An Inhomogeneous Jet Model for the Broad-Band Emission of Radio Loud AGNs in the Two-flow paradigm

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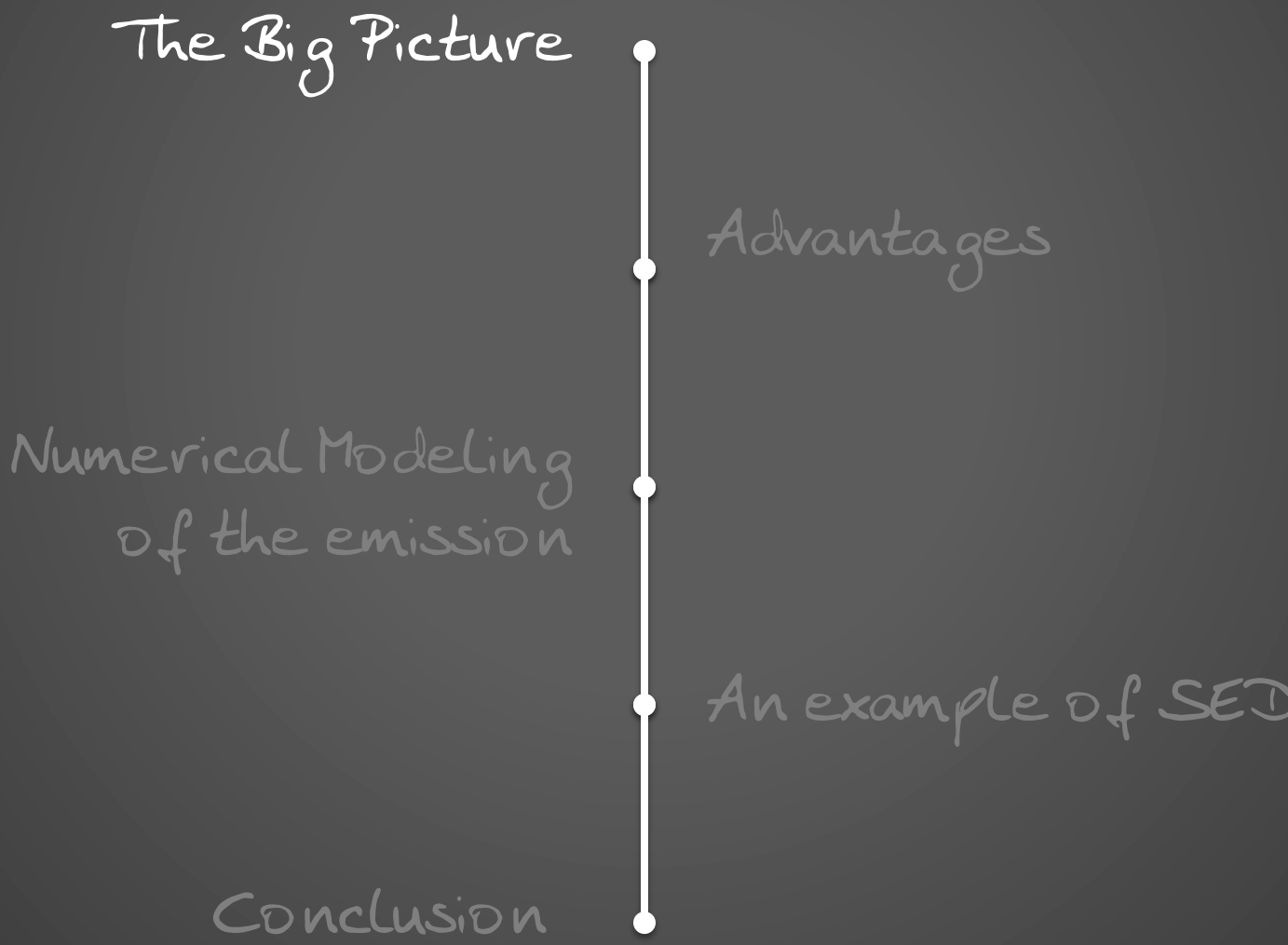
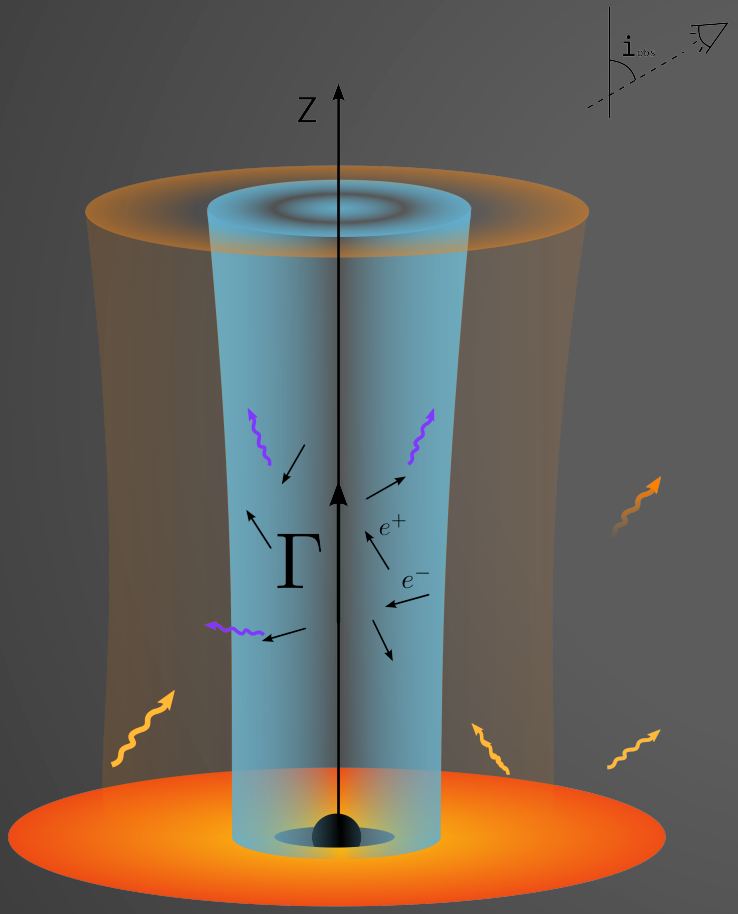
Open issues in AGNs

- *Jet composition ⇔ Jet power*
  (Celotti & Ghisellini ++)
- *Discrepancies in* Γ_b
  (Bulk Lorentz Factor Crisis, Henri & Saugé 06)
- *Acceleration and confinement of a highly relativistic flow*
  (Blandford's talk)
- *Link with BH spins*
- *Absence of Compton bump (Sikora)*
- *...*

The two flow paradigm



The two flow picture



*H. Sol, G. Pelletier, E. Asséo, 1989

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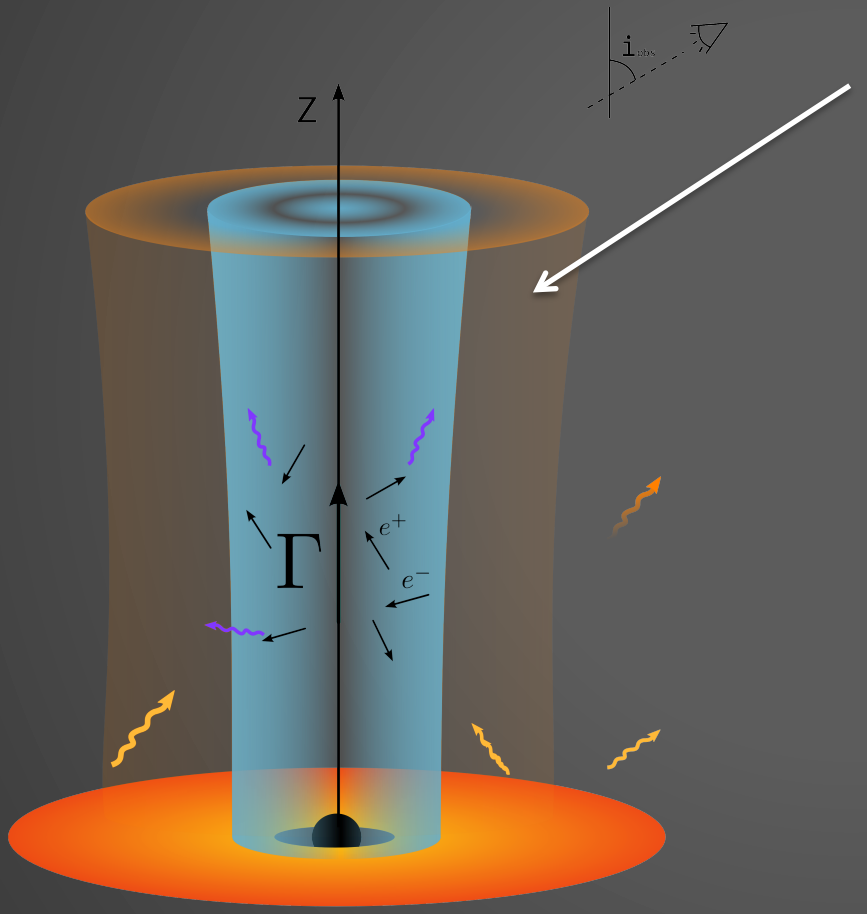

- *MHD jet or wind*
- *Fuelled by accretion disk*
- *Baryon loaded*
- *Midly relativistic (≈0.5c)*
- *Carries most of the power*

**H. Sol, G. Pelletier, E. Asséo, 1989*

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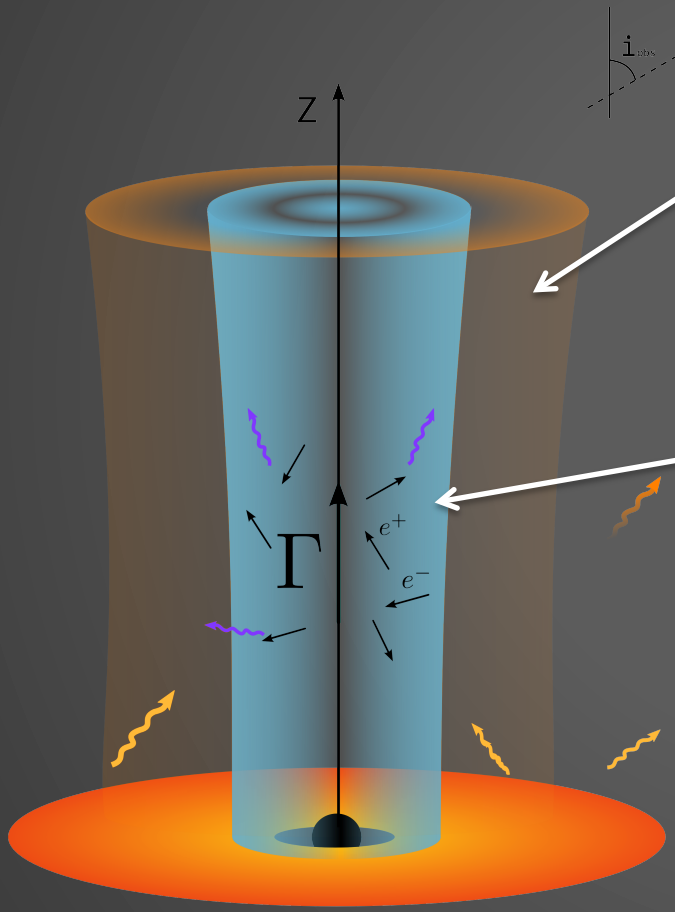

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  - *Pairs e^-/e^+ (NO baryons here)*
  - *Highly relativistic ($\Gamma \approx 10$)*
  - *Responsible for most of the non-thermal emission*

