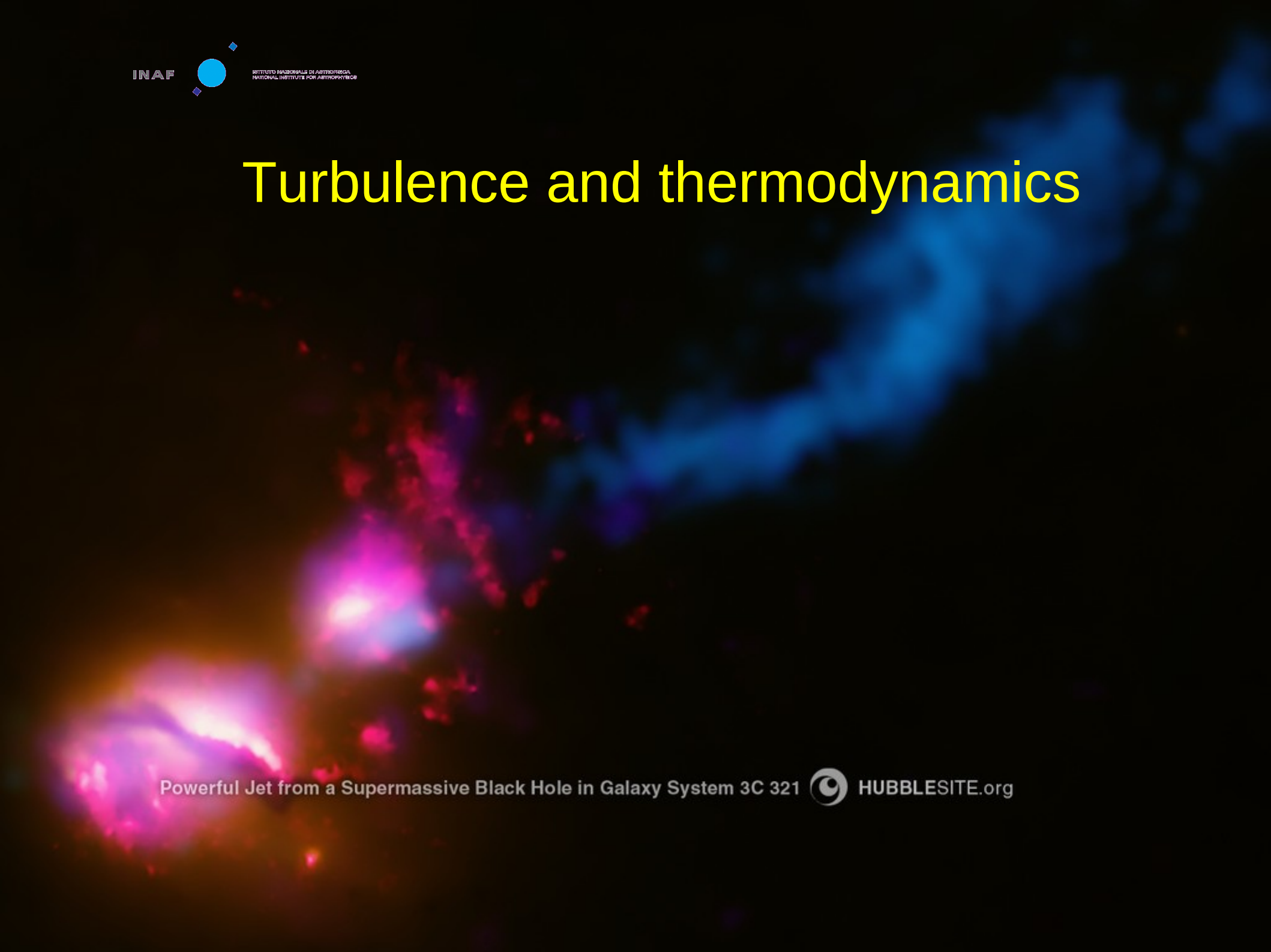
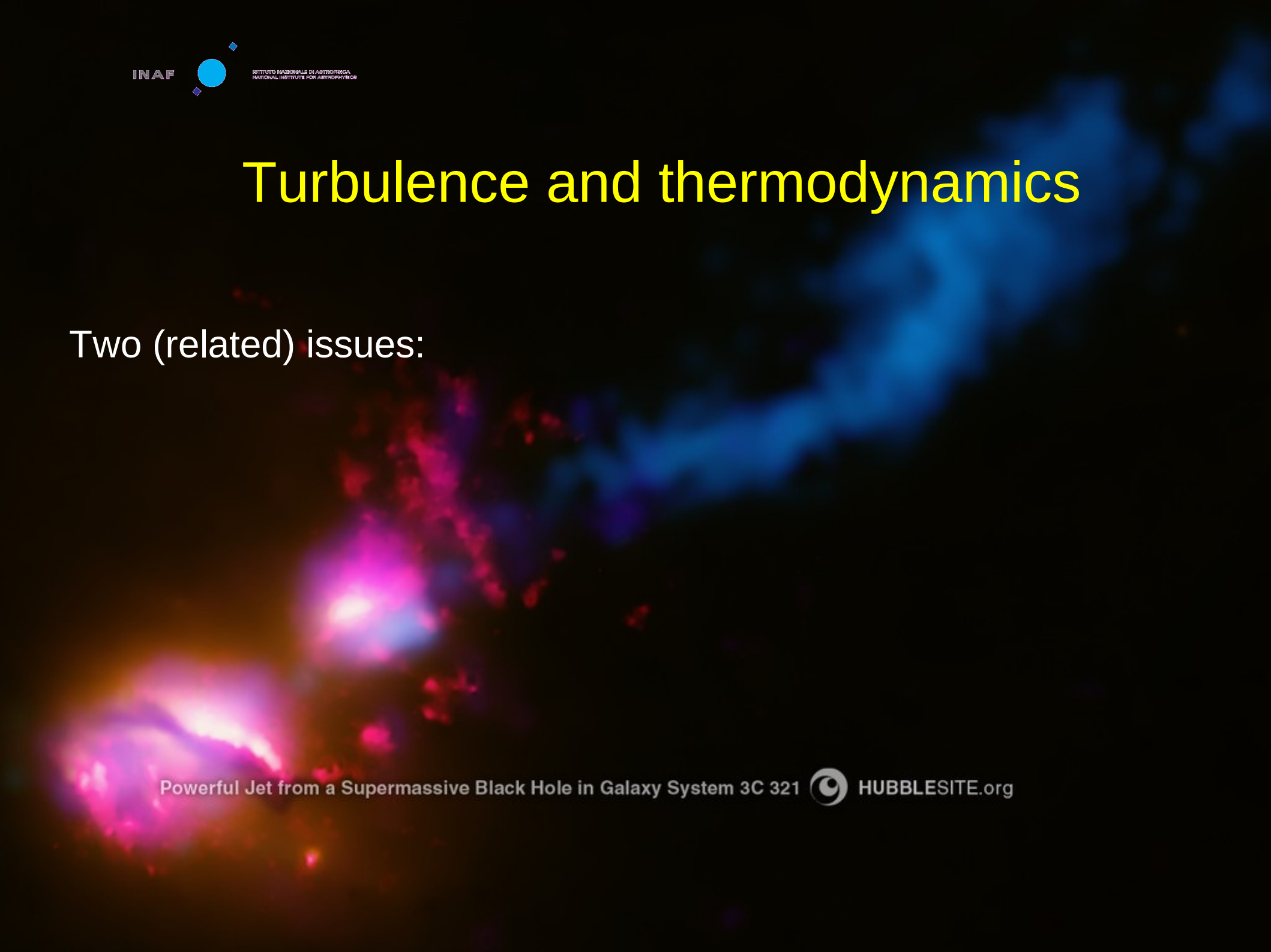
Turbulence and thermodynamics



Turbulence and thermodynamics

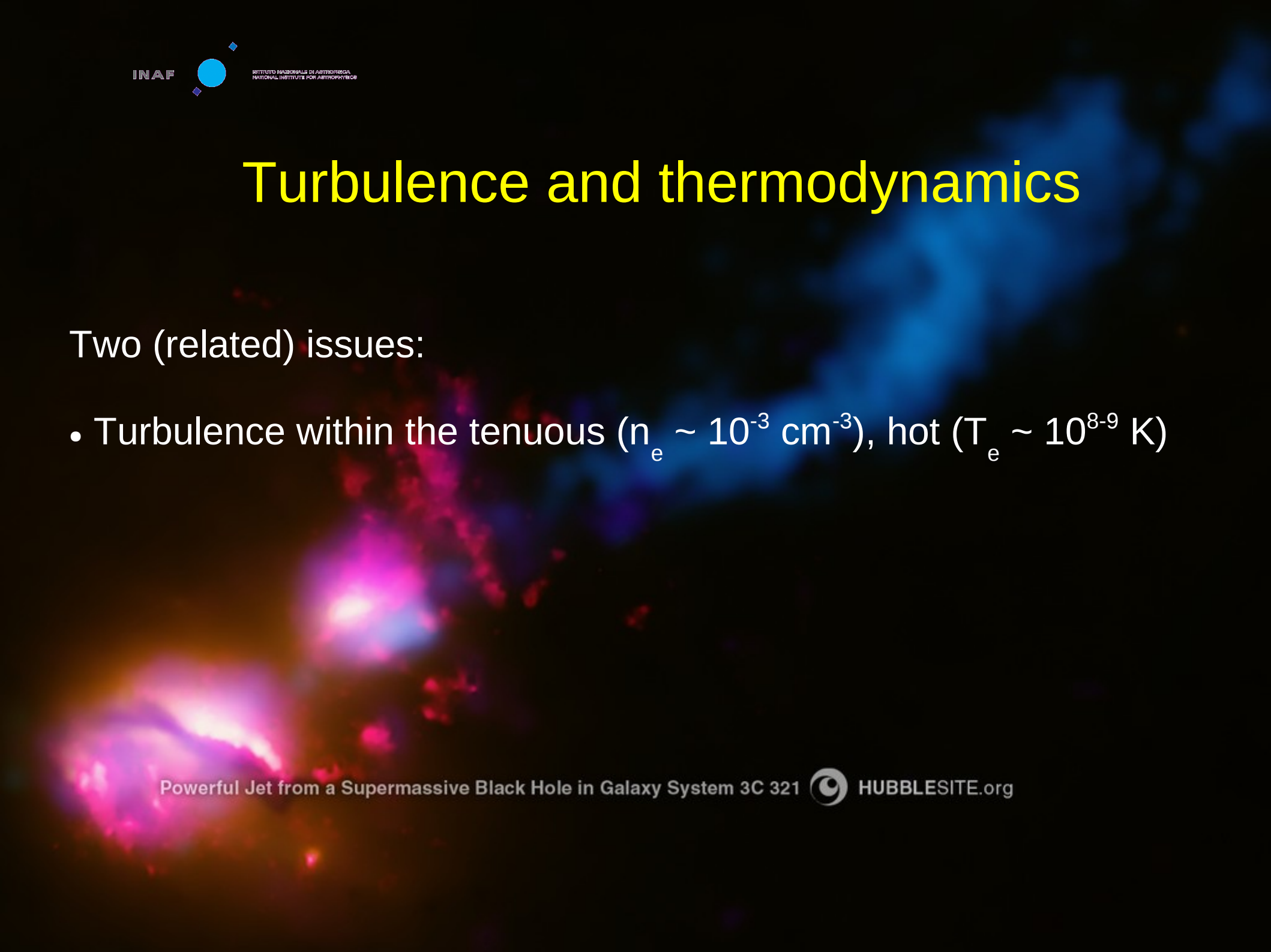
Two (related) issues:



Turbulence and thermodynamics

Two (related) issues:

