Speaker: Alexandre INVENTAR

PhD Supervisor: Stefano GABICI

γ-ray signatures of particle acceleration from stellar clusters up to PeV energies

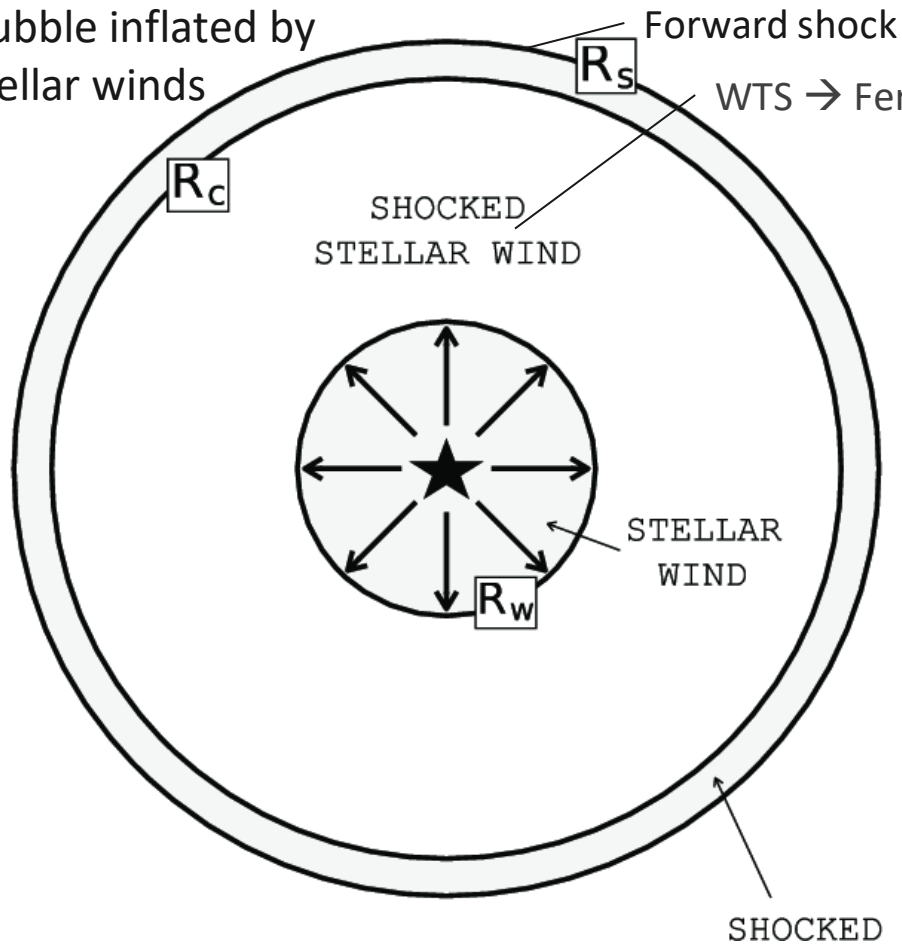
INTRODUCTION AND MOTIVATIONS

Main question: For which systems and parameters can we detect an excess of γ-rays generated through p-p interactions by CRs accelerated in star clusters?

Goal: Find corresponding existing systems, compare the models to LHAASO γ-ray flux

→ Identify contributions of star clusters to CR flux at different energies (especially at PeV)
→ Obtain better constraints on acceleration parameters (WTS efficiency, injection slope,…)
→ See if it can explain some unassociated PeVatrons (eg molecular clouds far from a cluster)

