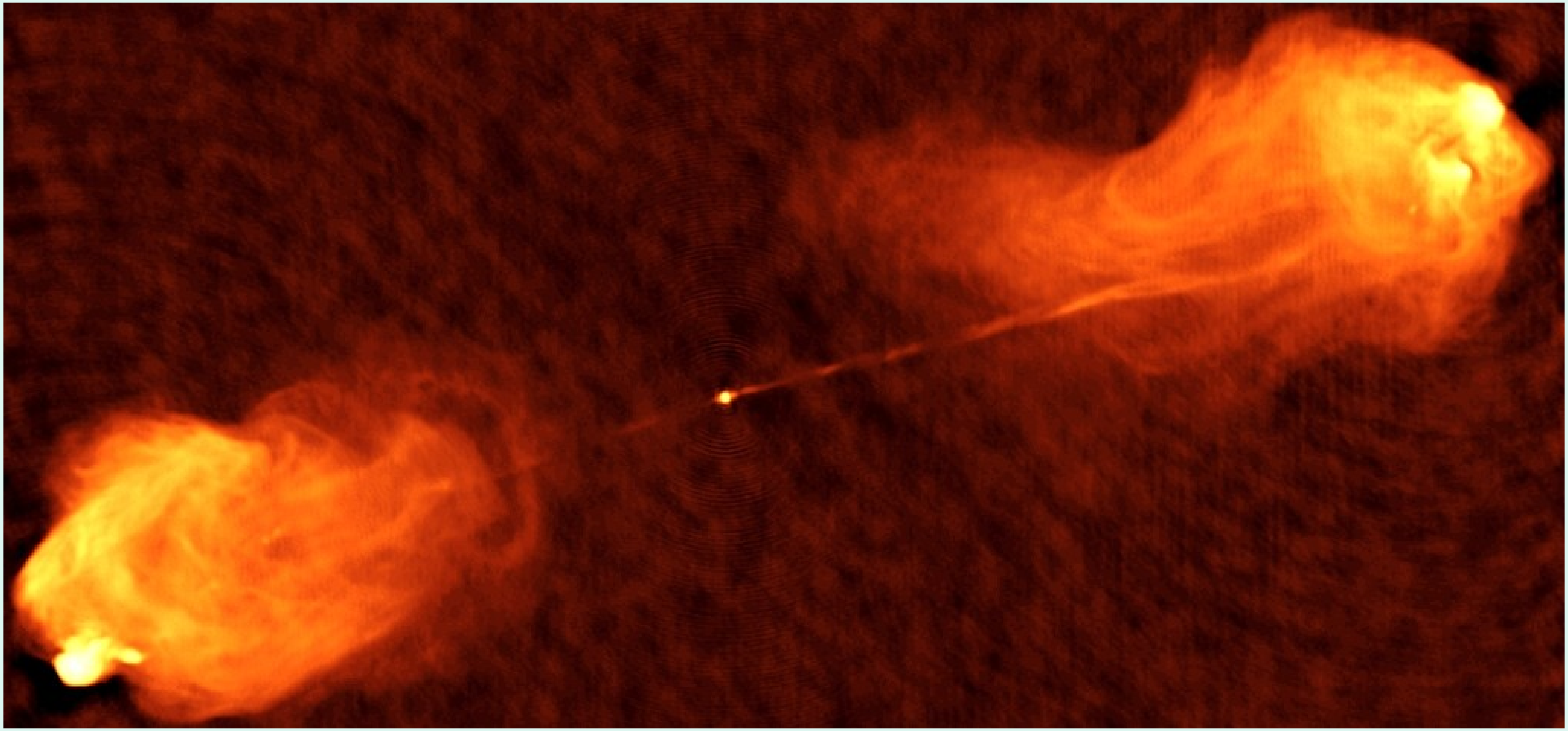
Квазар = QSO = quasi stellar object (1963, Maarten Schmidt)

Активные галактические ядра = квазары X 0.01 – 0.00001

Тепловая светимость 10^{40} – 40^{47} эрг/с

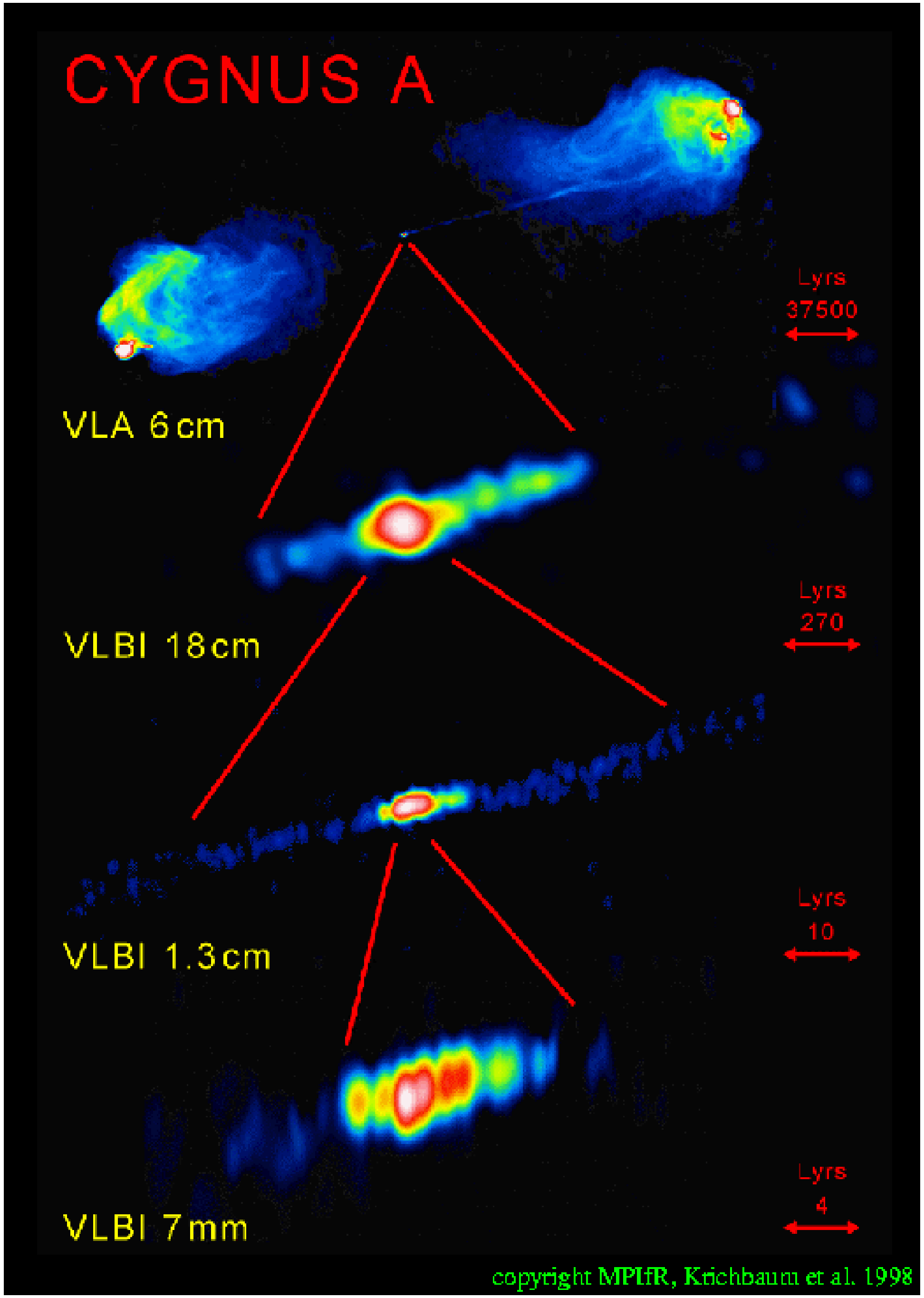
Суть явления: на черную дыру массой 10^{6} – 10^{10} =Мо падает вещество.