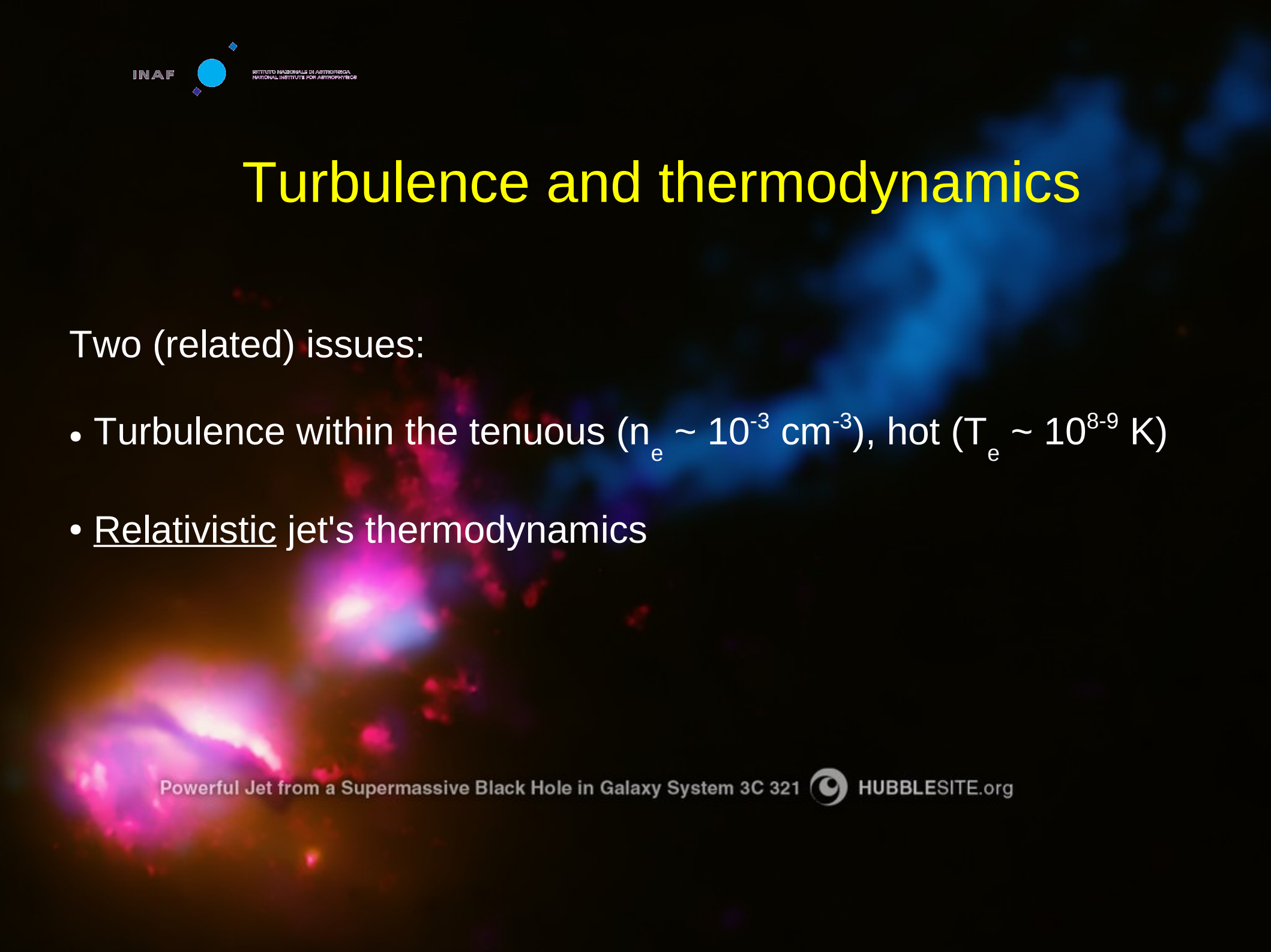
- Turbulence within the tenuous ($n_e \sim 10^{-3}$ cm^{-3}), hot ($T_e \sim 10^{8\text{-}9}$ K)



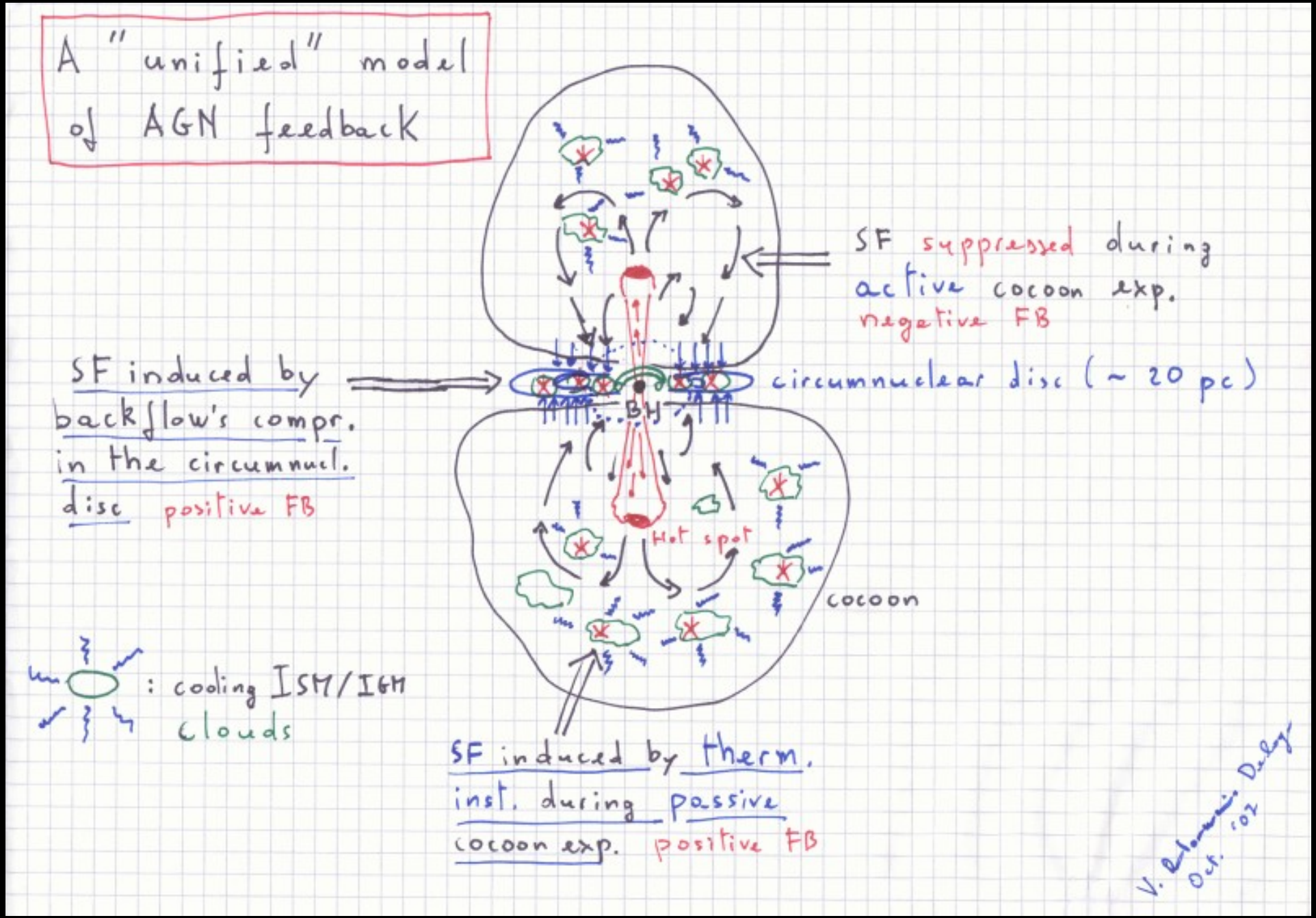
Turbulence and thermodynamics

Two (related) issues:

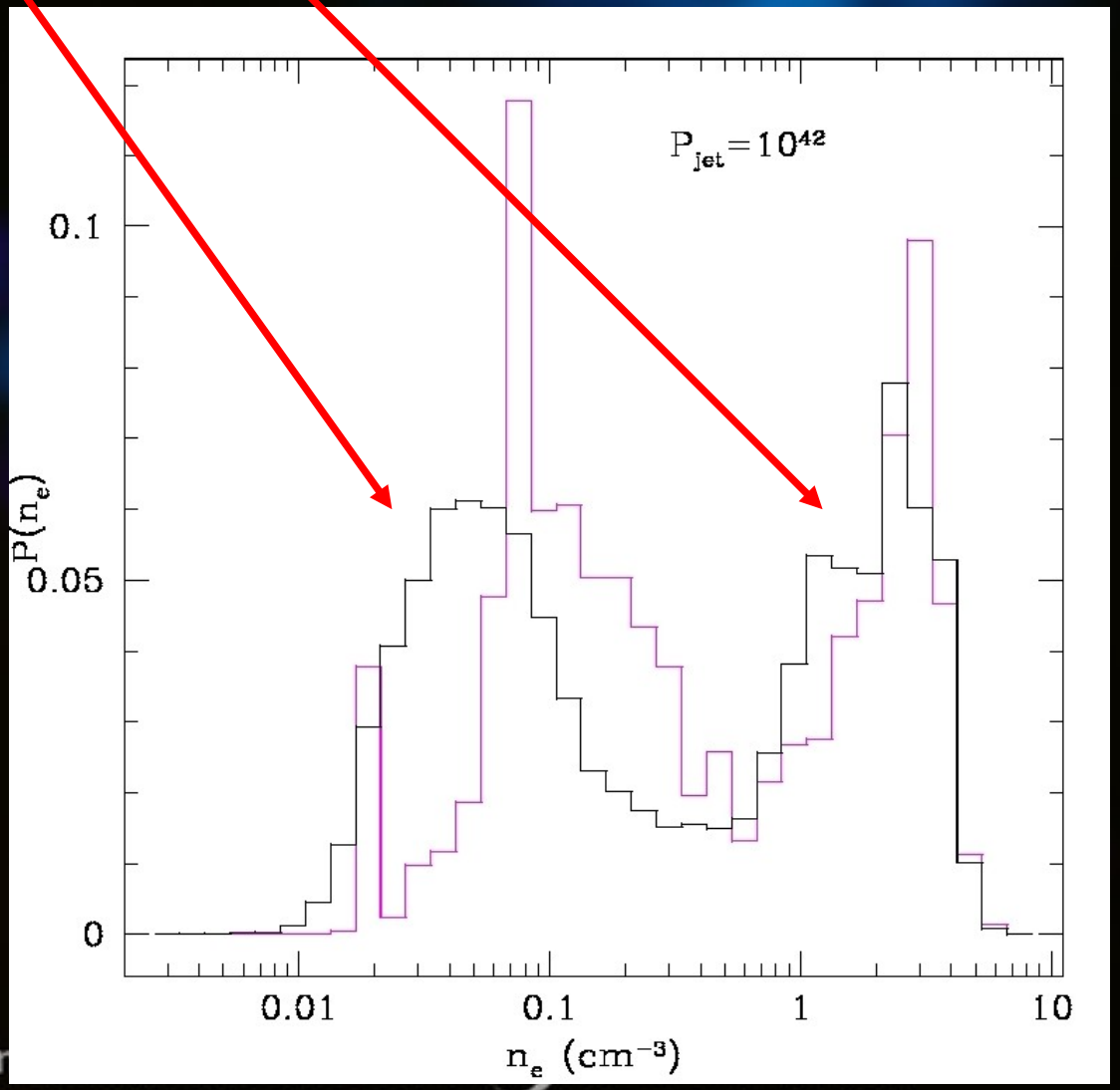
- Turbulence within the tenuous ($n_e \sim 10^{-3}$ cm^{-3}), hot ($T_e \sim 10^{8\text{-}9}$ K)
- Relativistic jet's thermodynamics



