Subparsec and parsec VHE emission from the core of LLAGNs

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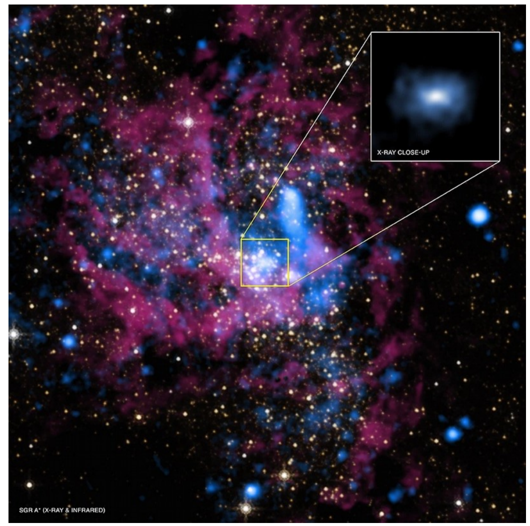
FAPESP

Overview

- Introduction
- Turbulent magnetic reconnection in BH accretion flows
- CR emission signatures of Sgr A* and Cen A
- Conclusions

Introduction: LLAGNs

- **Sagittarius A* (Sgr A*): LLAGN at the GC**



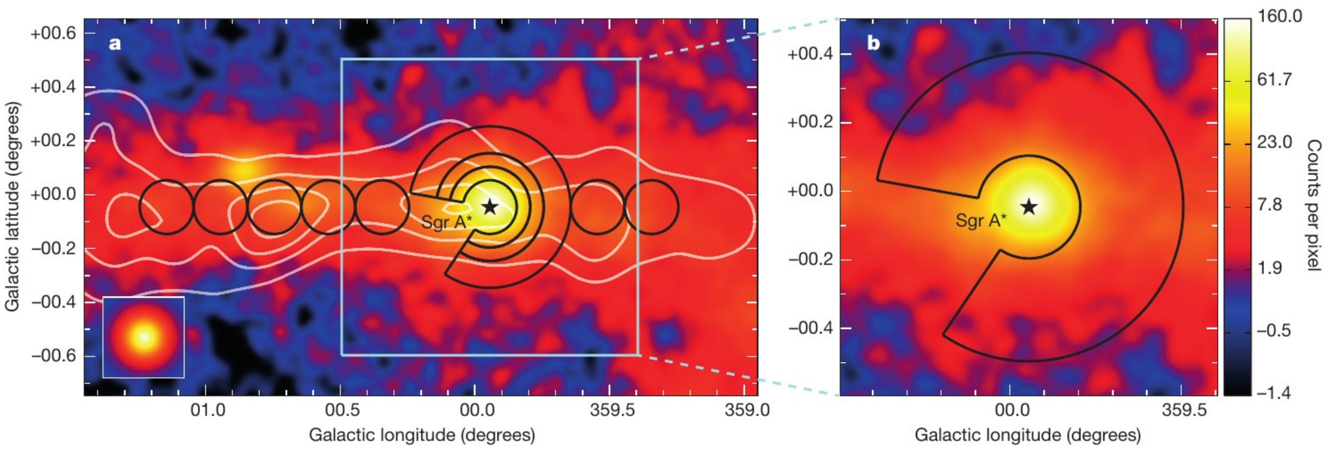
X-ray luminosity $<10^{42}$ erg s^{-1}

- **Associated with VHE γ-ray emission.**
- **Difficult to explain with SSC scenario.**