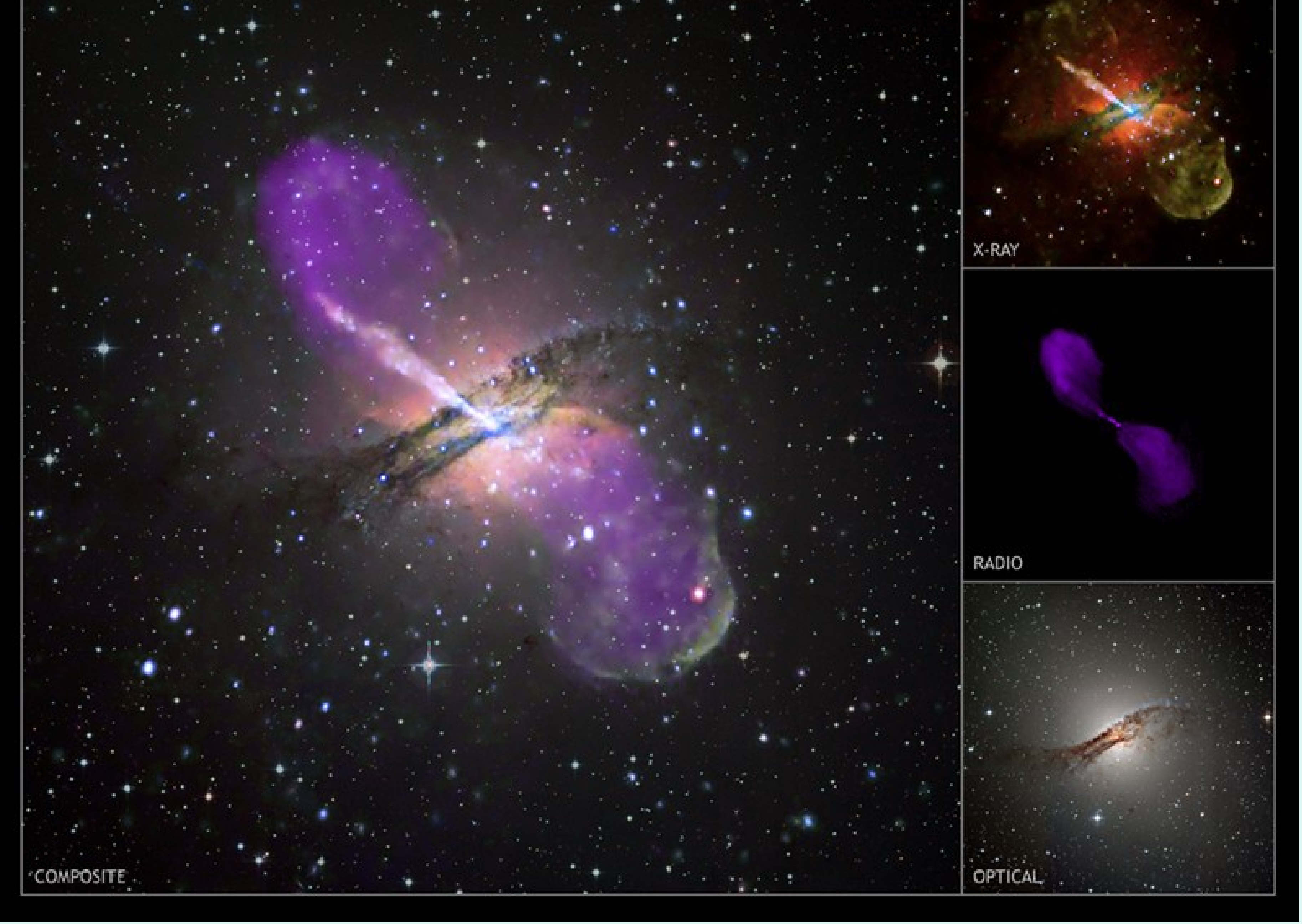
Аккреционные диски – источник света и джетов



FR II

Cyg A FR II


CYGNUS A
VLA 6cm
Lyrs
37500
VLBI 18cm
Lyrs
270
VLBI 1.3cm
Lyrs
10
VLBI 7mm
Lyrs
4
copyright MPIfR, Krichbaum et al. 1998

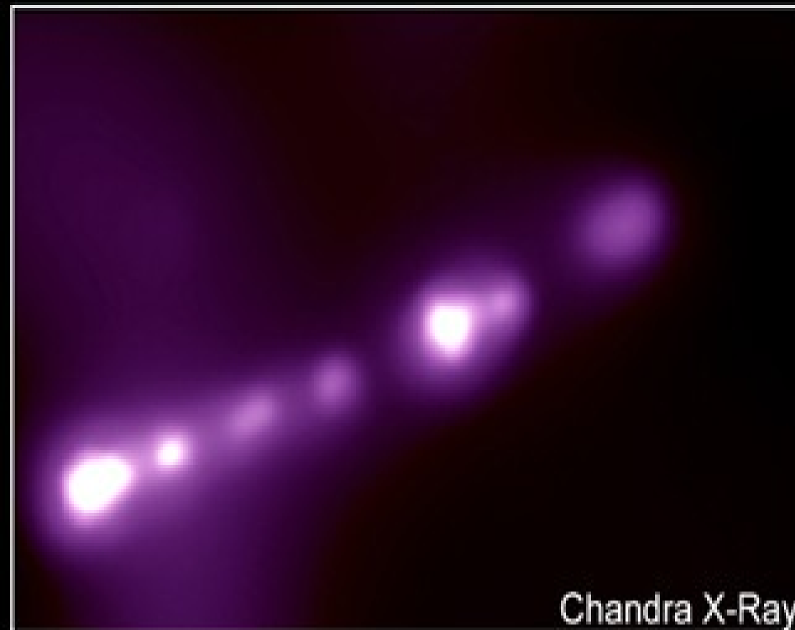


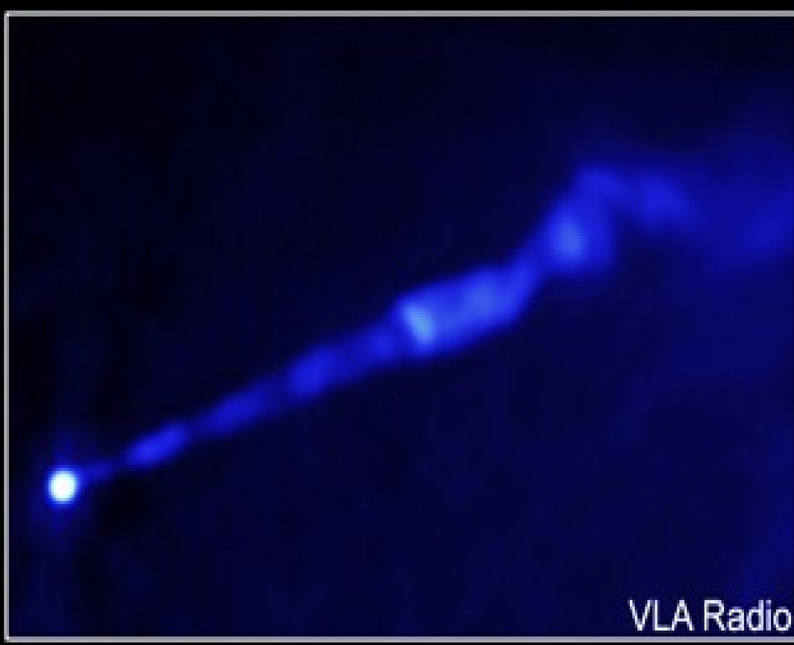
Cen A FR I

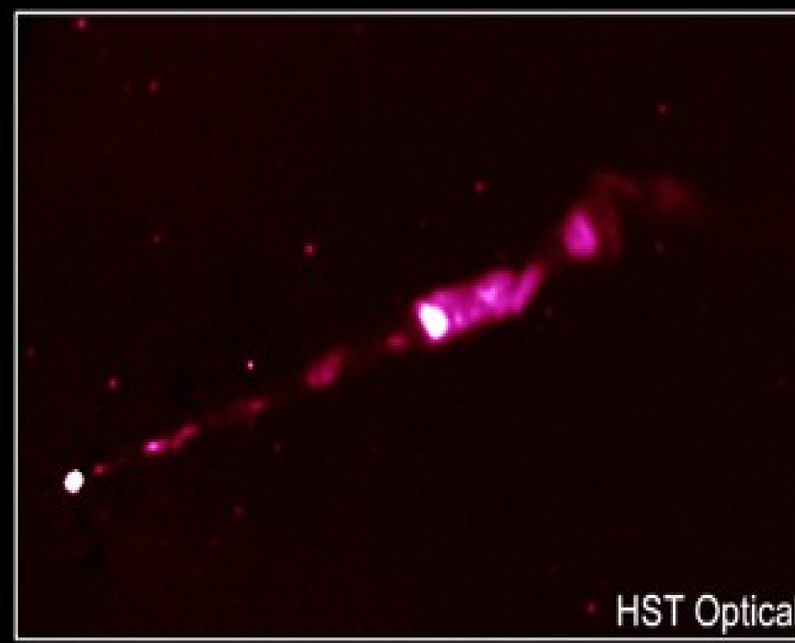
TeV emission

At 20 degrees

The extenal environment or a slow sheath?

