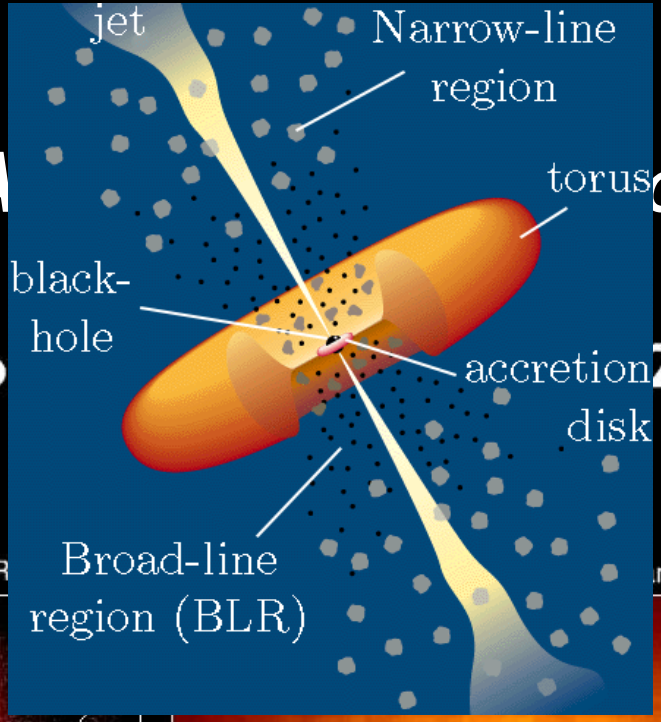
An optimization problem with a N-parameters emission model

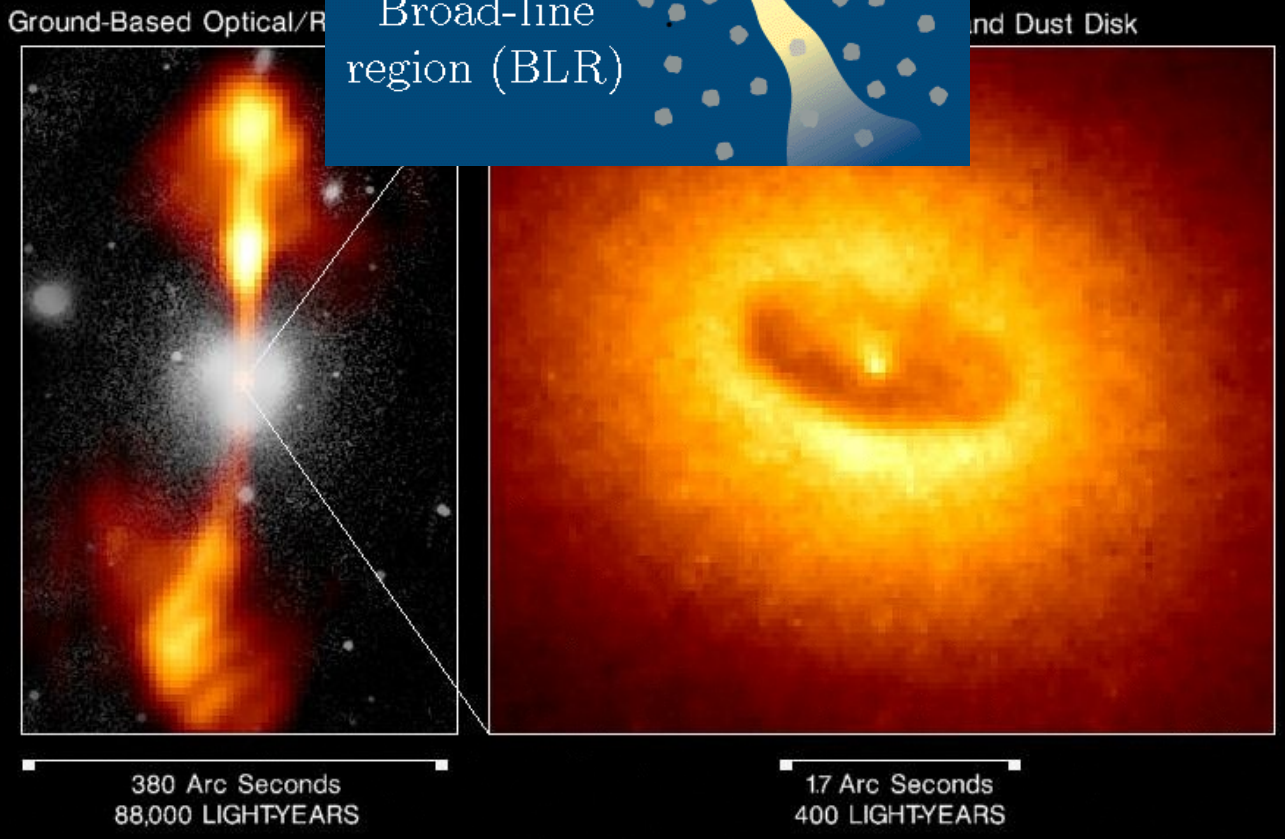
Thomas Vuillaume,

Rencontres d'Astrostatistique 2014

What's an A clei (AGN) ?



