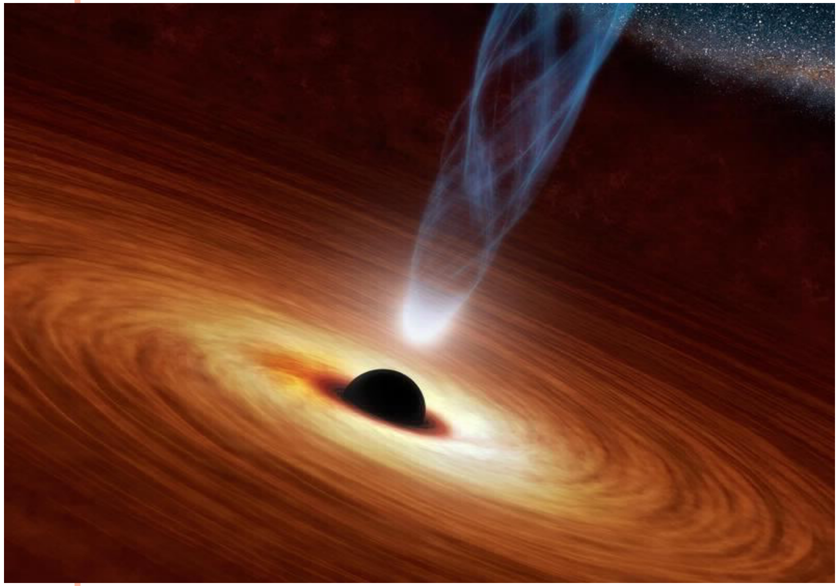

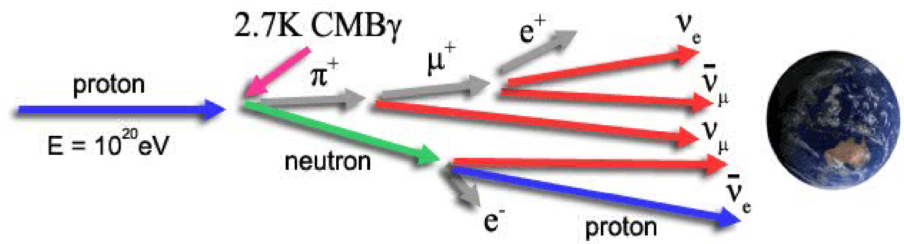

MAGNETIC AGN LUMINOSITIES AND UHECR LUMINOSITIES

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- Different types of extragalactic objects are known to produce TeV gamma-rays.

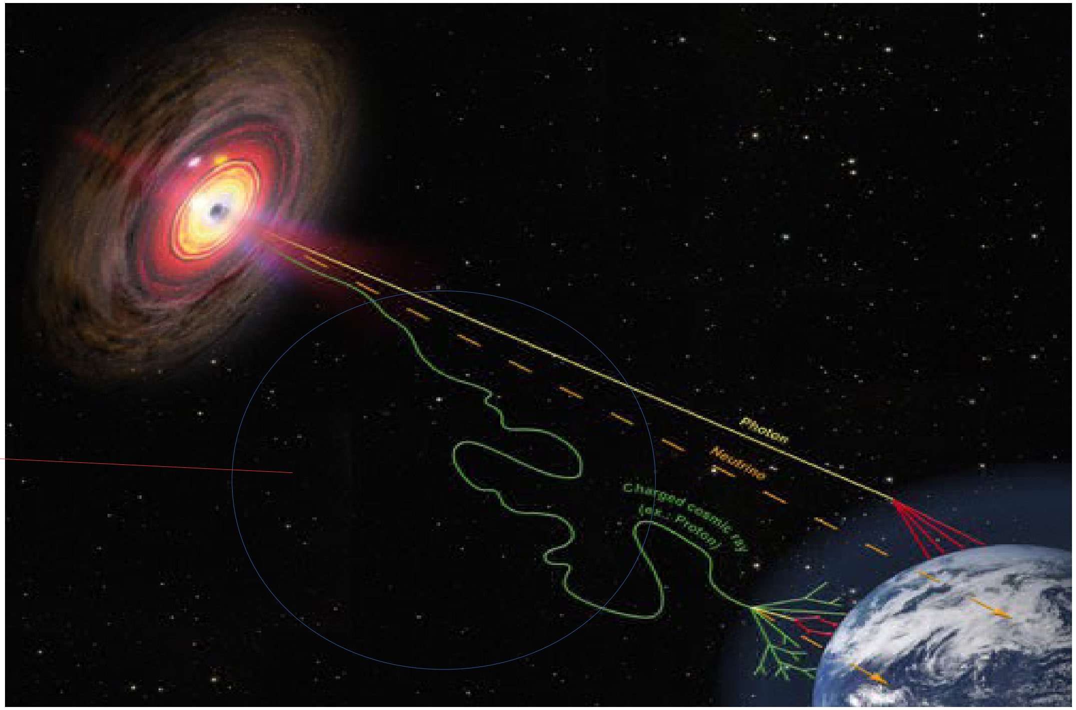
- Some of these objects are also the most probable candidates to accelerate cosmic rays up to 10^{20} eV.

