~~The multiwavelength signature of the multizone jets of Mkn 421~~

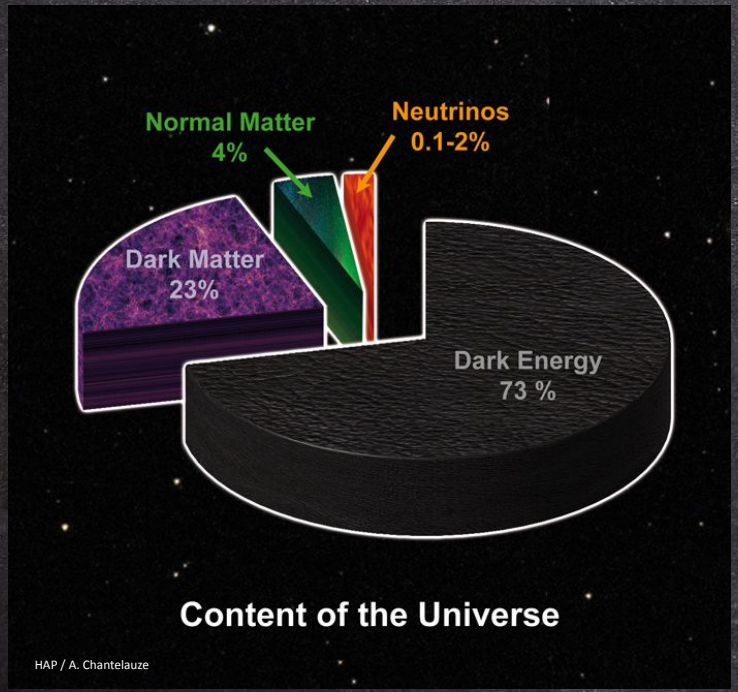
Indirect dark-matter searches with γ-rays

