Cosmic Ray Bursts

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"Theoretical" 10% >10%

(Eli Waxman, Glennys Farrar)

SUMMARY OF RESULTS

1. the origin of UHECR: they must come from bursting sources (explosions)

2. the energy and the duration of the UHECR-producing explosions can, in theory, vary

3. flares on supermassive black holes seem to be the only alternative to gamma-ray bursts

4.tentative predictions: these flares will be discovered

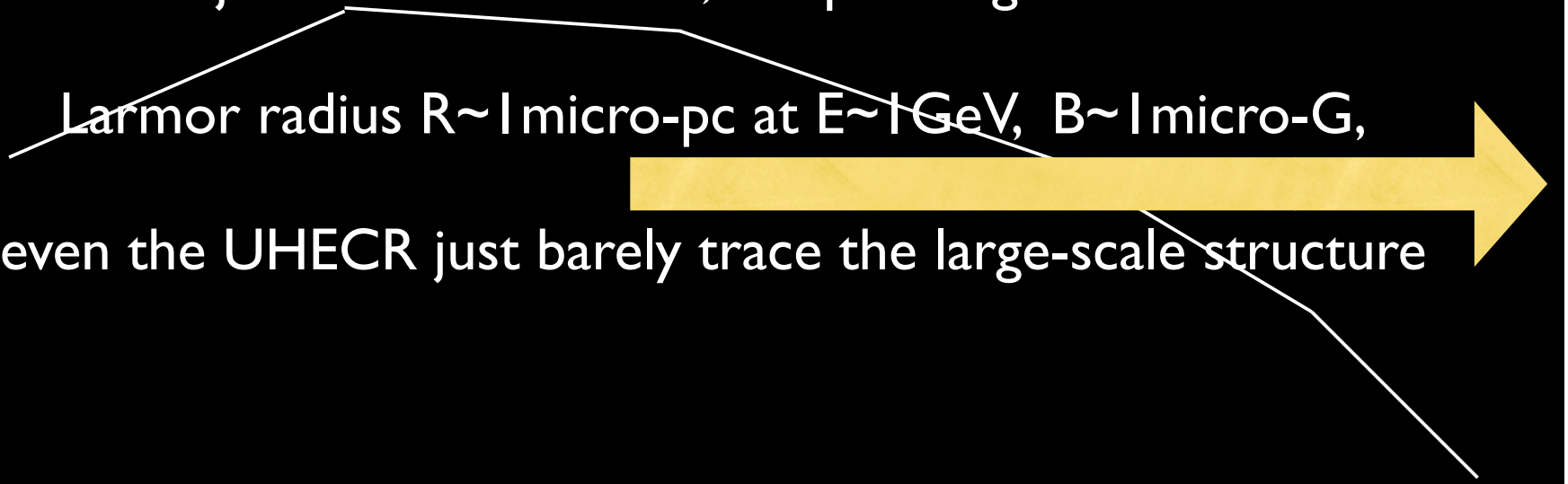
CR origin

type	energy	origin
solar	10 keV	solar flares
galactic	>1GeV	SN
UHECR	up to 10^20 eV	GRB, SMBH flares*

*in fact both might have problems, especially flares

How can we possibly say where the CR are coming from?

CR trajectories are curved, not pointing to the source:



Larmor radius R~1micro-pc at E~1GeV, B~1micro-G,

even the UHECR just barely trace the large-scale structure

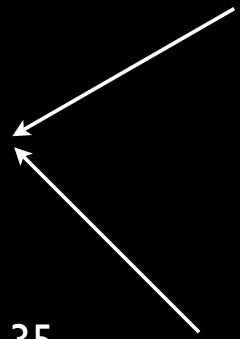
Then how do we know that galactic are from SN?

-we don't
-energy budget (need mild assumptions : equipartiton)
-photon emission by CR (many assumptions)
-adequate accelerator (many assumptions)

Energy budget for UHECR

flux at Earth -- energy density -- GZK -- power density:

~10^-38 erg/cm^3/s



star light 10^-31, SN 10^-32, SMBH 10^-32, GRBs 10^-35, SMBH flares 10^-35

non-thermal photon emission roughly OK for all candidates

why do we prefer the least powerfull (more CR efficiency needed) ?