DIFFERENT HADRONIC γ-RAYS PRODUCTIION SCENARIOS WITH STELLAR WIND



Gabici, Cosmic rays from star clusters

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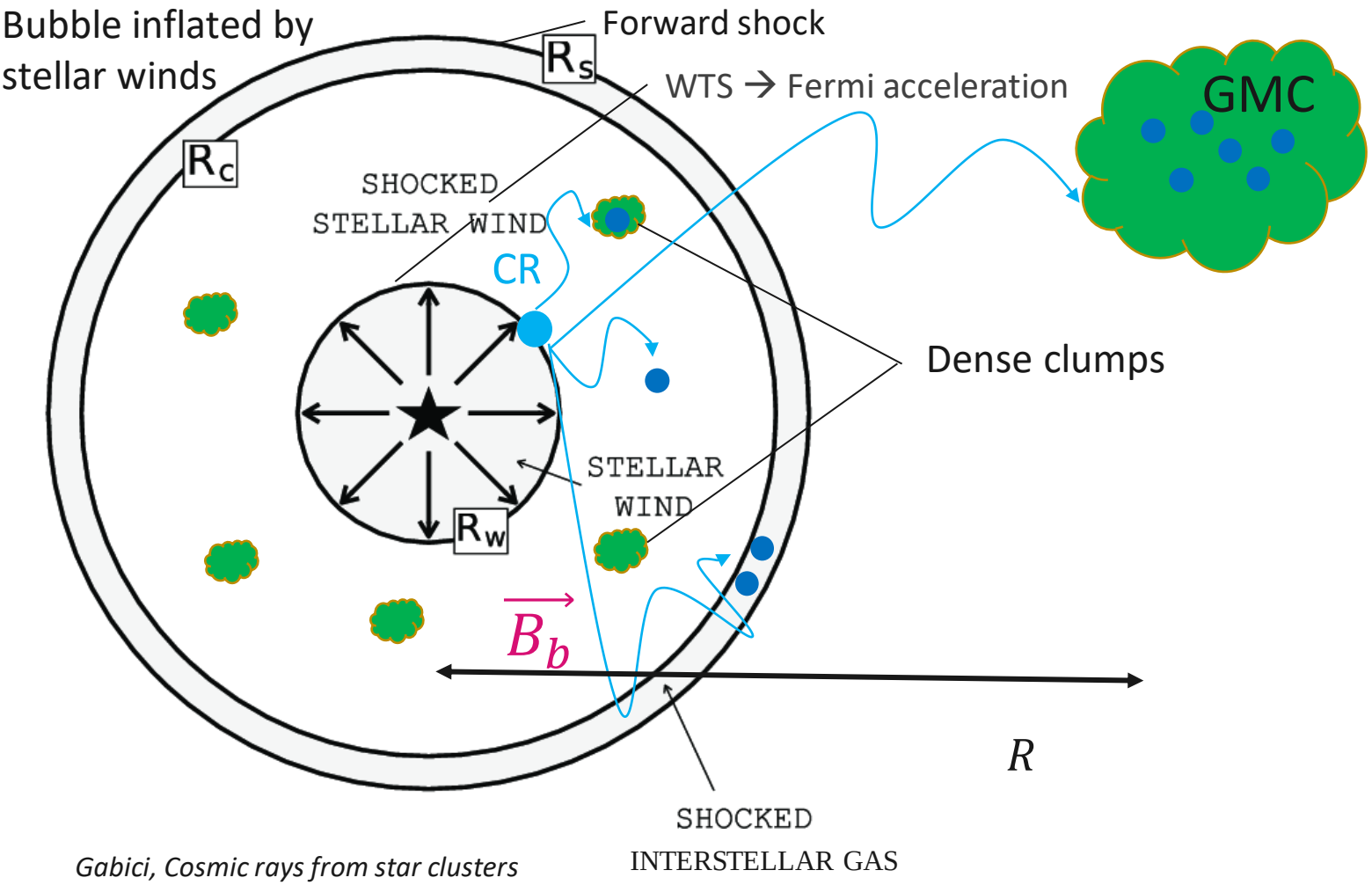

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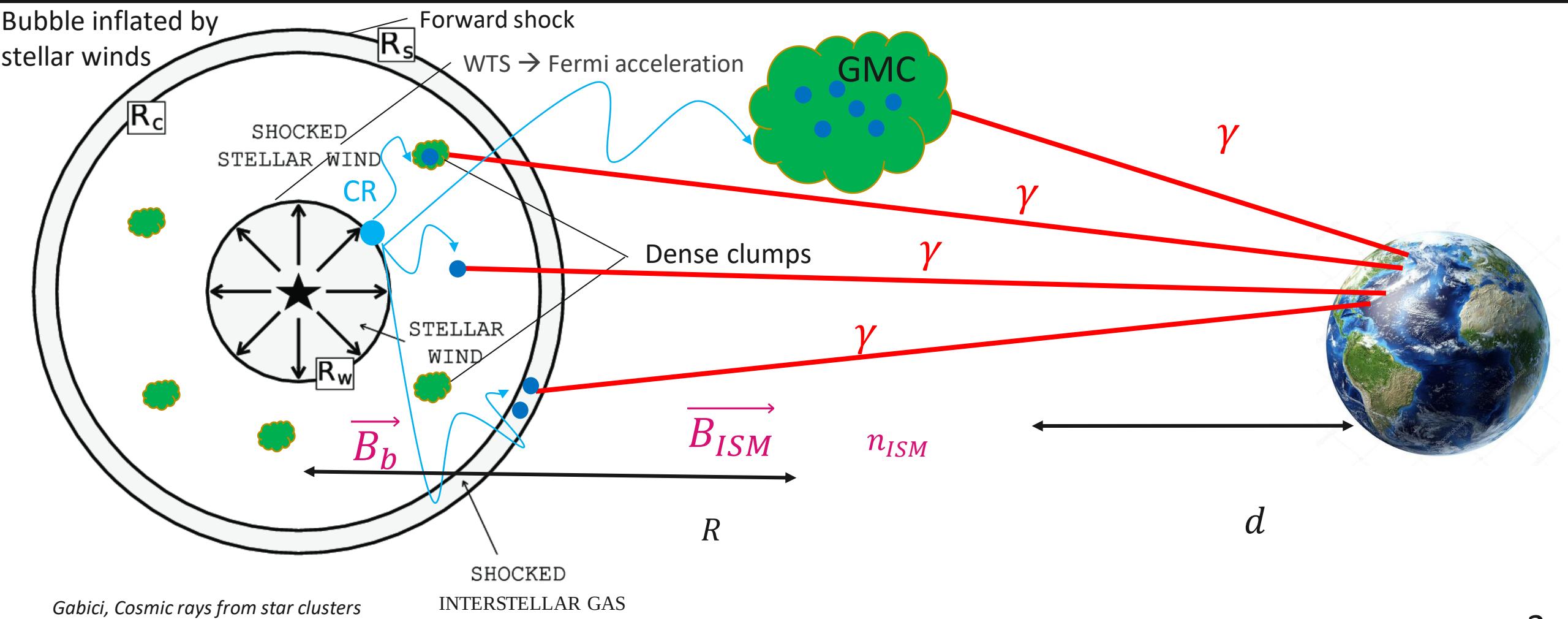