**H. Sol, G. Pelletier, E. Asséo, 1989*

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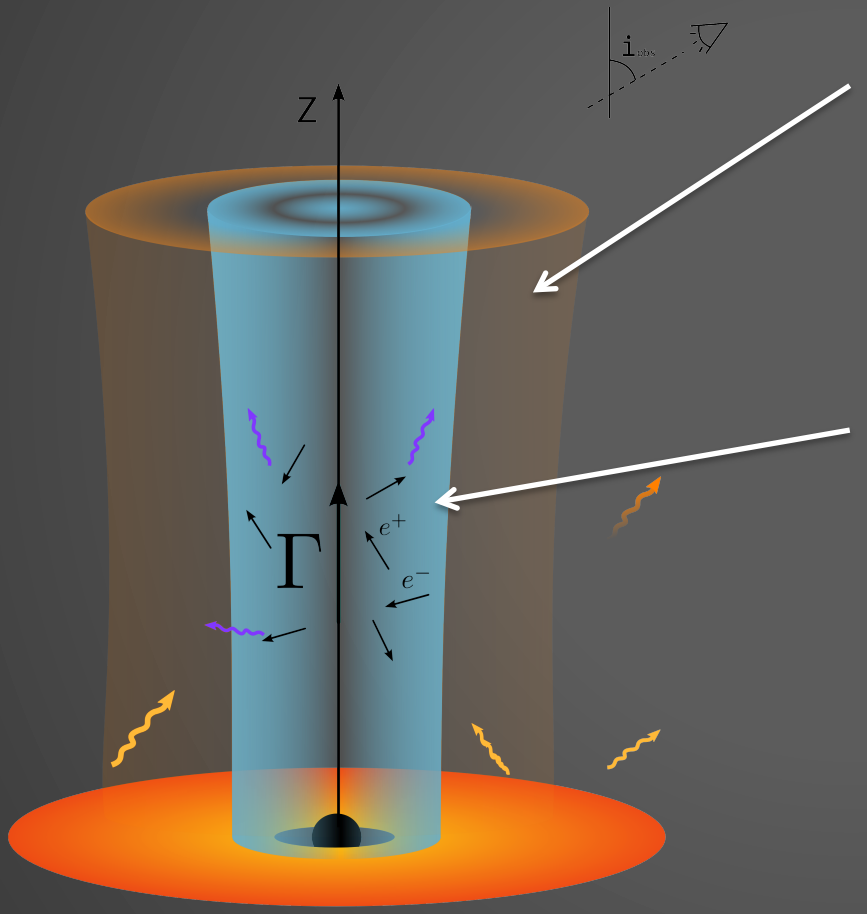

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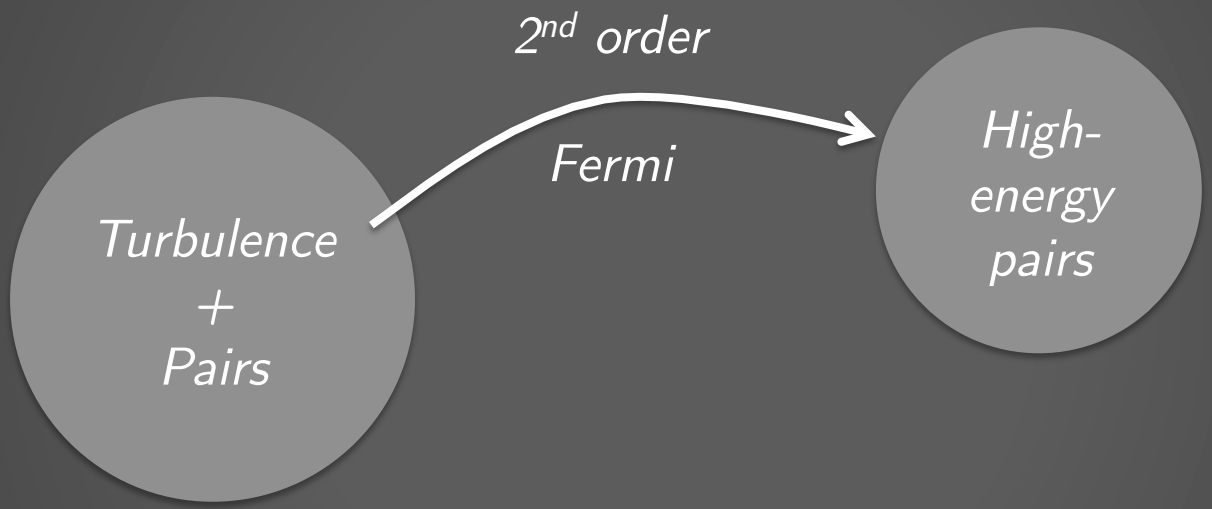
  - *Responsible for most of the non-thermal emission*
- *Pairs get energy through the two flows interaction (2^{nd} order Fermi process)*

**H. Sol, G. Pelletier, E. Asséo, 1989*

Formation of the inner jet by pair loading

Turbulence
+
Pairs

Formation of the inner jet by pair loading



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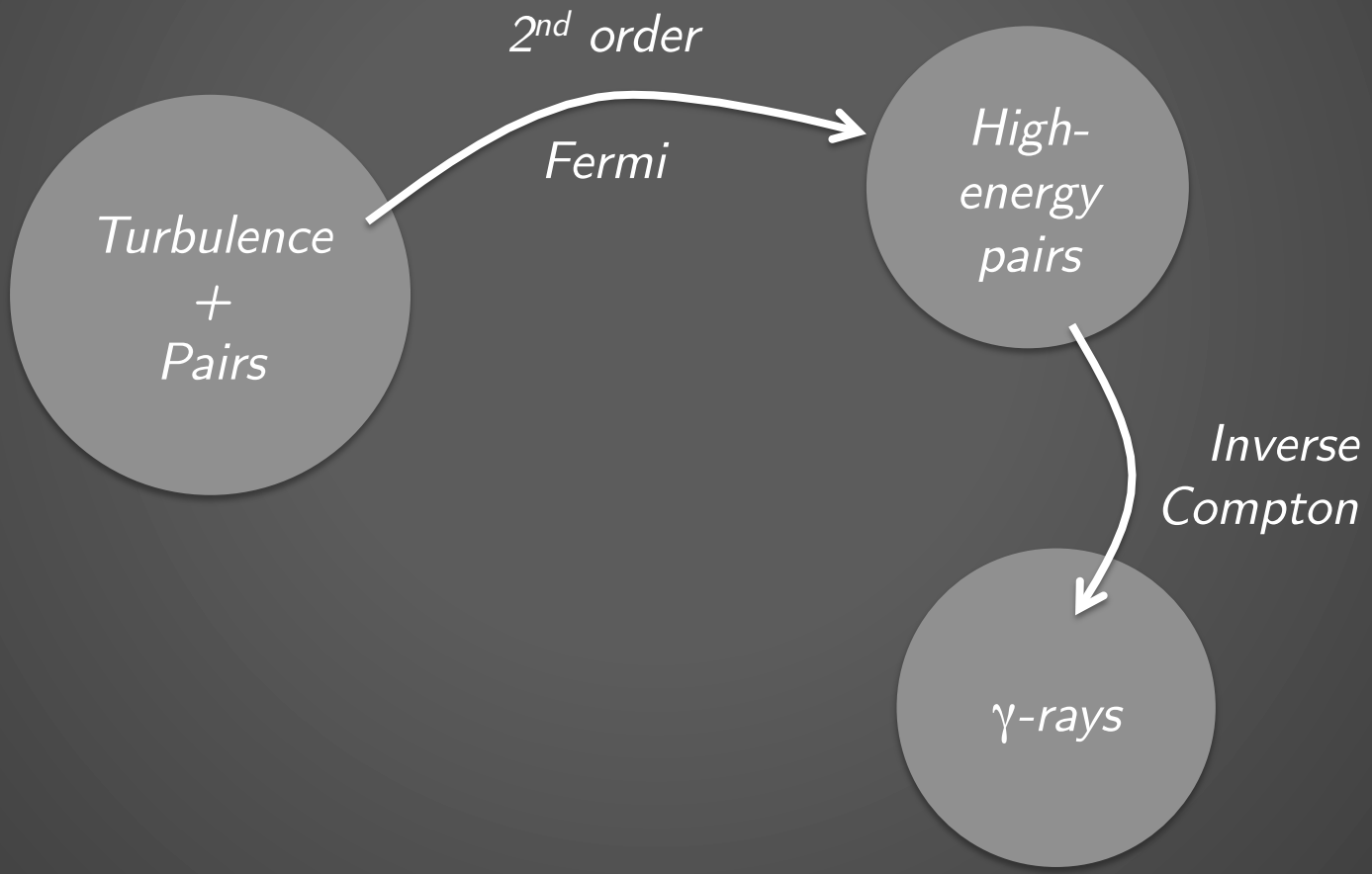

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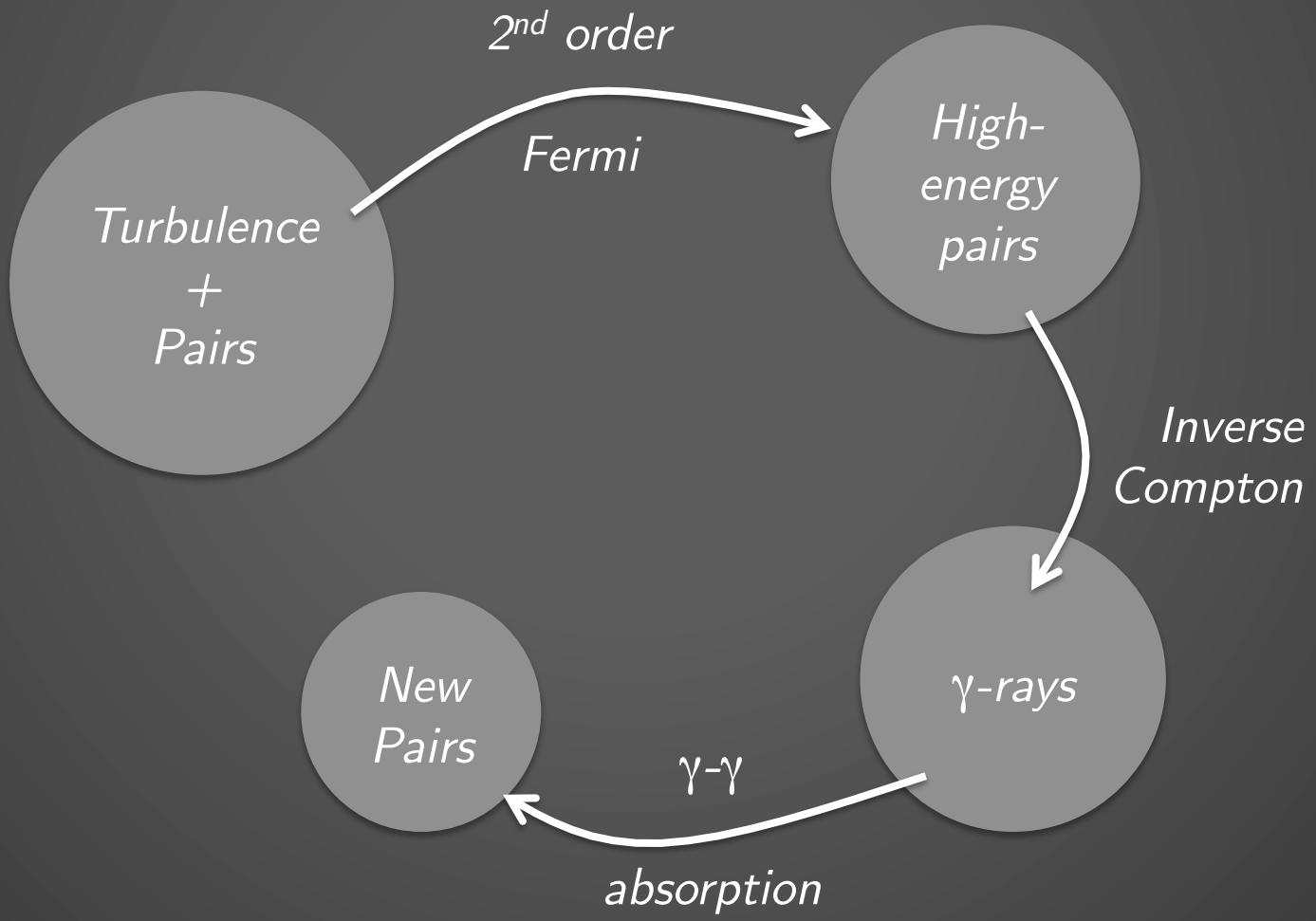

