Constraining particle dark matter using local galaxy distribution

Koji Ishiwata

Kanazawa University

Based on

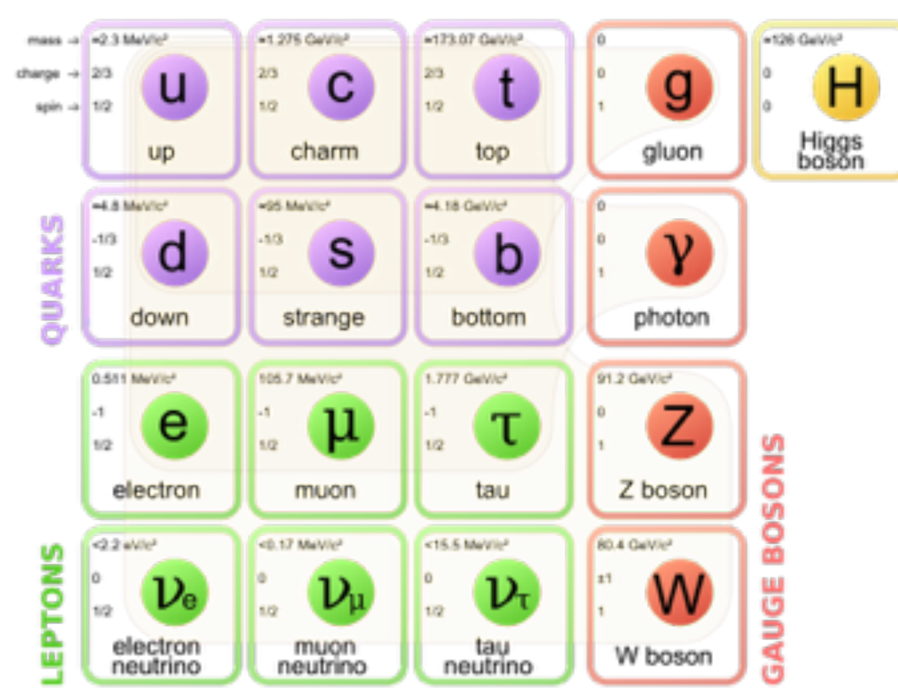
- JCAP 1505 (2015) 05, 024 (with S. Ando)
- JCAP 1606 (2016) 06, 045 (with S. Ando)

Hamburg, September 27, 2017

1. Introduction

After the Higgs discovery in 2012,

- The Standard model (SM) has been found to be a very good theory below a TeV scale
- But there're some inconsistencies, especially *cosmological* side



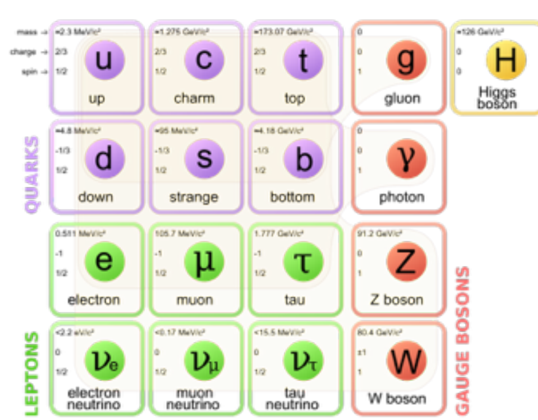
+ something

Cosmological issues:

- (Almost) isotropic, flat universe
- Baryon asymmetry
- Dark matter
- Dark energy

Cosmological issues:

- (Almost) isotropic, flat universe
- Baryon asymmetry
- ★ Dark matter
  - Dark matter (DM) is beyond the SM physics
  - Many DM searches are ongoing
- Dark energy



+ something

(DM, …)

DM searches

- Direct detection
- Indirect detection (via cosmic rays)
- Collider
- Axion like particle searches

Fermi-LAT

LHC

XENON1T

CAST

DM searches

Fermi-LAT

- Direct detection
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LHC

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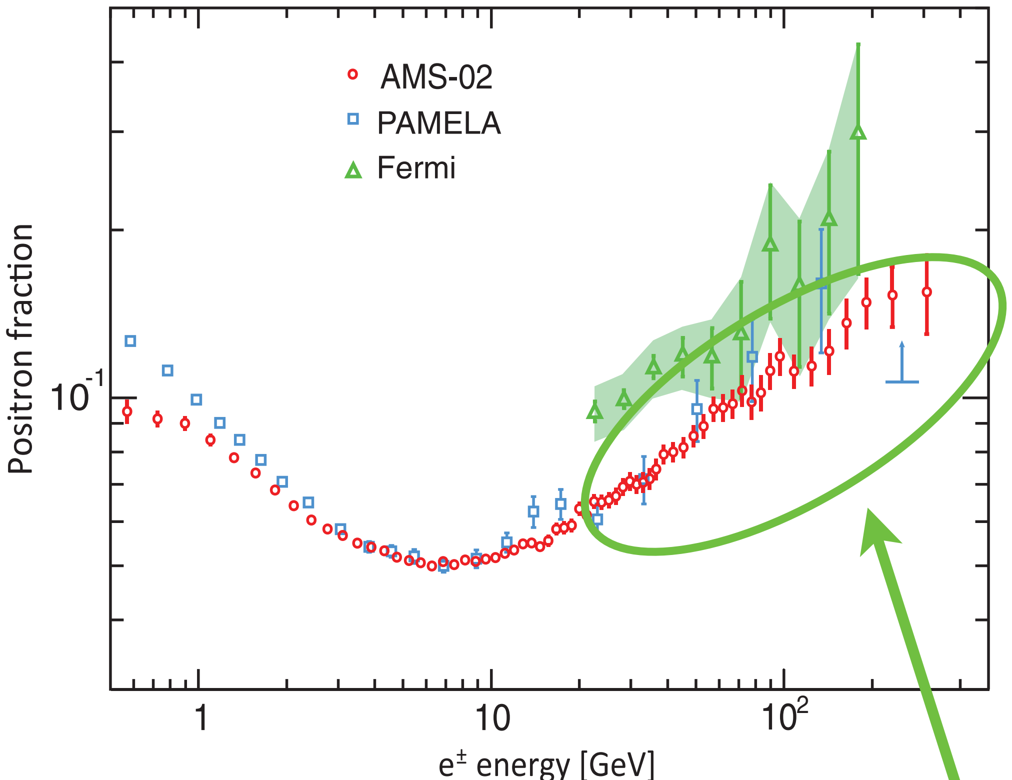
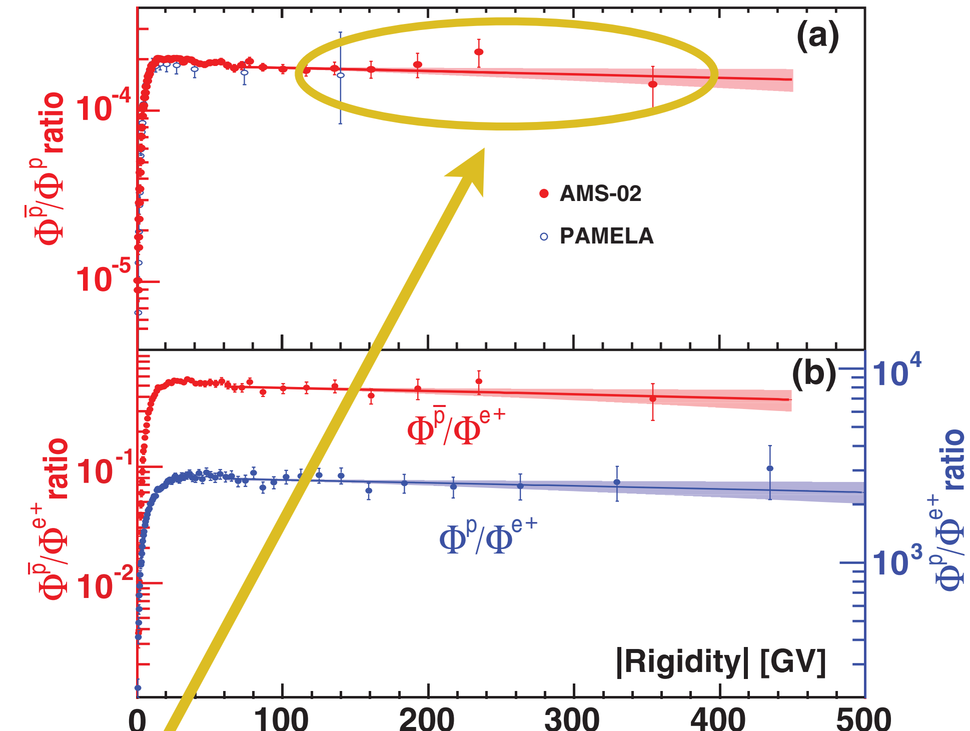
CAST

DM signals in cosmic rays?

- Positron AMS-02 '13



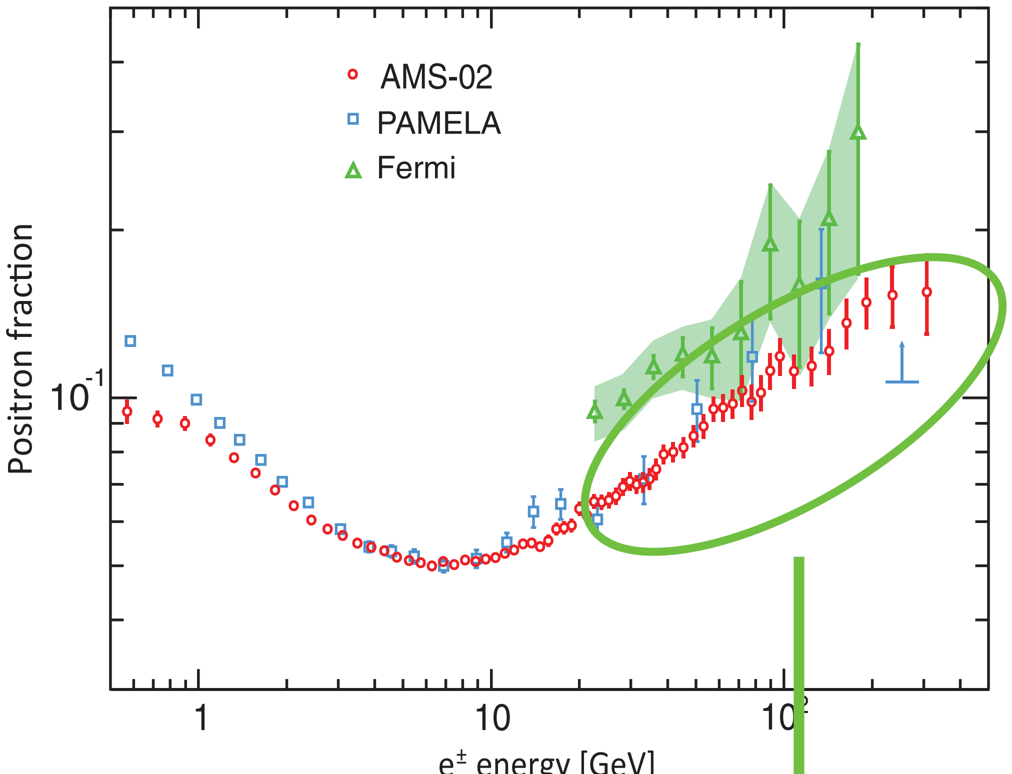
- Antiproton AMS-02 '16



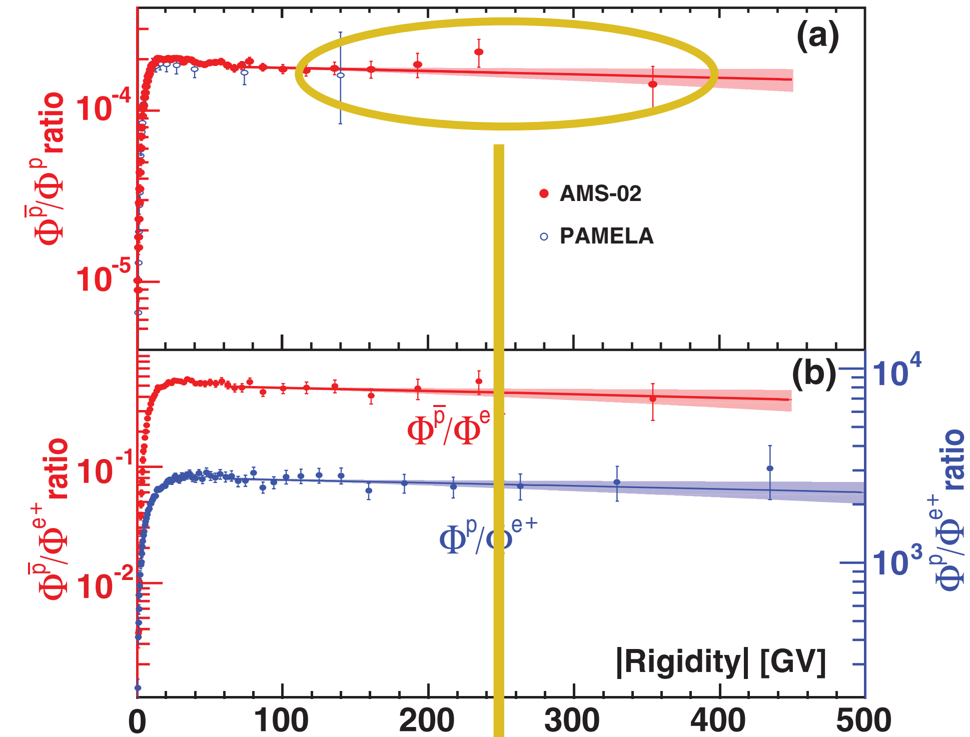
Excesses over 100 GeV

DM signals in cosmic rays?