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SPATIAL DEPENDENCE OF THE γ-RAY FLUX

- Find maximal distances up to which a detectable excess is possible, at fixed energy

- Injection spectrum in the bubble or in the ISM :

$$f_{inj} \sim \epsilon_w L_w p^{-\alpha_p} \exp\left(-\frac{E}{E_{max}}\right)$$

- Diffusion coefficient taken as

$$D(E) = D_{10}\left(\frac{pc}{10}\right)^{\delta}$$

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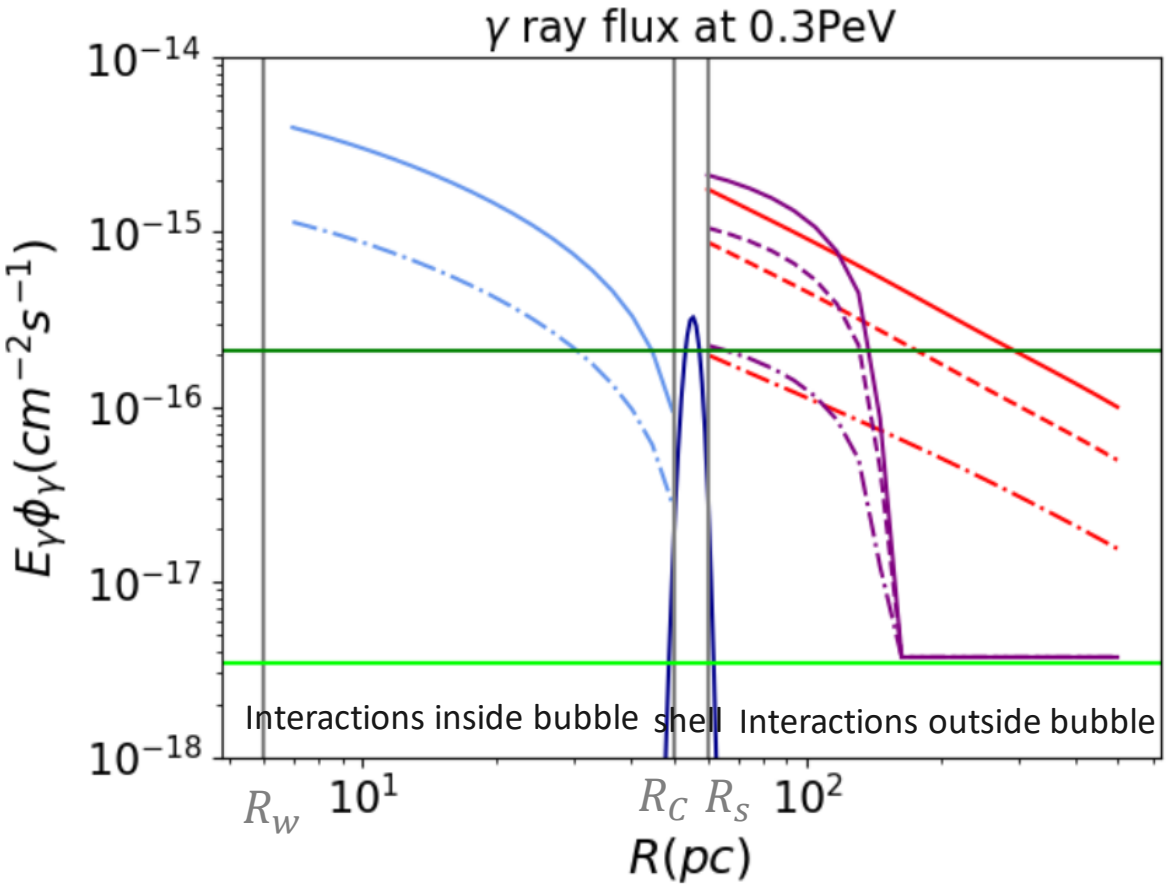

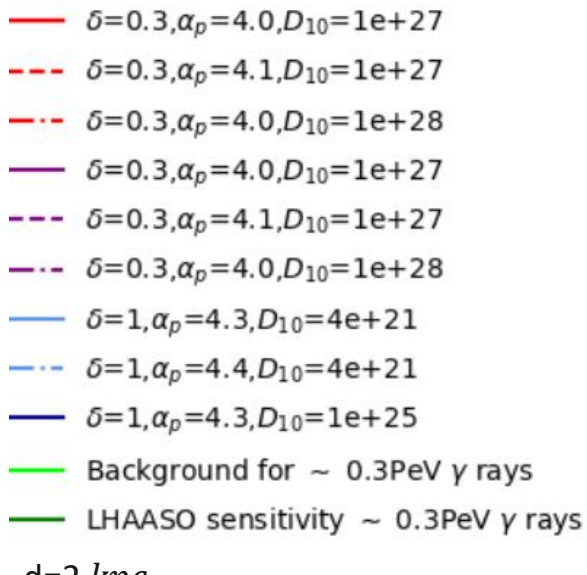

d=2 kpc
$M_{cloud} = 10^5 M_\odot$, $M_{clumps} = 10^4 M_\odot$
$L_w = 3 \cdot 10^{38}$erg/s
$n_{ISM} = 100 cm^{-3}$
$E_{max} = 3PeV$