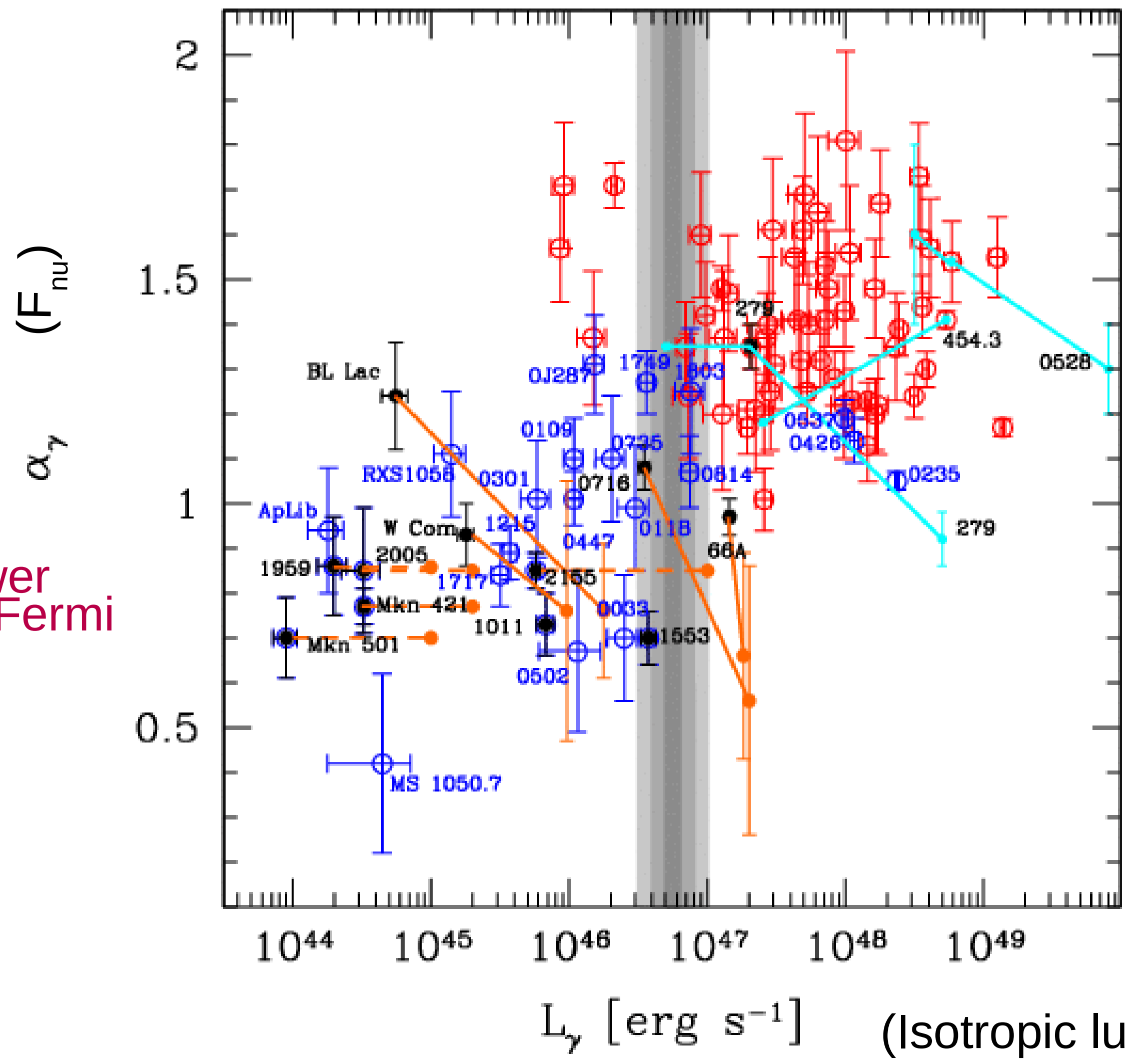






Blazars/BL-Lacs Fermi data

(From Ghisellini 2009)



Average power law index in Fermi range

(Isotropic luminosty)

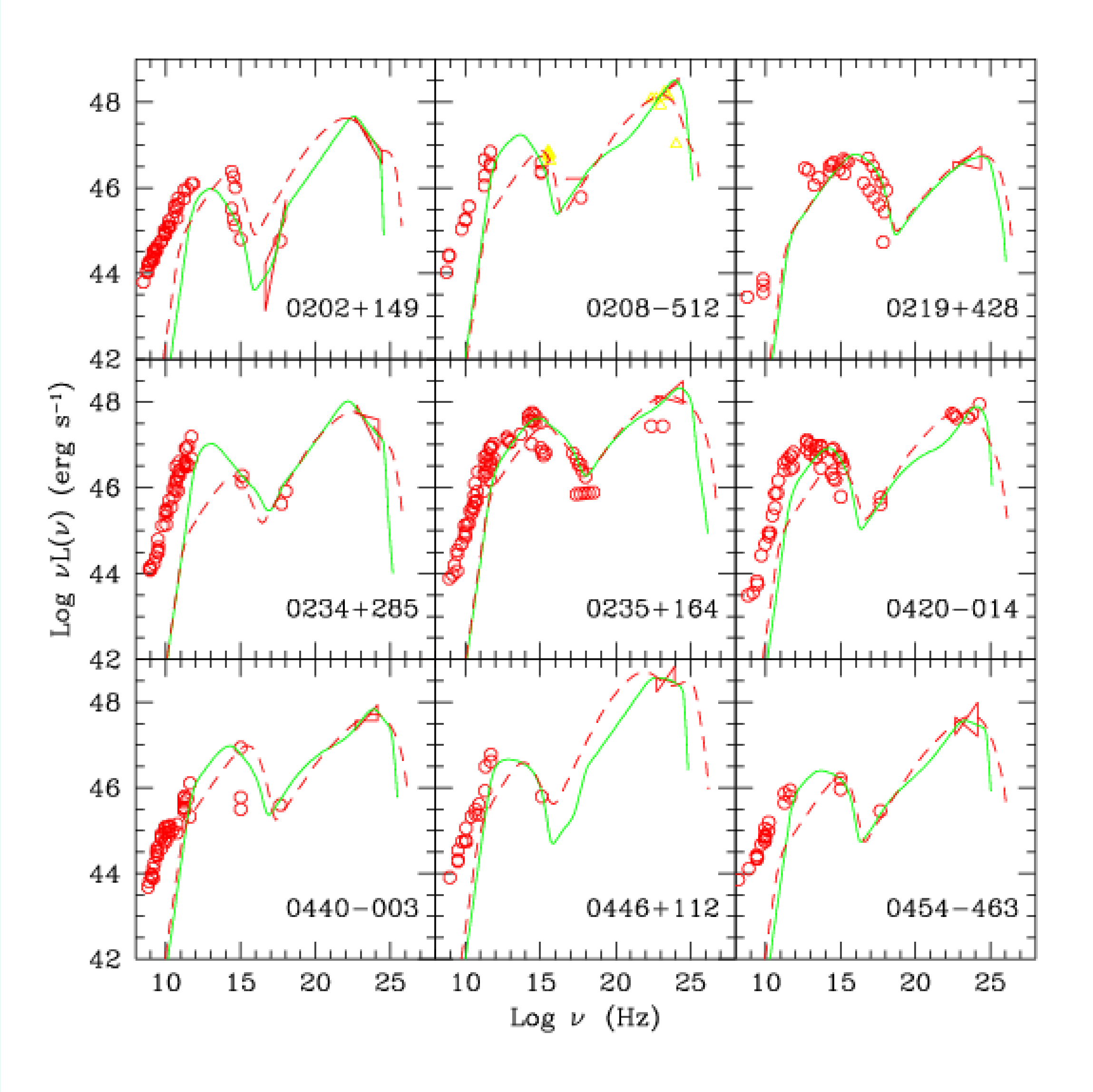
Spectra

Fit:

Synchrotron
-self
Compton

+

External
Compton



Ghisellini et al 1998

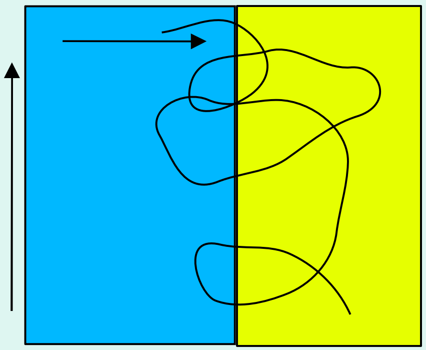
Converter mechanism: an alternative way of energy transfer from a relativistic fluid to particles

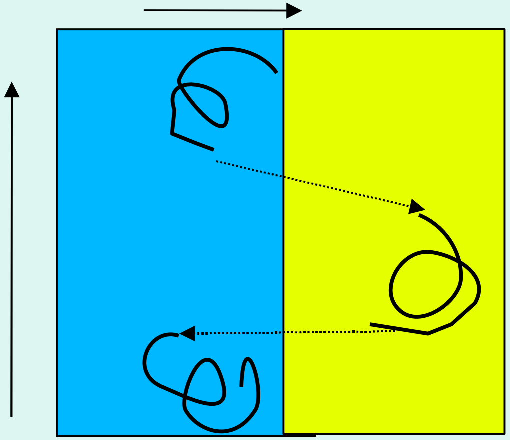
Fermi acceleration: a charged particle crosses a shock front back and forth gaining factor Γ^2 in energy at each round trip.

It is not efficient in the case of relativistic shocks.

Derishev et al. (2003) and Stern (2003) independently suggested an alternative: converter mechanism.

Fermi





P --> n

e --> γ

Charge conversion:

1. proton + photon--> n + π^+ (photomeson production)

2. electron + photon --> electron + photon
(inverse Compton scattering)

3. photon + photon --> e^+ e^-

A background of low energy photons with column density > $10^{25}/cm^2$ is required

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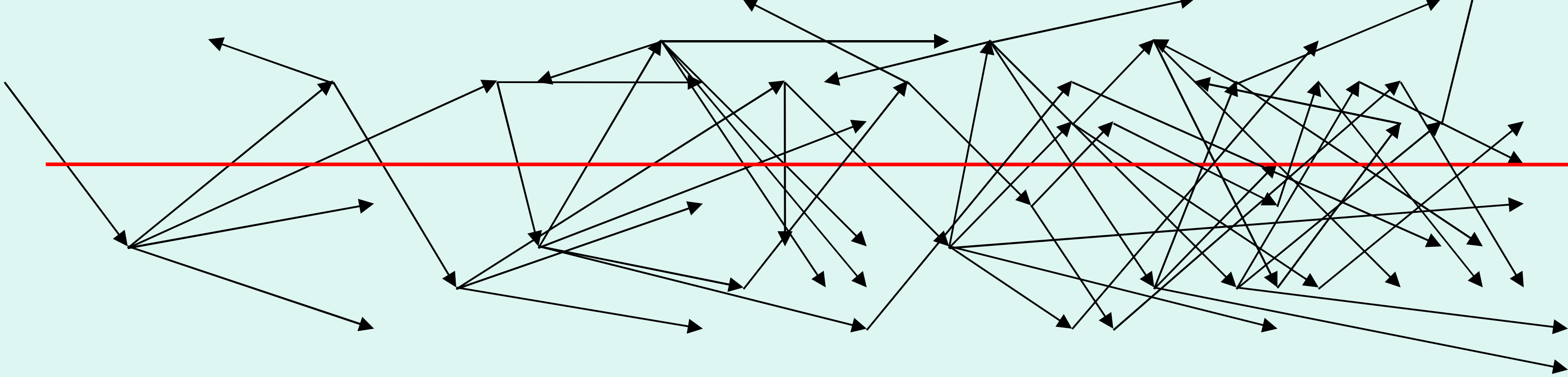
Fermi mechanism: small energy losses and a slow energy gain at a large Γ

Converter mechanism: large energy losses at the charge exchange and a fast energy gain at a large Γ



Photon breeding is the version of the converter mechanism with γ --> e+e --> γ conversion in the supercritical regime (nuclear pile).

Breeding rather than acceleration because the spectrum of particles evolves slowly while their number rapidly increases.