The “unified” model of AGN feedback

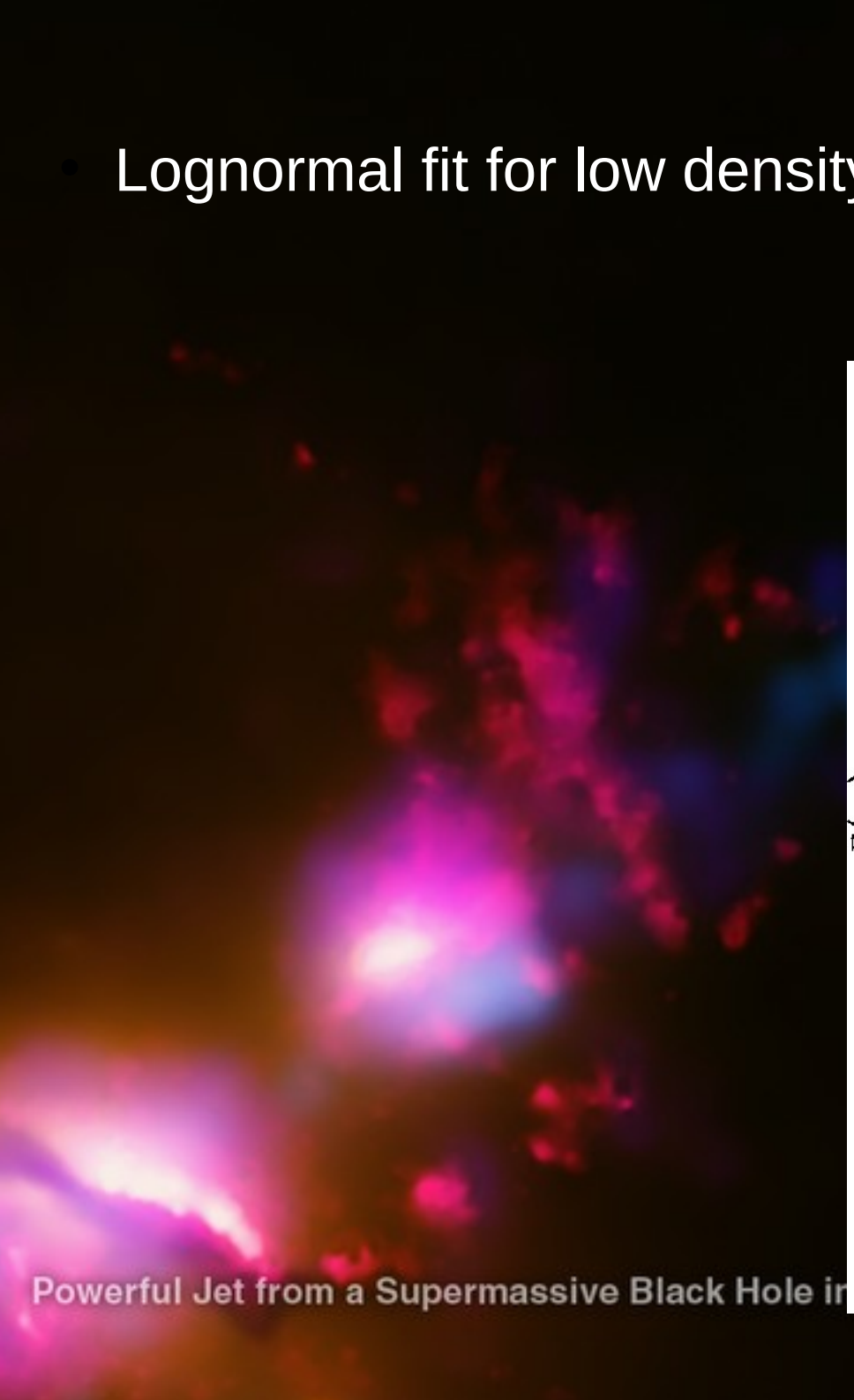


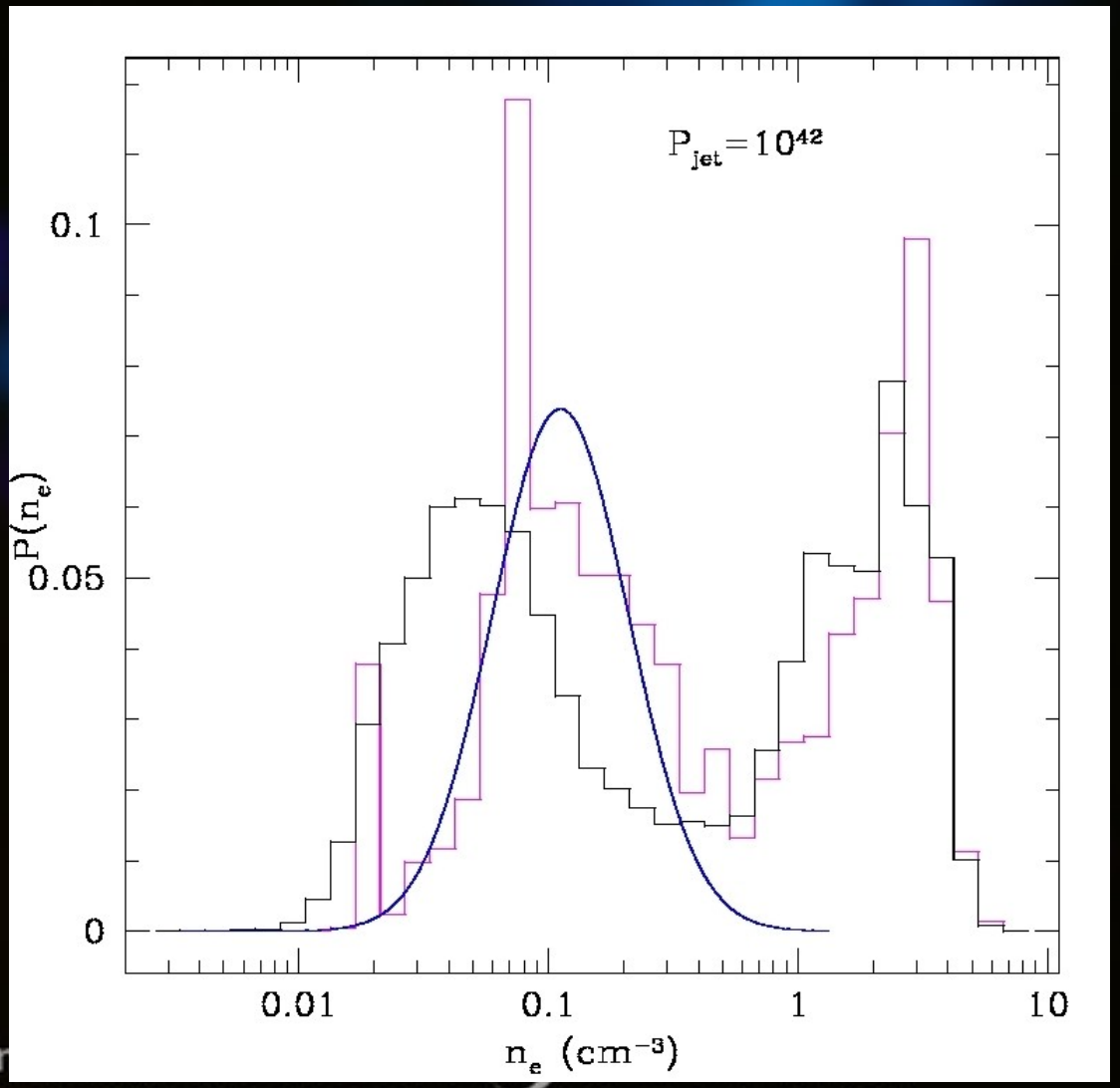
- PDF, 2 components: *low / high-density (cocoon/bow shock)*



Powerful Jet from a Supermassive Black Hole ir

- Lognormal fit for low density component





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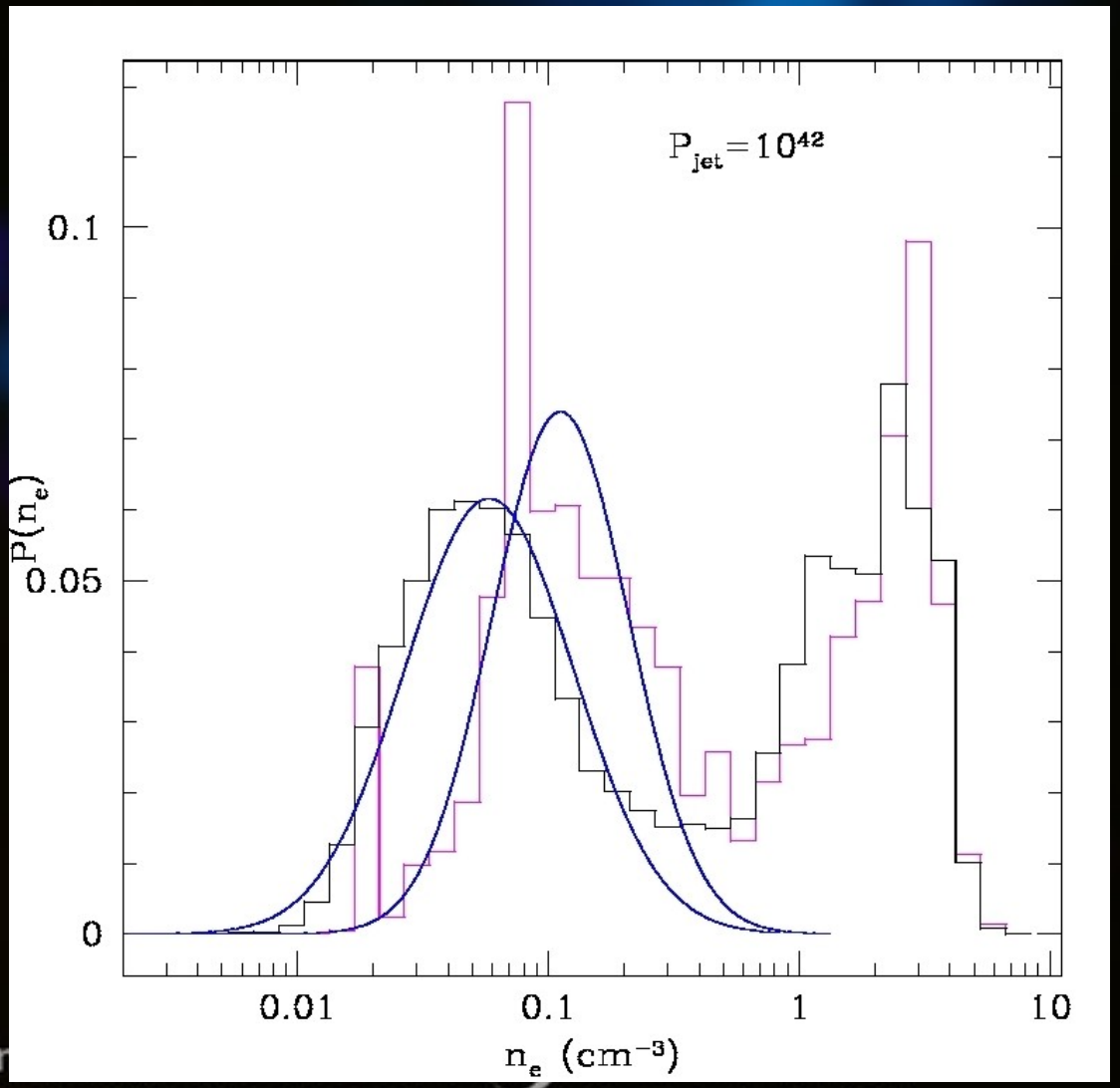


