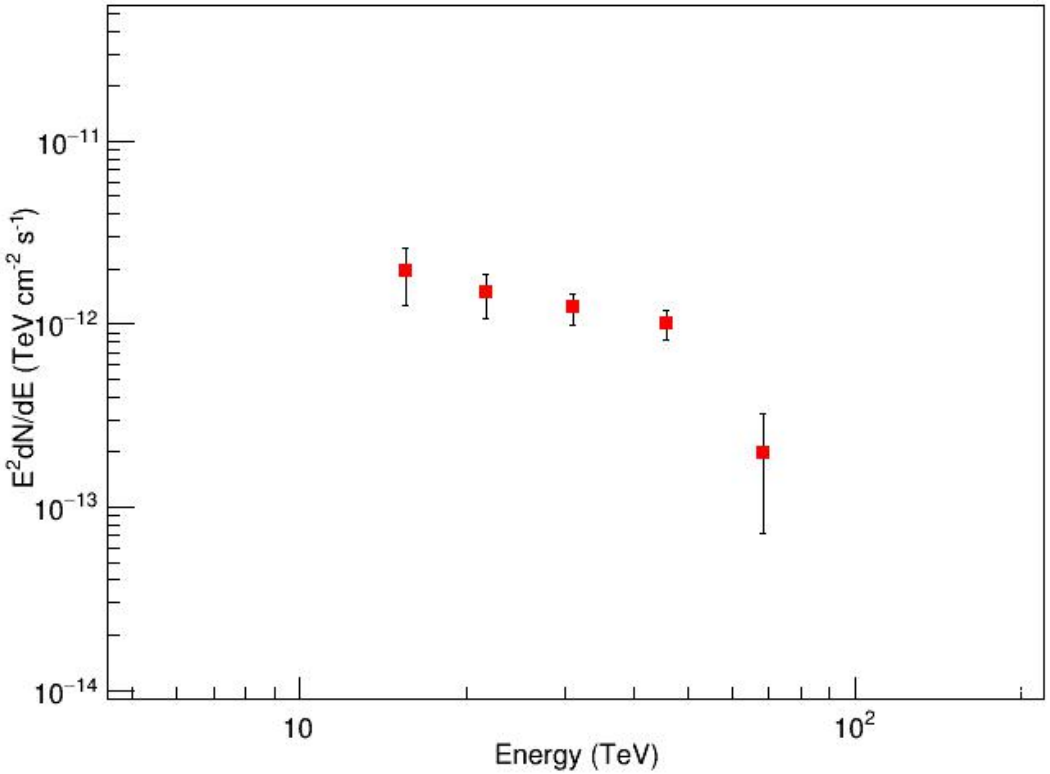
$$\int_{E_{\min}}^{E_{\max}} Q(t_s,E)EdE = \eta L$$

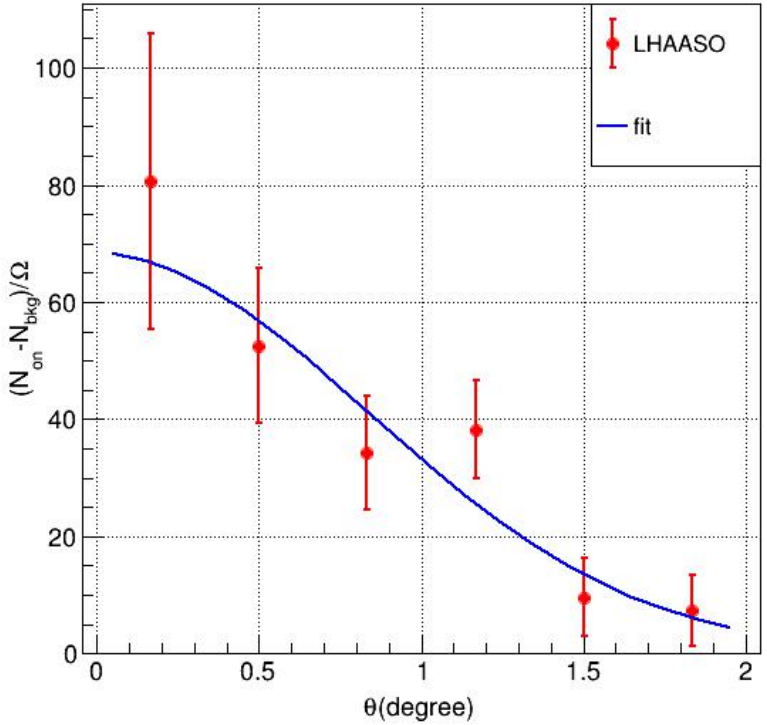
$$\lambda^2 = 4\int_E^{E_0} \frac{D(E')}{b(E')}dE' \simeq \frac{4D_0\left[1-(E/E_0)^{1-\delta}\right]}{b_0(1-\delta)E^{1-\delta}}$$