Dimitrios Kantzas
LAPTh/CNRS

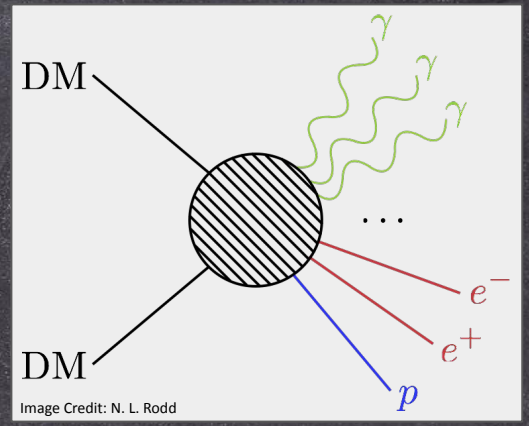
with
Francesca Calore, Marco Chianese

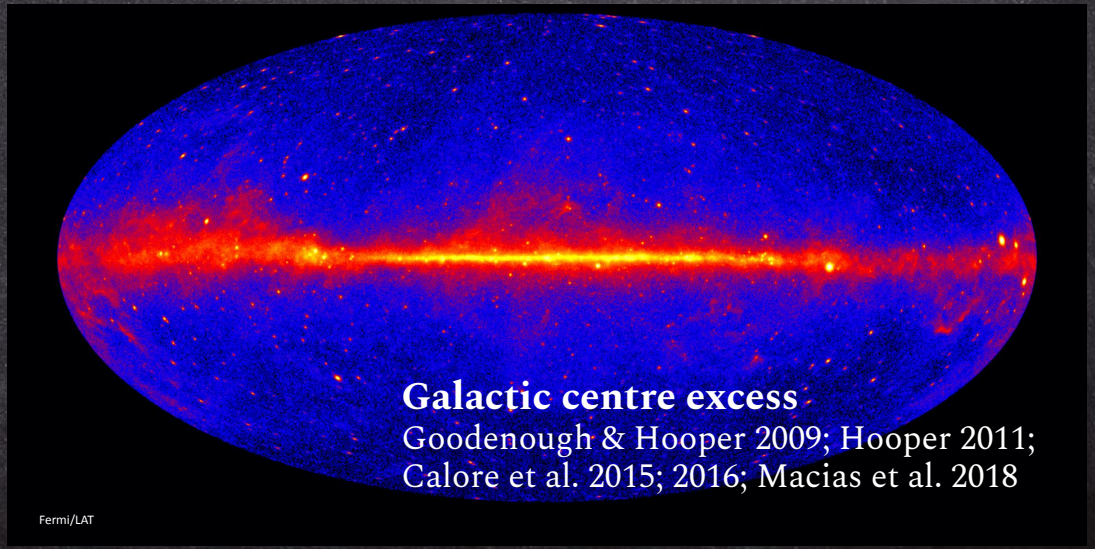
Image Credit: NASA/JPL-Caltech

Indirect dark matter searches

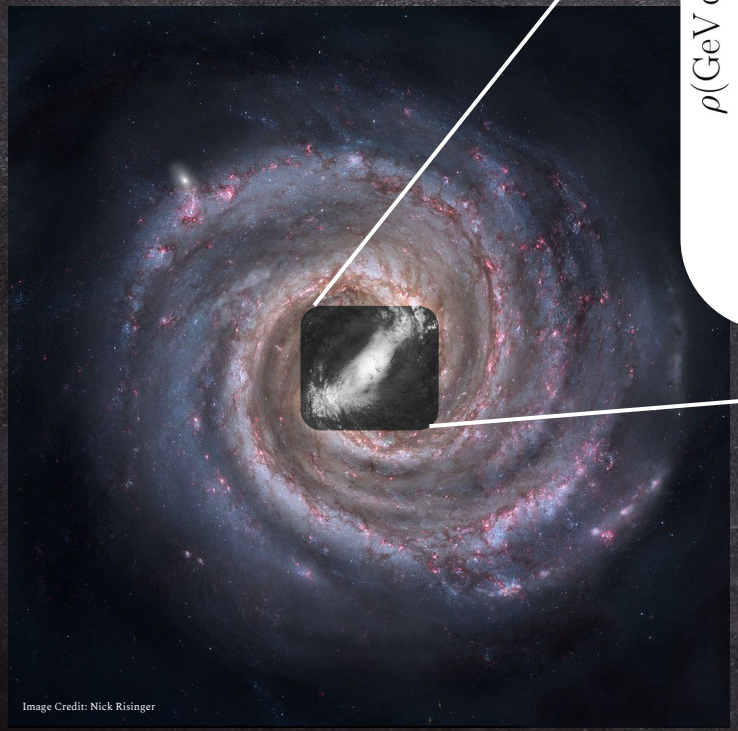


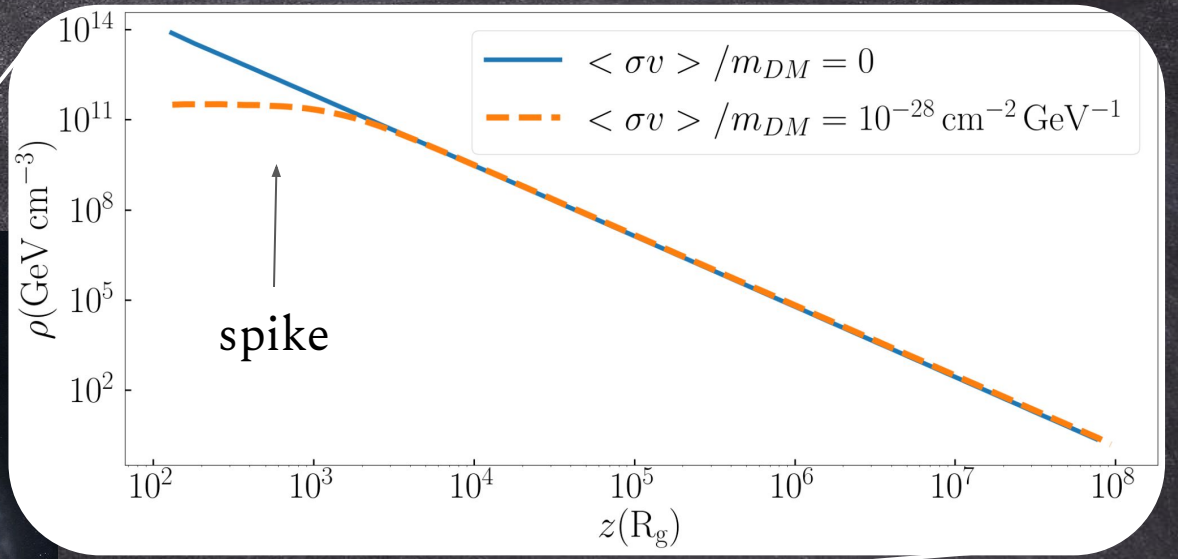
m_{DM} & $\langle\sigma v\rangle$





DM spikes

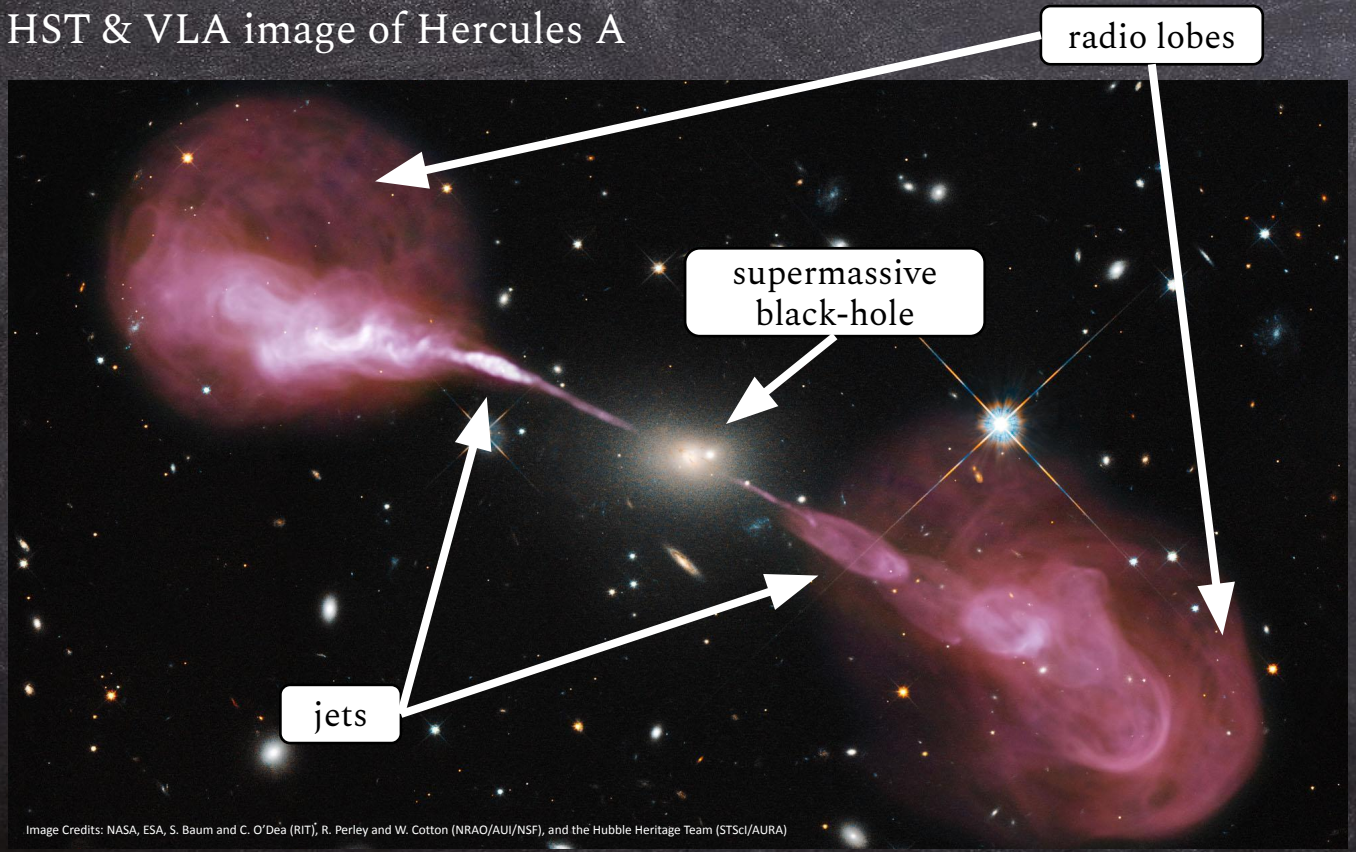




see e.g., Quinlan et a. 1995;
Gondolo & Silk 1999;
Gorchtein et al. 2010

Active galactic nuclei (AGN)