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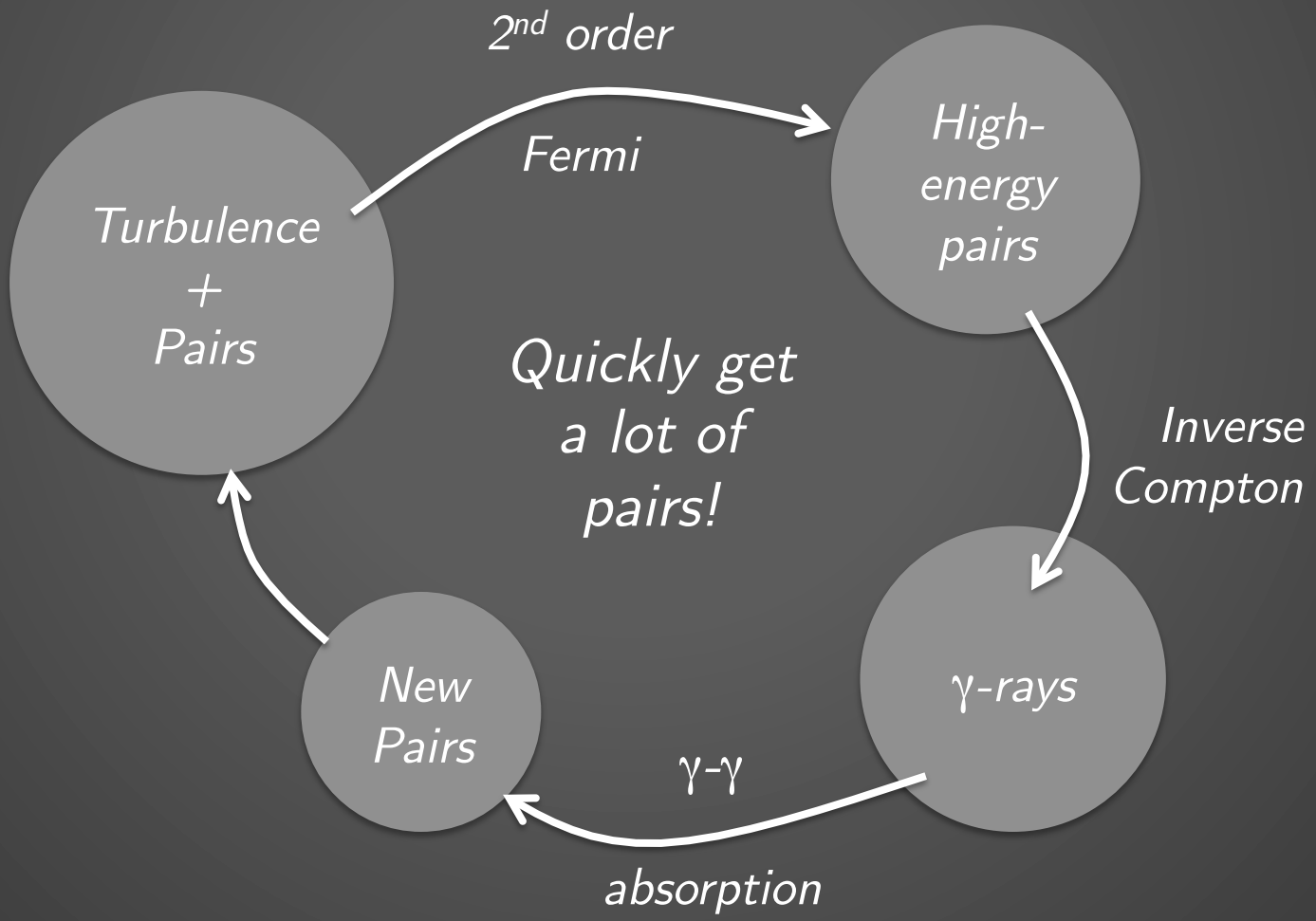

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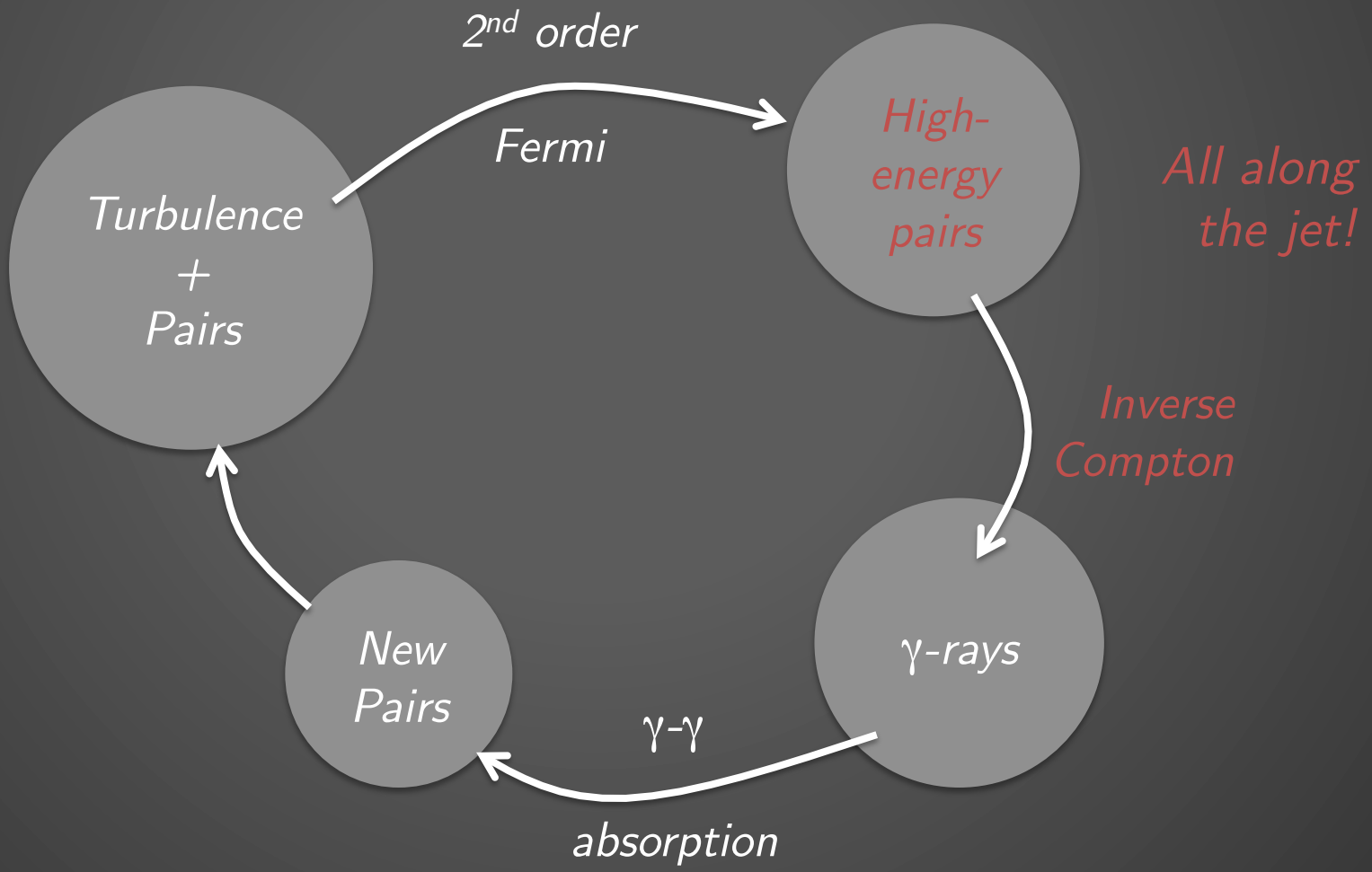


Acceleration of the inner jet

Hot pairs emitting γ-rays
along the jet

Acceleration of the inner jet

Hot pairs emitting γ-rays along the jet

$$+$$

$$t_{IC}(\gamma_e) \ll \frac{Z}{c}$$

Radiation dominates the dynamic of hot pairs!

$$\frac{1}{\gamma_e l_s}\frac{Z}{c} \quad \text{with } l_s = \frac{m_p}{m_e}\frac{L}{L_{edd}}\frac{R_g}{Z}$$

$$\gg 1 \quad \text{near Eddington}$$

$$\text{and } \gamma_e \gg 1$$

Acceleration of the inner jet

Hot pairs emitting γ-rays along the jet

$$+$$

$$t_{IC}(\gamma_e) \ll \frac{Z}{c}$$

Radiation dominates the dynamic of hot pairs!

↓

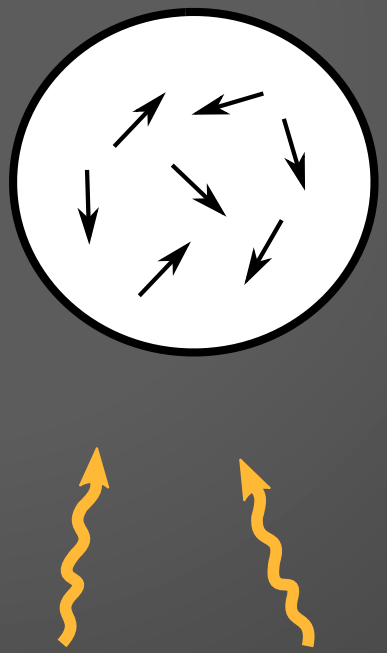
Anisotropic photon field

Compton Rocket

**(O'Dell 81, Phinney 82)*

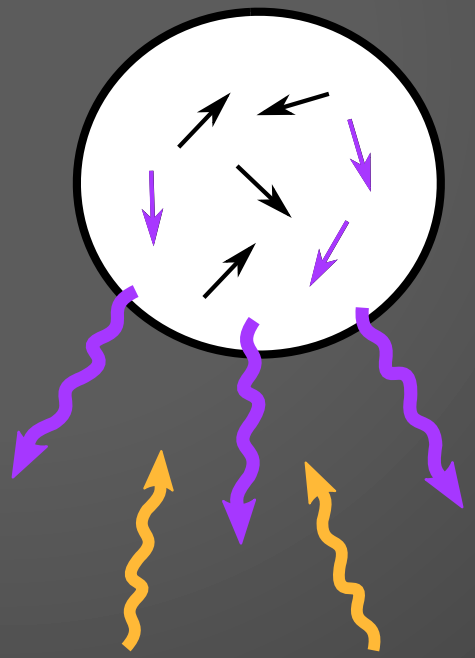
Acceleration via Compton Rocket

External photon



Acceleration via Compton Rocket

External photon
Inverse Compton photon

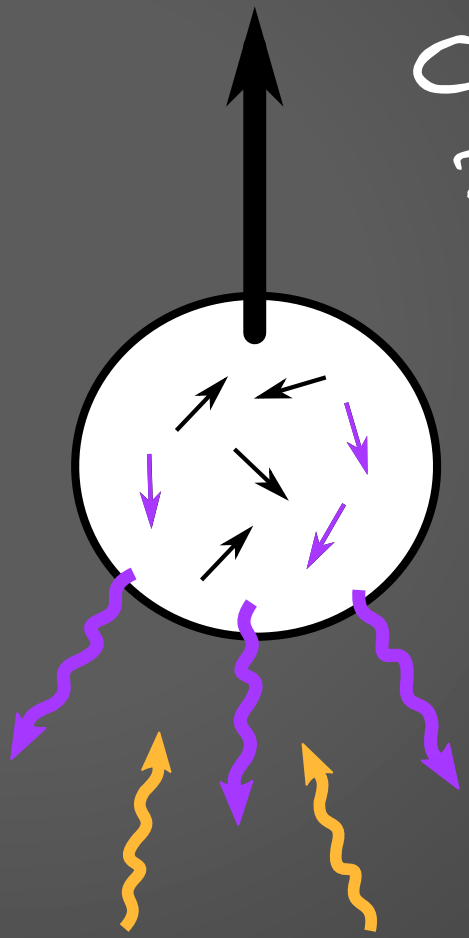


Acceleration via Compton Rocket

External photon
Inverse Compton photon

Cooling compensated by continuous re-acceleration (≠ Phinney 82)