Stern & Poutanen (2006, 2008)

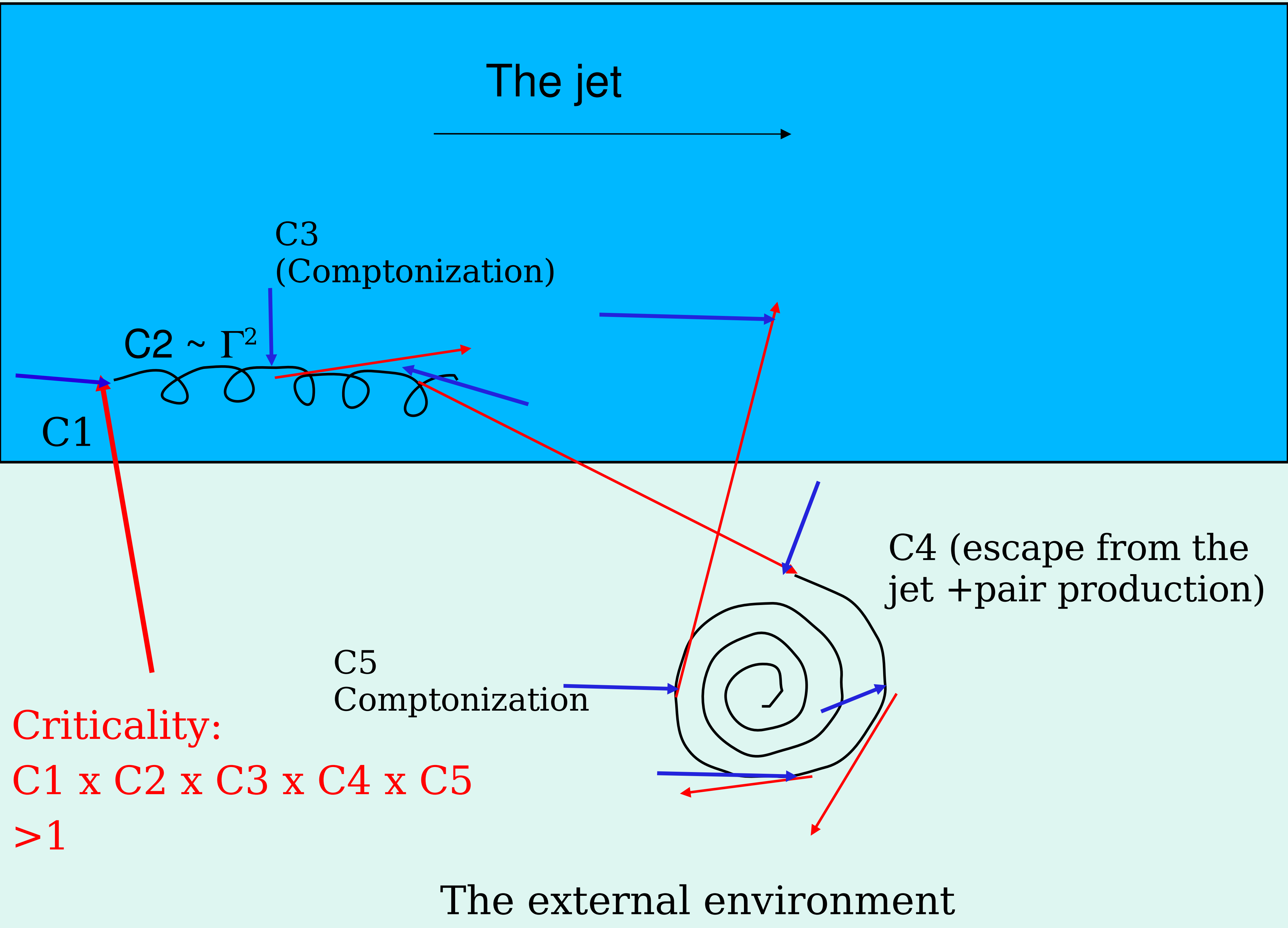
Dissipation of the jet bulk energy into gamma-rays via the photon breeding

Photon breeding mechanism in jets and its observational signatures

Stern & Poutanen 2006 MNRAS (description of the mechanism, analytical estimates problem setup, 1D simulations)

Stern & Poutanen 2008 MNRAS (more extensive 2D simulations,astrophysical implications)

Stern & Tikhomirova 2009 MNRAS accepted (possible observational signature: synchrotron cutoff in GeV range)



The jet
C3
(Comptonization)
C2 ~ Γ²
C1
C4 (escape from the
jet +pair production)
C5
Comptonization
Criticality:
C1 x C2 x C3 x C4 x C5
>1
The external environment

What we need to launch the mechanism:

1. Transversal magnetic field in the jet H_j --> energy gain.

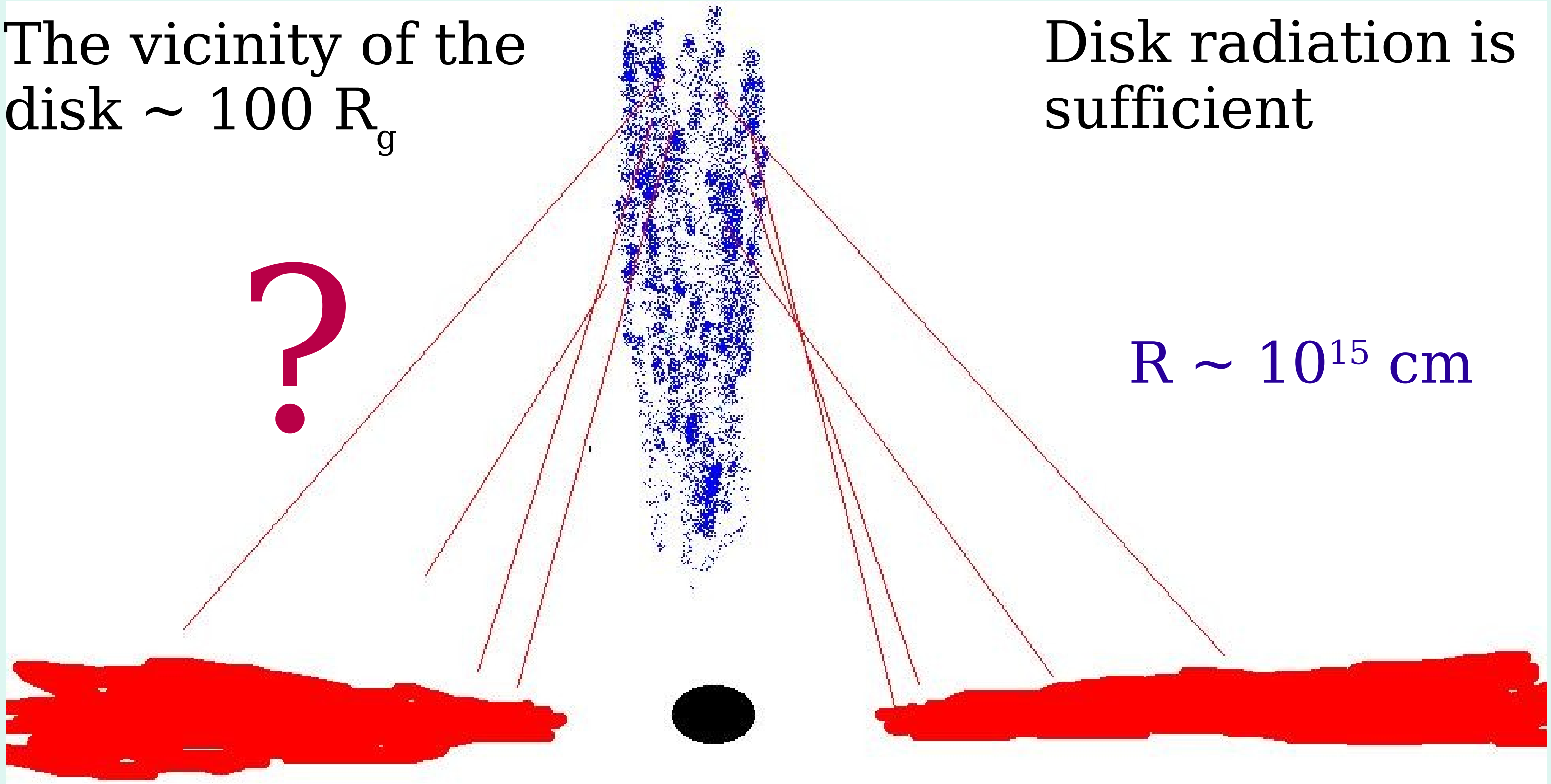
2. Transversal magnetic field H_e outside --> reflection.
3. Soft background radiation. --> charge conversion

(i) Radiation of the disk, F_d, (mainly along the jet) - insufficient

(ii) A scattered, nearly isotropic component F_t.