电子谱: $E^{-\gamma}e^{-\left(\frac{E}{E_{cut}}\right)^{\beta}}$ β=2

扩散系数: $D = D_0\left(\frac{E}{E_0}\right)^{\delta}$ δ= 0 .33

模型参数: D0, eta, gam, Ecut



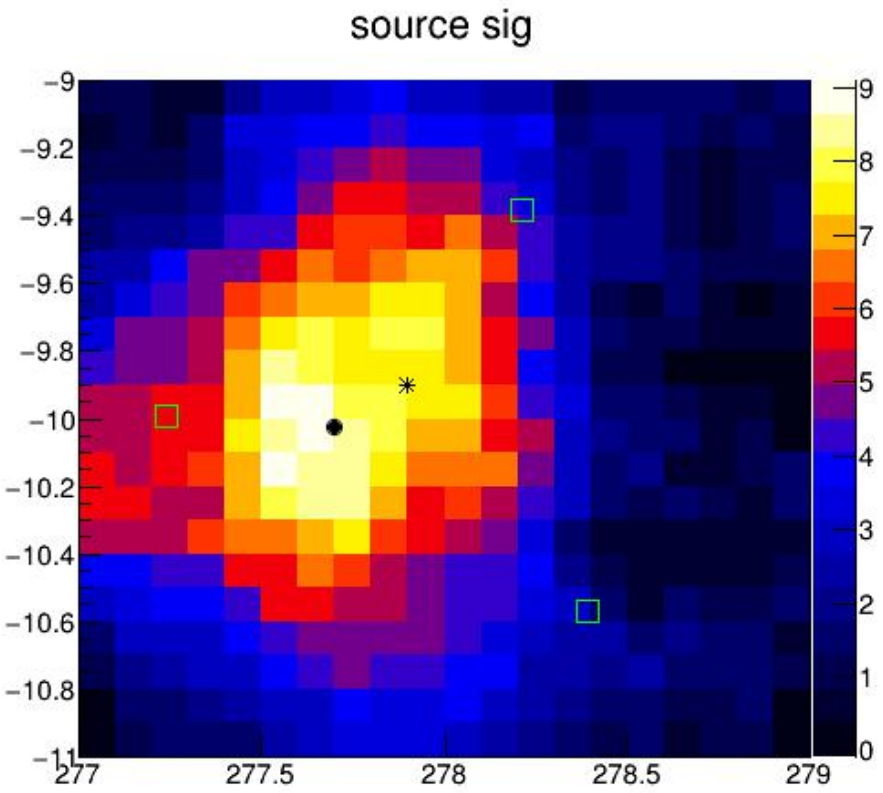


gam=1.0

Ecut=114 TeV
eta=0.41

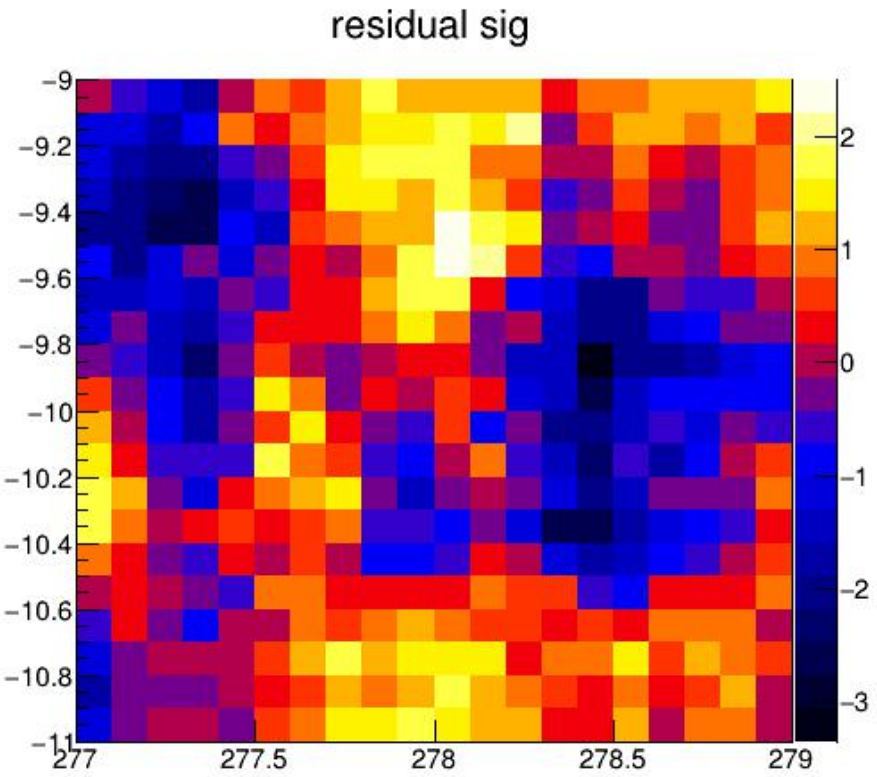
D100: 1.15e28 ± 0.55e28

J1831-0952

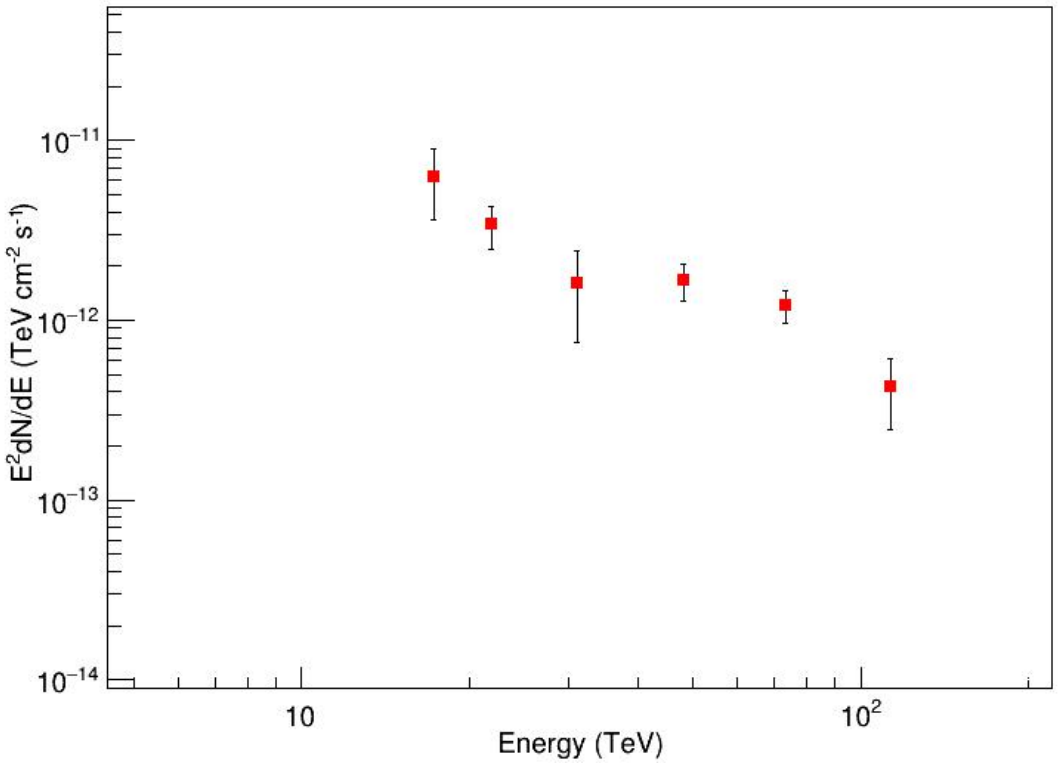


