Black Holes-galaxies co-evolution
Physical Models

V. Antonuccio-Delogu
INAF-Catania Astrophysical Observatory

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Galaxy-SMBH connection: the numerical gap

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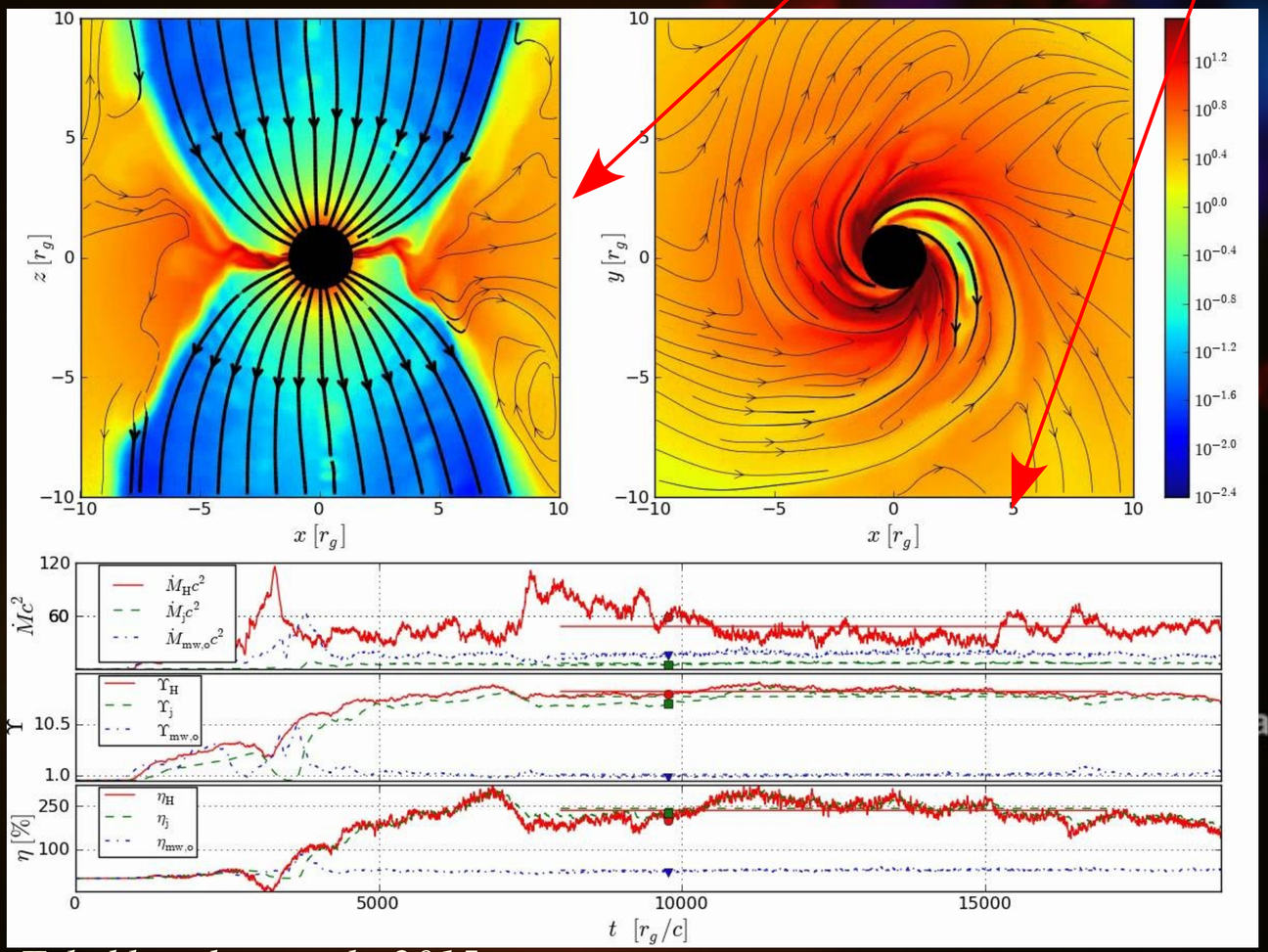
Galaxy-SMBH connection: the numerical gap

- Accretion/jet production region: $R_d \sim 10^3\ r_g$ $(\sim 4.78 * 10^{-3}\ \mathrm{pc})$



Tchekhovskoy et al., 2015

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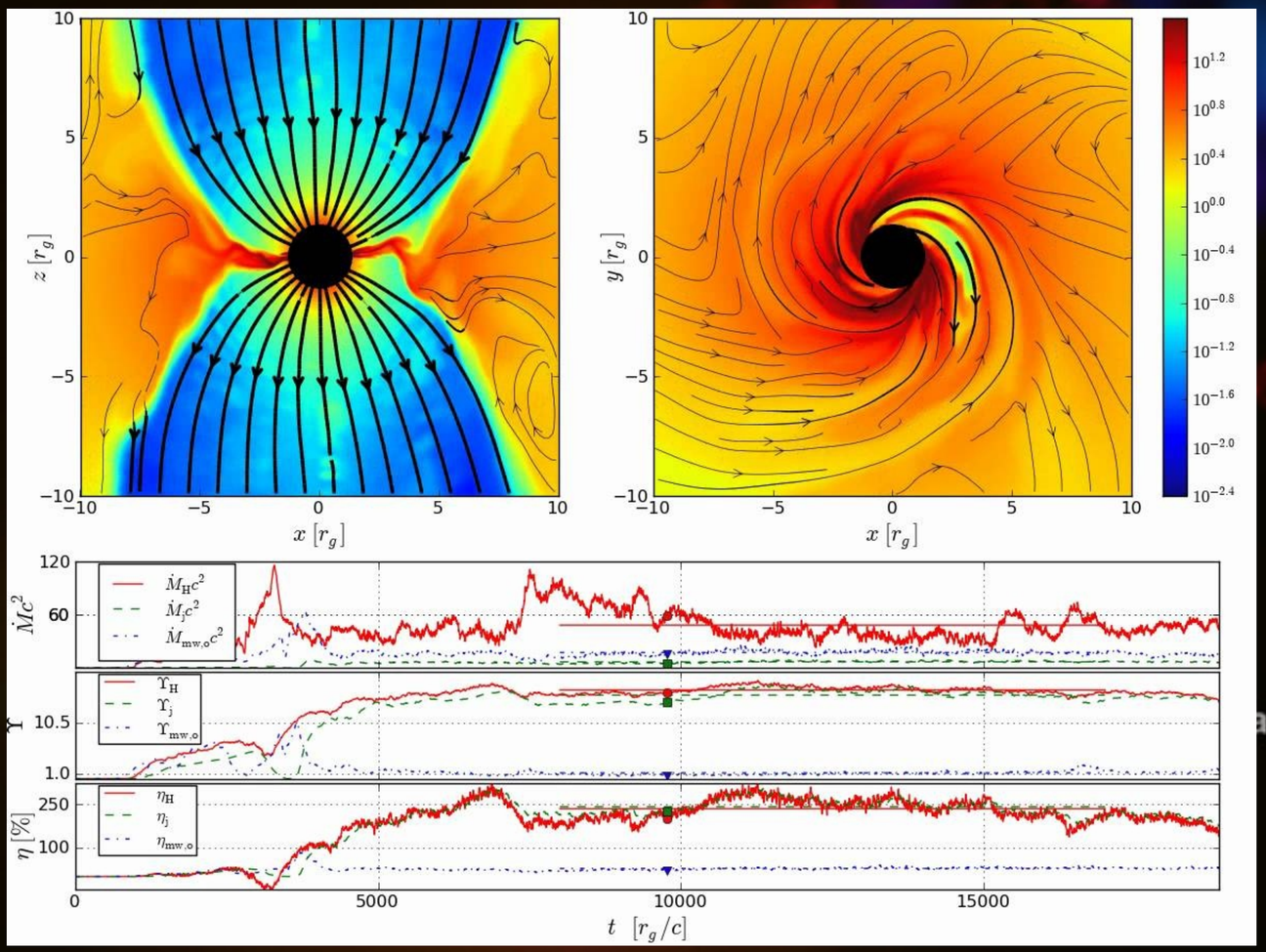

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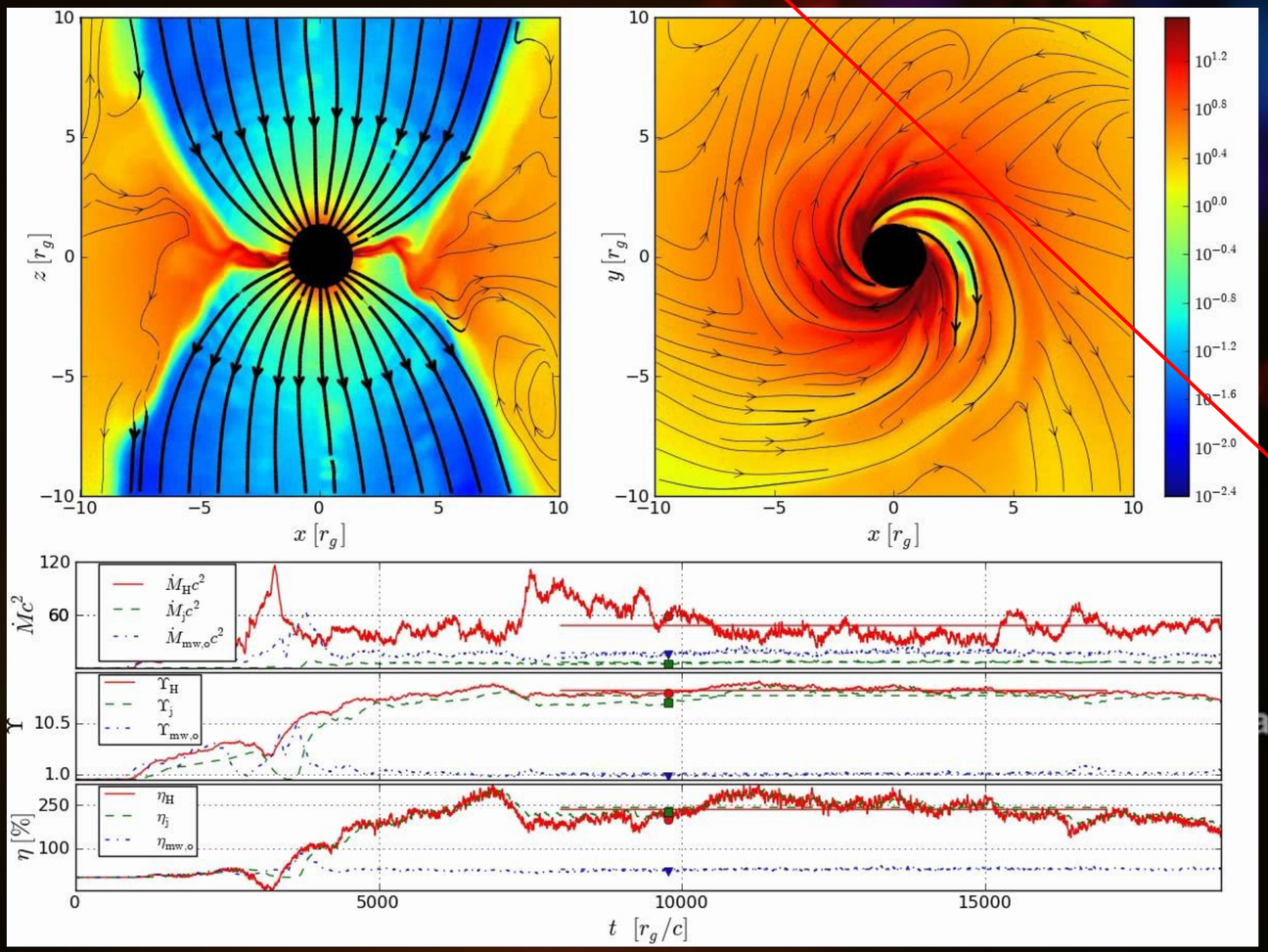

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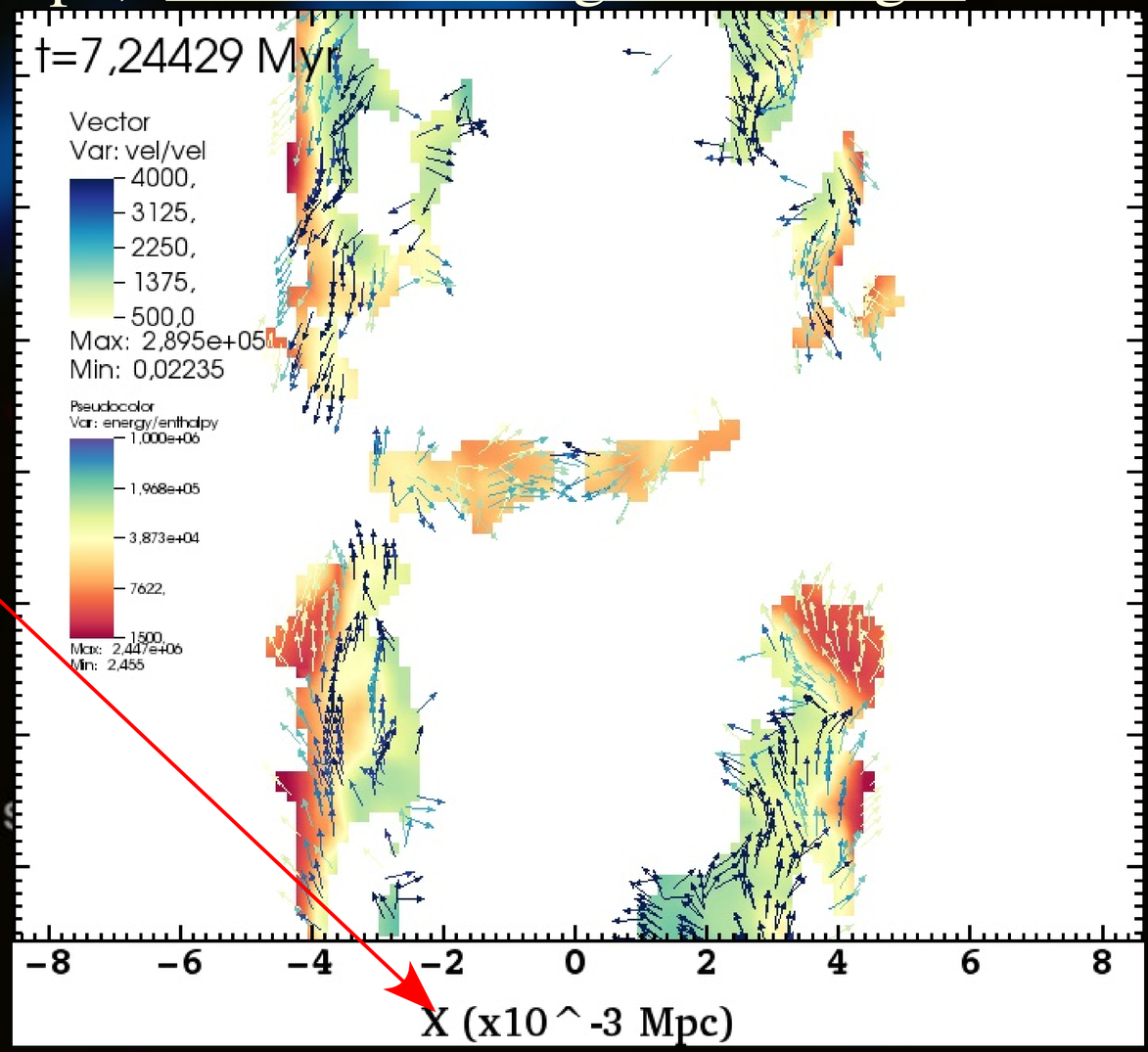
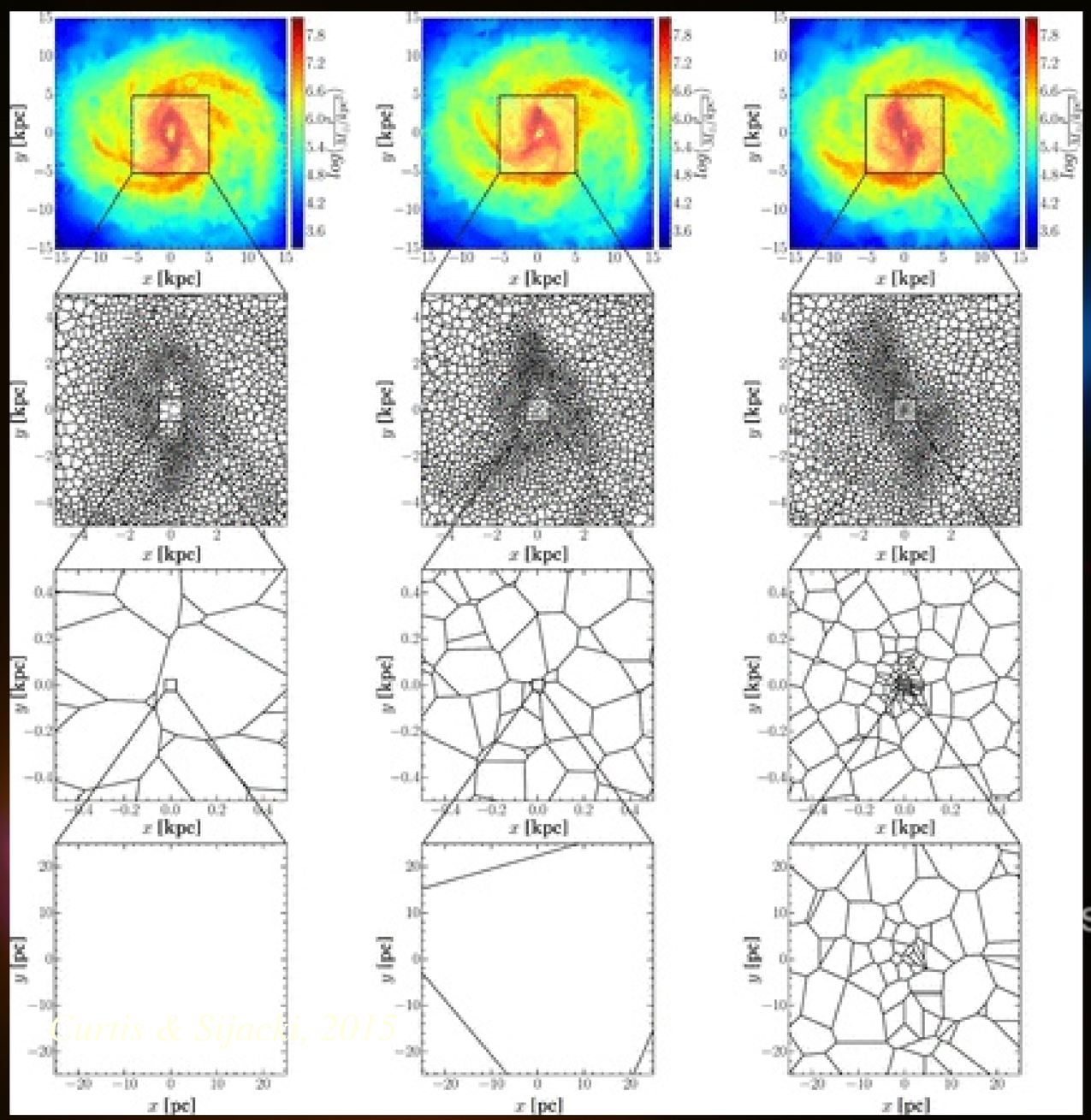


Cielo et al et al., 2015

Galaxy-SMBH connection: HOW TO FILL the numerical gap?