- **Positron** AMS-02 '13

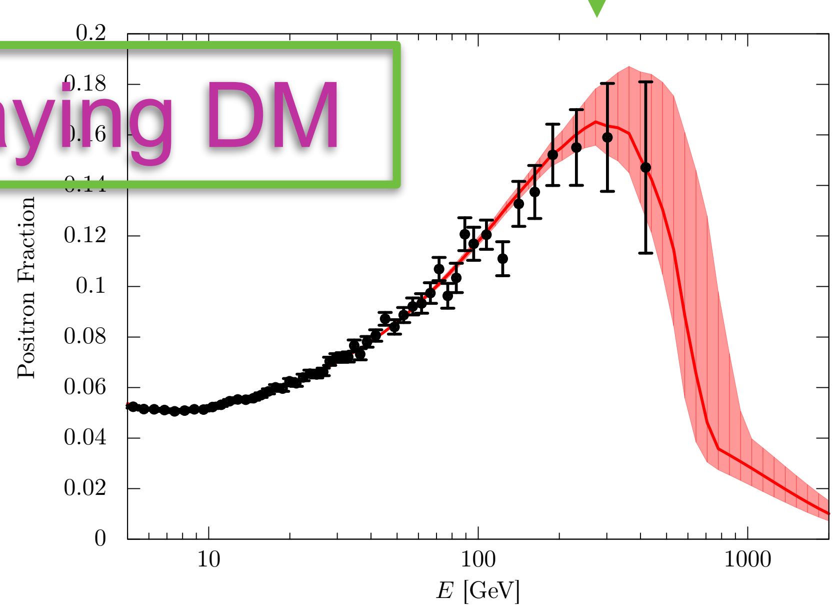


- **Antiproton** AMS-02 '16

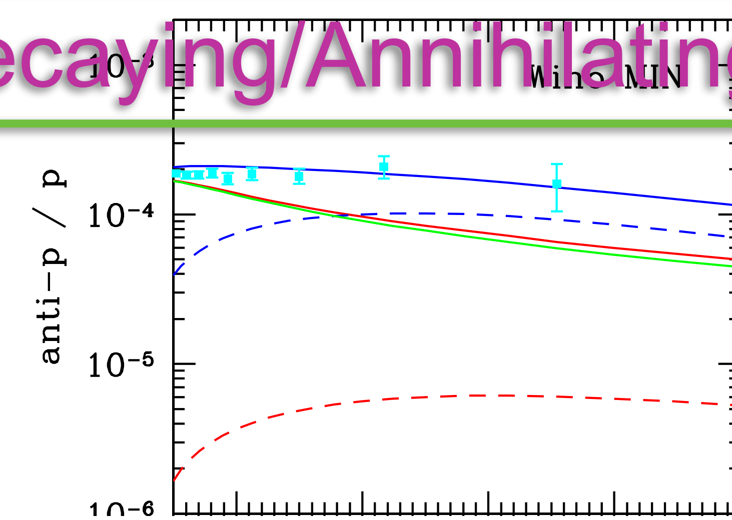


e.g.,

Decaying DM



Decaying/Annihilating DM

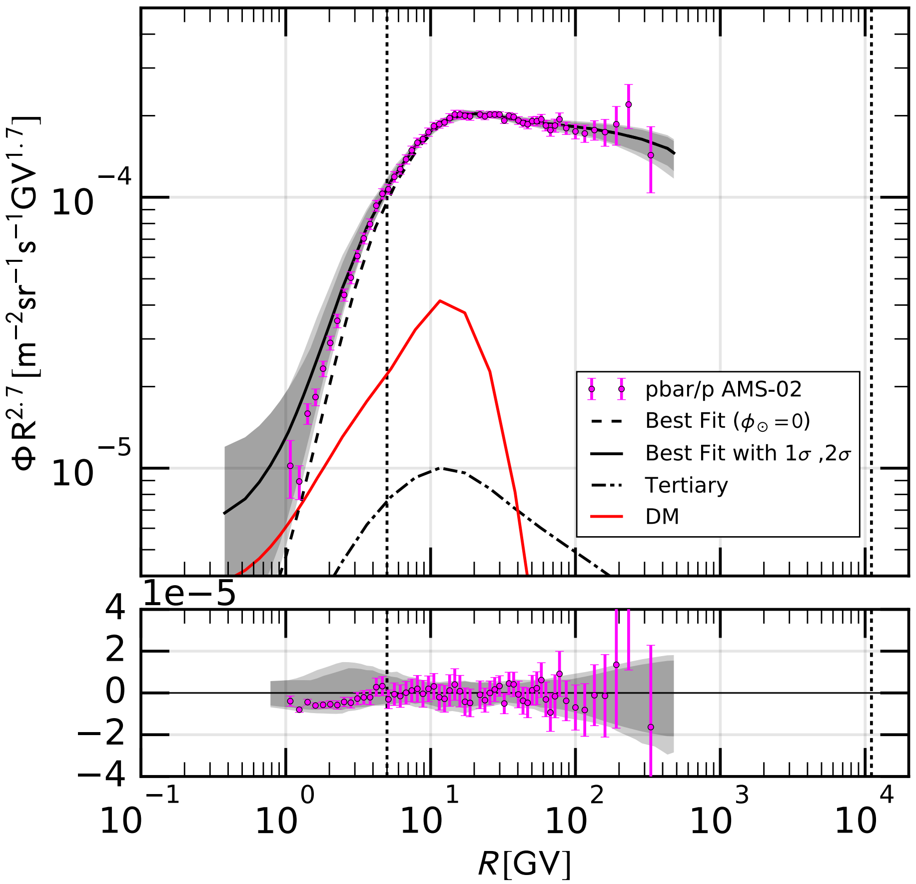


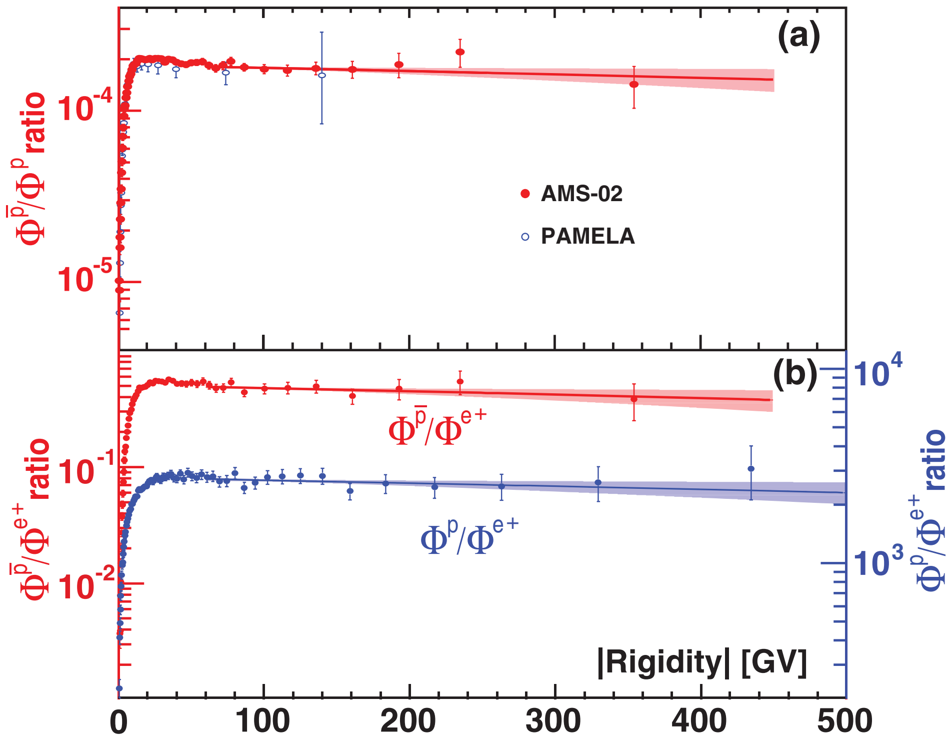
Ibe, Matsumoto, Shirai, Yagagida '14

Hamaguchi, Moroi, Nakayama '15

DM signals in cosmic rays?

- Antiproton AMS-02 ’16





4.5σ indication of a DM signal for DM masses near 80 GeV

Cuoco, Krämer, Korsmeir ’17

Cui, Yuan, Tsai, Fan ’17

Detailed discussion in Alessandro’s talk

And in Martin’s talk

Are those really DM signals?

Are those really DM signals?

→ We may check with other observables

Today's topic

DM search using *local galaxy distribution*

Important ingredients for our study:

a). Inverse-Compton (IC) γ-rays in the *extragalactic* region

b). Astrophysical sources in the *extragalactic* region

c). Tomographic cross-correlation using local galaxy distribution

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a). Inverse-Compton (IC) γ-rays in the *extragalactic* region

KI, Matsumoto, Moroi '09

Profumo, Jeltema '09

b). Astrophysical sources in the

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Ando, KI ’15

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Cuoco, Xia, Regis, Branchini, Fornengo, Viel ’15

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Our present study

Outline

1. Introduction
2. Overview of the analysis
3. Results
4. Conclusion

2. Overview of the analysis

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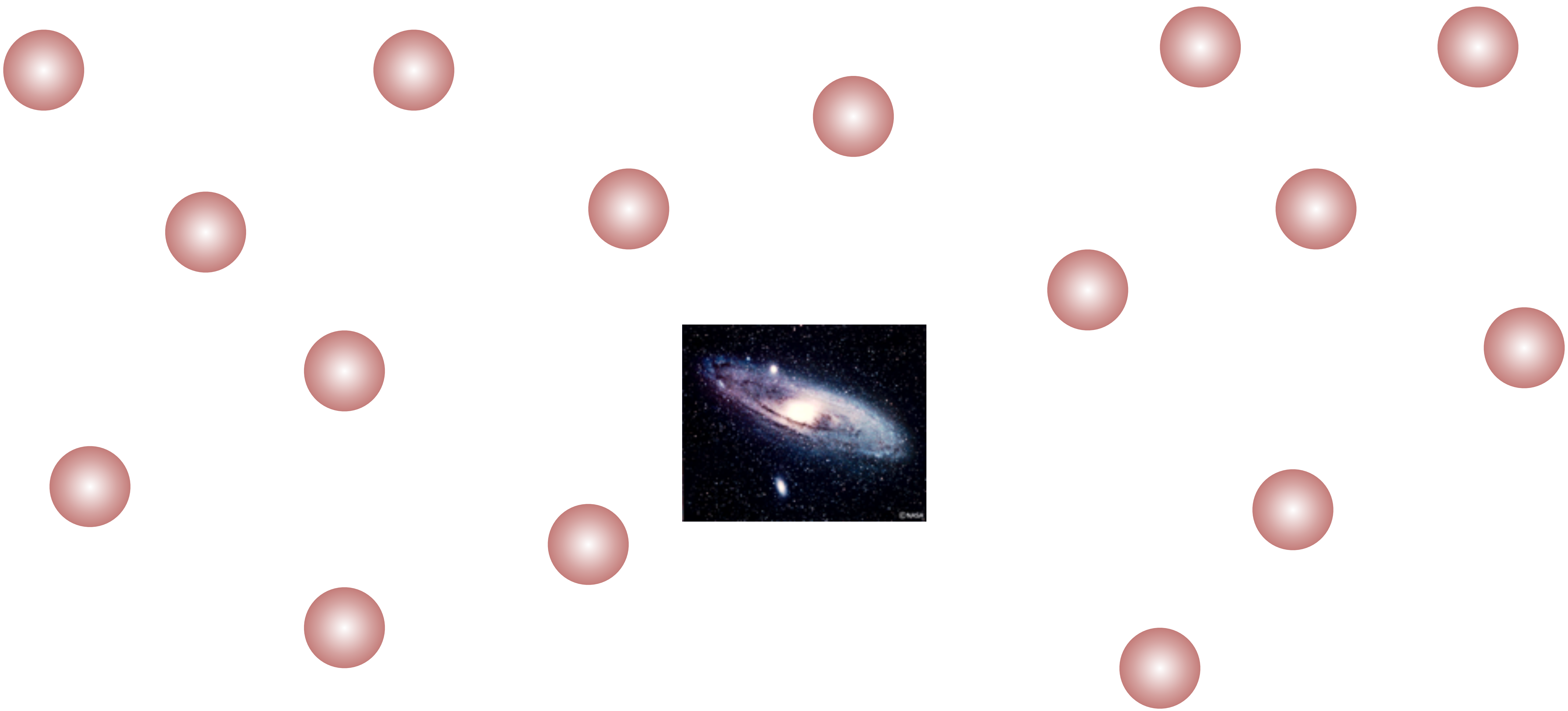
a). Inverse-Compton (IC) γ -rays in the extragalactic region

1. About 27% of the total energy of the universe is DM
2. Assume that high energy $e^{\pm}$ are produced by decay or annihilation of DM
3. They hit the CMB photons and produce high energy γ-rays



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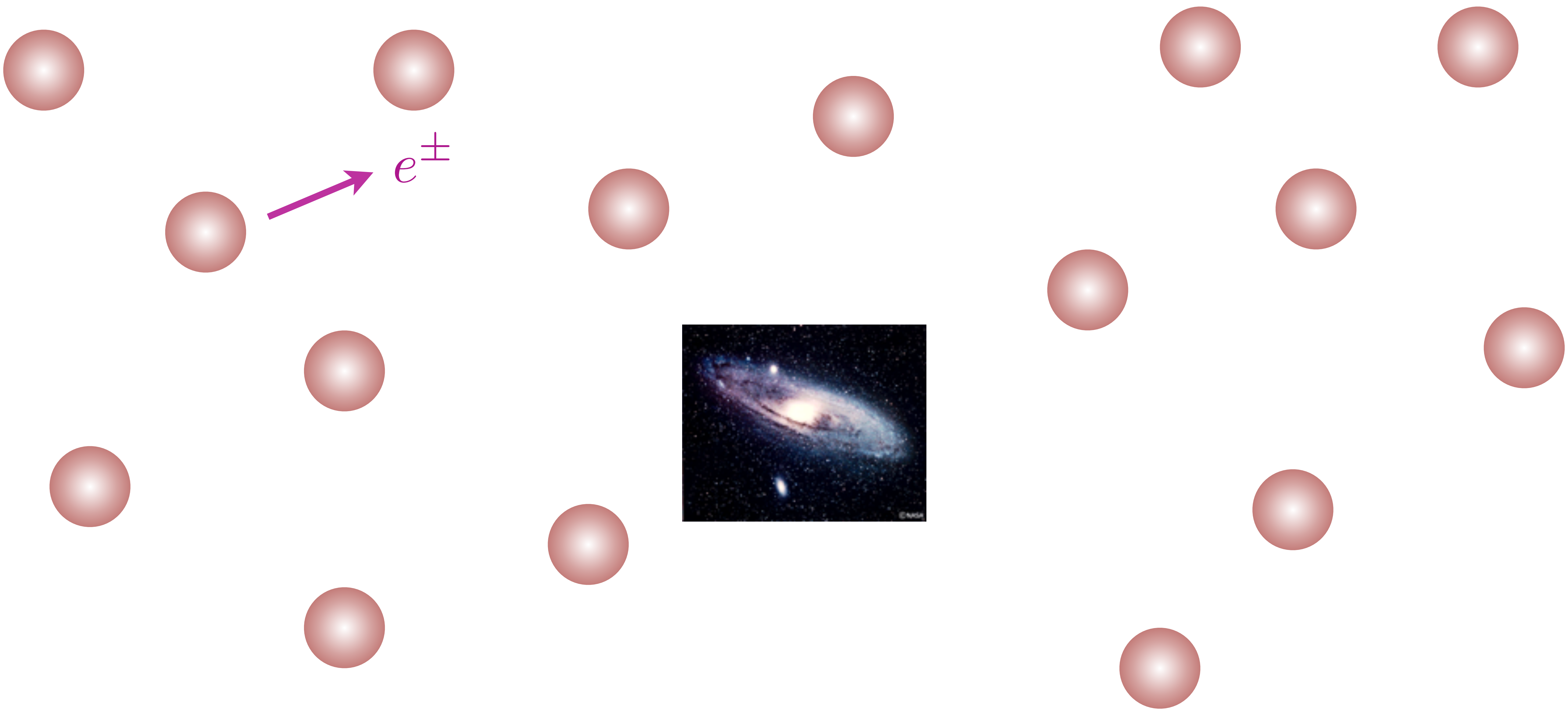