Energy source = MHD turbulence NOT external photon field



Acceleration via Compton Rocket

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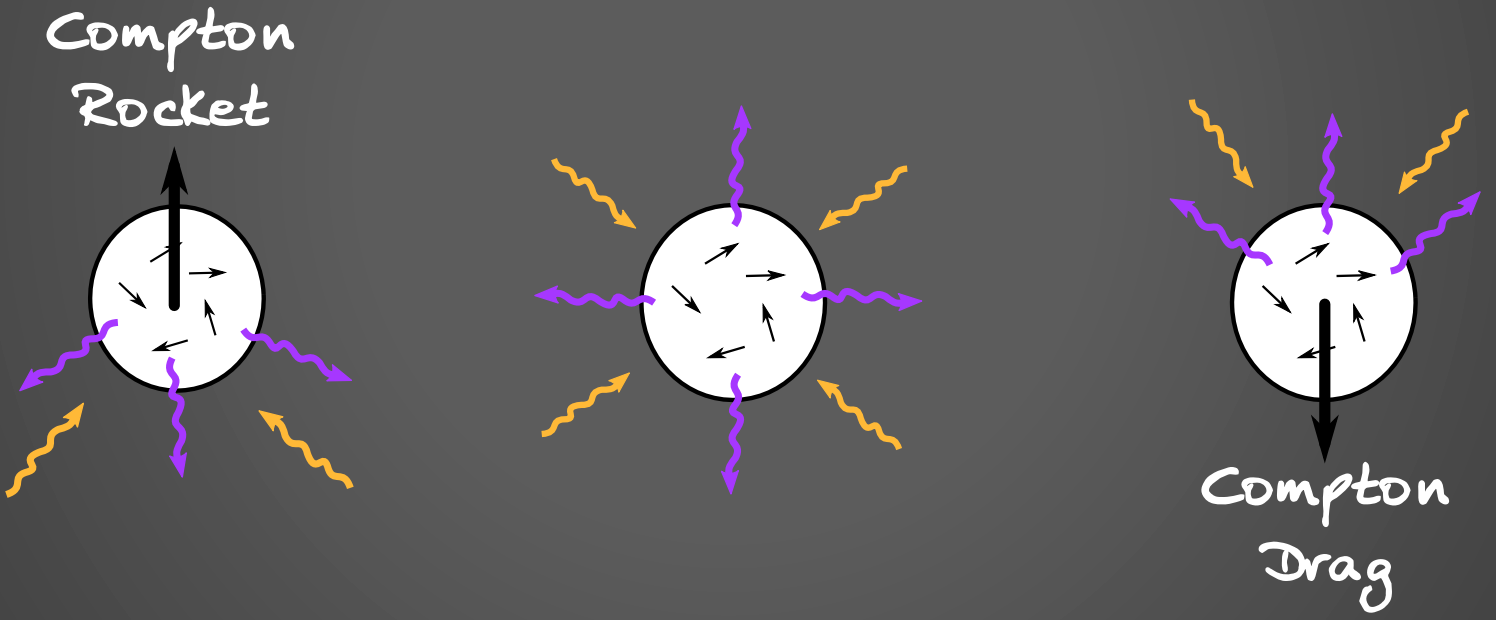
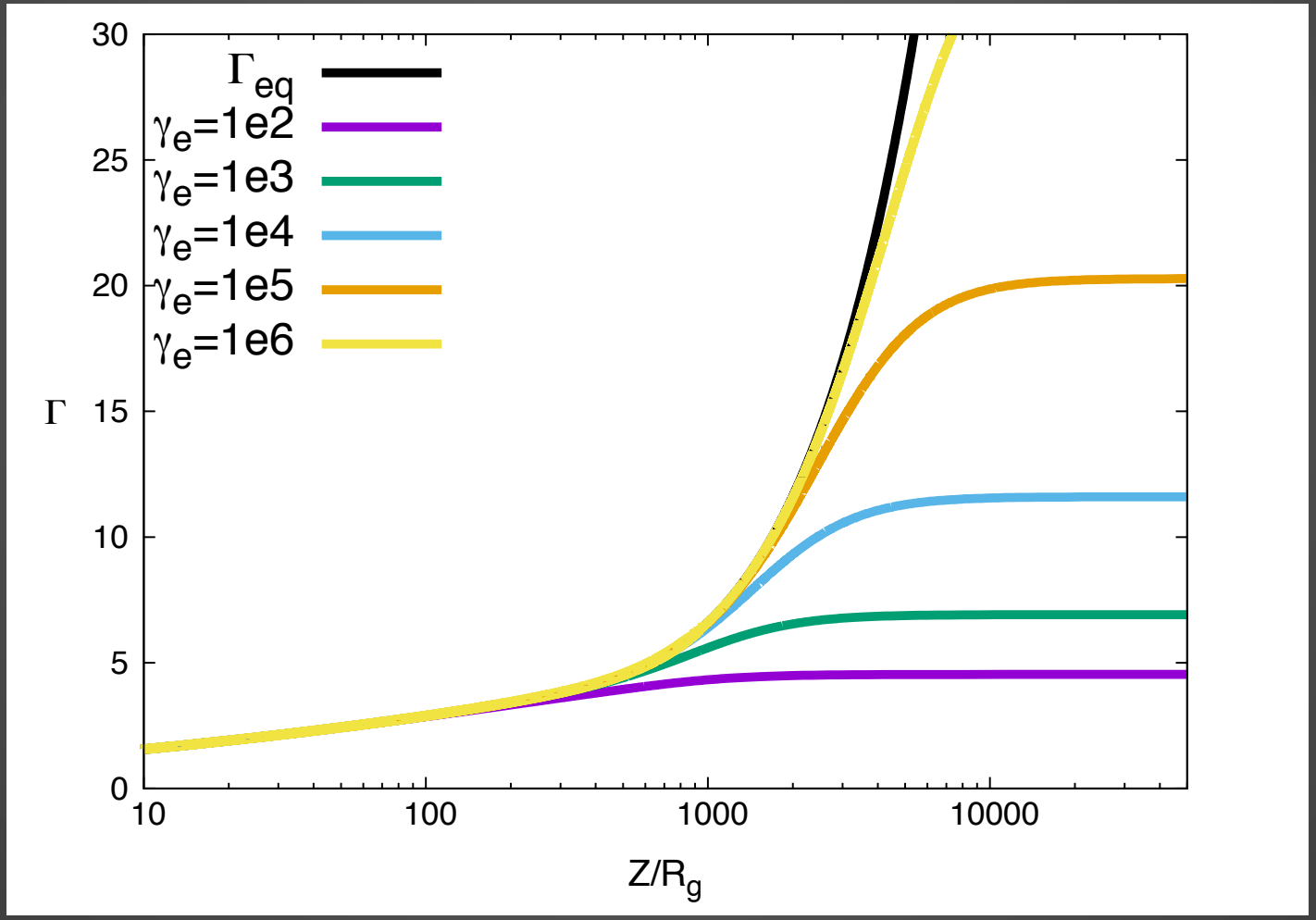
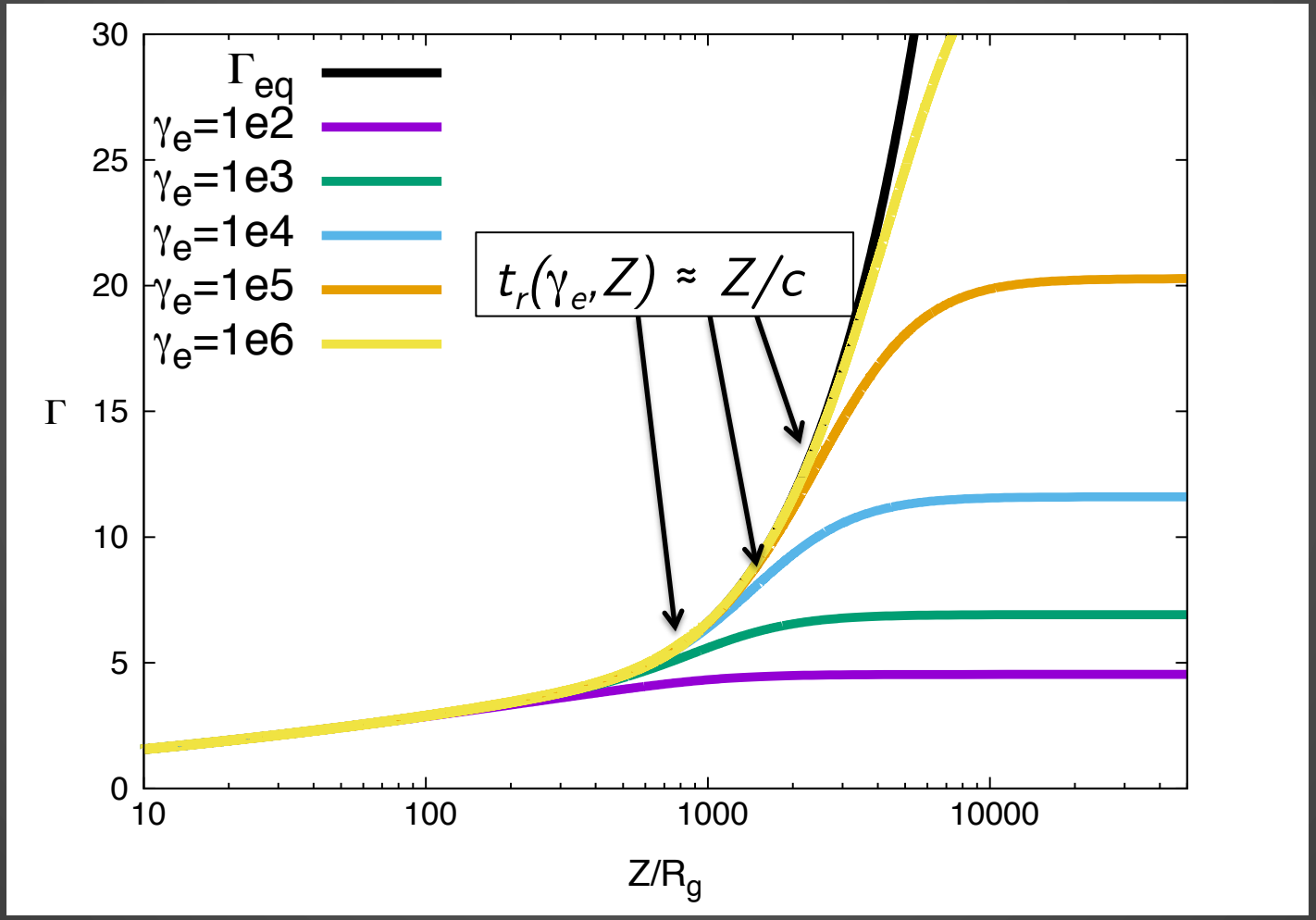


$\Gamma < \Gamma_{eq}$ $\Gamma = \Gamma_{eq}$ $\Gamma > \Gamma_{eq}$

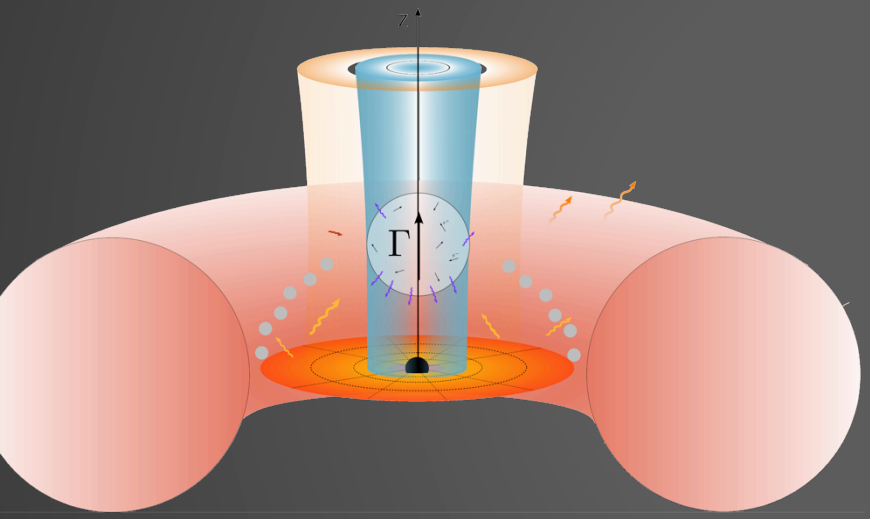
Compton Rocket with an accretion disc



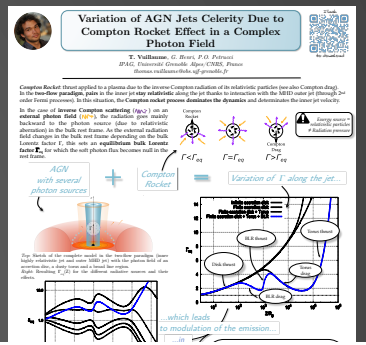
Compton Rocket with an accretion disc

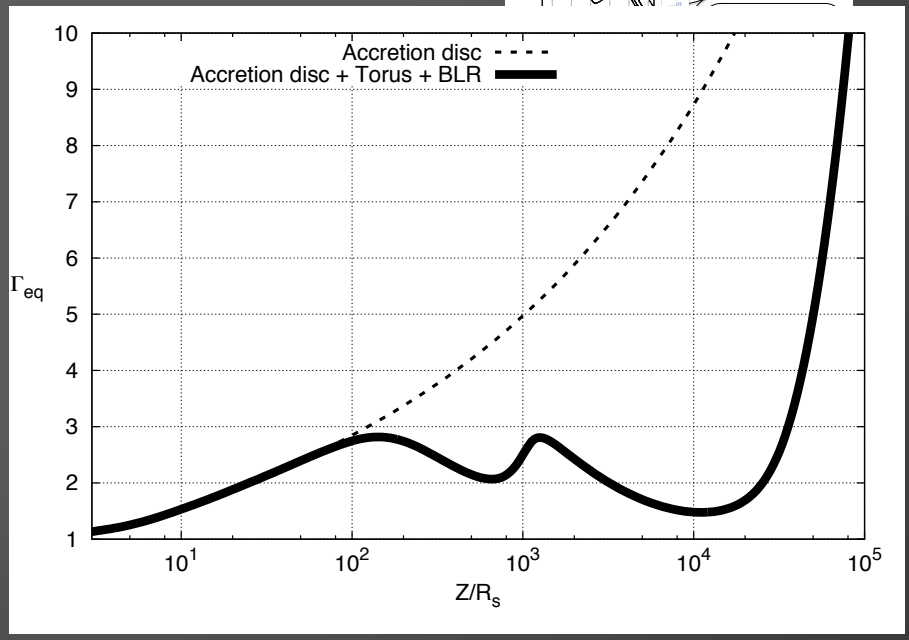


Compton Rocket in a complex photon field...