- AREPO (TreeSPH, *Springel*) + HPC parallel *simulations*



Curtis & Sijacki., 2015

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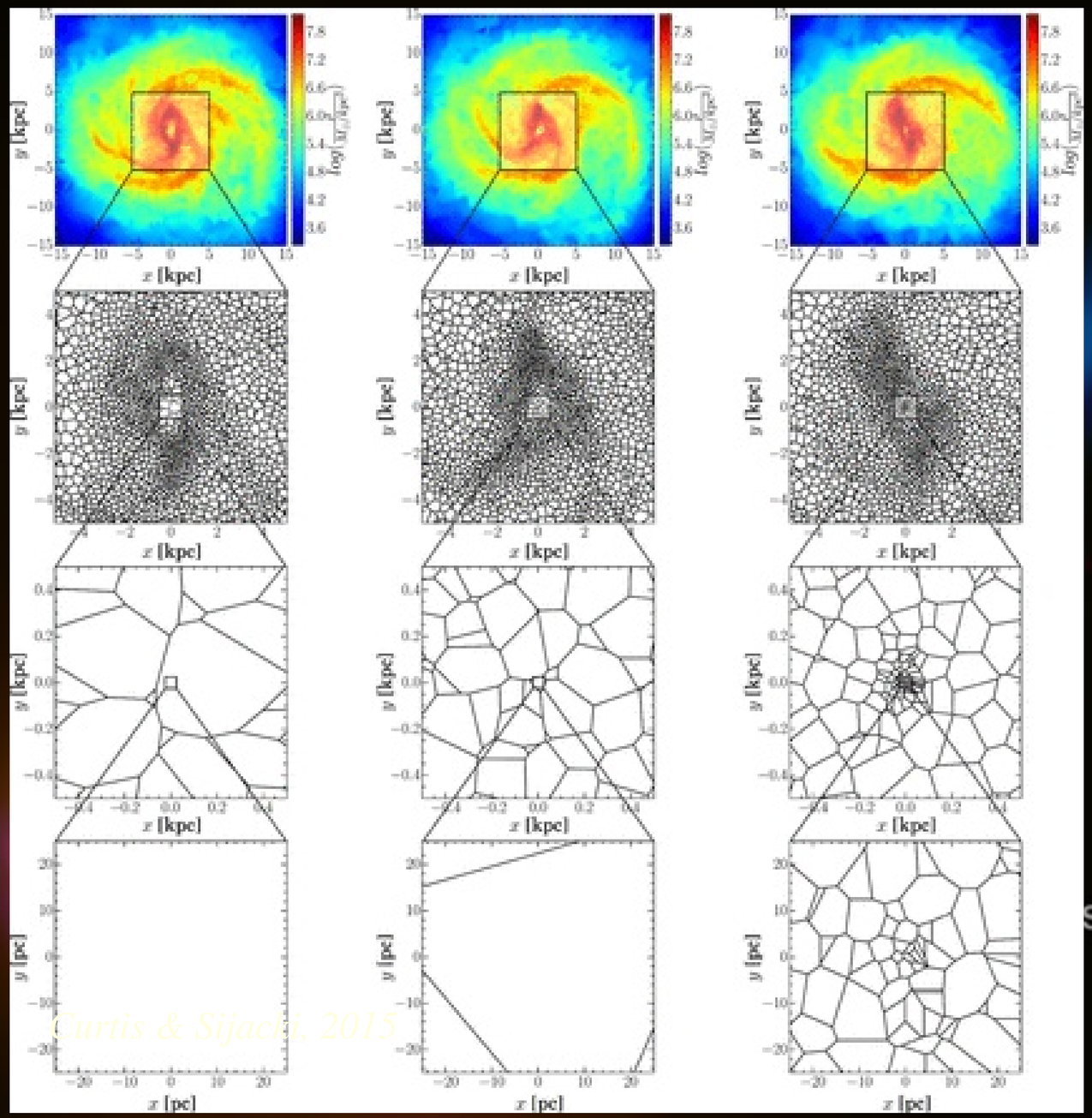

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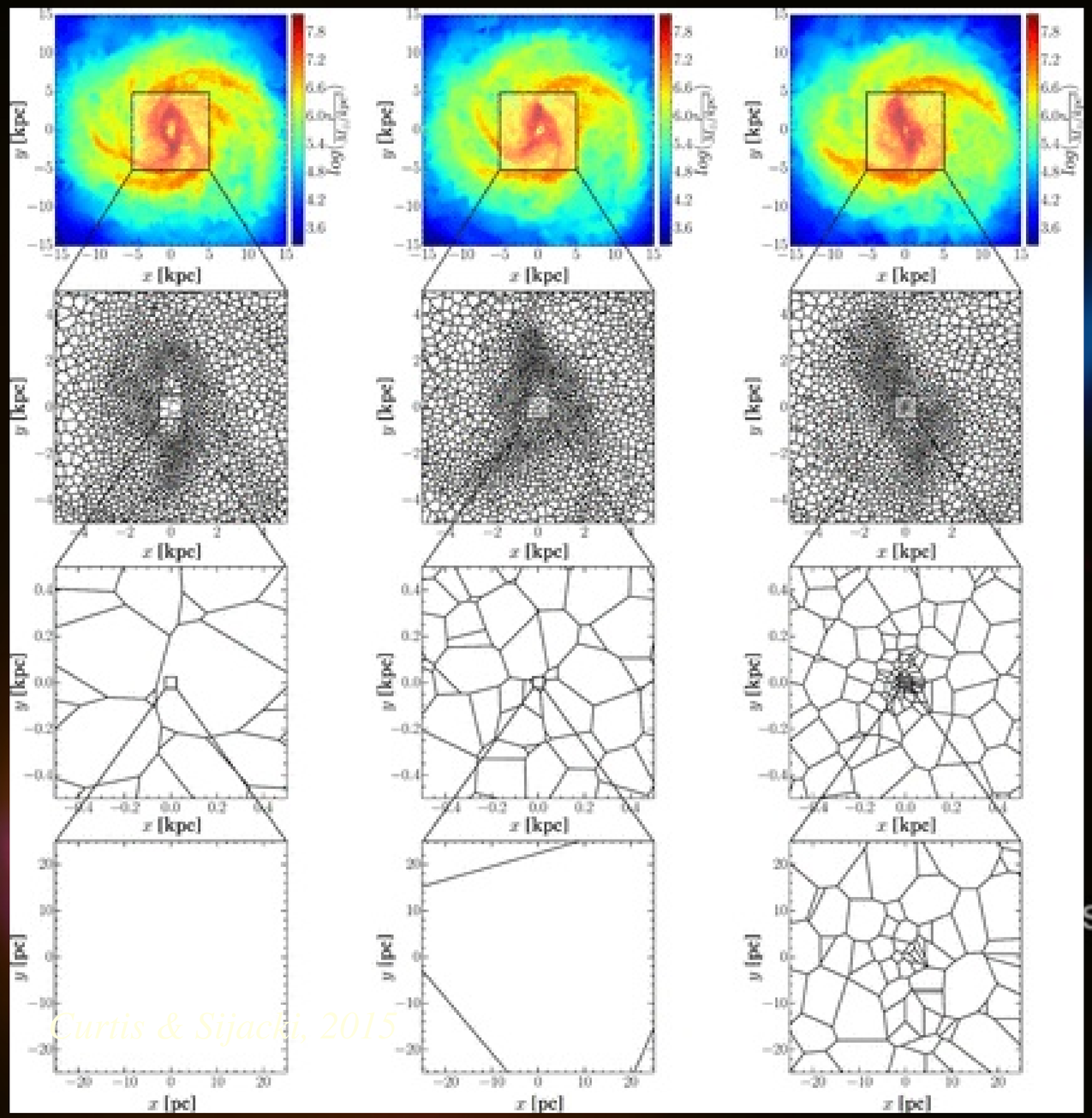

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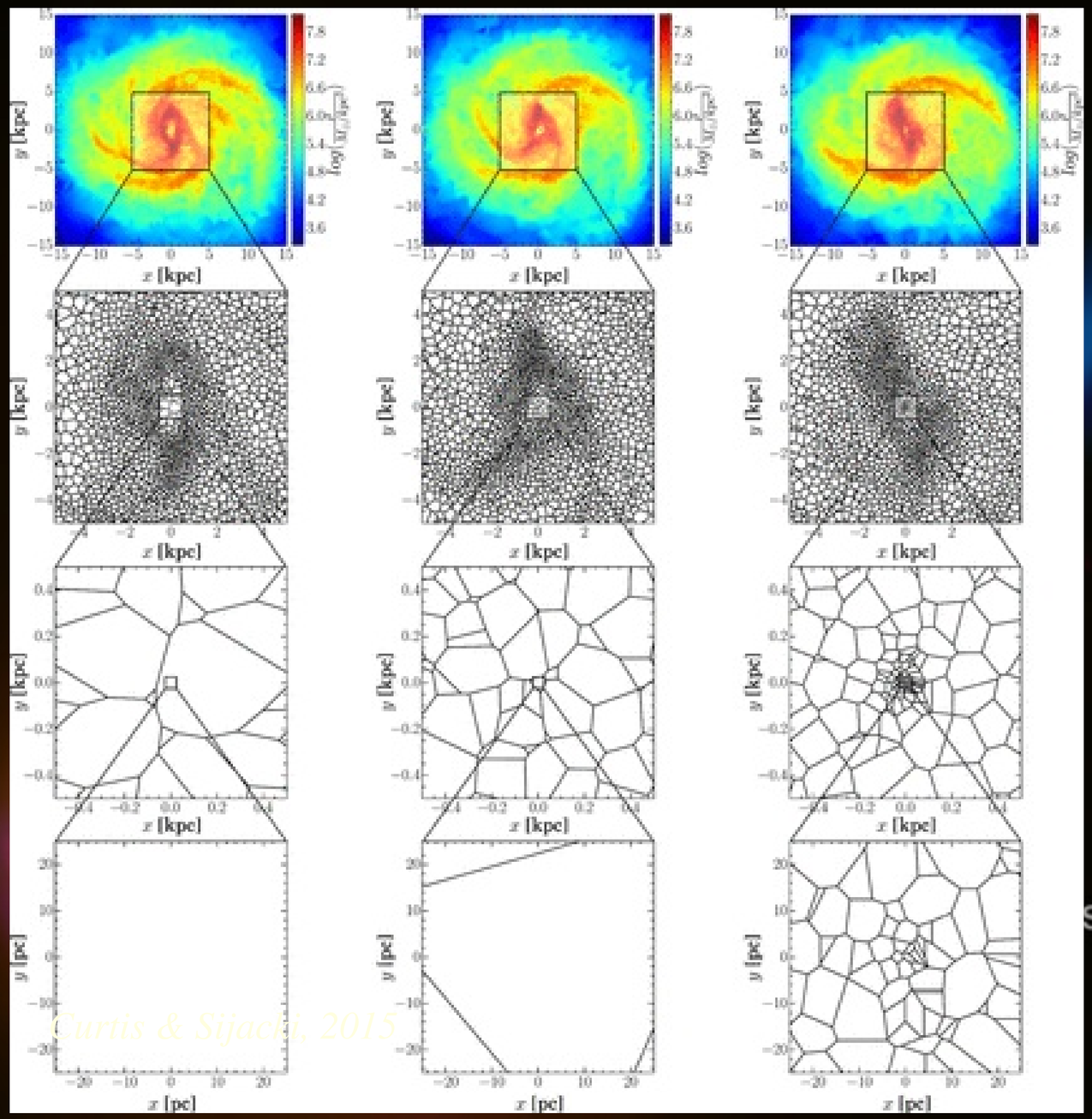

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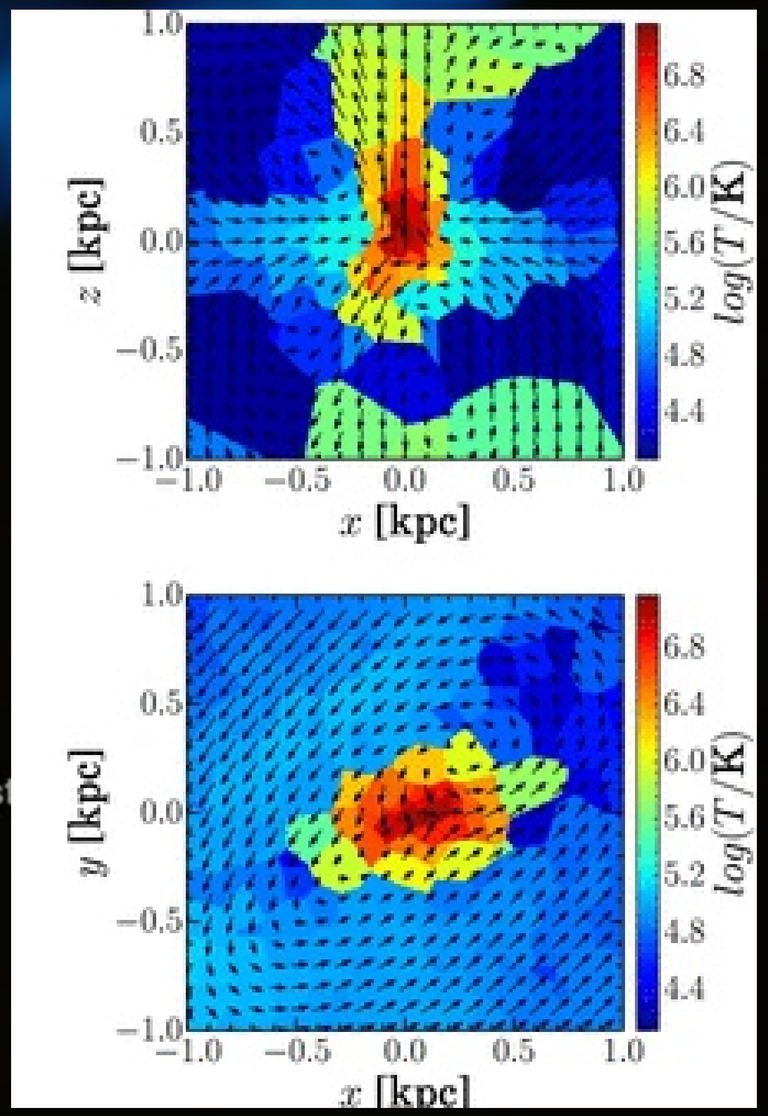

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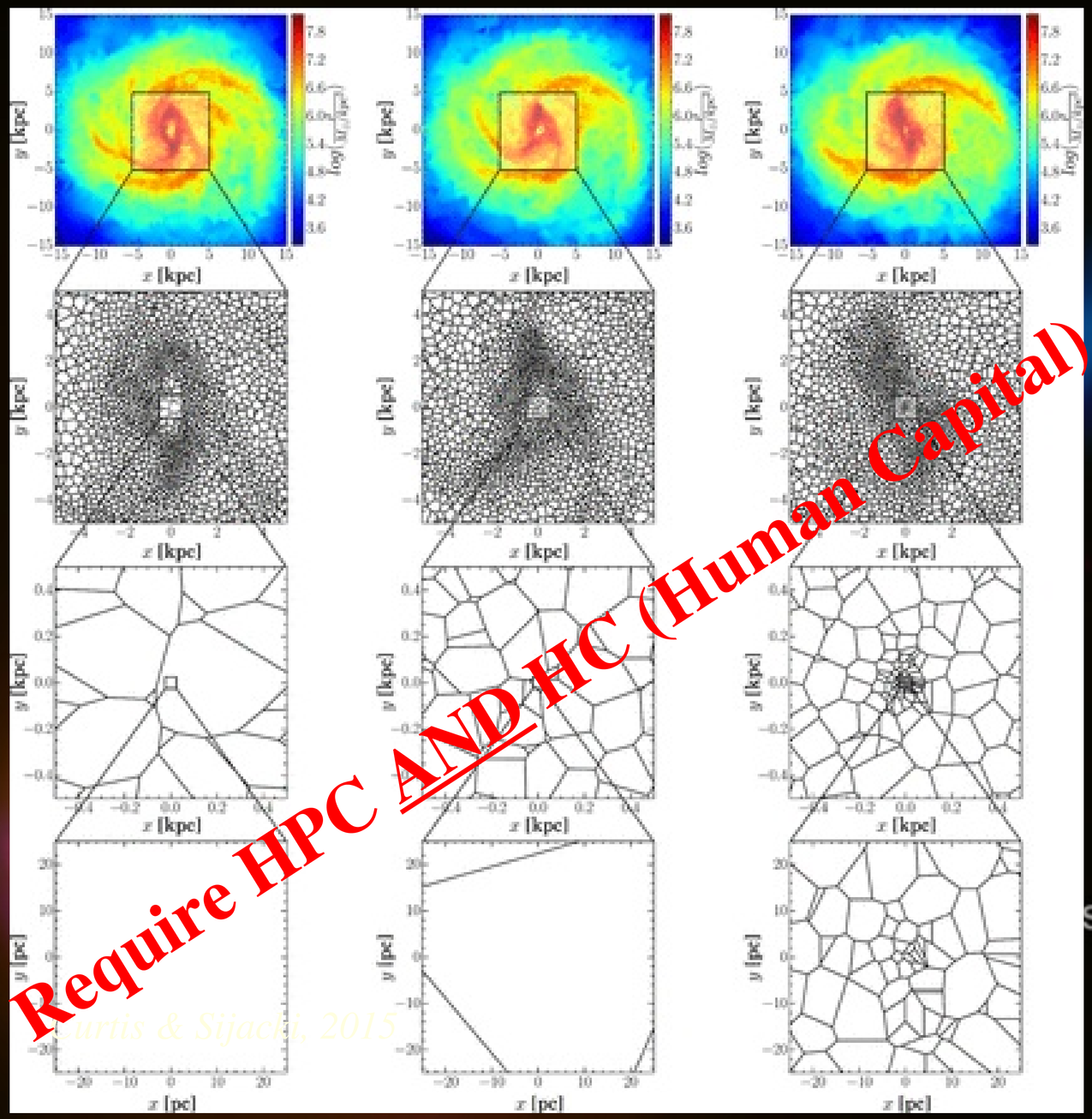