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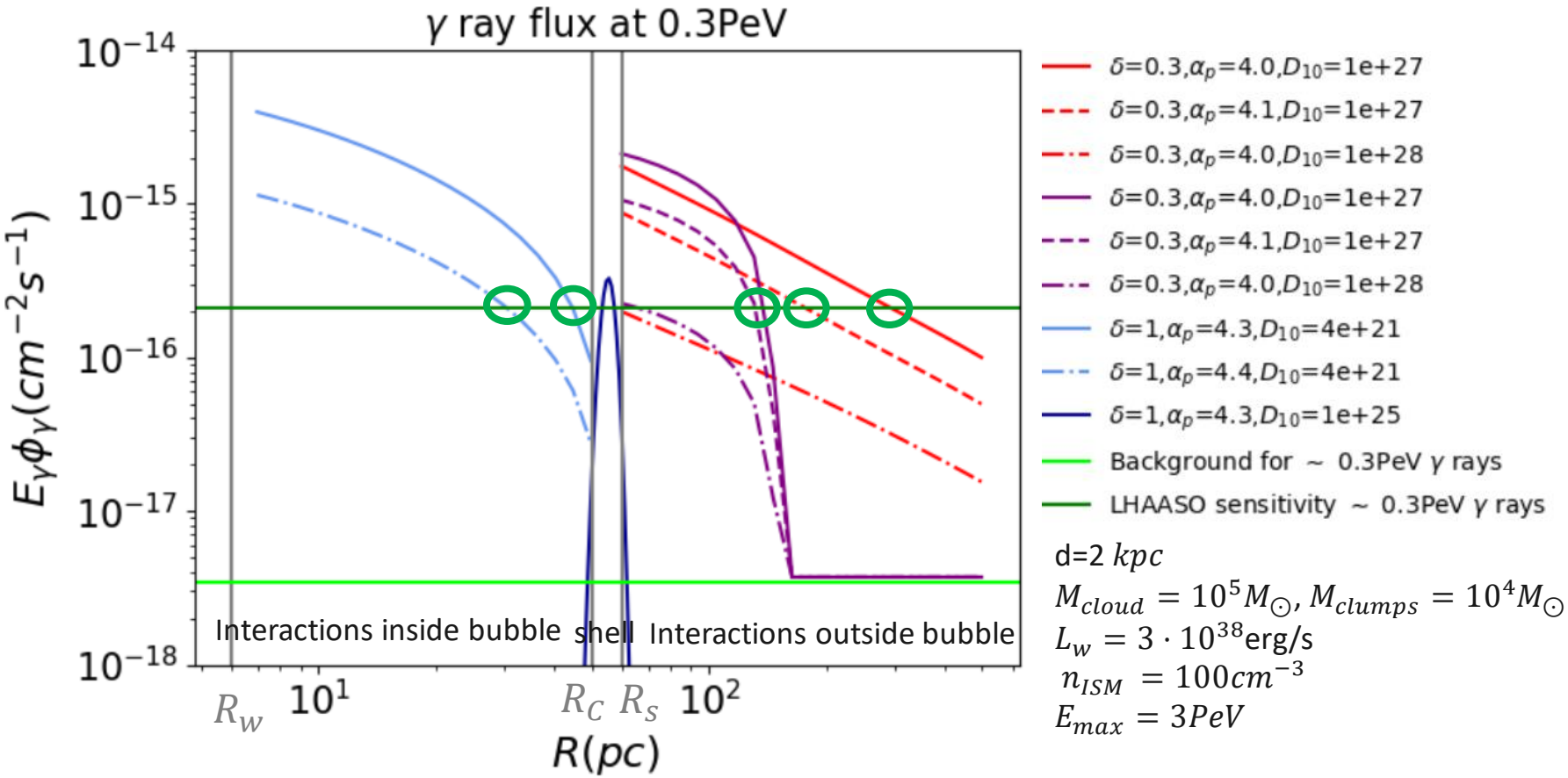