- It is very well known that gamma-rays can be produced as a result of the cosmic ray propagation through the intergalactic medium.

- These gamma-rays contribute to the total flux observed in the direction of the source.

- Cascading background to produce GeV-TeV gammas: 1) EBL (10-10^{5} GeV gammas); 2) CMB (10^{5}-10^{10} GeV); 3) Radio background (10^{10}-10^{13} GeV); see more details in Blumenthal 1970; Puget et al 1976; Kelner & Aharonian 2008, PRD; De Angelis et al 2013, MNRAS.

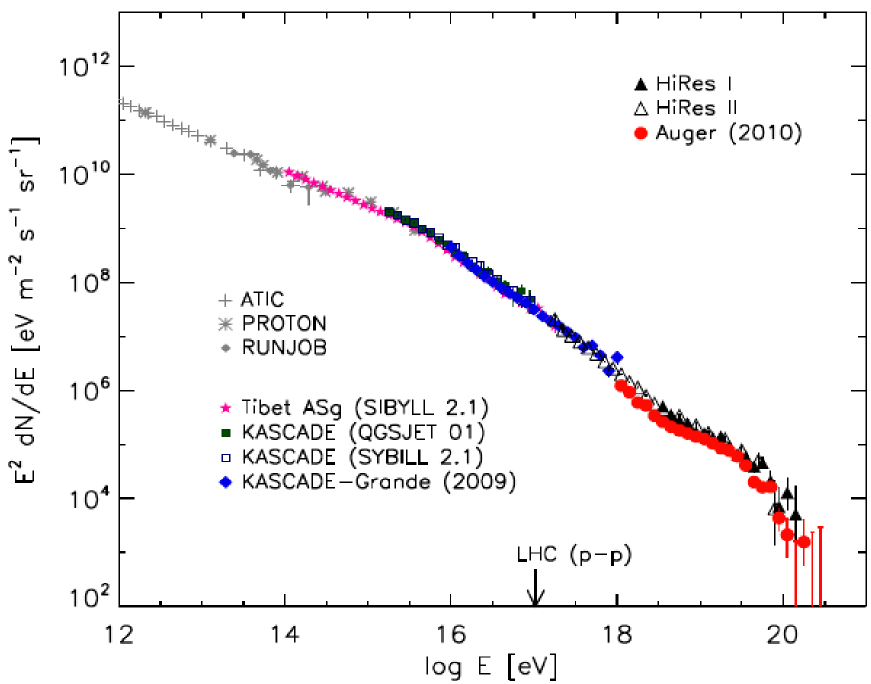
Production
of gammas



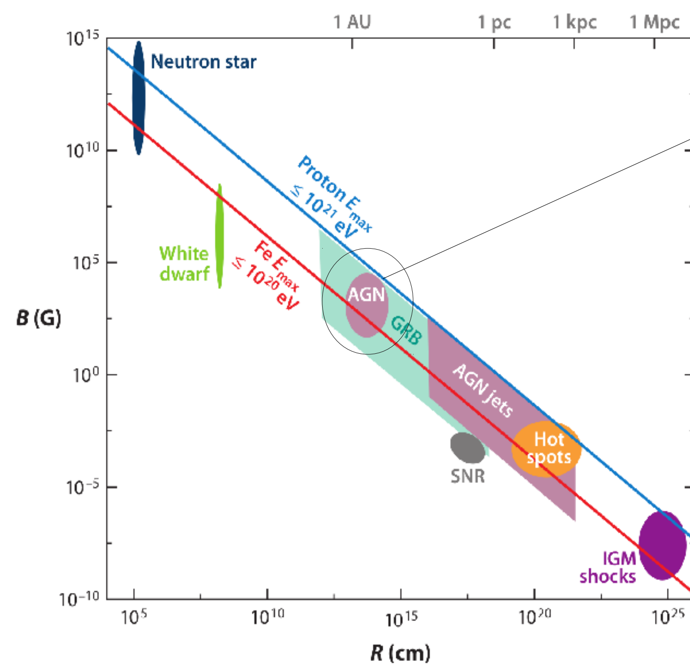
ULTRA HIGH ENERGY COSMIC RAYS

- How are they produced?
- Which are the possible main mechanisms?
- How do they acquire their energy?

