高エネルギーガンマ線天文学 A

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Tokyo, Japan

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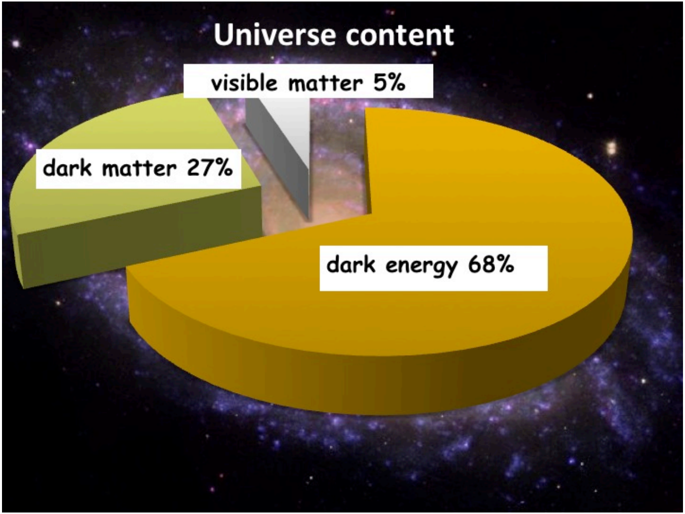
Dark matter in the Universe



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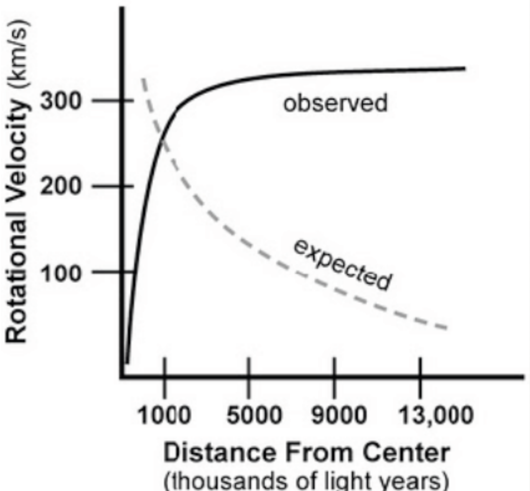
The fact of astronomical observation