6. A seed high energy photon.

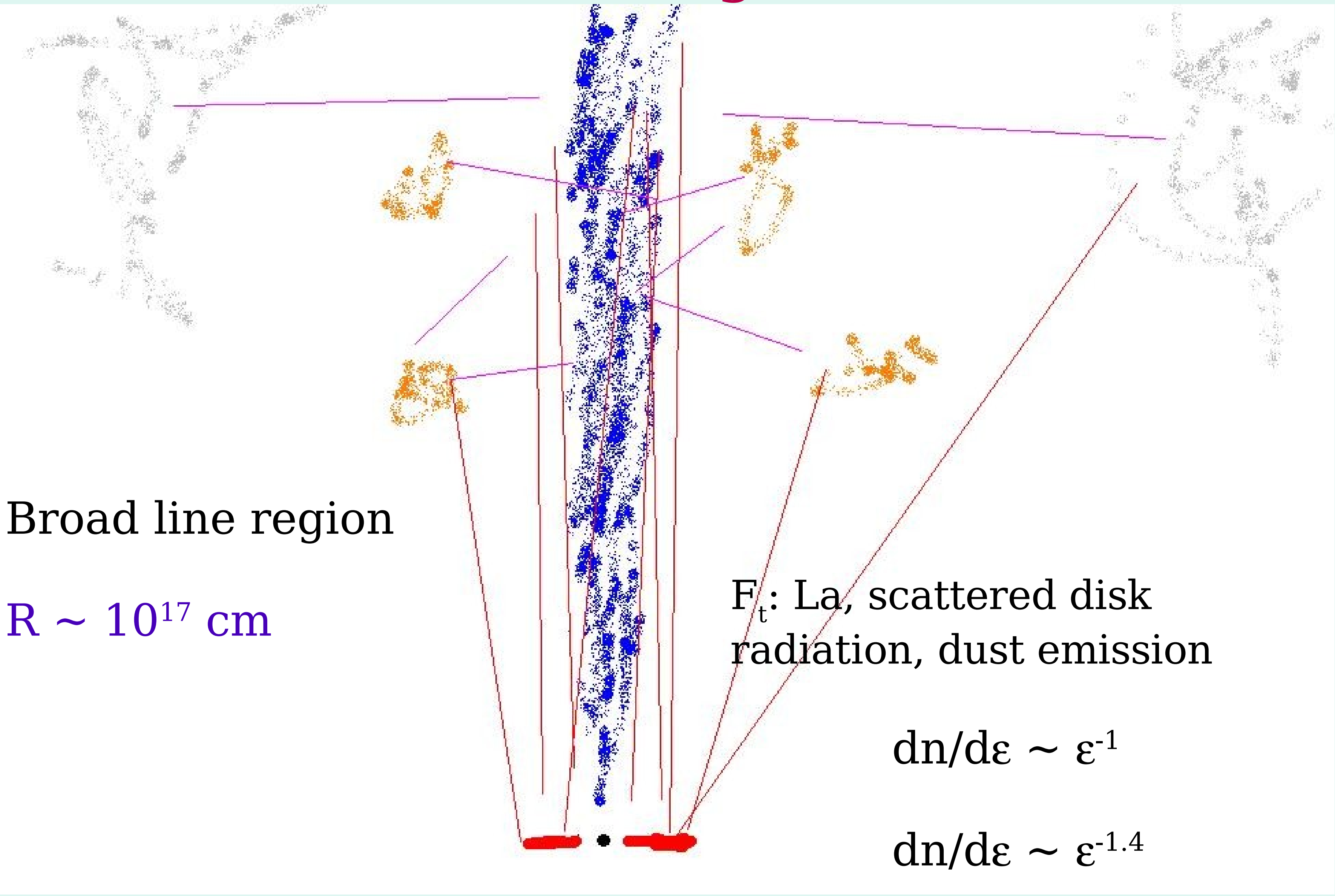
Photon breeding sites



Model C

No F_t

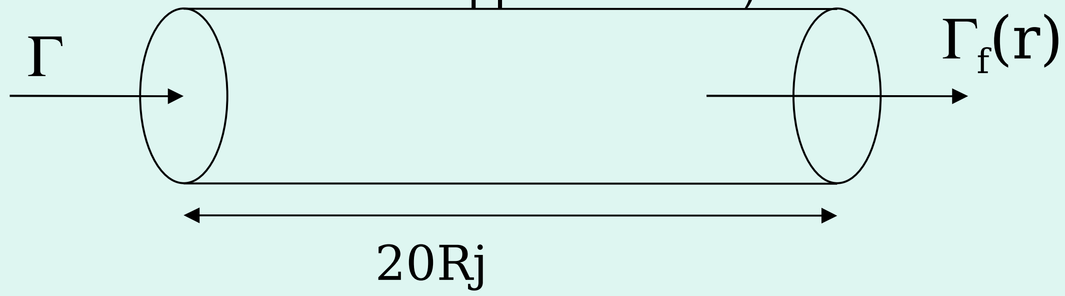
Photon breeding sites



The numerical model

Jet: a cylinder or a cone split into 64 X 20 cells which can independently decelerate, (two

dimensional ballistic approximation). R = 2 10^{17} cm, R_j = 10^{16} cm



Soft photon field: disk radiation (multicolor spectrum) along the jet +

isotropic radiation, spectral number index Γ= -1.4, x_{max} = T_{max} = 5 eV

$F_{iso} = F_d/20$

Magnetic field:

(B_{ext} = 10^{-3} G).

Boundary conditions: Γ = const at the inlet The fixed cylindrical boundary. The external

Numerical experiments with a relativistic radiating jet

The tool: Large Particle Monte-Carlo Code (nonlinear) – LPMC

Stern et al 1995

Synchrotron radiation

Compton scattering

Photon-photon – e+e- pair production

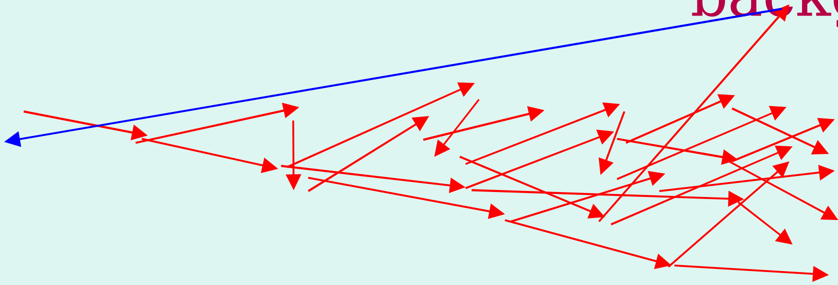
Pair annihilation

Synchrotron selfabsorption

Bremstahlung

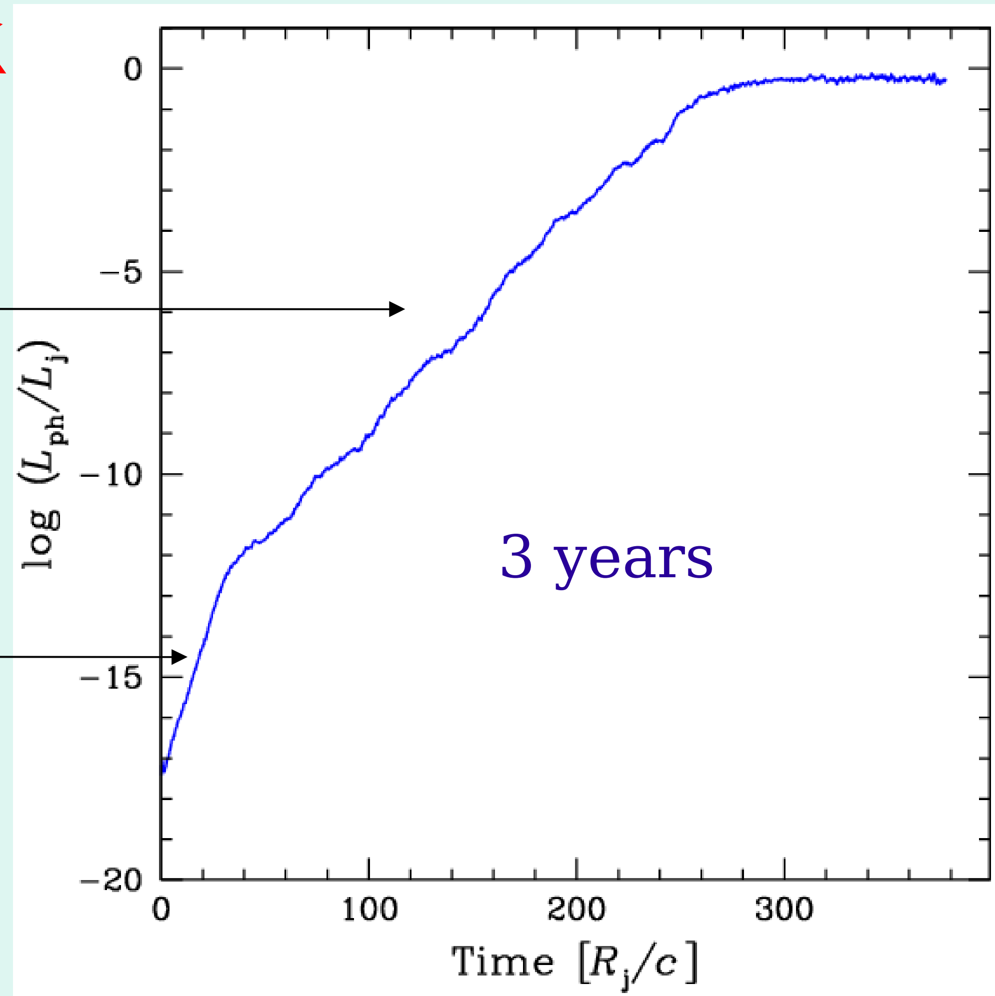
Exact 3D particle transport + space cells for the partner sampling

Exponential regime: Start of the breeding from extragalactic gamma-ray background



Breeding due to downstream-upstream feedback loop

Upstream – downstream photon avalanche



Results

$R=2\ 10^{17}$ cm

Γ=20, magnetically dominated L_B=L_d,

L	L_γ/L_j
$3\ 10^{45}$ erg/s,	0.25
10^{45}	0.32
$3\ 10^{44}$	0.26
10^{44}	0.05
$3\ 10^{43}$	0.