→ Some theories, models and computational simulations present partial answers to those questions.



Kotera and Olinto 2010

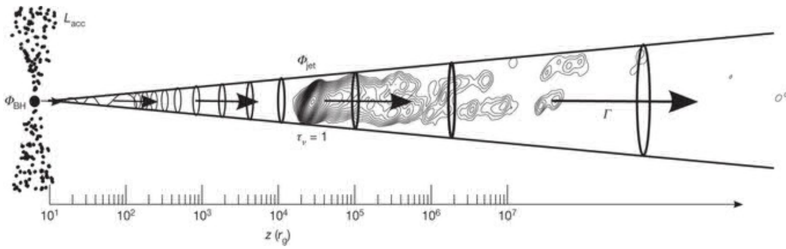


Hillas 1984

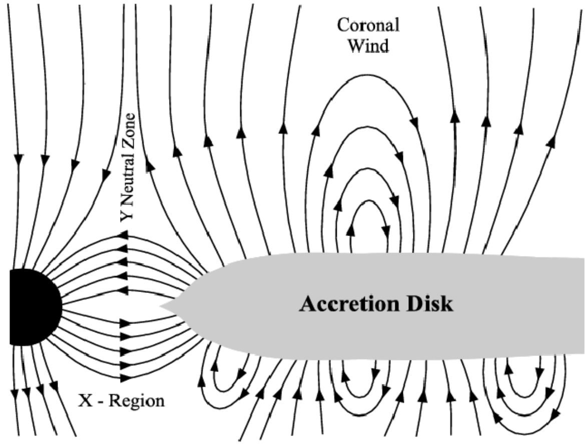
The focus of our present talking

AGNS AS SOURCES OF UHECRS

- AGN Unification Model successfull, but knowledge about inner mechanisms are in construction:
  - Accretion?
  - Magnetic fields?
  - Jet mechanisms?
  - Particle acceleration mechanisms?
  - Black hole physics ↔ SMBHs astrophysics?



Zamaninasab et al 2014, Nature



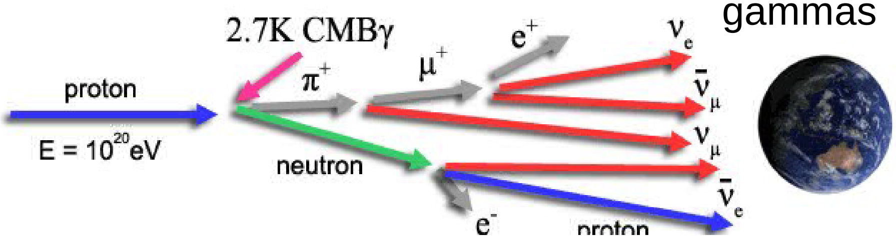
Gouveia dal Pino and Lazarian 2005

UPPER LIMIT ON THE UHECR EMISSION OF INDIVIDUAL AGN SOURCES

- Originally, restrictions in calculation due to presence of the inter and galactic magnetic fields → the reconstructed direction of a charged cosmic ray particle might not point back exactly to its source
- But, GeV-TeV gamma rays produced by UHECRs are not deviated

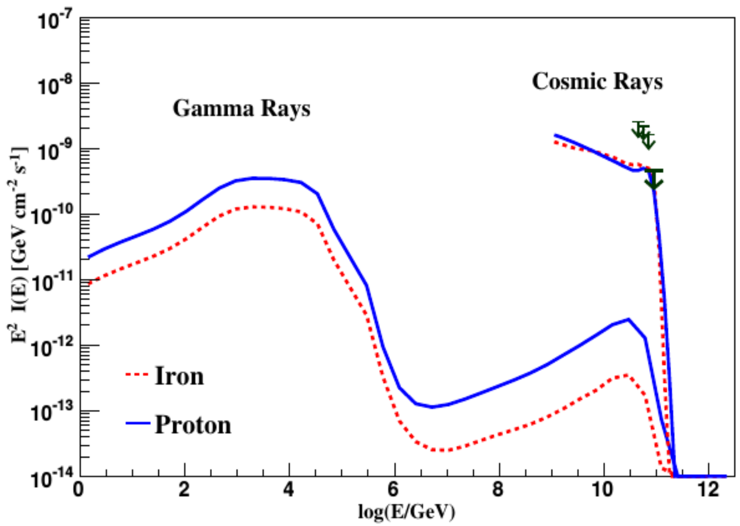
  Supanitsky and Souza 2013, JCAP
  Anjos, Souza, Supanitsky 2014, JCAP