HST & VLA image of Hercules A

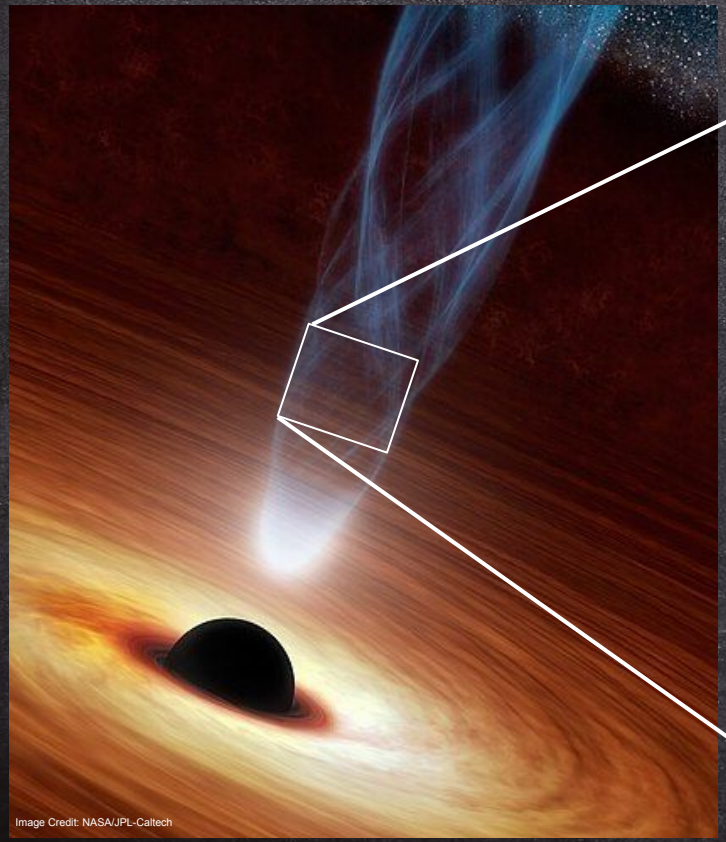


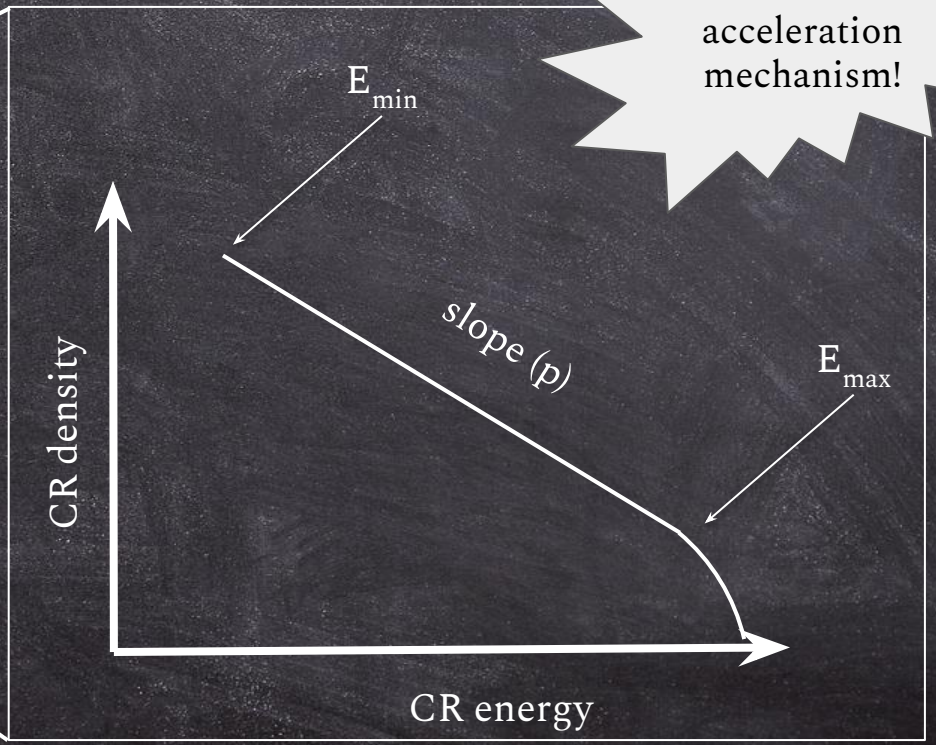
Supermassive BH
- powers jets

Jets
- accelerate CRs

Radio lobes
- feedback

Cosmic ray (CR) acceleration in AGN jets

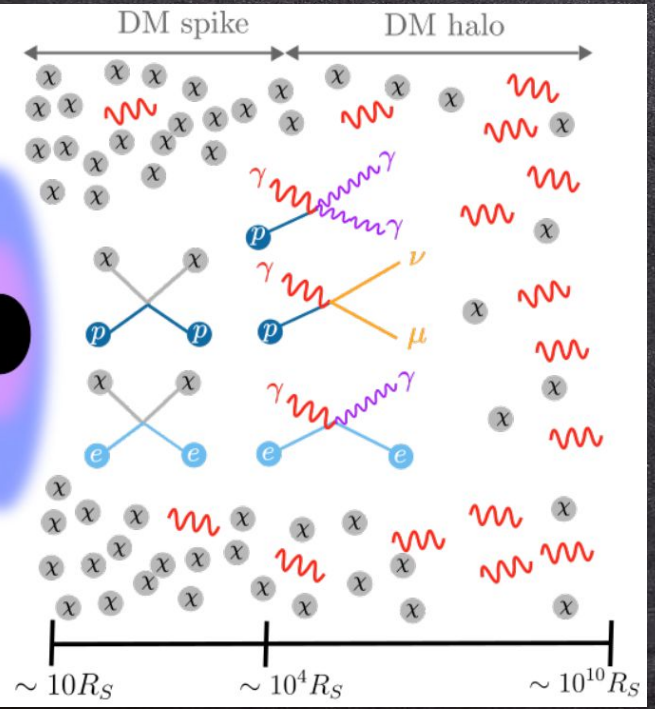




CR acceleration mechanism!

CR cooling due to DM or boosted DM

e.g., Bringmann & Pospelov 2019; Ema et al. 2019;
Cappiello & Beacom 2019; Guo et al. 2020; Wang et al. 2022



Herrera & Murase, 2024

$\chi + e^-/p^+ \rightarrow \chi + e^-/p^+$ — elastic CR-DM

$\chi + p^+ \rightarrow \chi + p^+ + \ldots +$ **γ-rays** + **neutrinos** — inelastic CR-DM

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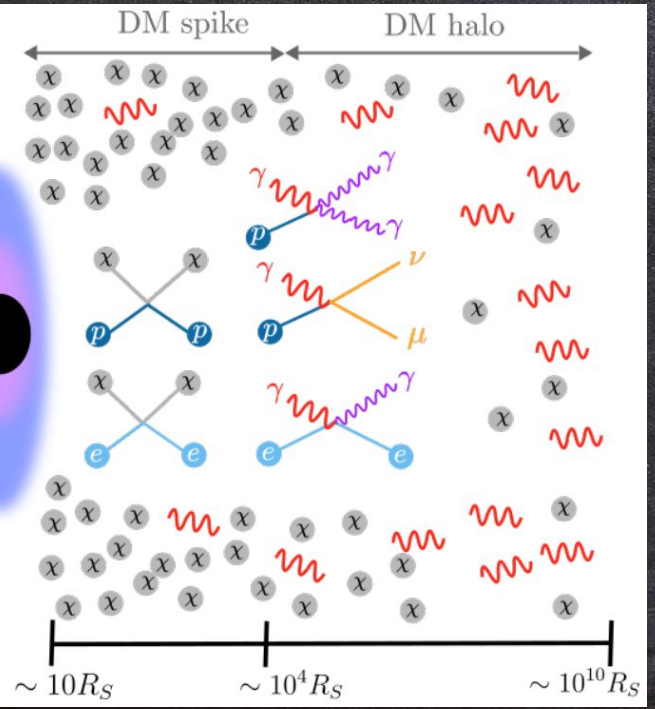

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$\chi + e^-/p^+ \rightarrow \chi + e^-/p^+$ — elastic CR-DM

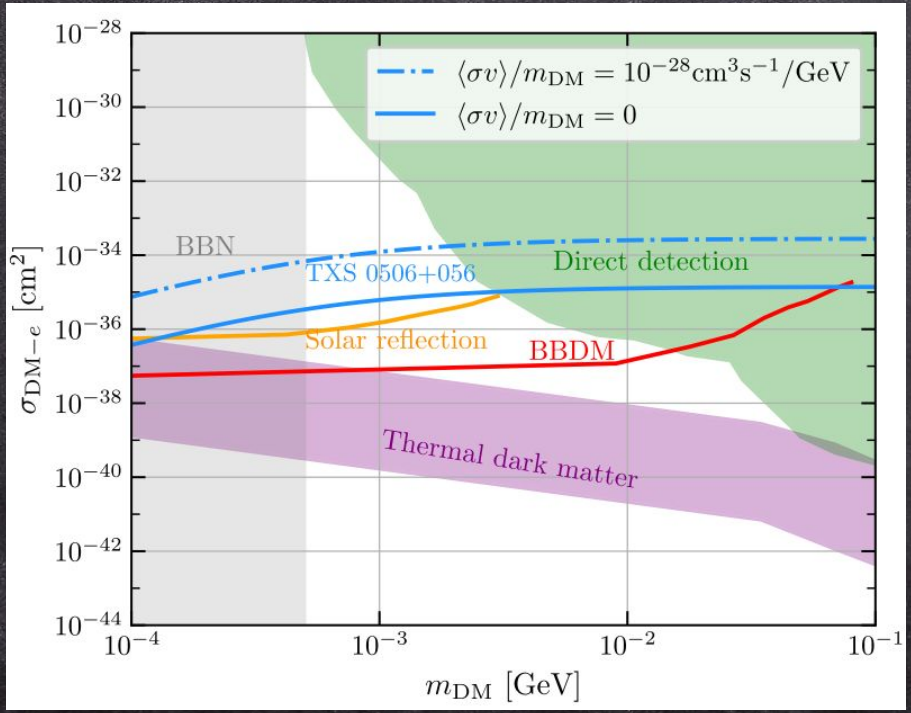
to present here …

$\chi + p^+ \rightarrow \chi + p^+ + \ldots +$ **γ-rays** + **neutrinos** — inelastic CR-DM

Elastic CR-DM collisions in AGN jets

Herrera & Murase, 2024

CR electrons + DM



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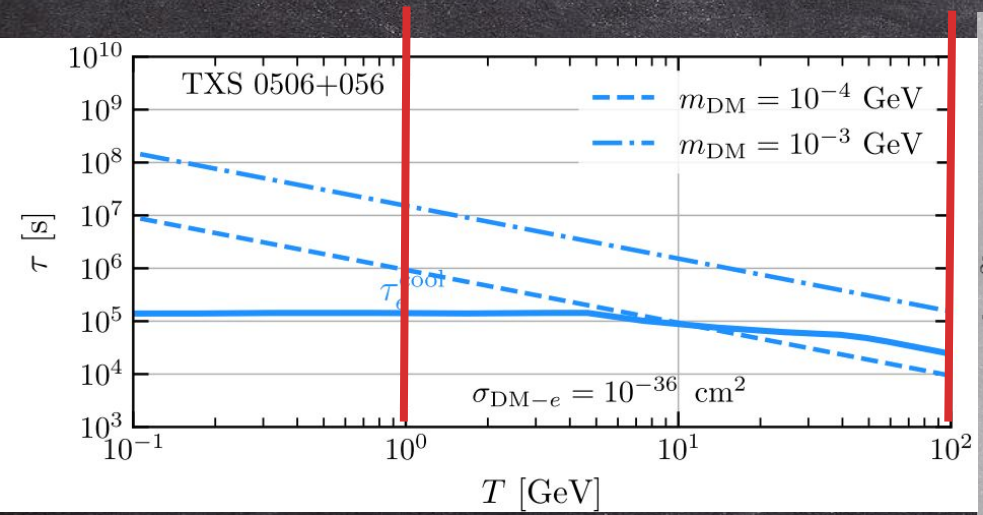