Rotation curve analysis

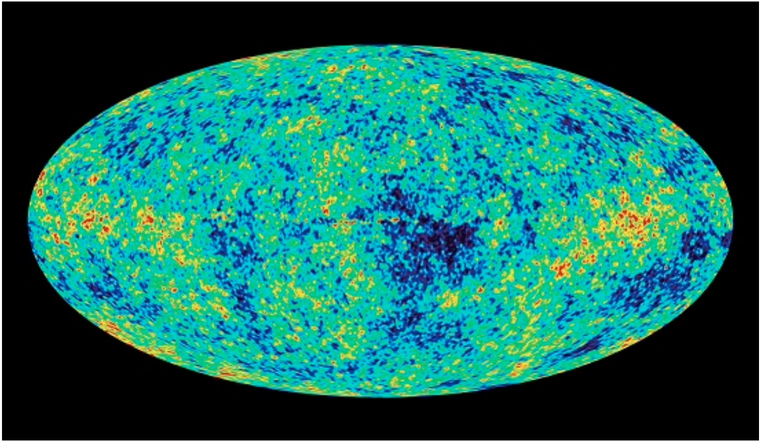


The fact of astronomical observation

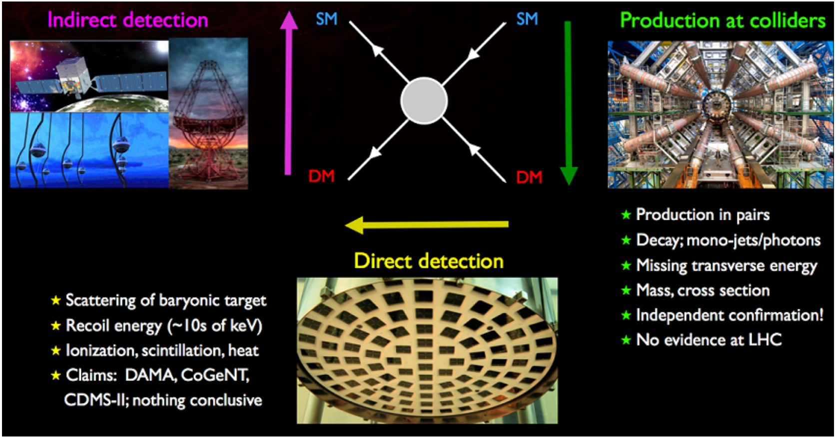
Gravitational lensing

The fact of astronomical observation

Cosmic Microwave Background

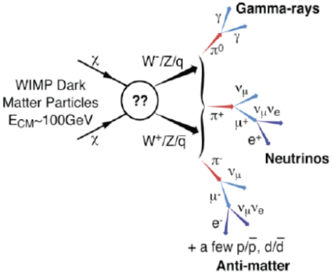


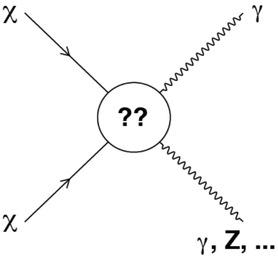
Particle physics candidate



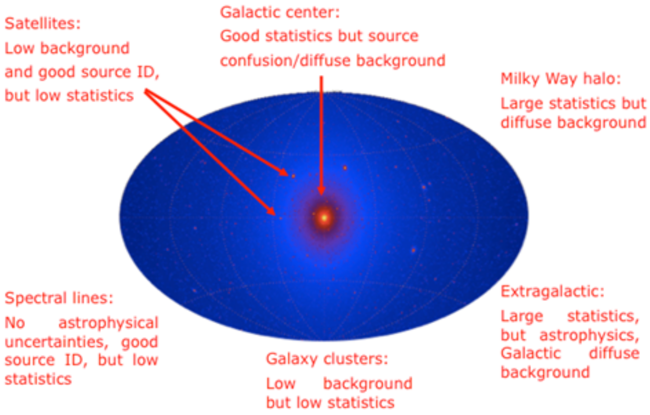
Particle physics candidate

$$\Phi(E,\Psi)_{\mathrm{WIMP}} = \underbrace{\frac{1}{2}\frac{\langle\sigma v\rangle}{m^2_{\mathrm{WIMP}}}\sum_f \frac{dN_f}{dE}B_f}_{\text{Particle physics factor}} \times \underbrace{\int_{l.o.s} dl(\Psi)\rho^2(l)}_{\text{Astrophysical factor}}$$





Searching dwarf galaxy



We observed spheroidal dwarf galaxy, Segue1

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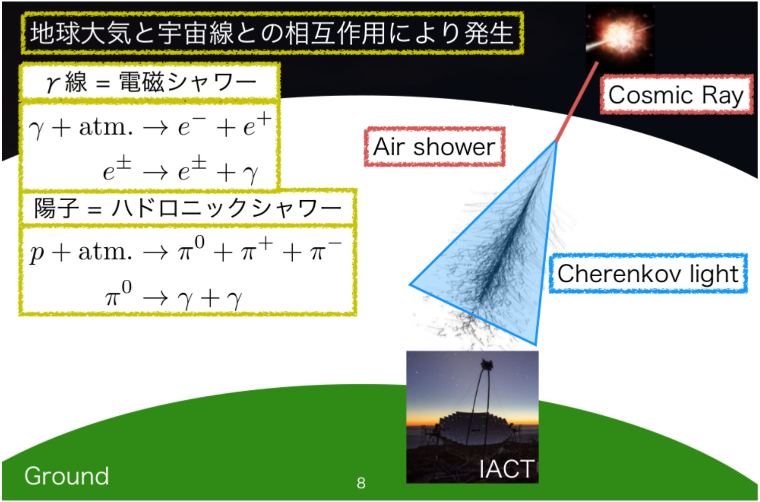
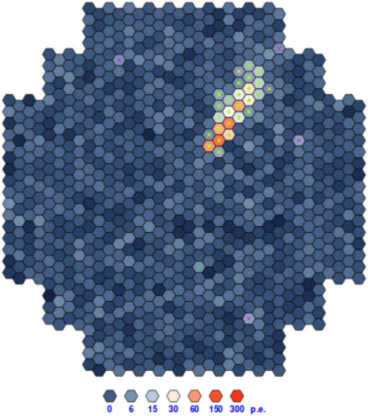
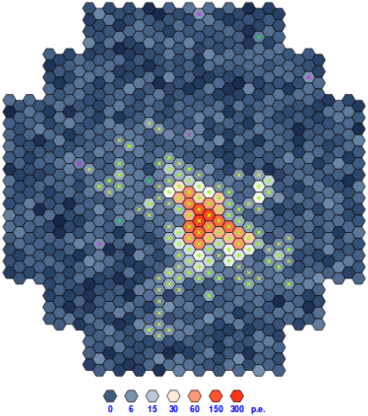
Air shower