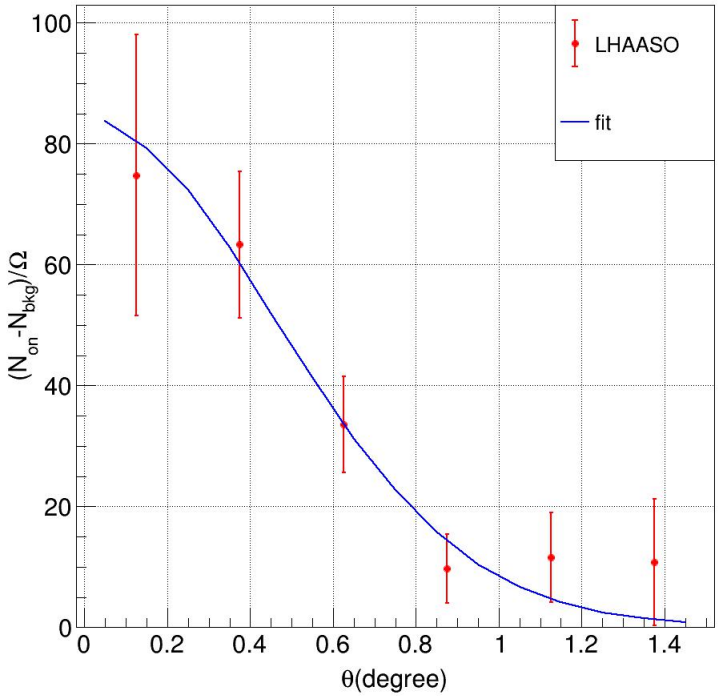
HESS J1831-098

HESS J1832-093
HESS J1833-105
HESS J1828-099



Energy	Model	Ra(°)	Dec(°)	Extend(°)	Np	TS
>40TeV	Point	277.7±0.05	-10.0±0.06	-	3	101.3
	Gauss	277.7±0.01	-10.0±0.01	0.36±0.08	4	114.3
	HAWC	277.7±0.02	-10.0±0.01	0.84±0.28	4	115.1
	Gauss+3point	277.6±0.02	-10.1±0.01	0.29±0.09	7	115.9