+ GeV-TeV gammas



1) UHERC + CMB (or EBL) → GeV-TeV gammas
2) Such gamma flux can be given in terms of UHECR luminosity by

$$I_\gamma(E_\gamma) = \frac{L_{CR}}{4\pi D_s^2\ (1+z_s)\langle E\rangle_0}\ K_\gamma\ P_\gamma(E_\gamma)$$



3) See gammas detected by HESS, Fermi-Lat, Magic, Veritas from problable UHECR sources (as AGNs) to constrain UHECR luminosity

$$I_{CR}(E) = \frac{L_{CR}}{4\pi D_s^2\ (1+z_s)\langle E\rangle_0}\ K_{CR}\ P_{CR}(E)$$

Flux

Secondary gammas due to cosmic ray propagation

$$I_\gamma(E_\gamma) = \frac{L_{CR}}{4\pi D_s^2\ (1+z_s)\langle E\rangle_0}\ K_\gamma\ P_\gamma(E_\gamma)$$

Number of gammas generated per injected cosmic-ray particle (calculated via Monte Carlo)

Lcr can be calculated and can be translated to upper limits if

$$I_\gamma^{UL}(> E_\gamma^{th})$$

Kampert et al 2013 and Supanitsky and Souza 2013 for description of CRPropa

On the other hand, many mechanisms contribute to accelerate particles in AGNs (e.g. Fermi process), but, in last instance, driven by 'magnetic luminosity'. So, we will assume a very simple conversion efficiency such that

$$L_{CR}^{Theory} = \eta L_B$$

Estimate upper limits from gamma

Estimate from central BH dynamical issues

Estimate upper limits for conversion efficiency

$$L_B \simeq 4 \times 10^{-3} \Phi_{BH,\max}^2(\dot{M}) \frac{\Omega_{BH}^2}{c} f_a(\Omega_{BH})$$

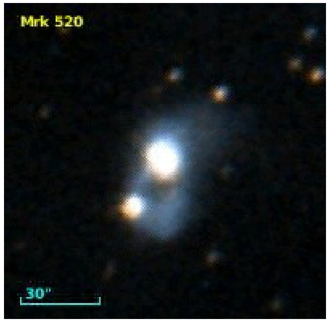
Assuming that $\Phi_d > \Phi_{BH,\max}(\dot{M})$

Blandford, Znajek 1977
McKinney, Tchekhovskoy, Blandford 2012, ApJL

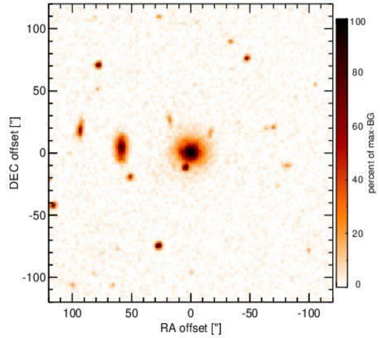
To integrate gamma flux, some of the chosen individual gamma sources