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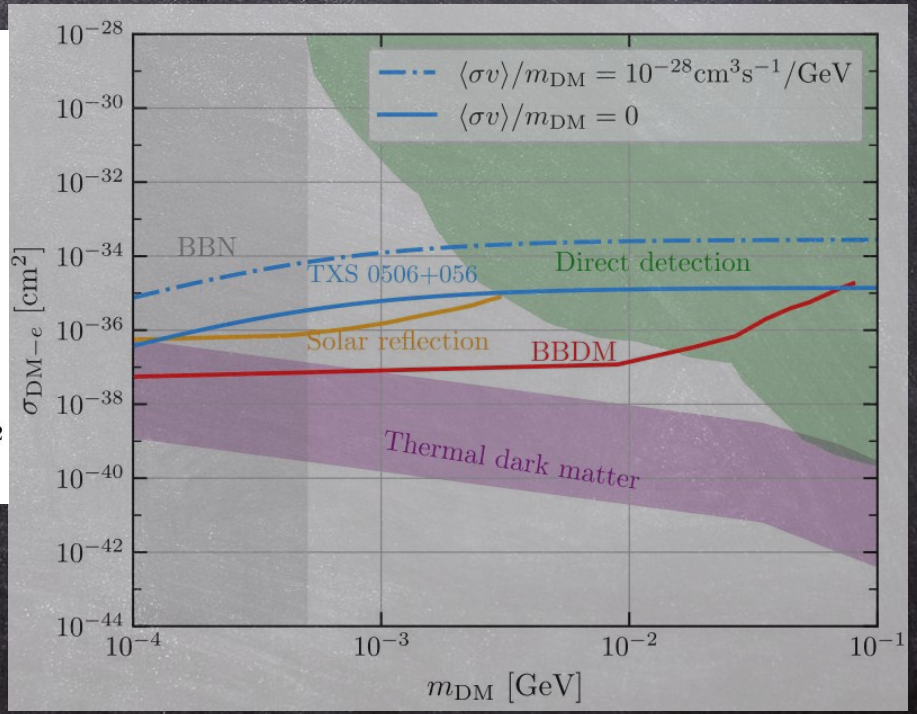
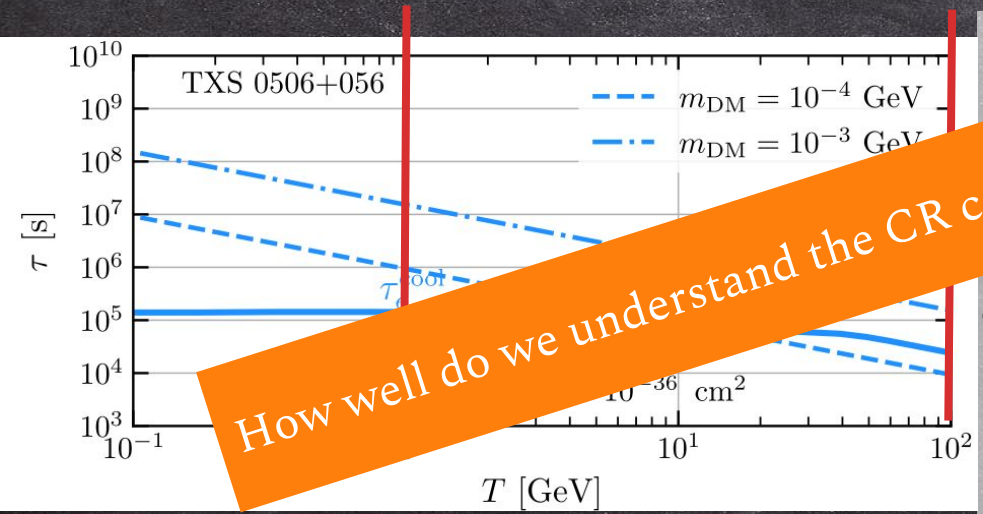


"Factor of 10 or less impact on the cooling time scale"

Elastic CR-DM collisions in AGN jets

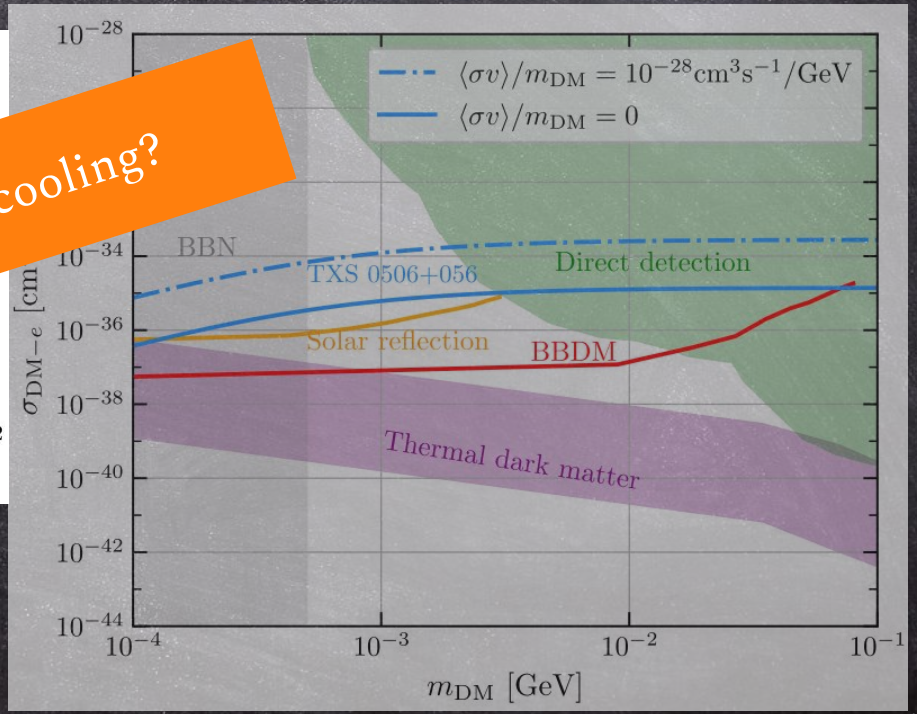
Herrera & Murase, 2024



How well do we understand the CR cooling?