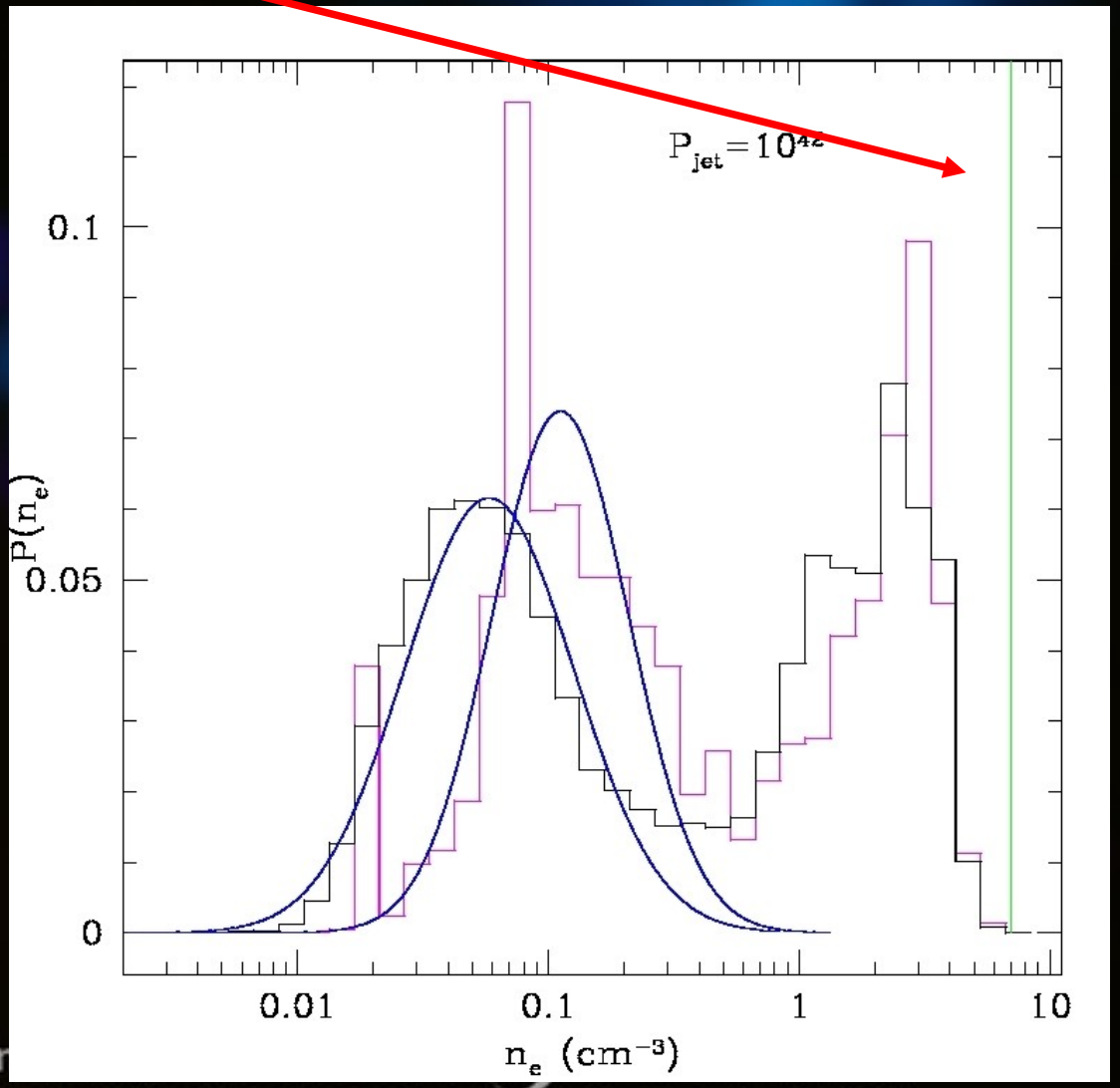
Powerful Jet from a Supermassive Black Hole ir

$\rho_{down}/\rho_{up} = 7$ (*Bouquet, Teyssier and Chieze, 2000*)

Valid for optically thick media (and/)OR for $\gamma \approx 4/3$

Radiative shock

- Most cells are strongly shocked only once!

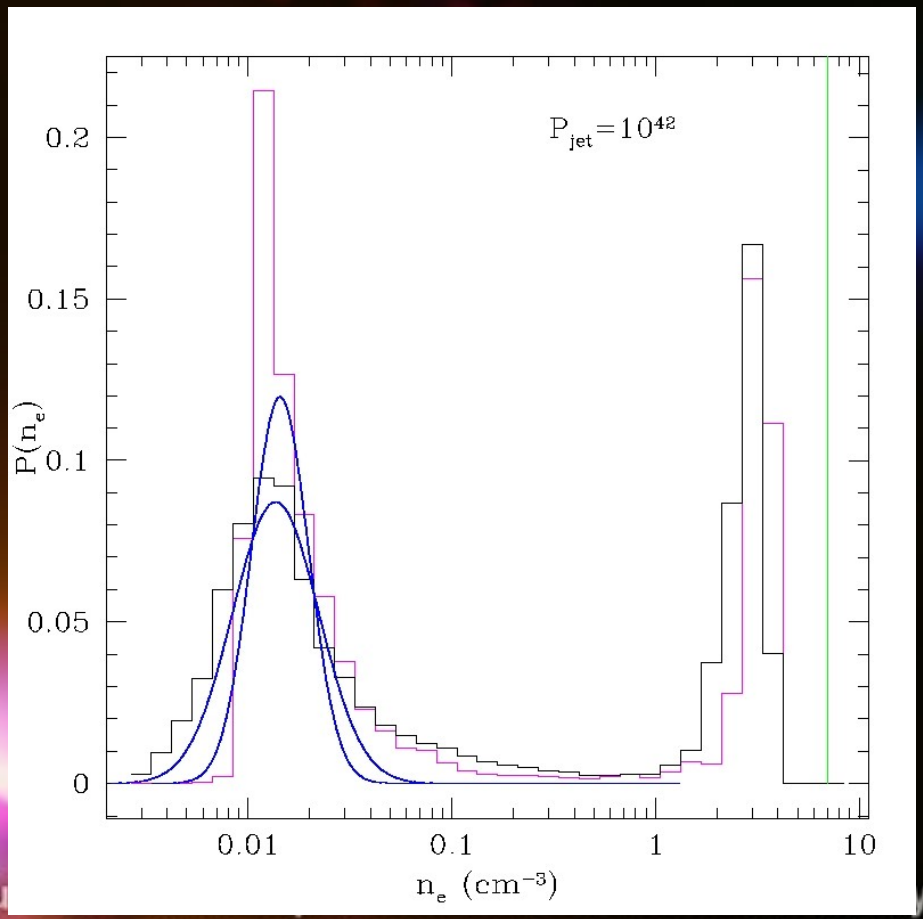


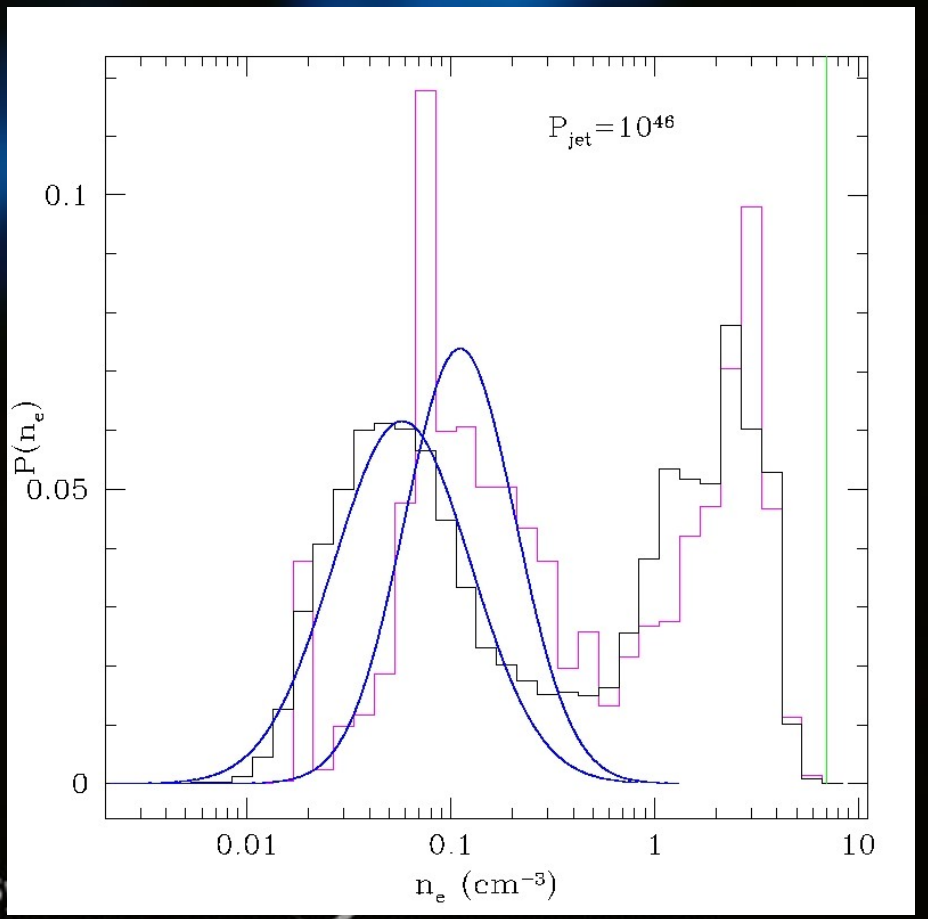
Powerful Jet from a Supermassive Black Hole in

- Lognormal fit for low density component

A universal density PDF

- Turbulence driver: mechanical energy → shear → KH inst.
- Expanding cocoon → stationary, externally driven turbulence





A (universal) density Probability Distribution Function

$$P(s;\gamma)ds = C(\gamma)\exp\left[\frac{-s^2 e^{(\gamma-1)s}}{2M^2} - \alpha(\gamma)s\right]ds$$

$S = \ln(\varrho - \langle\varrho\rangle_{vol})$

M: $\langle Mach\rangle_{vol}$

γ : effective adiabatic index (from fit, $1.11 \leq \gamma \leq 1.27$)

C(γ) : from $\int P(s;\gamma)ds = 1$

α(γ) : from mass normalisation $\int e^s P(s;\gamma)ds = 1$

- Scalo, Passot, Vázquez-Semadeni (1997, 1998):

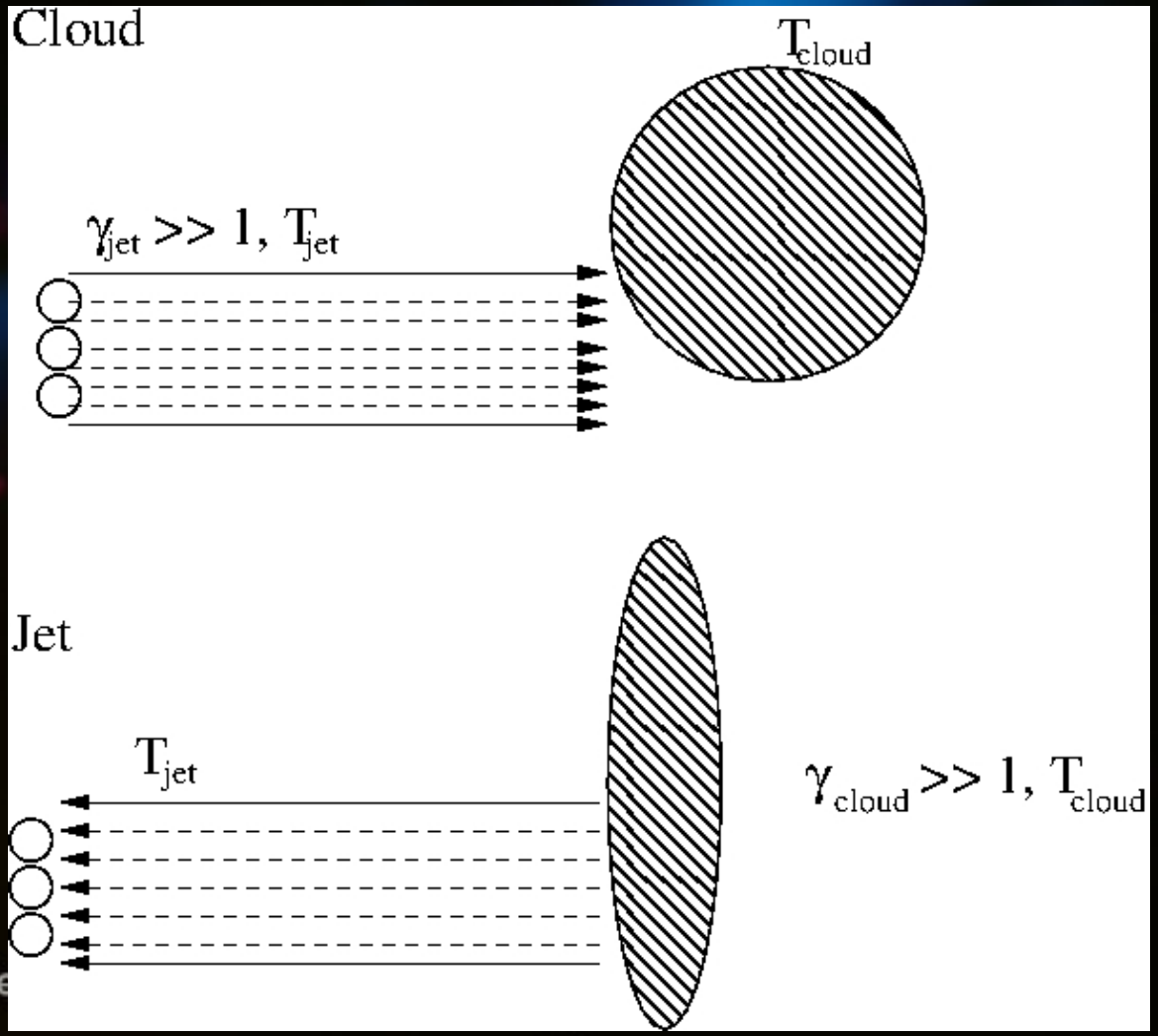
$P(s;\gamma)$ lognormal for $M \approx 1$, $\gamma \simeq 1$, $\propto \varrho^{-1.7}$ for $\gamma < 1$ (applies to ISM)

- Norman, Padoan, Kritsuk (1997, 1999, 2007):

$P(s;\gamma)$ lognormal with disp: $\sigma^2 = 2\ln(1 + b^2M^2)$, $b=0.26\mp0.001$

How *HOT* is a relativistic jet?