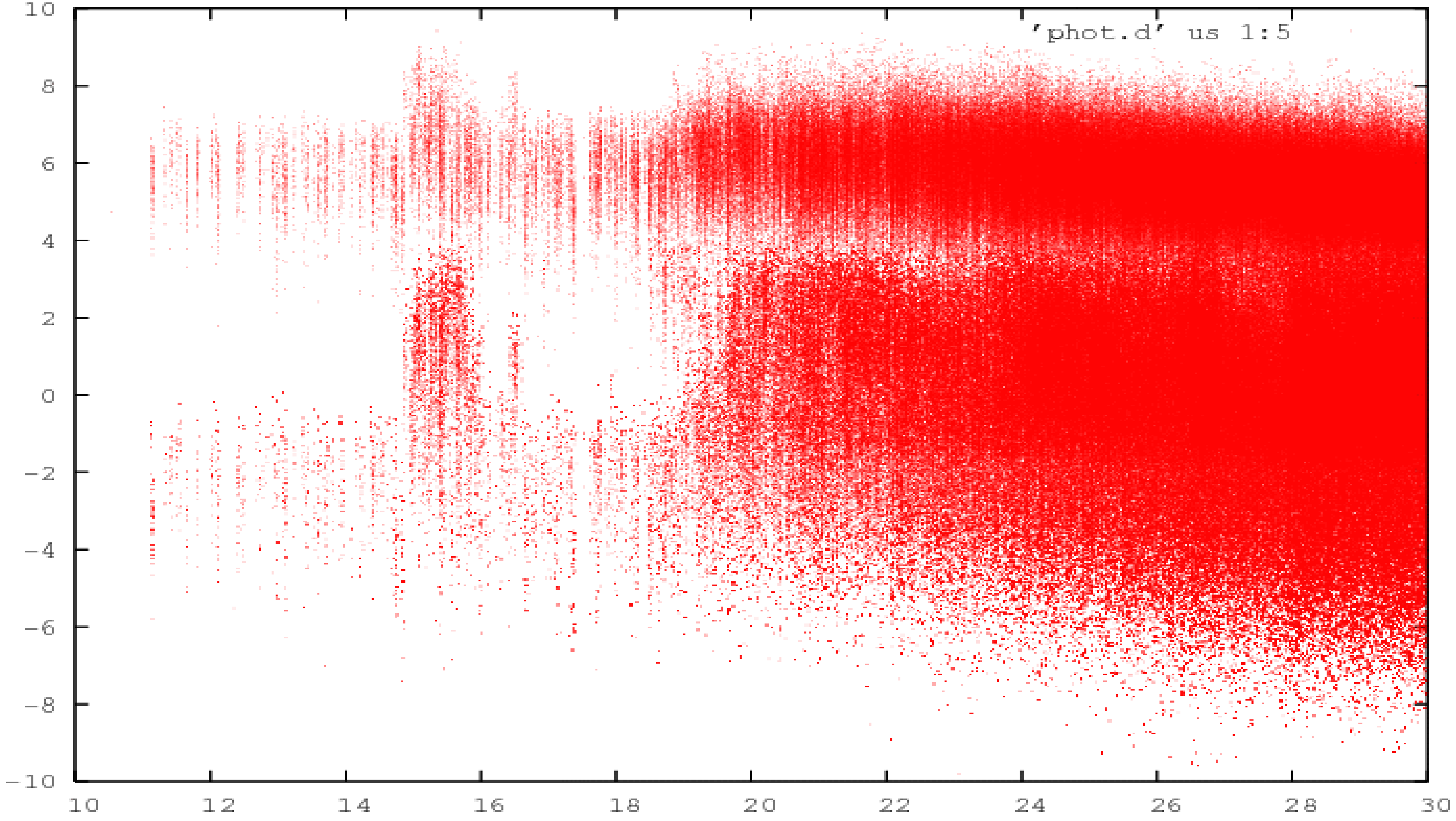
Γ=20, L_B = 0.2 L_d

10^{46}	0.42
$3\ 10^{45}$	0.44
10^{45}	0.50
$3\ 10^{44}$	0.56
10^{44}	0.41
$5\ 10^{43}$	0.12
$3\ 10^{43}$	0

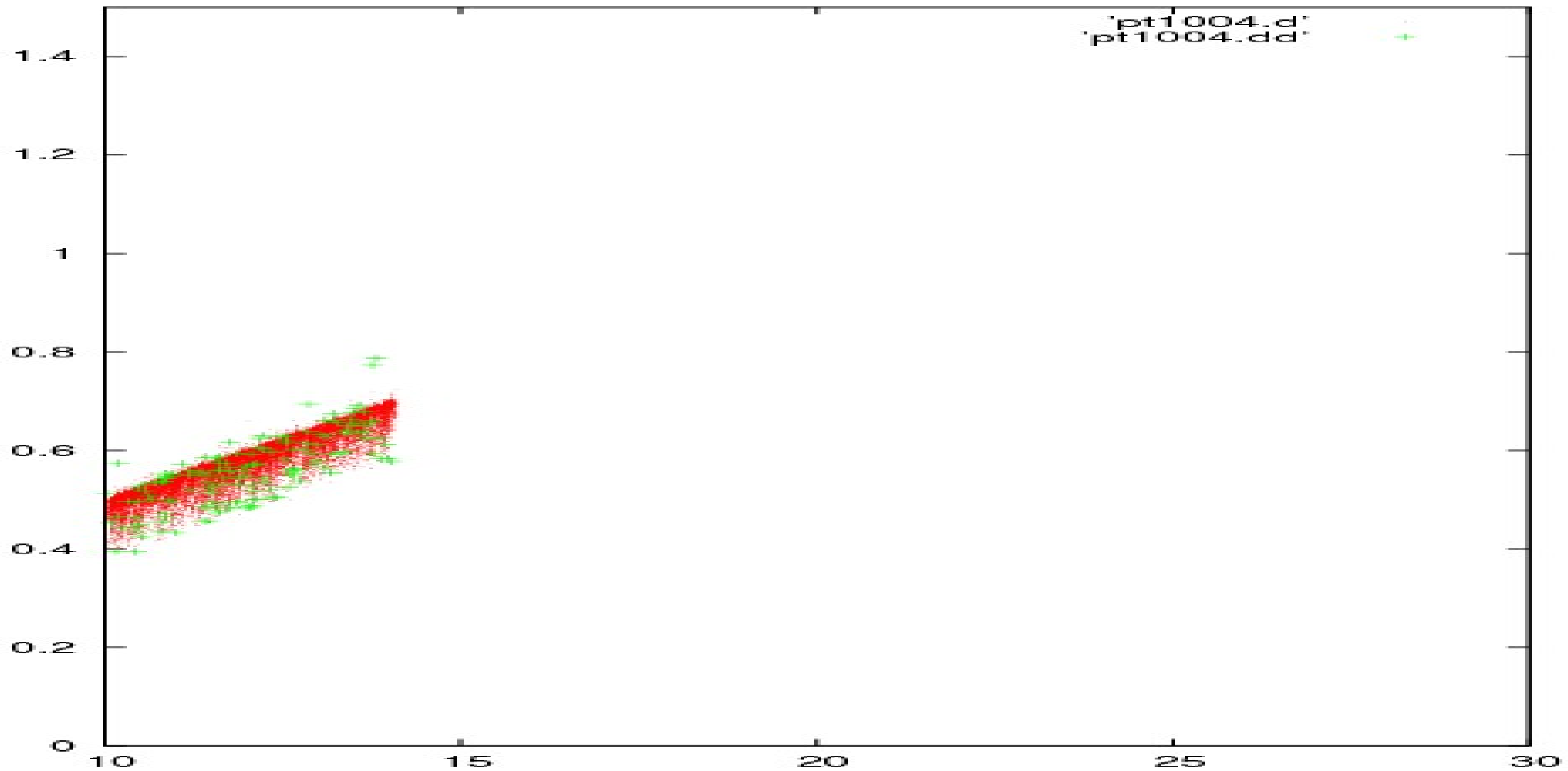
L_B = 0.2 L_d, L_d = 3 10^{44} erg/s

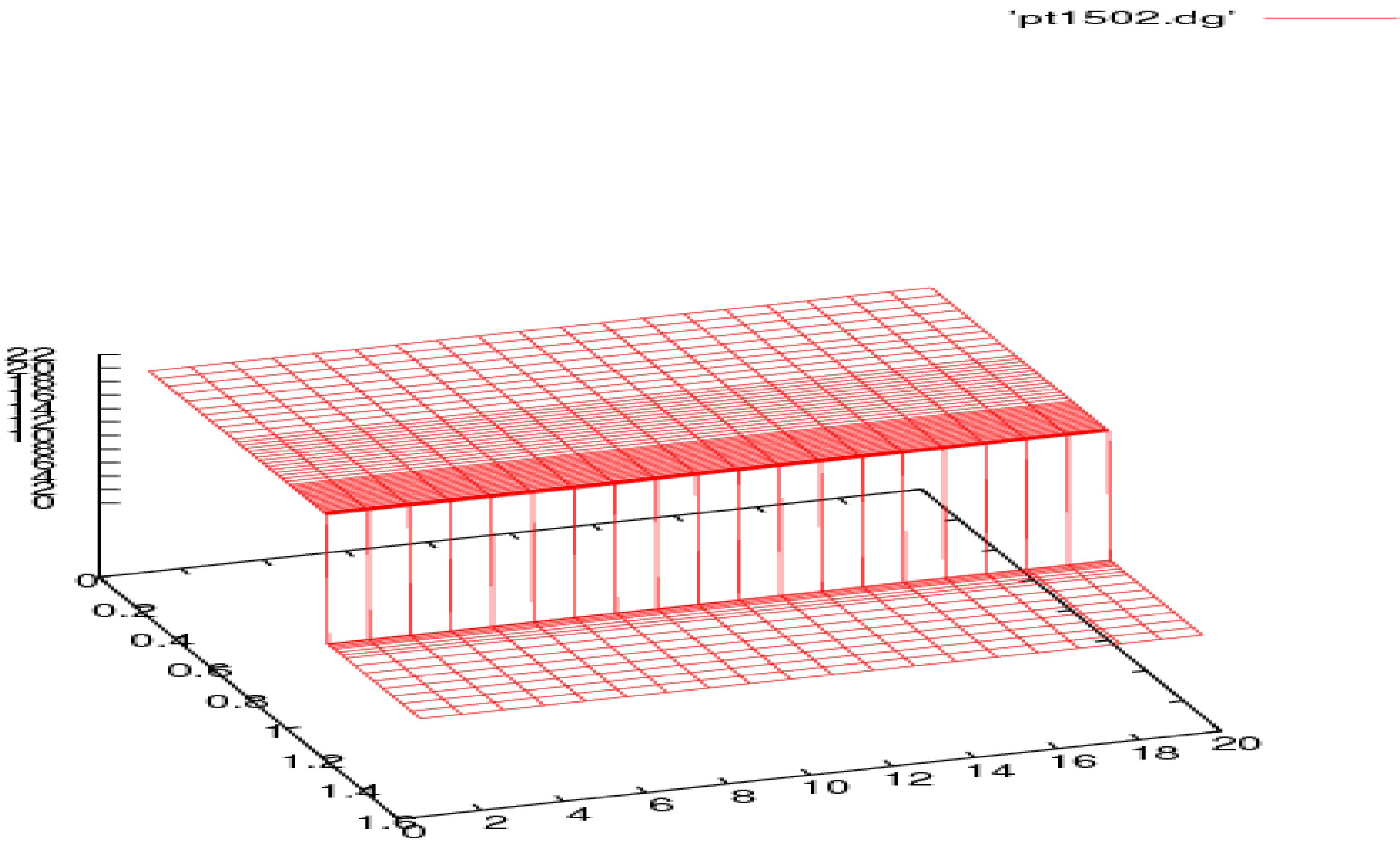
Γ	Γ_f	$L\gamma/Lj$
40	11.5	0.81
30	12.4	0.76
20	13.6	0.56
14	13.6	0.12
12	12.	0.