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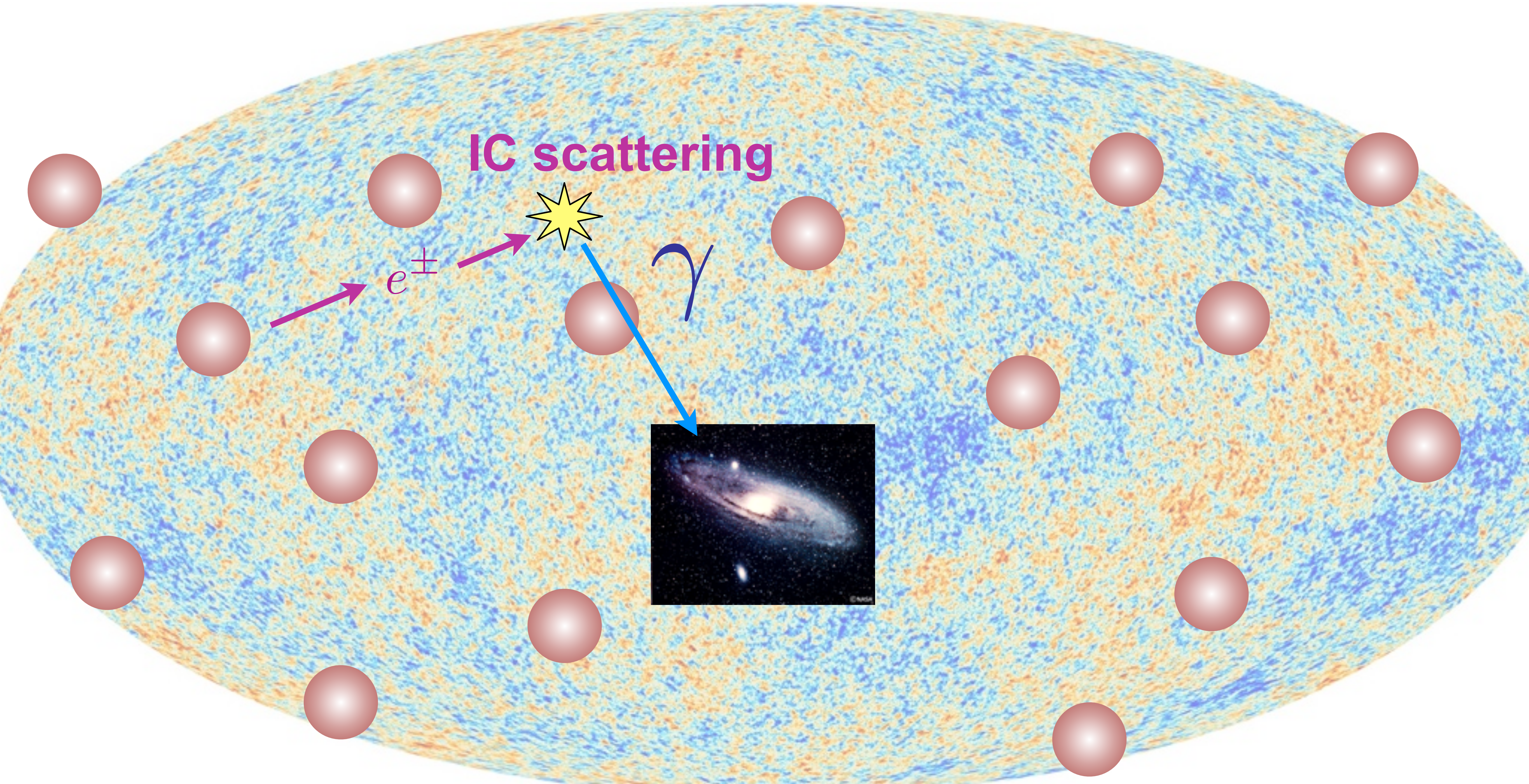


a). Inverse-Compton (IC) γ-rays in the extragalactic region

KI, Matsumoto, Moroi '09

Profumo, Jeltema '09

- The story is very simple
- If we specify DM model, the QED tells us the IC spectrum exactly especially for decaying DM
- A good tool to test DM scenarios which accommodate the anomalous positron or antiproton excess

Important ingredients for our study:

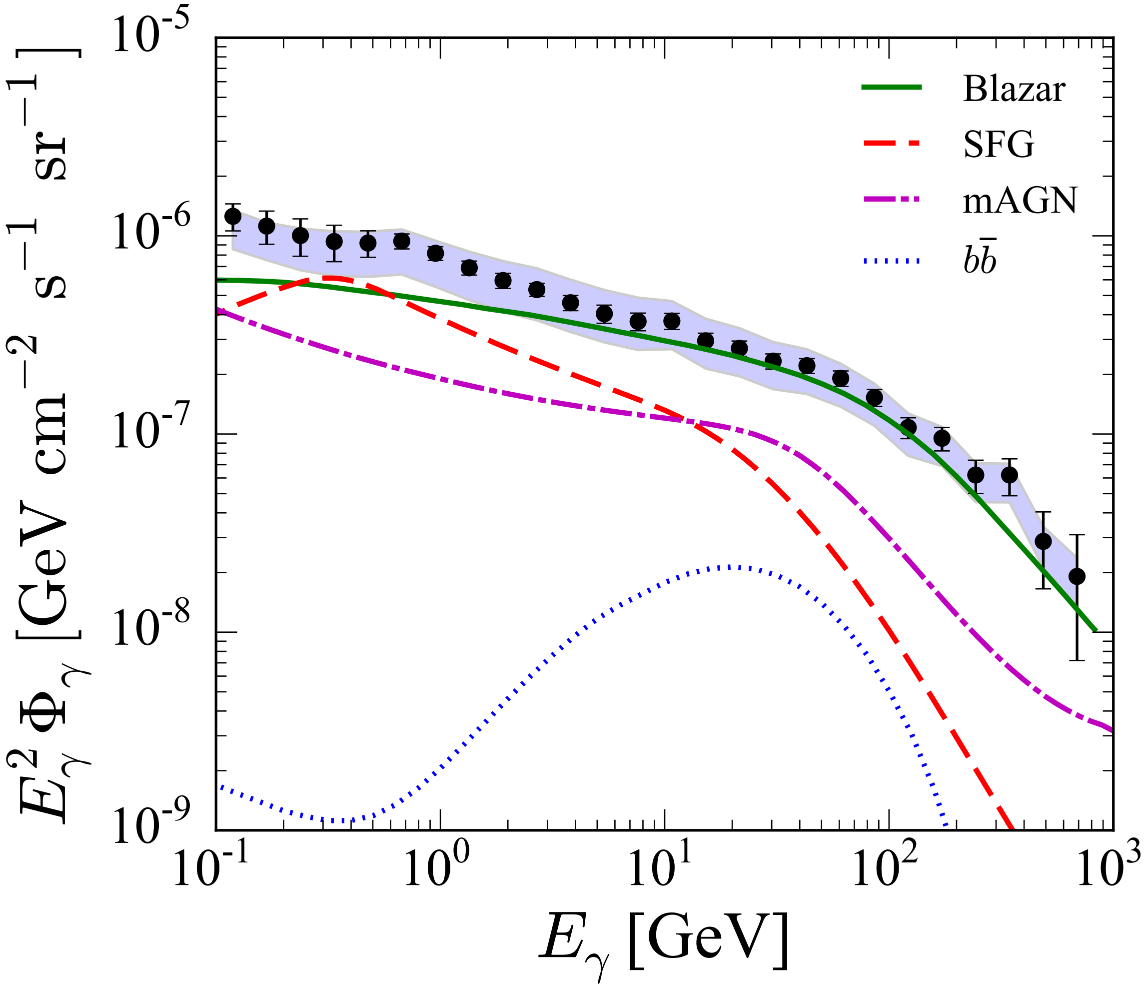
a). Inverse-Compton (IC) γ-rays in the

b). Astrophysical sources in the *extragalactic* region

c). Tomographic cross-correlation using local galaxy distribution

b). Astrophysical sources in the extragalactic region

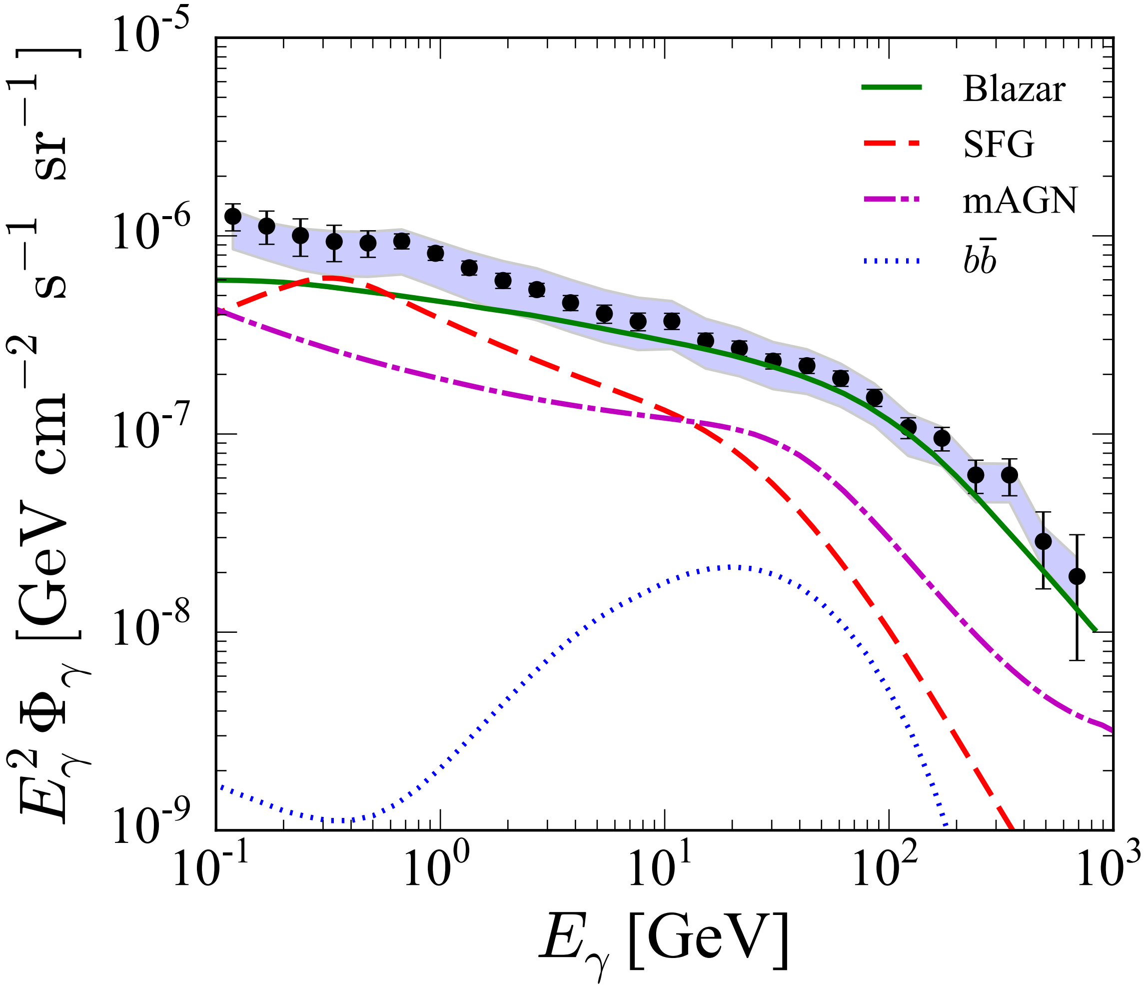
Ando, KI '15



The known sources well explain the observed gamma rays

b). Astrophysical sources in the extragalactic region

Ando, KI ’15



The known sources well explain the observed gamma rays

→ Constraints on DM scenarios

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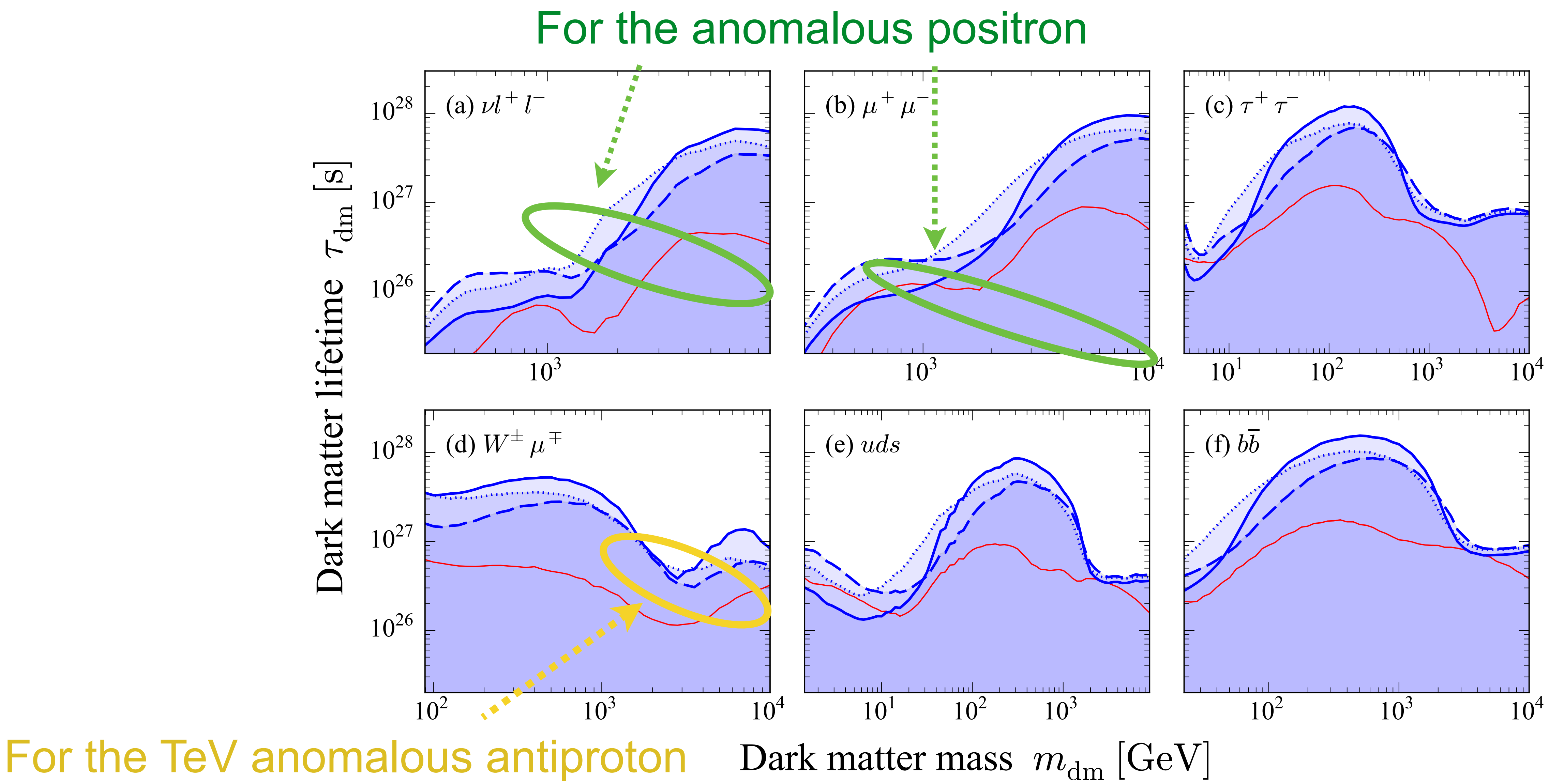
b). Astrophysical sources in the *extragalactic* region

Ando, KI '15

c). Tomographic cross-correlation using local galaxy distribution

Decaying DM

Ando, KI '15



Decaying DM scenarios to explain the anomalous positron or antiproton are partly excluded

In the study, we considered that the gamma rays from the extragalactic region is

- Statistically isotropic
- Integrated over the cosmological distances

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- Statistically isotropic
- Integrated over the cosmological distances