Fluid parcels within a jet are launched at relativistic speed ($\gamma \gg 1$) from the accretion disc with *internal energy e* and temperature T_0 (jet's rest frame)



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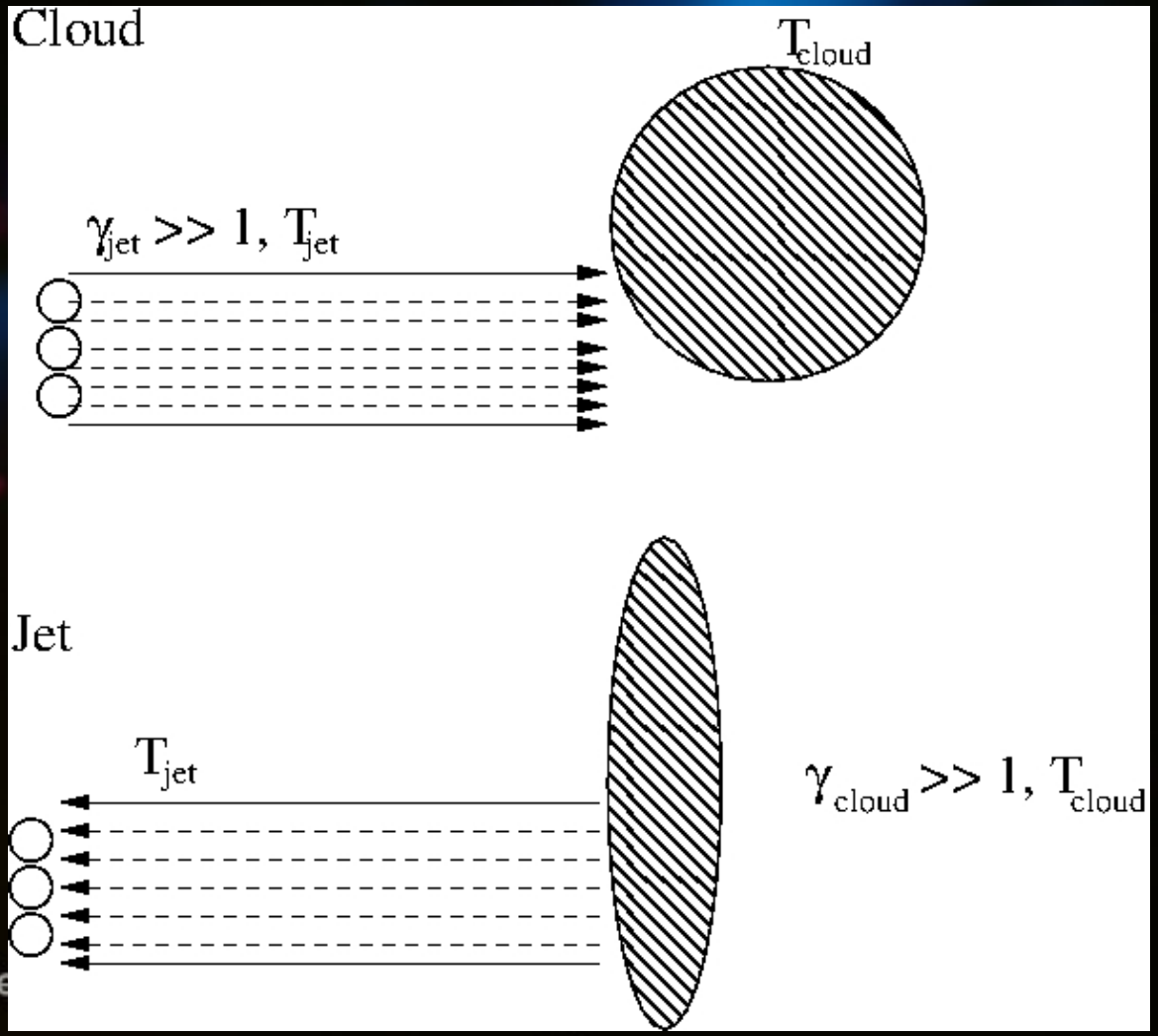

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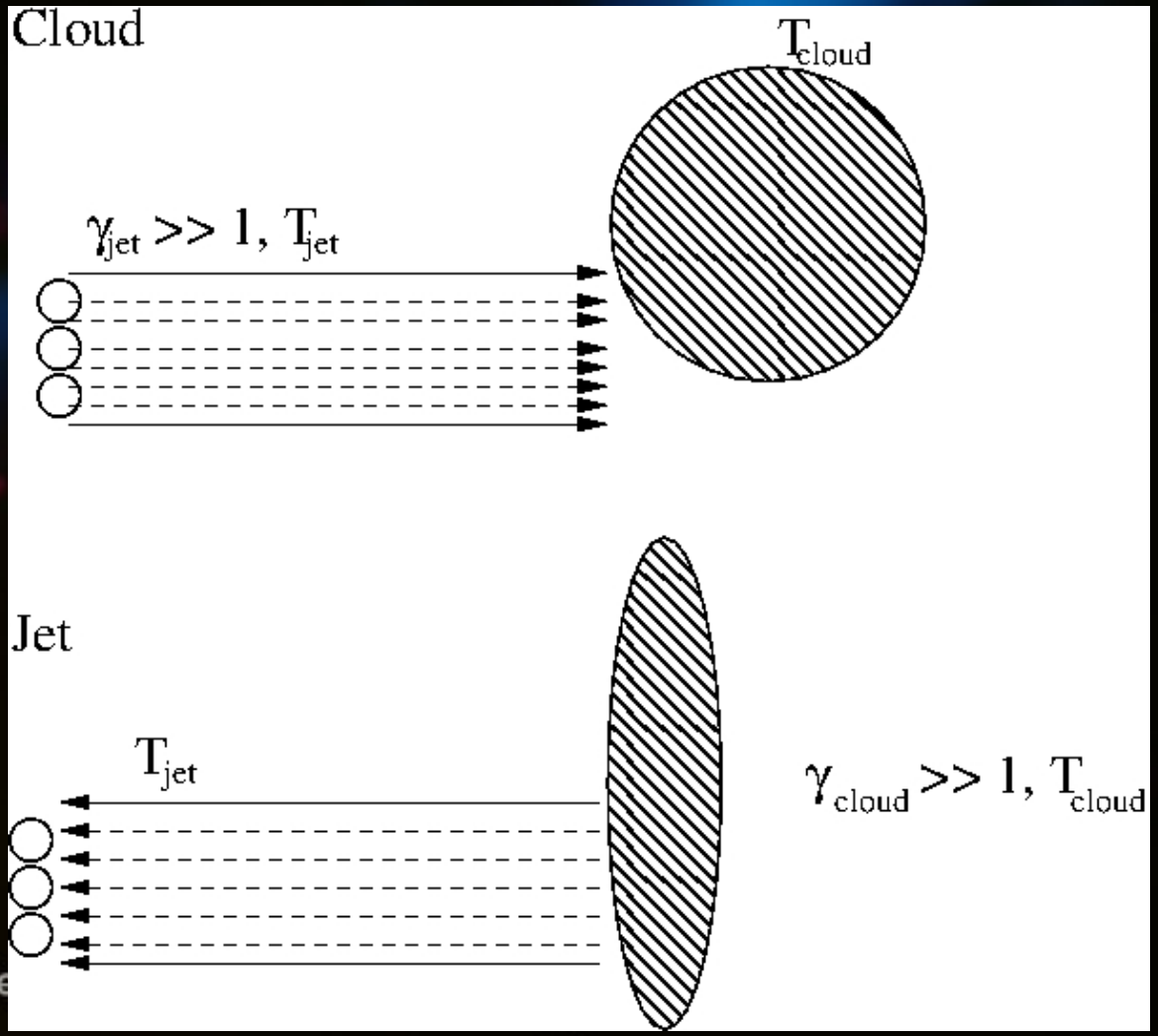
No unique relativistic temperature transformation!