Co 26l

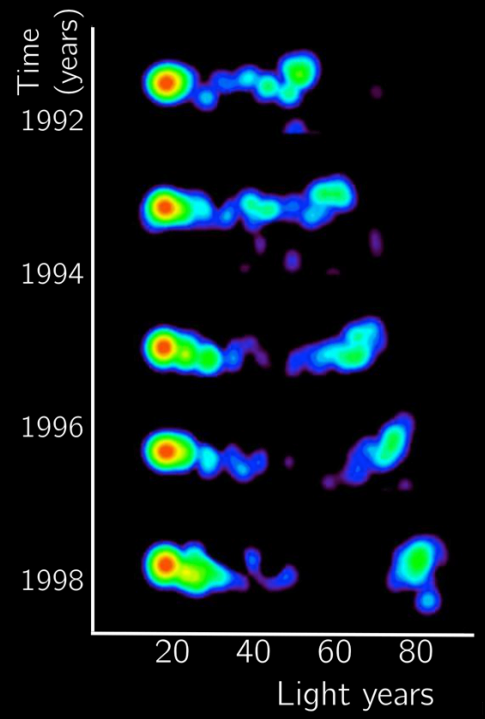


Active Galactic Nuclei: high Γ

$$\beta = \frac{v}{c} \qquad \gamma = \frac{1}{\sqrt{1-\beta^2}}$$

Bulk Γ

Evolution of 3C279



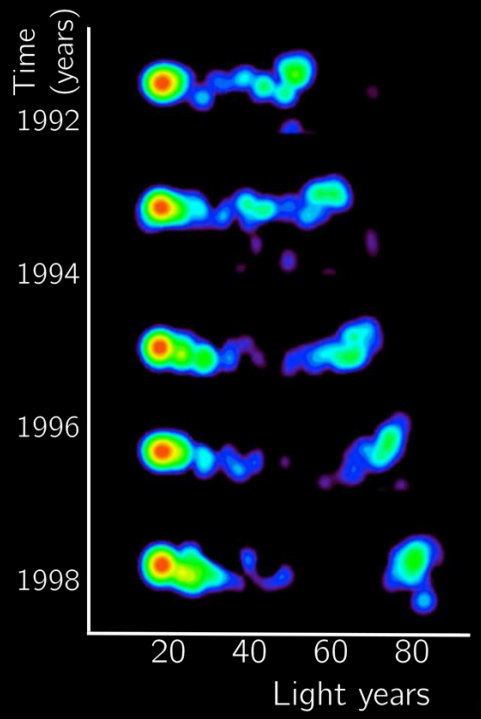
Apparent superluminal motion requires relativistic speeds
$\Rightarrow$ *high* Γ

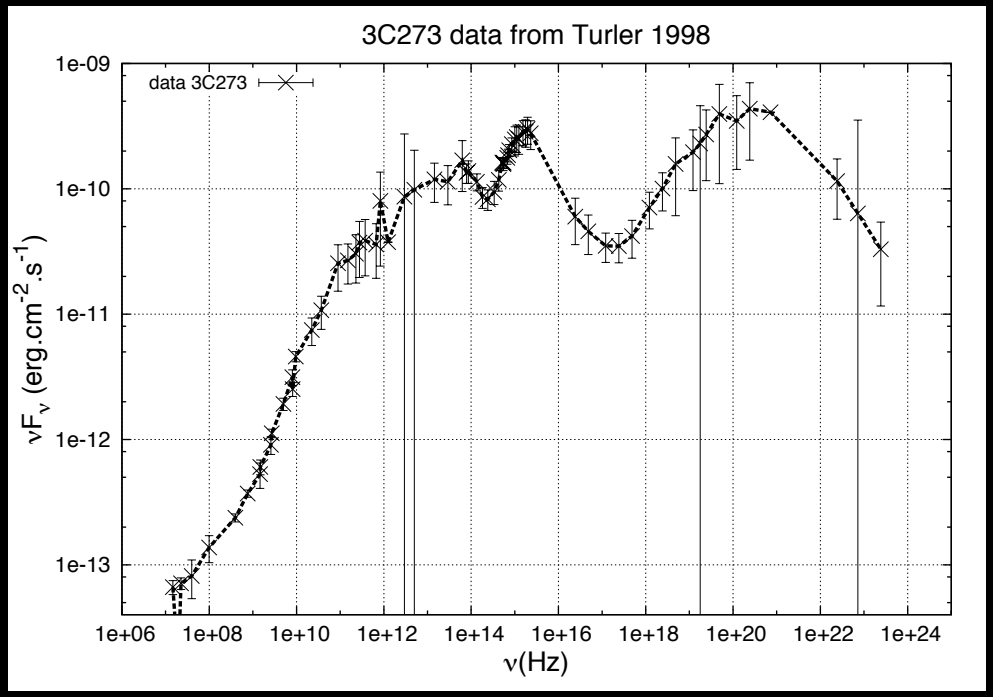
Active Galactic Nuclei: high Γ and high γ