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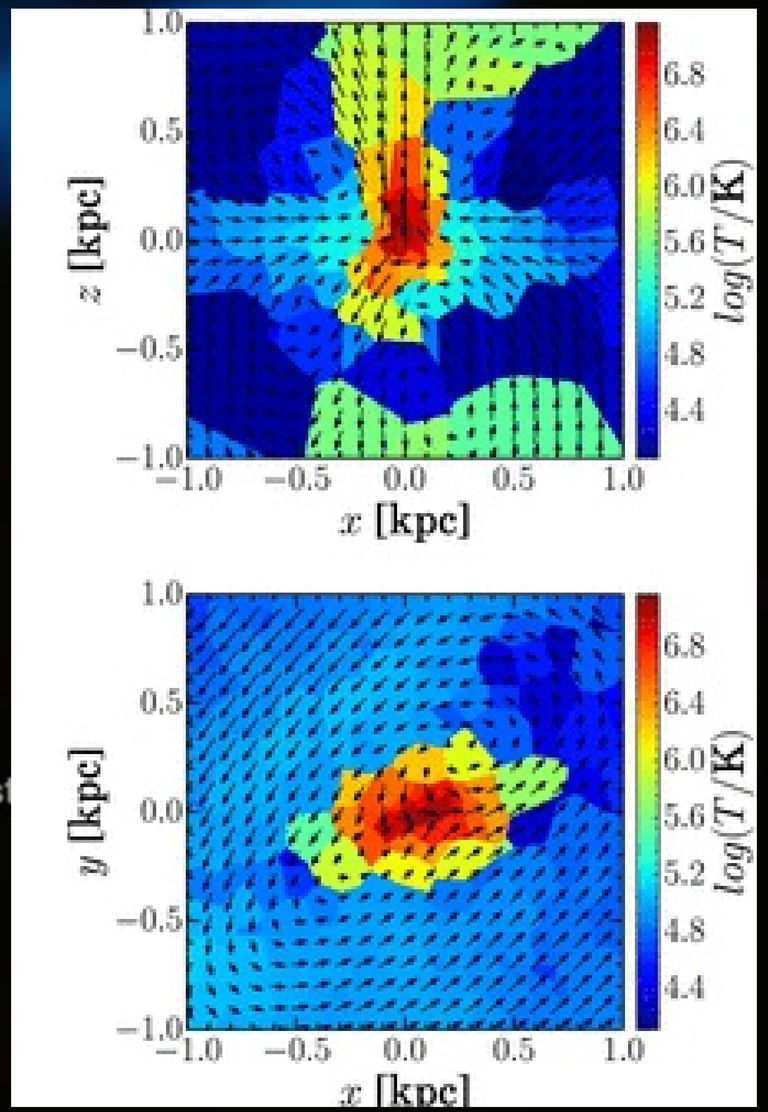
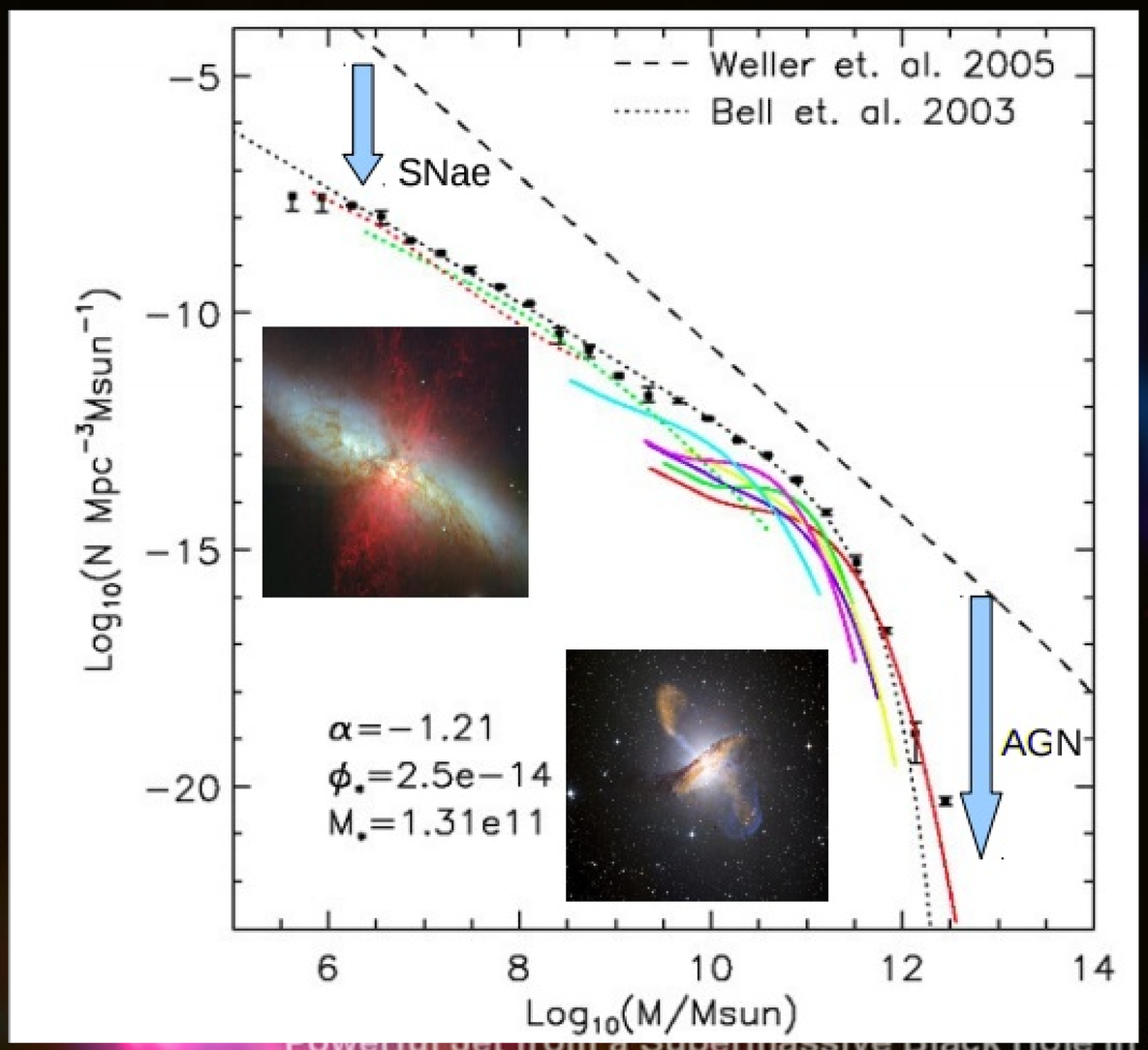


Require HPC AND HC (Human Capital)

Negative AGN feedback ("*quenching*")



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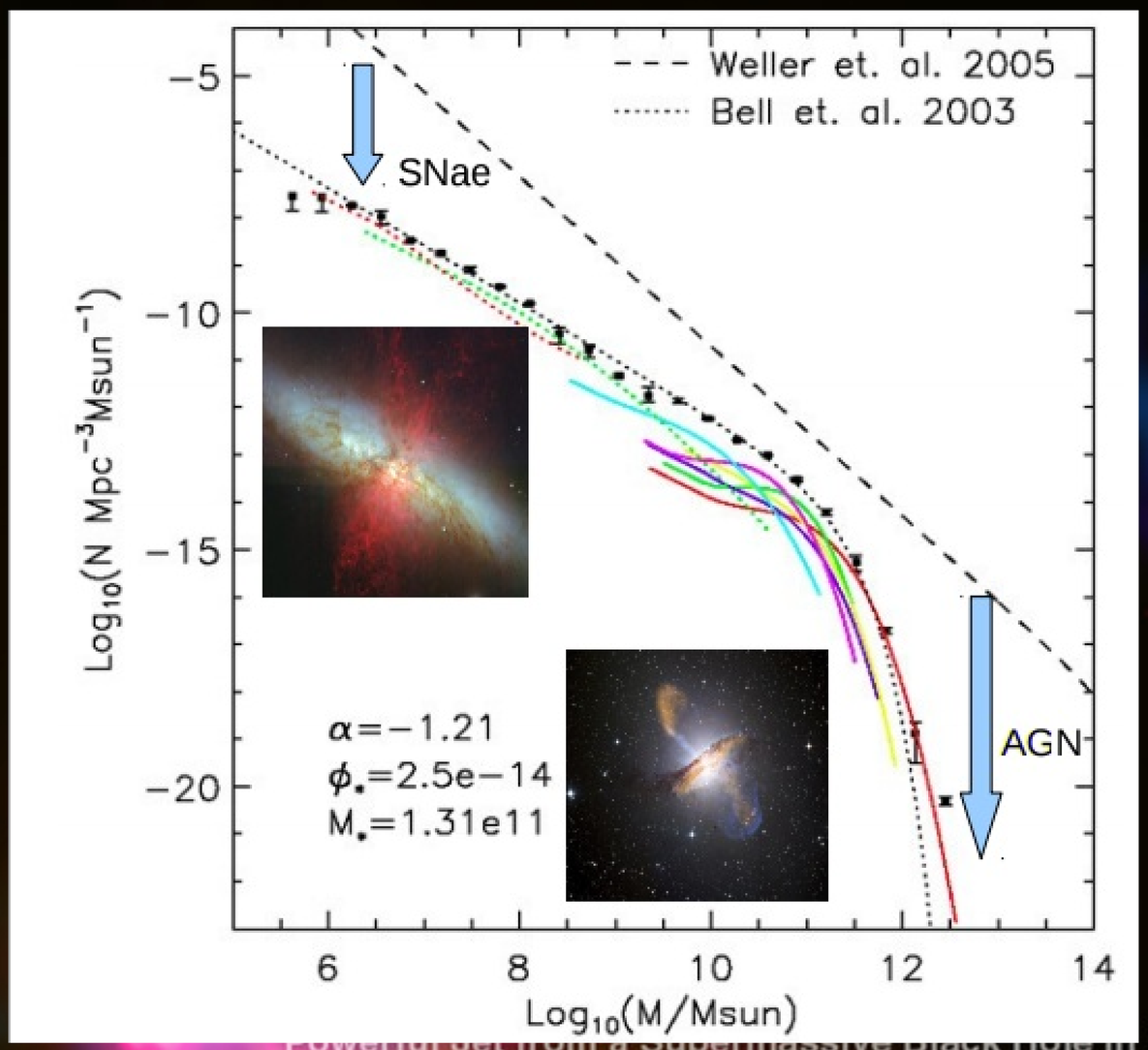

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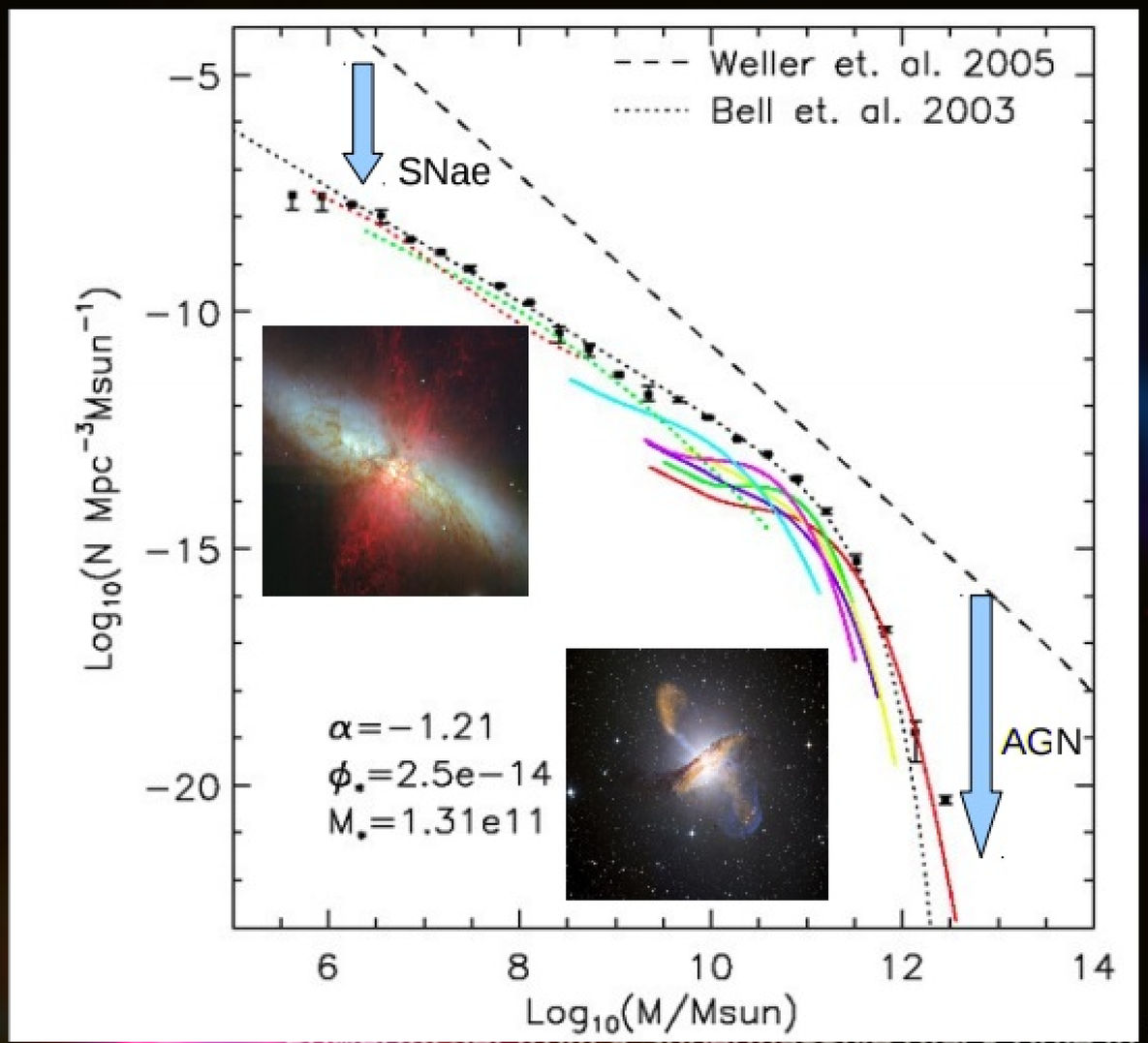

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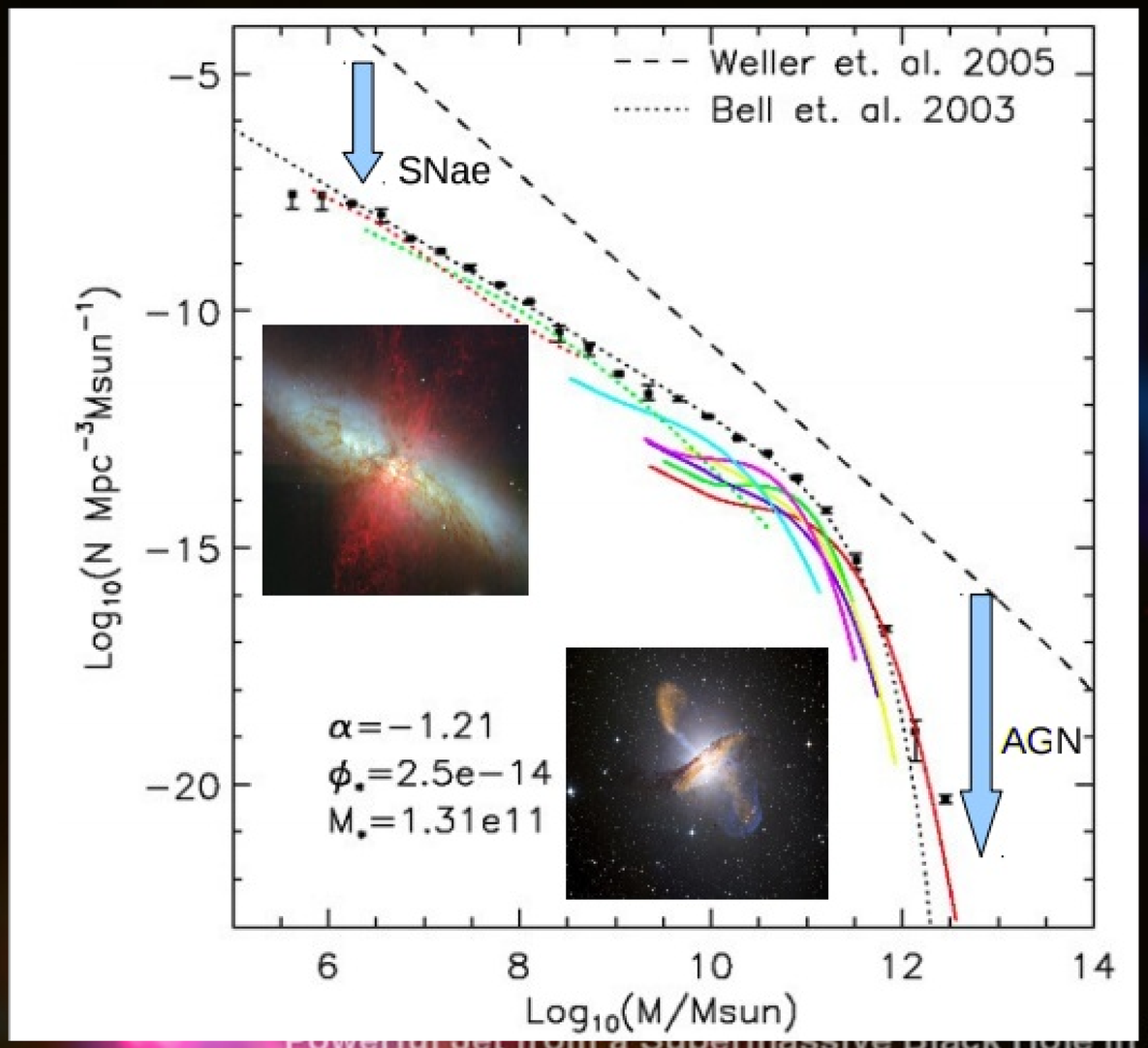

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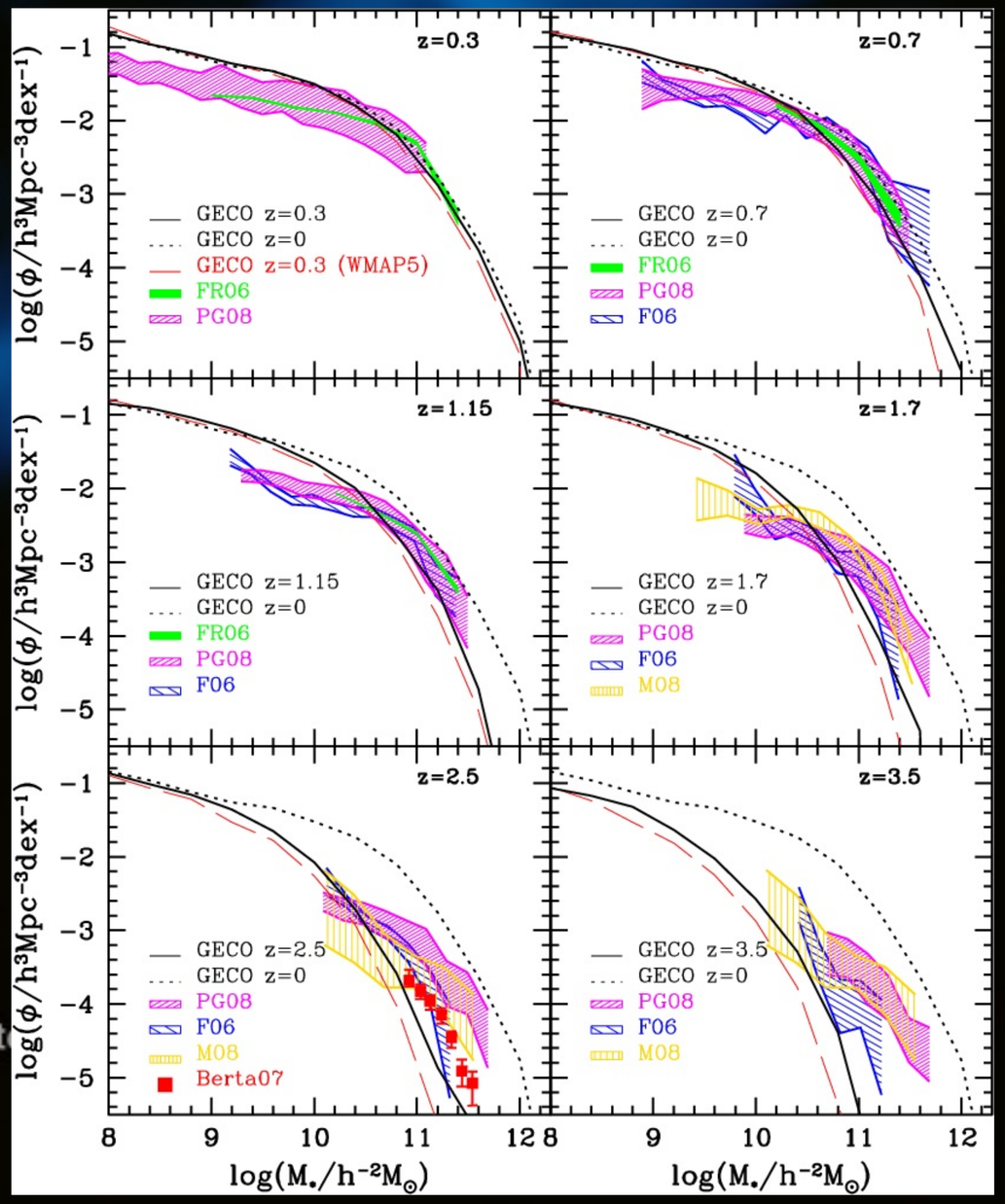