"Factor of 10 or less impact on the cooling time scale"

CR electrons + DM



Semi-analytical, multi-zone jet model

`BHJet`: a multi-zone model (Lucchini..., **DK** et al. 2022)

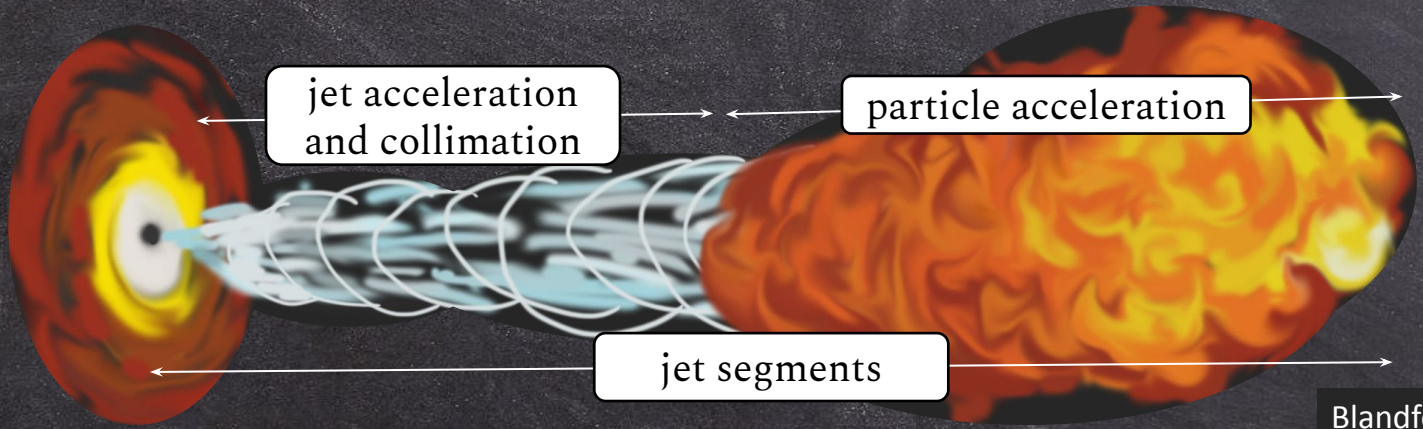


Image Credit: T. Revolta

Blandford & Königl 1979;
Hjellming & Johnston 1988;
Falcke & Biermann 1995;
Markoff et al. 2001, 2005;
Maitra et al. 2009;
Crumley et al. 2017;
Lucchini et al. 2019, 2022**;**
Kantzas et al. 2021, 2022, 2023a

The study case of Markarian 421

- BL Lac object
- @122Mpc (z=0.0308)
- The 1st extragalactic TeV source (Punch et al. 1992)
- One of the brightest quasars