$$\beta = \frac{v}{c} \qquad \gamma = \frac{1}{\sqrt{1-\beta^2}}$$

Bulk ↑ Γ *particles* ↑ γ

Evolution of 3C279

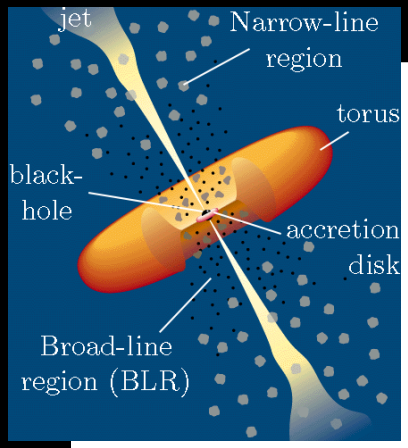


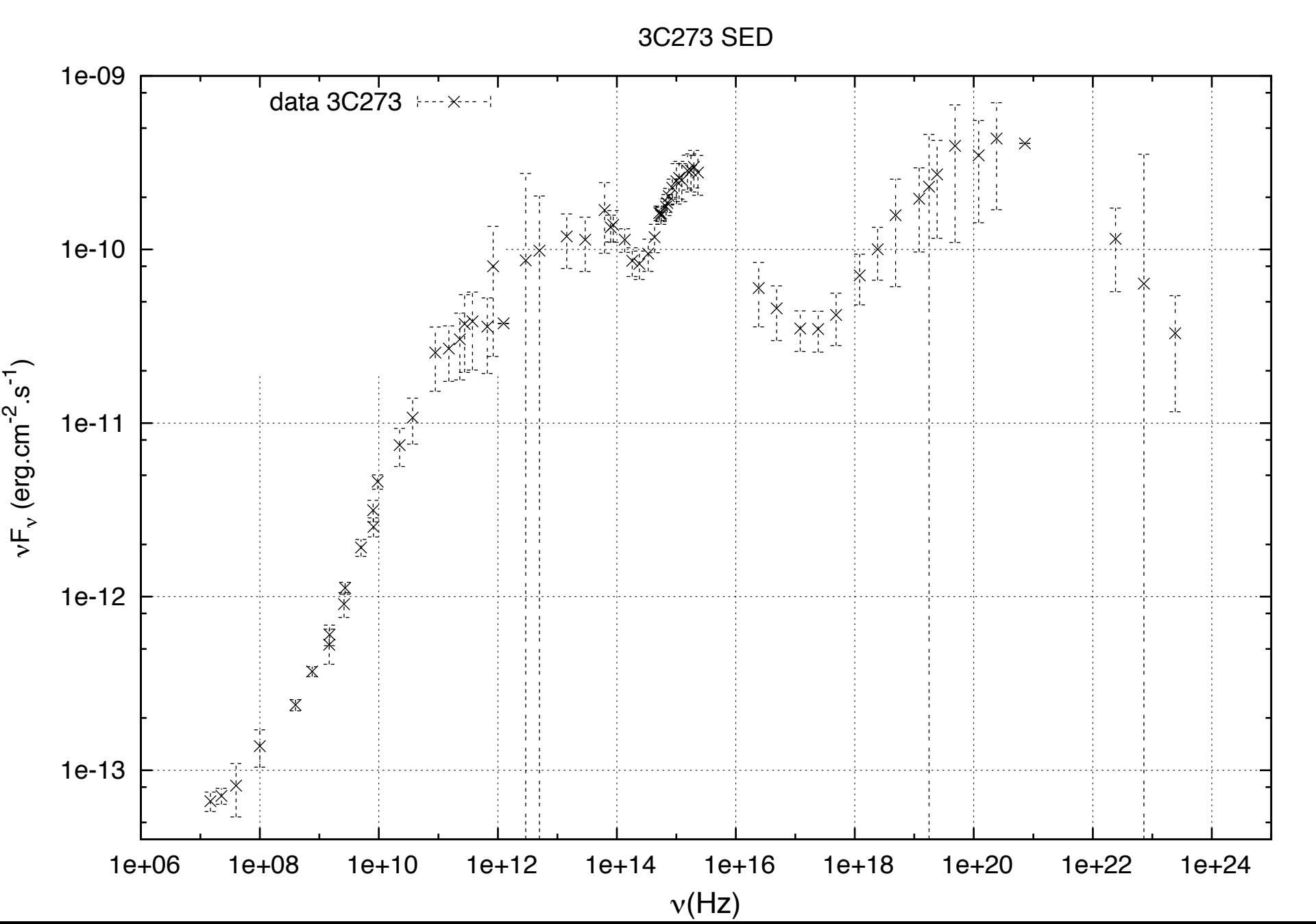


Apparent superluminal motion requires relativistic speeds
⇒ high Γ

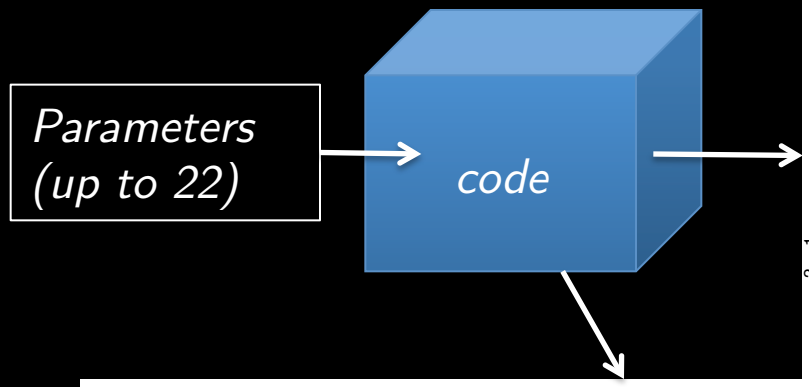
Very high energy photons require very high energy particles to be produced
⇒ high γ