GECO: Ricciardelli & Franceschini, 2010

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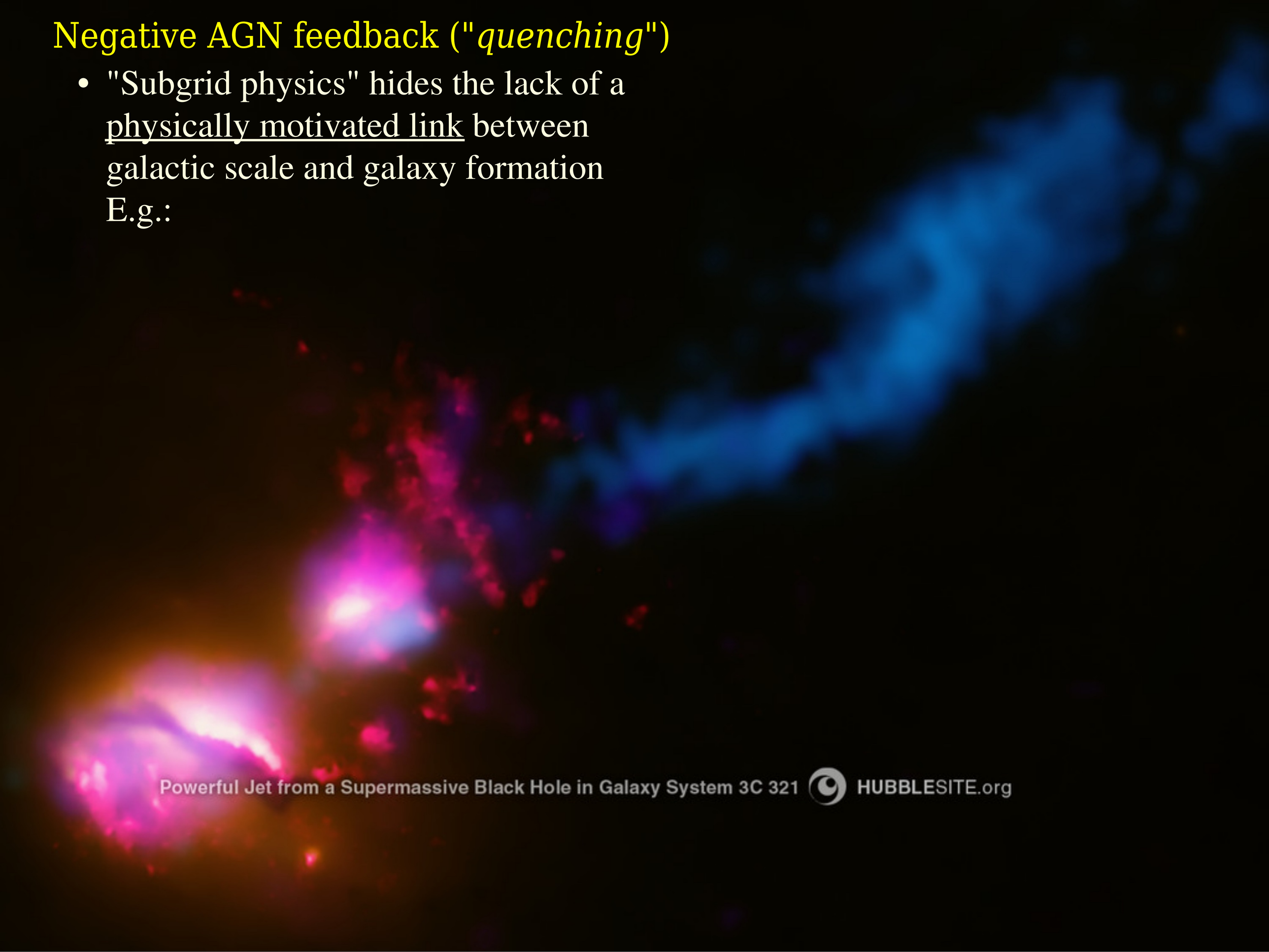

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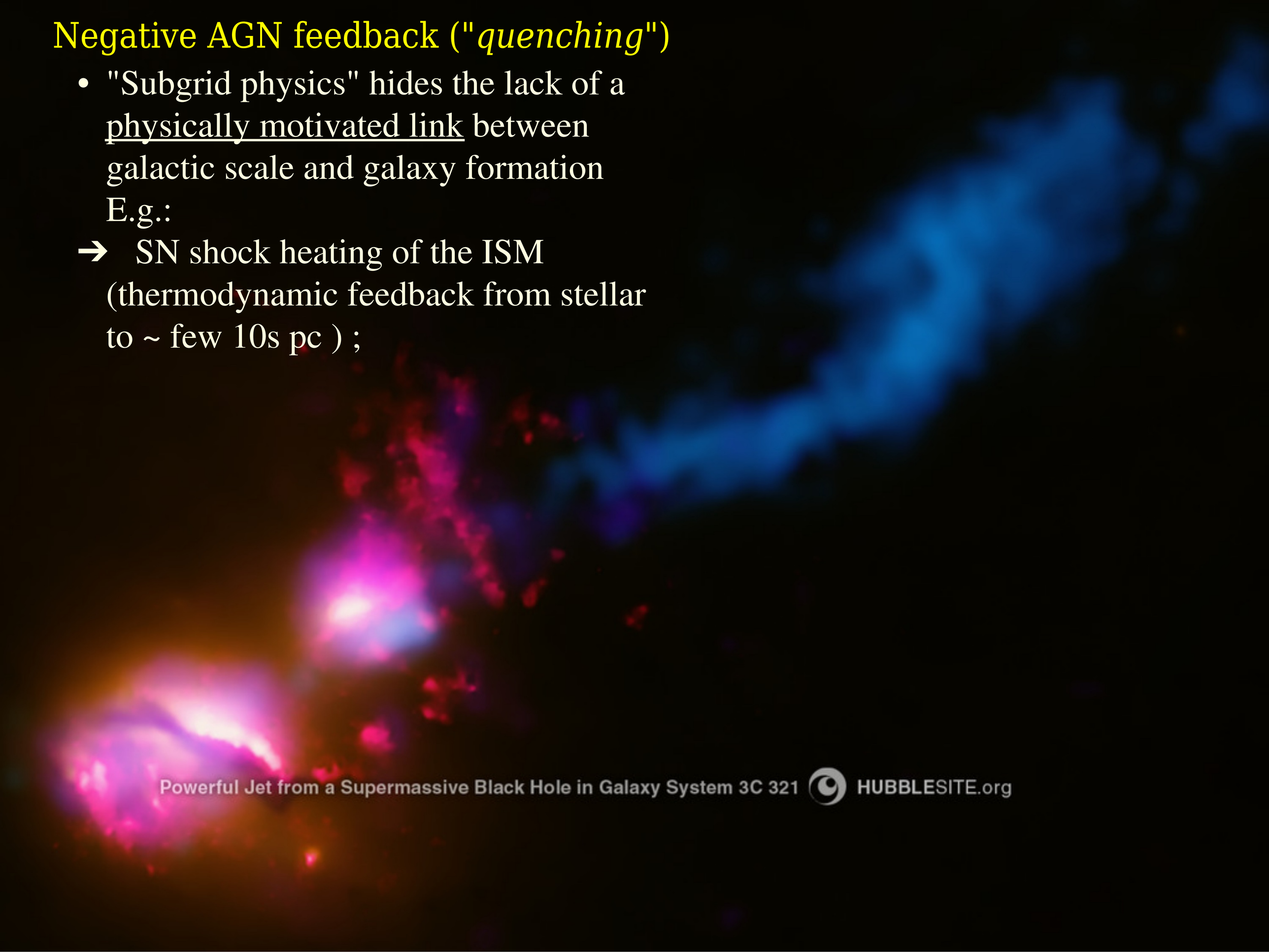

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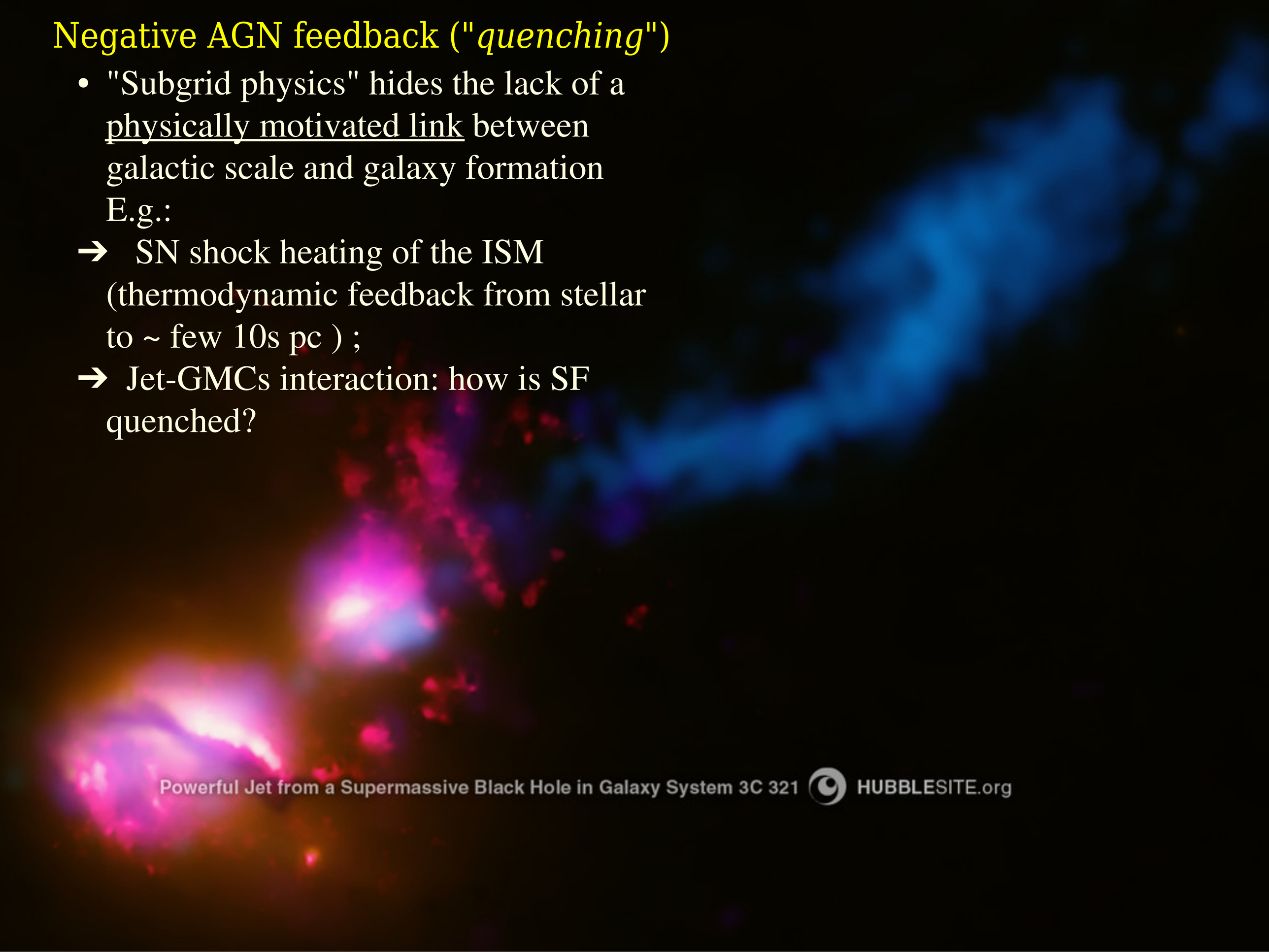

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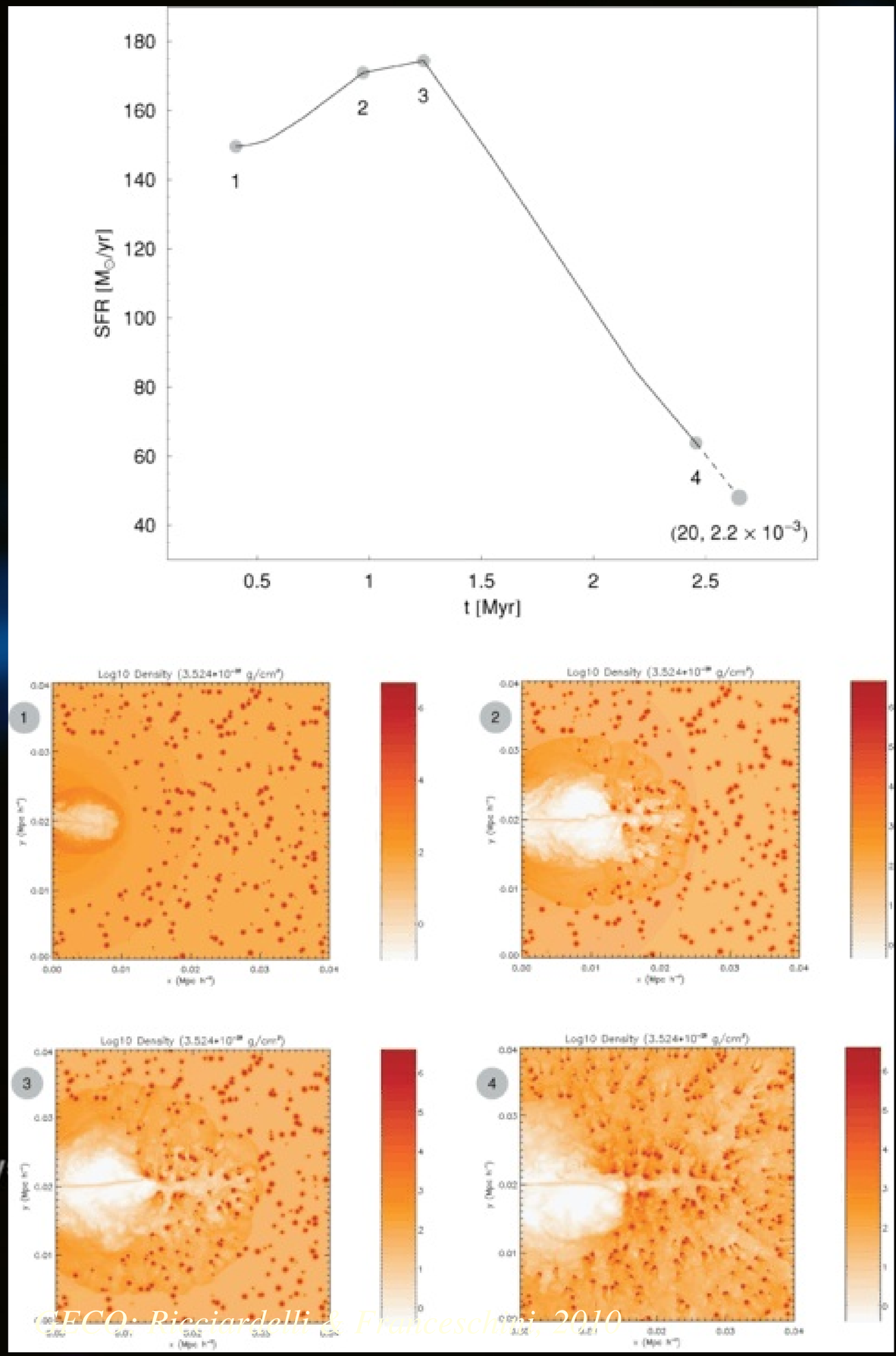

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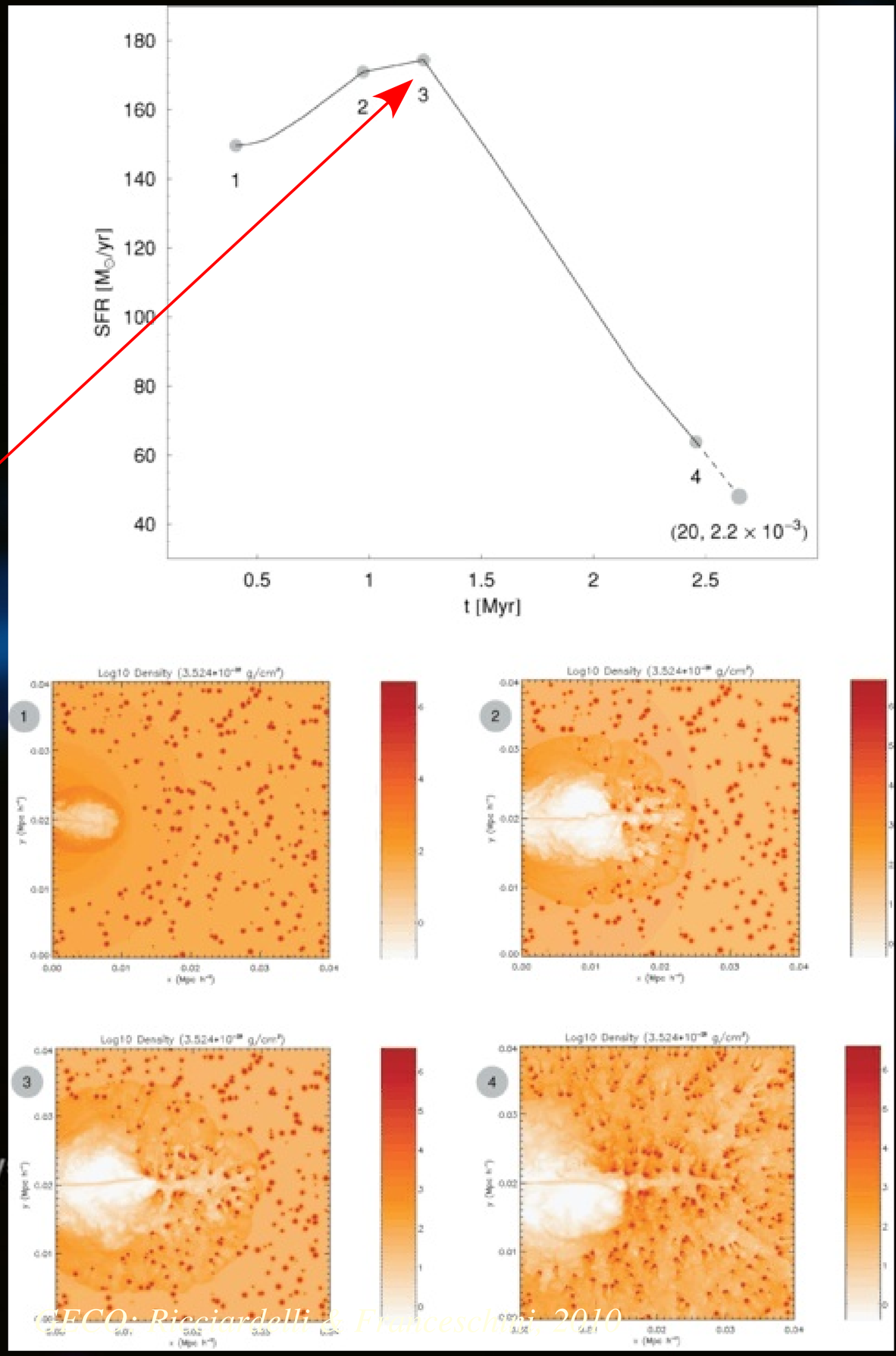

