Electromagnetic cascade in the vicinity of a super-massive black hole

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TeVPa
July 19-23, 2010, Paris

Motivations

✯ In the recent years, radio-galaxies (Centaurus A & M87) have emerged as a new class of VHE γ-rays emitters

✯ Proximity and multi-wavelength campaign enable unique studies of the physics of the immediate surrounding of supermassive BH

✯ Day scale variability implies compact region ~ few $R_{\text{Schw.}}$

✯ Pulsar-type scenarios have already been invoked to explain VHE emission from BHs (*Beskin et al., 1992; Hirotani & Okamoto, 1998; Levinson, 2000; Neronov & Aharonian, 2007*)

BH electrodynamics in force-free approx.

(*Blandford & Znajek, 1977; Thorne & MacDonald, 1982; Komissarov, 2004*)

☆ Force-free approx. is a low inertia limit of MHD

☆ Plasma inertia and temperature small compared to e.m. energy density, the role of the plasma is to carry charges

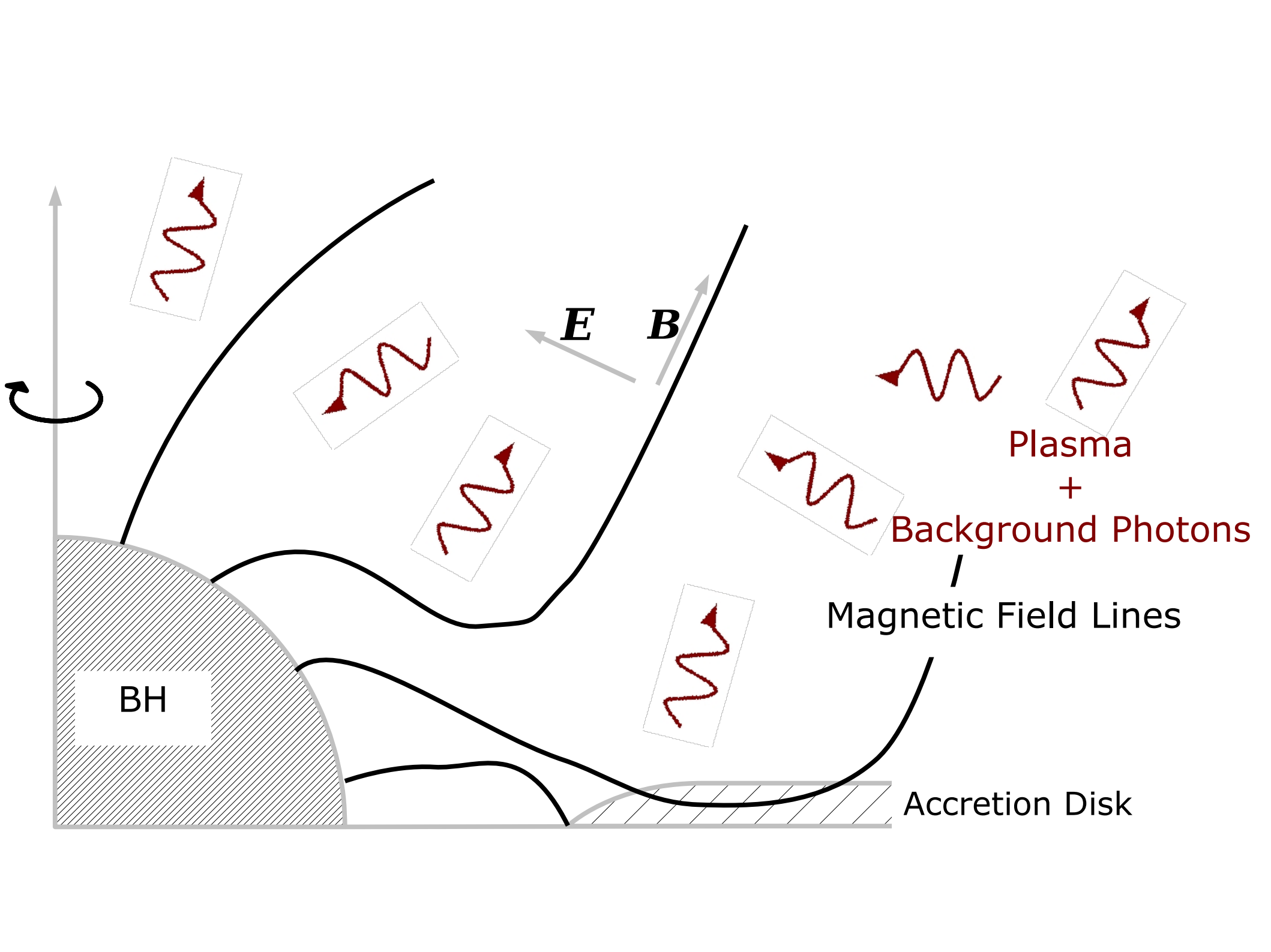
Eq. of motion in MHD : $\rho_e \boldsymbol{E} + \boldsymbol{j} \times \boldsymbol{B} = \rho_m \left(\partial_t + \boldsymbol{v}.\nabla \right) \boldsymbol{v}$