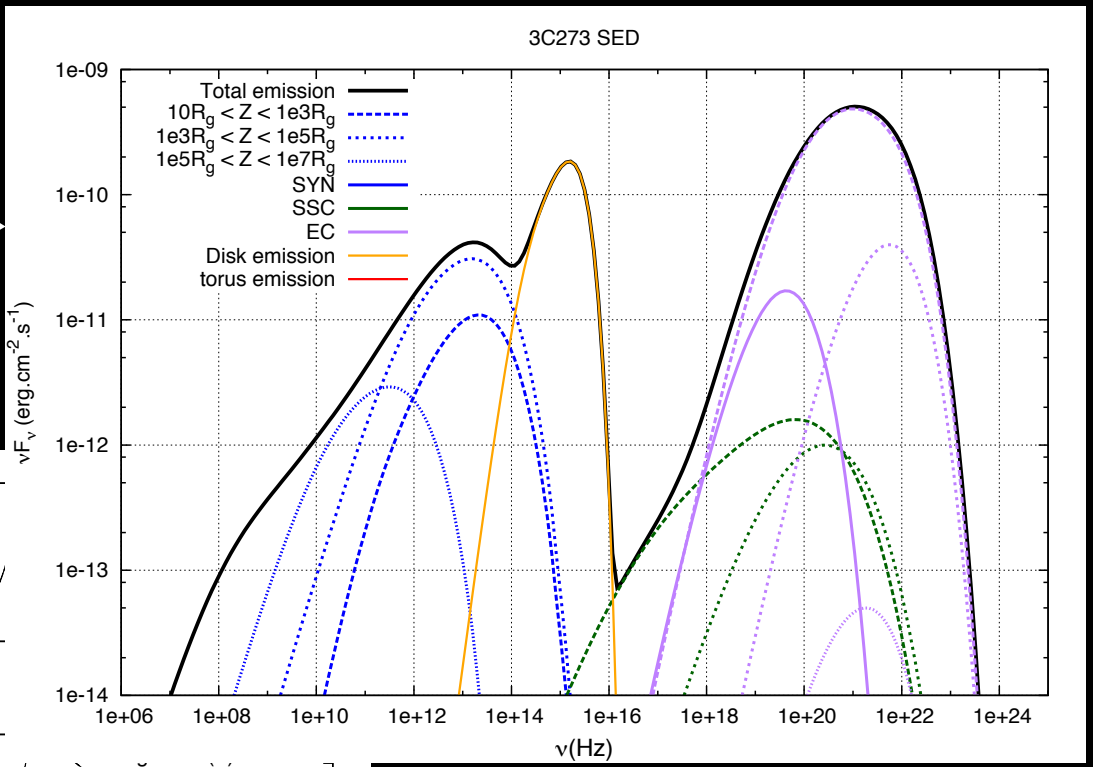
Application to AGN jets: full model

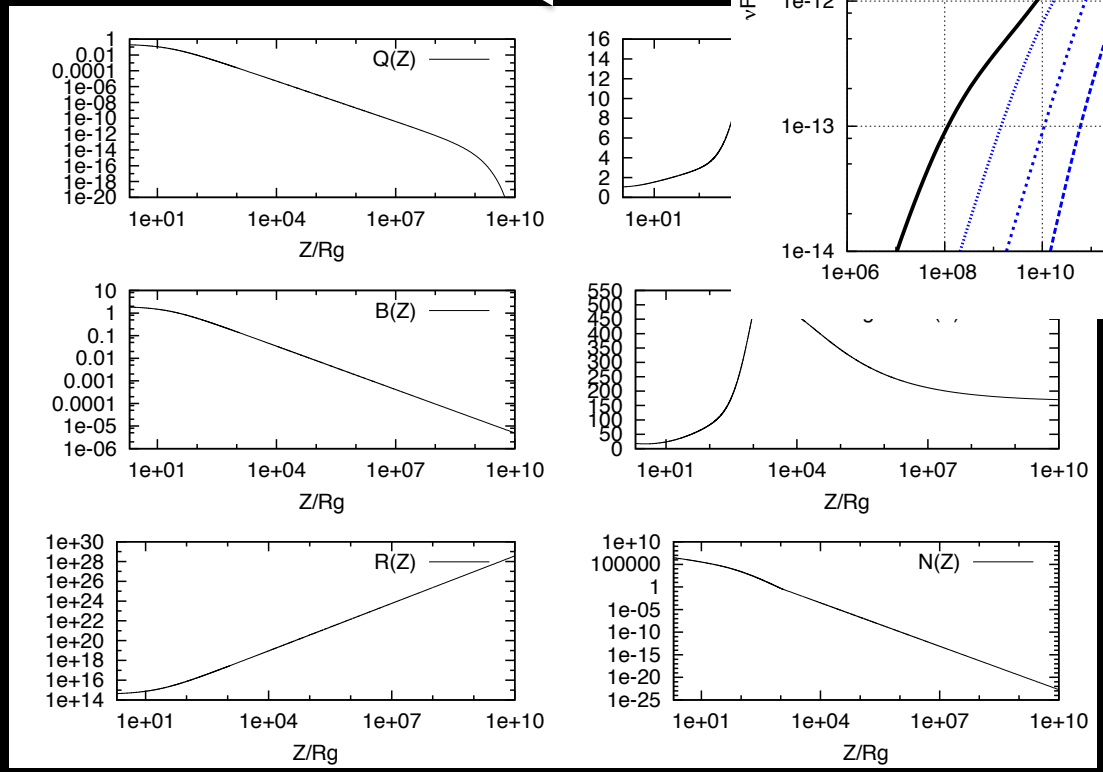


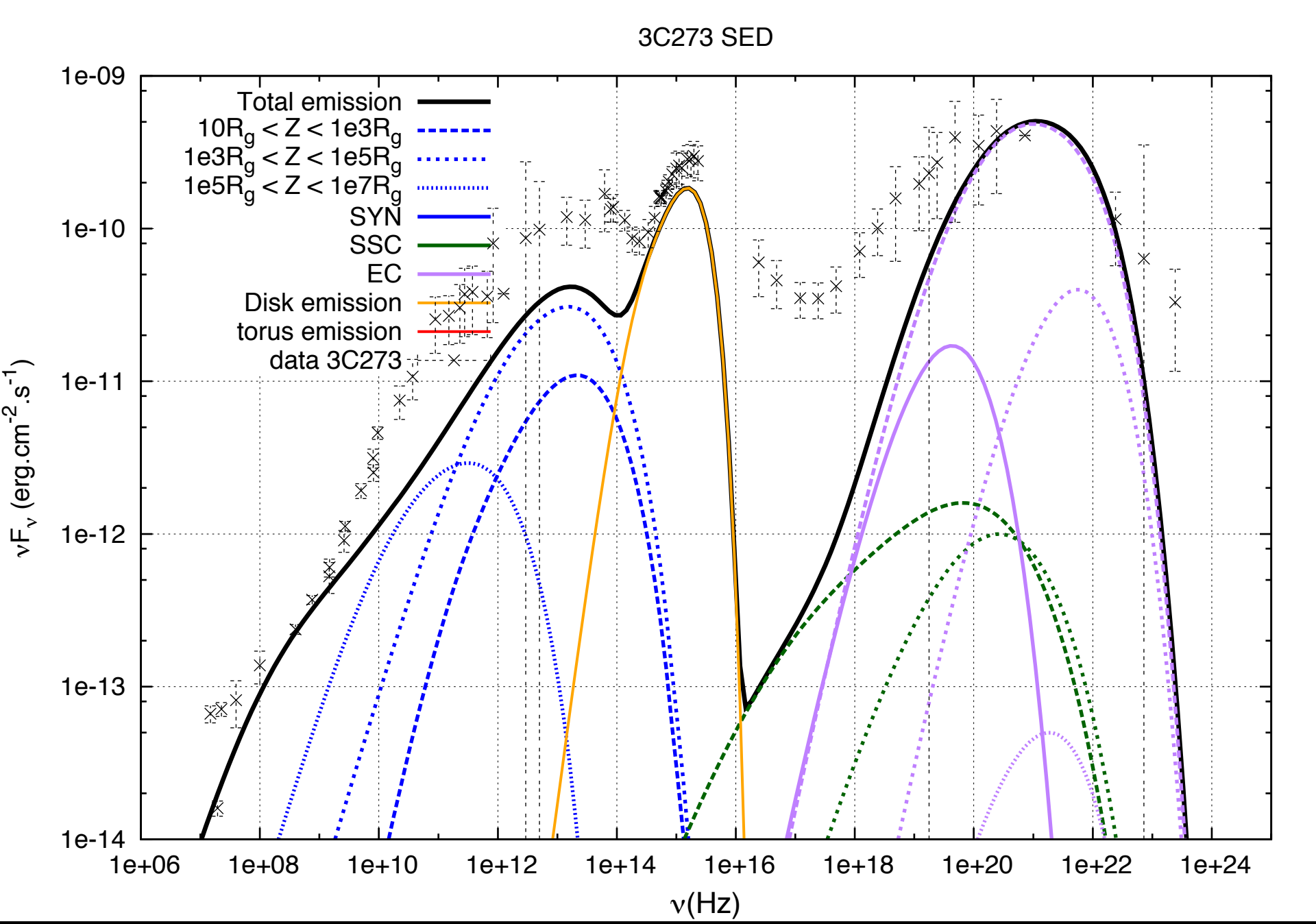

3C273 SED
data 3C273
1e-09
1e-10
1e-11
1e-12
1e-13
νF_ν (erg.cm^-2.s^-1)
1e+06
1e+08
1e+10
1e+12
1e+14
1e+16
1e+18
1e+20
1e+22
1e+24
ν(Hz)

SED modeling








3C273 SED
Total emission
10Rg < Z < 1e3Rg
1e3Rg < Z < 1e5Rg
1e5Rg < Z < 1e7Rg
SYN
SSC
EC
Disk emission
torus emission
data 3C273
νFν (erg.cm-2.s-1)
ν(Hz)
1e-09
1e-10
1e-11
1e-12
1e-13
1e-14
1e+06
1e+08
1e+10
1e+12
1e+14
1e+16
1e+18
1e+20
1e+22
1e+24

R_0