- **Centaurus A (Cen A): The closest active radio galaxy at 3.8 Mpc**

SgrA*

Diffuse VHE emission correlated to the MC complex

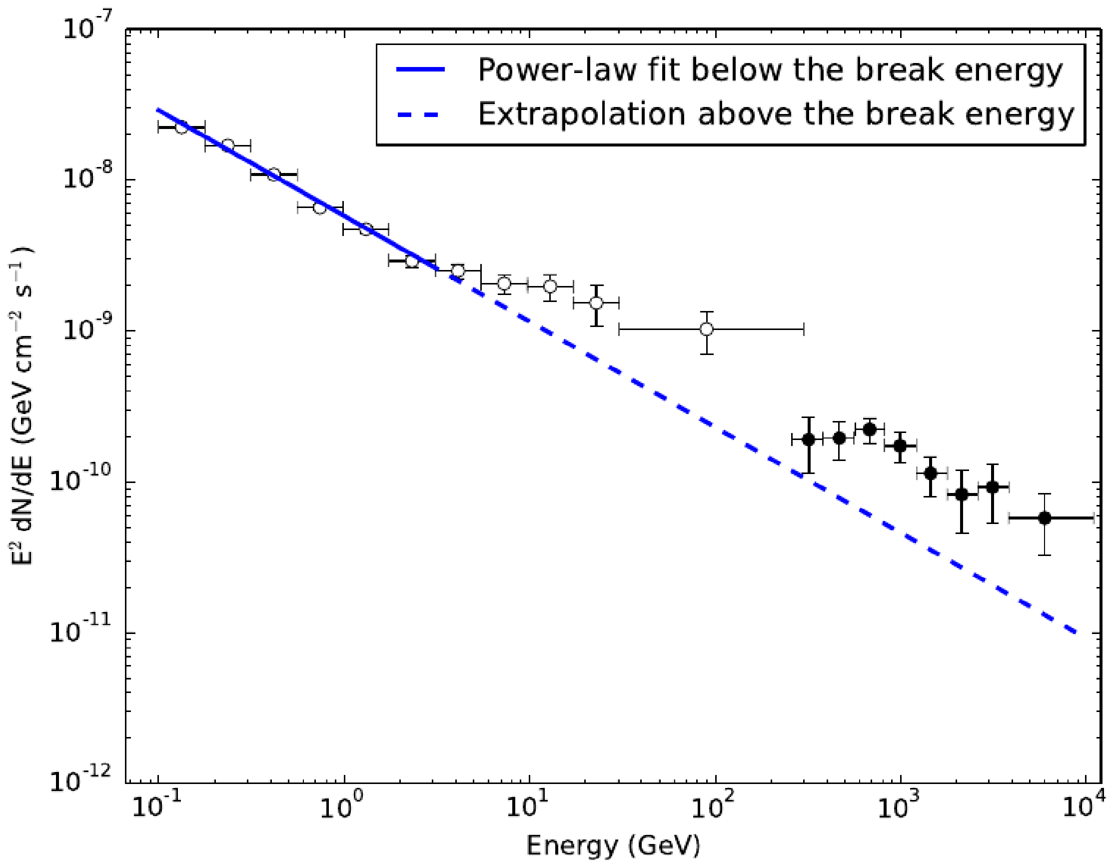


- **Suggestive of hadronic emission origin.**
- **SMBH is a strong PeVatron candidate**

H.E.S.S Collab. (2016), Nature.

Cen A

- **SED hardens at ~ 3 GeV**
- **No significant variability detected at GeV – TeV**
- **Extended VHE emission aligned with kpc jets. (see GAI5e talk by M. de Naurois HESS Collab.)**



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Cen A

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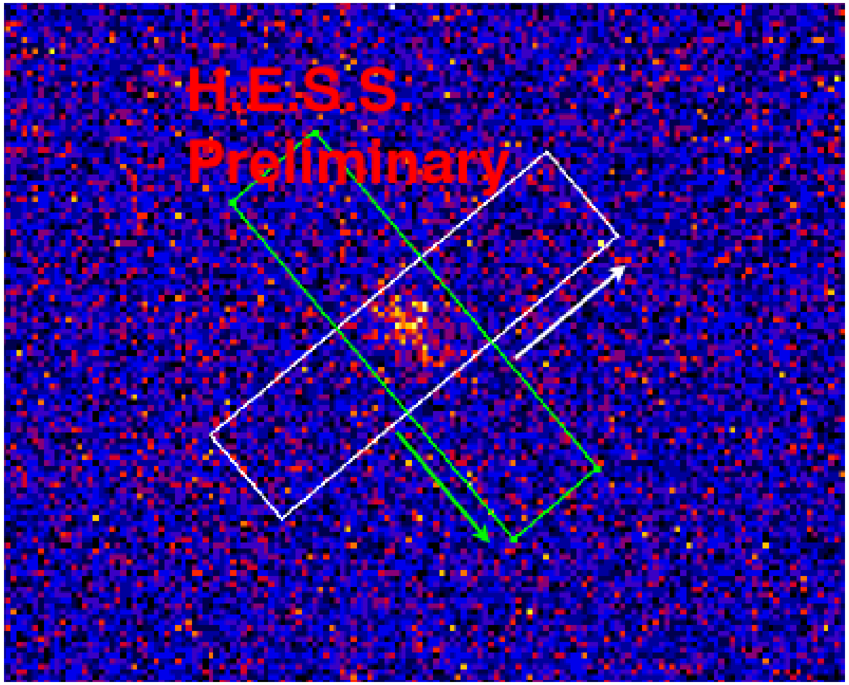


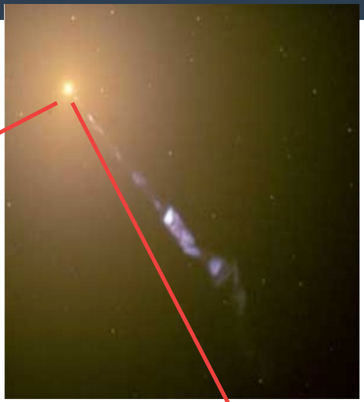
This talk

- ***Can we use current IACTs observations to investigate CR acceleration in the nuclear region of LLAGNs?***

- ***What is the acceleration mechanism?***

- ***How much does the emission of these CRs contribute to the current observed SEDs?***

CR acceleration by turbulent magnetic reconnection



- **In the coronal region of thin and cold BH accretion flows**

  de Gouveia dal Pino & Lazarian (2005)