Breeding works down to Γ=8 at a low magnetization



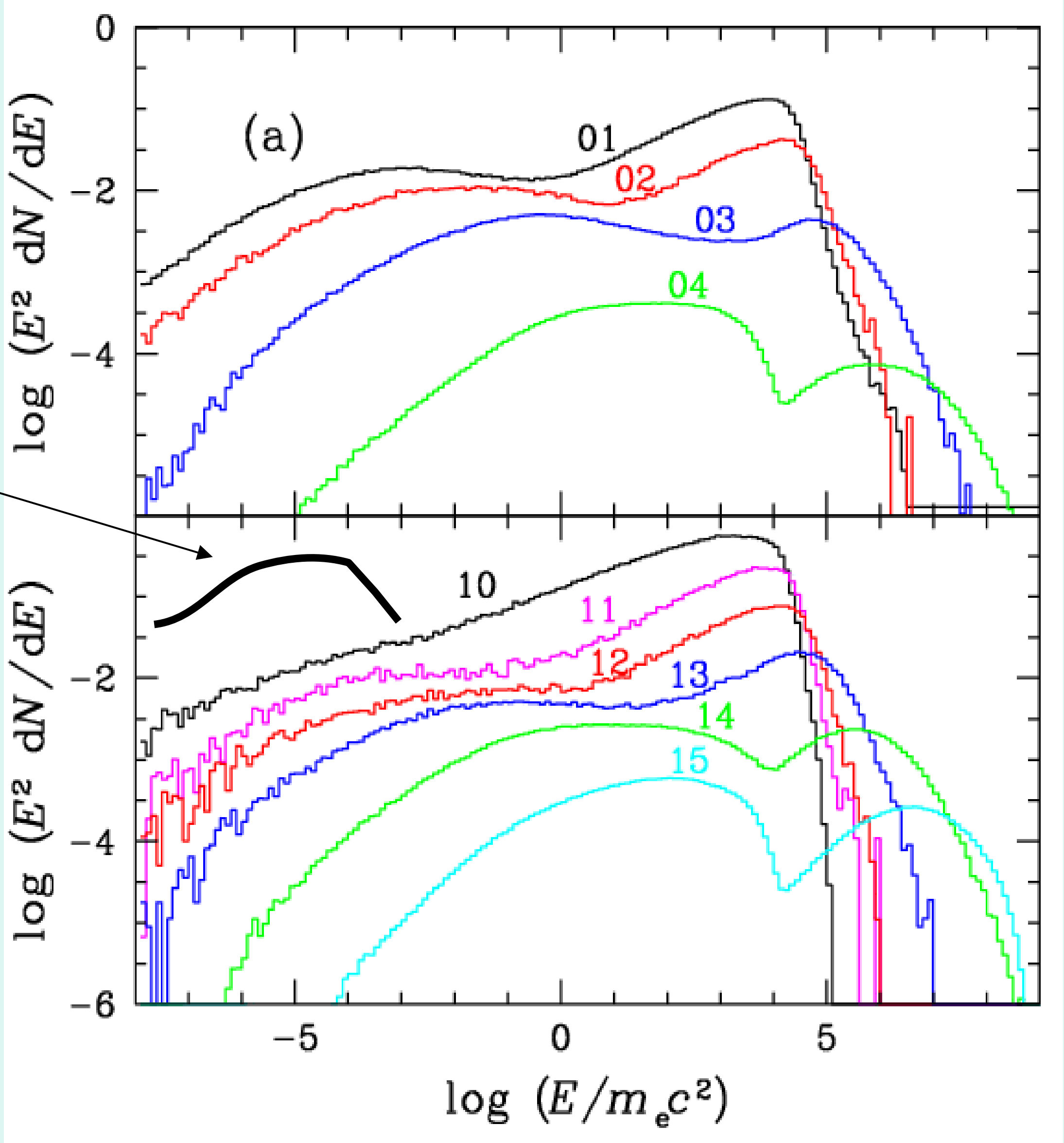
'phot.d' us 1:5
10
8
6
4
2
0
−2
−4
−6
−8
−10
10
12
14
16
18
20
22
24
26
28
30


'pt1004.d'
'pt1004.dd'
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
15
20
25
30


'pt1502.dg'
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0
2
4
6
8
10
12
14
16
18
20

Beam-on photon spectra "at infinity".

An important detail is missing or poorly expressed: the "synchrotron peak"



The ultimate synchrotron cutoff
(Guilbert, Fabian, Rees, 1983)