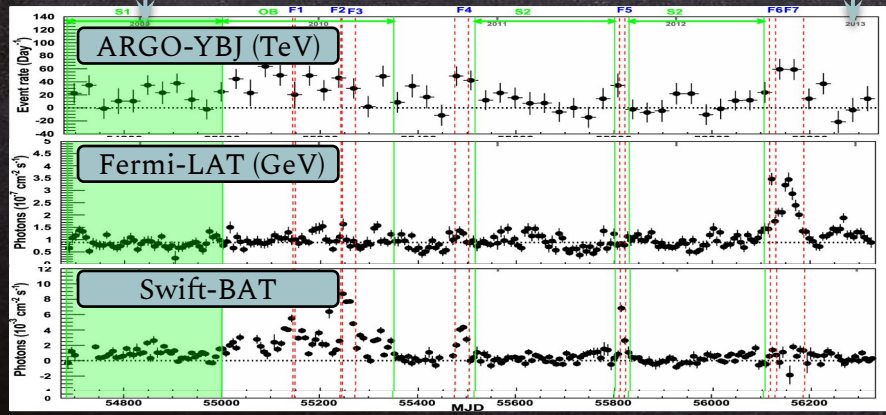
2009

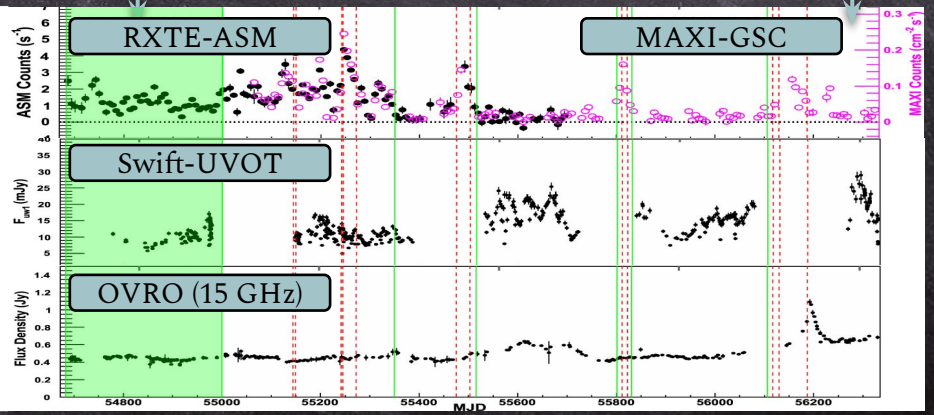
2013

2009

2013

Bartoli et al. 2016





The jets of Mkn 421

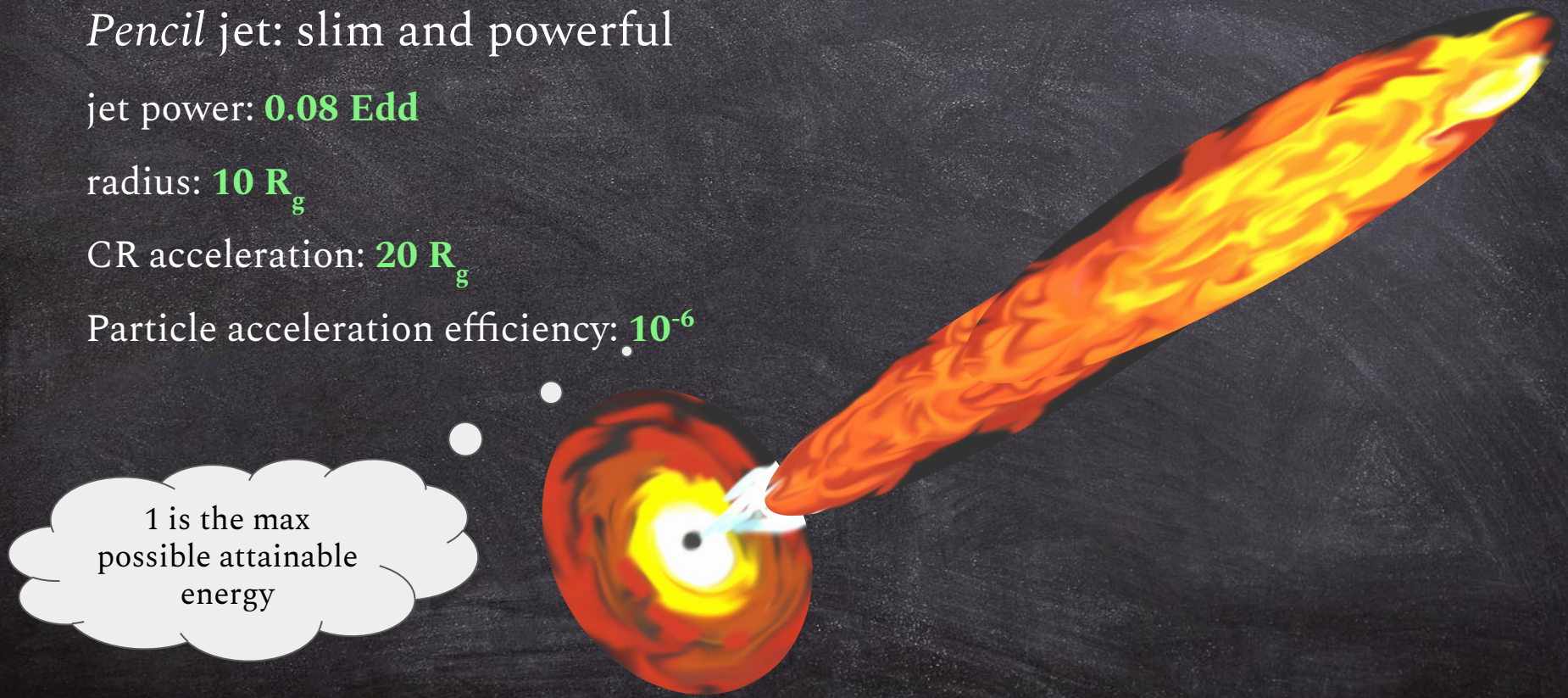
Pencil jet: slim and powerful

jet power: **0.08 Edd**

radius: **10 R_g**

CR acceleration: **20 R_g**

Particle acceleration efficiency: **10^{-6}**



The multiwavelength spectrum of Mkn 421

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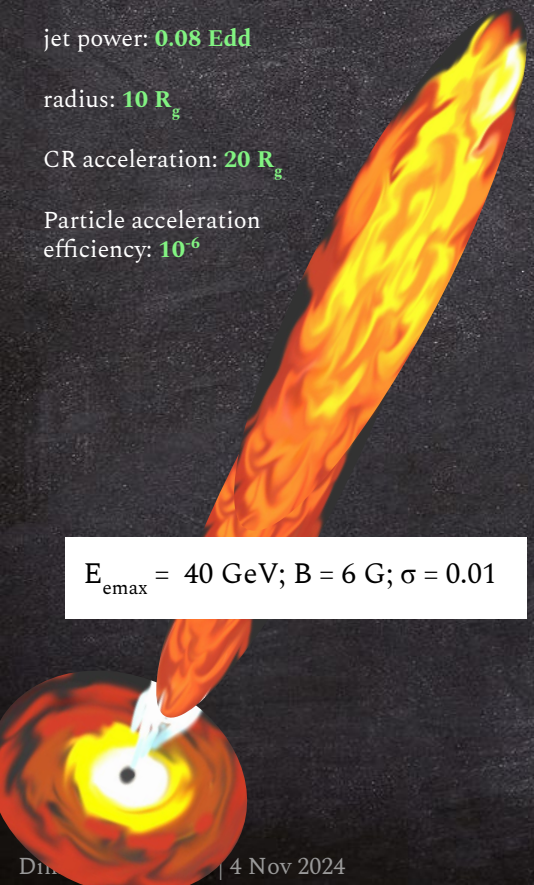
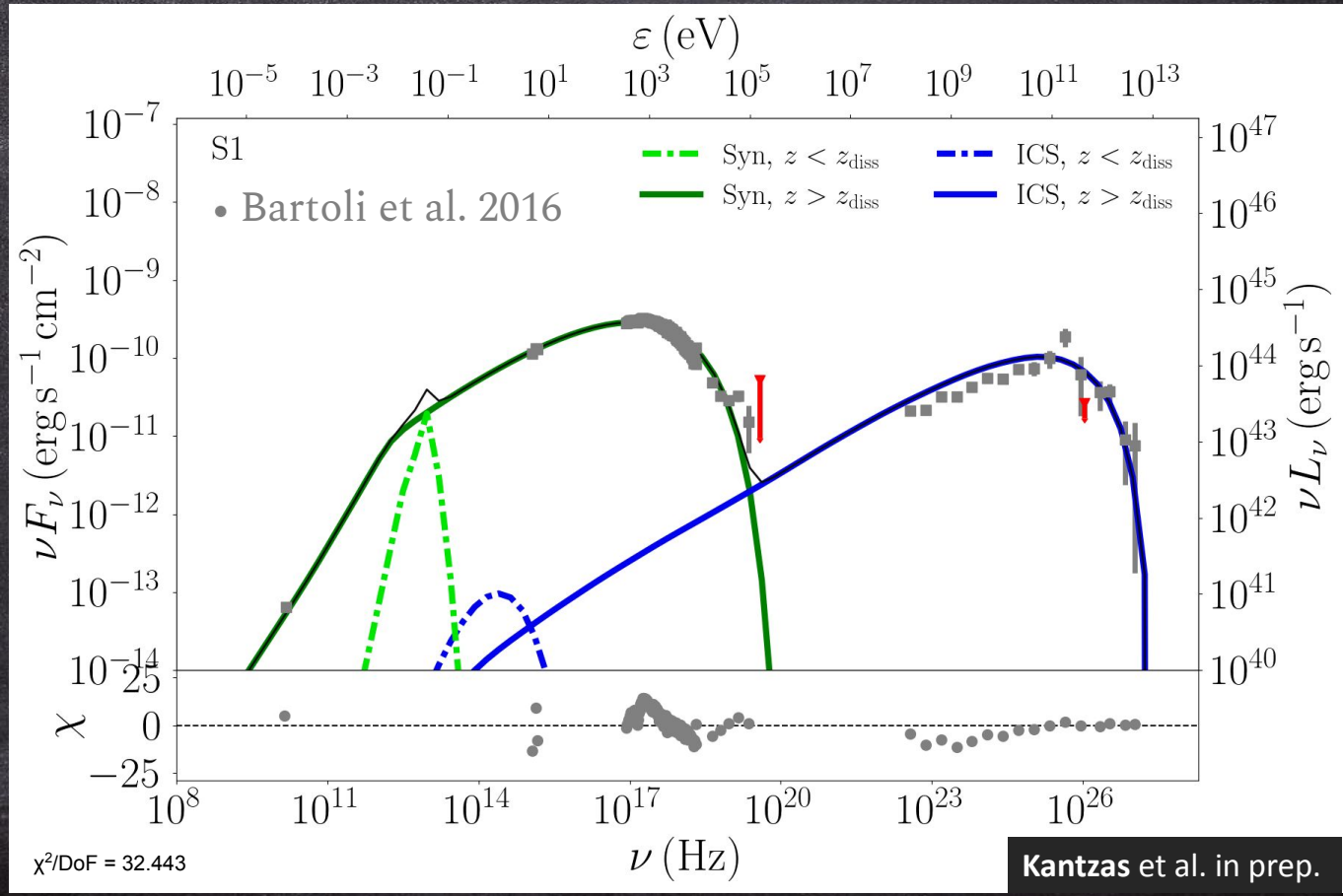
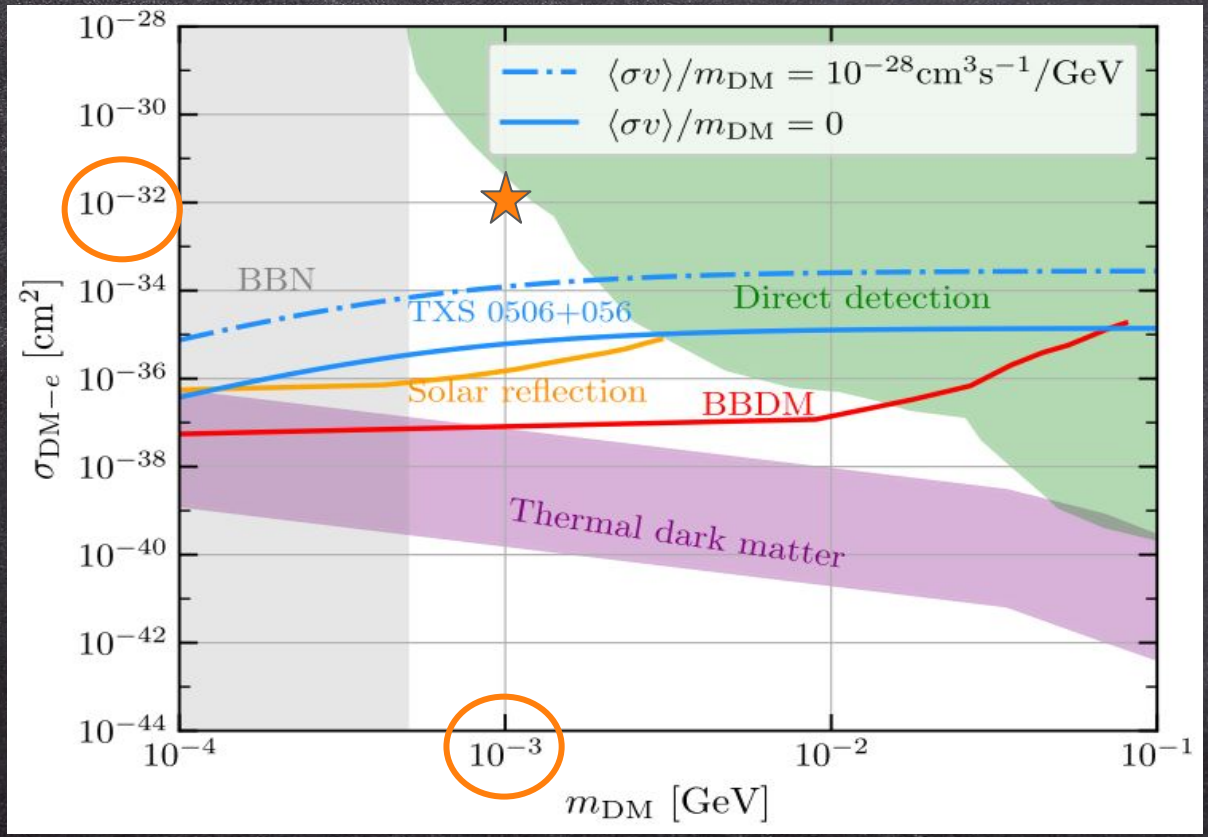


E_{emax} = 40 GeV; B = 6 G; σ = 0.01



Kantzas et al. in prep.