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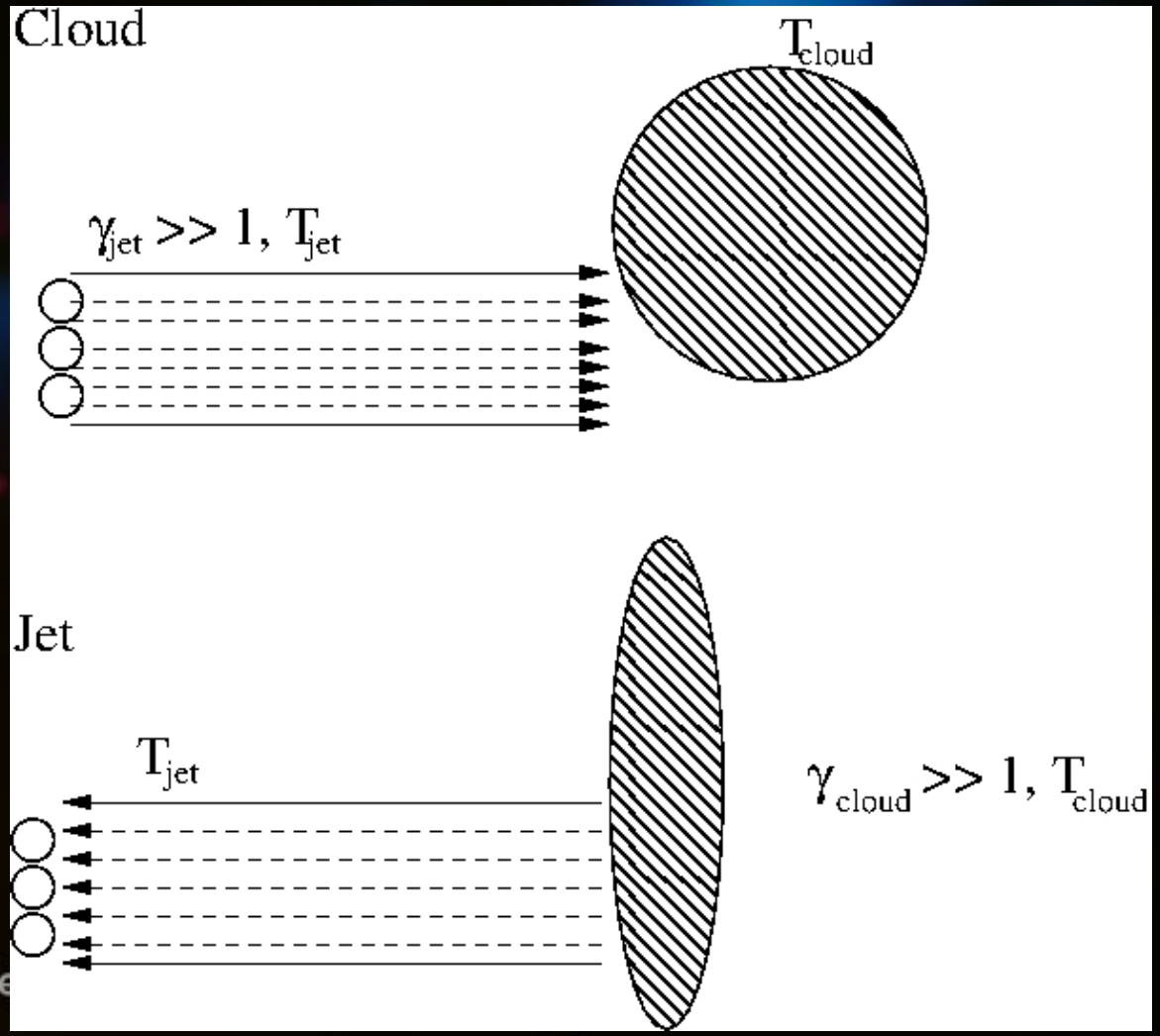
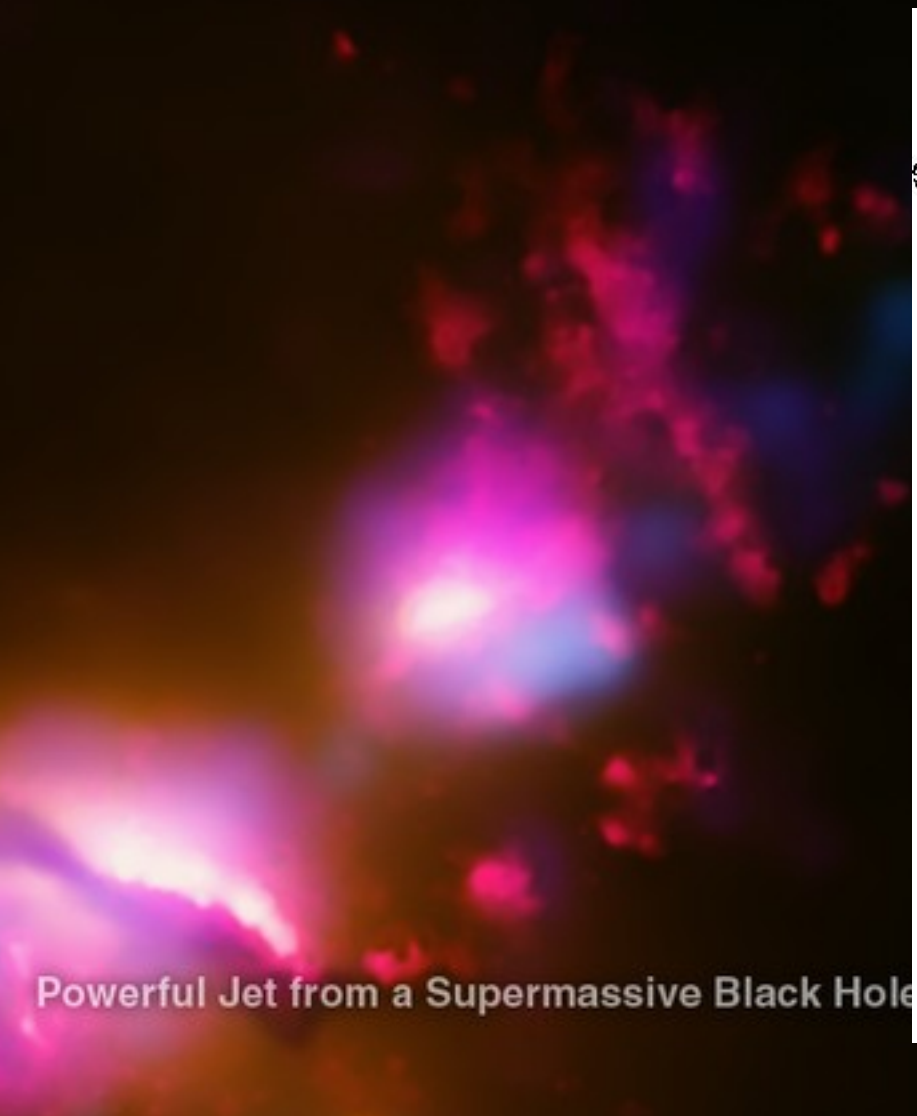
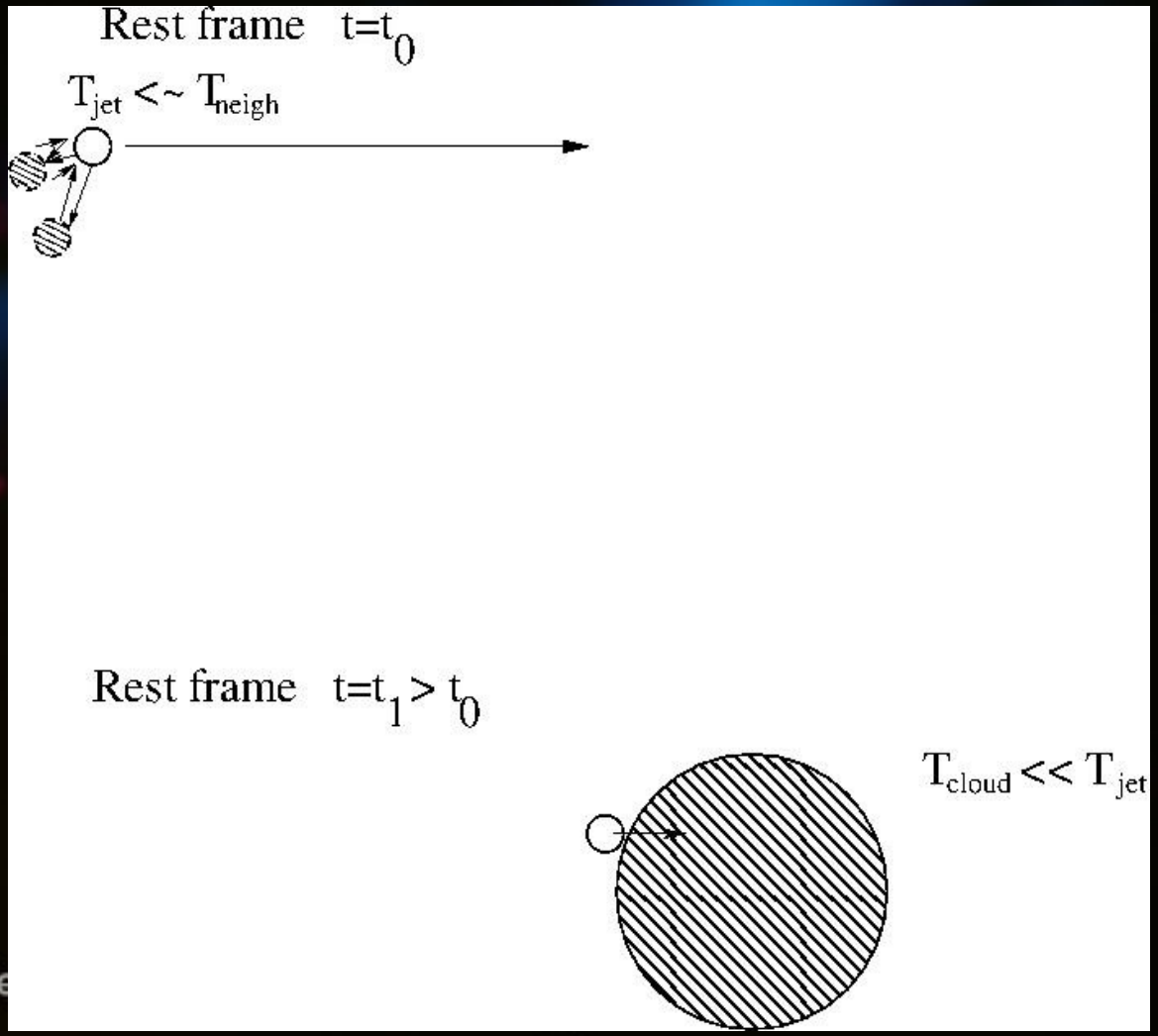
Astrophysicists implicitly assume $T_l = T_0$ **but** only *p* and *S* are scalars in SR



How *HOT* is a relativistic jet (contd.)?

In relativistic fluids the T transformation depends on the *thermodynamic process*





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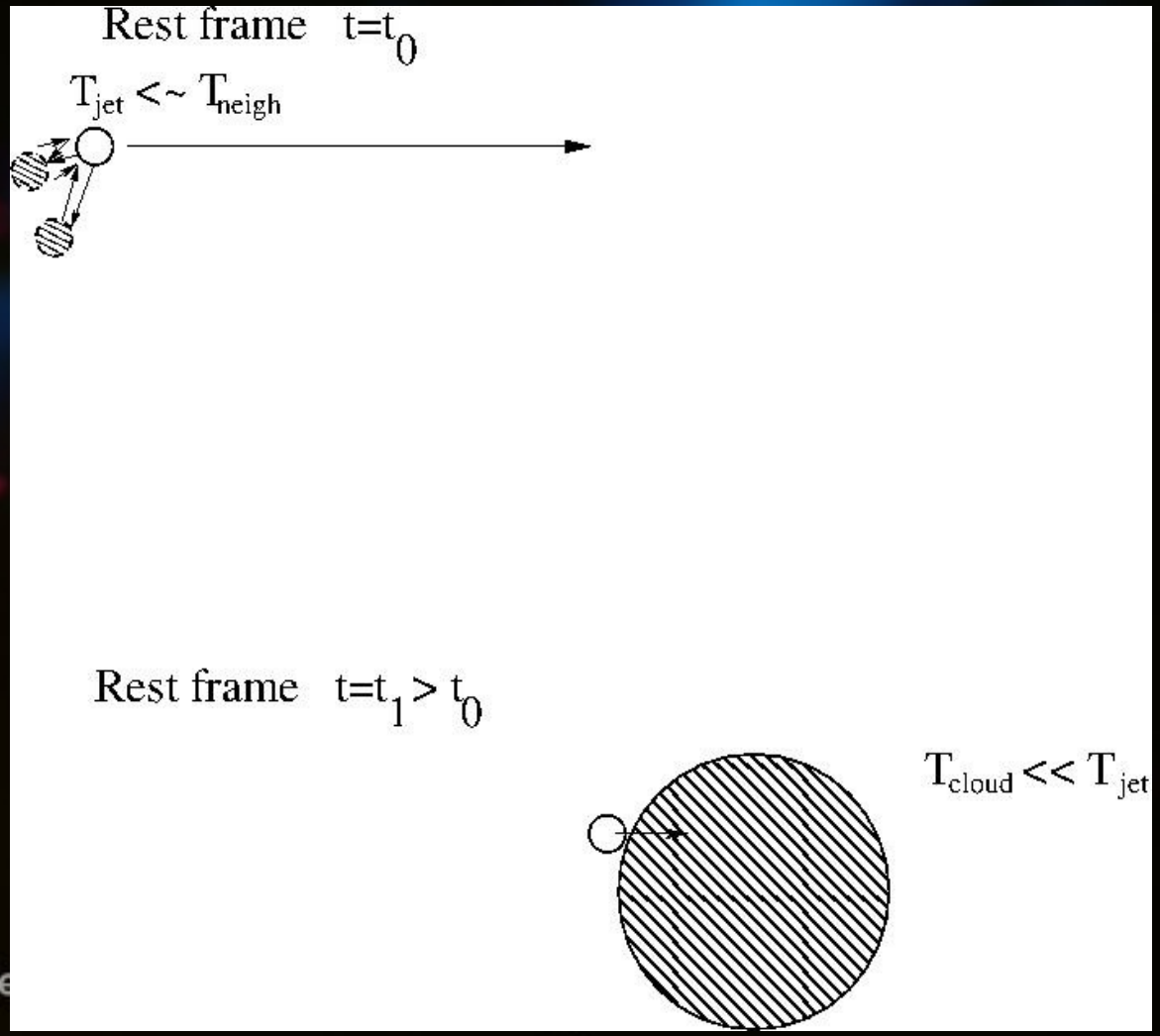
A fluid parcel exchanges some heat δQ at (rest frame) temperature T_{neigh}