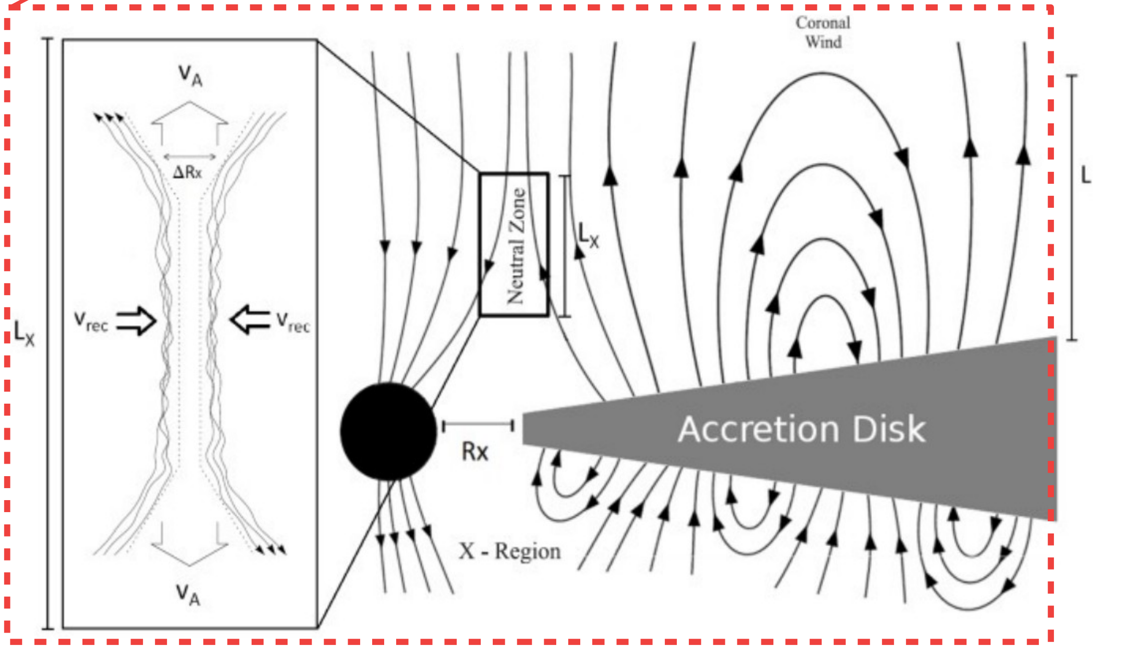
  Kowal, de Gouveia Dal Pino & Lazarian (2011,12)

  Kadowaki, de Gouveia Dal Pino & Singh (2015)

- **In thick and hot magnetised accretion flows**

  Singh, de Gouveia Dal Pino & Kadowaki (2015)

  Kimura, Tomida & Murase (2019)

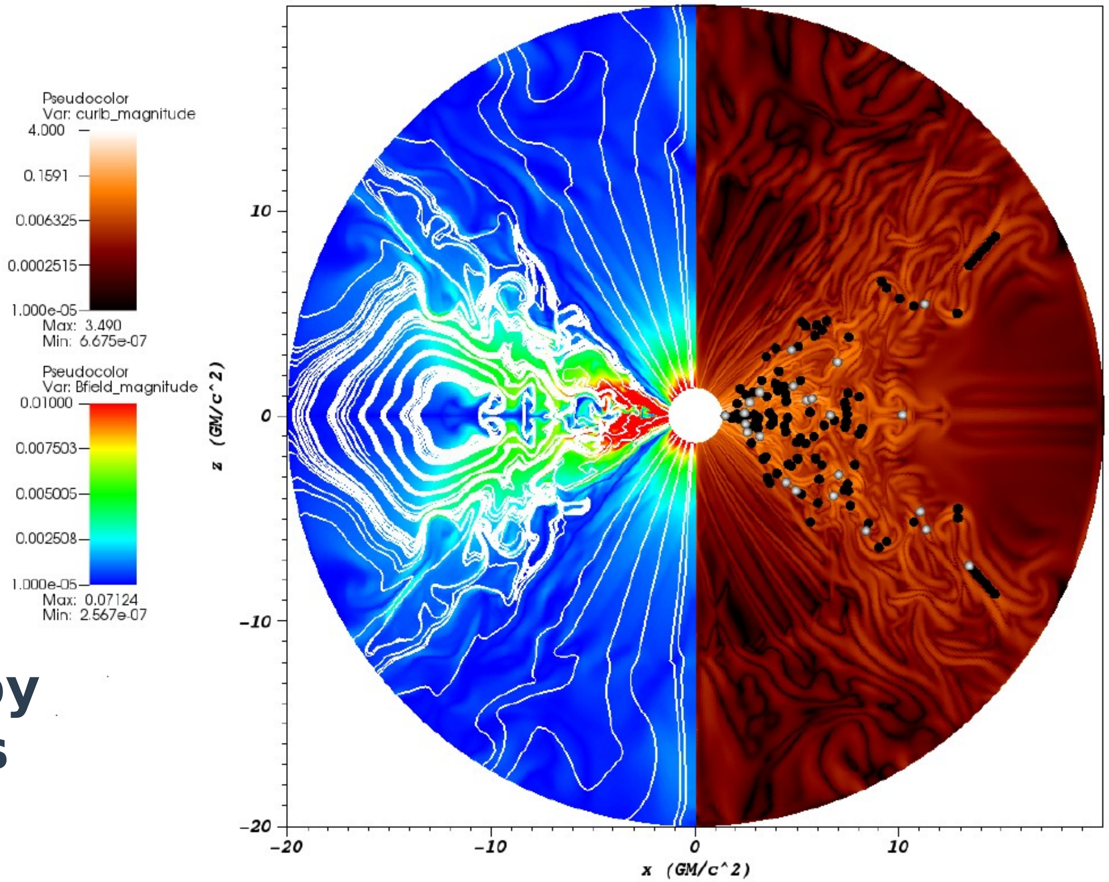


CR acceleration by turbulent magnetic reconnection

Fast magnetic reconnection current-sheet-search algorithm

Kadowaki, de Gouveia Dal Pino & Stone (2018)