But due to the recent observational developments,

- Anisotropies
- Cosmological distances

of the gamma rays can be used for the study

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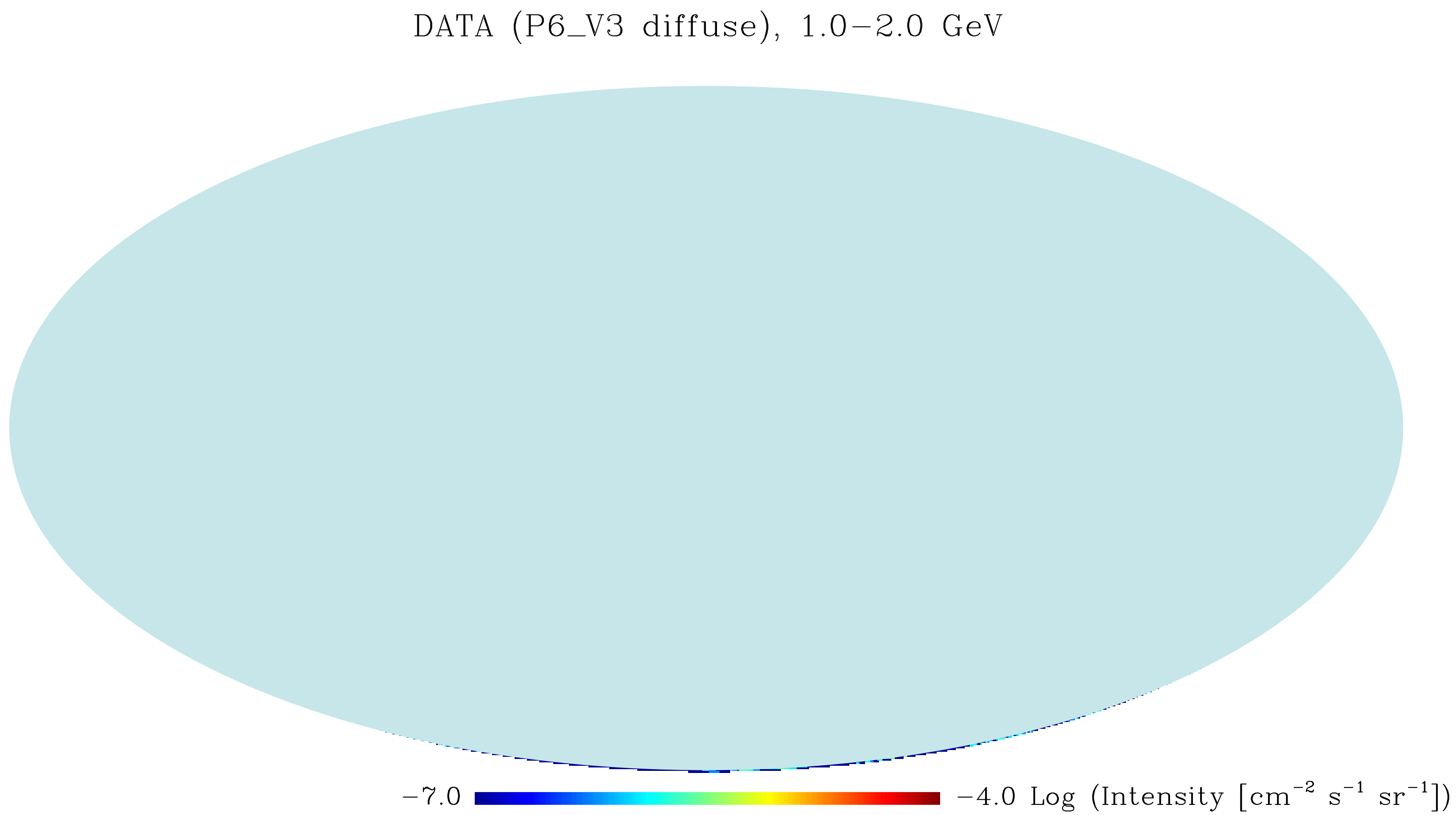
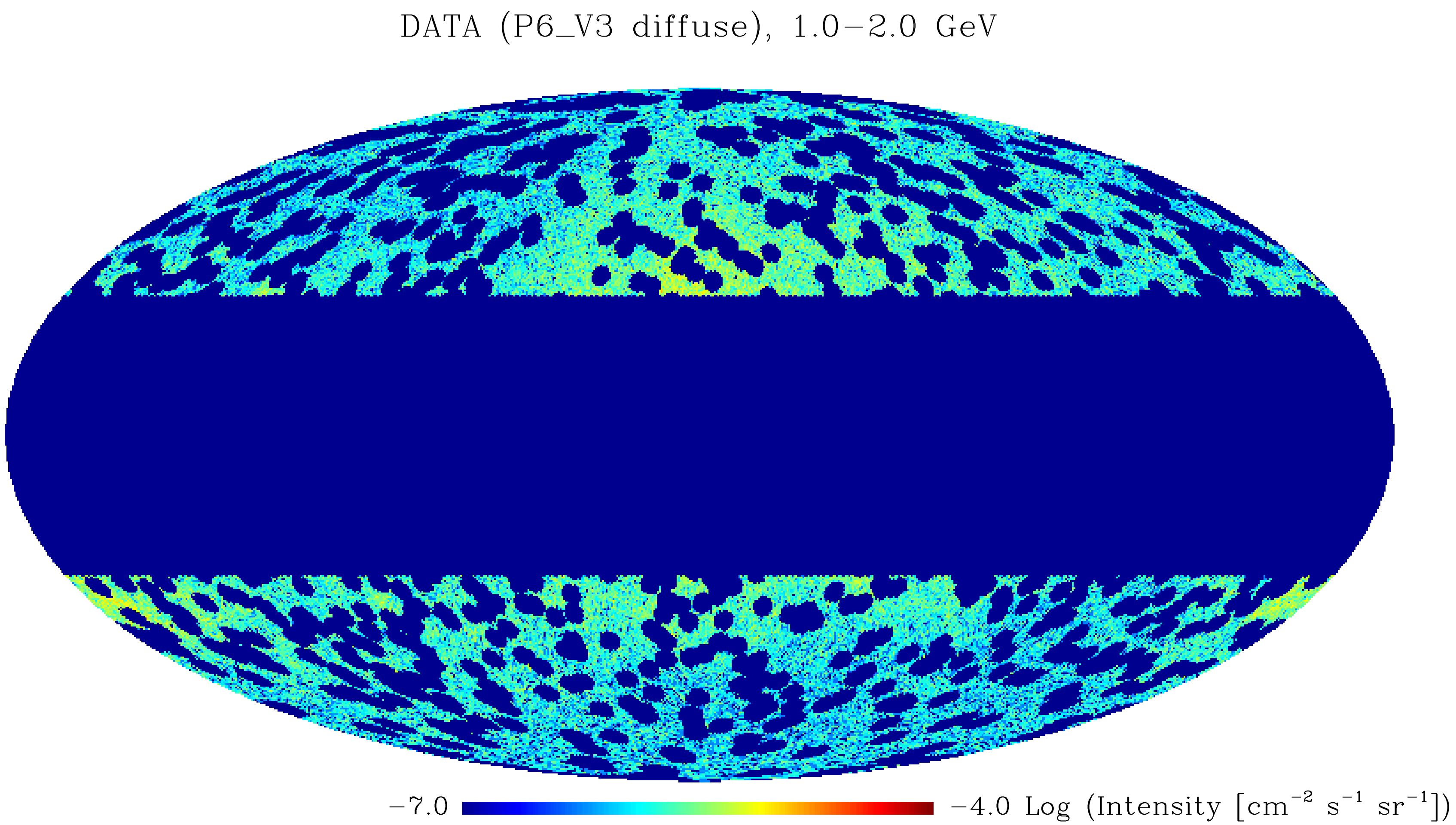
Gamma rays are almost isotropic, but ..



c). Tomographic cross-correlation using local galaxy distribution

There're **anisotropies**



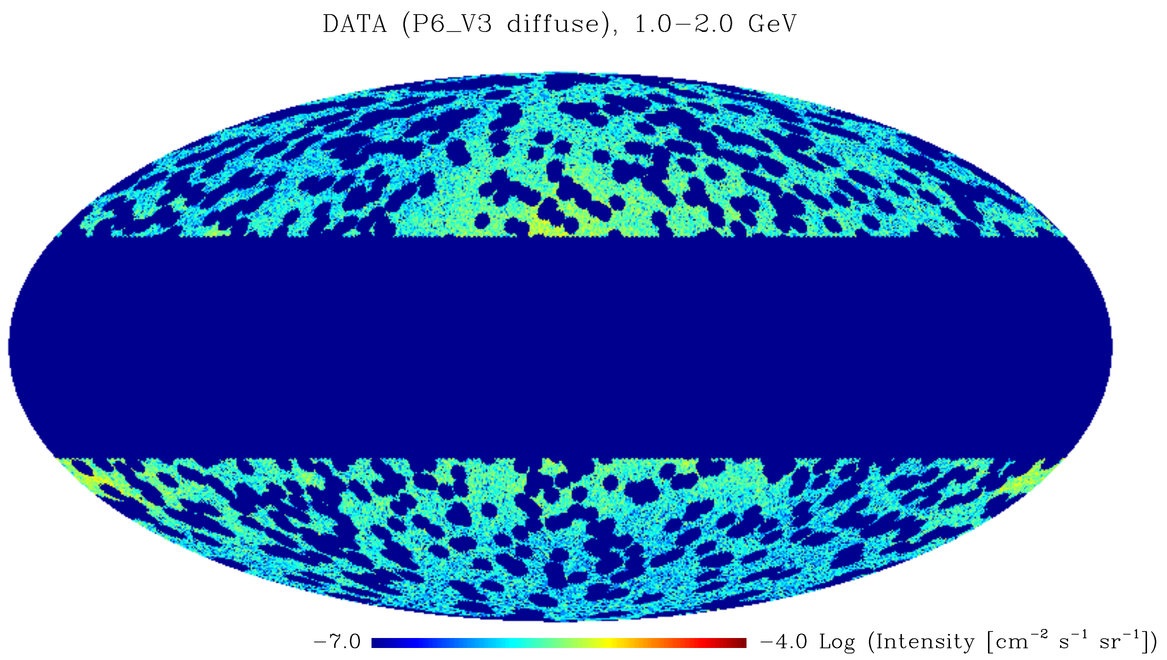
Fermi-LAT '12

c). Tomographic cross-correlation using local galaxy distribution

Ando, Benoit-Lévy, Komatsu ’13
Fornengo, Regis ’13

- Anisotropies

Gamma rays



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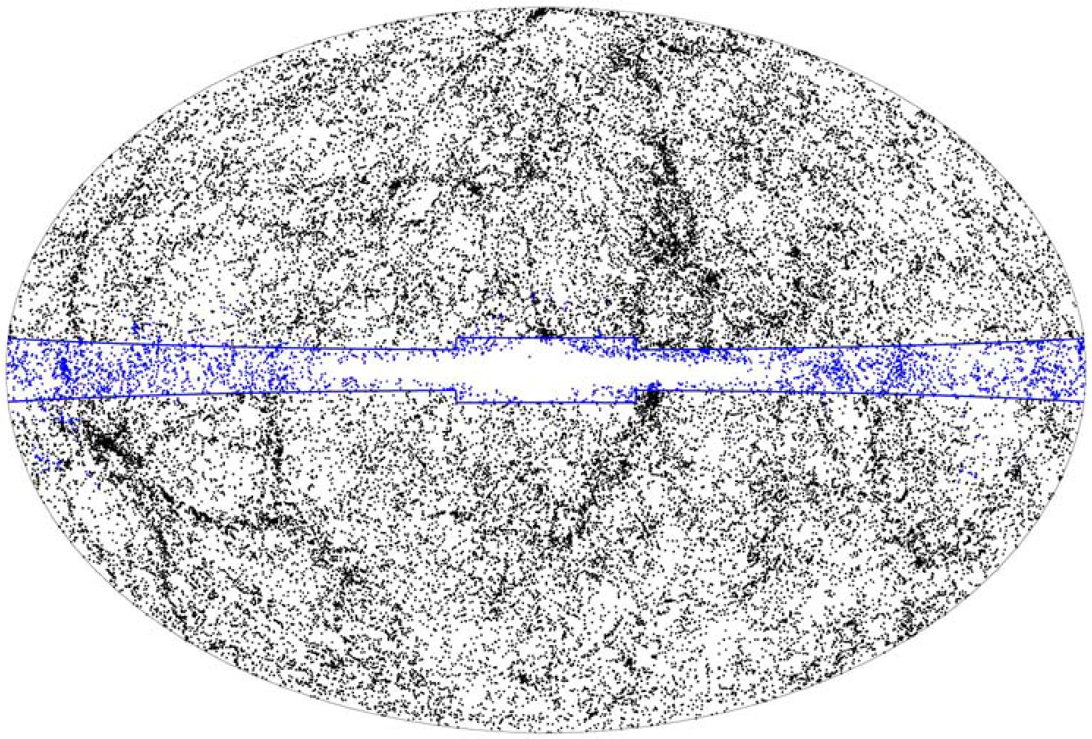
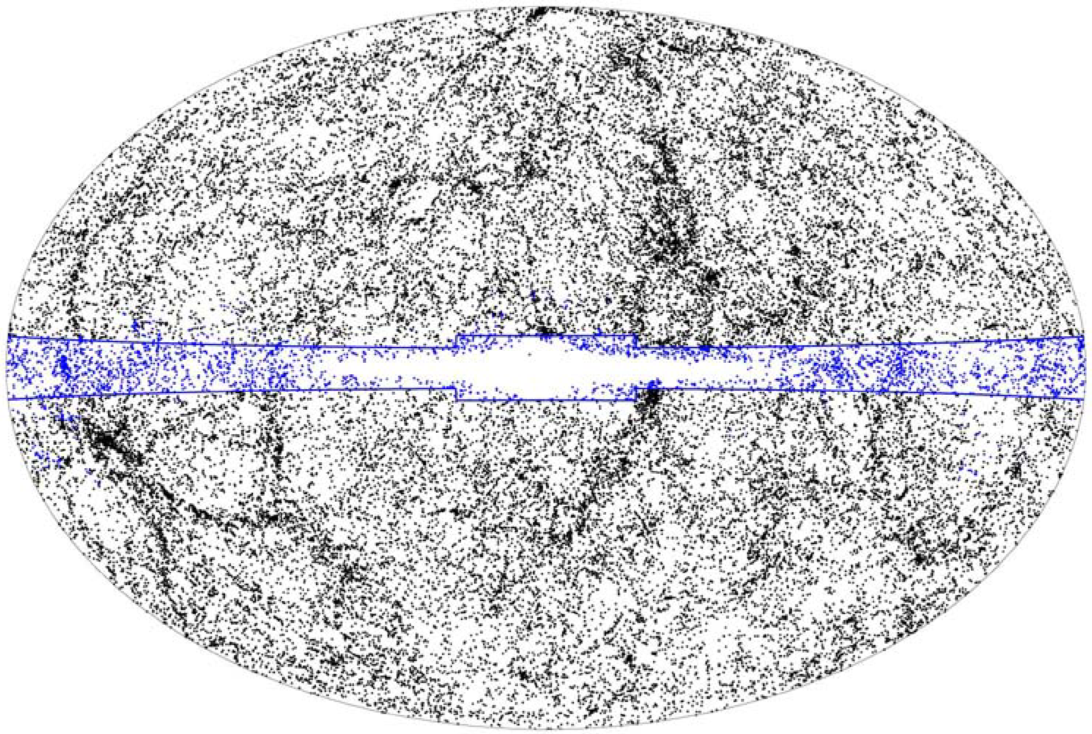
Local galaxy distributions



2MRS ’11
(QSO, 2MASS, NVSS, MG, LRG)