地球大気と宇宙線との相互作用により発生
γ線 = 電磁シャワー
$\gamma + \mathrm{atm.} \to e^- + e^+$
$e^\pm \to e^\pm + \gamma$
陽子 = ハドロニックシャワー
$p + \mathrm{atm.} \to \pi^0 + \pi^+ + \pi^-$
$\pi^0 \to \gamma + \gamma$
Cosmic Ray
Air shower
Cherenkov light
IACT
Ground

How to distinguish between Hadron and γ ray



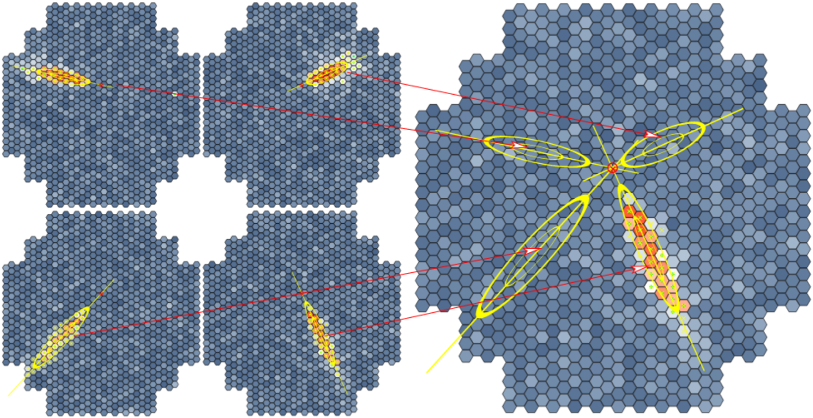
1.0 TeV gamma shower



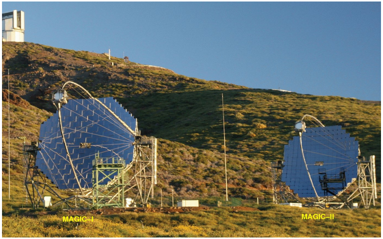
2.6 TeV proton shower

Arrival direction

Multiple telescope



MAGIC telescope



- Location : La Palma, Spain
- FoV $\sim 3.5\,\mathrm{deg}$
- Energy : $\sim 50\,\mathrm{GeV}$ - 100 TeV
- Sensitivity : $\sim 0.7\,\%$ of Crab Nebula units
- Energy resolution $\sim 16\,\%$
- Spatial resolution $\sim 0.07\,\mathrm{deg}$

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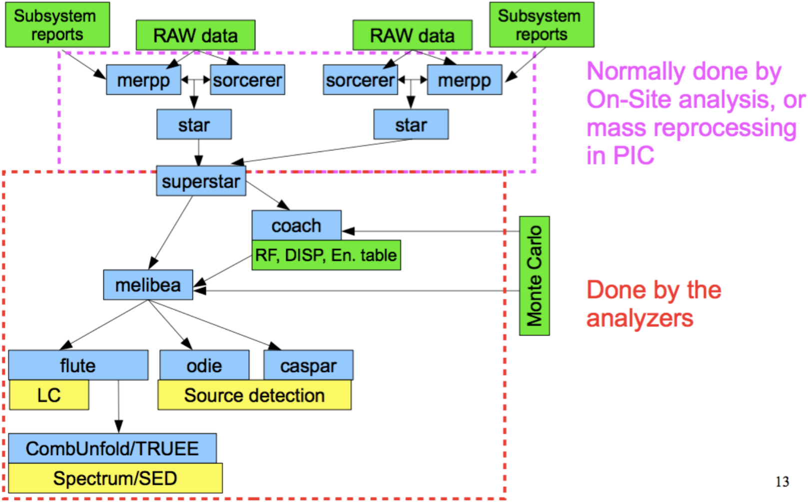
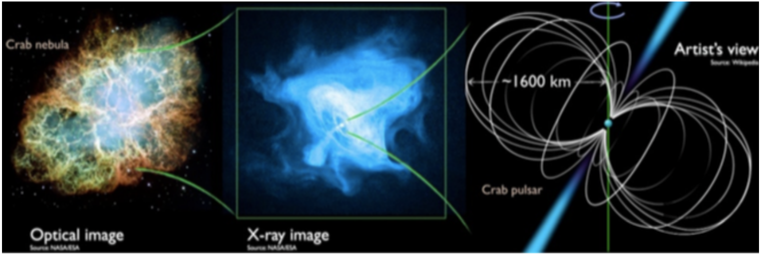
How to analyze our data — MARS