Z_0
Z_c
B_0
Q_0
N_0
$0 < \omega < 1$
$1 < \lambda < 2$
ζ

```
2.5             # power-law index

3e39            # M (masse trou noir) [kg] (Ms = 2e30kg)
0.08            # dM_dt/dM_dt(Edd) (accretion rate/Eddington accretion rate)

0.9568          # cosi
16              # R_0/Rg > 3
2e3             # Z_0/Rg > 10 !!!
5e6             # Z_c/Rg >
0.5e-3          # B_0/Beq : Beq is B at equipartition of energy
2e-3            # Q_0
6e9             # N_0
0.5             # omega : variation de R
1.              # lambda : variation de B
2.              # zeta : variation de Q
1.e9            # Zmax/Rg > Z_0/Rg
0.158           # Zr
3.01            # r_min(disk)/Rg >1
5e3             # r_max(disk)/Rg >1

5e4             # D_torus/Rg  = distance of the torus center
4.5e4           # R_torus/Rg  = torus radius
1.              # emissivity Torus (GreyBody)

2e3             # R_blr/Rg    = BLR radius
0.01            # cos(omega_min) BLR
0.8             # cos(omega_max) BLR

0.06            # emissivity BLR (Grey Body)
2e-5            # eps_blr
1.               # gam_min - inutile pour pile-up
1e6              # gam_max  - inutile pour pile-up
```