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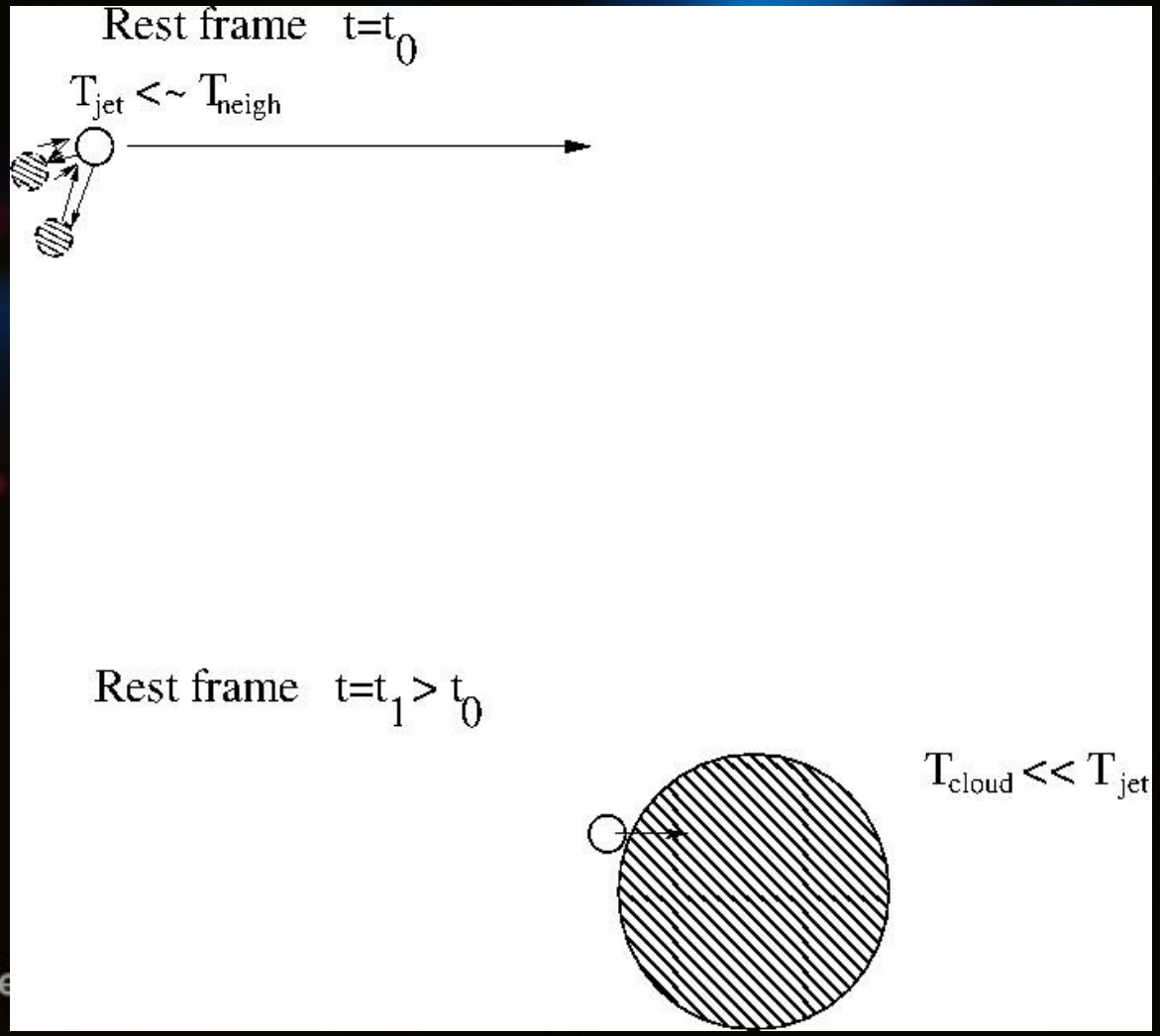

Powerful Jet from a Supermassive Black Hole

How *HOT* is a relativistic jet (contd.)?

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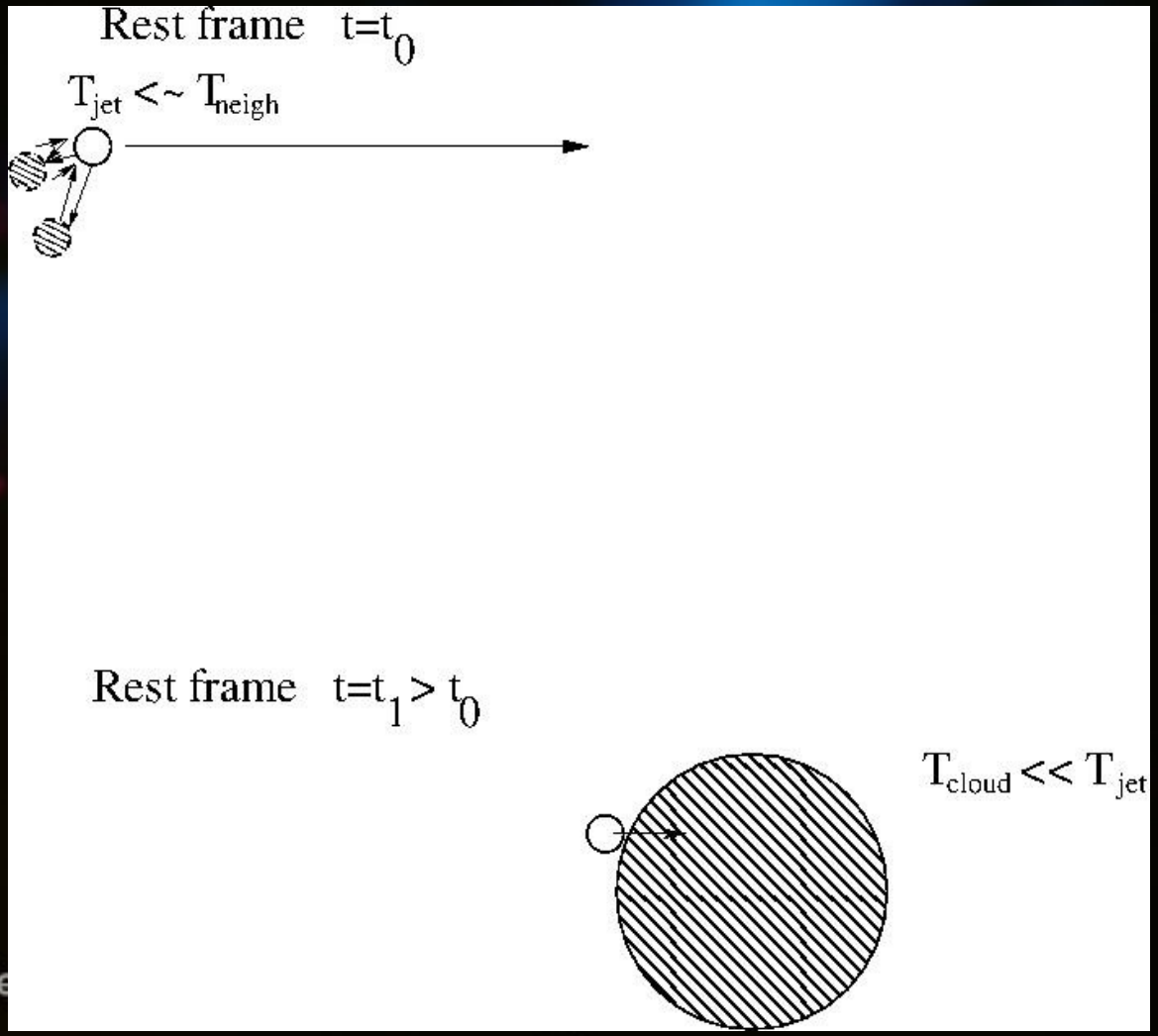
A fluid parcel exchanges some heat δQ at (rest frame) temperature $T_{jet} \sim T_{neigh}$

The parcel is then accelerated to rel. speed

The parcel hits a cloud ($T_{cloud} << T_{jet}$) and slowed down. It then releases some heat $\delta Q' = \gamma \delta Q$



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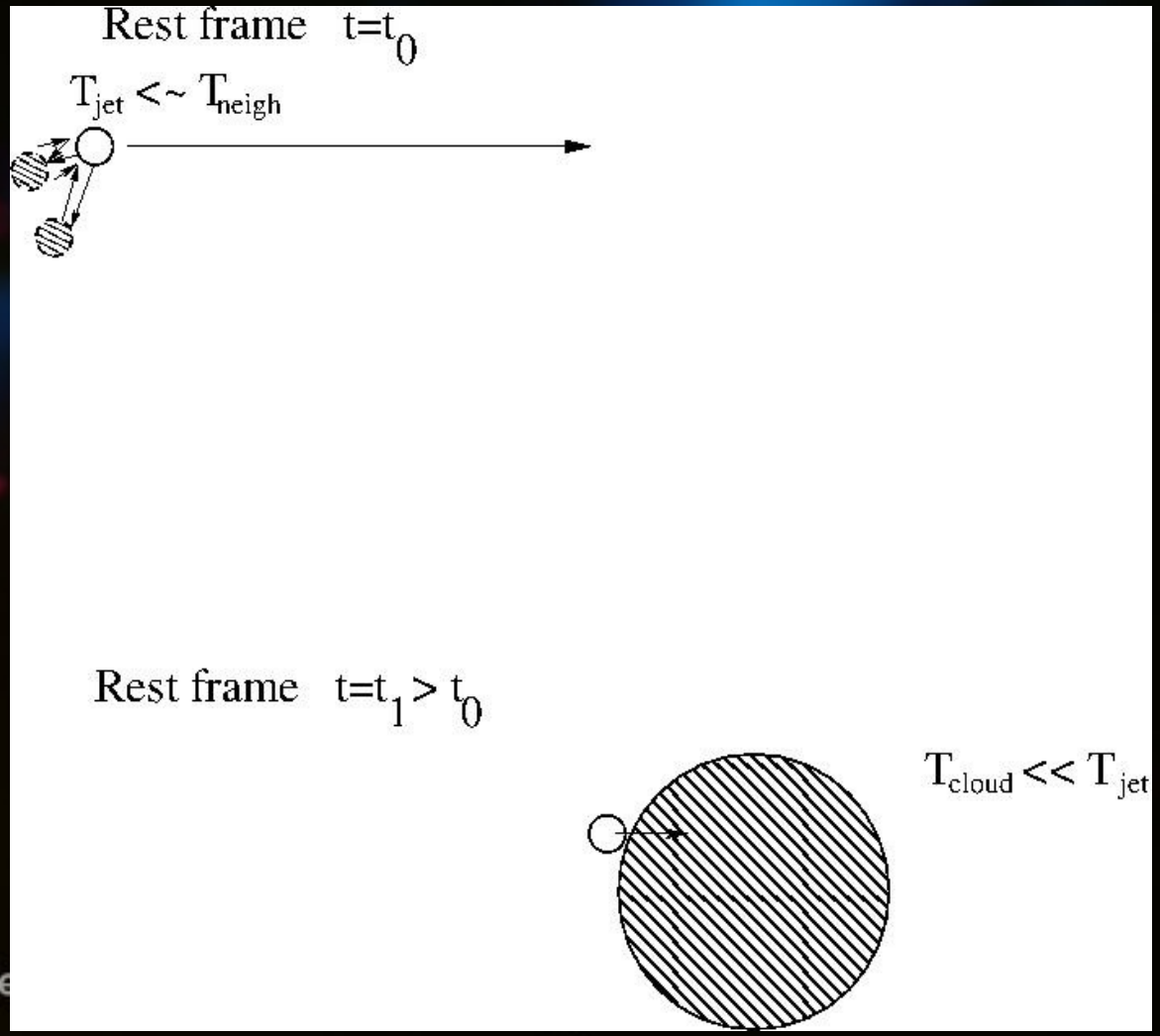
This is a Carnot cycle similar to Ott (1983). All transf. Are reversible, thus:
$\delta S = \delta Q'/T_{jet} + \delta Q/T_0 = 0$