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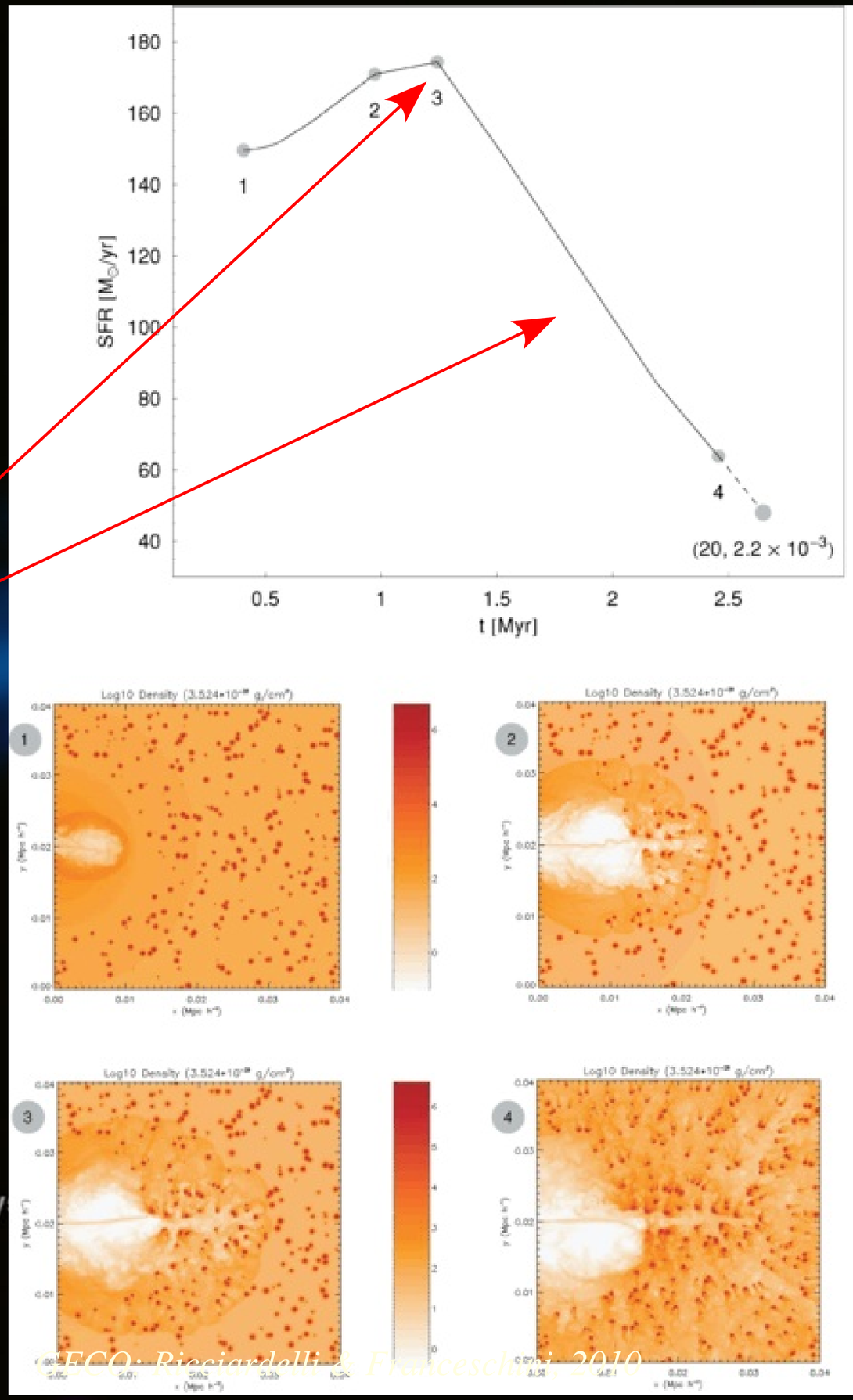

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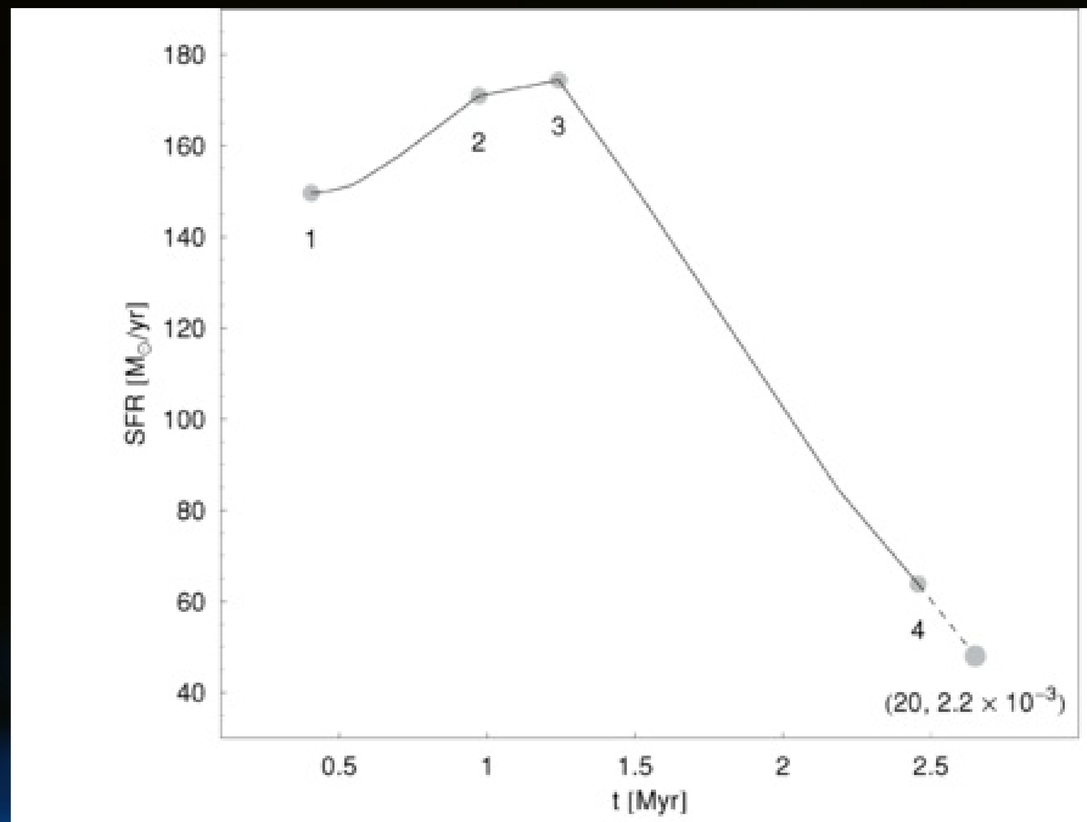

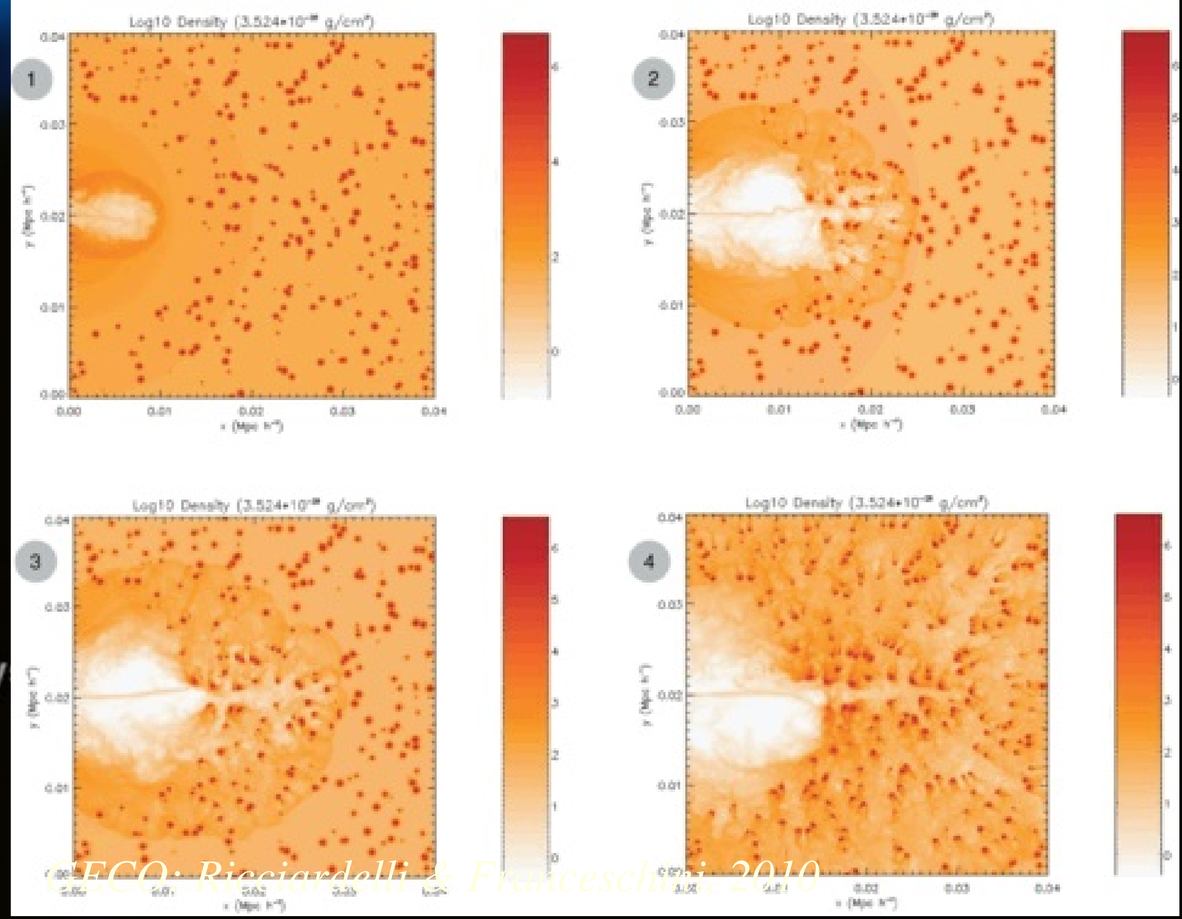

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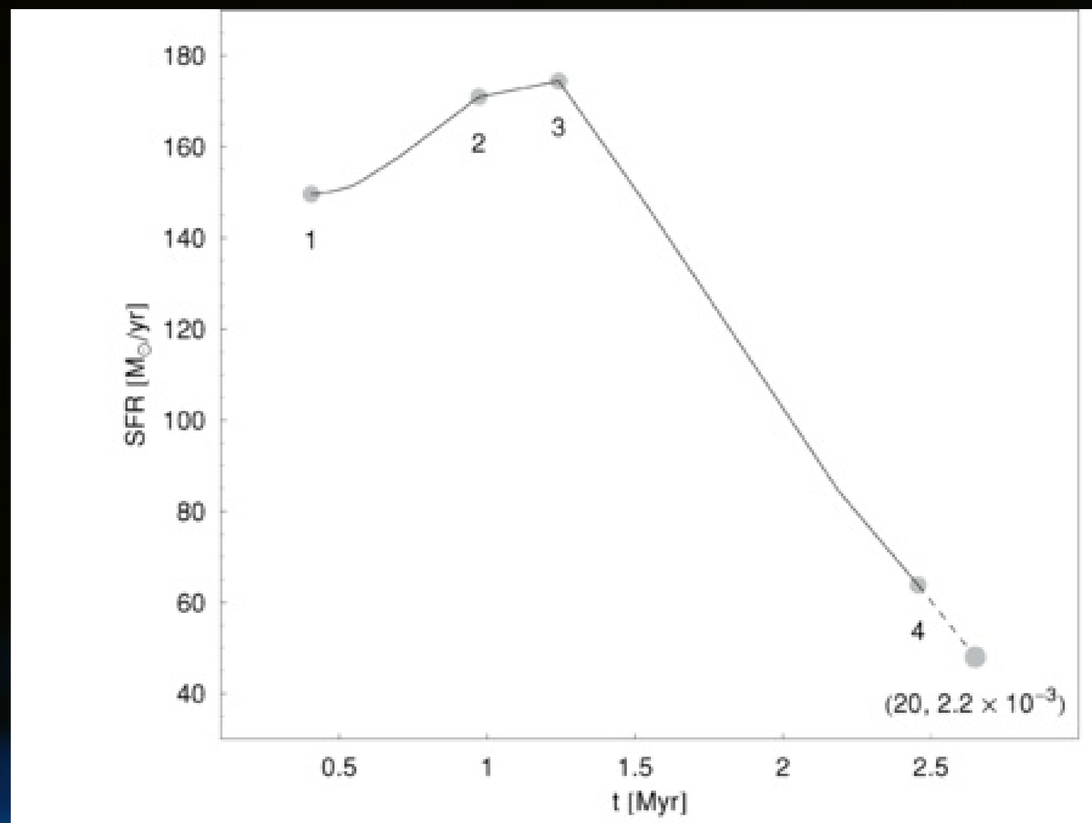

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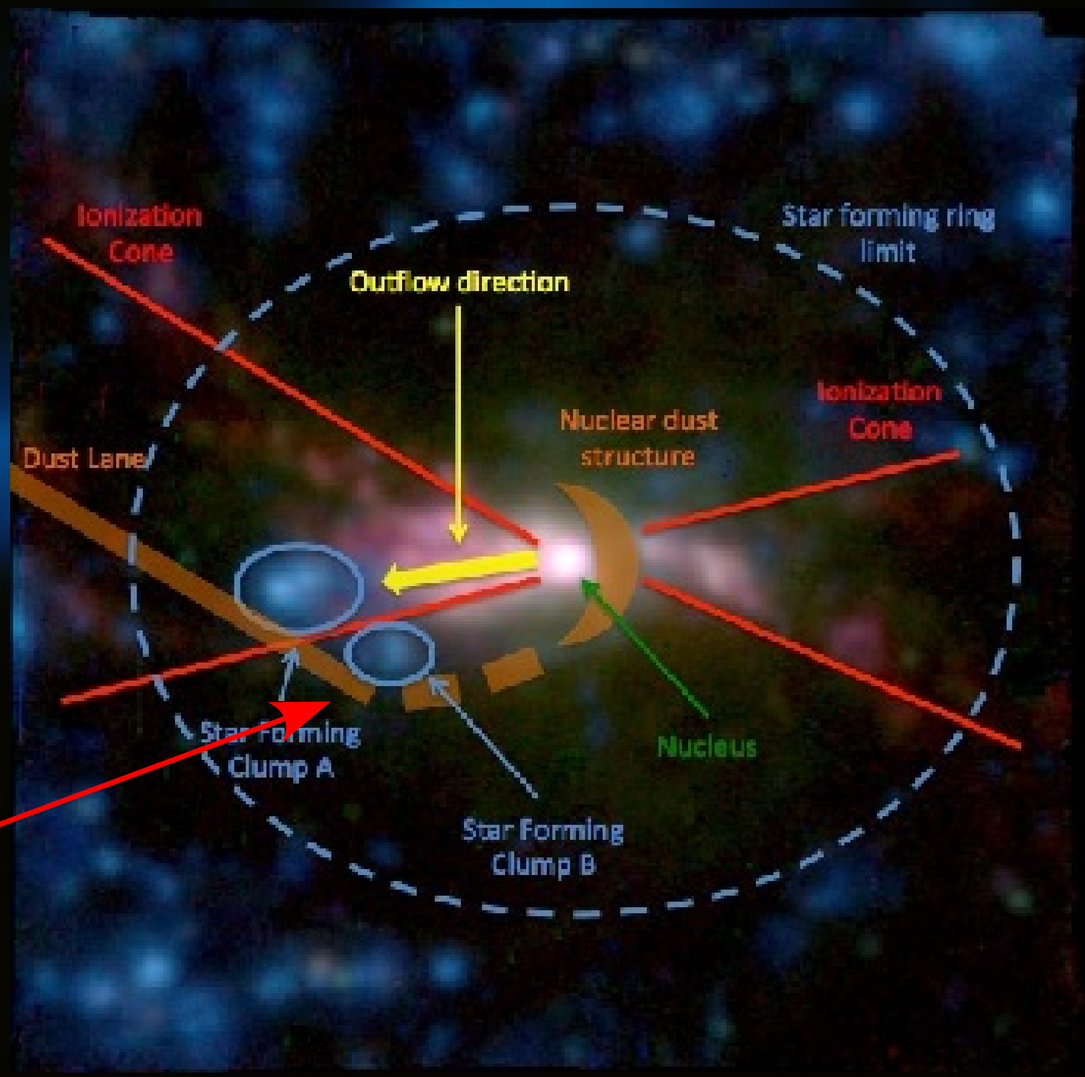

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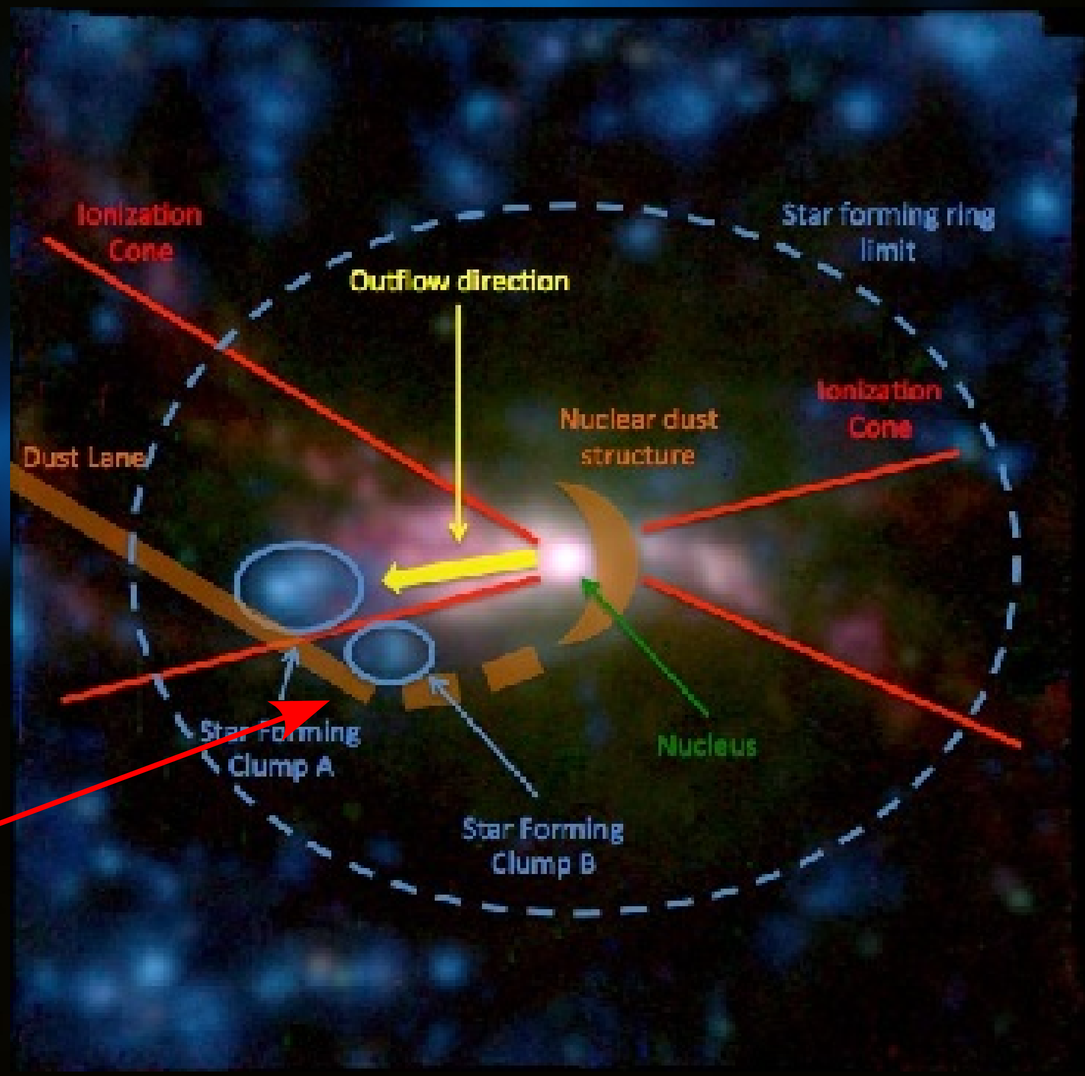

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Positive feedback lasts lesser than quenching.....