The MW spectrum of Mkn 421 with DM



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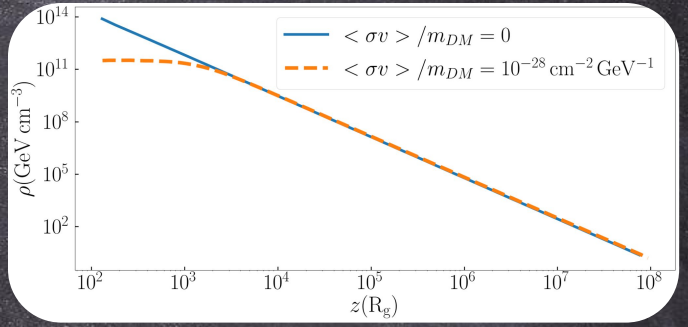
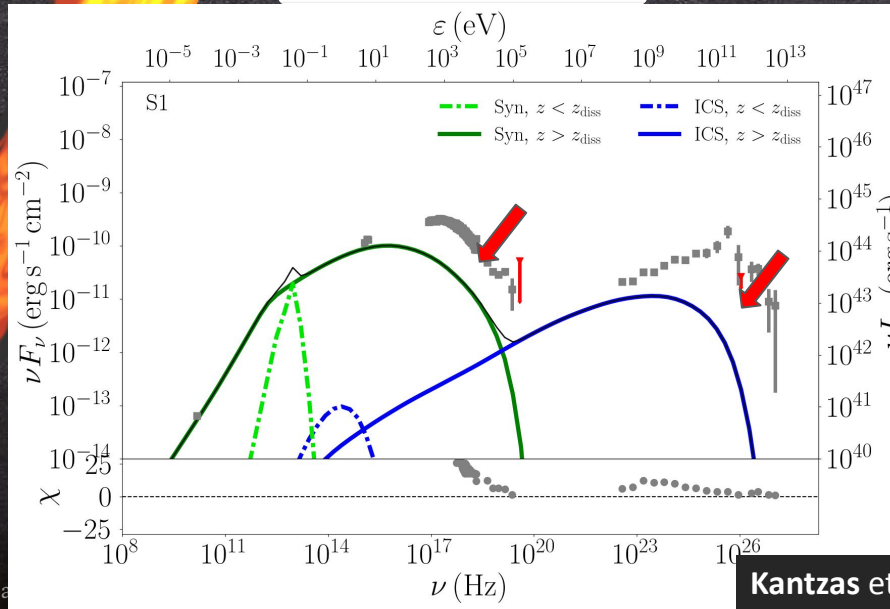
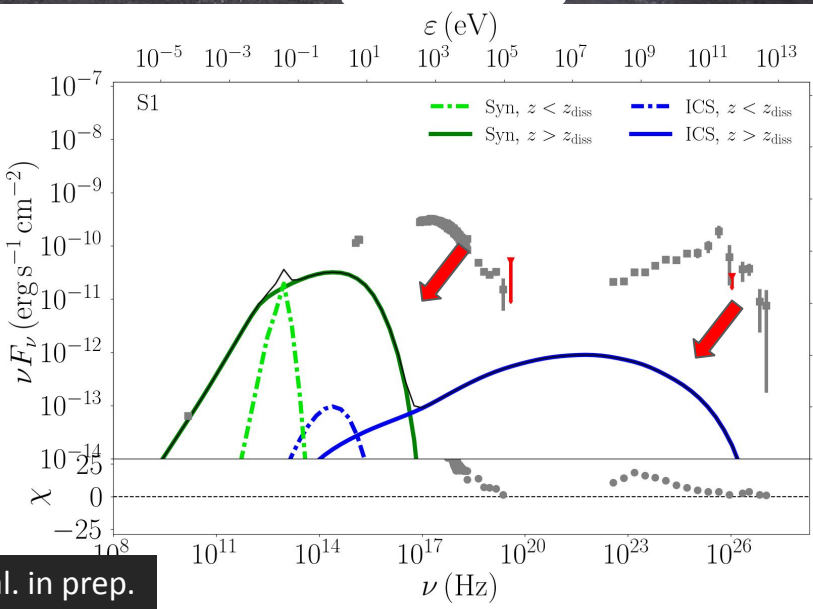


$< \sigma v > /m_{DM} = 10^{-28}\,\mathrm{cm}^{-2}\,\mathrm{GeV}^{-1}$



$< \sigma v > /m_{DM} = 0$



Kantzas et al. in prep.

The cooling timescales

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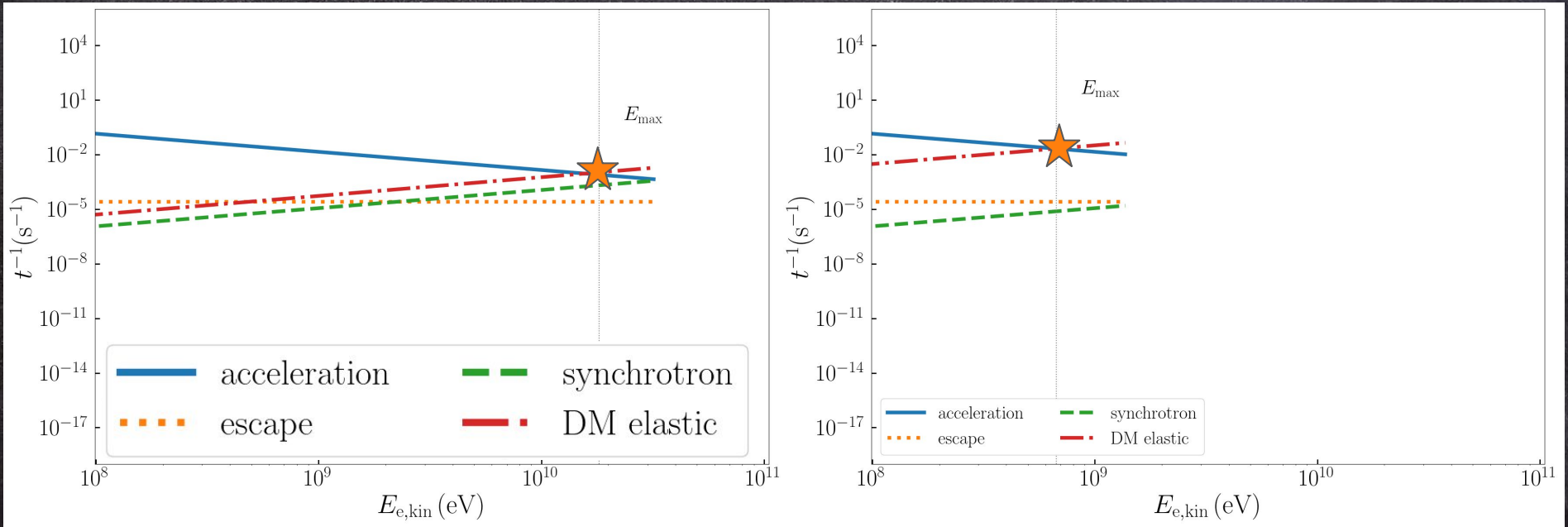