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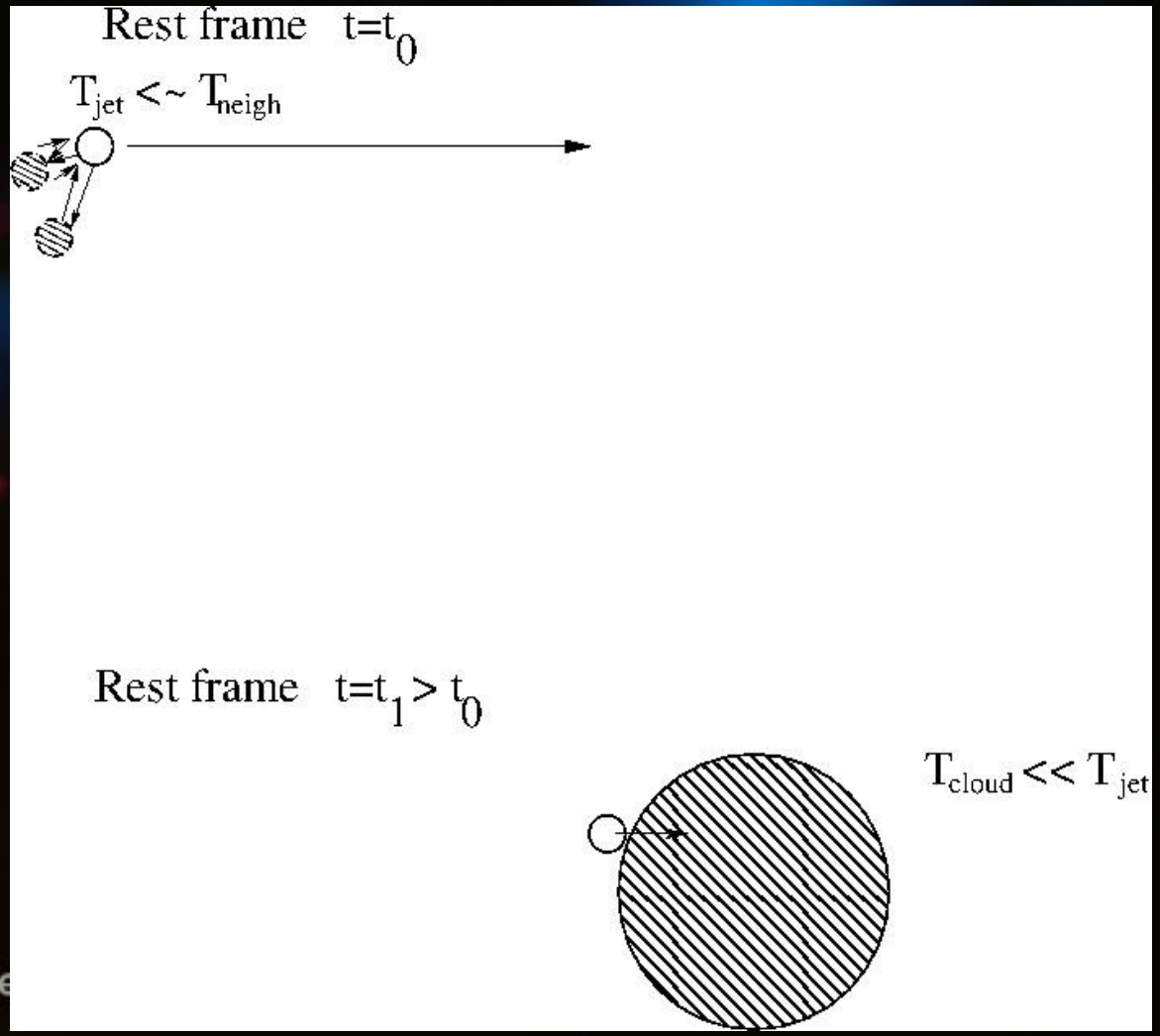
The jet appears **<u>hotter</u>** to the cloud



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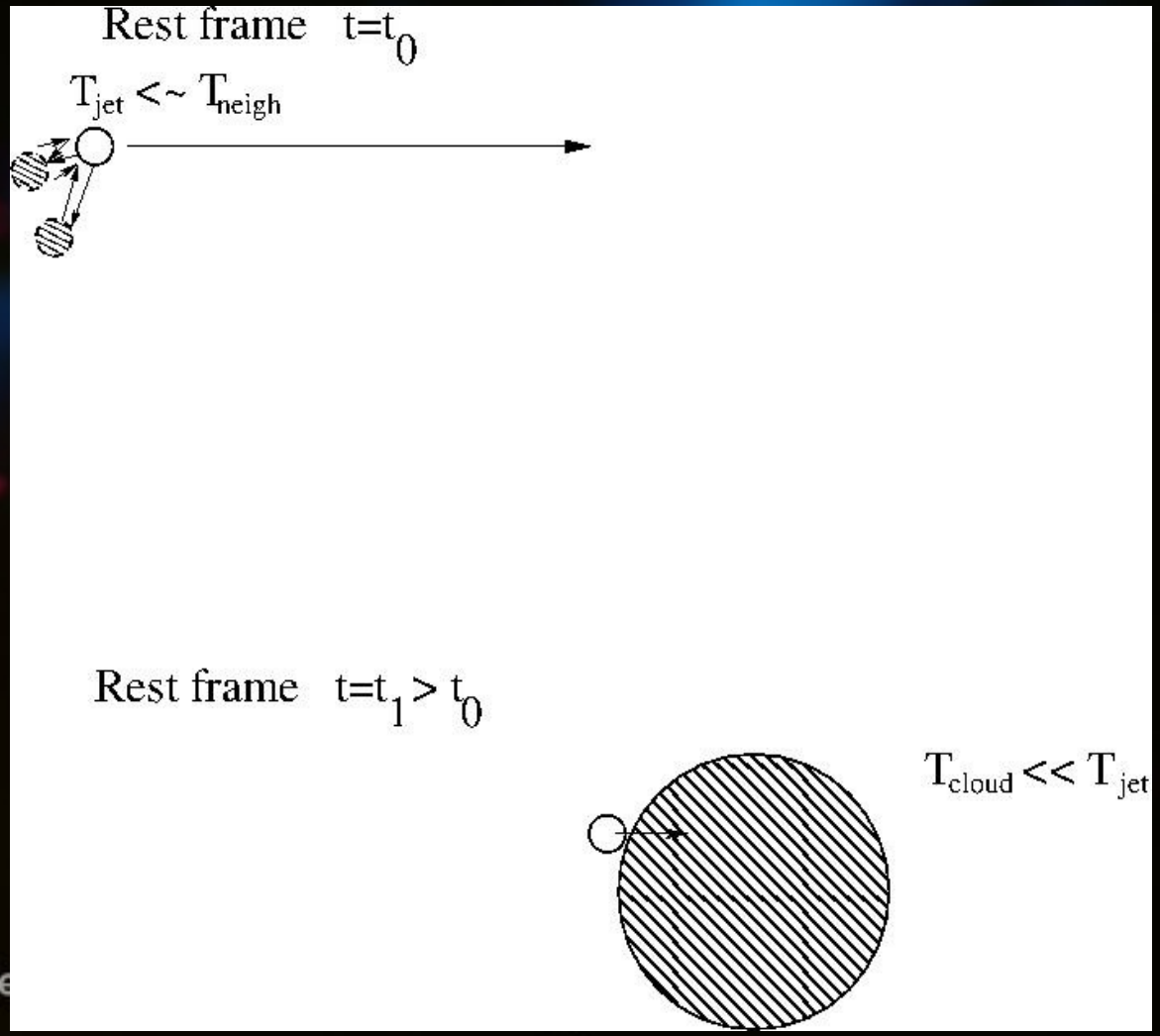
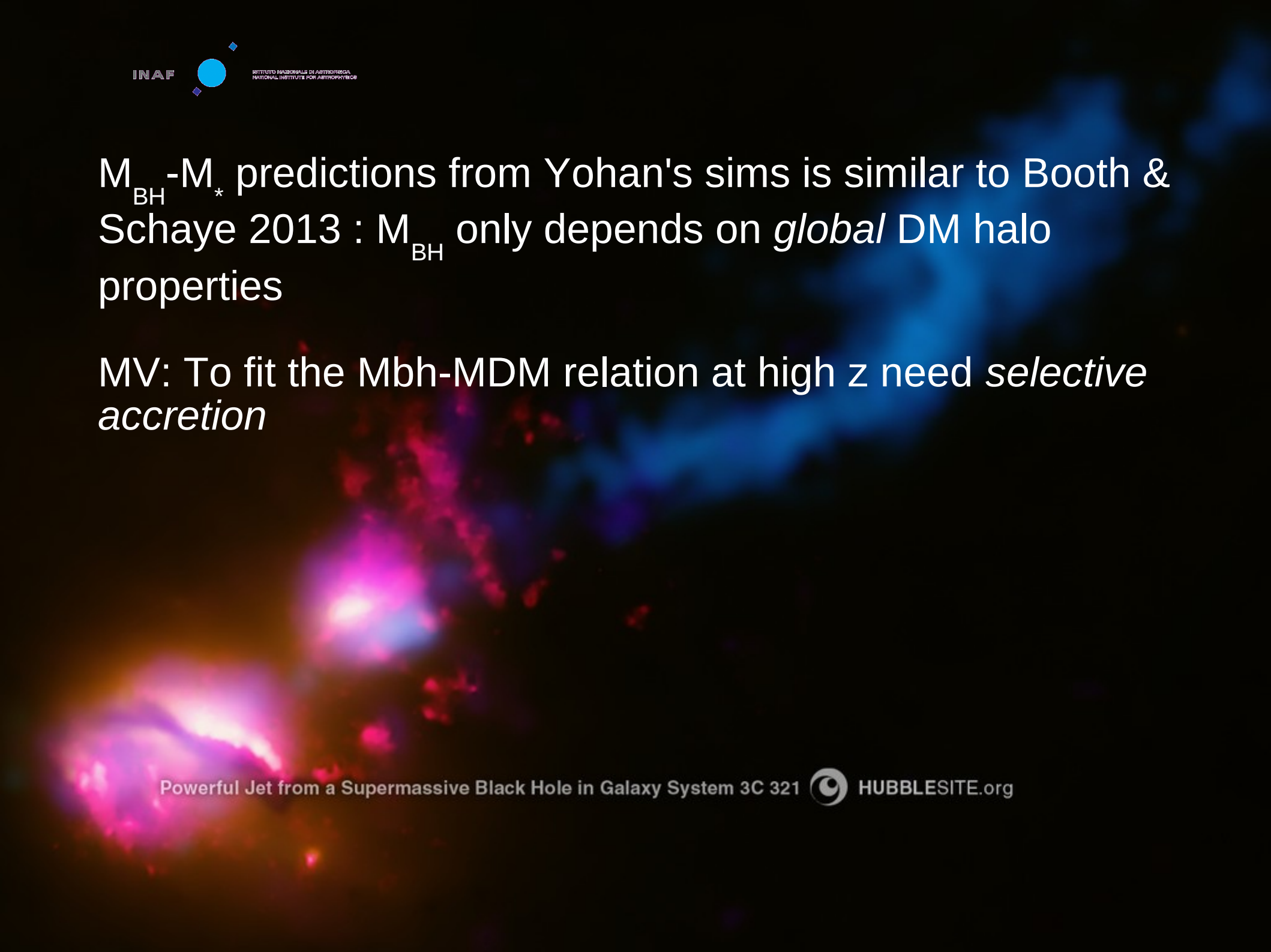
Spectral signature



M_{BH}-M_* predictions from Yohan's sims is similar to Booth & Schaye 2013 : M_{BH} only depends on *global* DM halo properties

MV: To fit the Mbh-MDM relation at high z need *selective accretion*



Open issues

-> Backflows: always present before t < 10-20 Myrs
Go to ~10-103 pc simulations, BH+disc dominate

-> Get ε_f for cosmological simulations (Yohan) from actual jet simuls. within *inhomogeneous* galaxies (cold, SF clouds)

-> ?