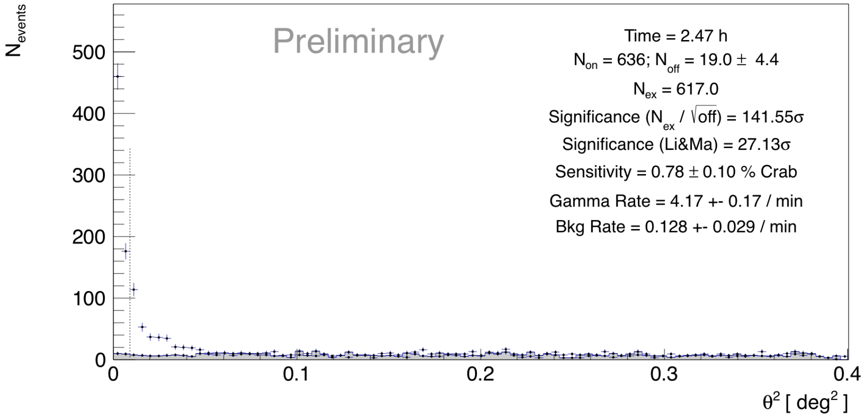
Analyzing data from Crab Nebula

Crab Nebula is the brightest γ-ray source in the galaxy. Inside the nebula, there is a young pulsar, emitting γ-rays. We analyzed the data and got:

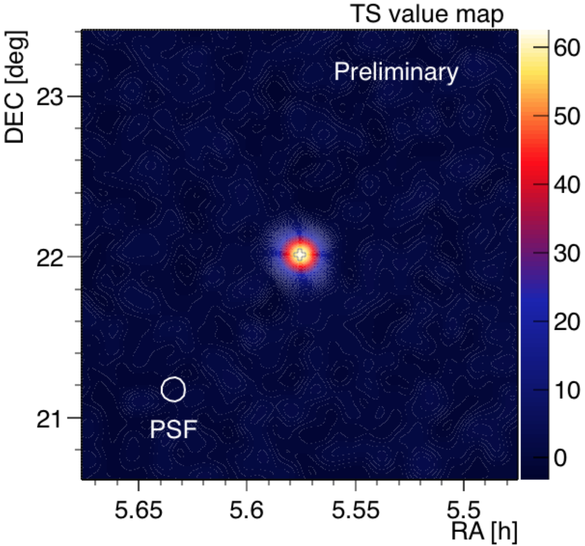
- evidence that there are signals
- skymaps
- data of flux



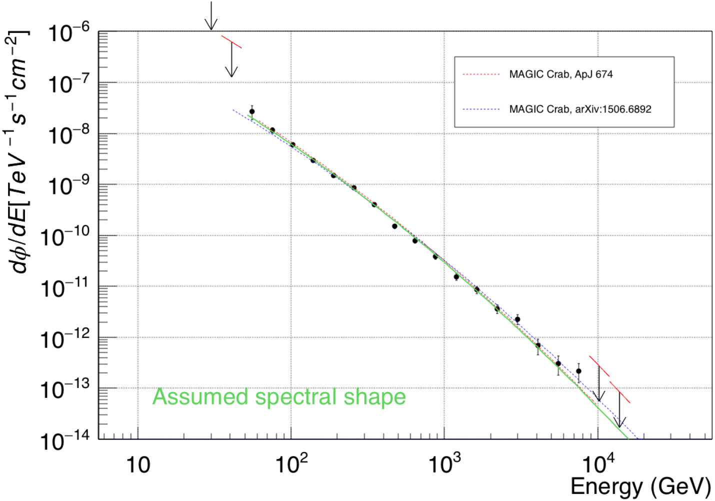
Our result — Are there signals from Crab Nebula?