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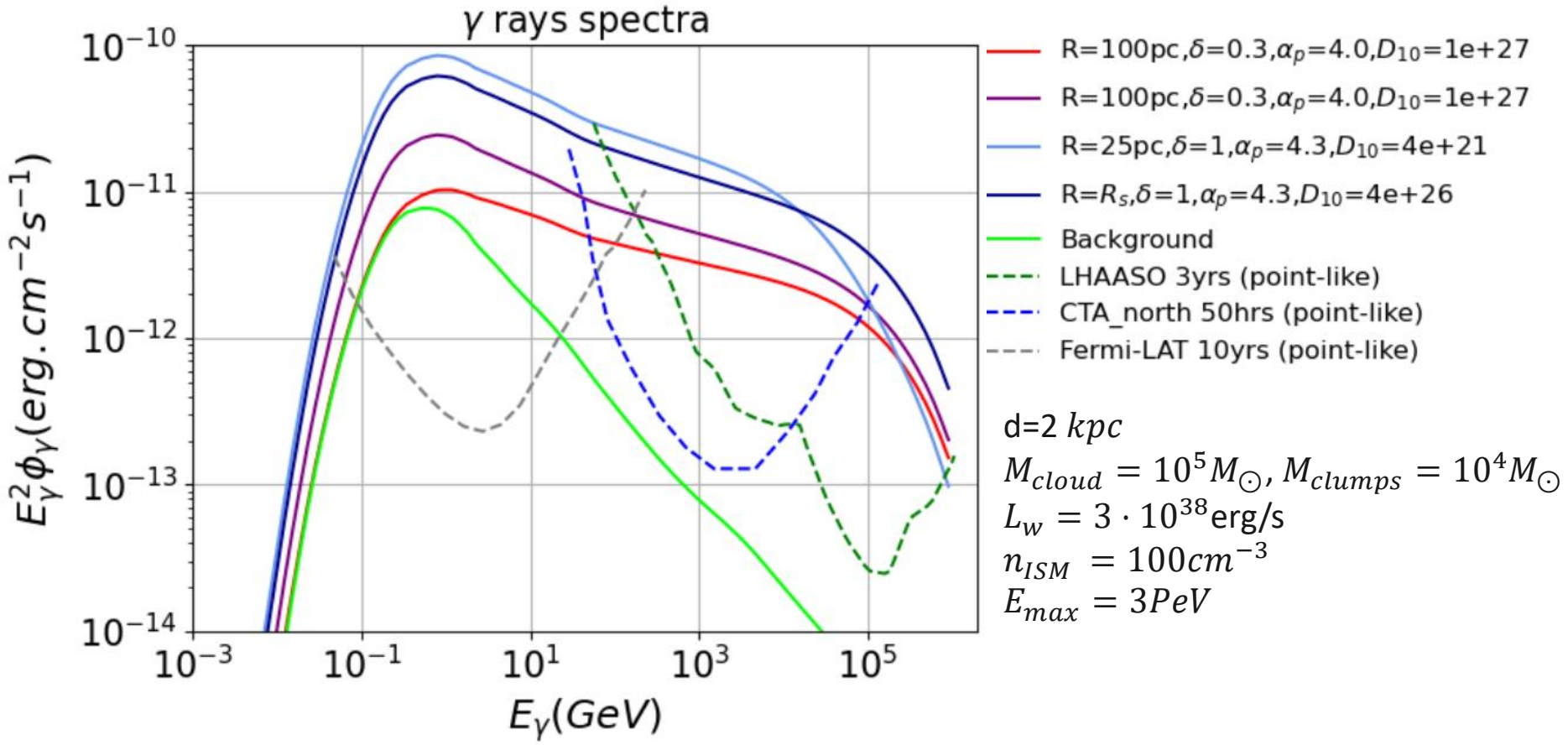
At high energies, sensitivity gives an effective maximal distance to have a detectable excess $\boldsymbol{R_{max,effective}}$

γ-RAY SPECTRA

- Fixing distances, compute the flux for any energy to compare with observed spectra and deduce the minimal parameters configurations enabling a detectable excess



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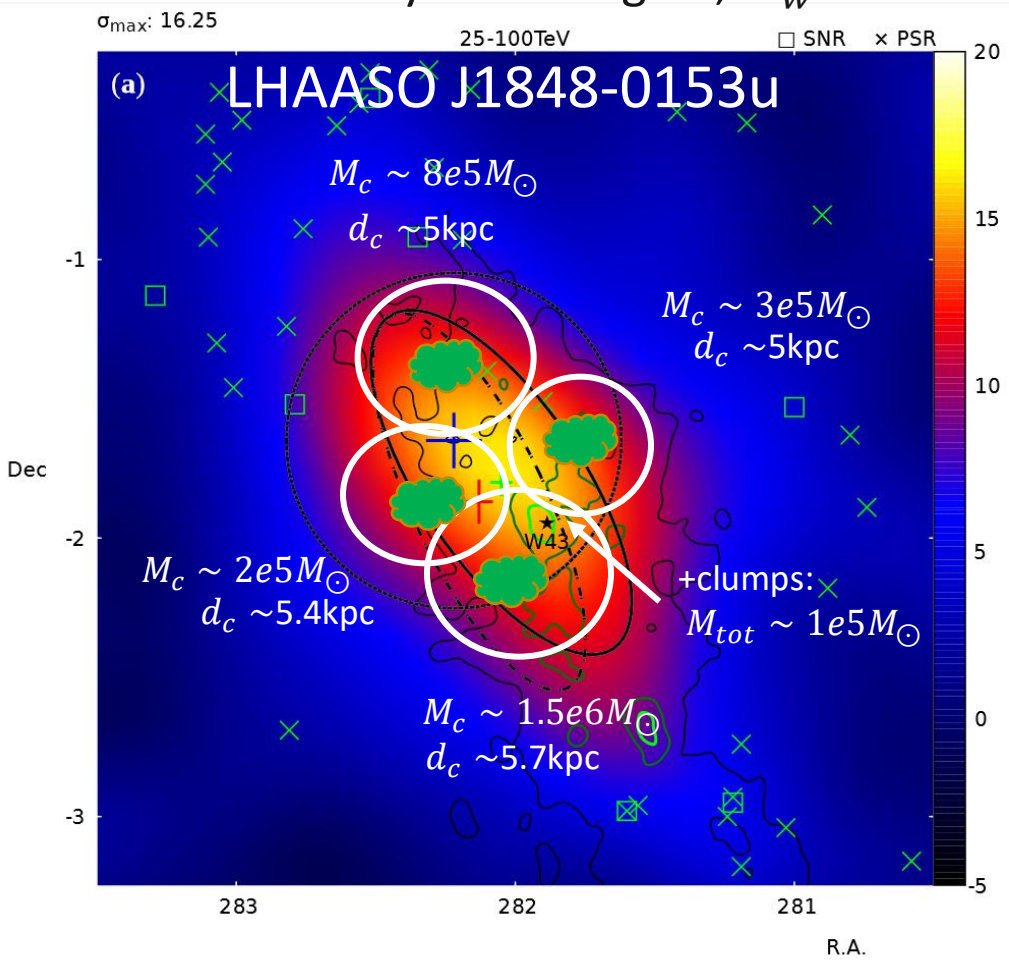
APPLICATION: W43 MAIN