Force-free : $\rho_e \boldsymbol{E} + \boldsymbol{j} \times \boldsymbol{B} = 0$

$\boldsymbol{E} \,.\, \boldsymbol{B} = 0$

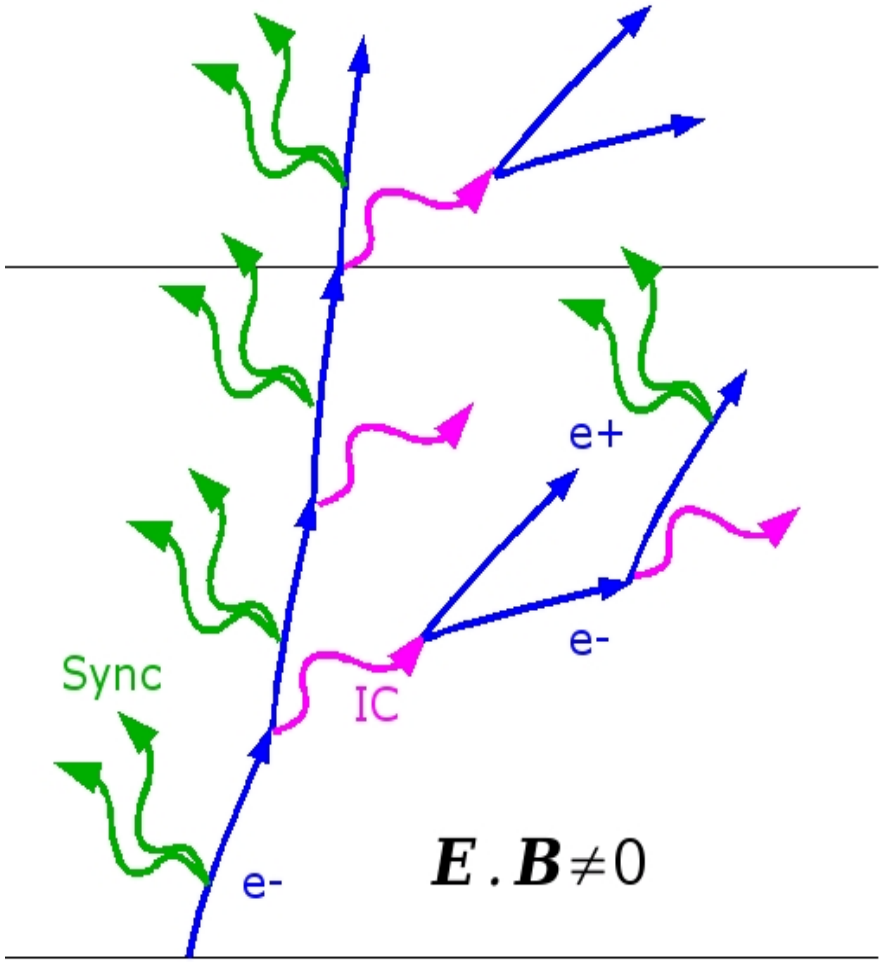
Goldreich & Julian charge density : $\rho_{GJ} \equiv \frac{\nabla \,.\, \boldsymbol{E}}{4\pi} = \frac{-\boldsymbol{v}_F \times \boldsymbol{B}}{c}$