Our reslut — Significance map



Our result — Flux

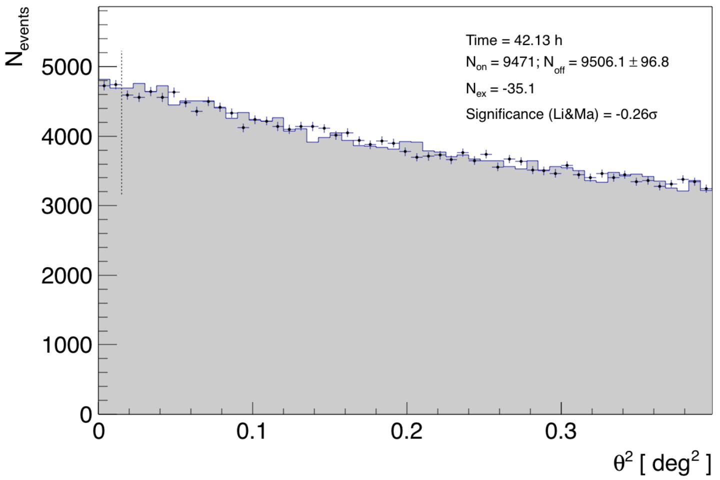


Searching dark matter by analyzing Segue1

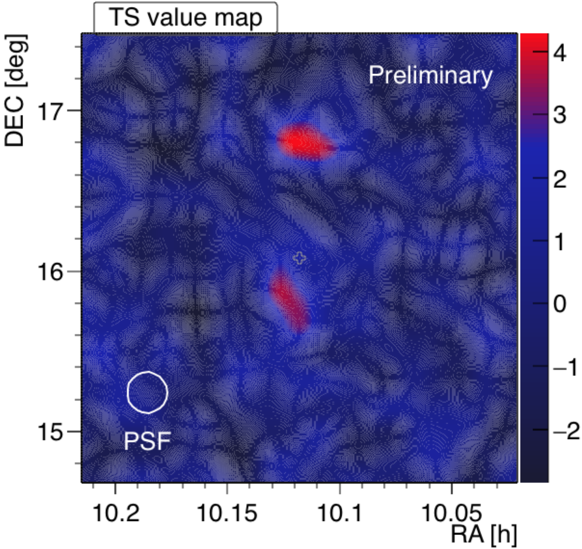
If we can detect γ-rays from Segue1, there is high probability that they are emitted by DM pair annihilation.
We analyzed Segue1 data in the same way as Crab Nebula, getting skymaps and data of flux. Referring upper limit of flux, we calculated:

- the upper limit of $\langle\sigma v\rangle$: $\langle\sigma v\rangle^{UL}$
  (σ is cross section of DM annihilation of each reaction.)
- the lower limit of τ: τ^{LL}
  (τ is the decay time of single DM.)

Our result — Are there signals from Segue1?



Our reslut — Significance map



How to calculate $\langle\sigma v\rangle^{UL}$ and τ^{LL}

ANNIHILATION

$$\frac{dN_\gamma}{dE} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2M_\chi^2}\sum_f B_f \frac{dN_\gamma^f}{dE}\int_{\Delta\Omega}\int_{l.o.s.} d\Omega \; dl \;\; \rho(l)^2$$

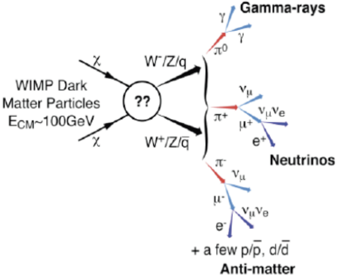
DECAYS

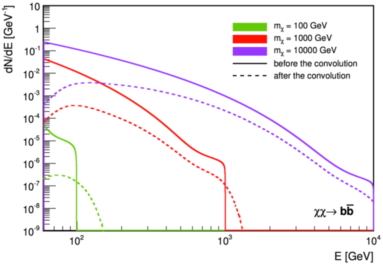
$$\frac{dN_\gamma}{dE} = \frac{1}{4\pi}\frac{1}{M_\chi \tau}\sum_f B_f \frac{dN_\gamma^f}{dE}\int_{\Delta\Omega}\int_{l.o.s.} d\Omega \; dl \;\; \rho(l)$$

DM annihilation and decay

First, we assumed these patterns of annihilation and decay.