Kadowaki, de Gouveia Dal Pino & Medina-Torrejon (2019)



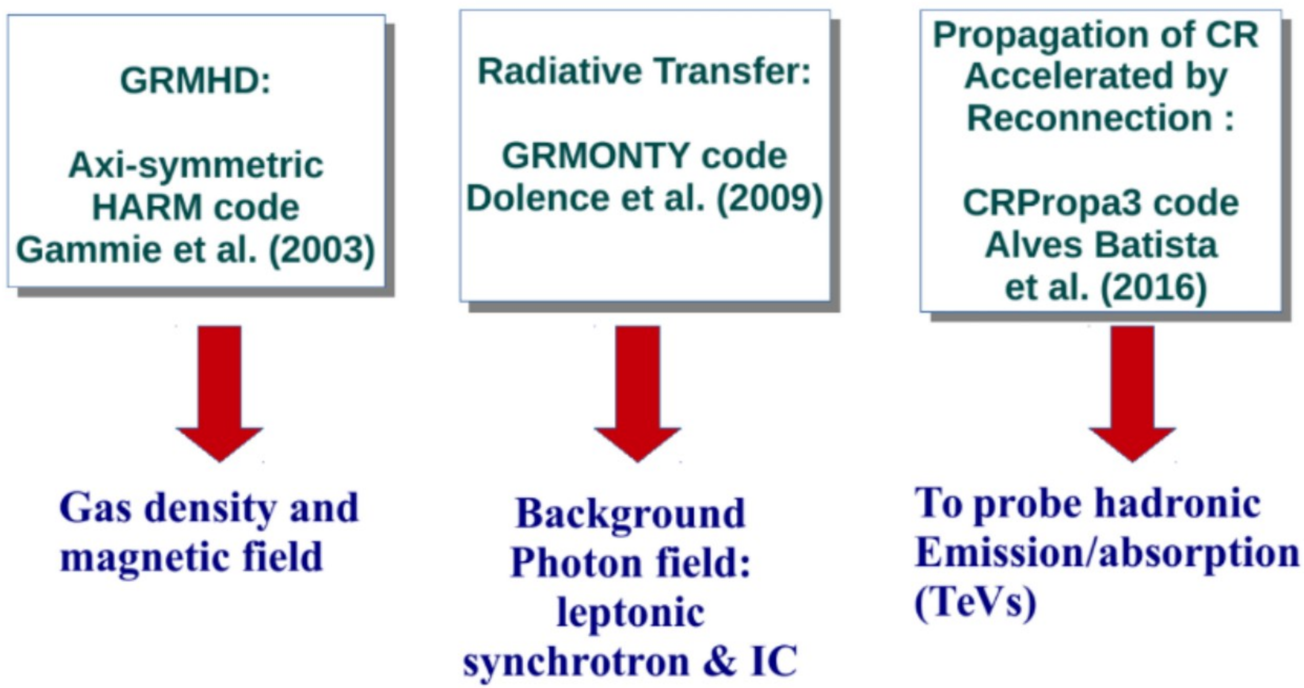
Also in reconnenction induced by kink stability in magnetised jets

de Gouveia Dal Pino et al. (2019)

Athena++ code

CR emitting in the acceleration zone

We combine three numerical techniques:



We tested this approach to calculate potential VHE emission from the RIAF of SgrA*:

Rodríguez-Ramírez et al. (2019) ApJ 843, 136

CR emitting in the acceleration zone

We combine three numerical techniques:

$$\lambda_{pp}^{-1}(E_p, R_i, \theta_j) = \sigma_{pp}(E_p) n_i(R_i, \theta_j),$$

$$\lambda_{p\gamma}^{-1}(E_p, R_i, \theta_j) = \frac{m_p^2 c^4}{2E_p^2} \int_0^\infty d\epsilon \times \frac{n_{ph}(\epsilon, R_i, \theta_j)}{\epsilon^2} \int_{145MeV}^{\frac{2E_p\epsilon}{m_p c^2}} d\epsilon' \epsilon' \sigma_{p\gamma}(\epsilon'),$$