NGC 985

NGC 1142



Mrk 520



LEDA 170194

MCG-01-24-012

NGC 5995

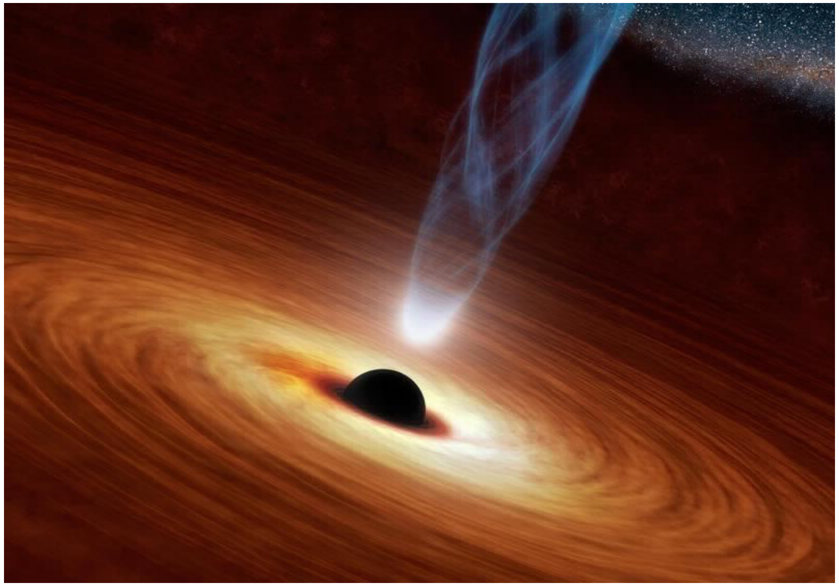
And 16 more from Fermi-Lat (UL)

Image credits: aladin.u-strasbg.fr, nasa.gov, dc.zah.uni-heidelberg.de

Cosmology/BH properties

Upper limits of GeV-TeV gammas

$$\eta(a)_{pr} = \frac{4\pi D_s^2(1+z_s)}{10(\phi/50)x_a^2 f_a(x_a)\dot{M}c^2} \times \frac{\langle E\rangle_0 I_\gamma^{UL}(>E_\gamma^{th})}{K_\gamma \int_{E_{th}}^{\infty} dE_\gamma P_\gamma(E_\gamma)}$$