The luminosity requirement

- Eddington: M to L : 10^38 erg/s (M/M_sun), it apparently works, for stellar and SMBH

- ???????????: E to L : 10^45 erg/s (E/10^20 eV)^2, it should work (?)

$$L \sim (c/e^2)E^2$$

random buffetting
confine by magnetic field B in size R: E~eBR
Umov flux L~cB^2R^2

The luminosity requirement

- M to L : 10^38 erg/s (M/M_sun)
- E to L : 10^45 erg/s (E/10^20 eV)^2

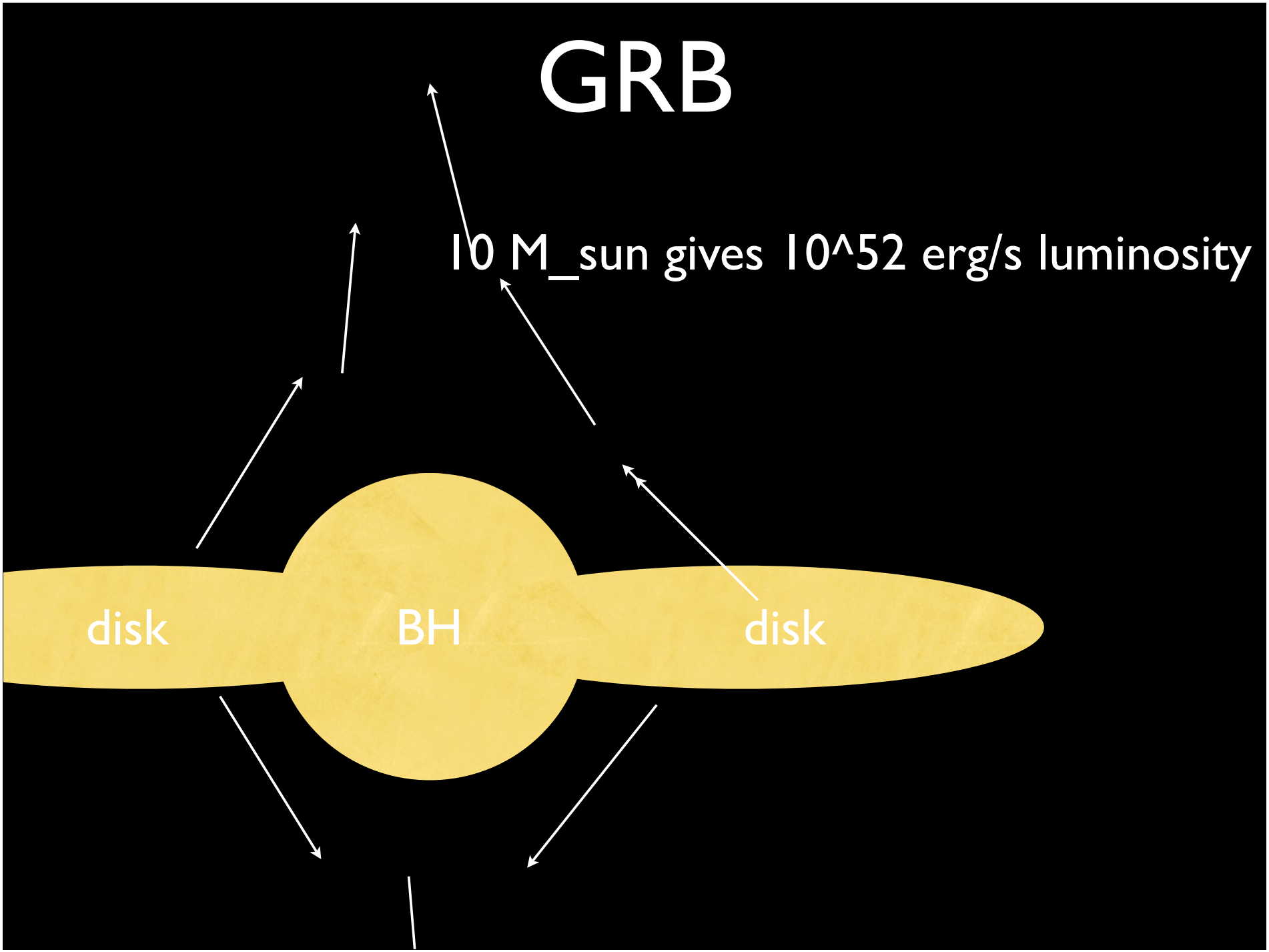
UHECR from 10^45 AGN (near Eddington 10^7 SMBH) ?