Very active region, $L_w \sim 3e38\ erg/s,\ t \sim 6Myr,\ n_{ISM} \sim 100cm^{-3},\ d \sim 5\ kpc$



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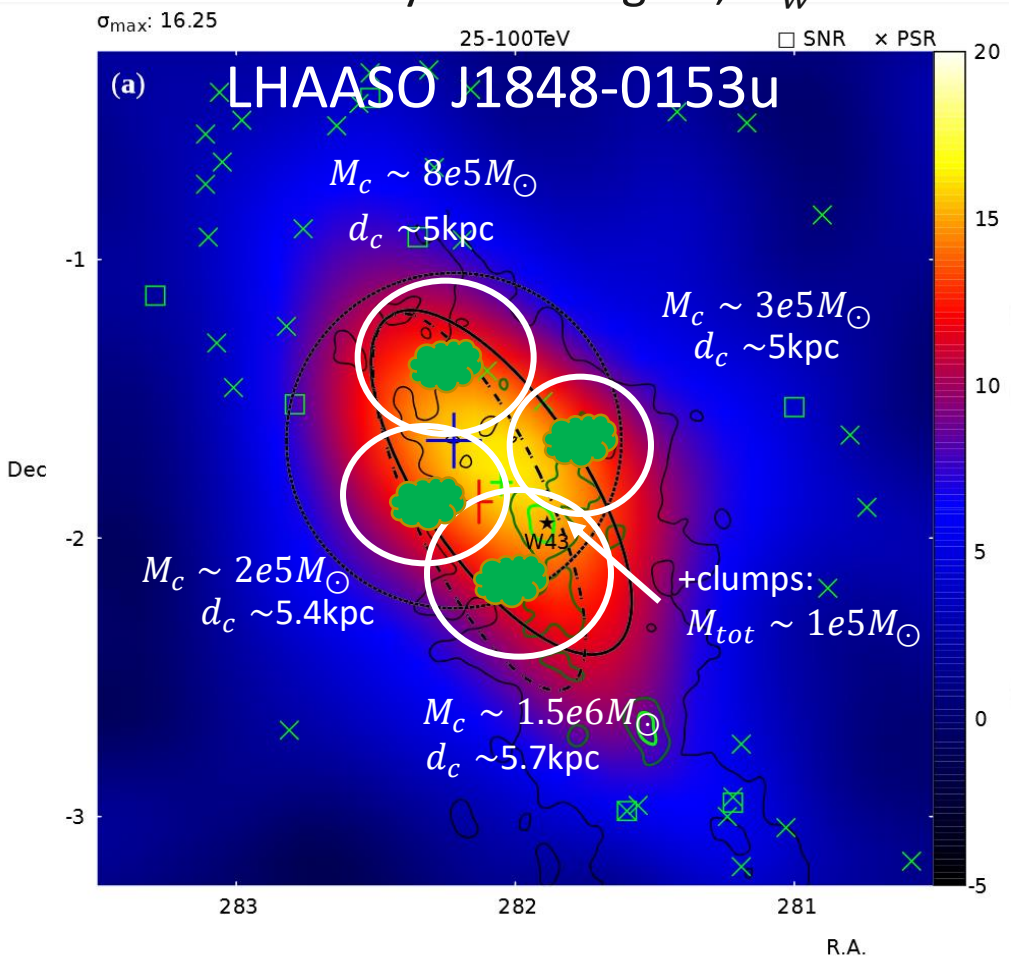