Is positive feedback cosmologically relevant to galaxy stellar formation @ $z \gtrsim 2$?

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Only modelling (incl. *numerical experiments*) can provide us with unbiased , realistic hints.

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Backflows within AGNs relativistic jets:
The link between large- and subparsec scale feedback

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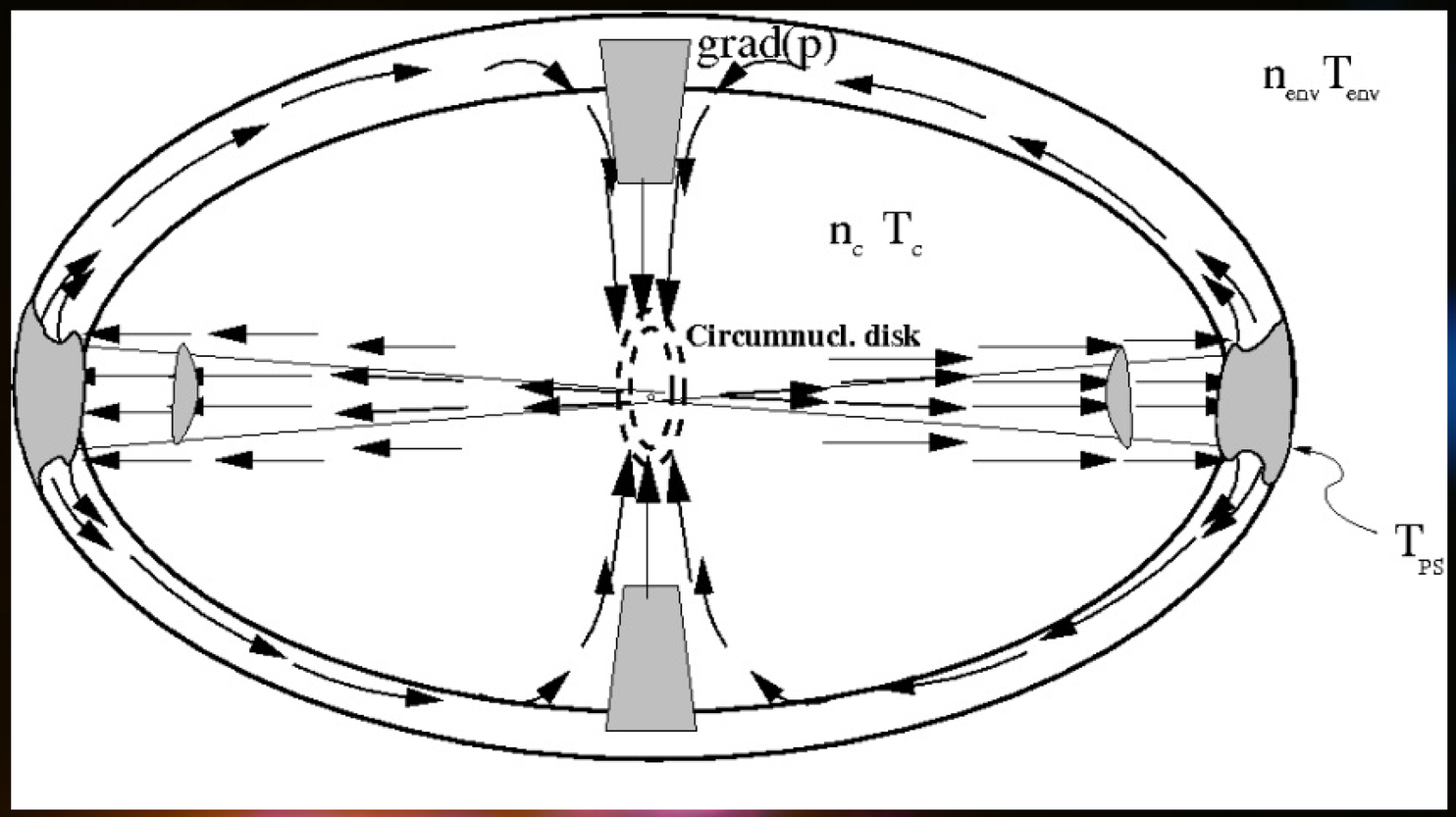

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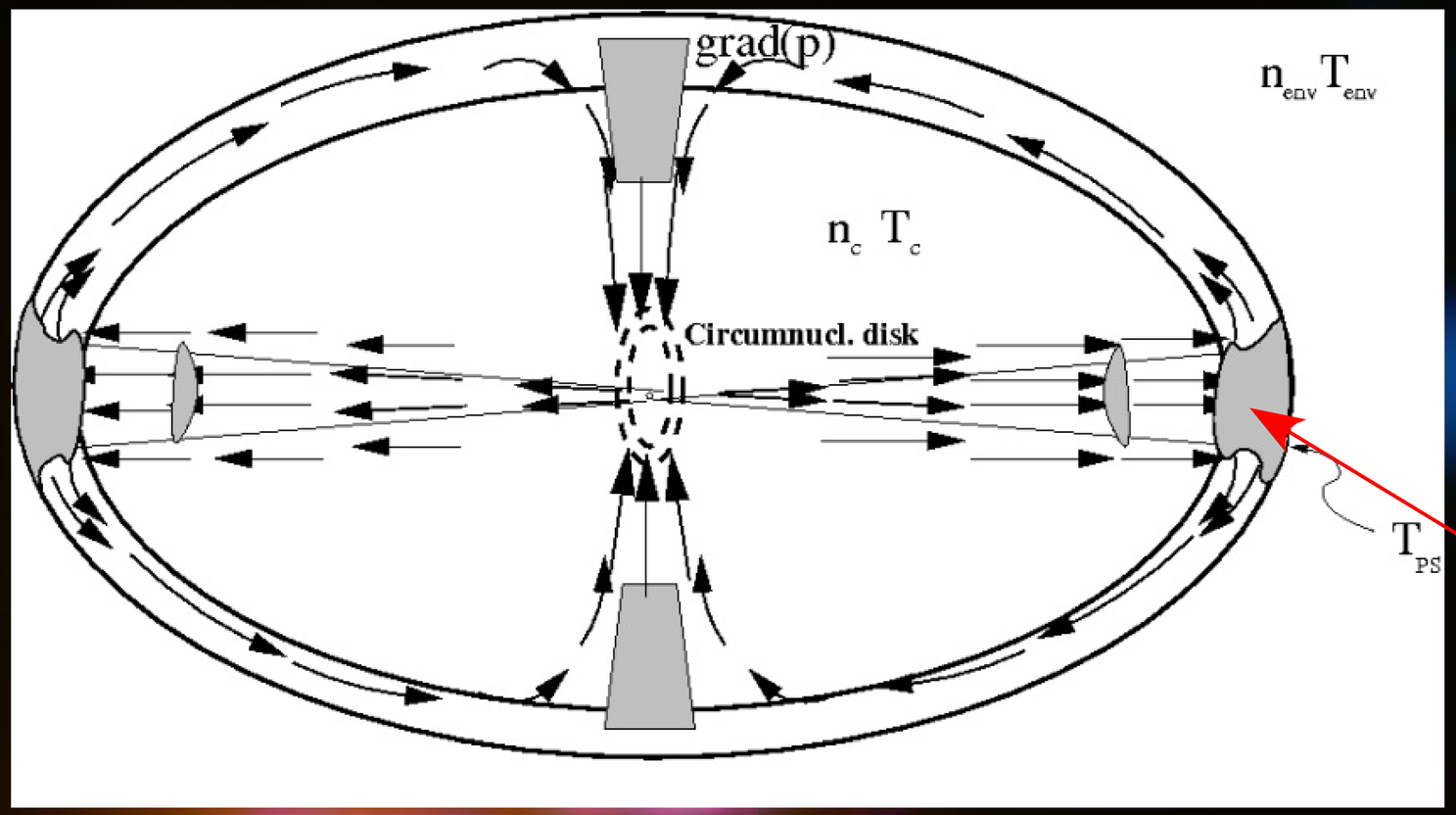

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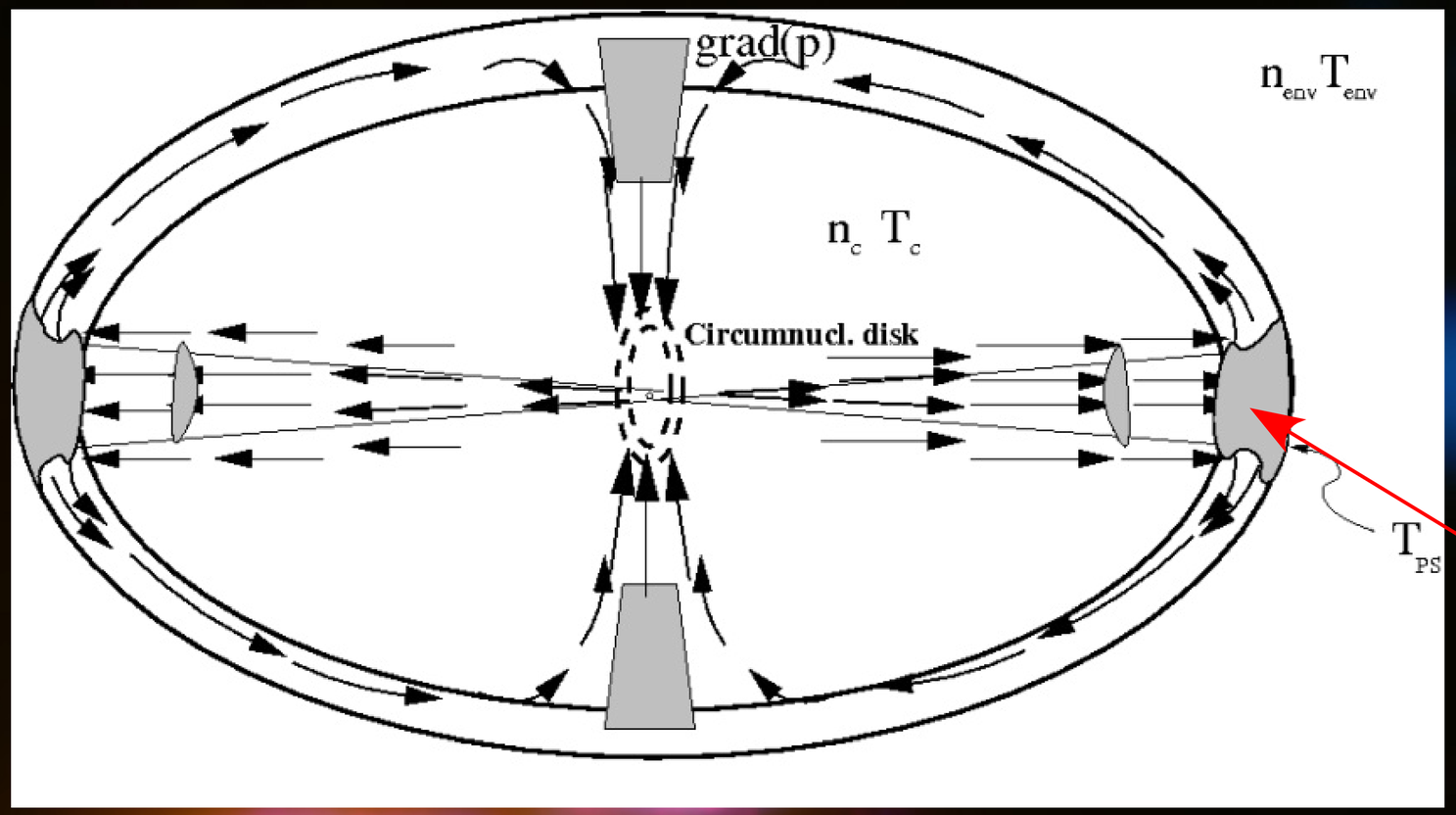

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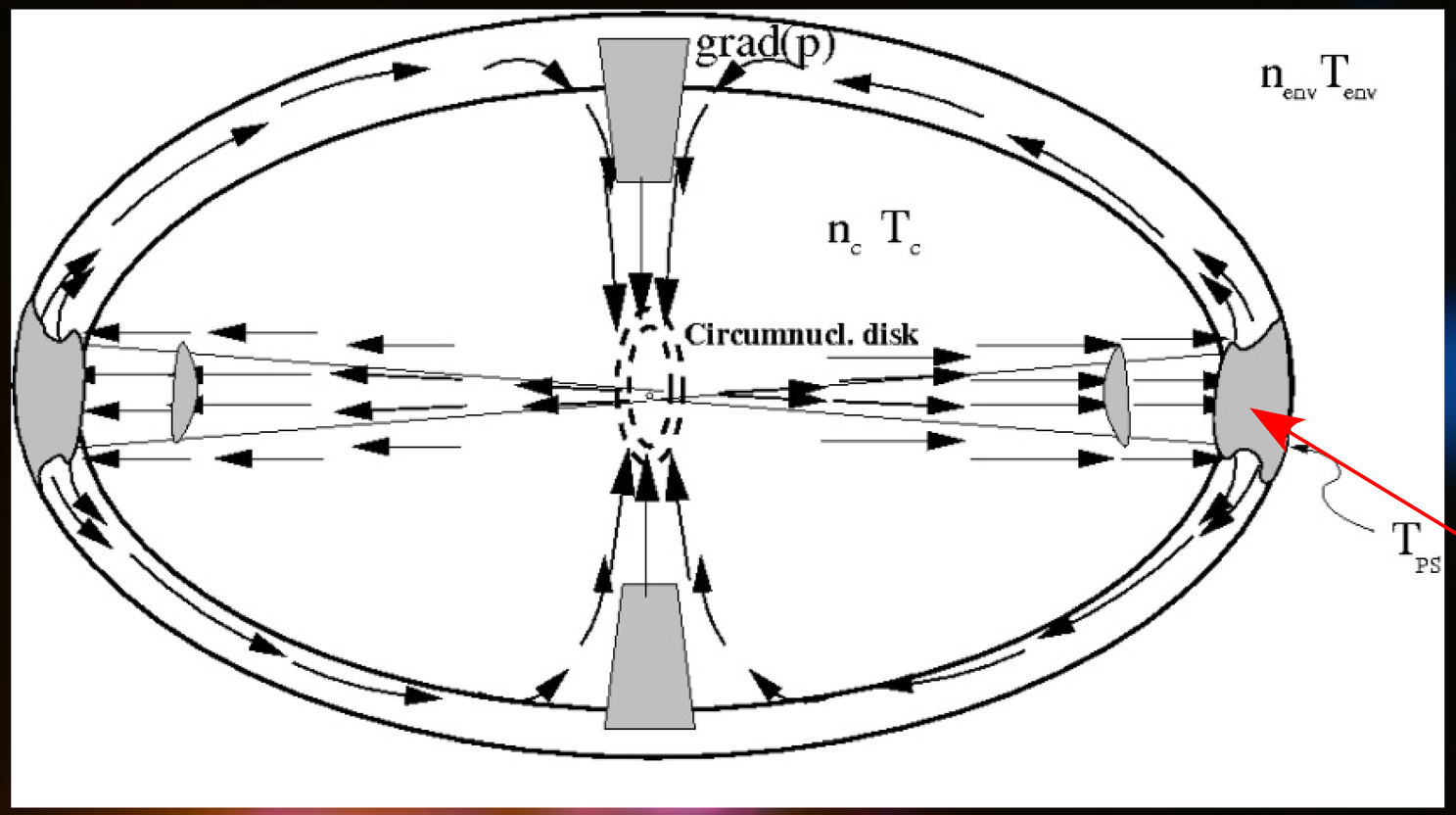

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Observational evidence for backflows

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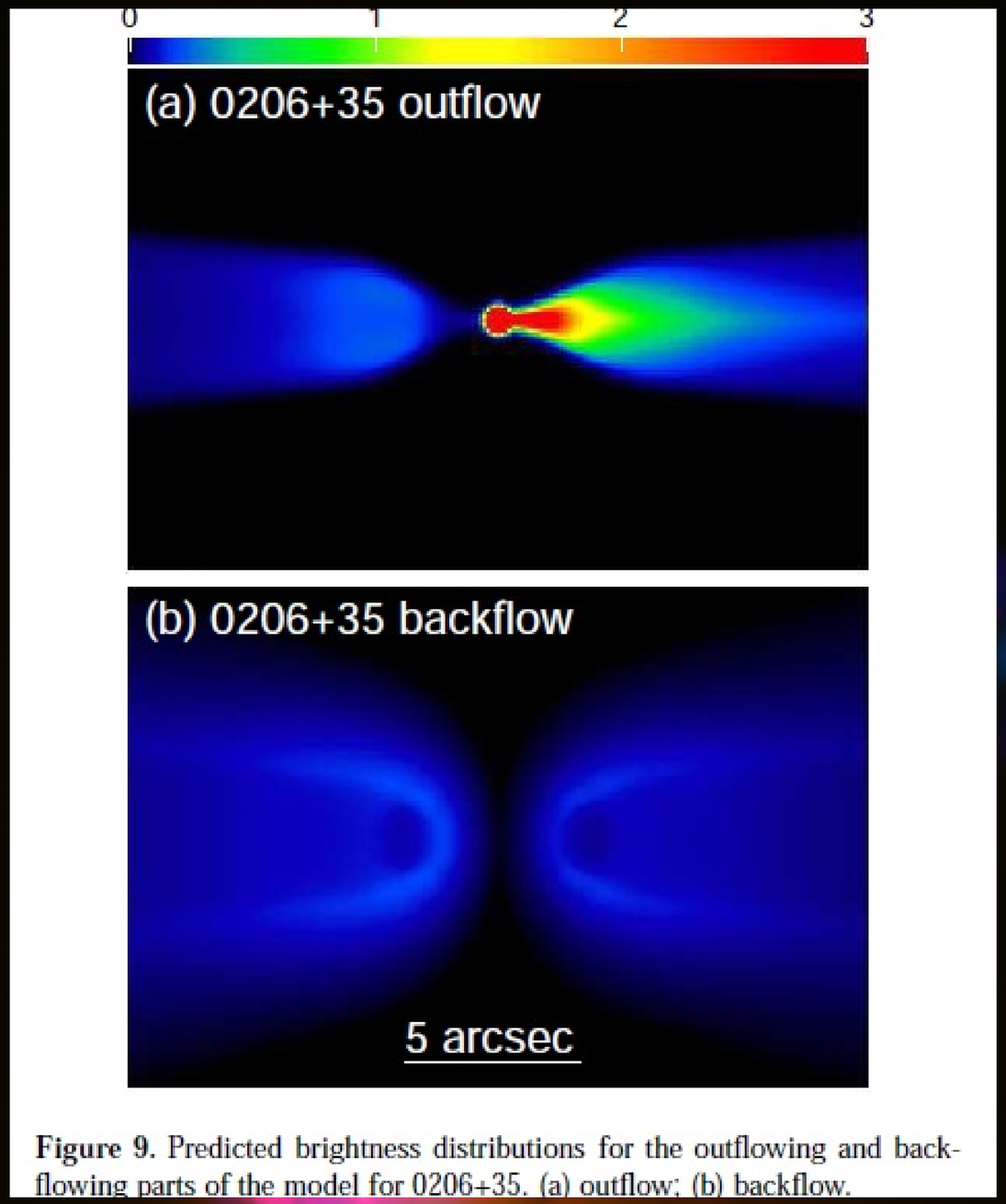

Figure 9. Predicted brightness distributions for the outflowing and backflowing parts of the model for 0206+35. (a) outflow; (b) backflow.