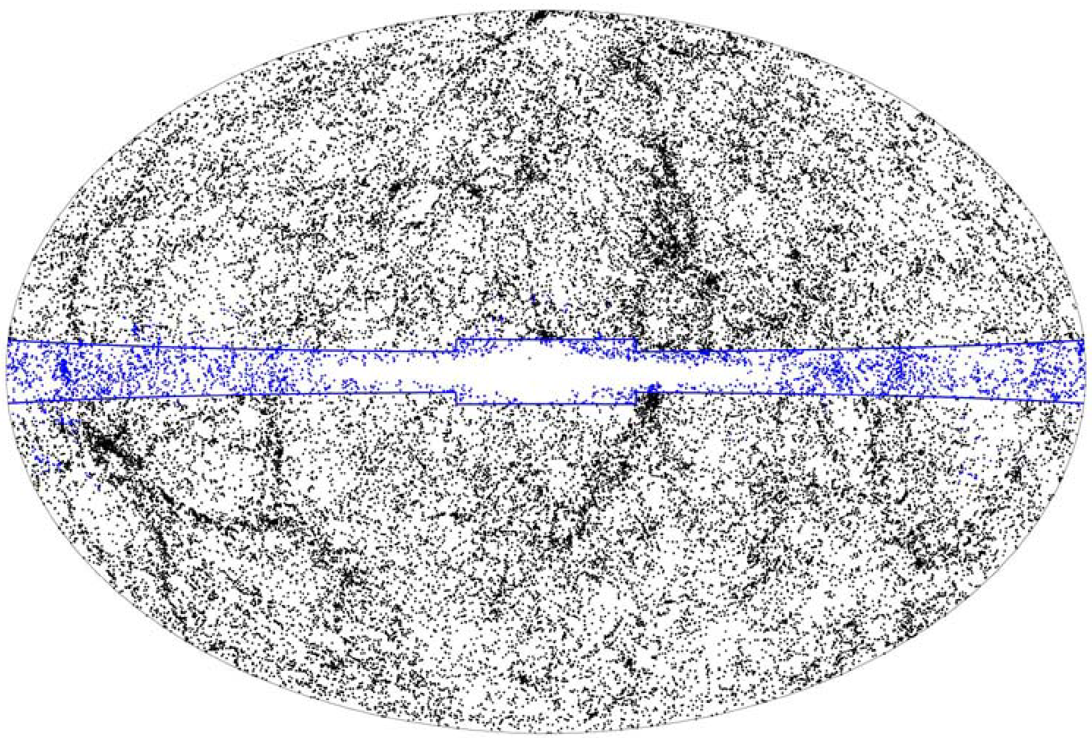
We cross-correlate the gamma rays with local galaxy distribution

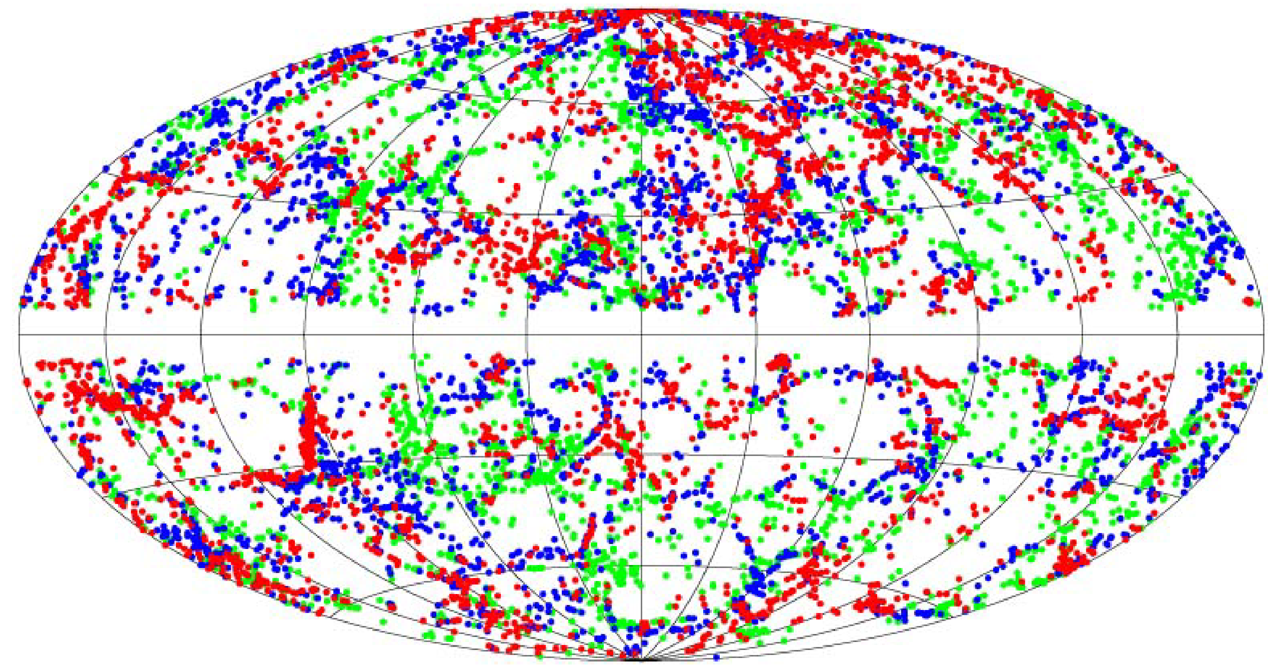
c). Tomographic cross-correlation using local galaxy distribution



c). Tomographic cross-correlation using local galaxy distribution

2MRS '11





6000<v<7000km/s

7000<v<8000km/s

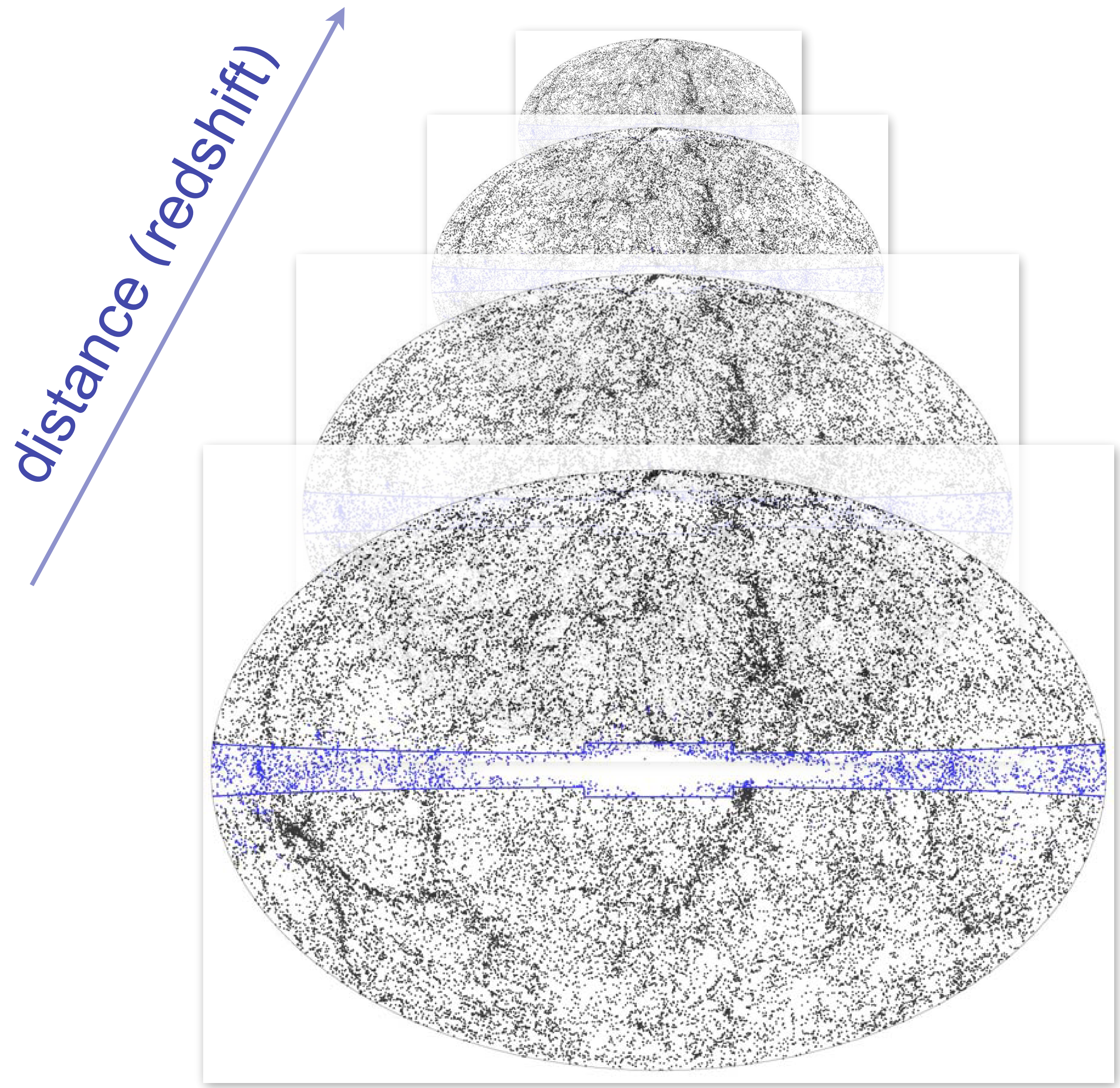
8000<v<9000km/s

We know the distance from each galaxy by its redshift

c). Tomographic cross-correlation using local galaxy distribution

- Cosmological distance

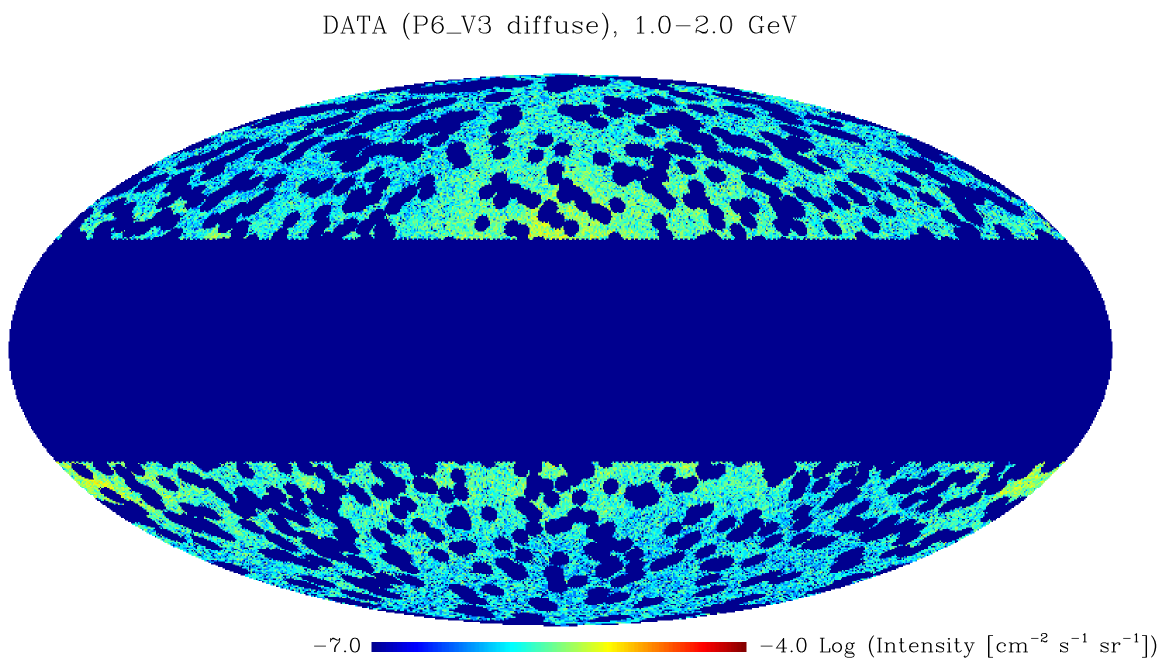
Ando '14



We have "tomography" regarding cosmological distance

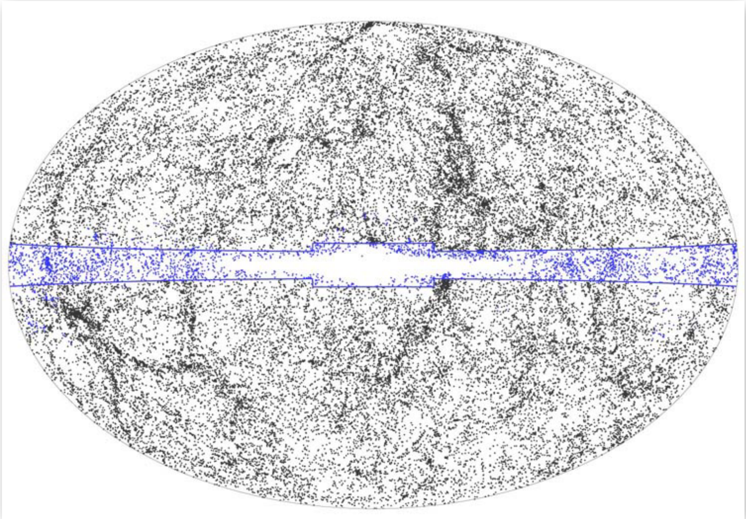
c). Tomographic cross-correlation using local galaxy distribution