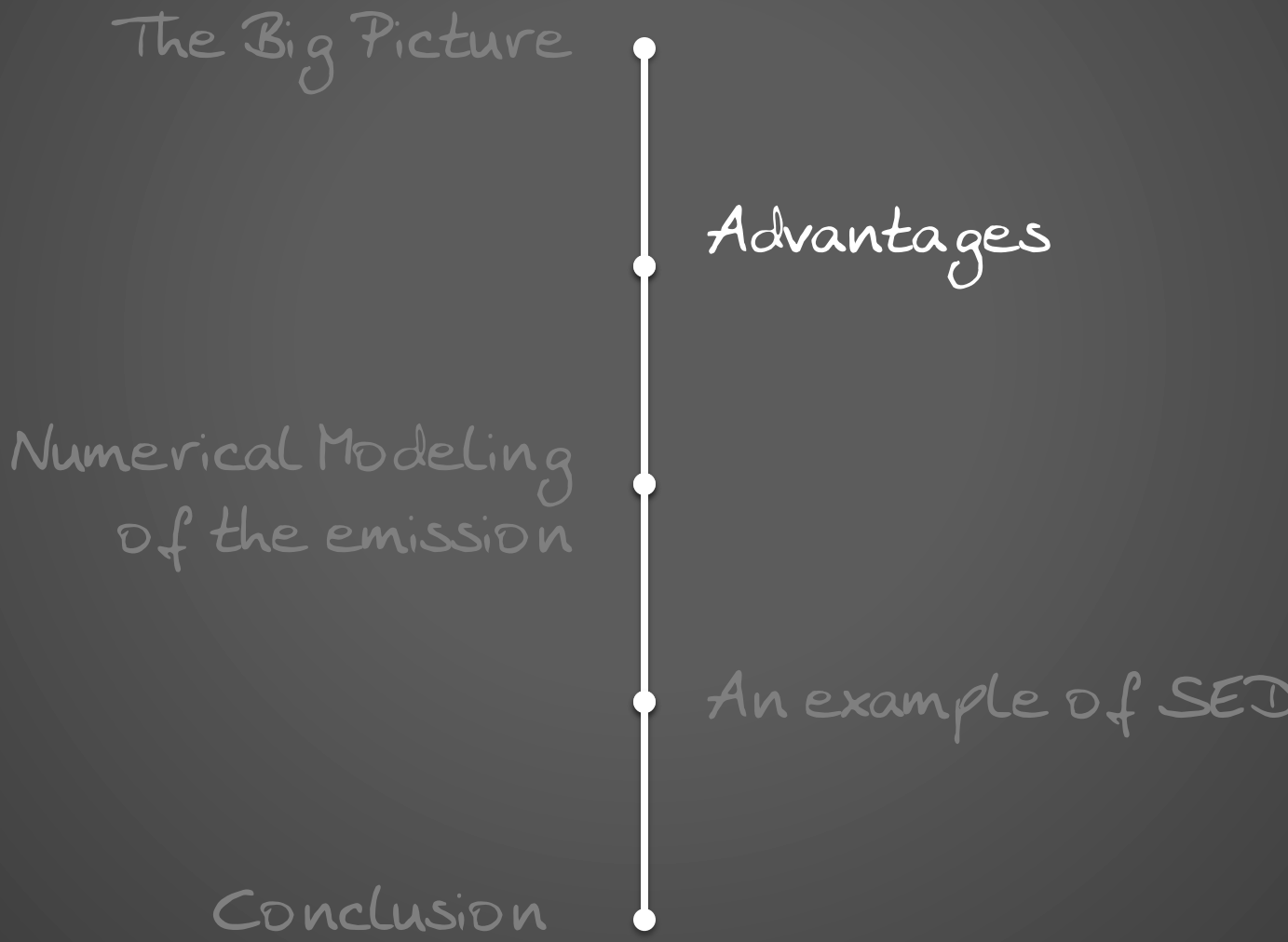
Poster !





⇒ more complex behavior of Γ_{eq}

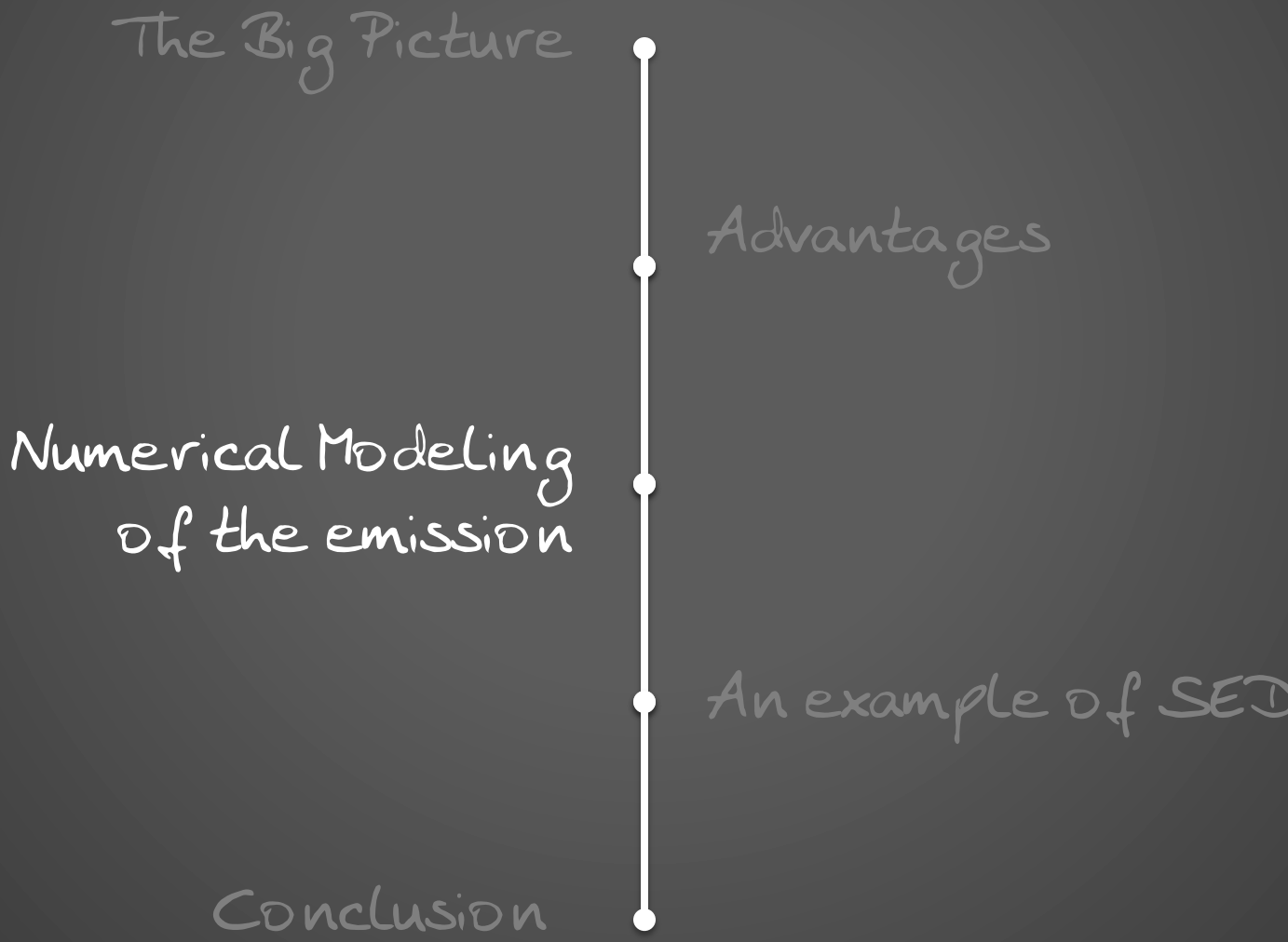
The two flow paradigm



Model advantages

- *Many problems disappear or seem easier to overcome in this paradigm:*
  - ✓ *Discrepancy in bulk speeds => natural explanation*
  - ✓ *Jet composition and power => e^-/e^+ at high Γ and e^-/p^+ midly relativistic carrying the power*
  - ✓ *Only hot particles move at relativstic bulk motion = no Sikora bump*
  - ✓ *Compton drag/rocket not an issue but a solution to the acceleration to relativistic speed issue*
  - ✓ *Not necessarily BZ process => ~~link with BH spin~~*

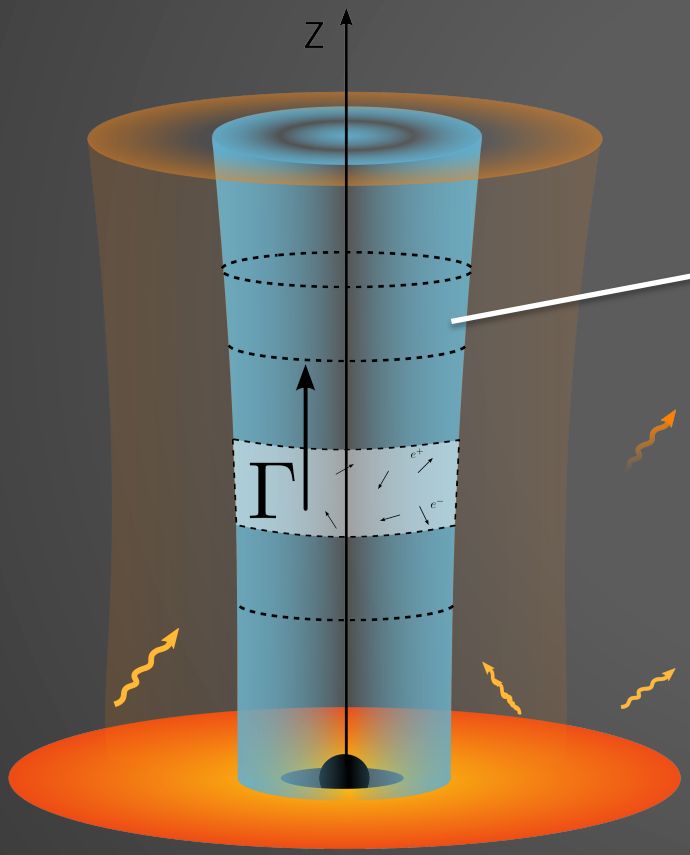
The two flow paradigm



Modeling: stratified jet

- *Diffuse acceleration => diffuse emission*
- *~~1 zone modeling~~ => continuous emission = stratified jet*

Modeling: stratified jet



$B(Z)$
$R(Z)$
$Q(Z)$

+

Initial conditions at the base of the jet

Particle heating term modeling tubulence

≈ *number of parameters for 1 zone modeling*

$\Gamma(Z)$ *and* $n_e(\gamma_e, Z)$ *computed !*

Modeling: particle distribution

- *Pile-up:*

Result from stochastic acceleration processes

$$n_e(\gamma, Z) = N_e(Z) \frac{\gamma^2}{2\bar{\gamma}^3(Z)} \exp\left(-\frac{\gamma}{\bar{\gamma}(Z)}\right)$$

Modeling: particle distribution

- *Pile-up:*

Result from stochastic acceleration processes

$$n_e(\gamma, Z) = N_e(Z) \frac{\gamma^2}{2\bar{\gamma}^3(Z)} \exp\left(-\frac{\gamma}{\bar{\gamma}(Z)}\right)$$

Computed parameters!