Laing & Bridle, 2012: FRI, mildly relativistic velocities

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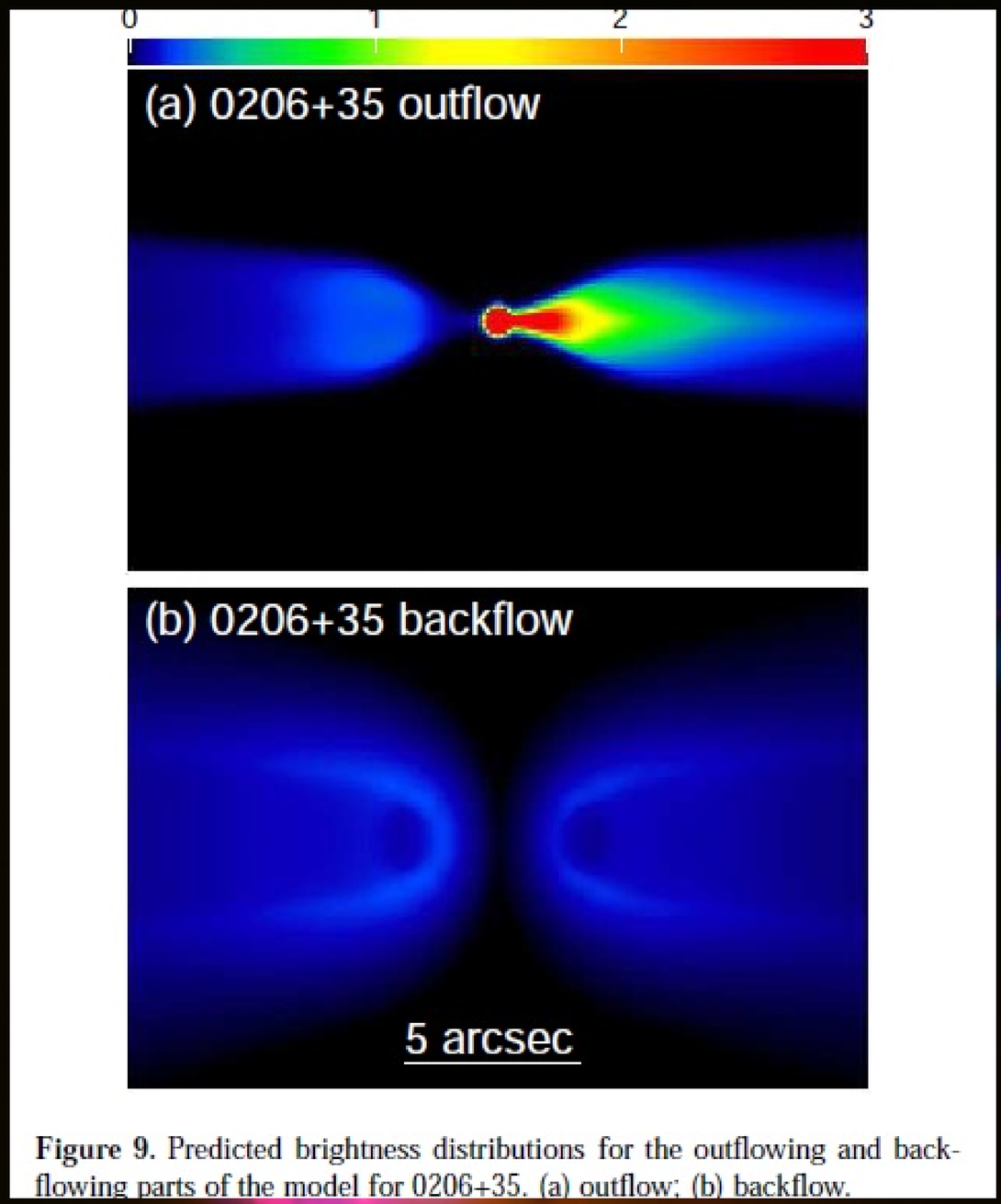

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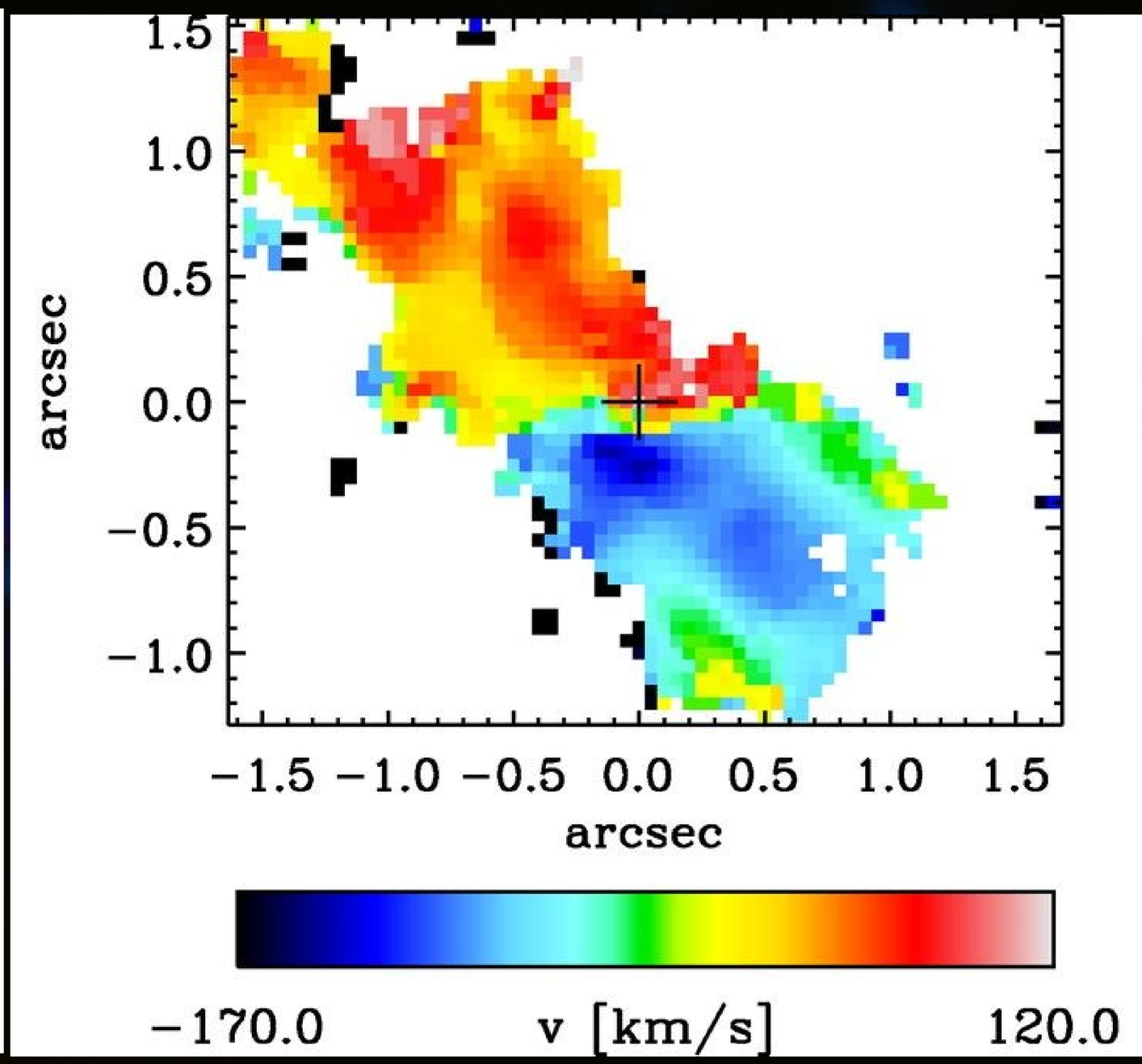
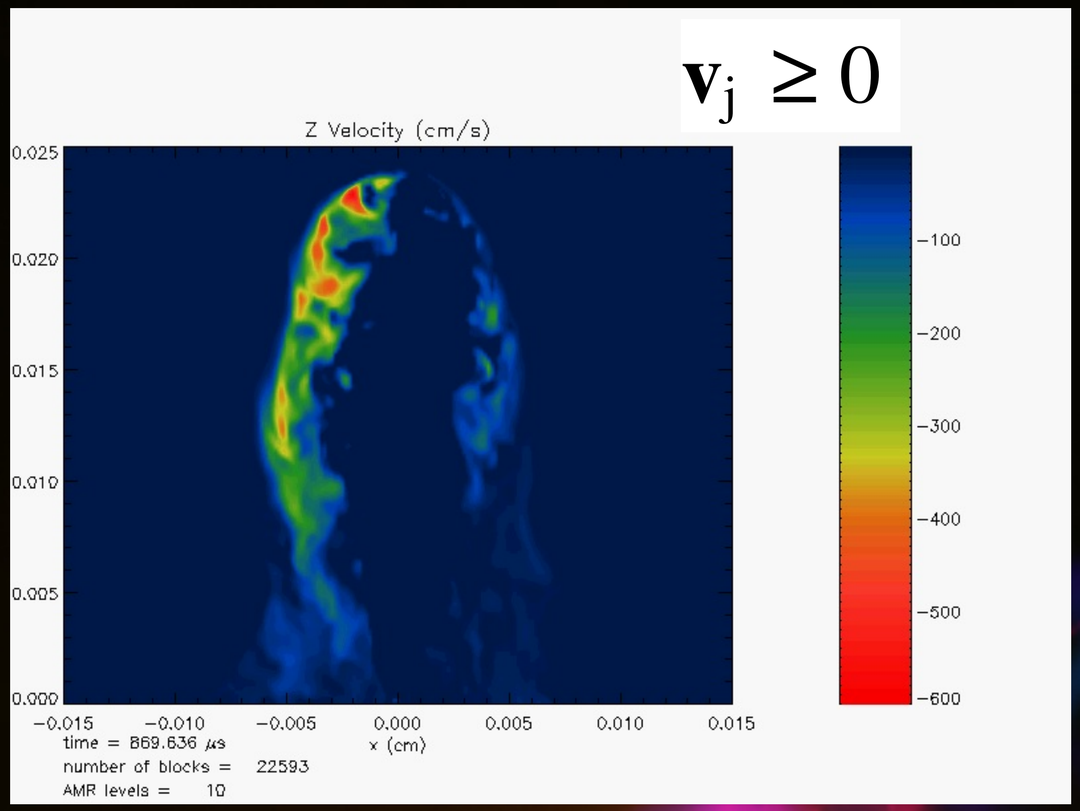
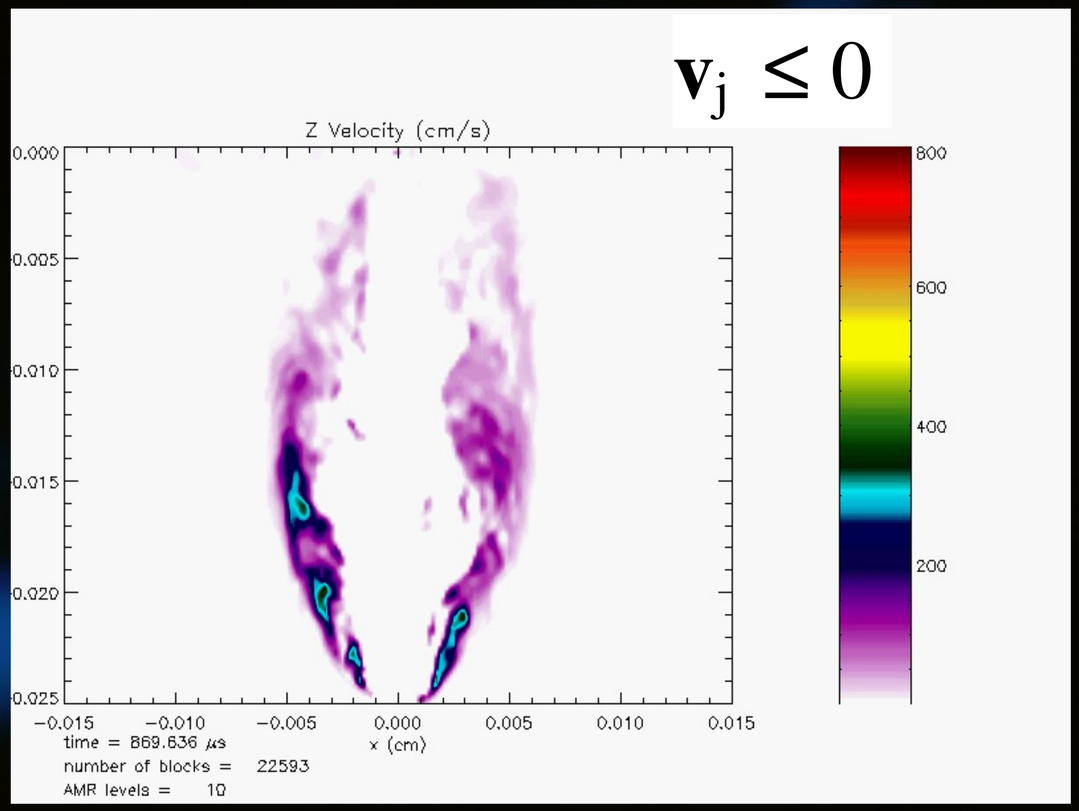


Neumayer et al, 2007: CEN A
Deeper analysis with MUSE: Hamer et al., 2015

Numerical experiments

Numerical experiments

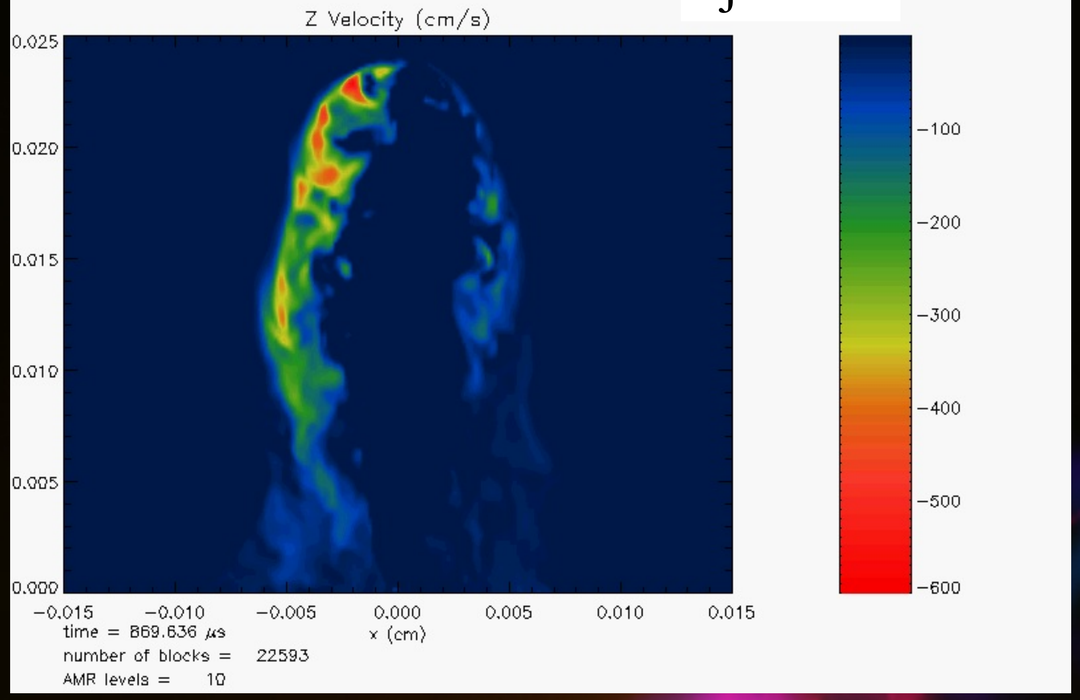




- Plotting only counterstreaming gas ($\mathbf{v}_z \cdot \mathbf{v}_j \leq 0$)