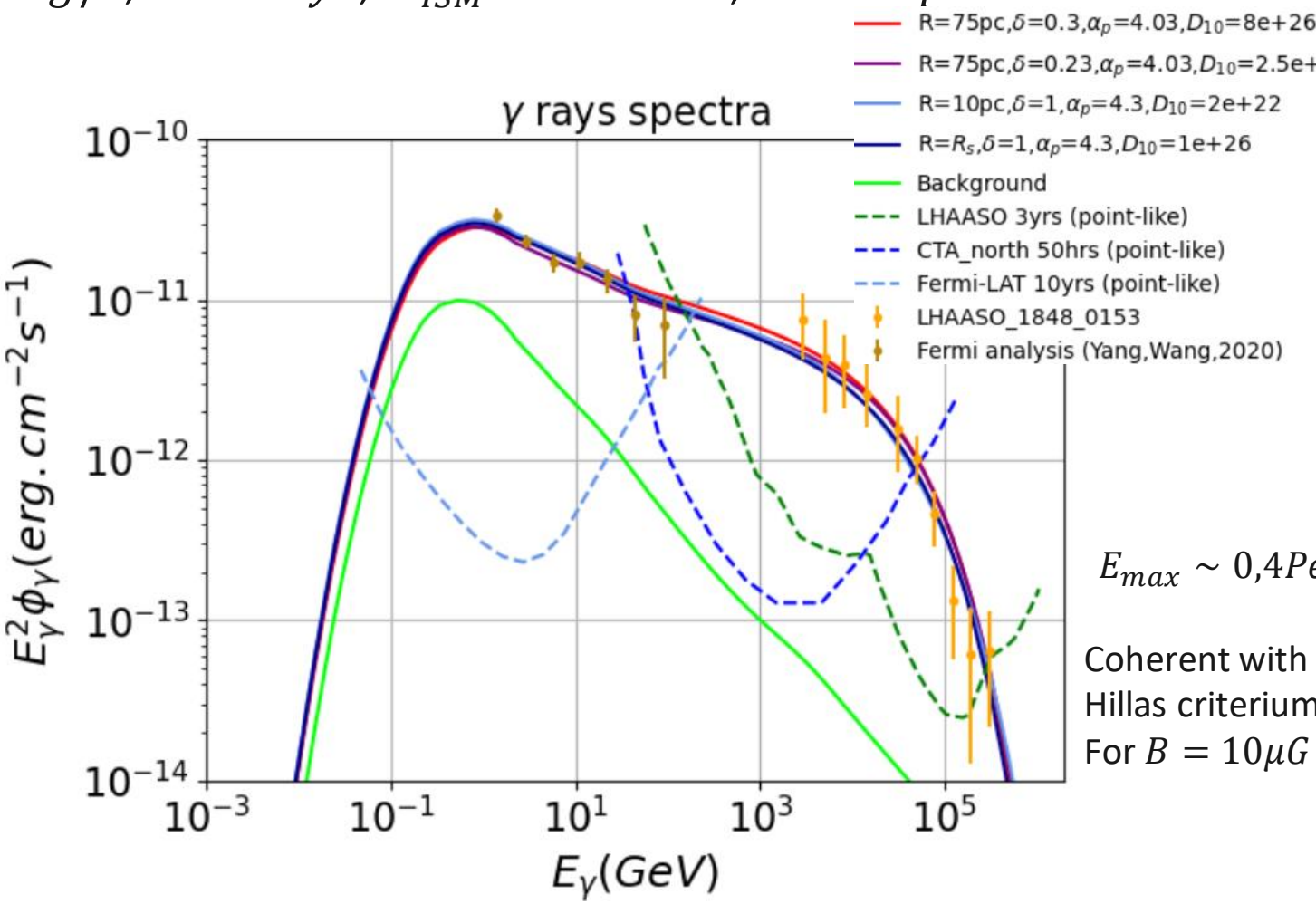

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Coherent with Hillas criterium For $B = 10\mu G$

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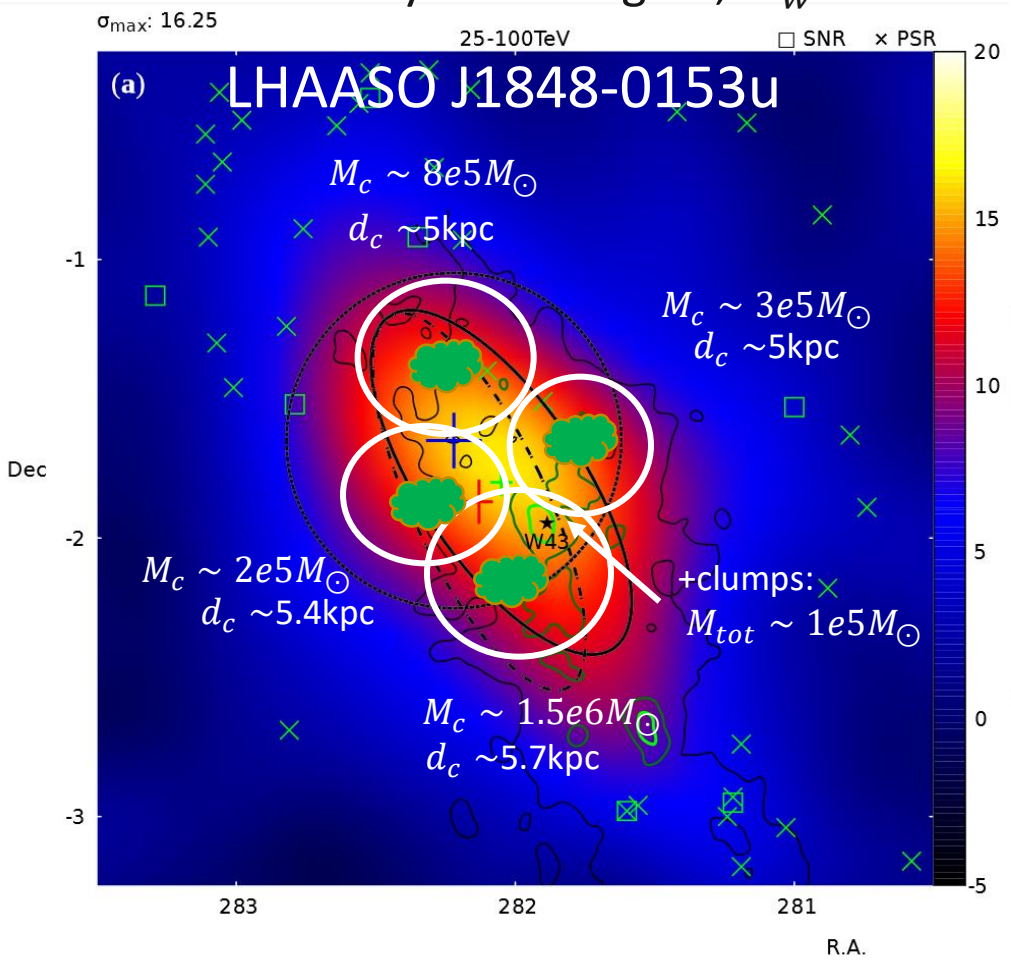