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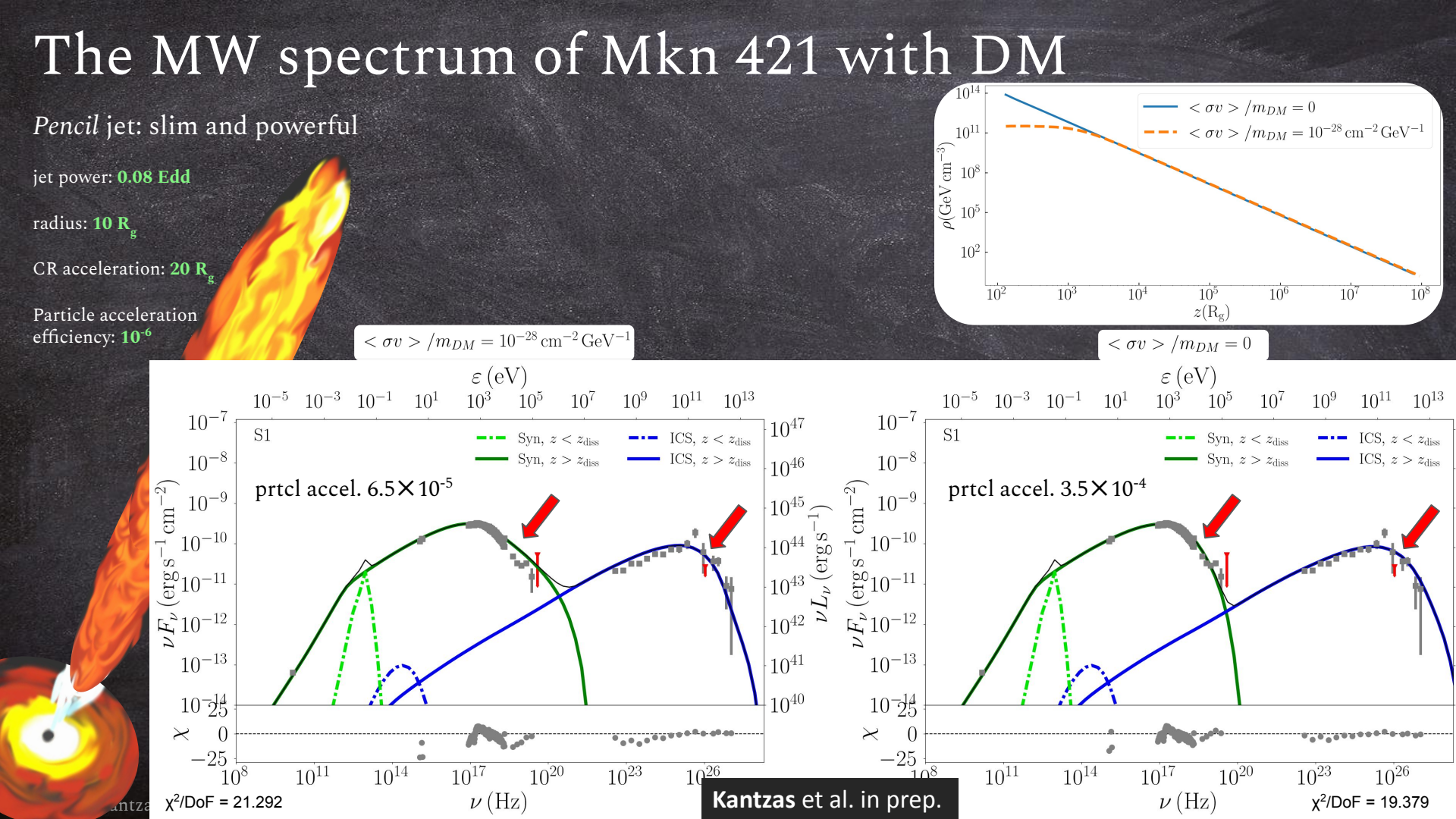

Kantzas et al. in prep.

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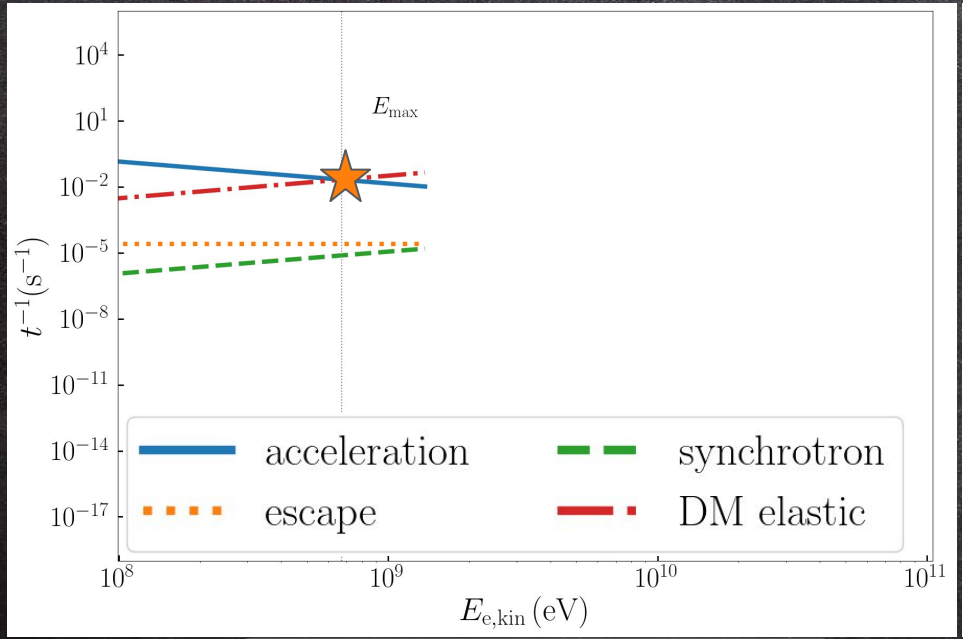
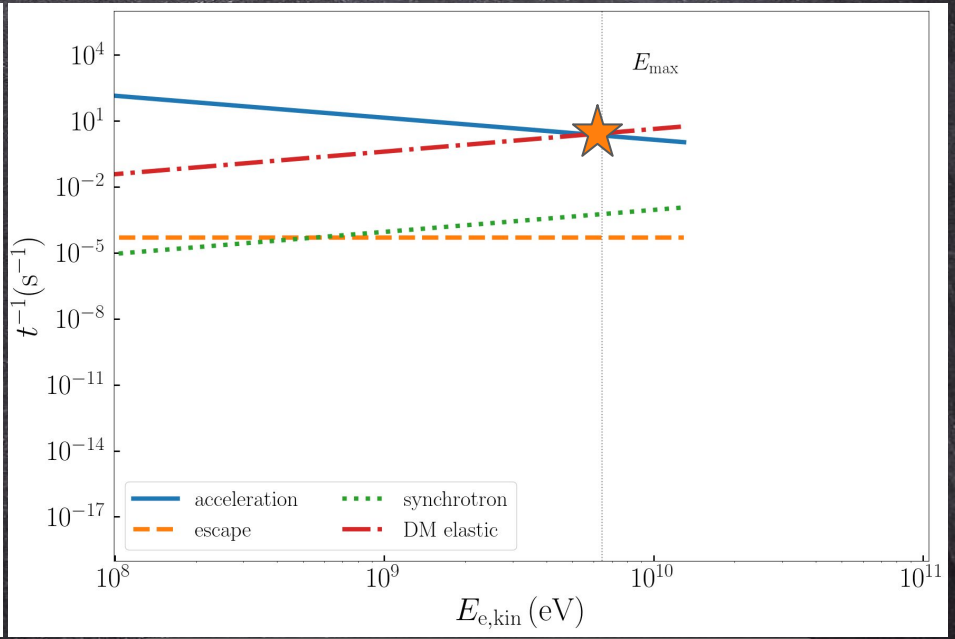
$$< \sigma v > / m_{DM} = 0$$

particle acceleration efficiency. 10^{-6}



Fails to reproduce the spectrum

particle acceleration efficiency. 3.5×10^{-4}



Manages to reproduce the spectrum

Kantzas et al. in prep.

Conclusions

- CRs may cool due to CR-DM collisions !
- We cannot draw conclusions on the DM nature unless we better constrain jet physics !!
- More physically driven jet models are required !!!

Merci ...