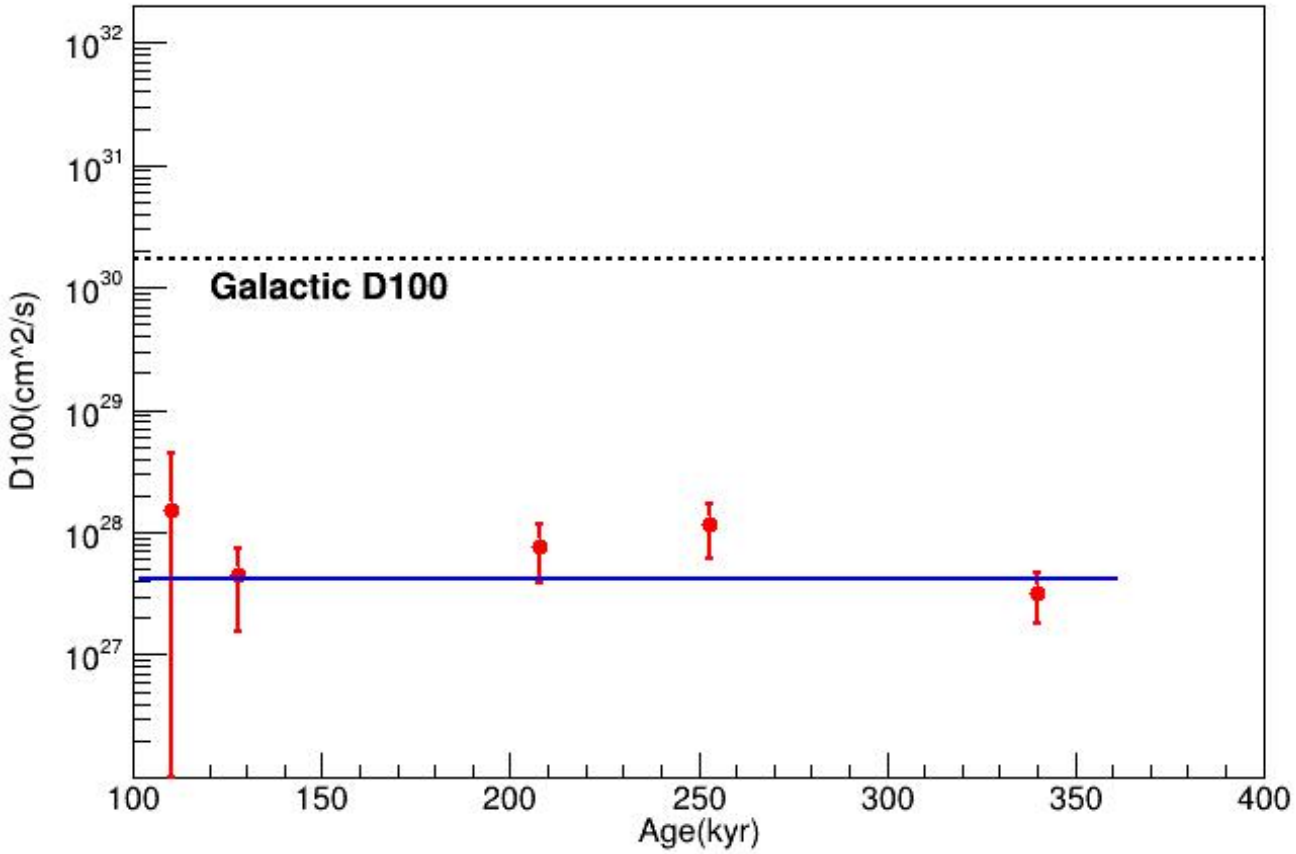


gam=1.0

Ec=186
eta=0.11

D100: 4.45e27 ± 2.9e27

Slow diffusion ?



Monogem

J1831-0952

J0622+3749

B0540+23

Geminga

chi2/ndf = 3.2/4

D100=4.2±1.2 e27

Conclusion

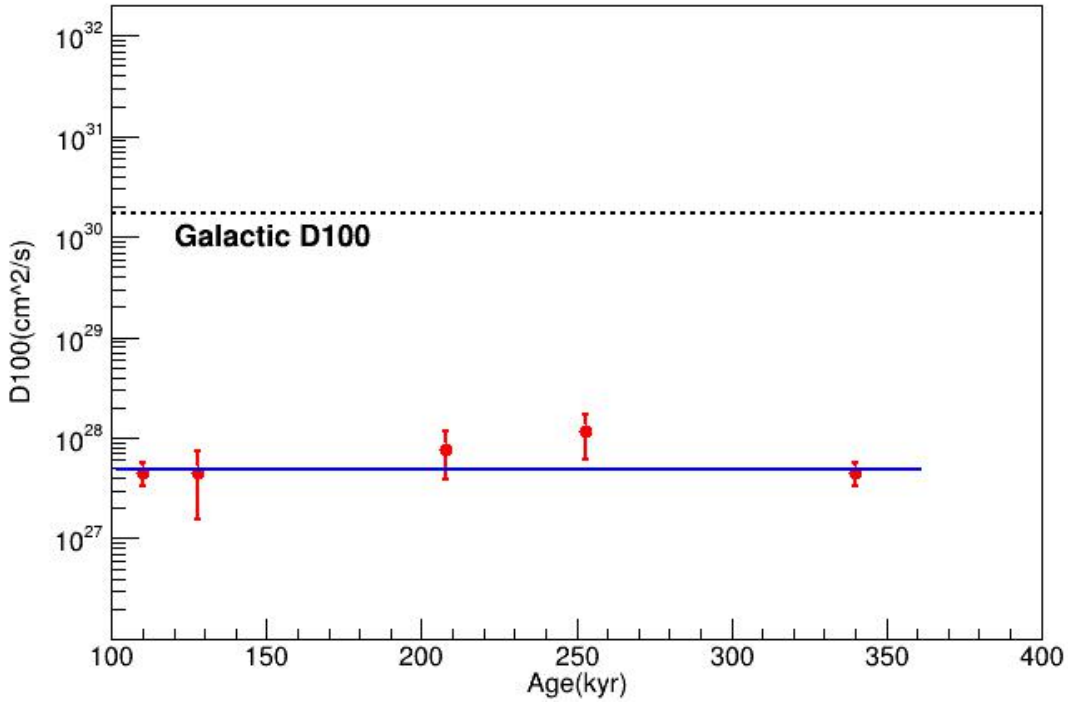
- We list pulsar halo candidates using KM2A data. Many pulsar halos will be found by LHAASO

- We analysis two LHAASO sources, corresponding to pulsar B0540+23 and J1831-0952. In diffusion model, their diffusion coefficient is similar to HAWC Geminga.

- For pulsar Geminga, Monogem, J0622+3749, B0540+23, J1831-0952, their halos have similar diffusion coefficient. Slow Diffusion is general for pulsar halos ?

Back up

Slow diffusion ?



Monogem

J1831-0952

J0622+3749

B0540+23

Geminga

chi2/ndf = 2.2/4

D100=4.77±0.78 e27