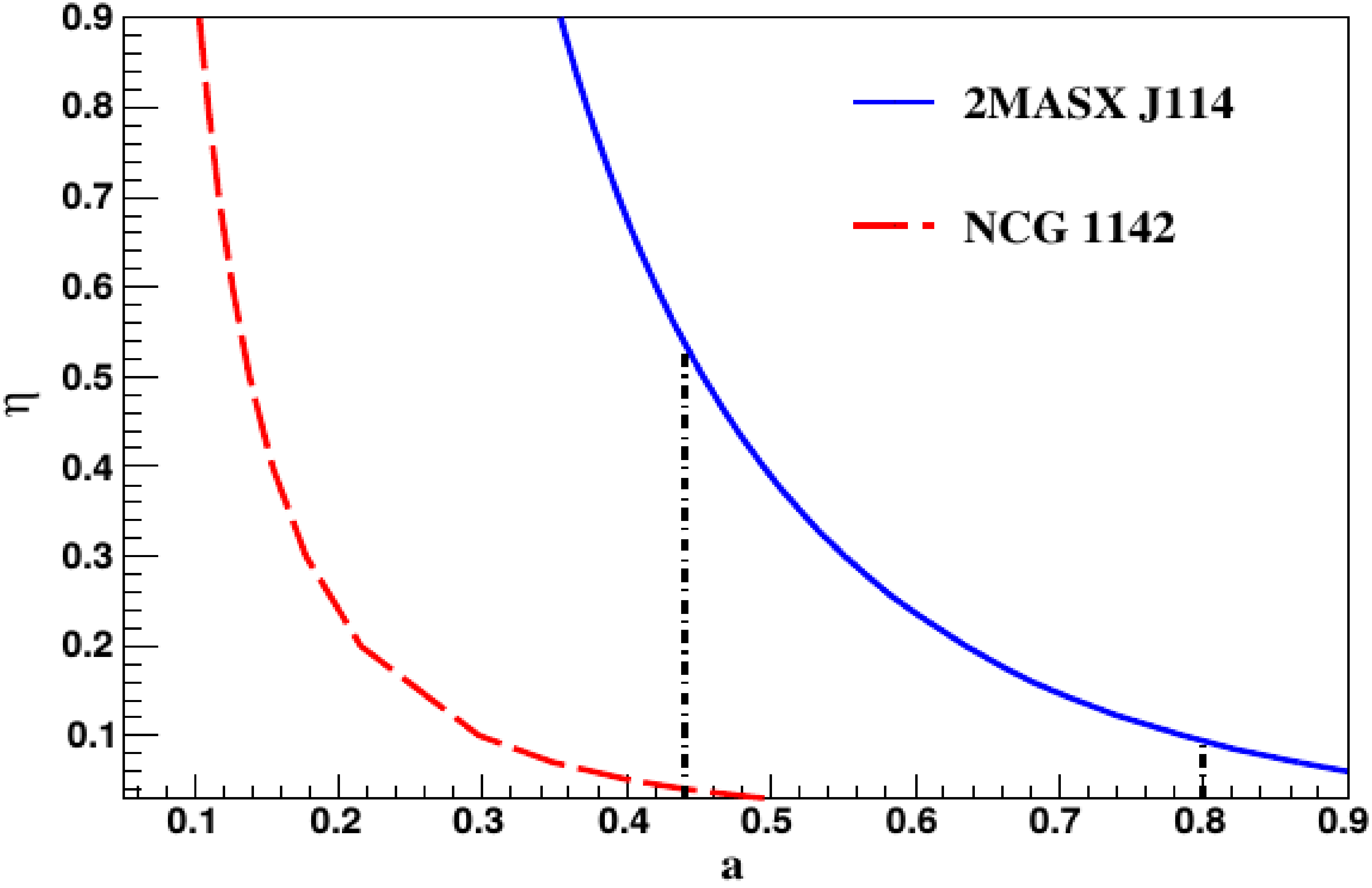


Coimbra-Araújo and Anjos 2015, PRD

$$x_a = r_g \frac{\Omega_{BH}}{c} = [2(1+\sqrt{1-a^2})]^{-1} a$$

$$f_a(x_a) \simeq 1 + 1.4x_a^2 - 9.2x_a^4$$

With *a* = J/M

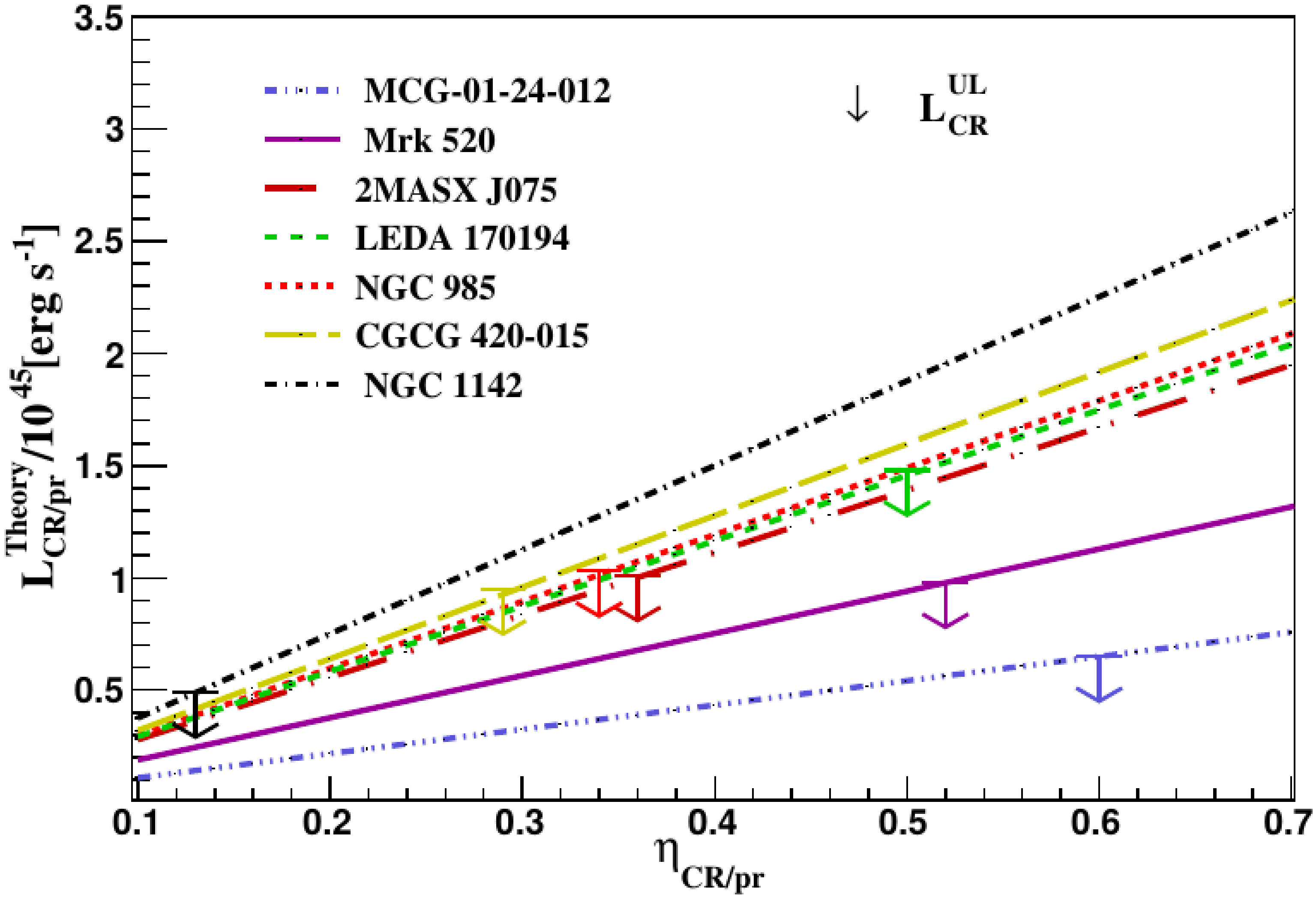


2MASX J114
NCG 1142
η
a
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Source name	z_s	$\log M_\odot$	L_{pr}^{UL} (Proton) [erg s^{-1} × 10^{45}]	L_B[erg s^{-1} × 10^{45}] $a = 0.45$	$a = 0.7$	$a = 0.45$ $L_{CRmin}^{Theory} - L_{CRmax}^{Theory}$ [erg s^{-1} × 10^{45}]	$a = 0.7$ $L_{CRmin}^{Theory} - L_{CRmax}^{Theory}$ [erg s^{-1} × 10^{45}]
NGC 985	0.04353	10.6	1.03	5.14	15.54	0.21 - 2.57	0.77 - 2.79
NGC 1142	0.02916	10.7	0.49	6.47	19.57	0.26 - 3.23	0.97 - 3.52
2MASX J07595347+2323241	0.03064	10.57	1.01	4.80	14.51	0.19 - 2.40	0.72 - 2.61
CGCG 420-015	0.02995	10.63	0.95	5.51	16.66	0.22 - 2.76	0.83 - 2.99
MCG-01-24-012	0.02136	10.16	0.65	1.86	5.64	0.07 - 0.93	0.28 - 1.02
2MASX J11454045-1827149	0.03616	10.0	1.30	1.29	3.90	0.07 - 0.64	0.19 - 0.70