- Anisotropies
- Cosmological distances



Gamma rays

×

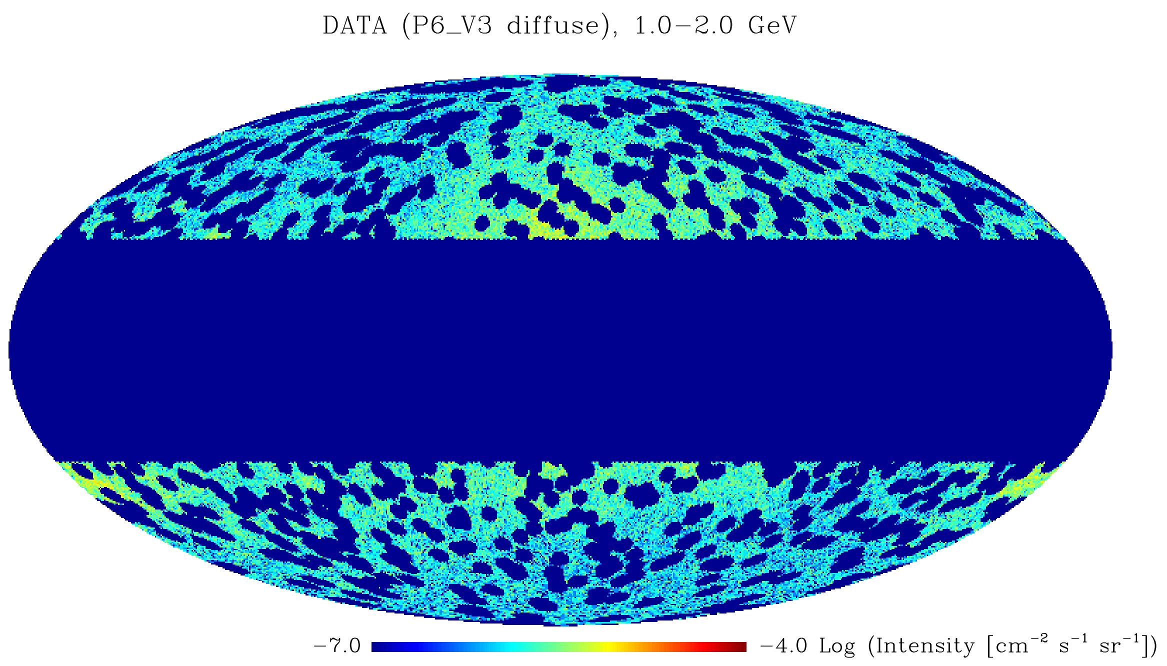


Local galaxy distribution

c). Tomographic cross-correlation using local galaxy distribution

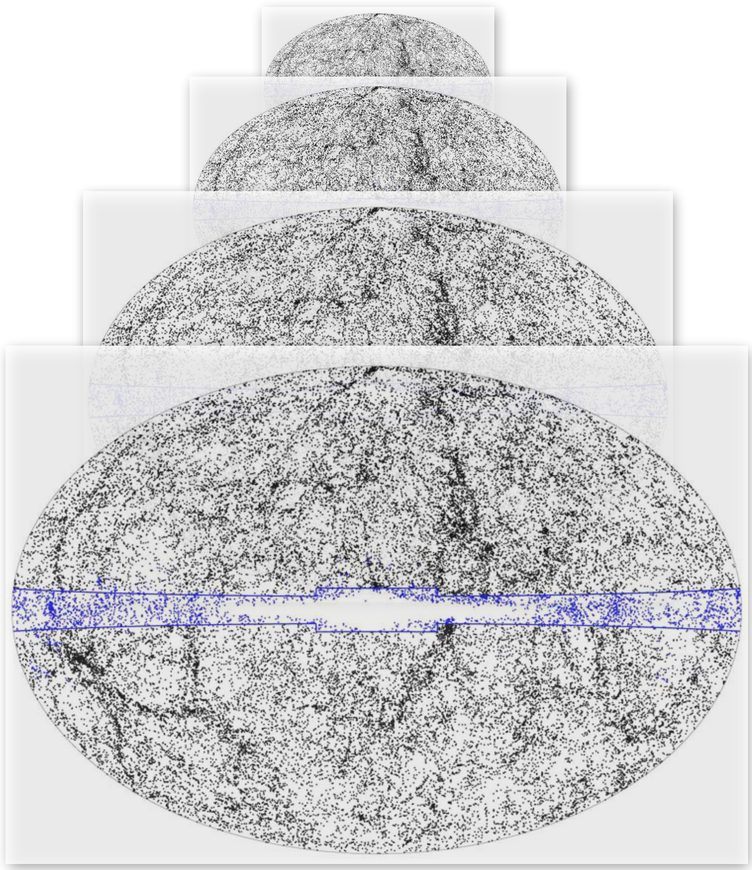
Xia, Cuoco, Branchini, Viel ’15

- Anisotropies
- Cosmological distances



Gamma rays

×



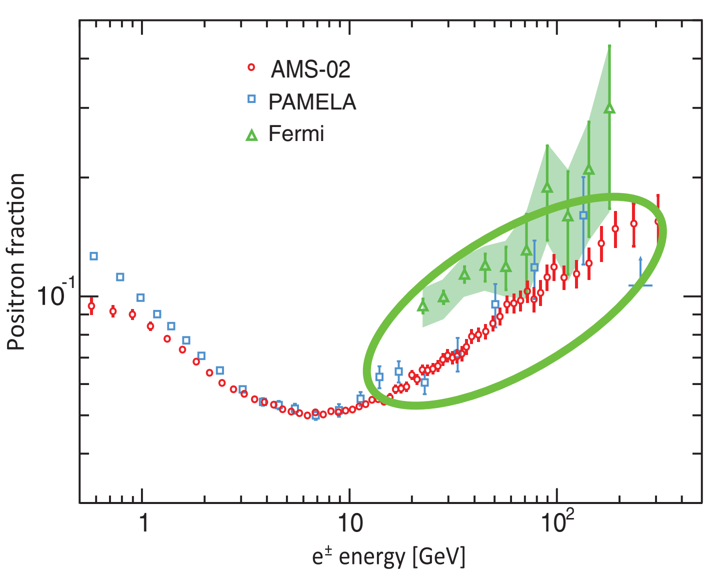
Local galaxy distribution

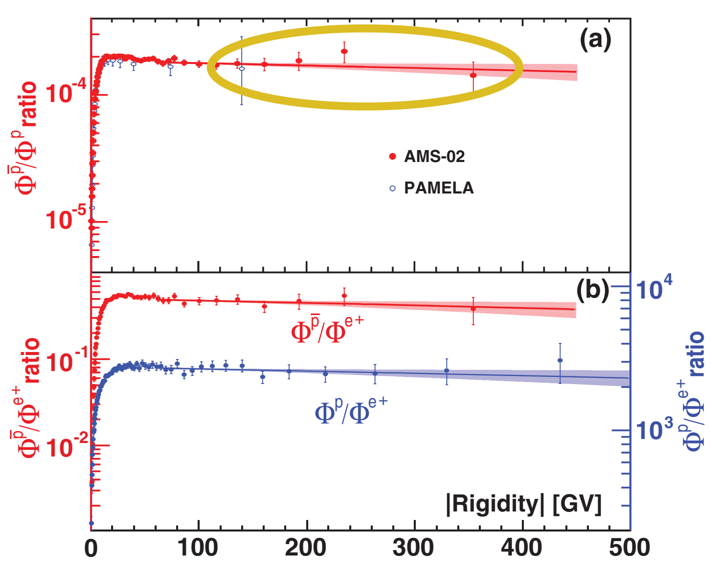
Tomographic cross-correlation using local galaxy distribution

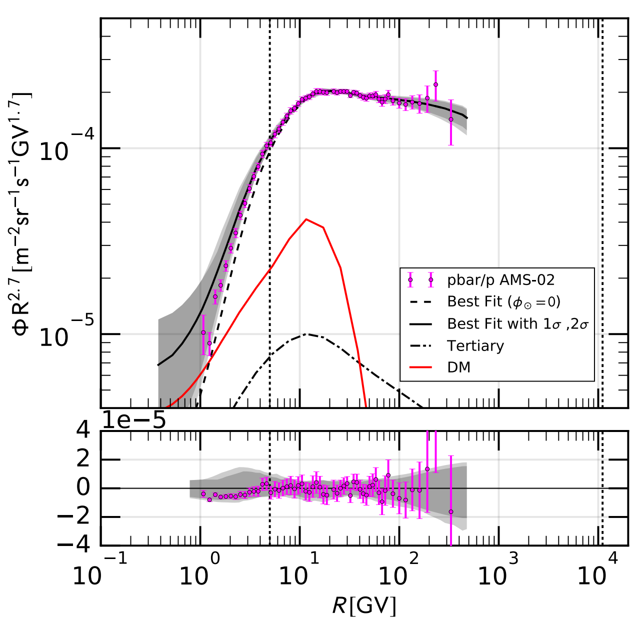
3. Results

The reported anomalous cosmic rays:

- Positron
- Antiproton (over 100 GeV)
- Antiproton (~ 80 GeV DM mass)







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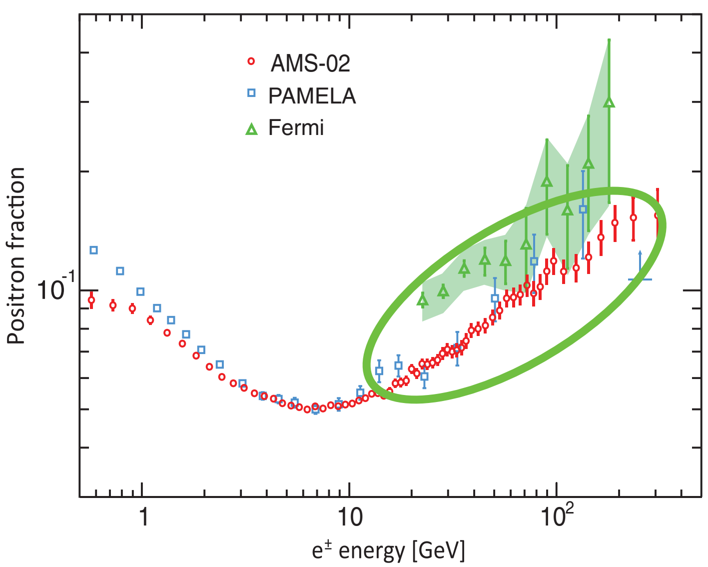
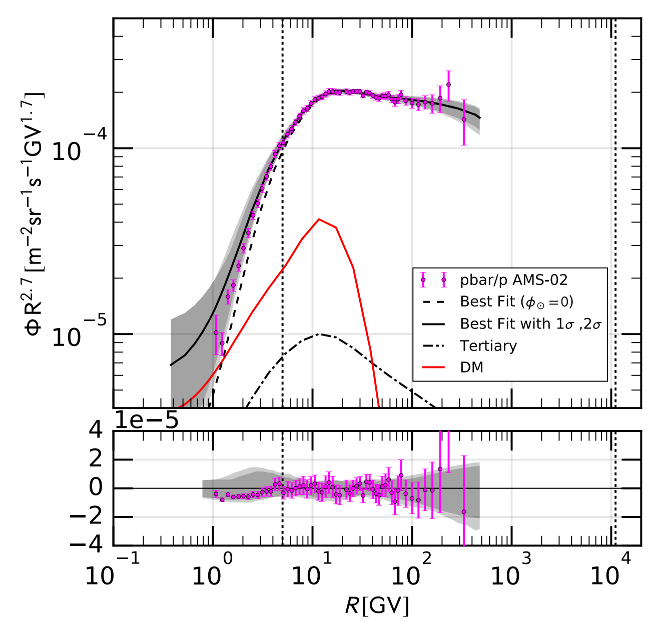




Decaying DM

Annihilating DM

Decaying DM (for the anomalous e^+)

Here we focus on three-body leptonic decay: $\mathrm{DM} \to \nu l^{\pm} l^{\mp}$

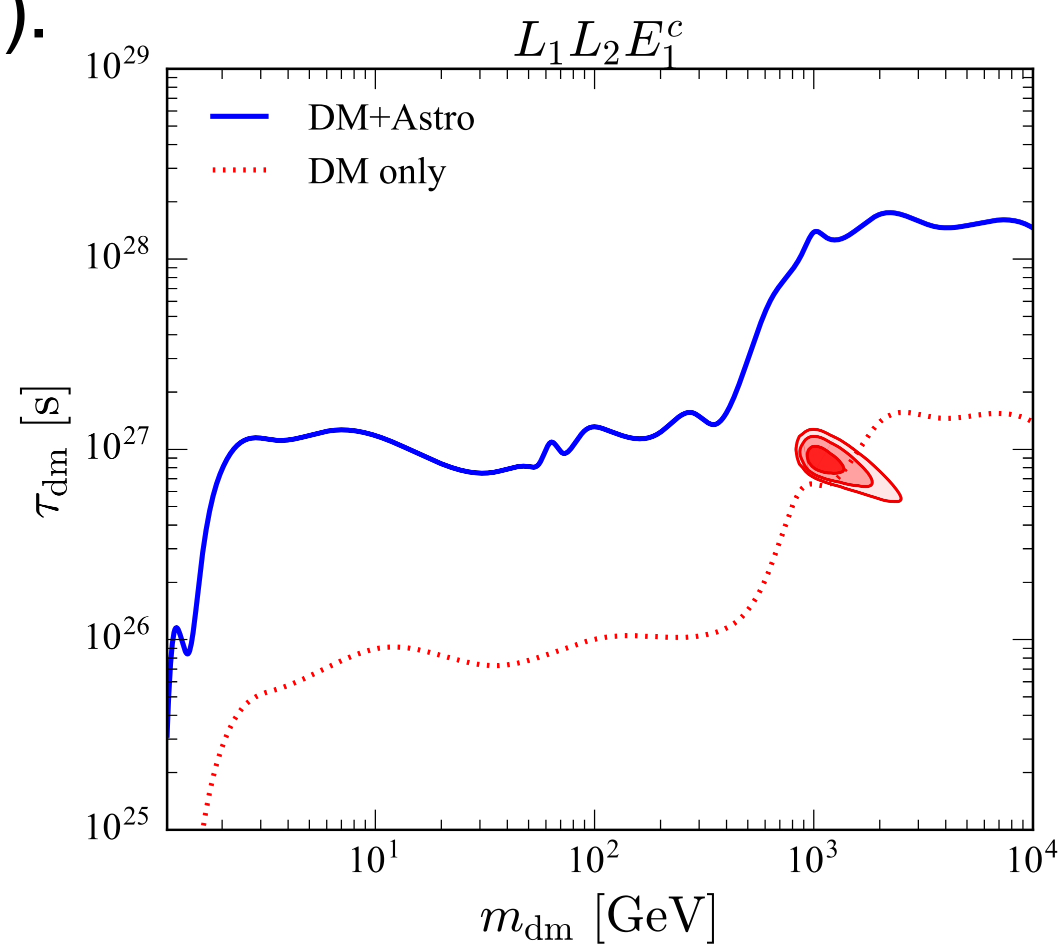
(a). $\nu\mu^{\pm}e^{\mp} \& \nu e^{\pm}e^{\mp}$ (mainly $e^{\pm}$)

(b). $\nu\mu^{\pm}\mu^{\mp} \& \nu e^{\pm}\mu^{\mp}$ (mainly $\mu^{\pm}$)

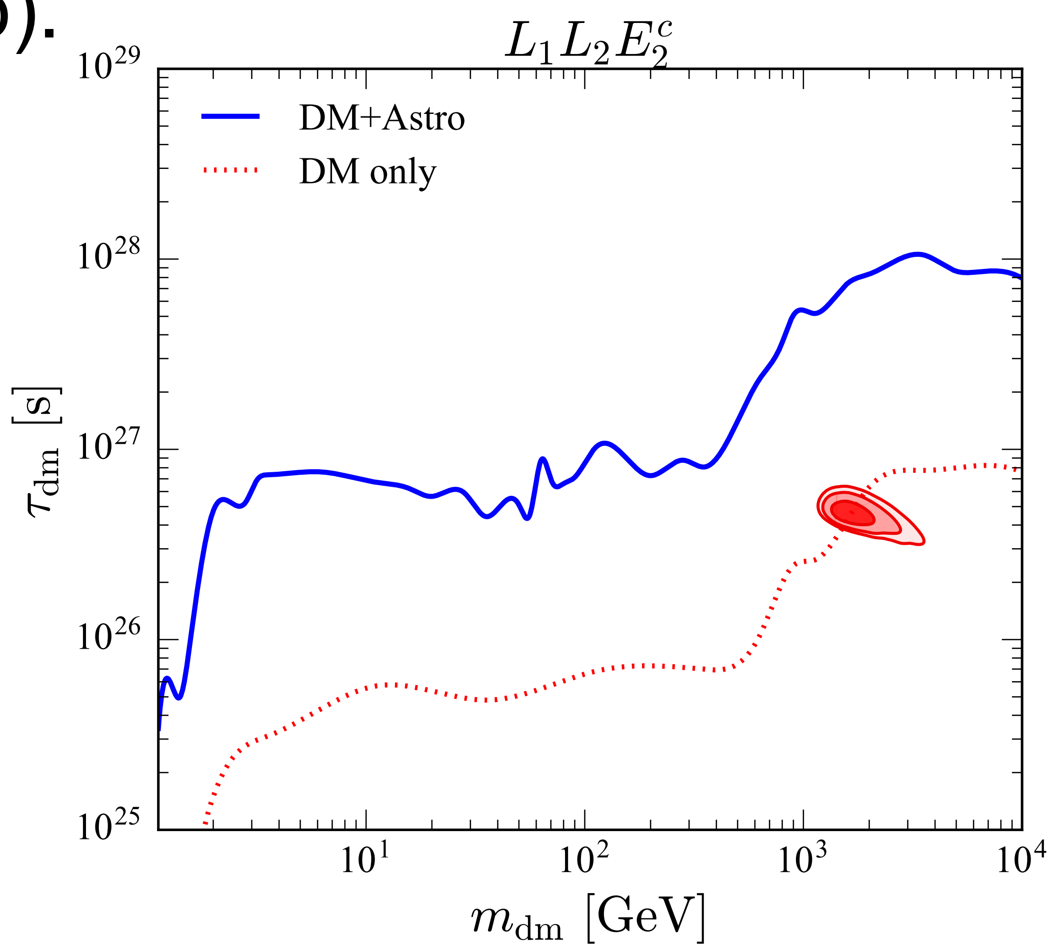
Decaying DM (for the anomalous e^+)

Ando, KI '16

(a).