Result from pair-production & annihilation

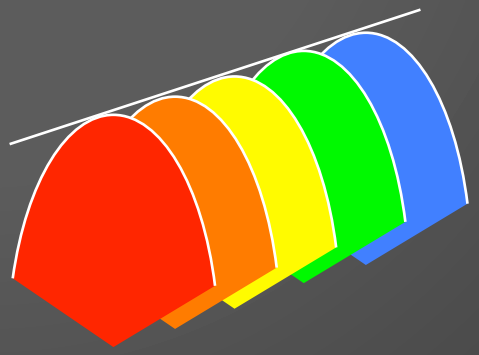
Result from balance between cooling and heating

Modeling: particle distribution

- *Pile-up:*

$$\boxed{n_e(\gamma, Z) = N_e(Z) \frac{\gamma^2}{2\bar{\gamma}^3(Z)} \exp\left(-\frac{\gamma}{\bar{\gamma}(Z)}\right)}$$

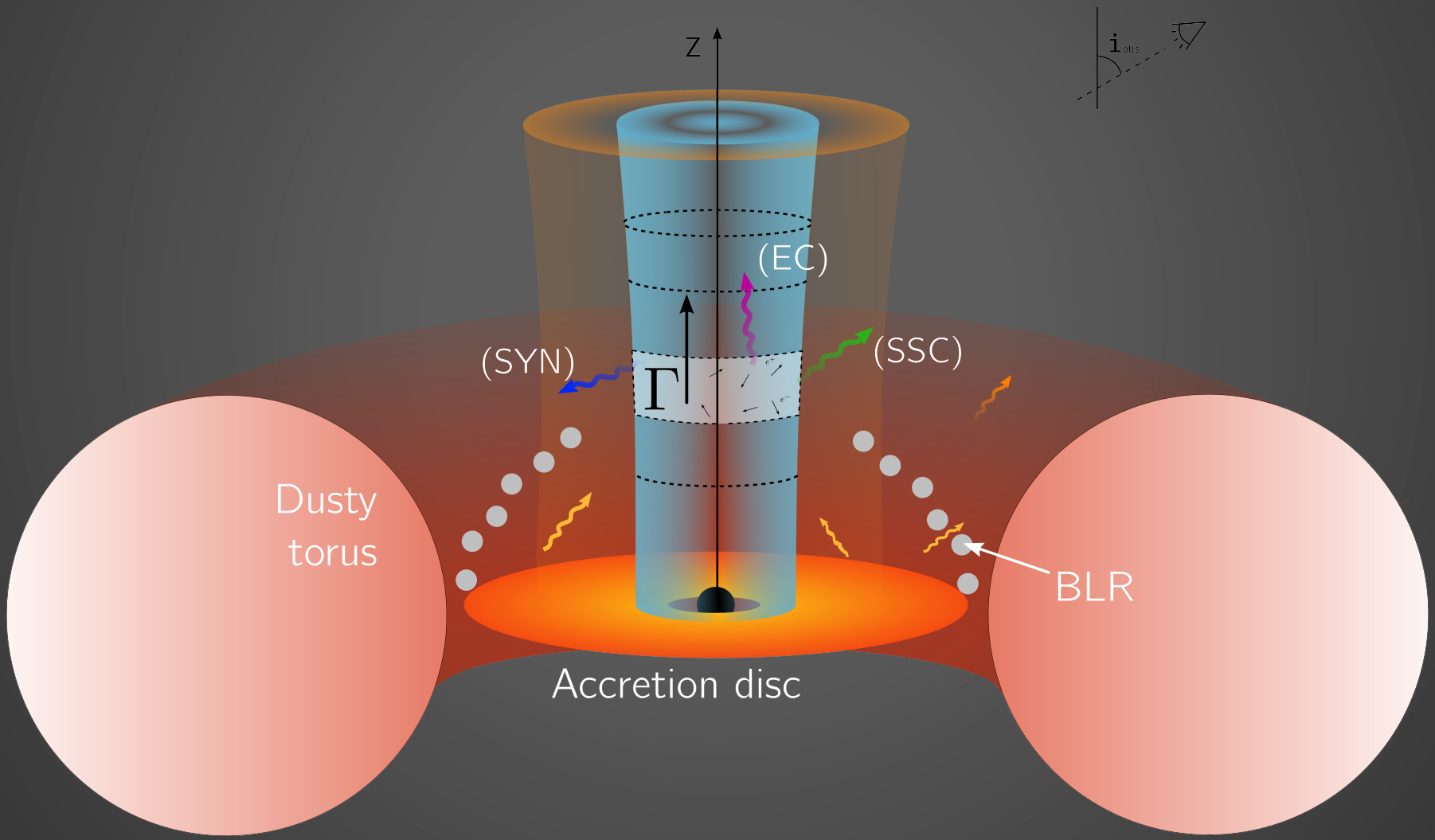
Can appear as a power-law by convolution...



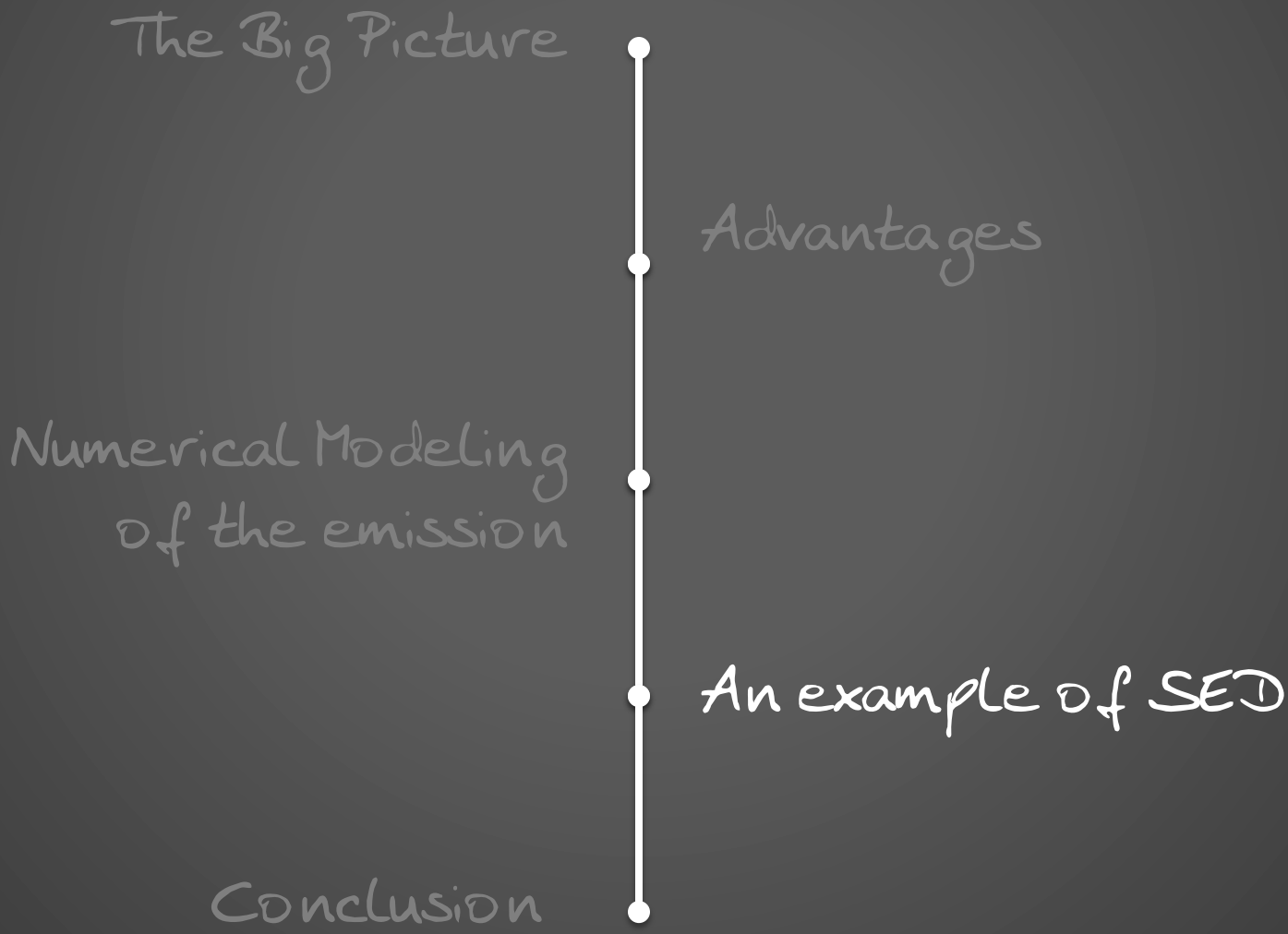
Complete modeling

- *Computation of radiative processes*
  - *Synchrotron*
  - *Synchrotron Self-Compton*
  - *External Compton (disc, dusty torus, BLR)*
- *Pair production and annihilation, absorption*
- *Anisotropy of the sources and emission*
- *Compton Rocket*