(*Goldreich & Julian, 1969*)


E
B
Plasma
+
Background Photons
Magnetic Field Lines
BH
Accretion Disk

Deficient charge supply : $\rho \neq \rho_{GJ}$

Solve Poisson equation : $E_{parallel} = 4\pi(\rho - \rho_{GJ})h$



Monte Carlo Simulation :

◦ Outside spacetime described by Kerr metric, Lense-Thirring effect

◦ Two different frames :
- Boyer-Lindquist frame, global calculations
- ZAMO (locally Minkowskian), local calc.

◦ Photon trajectories computed using geodesic equations, gravitational redshift

◦ Radiation reaction force on electrons

◦ Synchrotron radiation & IC scattering

✭ Comparisons with analytic approximation give confidence to our Monte-Carlo code (*Vincent & LeBohec, 2010*)

(*Acciari et al., 2009*)

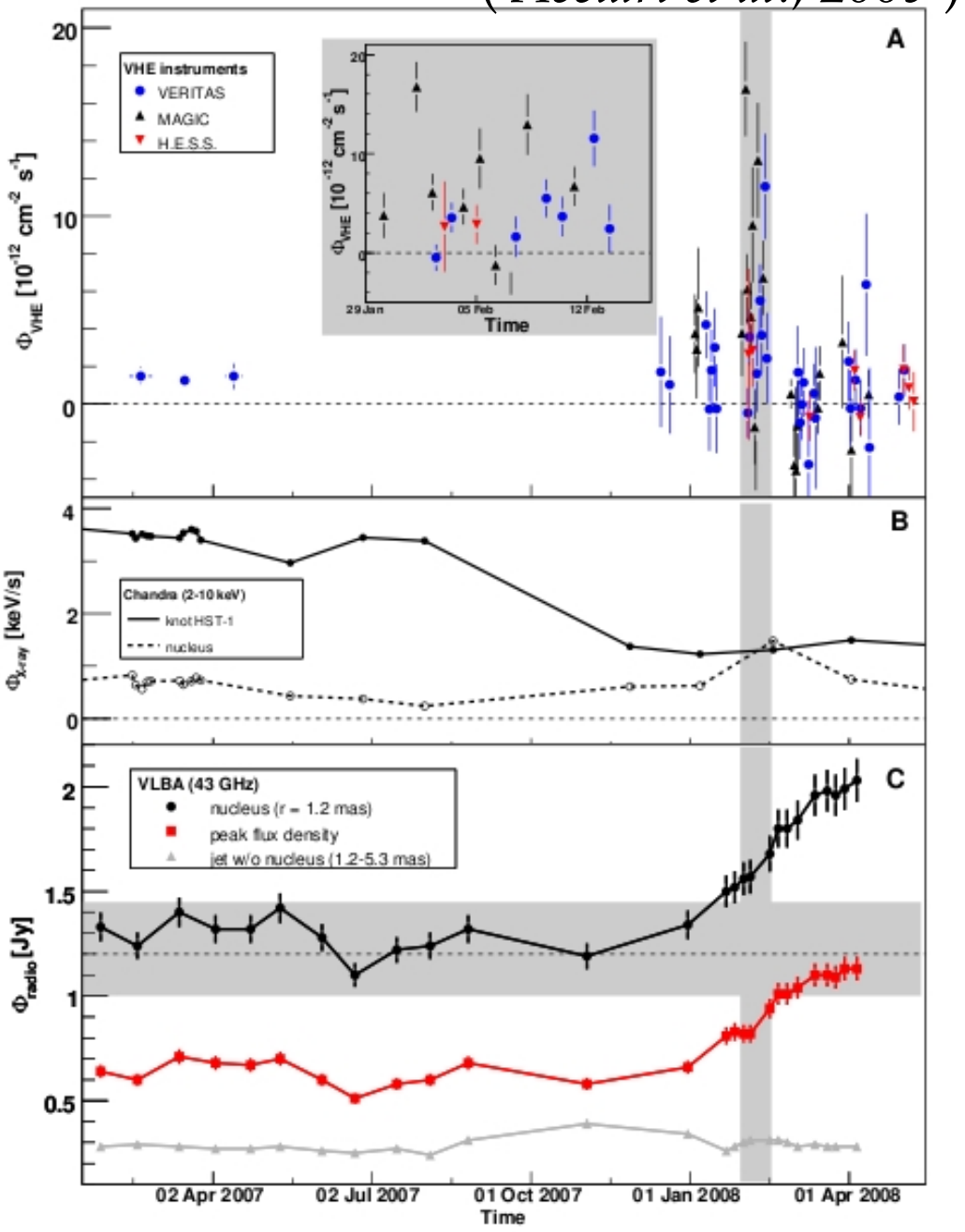
<u>First application M87:</u>

✭ $\sim 6 \times 10^9 M_\odot$

✭ located at a distance of 16 Mpc