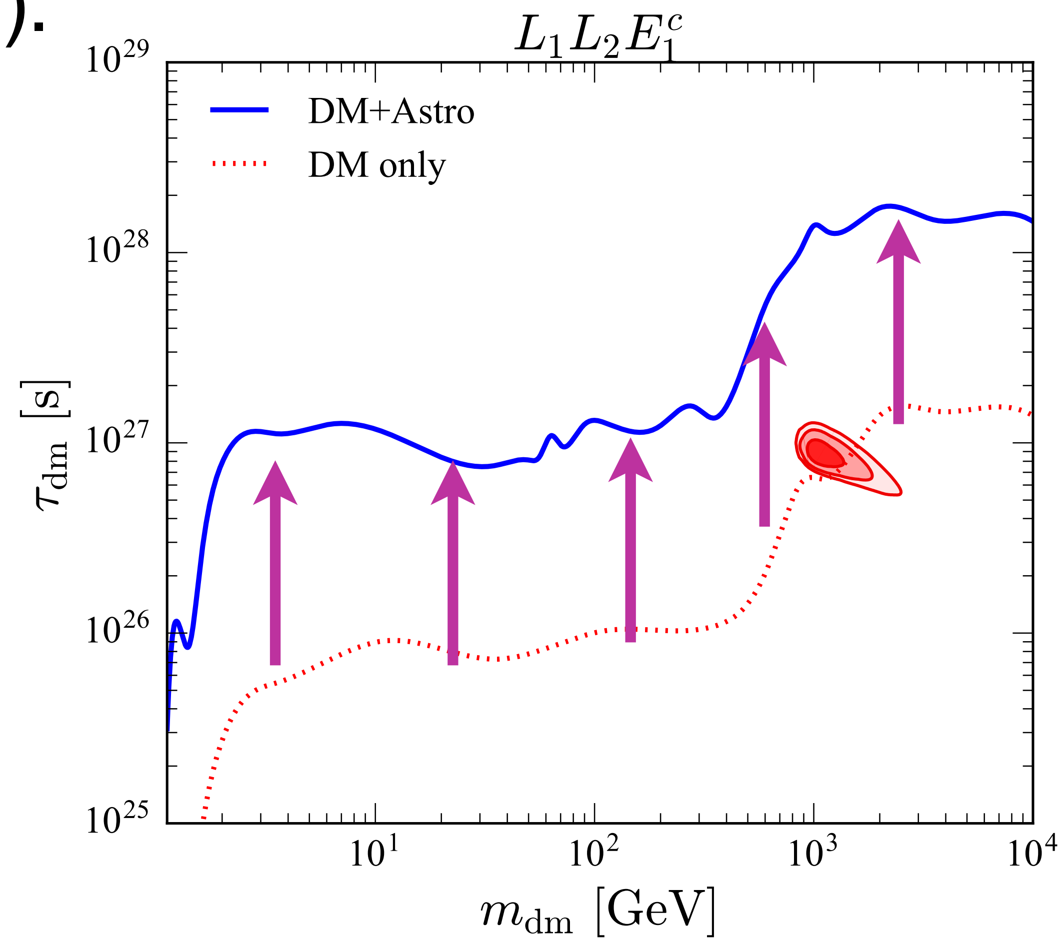
(b).



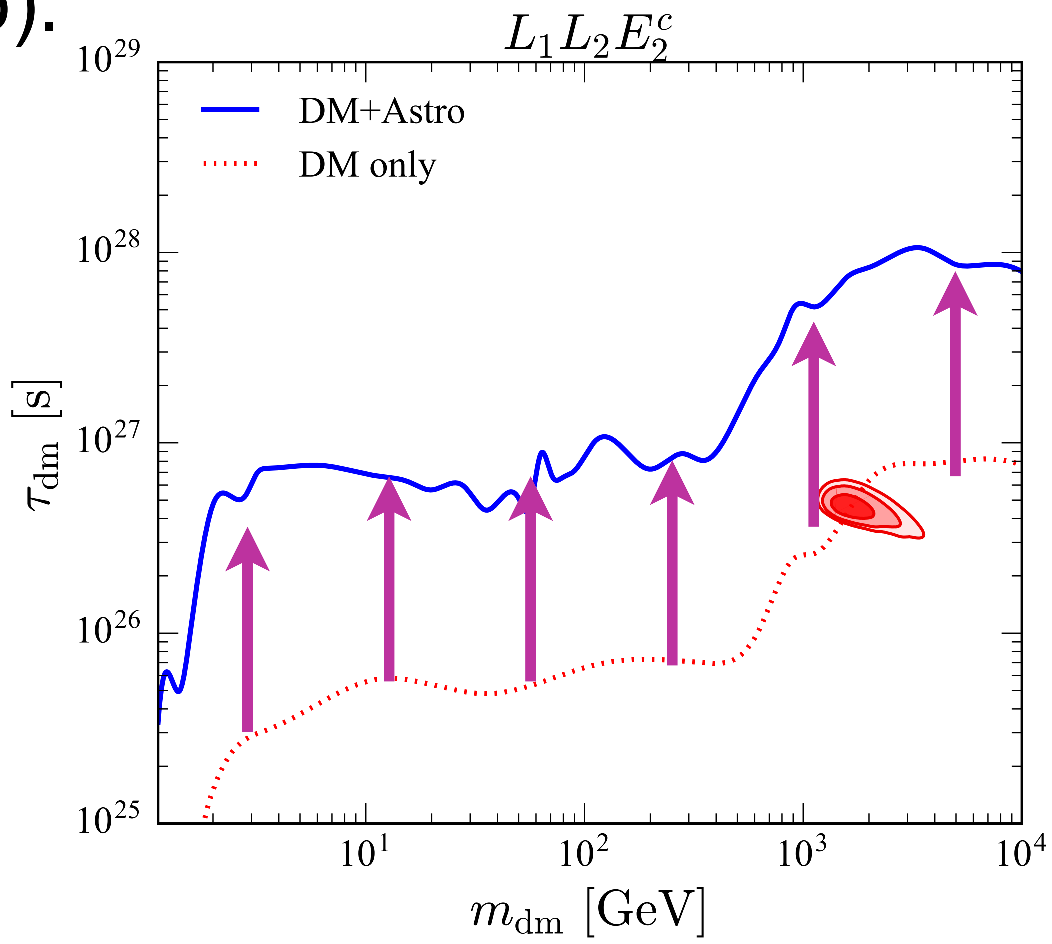
Decaying DM (for the anomalous e^+)

Ando, KI '16

(a).



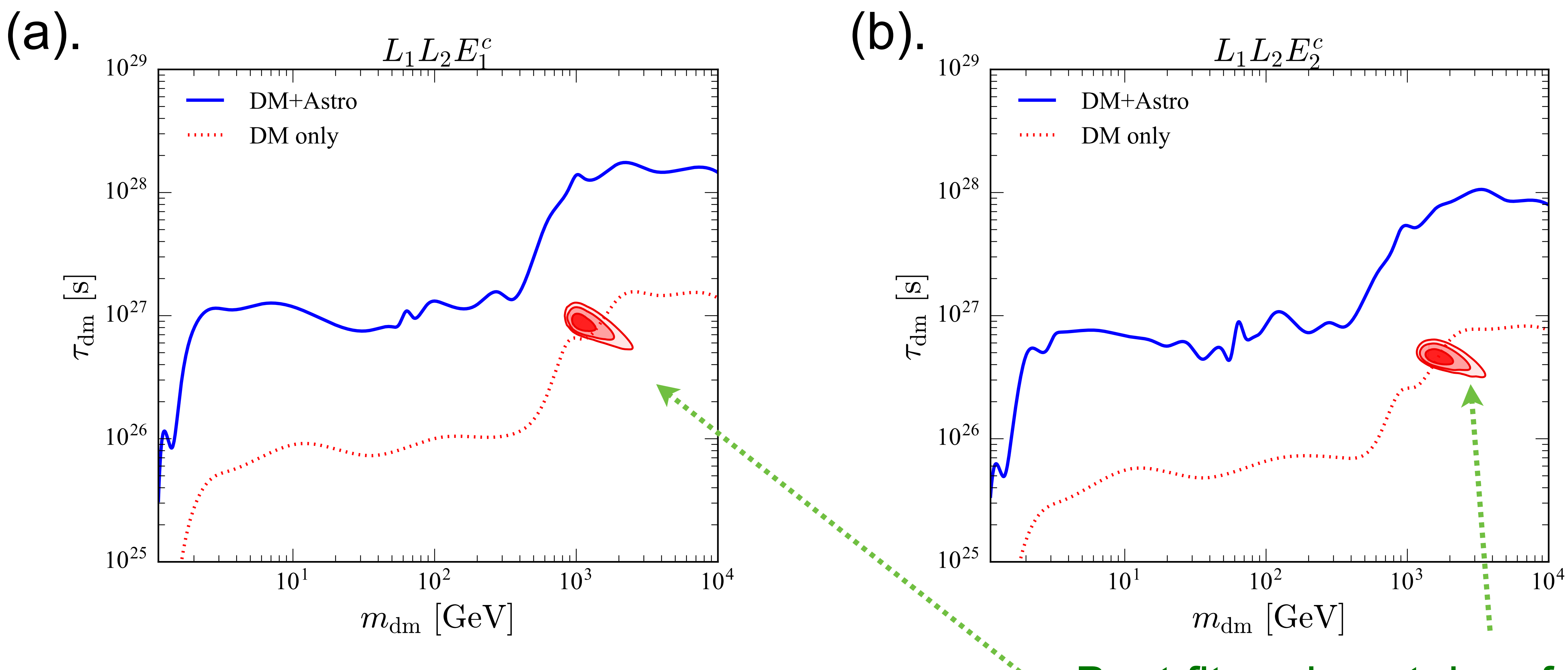
(b).



Including astrophysical sources give ~10 times stronger constraints

Decaying DM (for the anomalous e^+)

Ando, KI '16



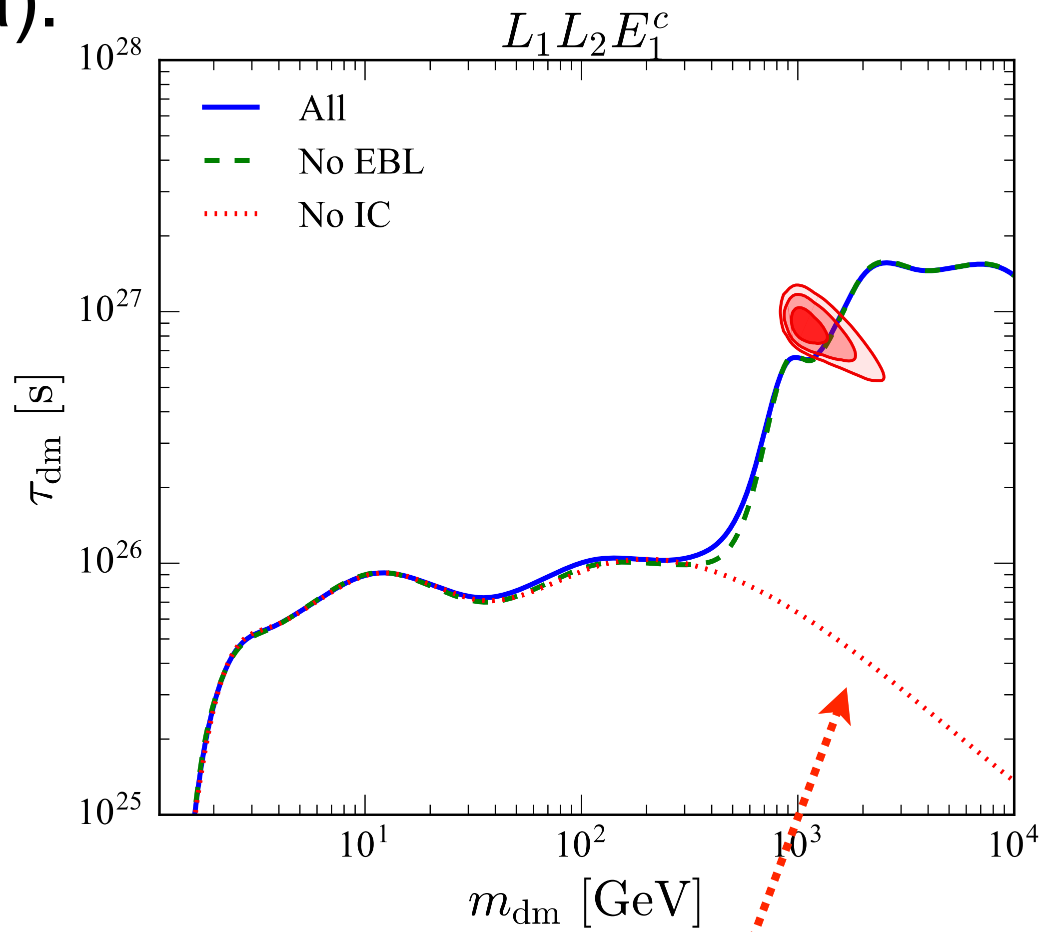
Best fit regions taken from
Ibe et al.'14

The preferred regions are excluded

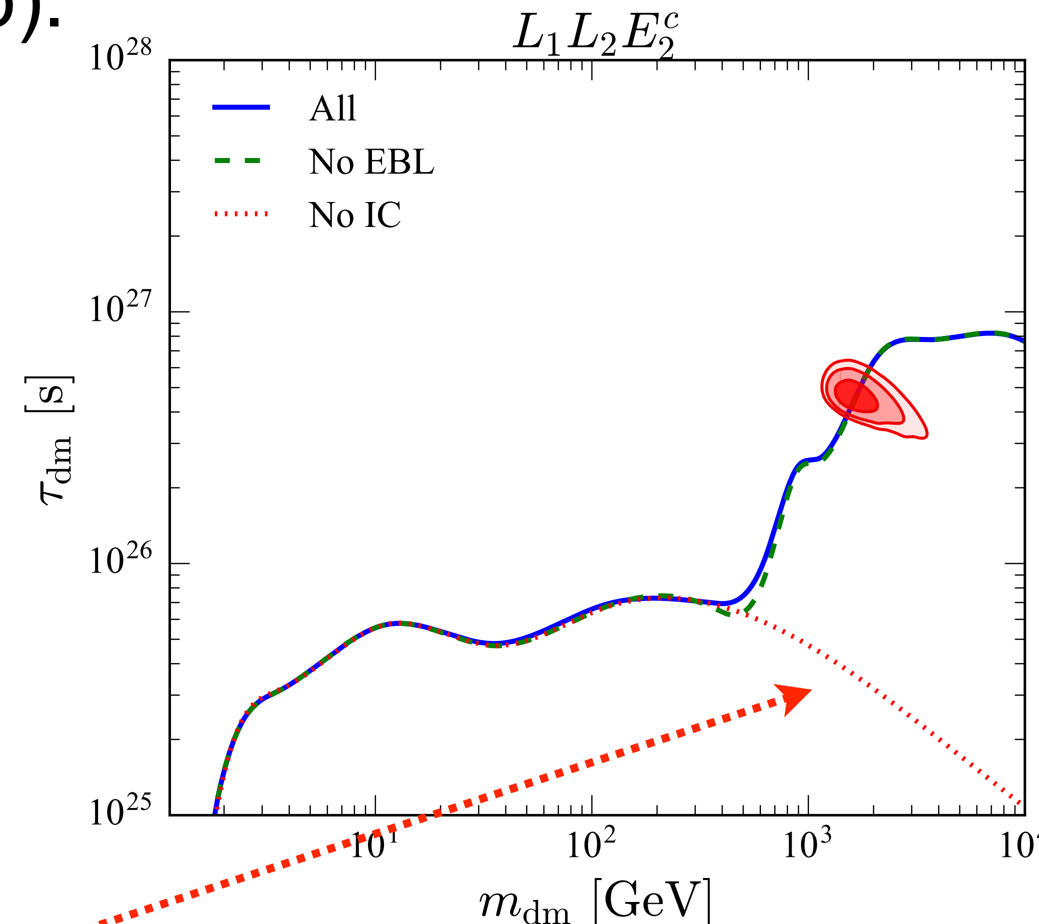
Impacts of IC gamma rays

Ando, KI '16

(a).



(b).