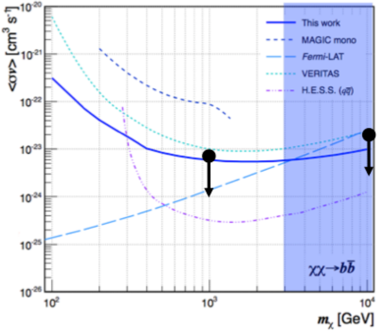
- ANNIHILATION: $\chi + \chi \to b + \bar{b} \quad \chi + \chi \to \tau^+ + \tau^-$
- DECAY: $\chi \to b\ \bar{b} \quad \chi \to \tau^+ \tau^-$



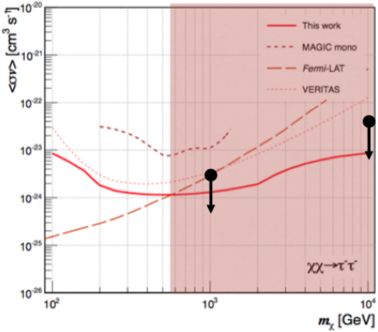


Our result — $\langle\sigma v\rangle^{UL}$ at $\chi+\chi\rightarrow b+\bar{b}$ & $\chi+\chi\rightarrow\tau^{+}+\tau^{-}$

$\chi+\chi\rightarrow b+\bar{b}$

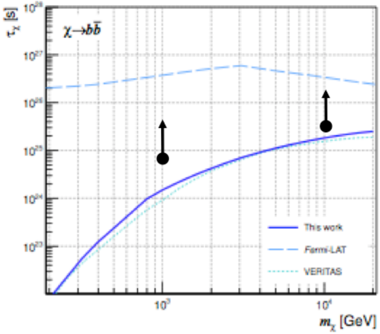


$\chi+\chi\rightarrow\tau^{+}+\tau^{-}$

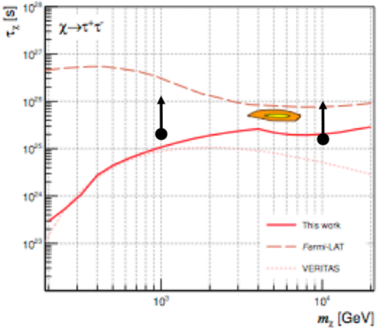


Our result — τ^{LL} at $\chi \to b\,\bar{b}$ & $\chi \to \tau^+\tau^-$

$\chi \to b\,\bar{b}$



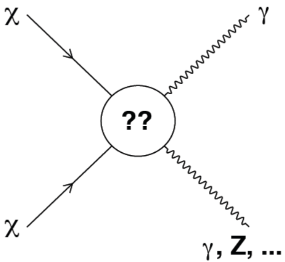
$\chi \to \tau^+\tau^-$

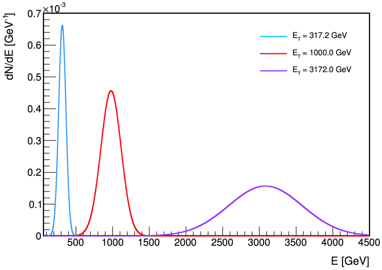


Another pattern

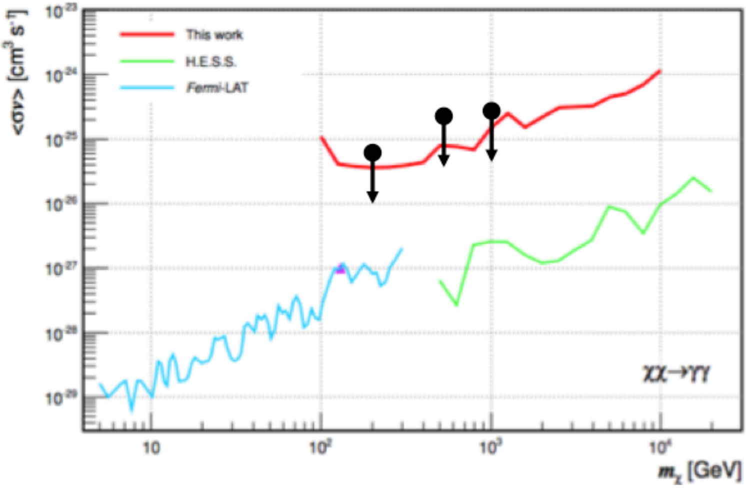
Next, we assumed:

- $\chi + \chi \to \gamma + \gamma$





Our result — $\langle \sigma v \rangle^{UL}$ at $\chi + \chi \to \gamma + \gamma$



Conclusion

- We confirmed data from Crab Nebula was consistent with previous research, showing detection of γ-ray.
- We cannot detect any γ-ray signal from Segue1, unlike Crab Nebula, which means no DM signal.
- We calculated $\langle \sigma v \rangle^{UL}$ and τ^{LL} from flux data. The calculation was comparable to previous researches in certain energy ranges.
- $\tau^{LL} \sim 10^{25}\,\mathrm{s} >> \mathrm{Hubble\ time} \sim 10^{17}\,\mathrm{s}$