LEDA 170194	0.04024	10.59	1.48	5.02	15.19	0.21 - 2.51	0.75 - 2.73
NGC 5995	0.02834	9.89	0.90	1.00	3.03	0.04 - 0.51	0.15 - 0.54
Mrk 520	0.02772	10.4	0.98	3.24	9.81	0.13 - 1.62	0.49 - 1.77

Source name	D [Mpc]	UL: $\mathcal{F}$ (> 0.1 GeV) [10^{-9} ph cm^{-2} s^{-1}]	L_{pr}^{UL} (Proton) [erg s^{-1} × 10^{45}]	L_{CR}^{UL} (Total) [erg s^{-1} × 10^{45}]
Mrk 1018	181.5	2.1	1.04	-
NGC 985	184.7	1.8	1.03	2.19
NGC 1142	121.5	1.1	0.49	-
2MASX J07595347+2323241	127.7	2.2	1.01	-
Mrk 704	130	2.0	0.91	-
MCG+04-22-042	143.6	1.6	0.75	1.74
Mrk 417	147.4	3.7	1.72	-
ESO 121-IG028	177.8	1.2	0.64	-
ESO 549-G049	111.1	2.5	1.11	-
CGCG 420-015	124.8	2.1	0.95	-
Ark 120	139.7	1.6	0.74	-
MCG-01-24-012	89.0	1.5	0.65	-
Mrk 110	156	1.9	0.90	-
2MASX J11454045-1827149	150.7	2.8	1.30	3.16
LEDA 170194	167.7	3.1	1.48	3.71
NGC 5252	108.4	1.4	0.62	-
Mrk 817	141.5	1.6	1.72	-
NGC 5995	118.1	2.0	0.90	-
Mrk 509	151.6	2.7	1.27	-
Mrk 520	115.5	2.2	0.98	-
Mrk 915	104	2.4	1.06	-
NGC 7603	126.5	2.0	0.91	-