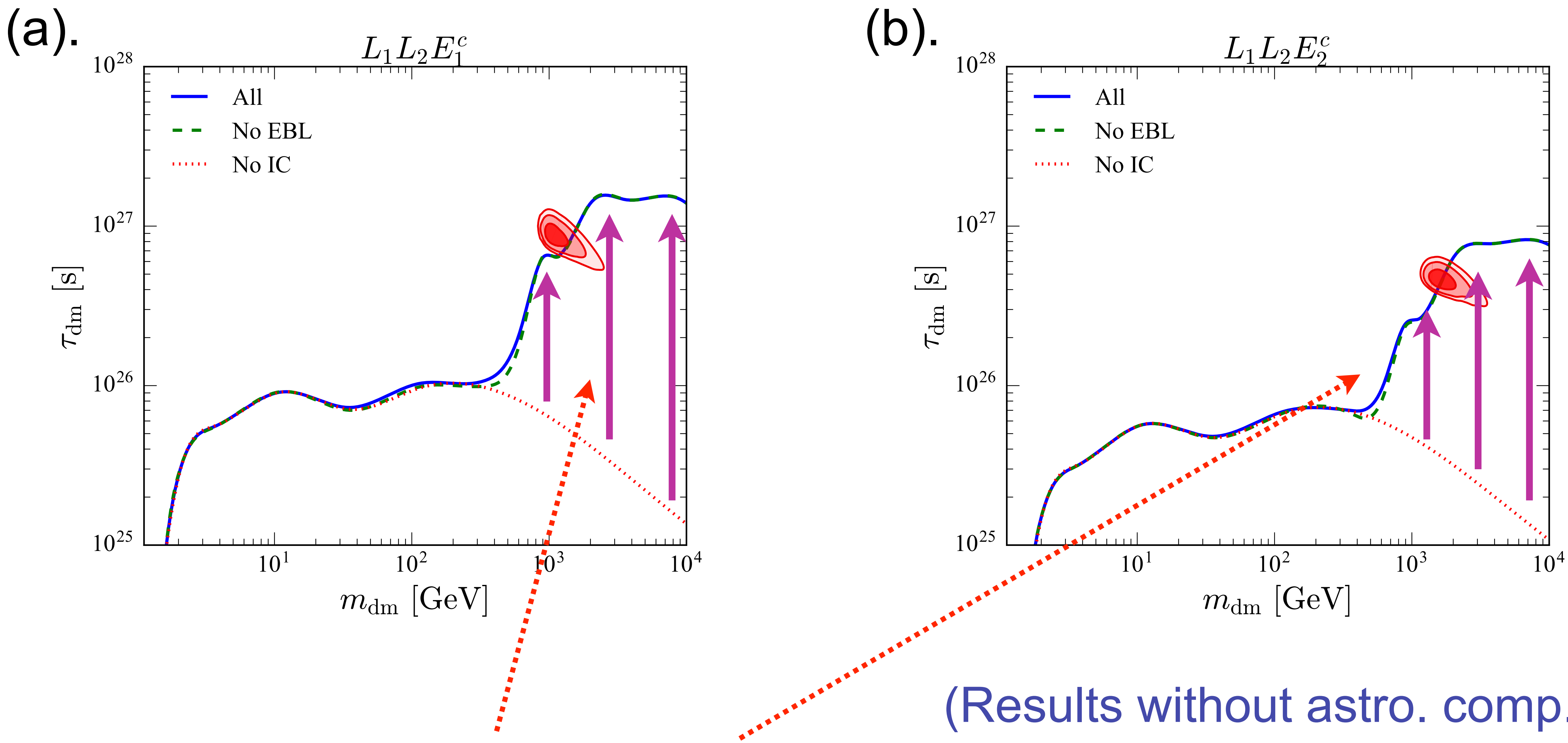


Results without IC
(consistent with Regis et al. '15)

(Results without astro. comp.)

Impacts of IC gamma rays

Ando, KI '16

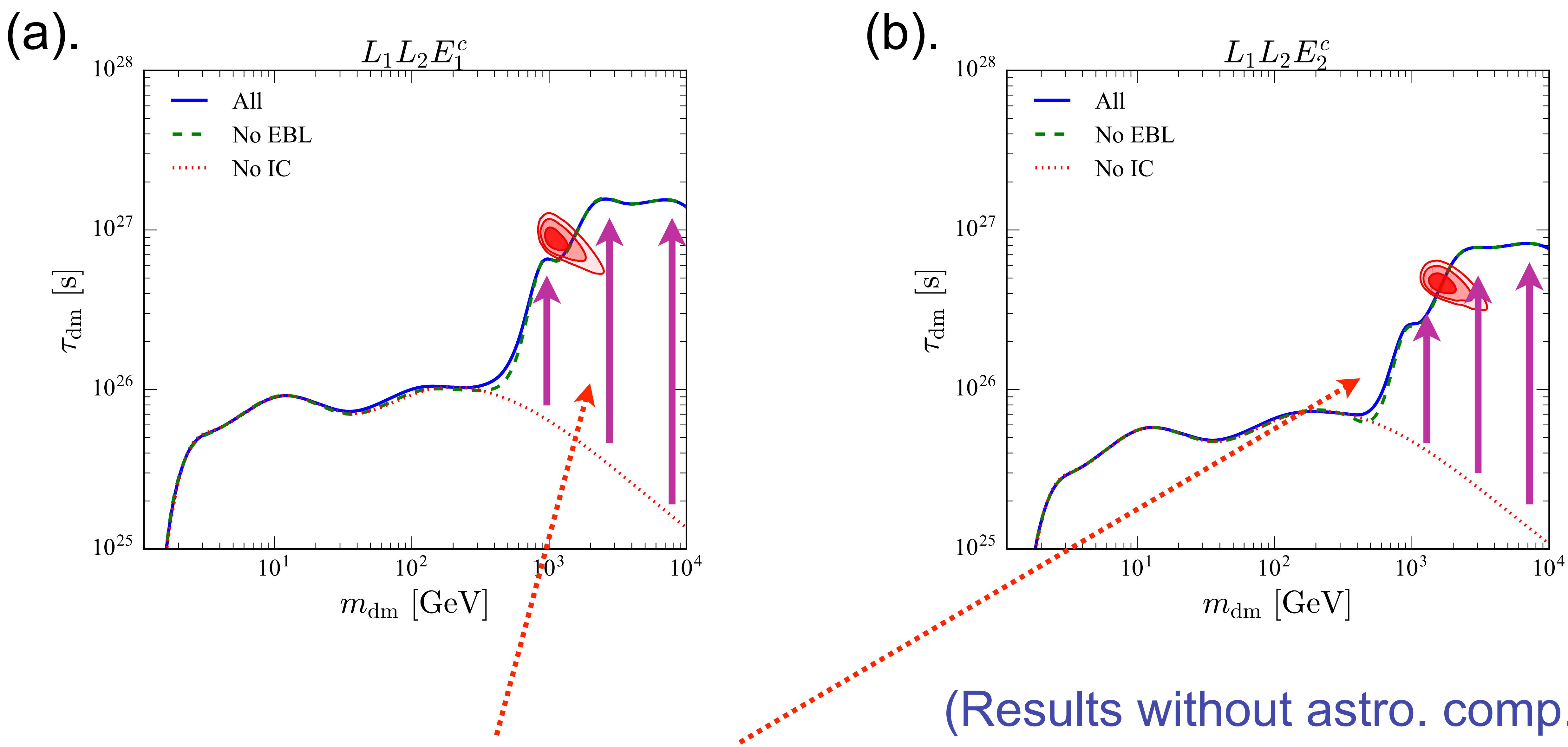


(Results without astro. comp.)

IC gamma gives 1-2 orders of magnitude stronger constraints over TeV region

Impacts of IC gamma rays

Ando, KI '16



(Results without astro. comp.)

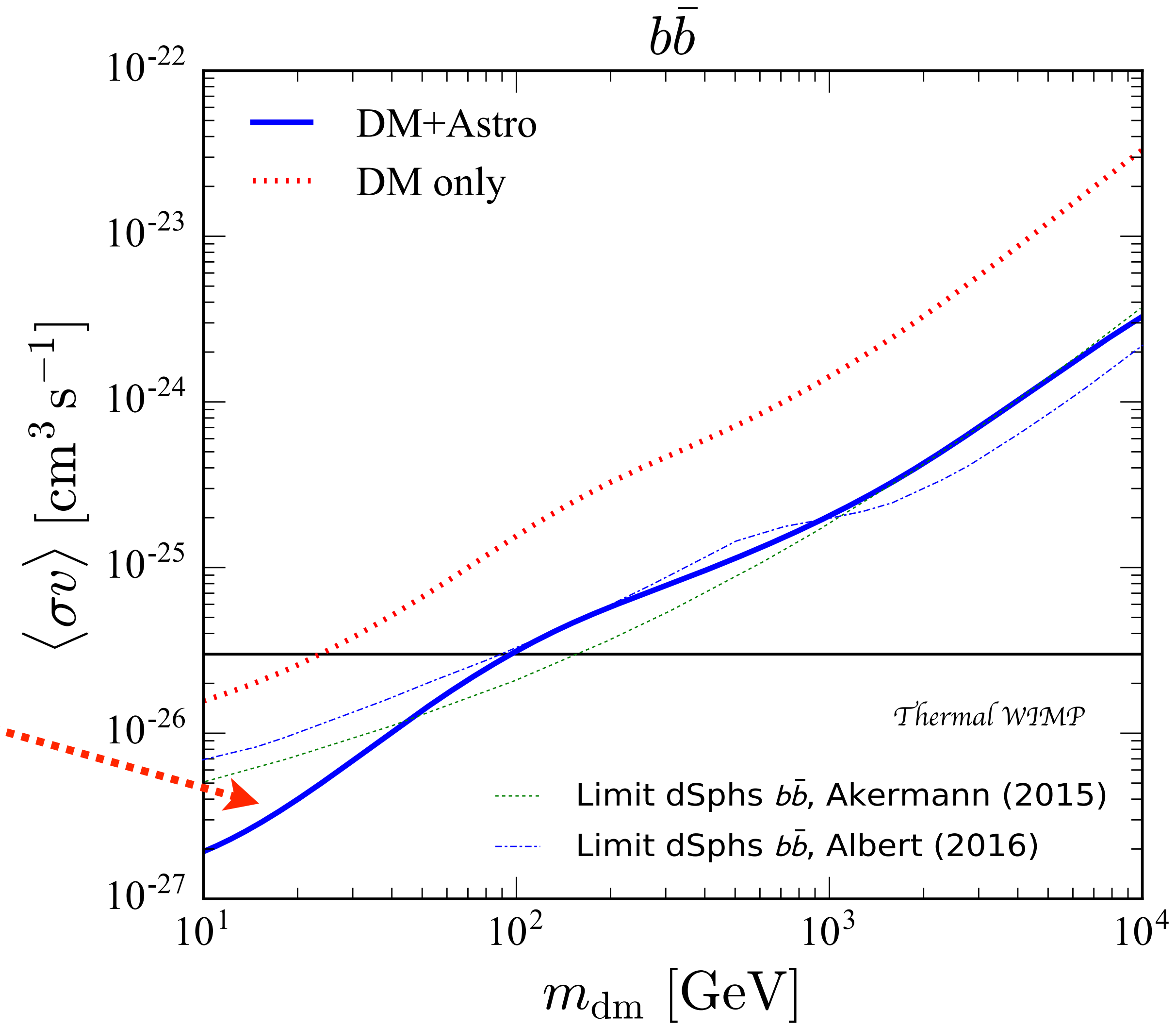
IC gamma gives 1-2 orders of magnitude stronger constraints over TeV region

→ IC gamma rays are crucial to constrain over TeV DM

Annihilating DM (for the anomalous $\bar{p}$)

$\mathrm{DM\ DM} \to b\bar{b}$

Ando, KI '16



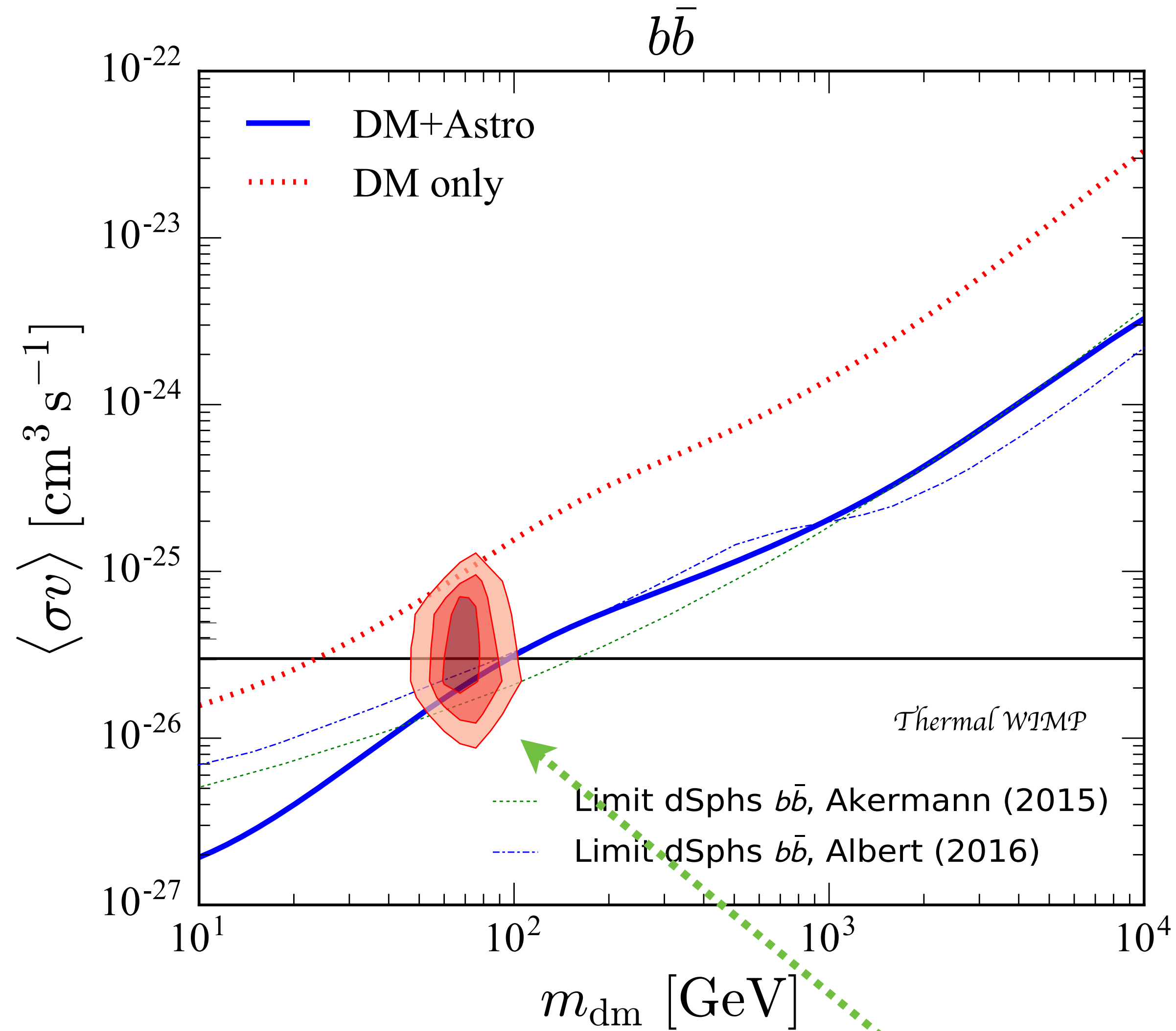
Obtained constraints are similar to those given by dwarf galaxy

(consistent with Cuoco et al. '15)

Annihilating DM (for the anomalous $\bar{p}$)

$\mathrm{DM\ DM} \to b\bar{b}$

Ando, KI '16



Best fit regions given by
Cuoco et al. '17

More data will be needed to check the anomaly

4. Conclusion

We have studied DM using local galaxy distribution

- The preferred regions for the anomalous positron flux $m_{\rm DM} = 1\text{-}10\ \mathrm{TeV},\ \tau_{\rm DM} = 10^{27\text{-}26}\,\mathrm{sec}$ are excluded
- IC-induced gamma rays are crucial for the exclusion
- This analysis will be another check for 80 GeV annihilating DM motivated by the anomalous antiproton