AGN ?
GRB ?

no 10^45 within GZK above Eddington

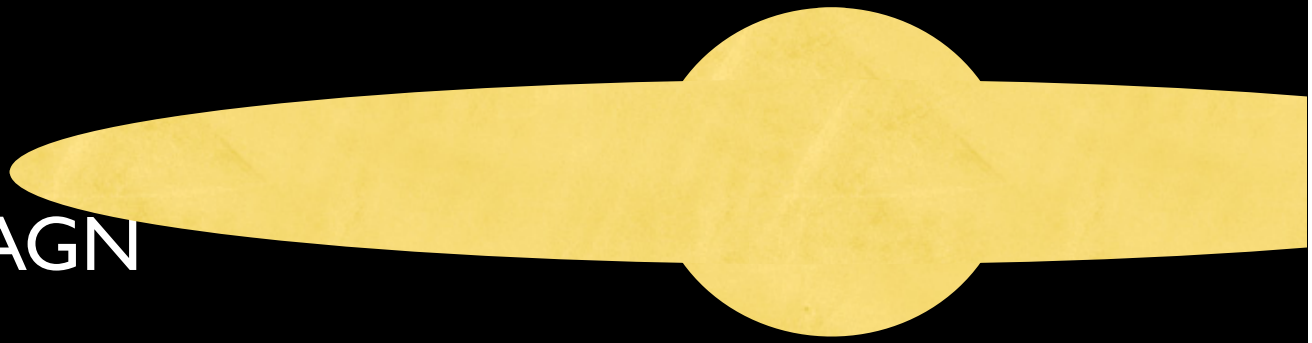
GRB

10 M_sun gives 10^52 erg/s luminosity



AGN

flares on weak AGN



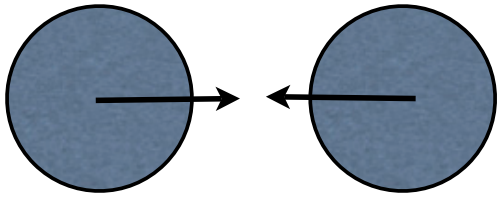
flares on dormant SMBH

COSMIC RAY BURSTS

An estimate of the parameters required to accelerate UHECRs

mean Lorentz factor Γ

variations of the Lorentz factor $\sim \Gamma$.



input parameters R, B

confine the cosmic ray, so

synchrotron power emitted

n the condition

$$RB \gtrsim 3 \times 10^{17}\, \Gamma^{-1}\, E_{20}.$$

$$B \gtrsim \Gamma^2\, E_{20}^{-2}.$$

field (Poynting luminosity) is of order

for avoiding excessive photo-pio

$$L \sim \tfrac{1}{6} c \Gamma^4 B^2 R^2 \gtrsim 10^{45} \Gamma^2\, E_{20}^2\ \mathrm{erg\ s^{-1}}.$$

$$RB^2 \lesssim 10^{17} E_{20}^{-1} \Gamma.$$

which is better a better candidate for the origin of UHECRs,

GRB or flares on SMBH?

- SMBH is exactly as good as GRB, because it is just a scaled-up version, both are CRBs
- GRB is much better, we have photon counterparts, these TBD for SMBHs

Experts (Waxman) say:

- Flares on SMBH is the only alternative to GRB
- L>10^50 bursts are favored by the current x-ray surveys

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