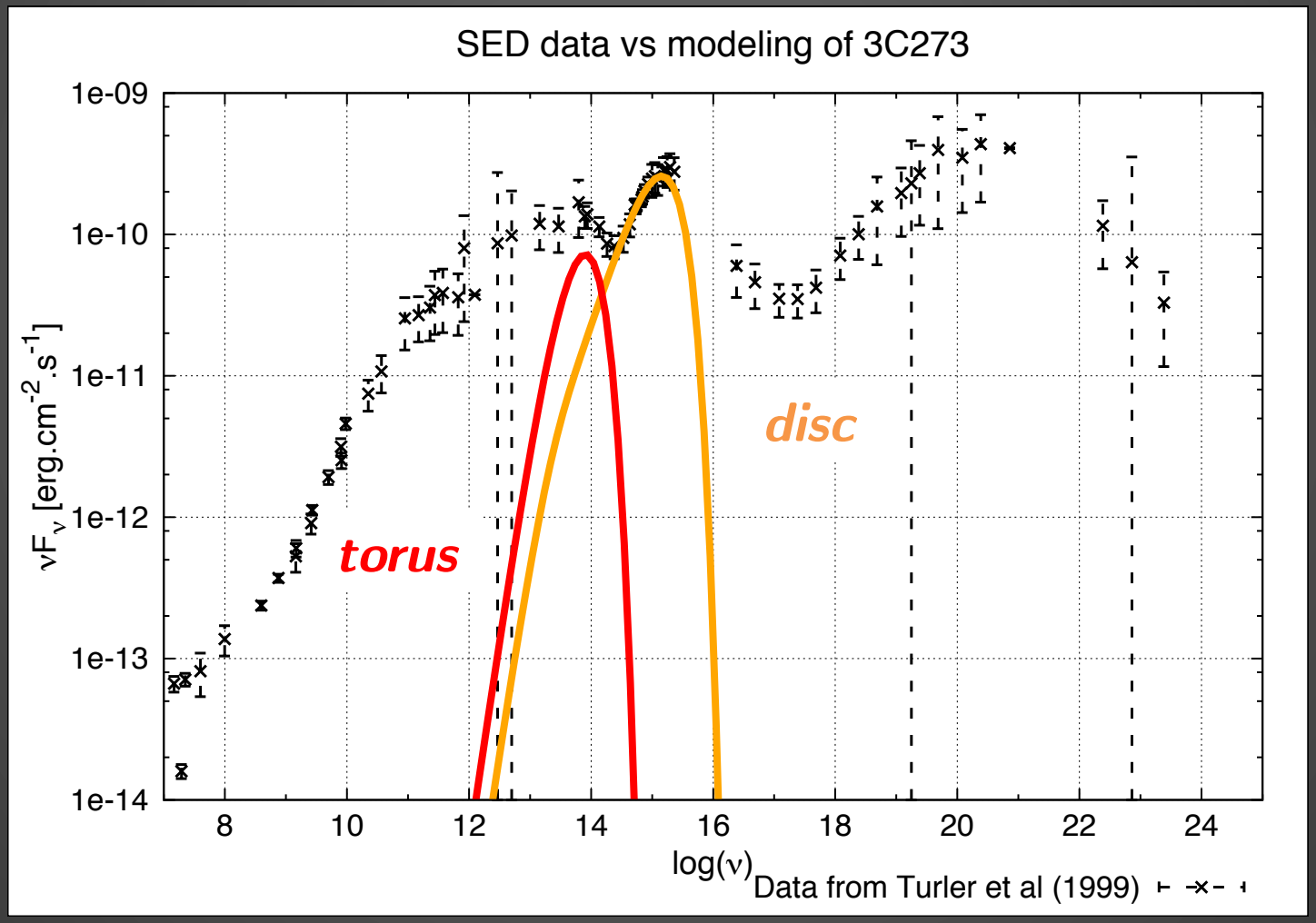
Complete modeling



The two flow paradigm

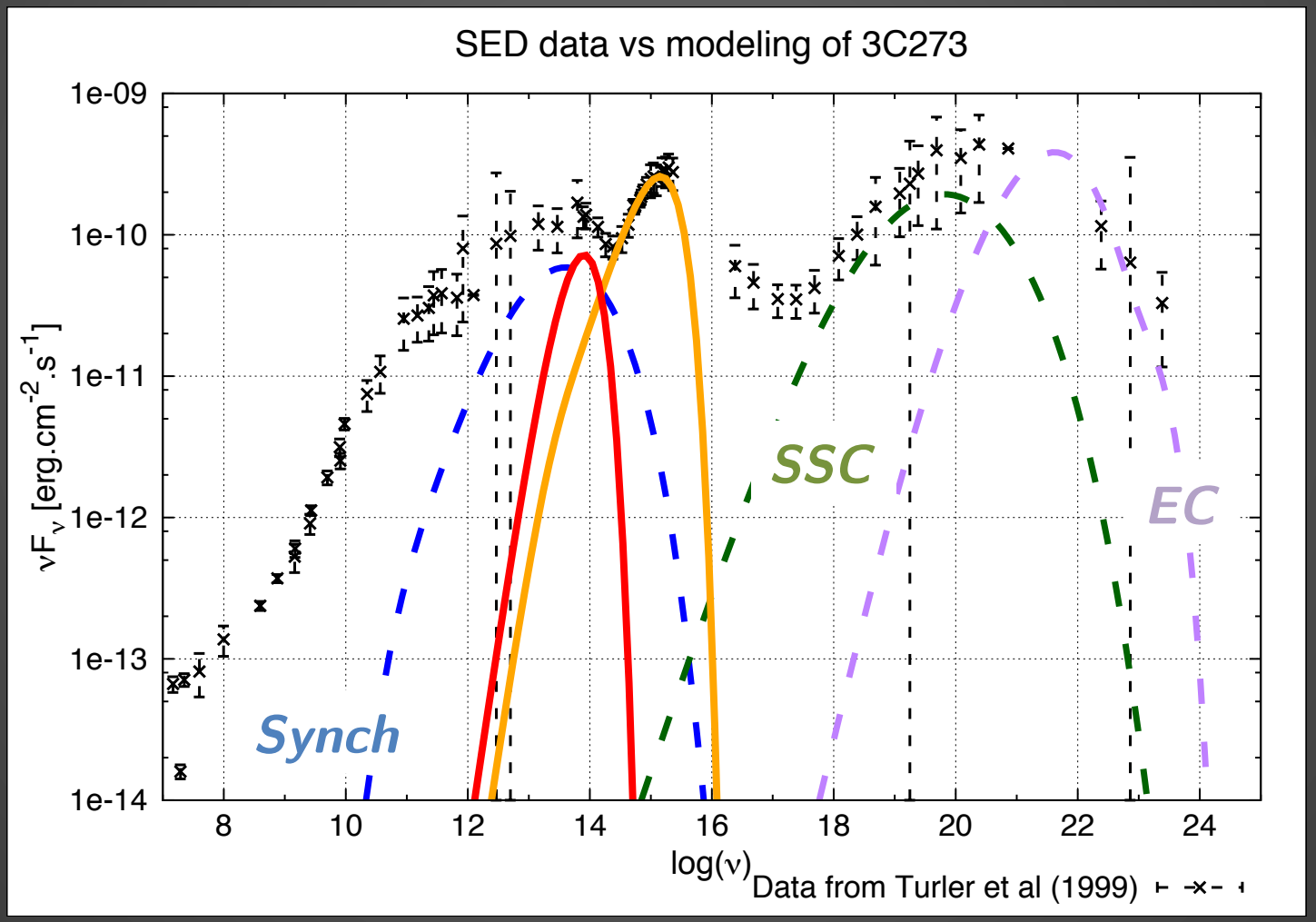


Example: FSRQ with Compton Rocket



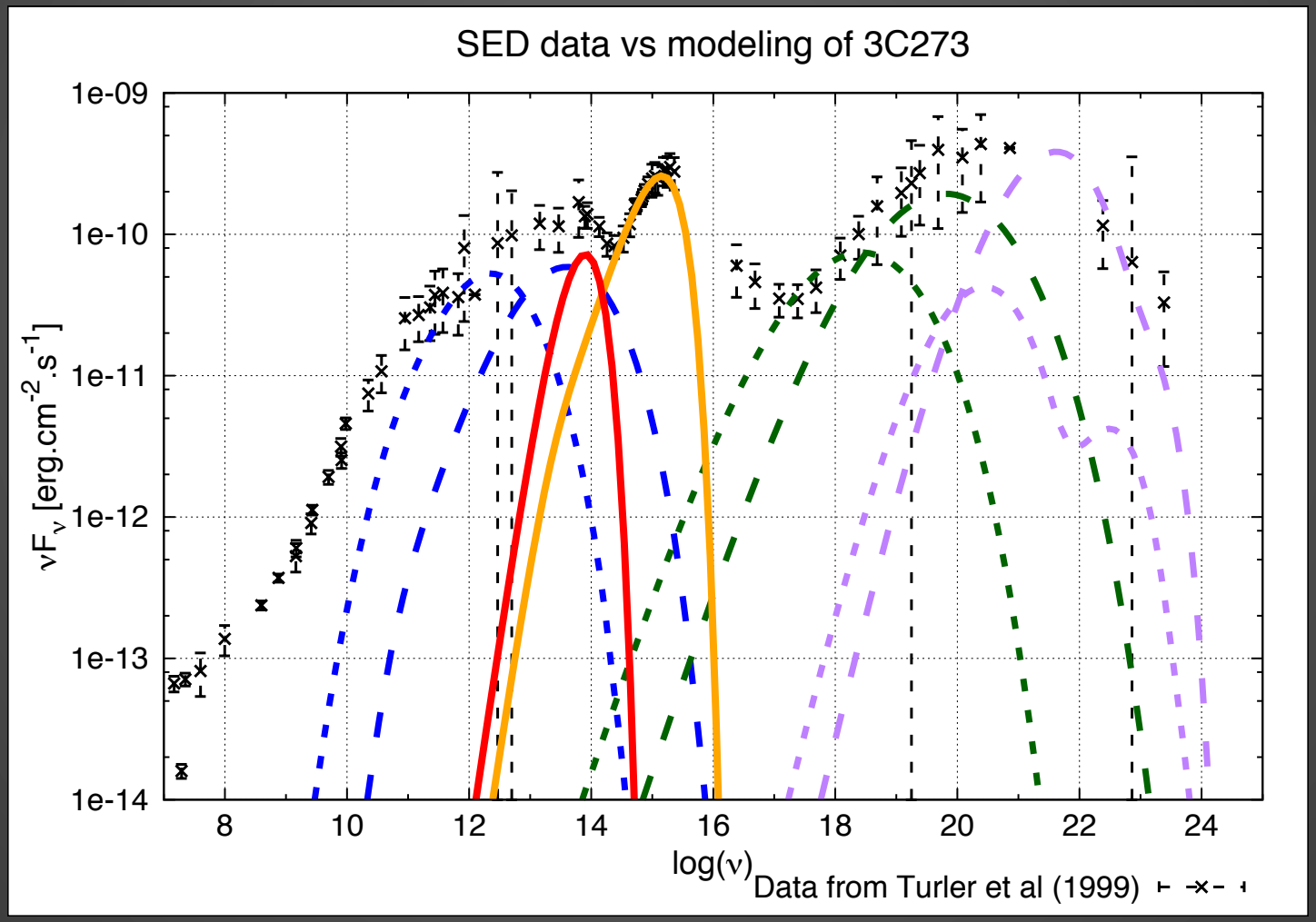
Example: FSRQ with Compton Rocket

$Z < 1e3\ R_s$



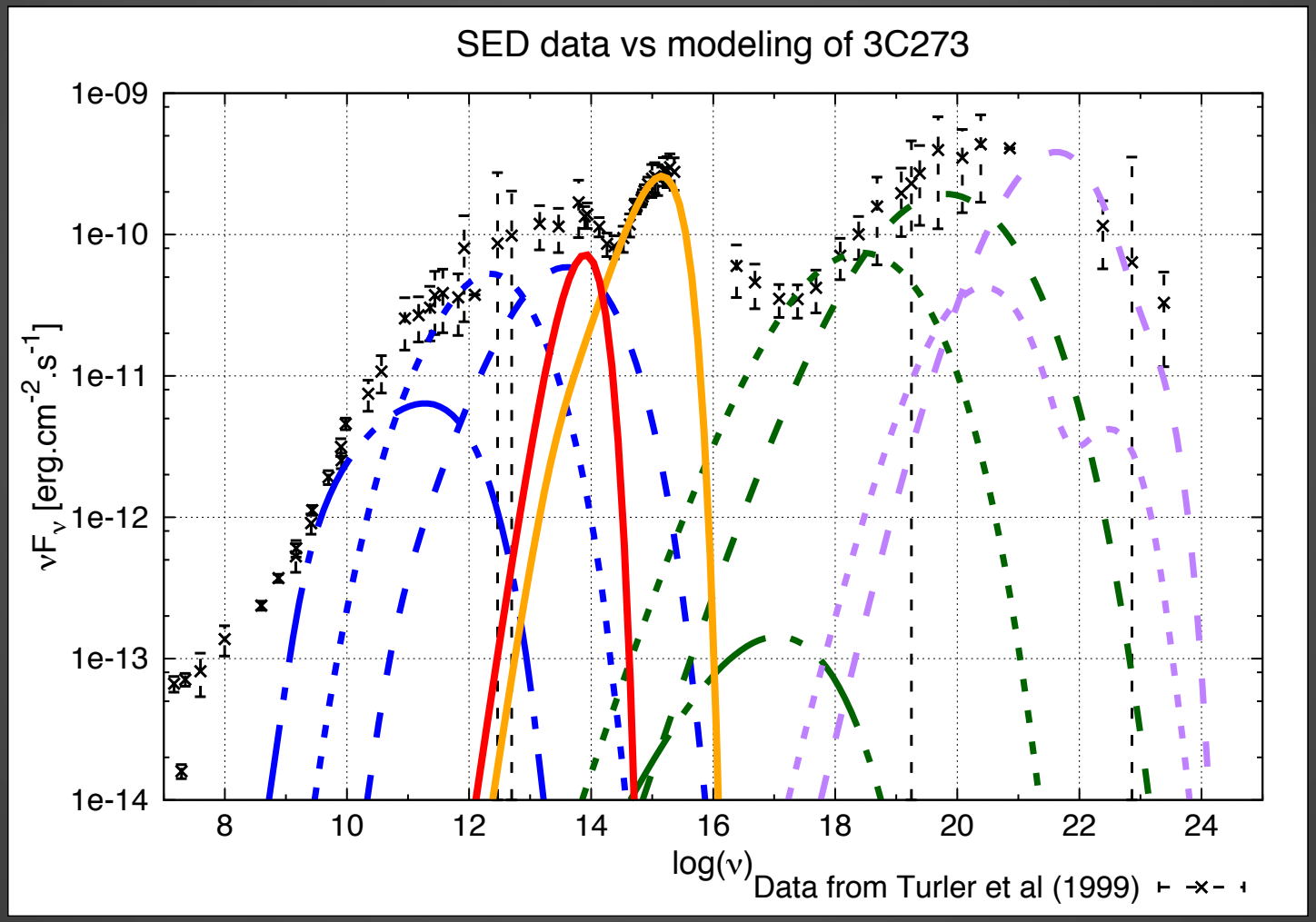
Example: FSRQ with Compton Rocket

1e3 R_s < Z < 1e5 R_s



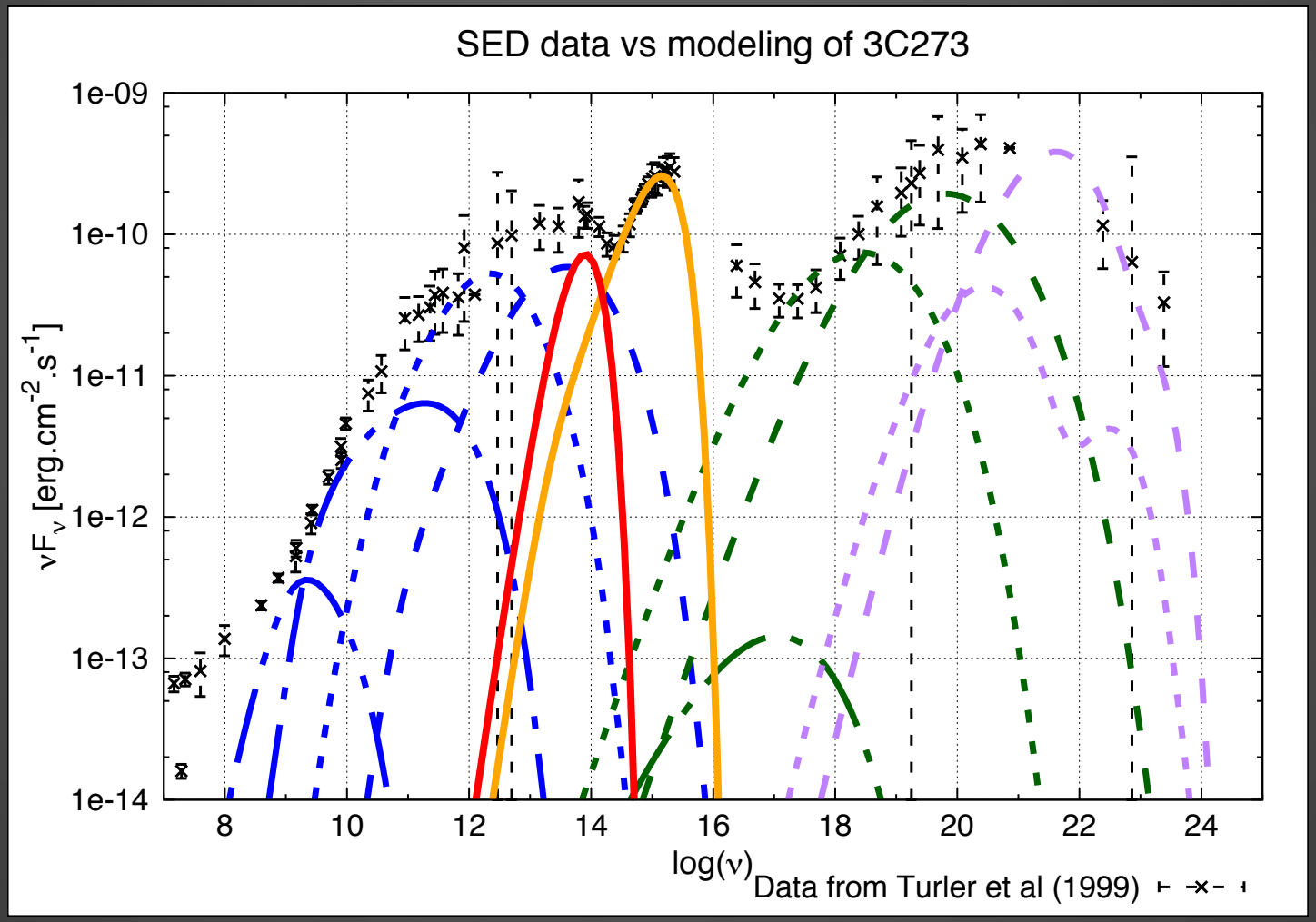
Example: FSRQ with Compton Rocket

1e5 R_s < Z < 1e7 R_s



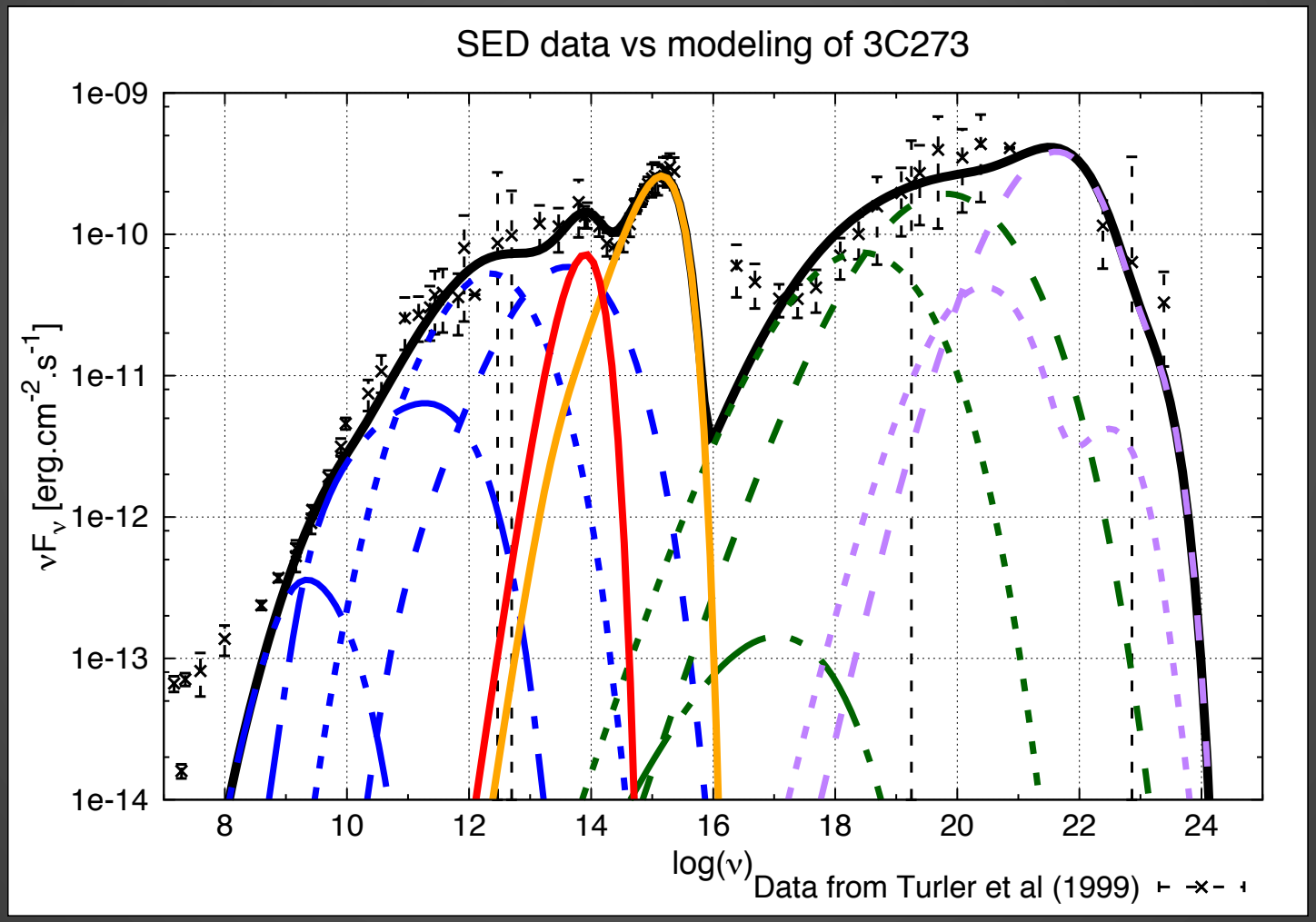
Example: FSRQ with Compton Rocket