CR emitting in the acceleration zone

We combine three numerical techniques:

$$\lambda_{\gamma\gamma}^{-1}(E_\gamma, R_i, \theta_j) = \frac{1}{8E_\gamma^2} \int_{2m_e^2c^4}^{4E_\gamma \epsilon_{max}} ds \times s\sigma_{\gamma\gamma}(s) \int_0^\infty d\epsilon \frac{n_{ph}(\epsilon, R_i, \theta_j)}{\epsilon^2},$$

$$\lambda_{IC}^{-1}(E_e, R_i, \theta_j) = \frac{1}{8\beta E_e^2} \int_{m_e^2c^4}^{m_e^2c^4 + E_e\epsilon_{max}(1+\beta)} ds \times \sigma_{IC}(s)(s - m_e^2c^4) \int_0^\infty d\epsilon \frac{n_{ph}(\epsilon, R_i, \theta_j)}{\epsilon^2}.$$

CR emitting in the acceleration zone

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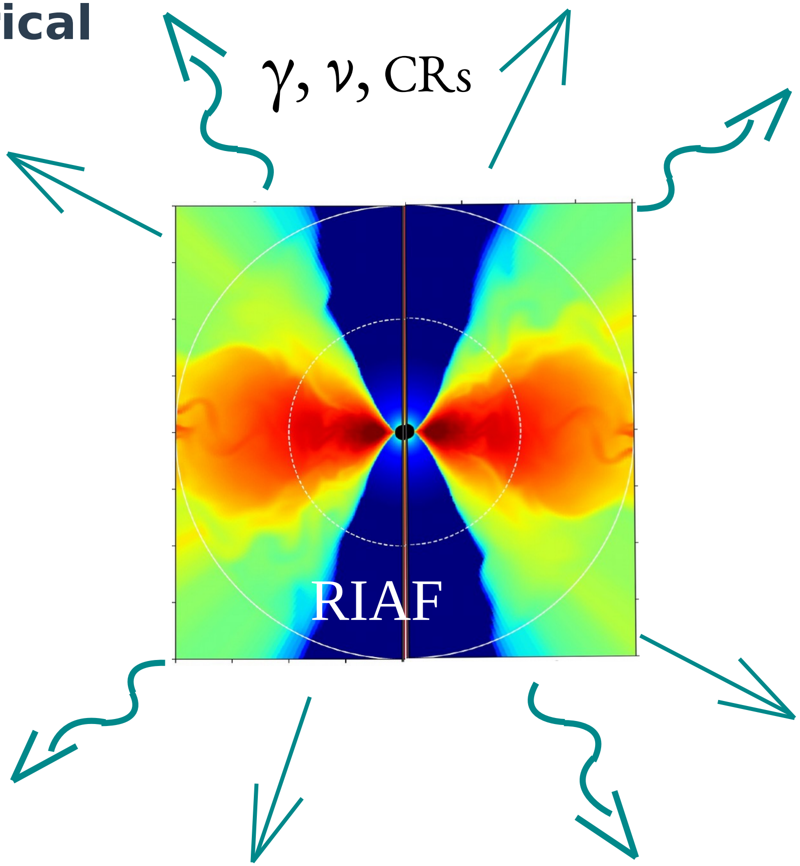

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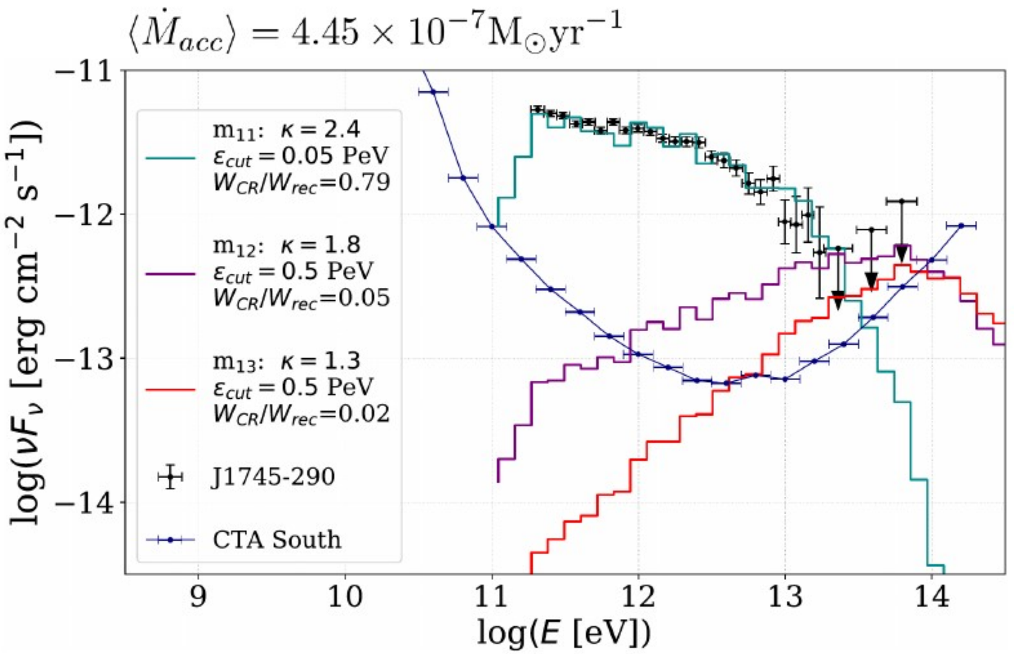
CR emitting in the acceleration zone