R_0
Z_0
Z_c
B_0
Q_0
N_0
$0 < \omega < 1$
$1 < \lambda < 2$
ξ

$$R = R_0 \left(\frac{Z}{Z_0} \right)^{\omega}$$

Jet radius

$$Q = Q_0 \left(\frac{Z}{Z_0} \right)^{\zeta} \exp\left(-\frac{Z}{Z_c} \right)$$

Particle heating

$$B = B_0 \left(\frac{Z}{Z_0} \right)^{-\omega\lambda}$$

Magnetic field

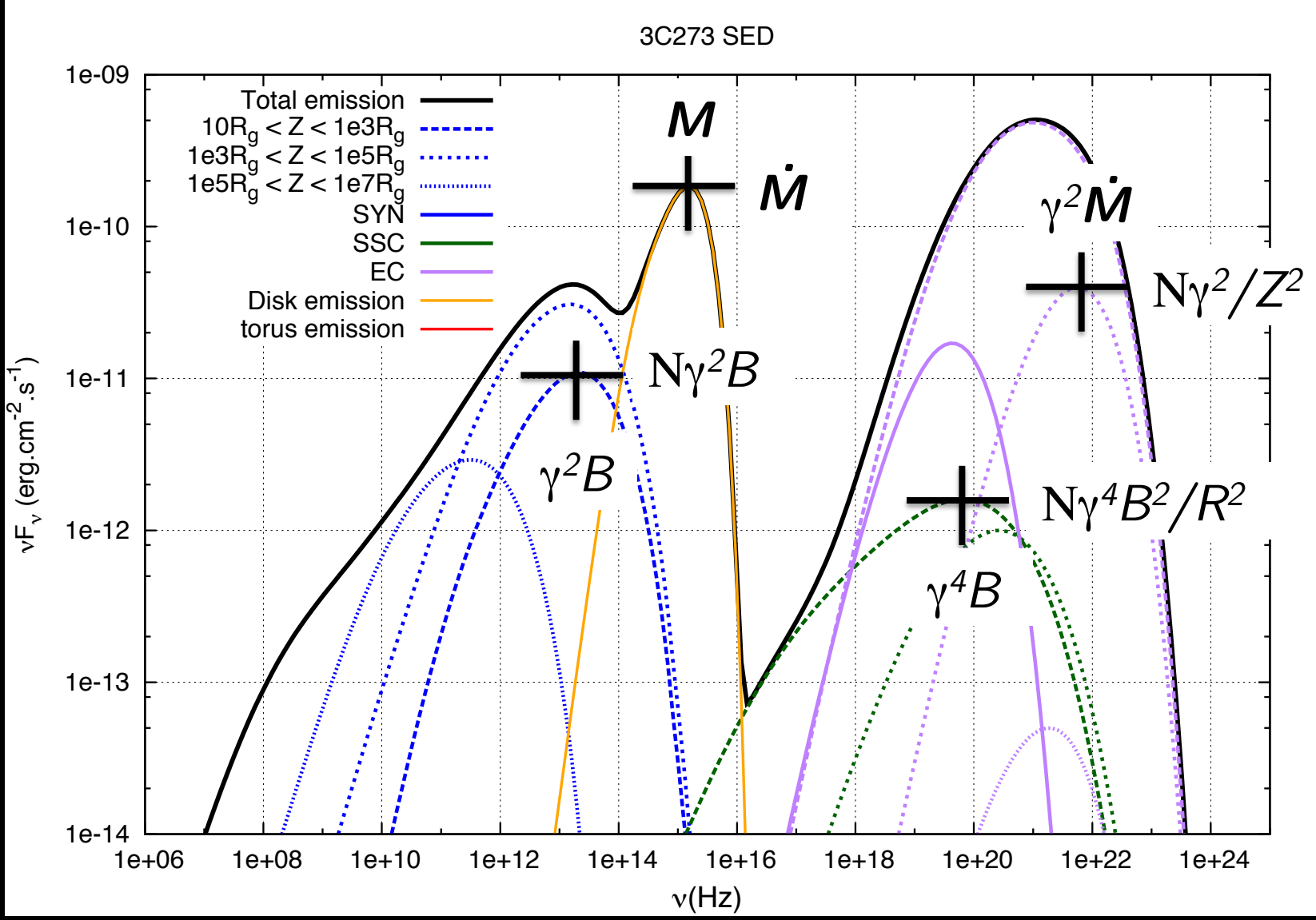
- *Energy conservation:*

$$\dot{\gamma} = \delta\left(\Gamma\right)\left[Q - \left(U_{syn} + U_{ssc} + U_{ec}\right)\left(\gamma^2 - 1\right)\right]$$
$$\propto \delta(\Gamma)\left[Q - \left(\gamma^2 B + N\frac{\gamma^4 B^2}{R^2} + N\frac{\gamma^2}{Z^2}\right)\left(\gamma^2 - 1\right)\right]$$