1e7 R_s < Z < 1e9 R_s



Example: FSRQ with Compton Rocket

Total integrated emission



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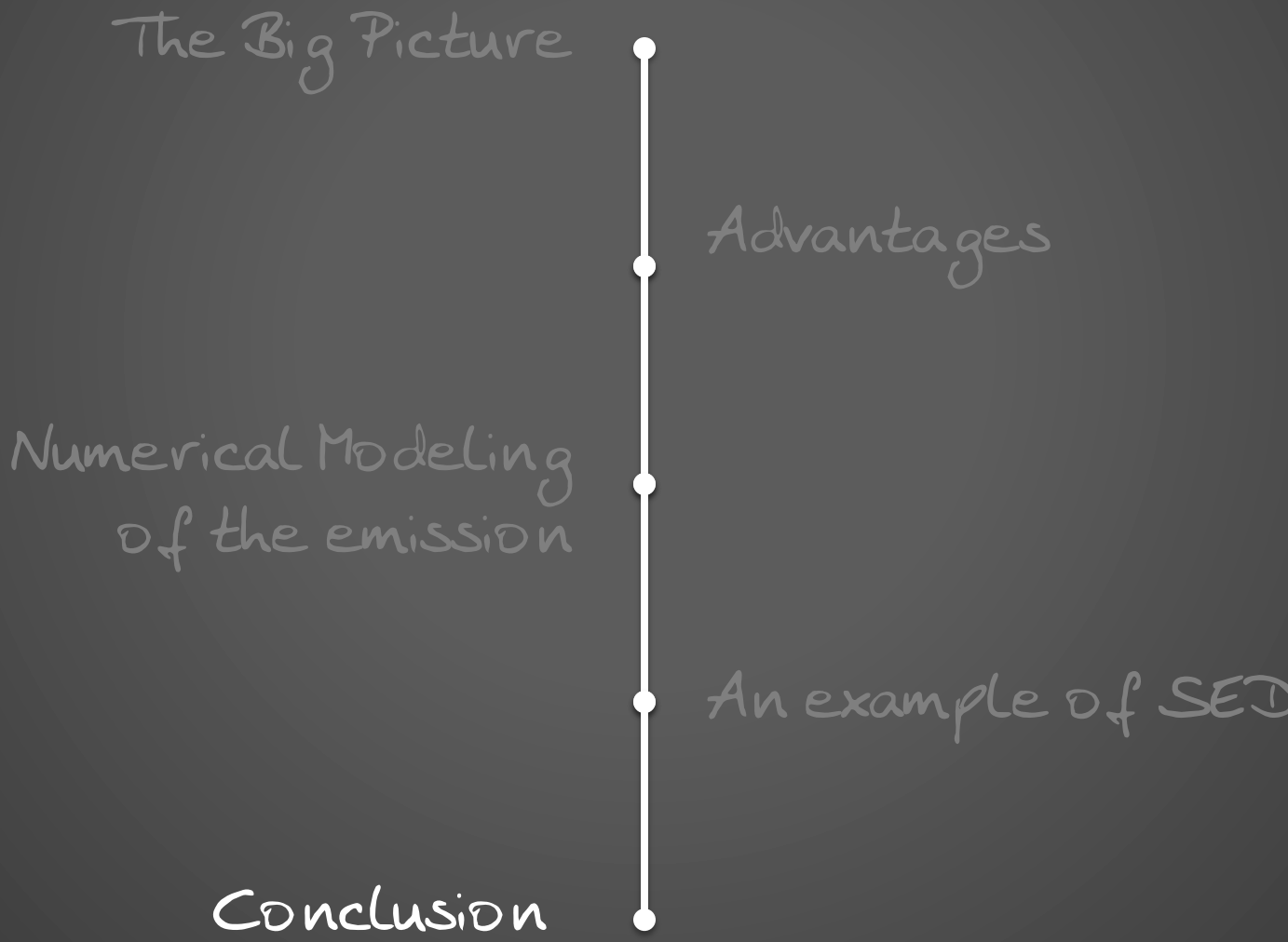

The two flow : summary

- *Coherent paradigm – not mainstream but with a lot of explanatory potential*
- *Important current issues easier to explain*
- *Self-consistent computation of physical parameters and emission*
- Γ *NOT free - imposed by external sources (through Compton Rocket effect)*
- *Future: time dependent version of the model*