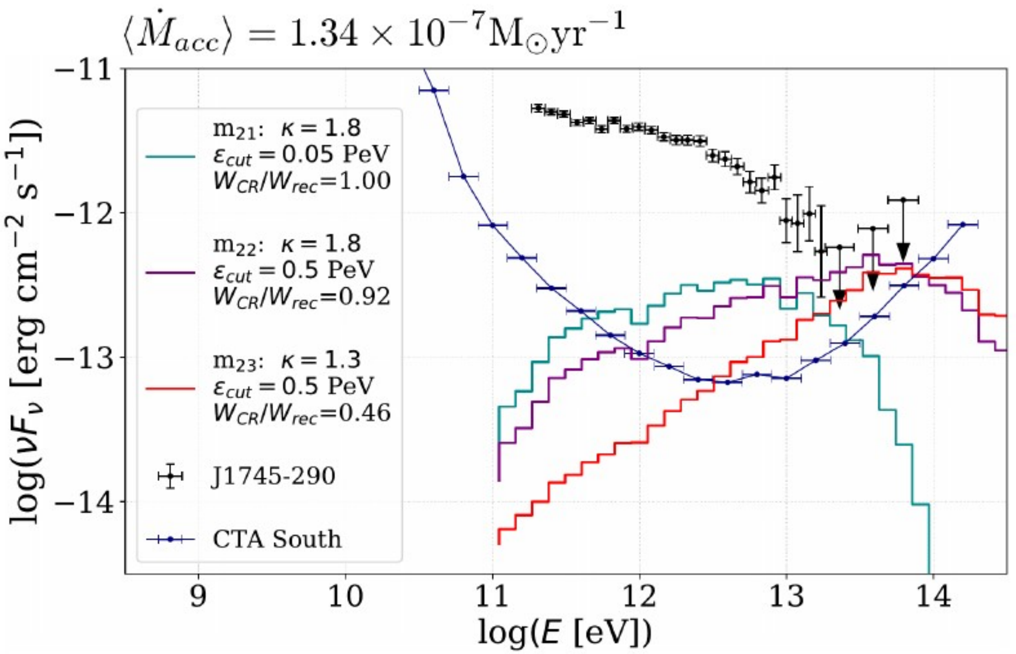
CR injection parametrised as

$$\frac{dN_{CR}}{d\epsilon} \propto \epsilon^{-\kappa} \exp\{-\epsilon/\epsilon_{cut}\}$$

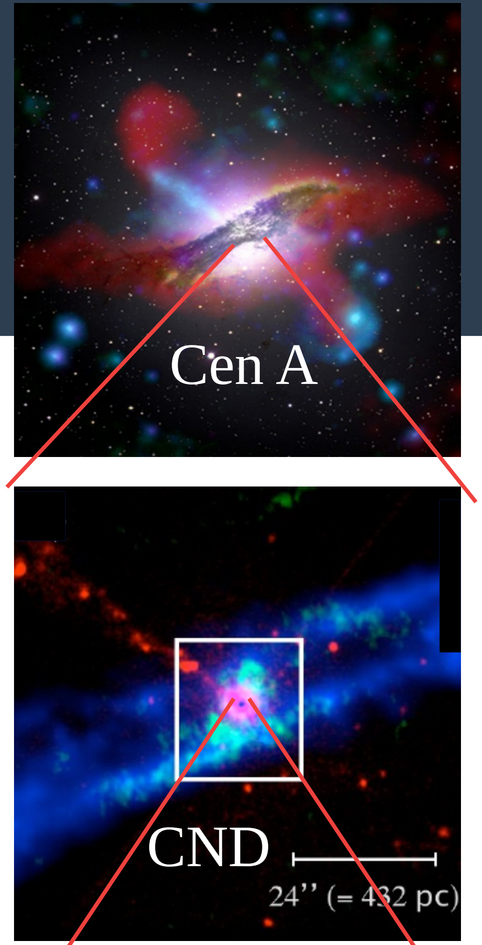
$$W_{rec} = 1.52 \times 10^{42} f \left(\frac{\dot{M}_{acc}}{\mathrm{M_\odot yr^{-1}}}\right)\left(\frac{T_p}{T_e}\right) \mathrm{erg\ s^{-1}}$$