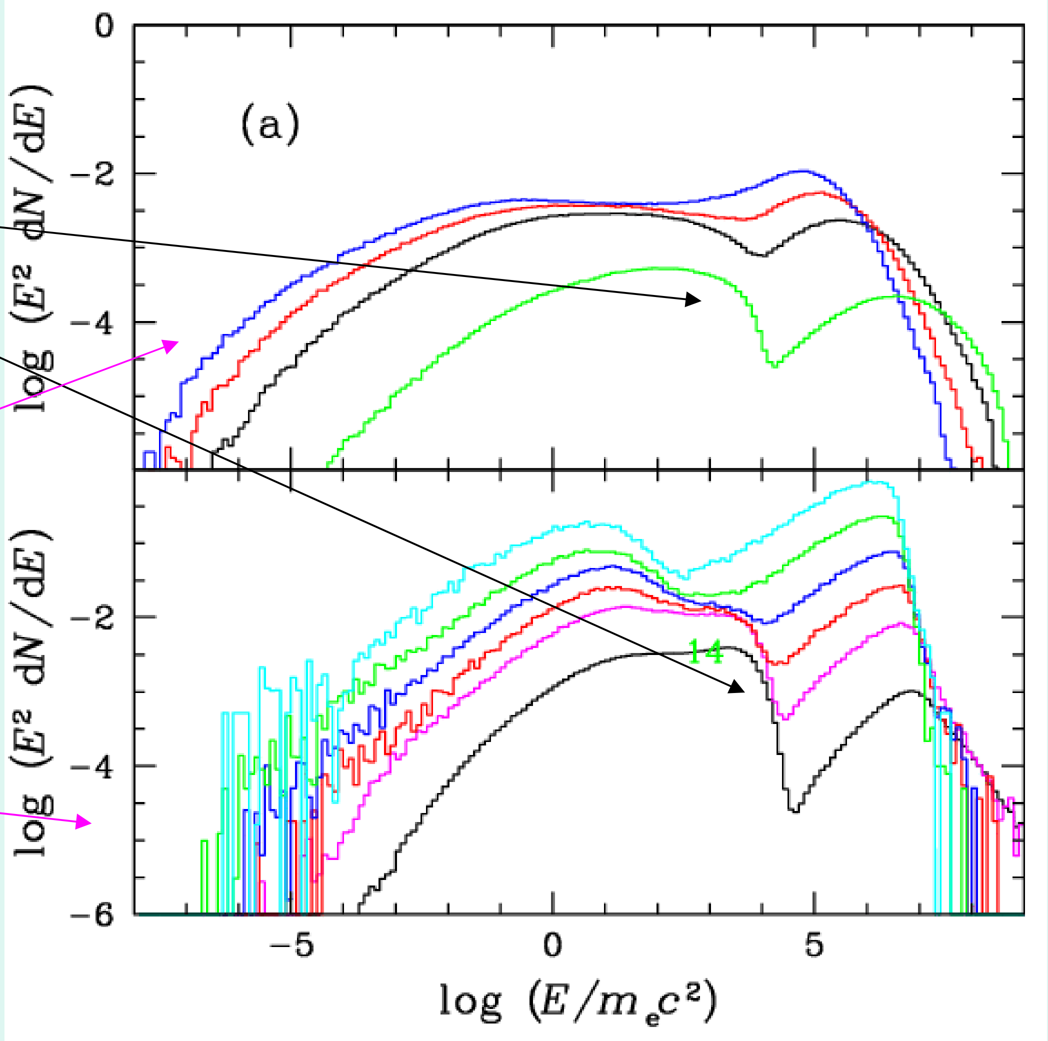
$E_{s,max} = m_e c^2/\alpha\, \Gamma$

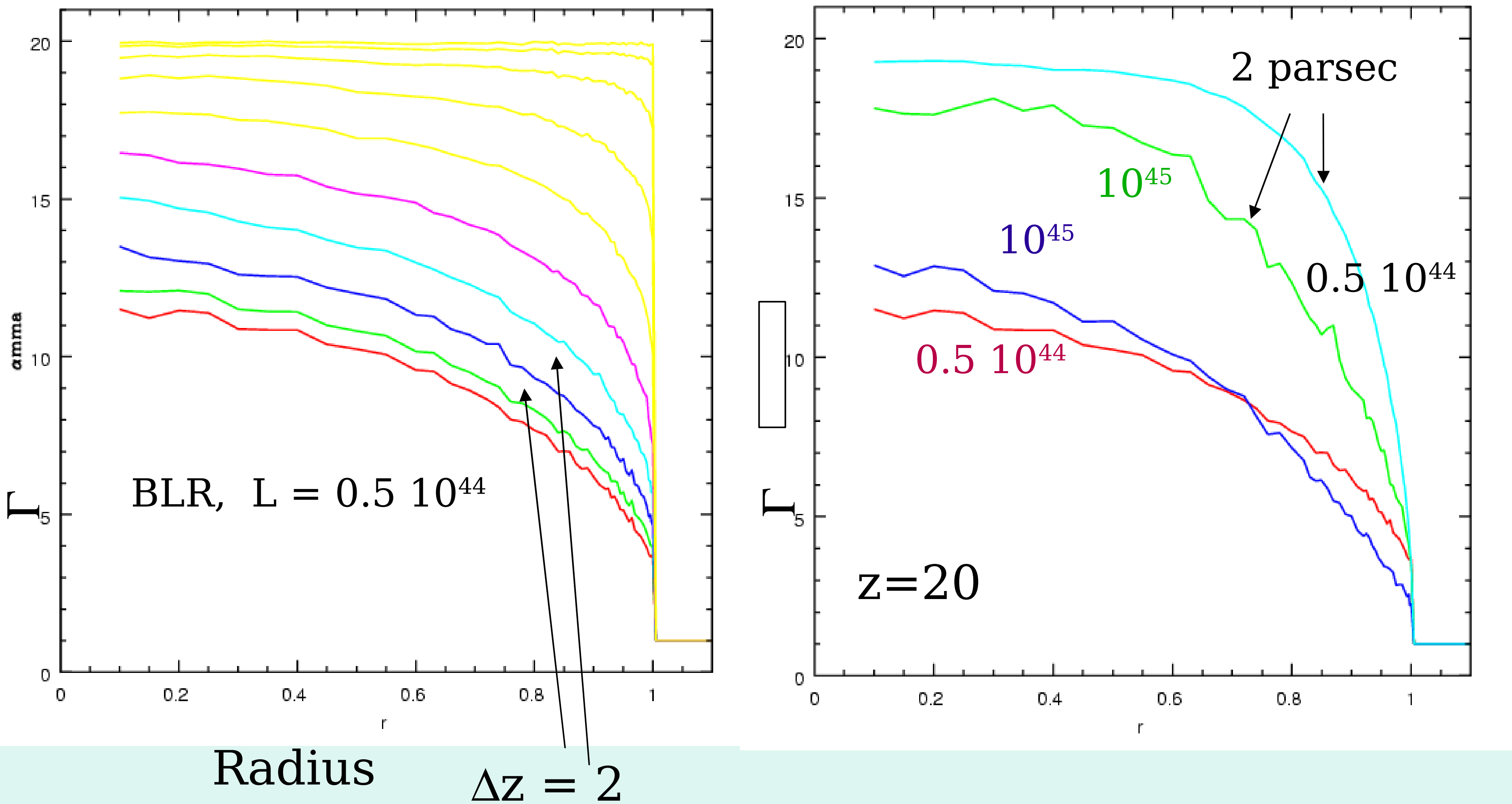
Low luminosity spectra have a feature observable by *Fermi*:

a dip at several GeV

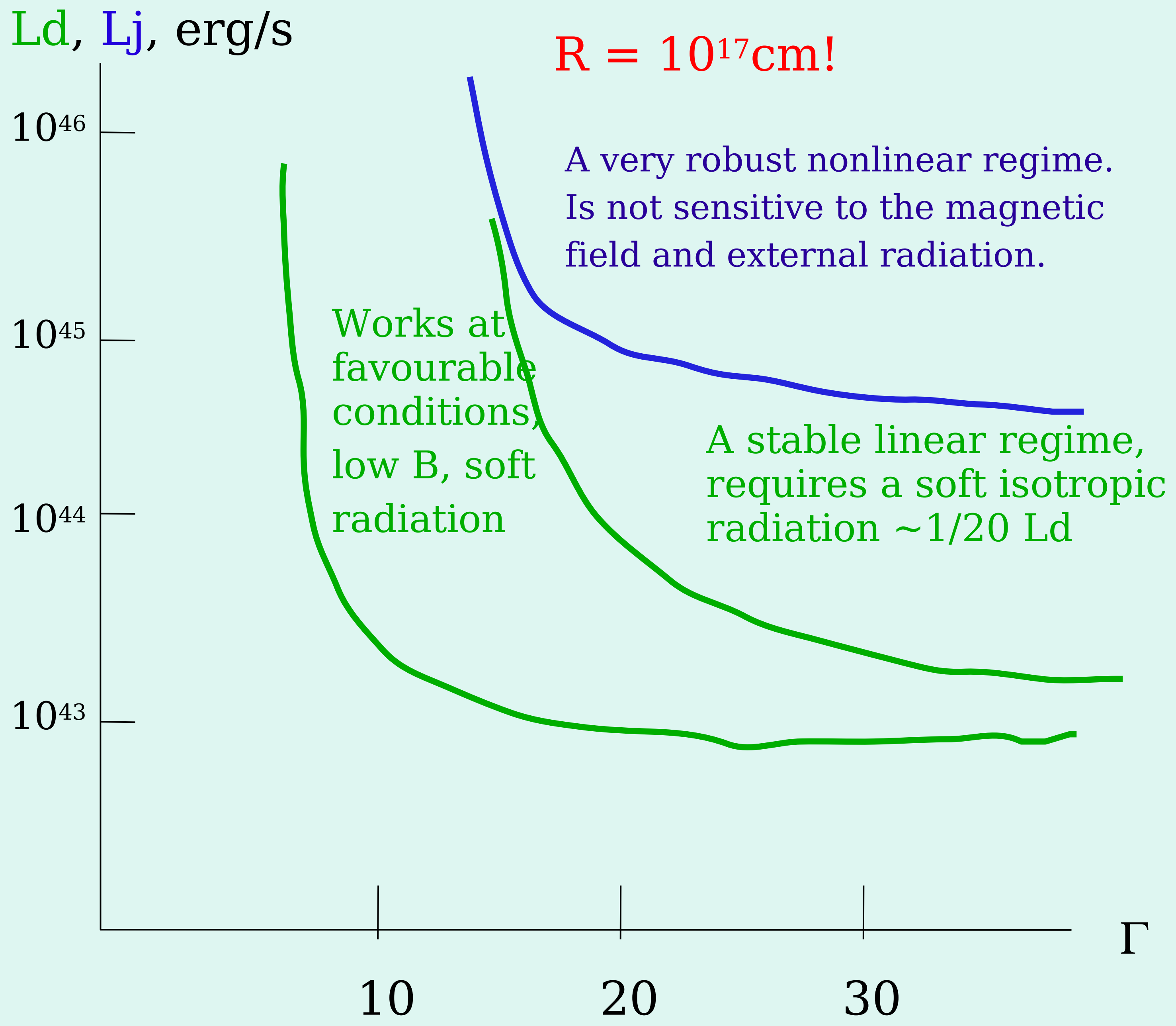
$F_t \sim 0.05\ F_d$

$F_t \sim 0.01\ F_d$





Deceleration of the jet


Ld, Lj, erg/s
R = 10¹⁷cm!
10⁴⁶
10⁴⁵
10⁴⁴
10⁴³
A very robust nonlinear regime.
Is not sensitive to the magnetic
field and external radiation.
Works at
favourable
conditions,
low B, soft
radiation
A stable linear regime,
requires a soft isotropic
radiation ~1/20 Ld
10
20
30
Γ

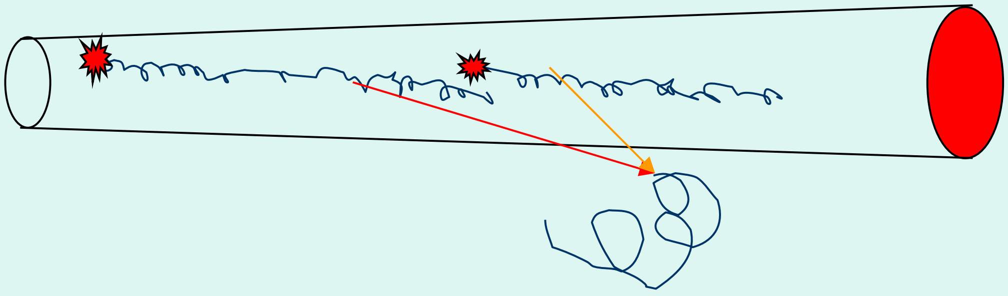
- In the case of powerful jets of AGNs it is difficult to avoid the dissipation via the photon breeding.

- It is motivated by the requirement of a high efficiency of Gamma-ray emission.

- It, when taken alone, can not explain the entire spectrum of blazars. The photon breeding should be followed by a moderate pair reheating, which is quite natural.

What about BL Lacs?

Disk luminosity is insufficient to produce a large optical depth across the jet



Particle acceleration in the jet = input

Photon breeding = amplifier