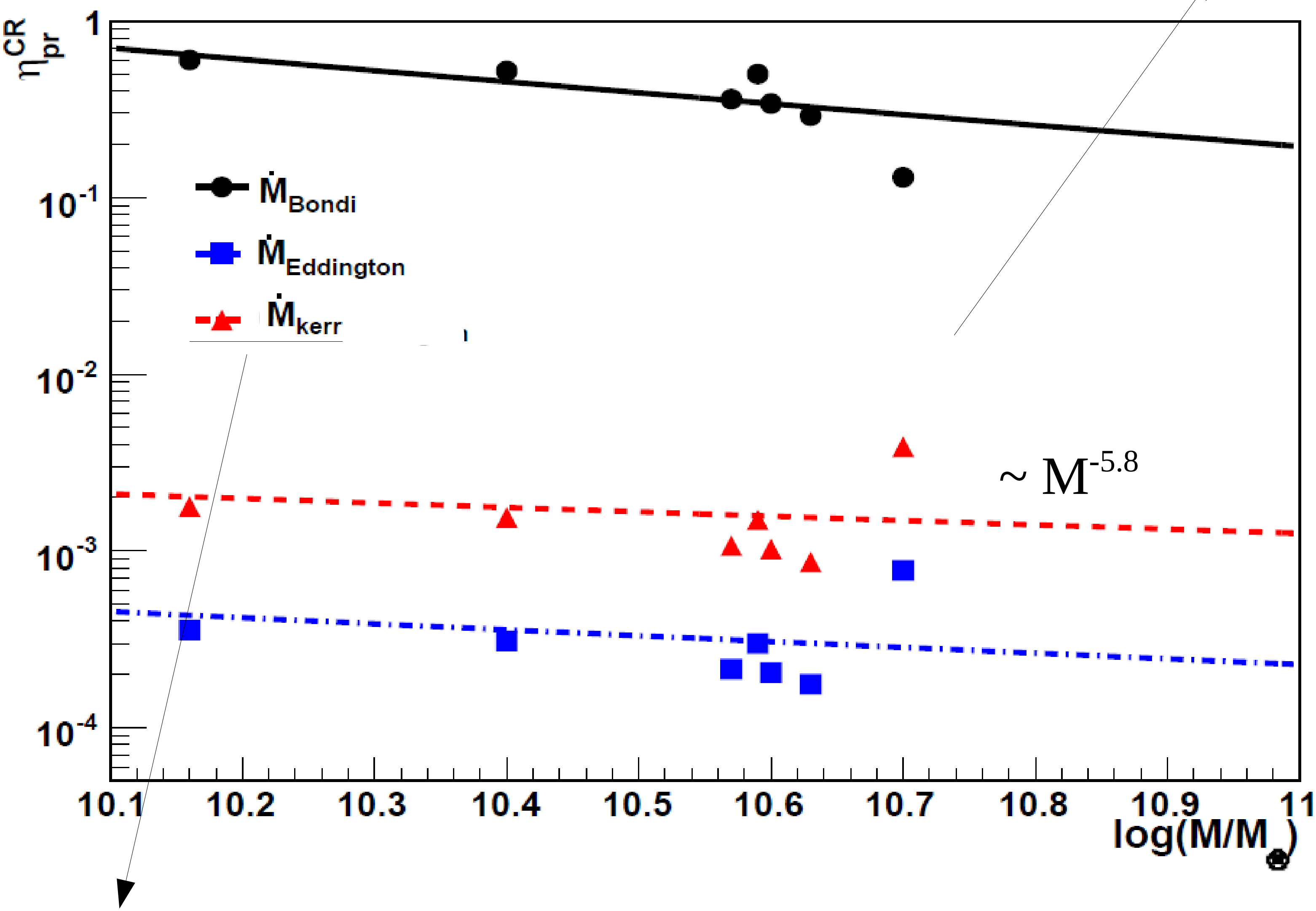
From 95% CL UL Fermi-Lat (ApJS 2010 and 2012)



Bondi accretion assumed

a = 0.7

Picture in construction, to contain more sources (work in preparation)



See the stability of such Kerr disks in Coimbra-Araújo & Anjos, CQG, 2016

a = 0.7

SUMMARY

- Novel method to calculated Lcr upper limits from GeV-TeV gamma upper limits (Supanitsky & Souza 2013; Anjos & Souza 2014)
- Linking Lcr upper limit with Lb by a conversion rate calculated here and developed in C-A, Anjos PRD, 2015; Anjos, C-A, Rocha, Souza, JCAP, 2016
- Since CTA will problably offer very strict upper limits at GeV-TeV, the method presented here can be used in many sources in manner to verify patterns in upper limits of Lb to Lcr conversion rates in function of AGN/BH properties.

→ At last, not least important, future perspectives: improve the approach for the case of neutrino propagation

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Thank you!