Rodríguez-Ramírez et al. (2019) ApJ 843, 136





CR emission regions in the core of Cen A



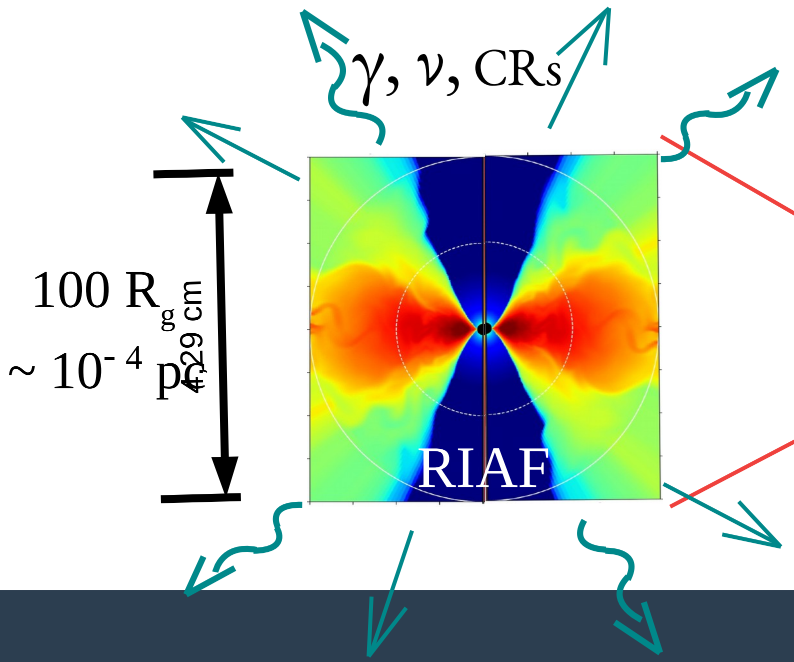
(i) CRs emitting in the acceleration region

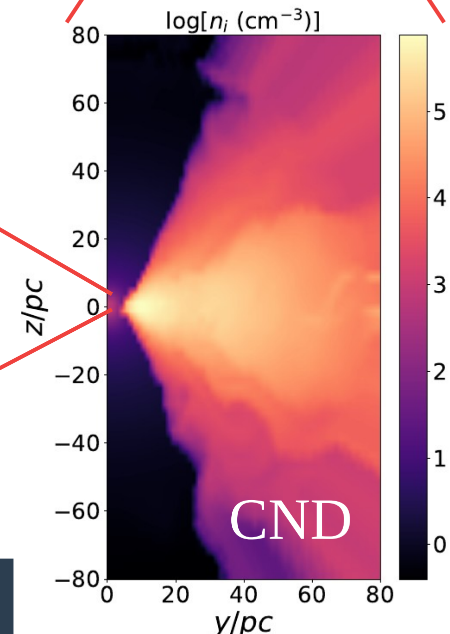
(ii) CRs that escape and emit due to interactions with the ISM at pc scales

$\sim 200 \times 400$ pc

$n = 10^{3-5}$ cm^{-3}

Israel et al. (2017)