- *Particle flux conservation:*

$$\frac{\partial}{\partial t}(N\Gamma R^2) + c\frac{\partial}{\partial Z}(N\Gamma R^2) = R^2\dot{N}$$

R_0
Z_0
Z_c
B_0
Q_0
N_0
$0 < \omega < 1$
$1 < \lambda < 2$
ζ



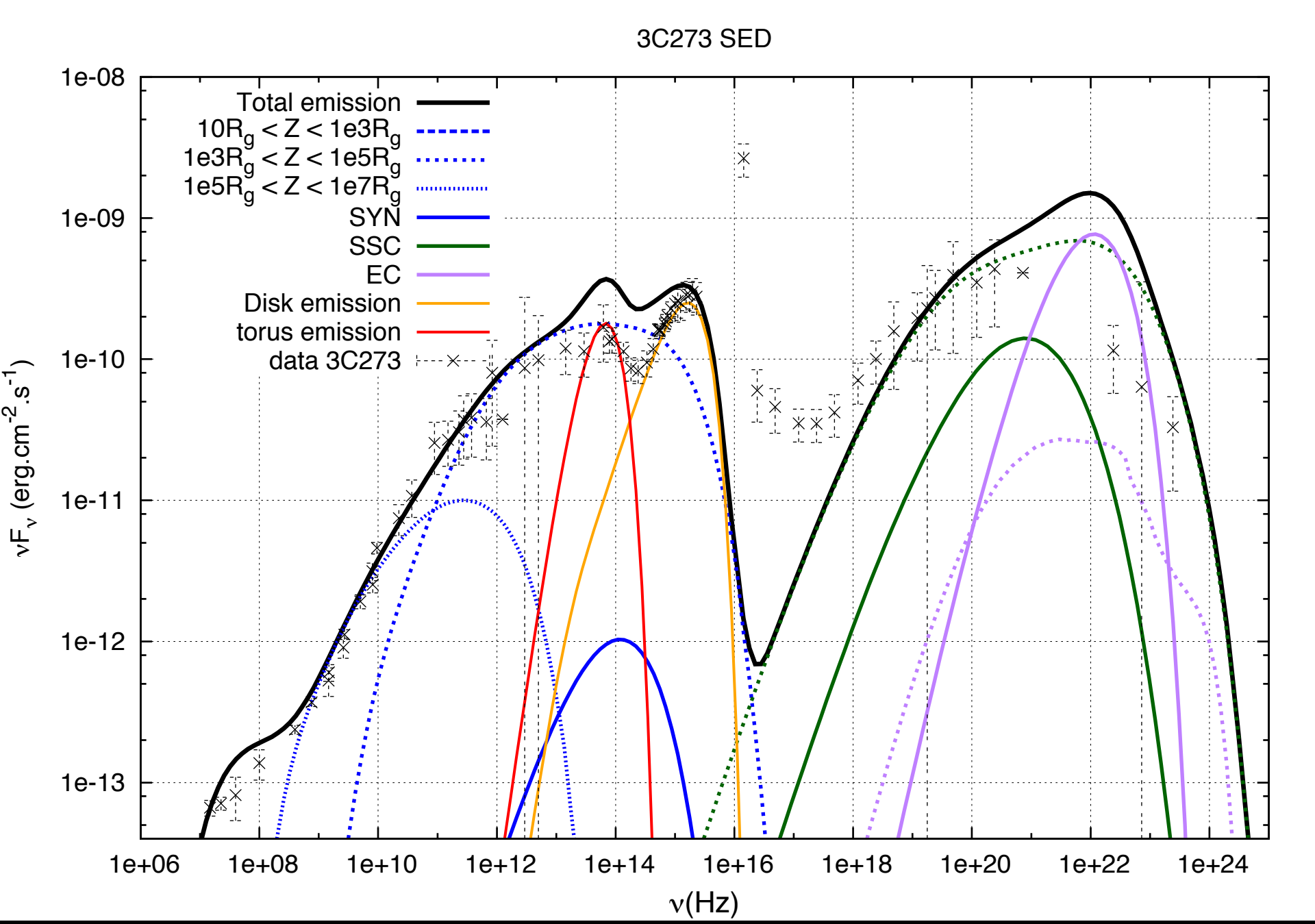
Least square reduction problem

$$\chi^2 = \sum_i \frac{(X_i - y_i)^2}{\sigma_i^2}$$

Gradient methods

Hand

Genetic Algorithm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1e+06
1e+08
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1e+12
1e+14
1e+16
1e+18
1e+20
1e+22
1e+24

Least square problem

~~*Hand ?*~~

~~*Levenberg-Marquardt ?*~~

Genetic Algorithm !

Parameters