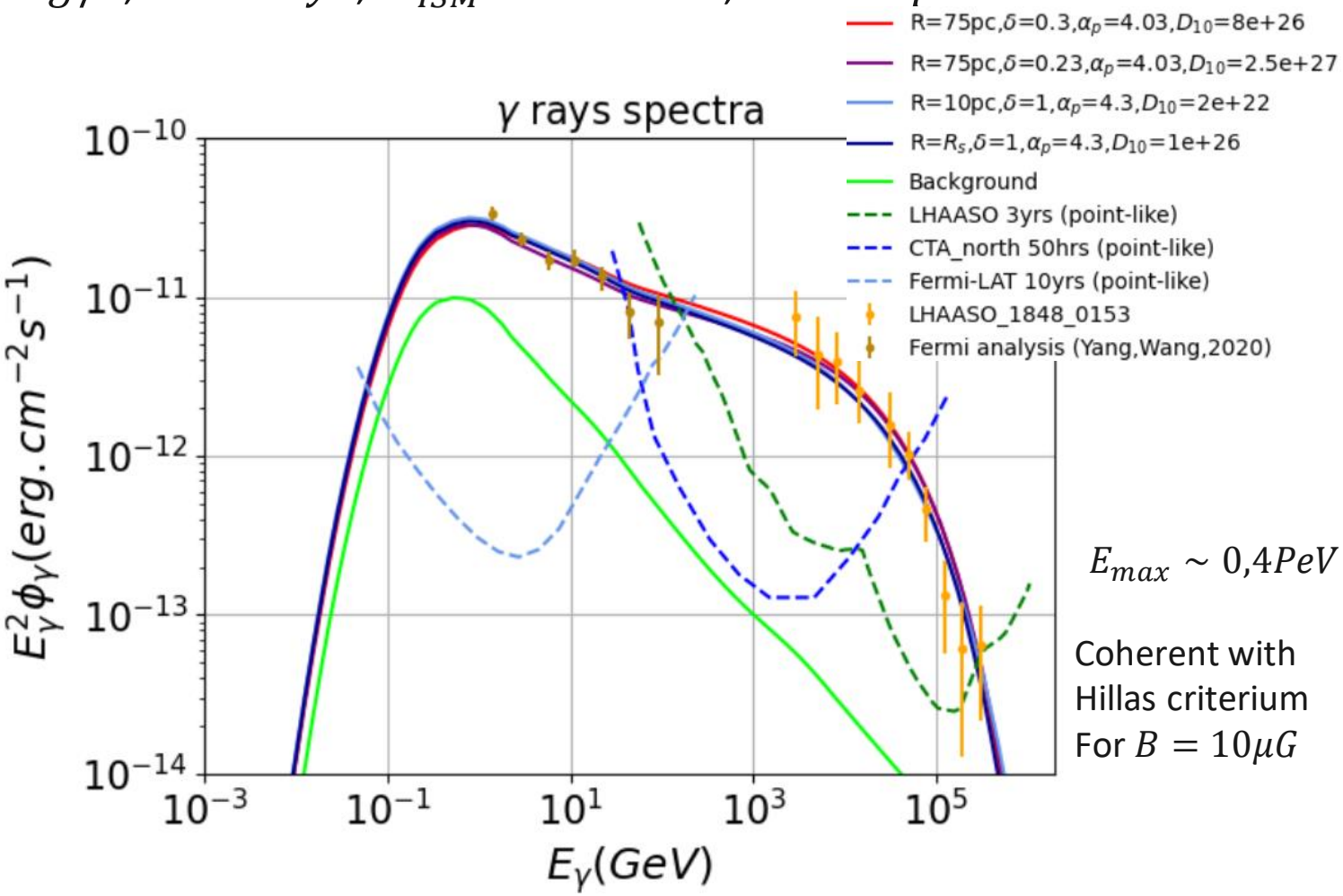

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- Can infer parameters from the models. Typically, with 3D diffusion and GMC: $\epsilon_w \frac{1e28cm^2s^{-1}}{D_{10}} \sim 1$ and $\alpha \sim 2,\ \ \delta \sim 0{,}3$
- Leptonic ? Big extension so difficult because of the cooling time

CONCLUSION AND OUTLOOKS

- Several possible hadronic scenarios for creating γ-rays
- Detector sensitivity implies effective maximal distances to detect γ-rays excess

→ **Constrain the subset of parameters and systems that enabling detectable excess**

- Can find systems in this subset (like W43) , and compare models to data

→ Identify **contributions of star clusters to CR flux**
→ Determine more precisely **the WTS efficiency and injection slope**
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Outlooks:
- Take into account embedded SNRs → acceleration and reacceleration
- Find other powerful star clusters and UHE γ-ray data to have more constraints

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THANK YOU FOR YOUR ATTENTION !