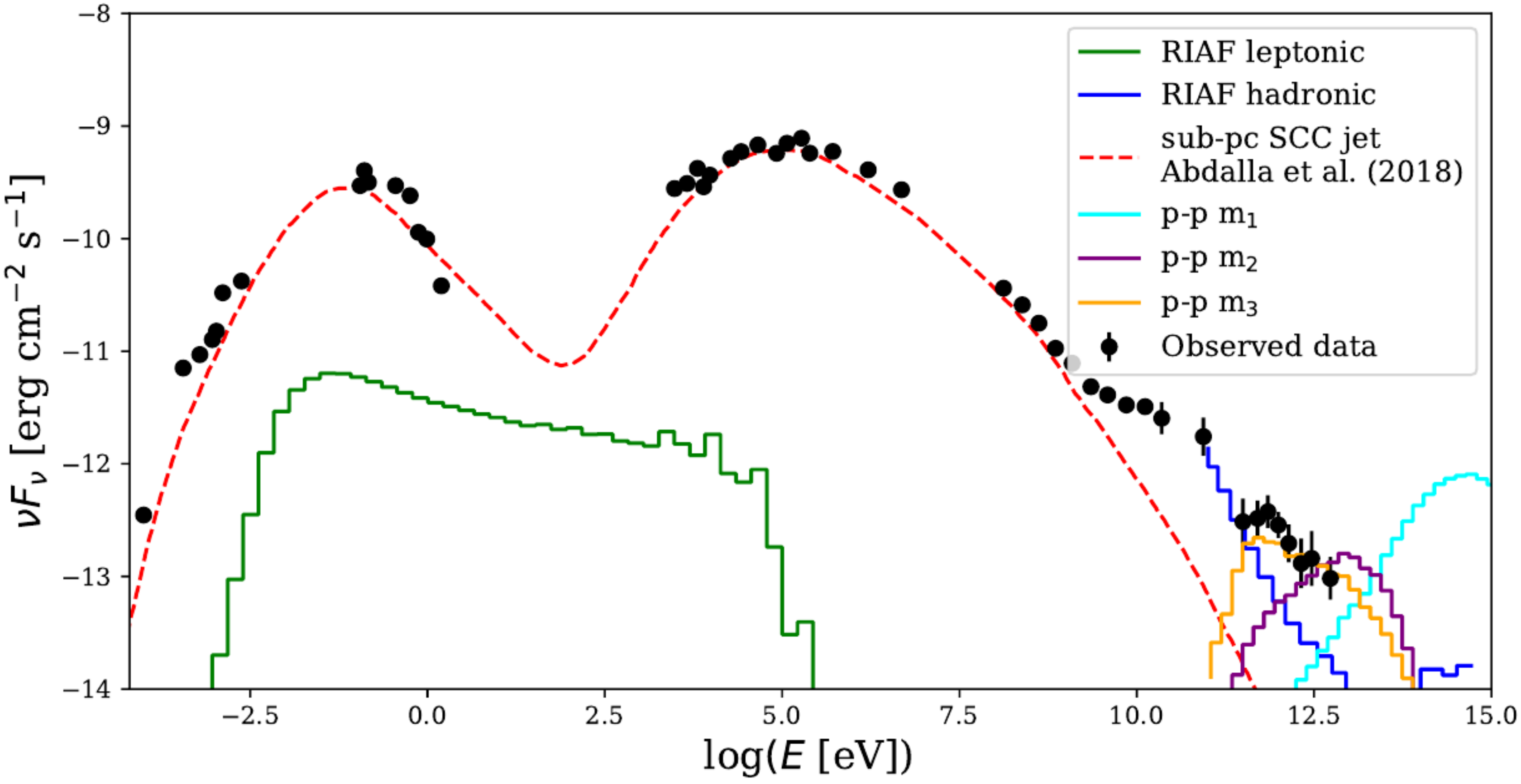




CND toy model:

$$B_\phi \propto n$$

SED models



(i) RIAF

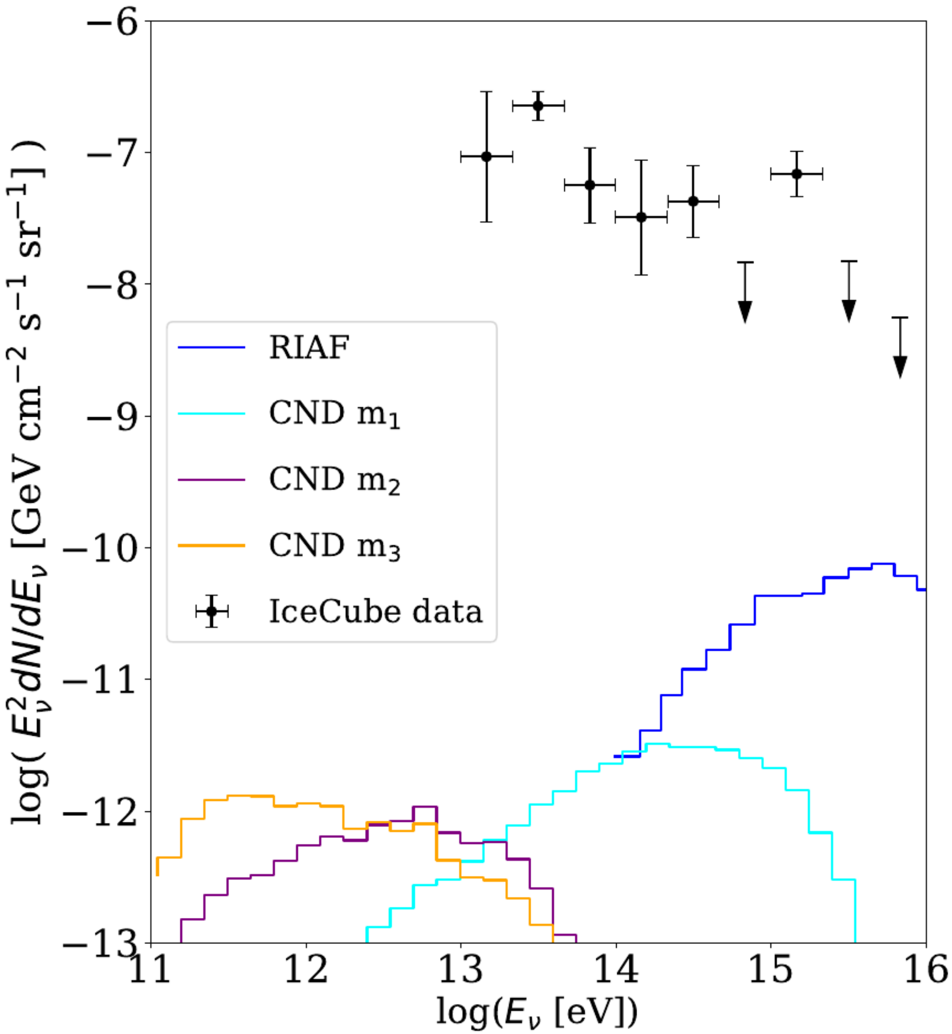
$$\dot{M}_{acc} = 1.3 \times 10^{-3}\ \mathrm{M}_\odot\ \mathrm{yr}^{-1}$$

$$W_{esc} = 2 \times 10^{40}\ \mathrm{erg\ s}^{-1}$$

(ii) CND

Model	W_{esc} $\times 10^{40}$ [erg s^{-1}]	p	ε_{cut} [PeV]
m_1	1.4	1.5	5
m_2	1.4	1.5	0.05
m_3	10	2.5	0.1

Neutrino emission



Conclusions

Assuming CR acceleration consistent with magnetic reconnection power, we derived CR emission signatures from the nuclear region of Sgr A* and Cen A finding that:

- CR emission produced within the RIAF of SgrA* is potentially detectable with CTA for BH mass accretion rates $\gtrsim 10^{-7}\ M_{\odot}\ yr^{-1}$.
- ɣ-ray produced within the BH accretion flow of Cen A is suppressed for E>300 GeV by the soft radiation of accretion flow.
- The emission of CR interacting within the CND of Cen A probably contributes to the current H.E.S.S. SED for E > 3 TeV.