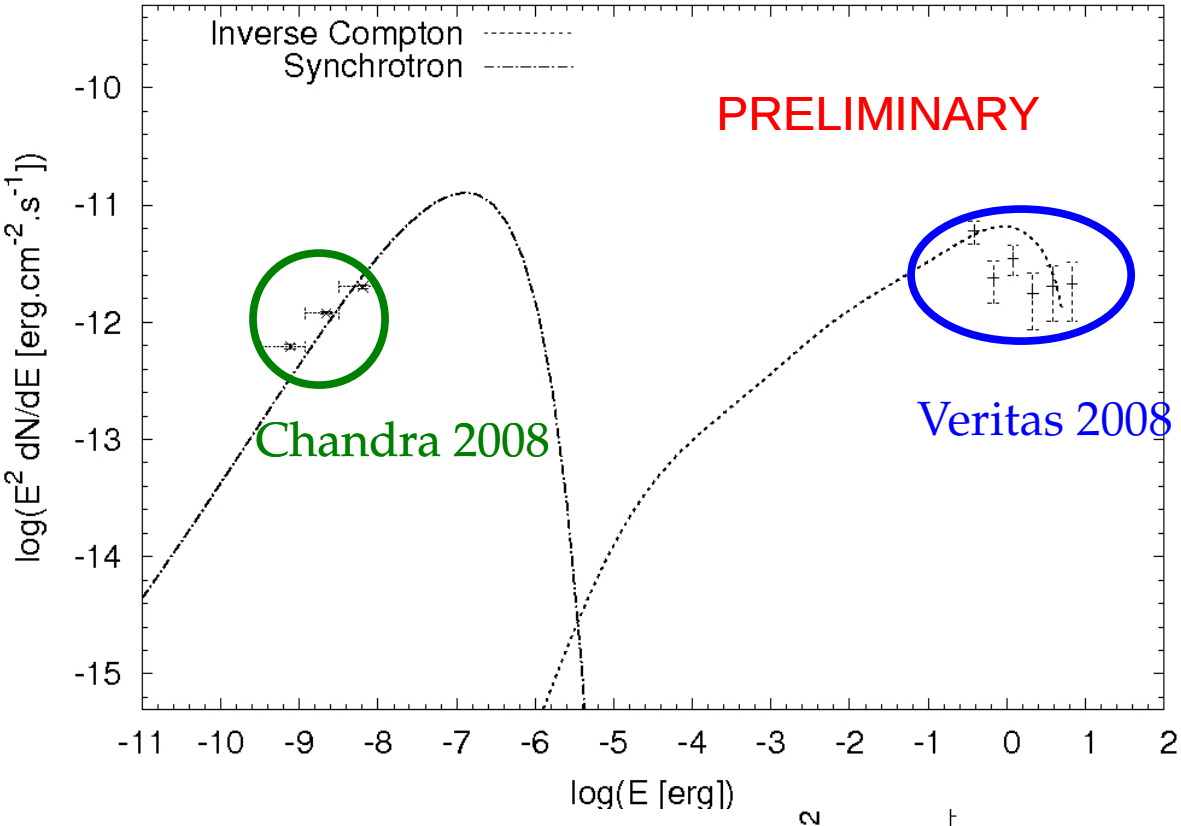
✭ 4 days variability

✭ Chandra & VLBA suggest the core as most likely VHE source

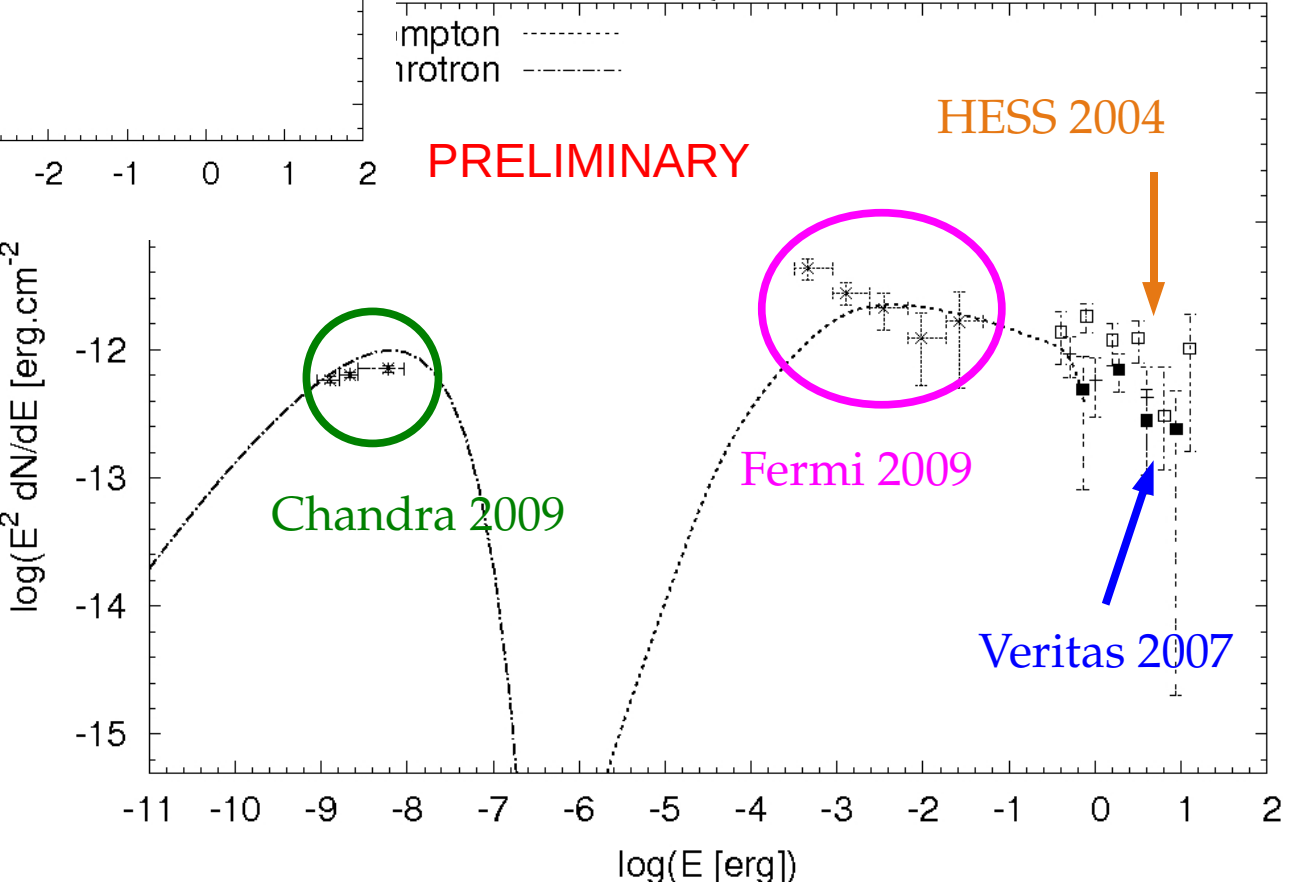


(*Abdo, 2009; Acciari et al., 2007 & 2009; Aharonian et al., 2006; Harris, 2009*)

Flare 2008



Quiet state



Summary

- ✭ Monte-Carlo simul. of e.m. cascade around SMBHs
- ✭ At this stage, the tool is ready to work
- ✭ First application to M87... still under investigations