Numerical experiments

$\mathbf{v}_j \geq 0$



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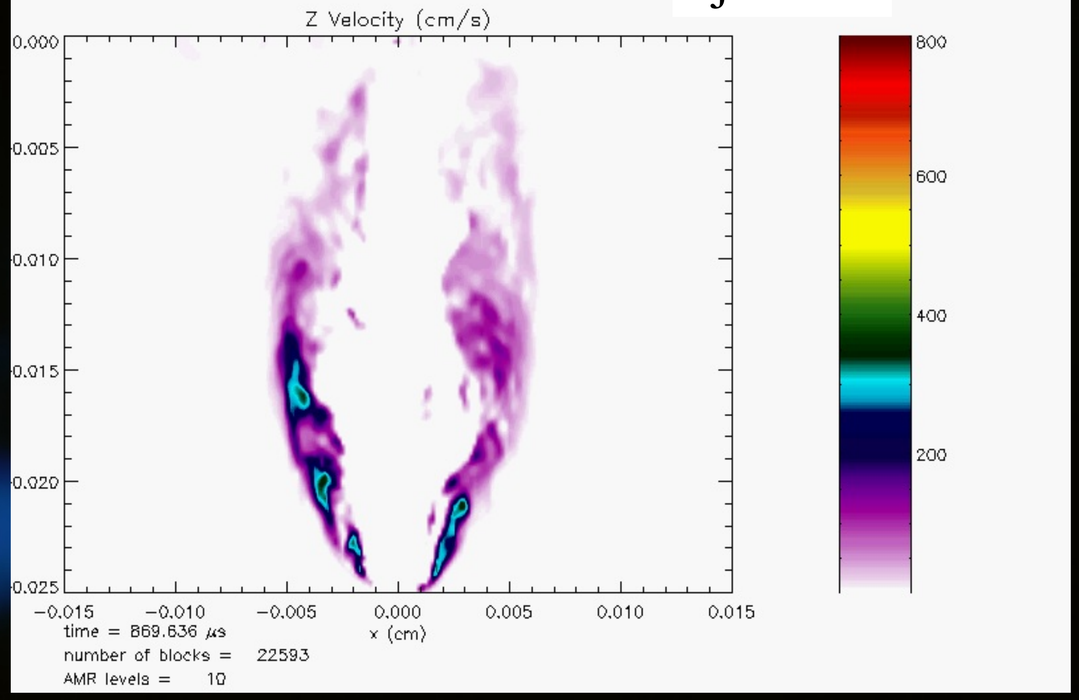

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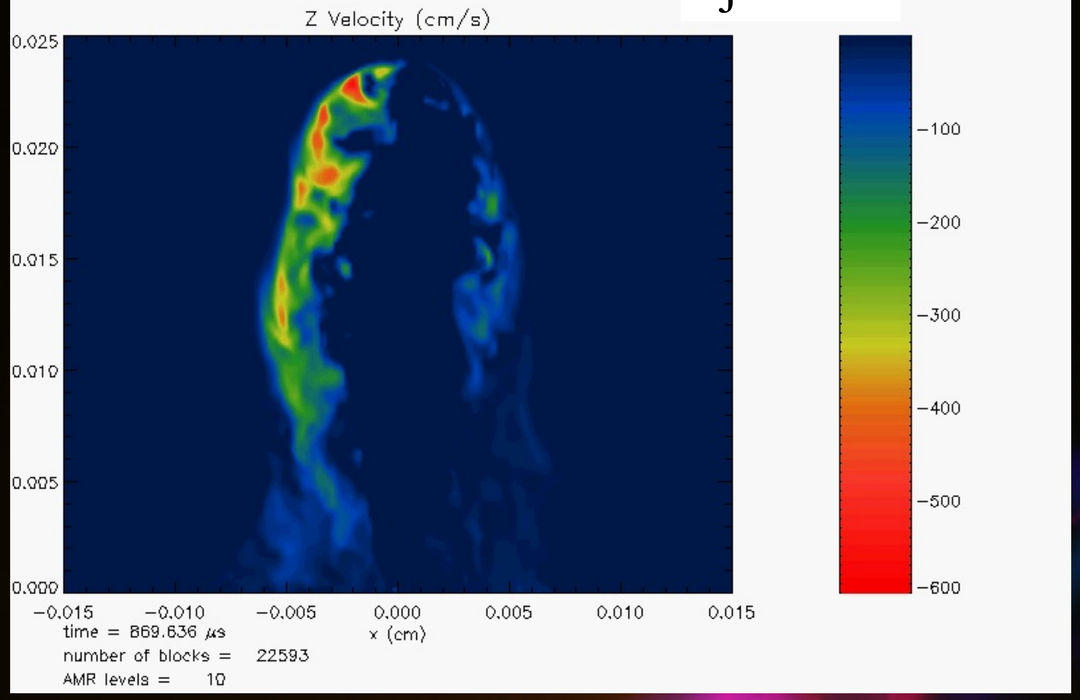

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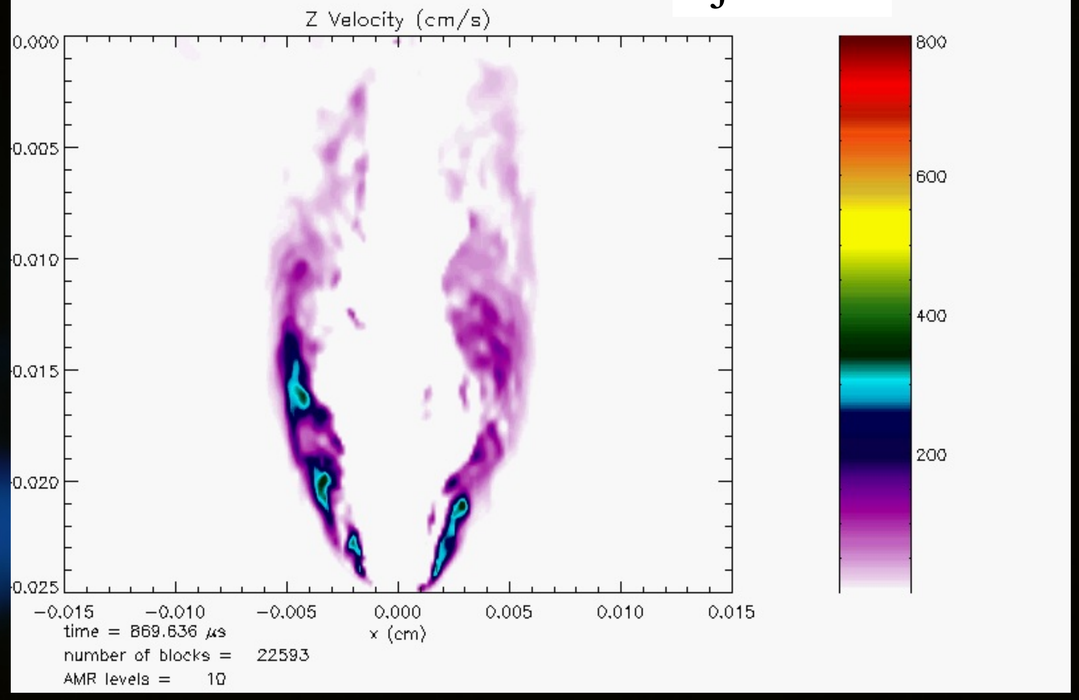

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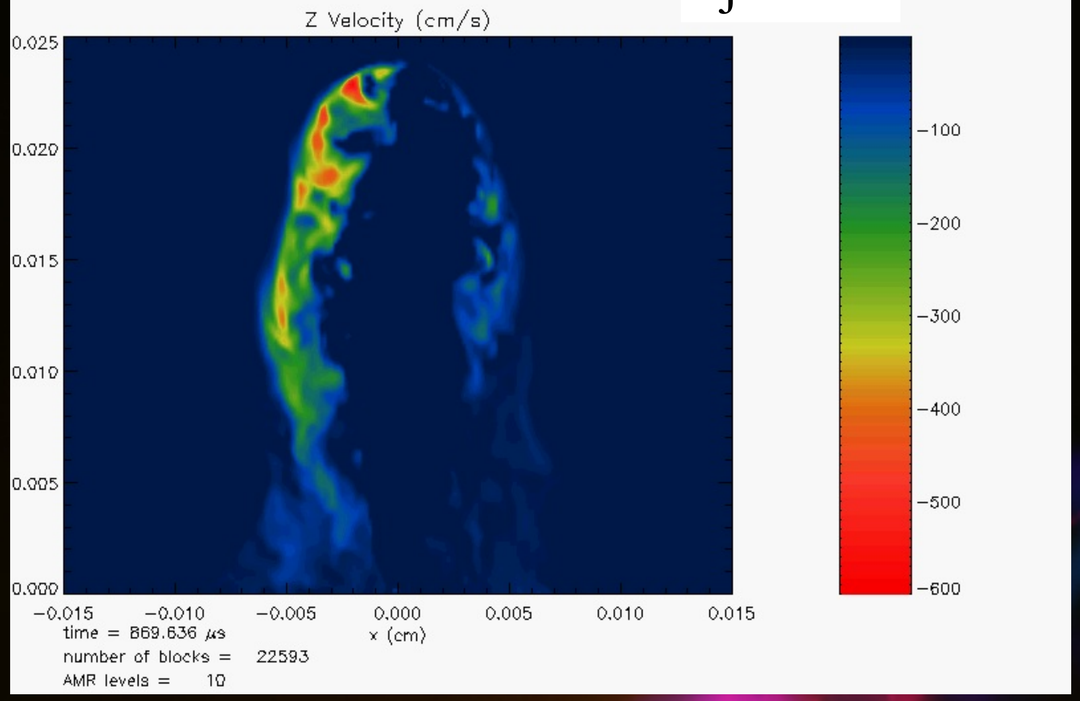

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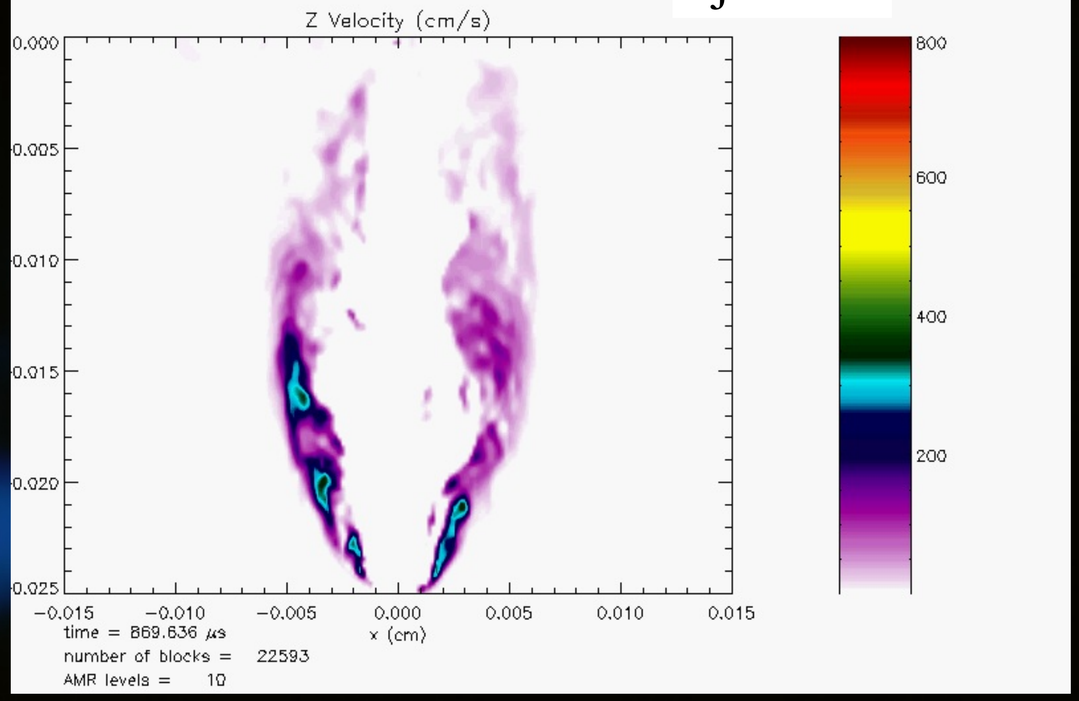

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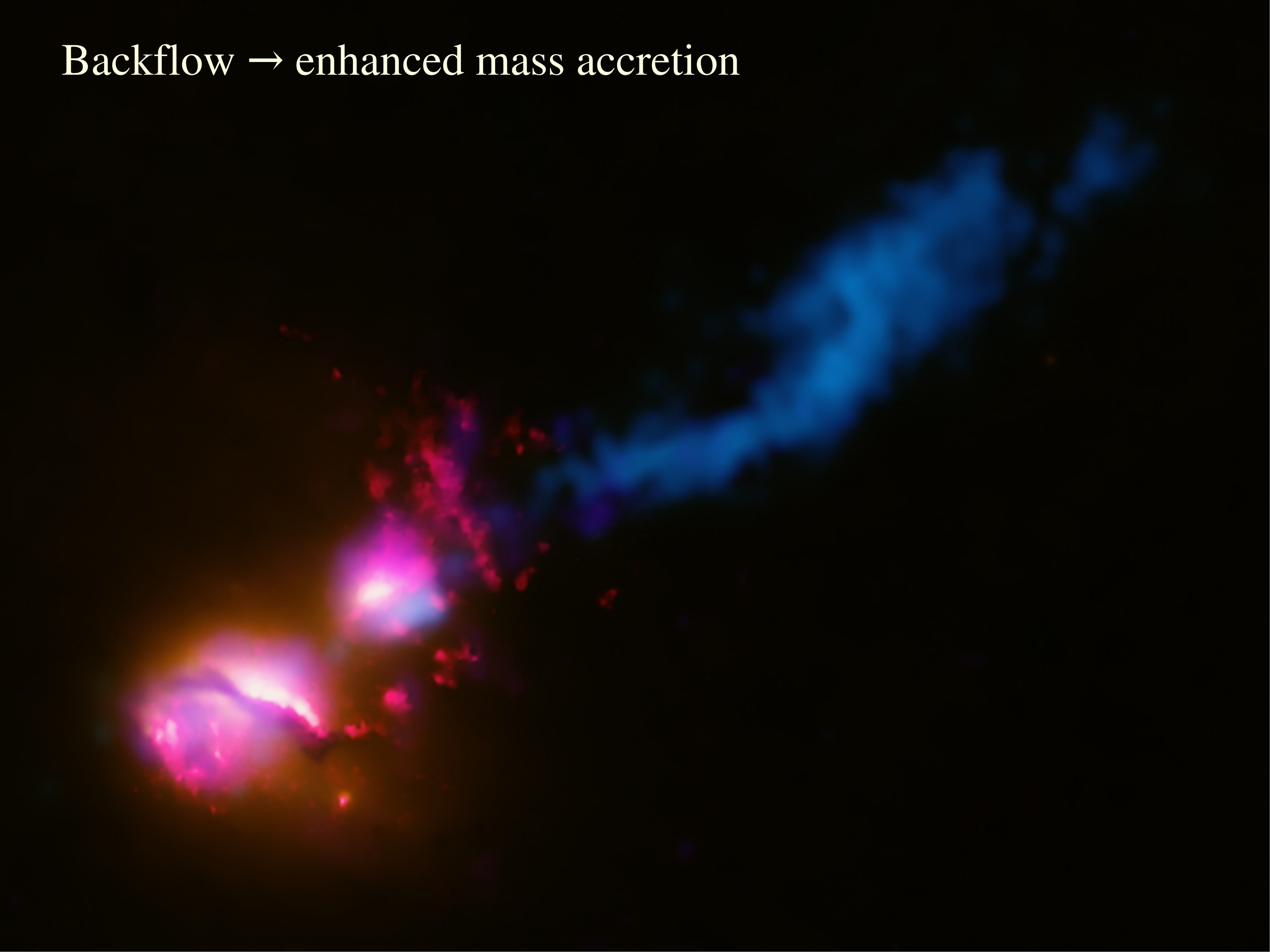
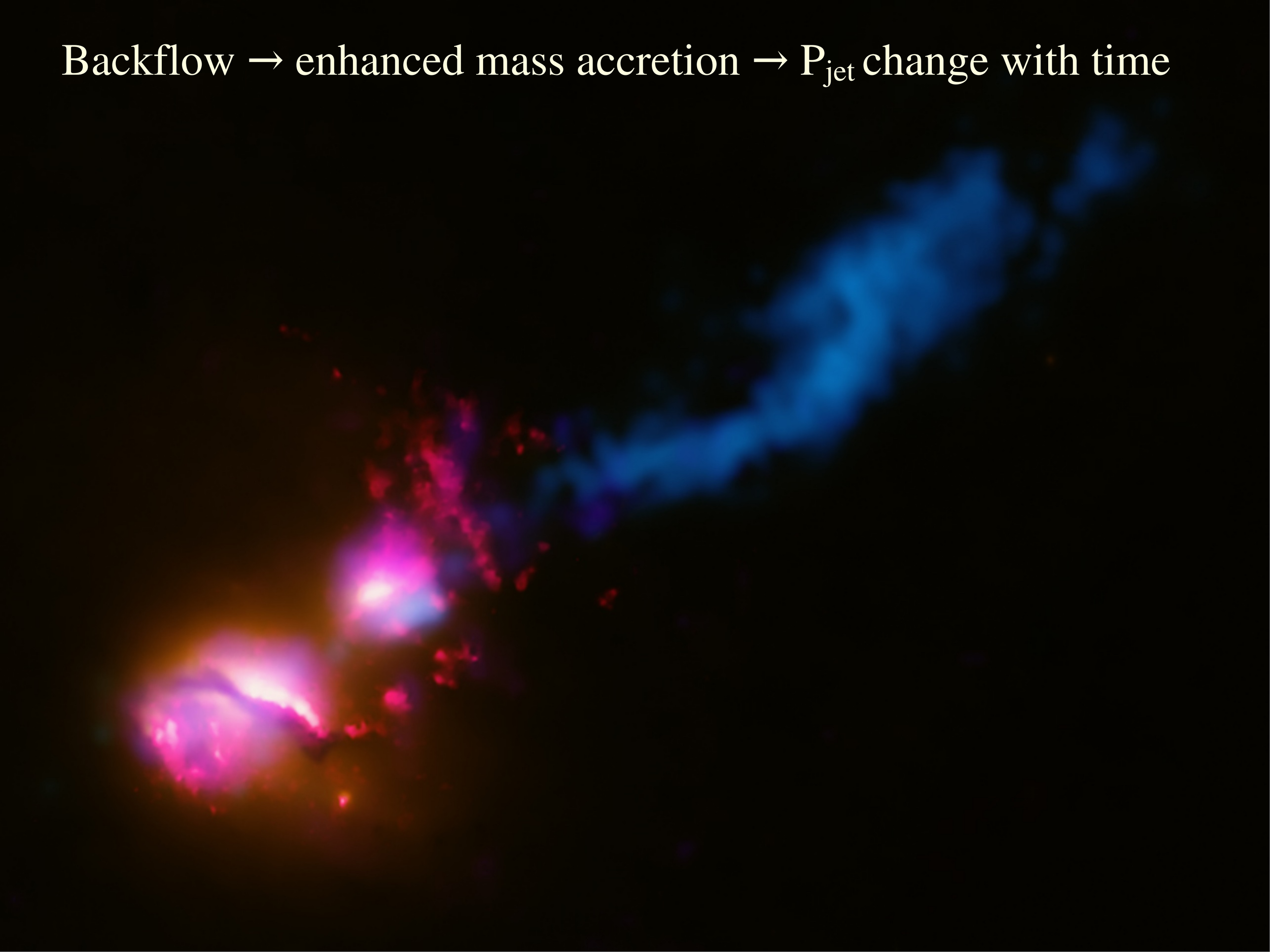
  3) No meridional plane bending of the flow is detected → perpendicolar backflow

Backflow

Backflow → enhanced mass accretion



Backflow → enhanced mass accretion → P_{jet} change with time



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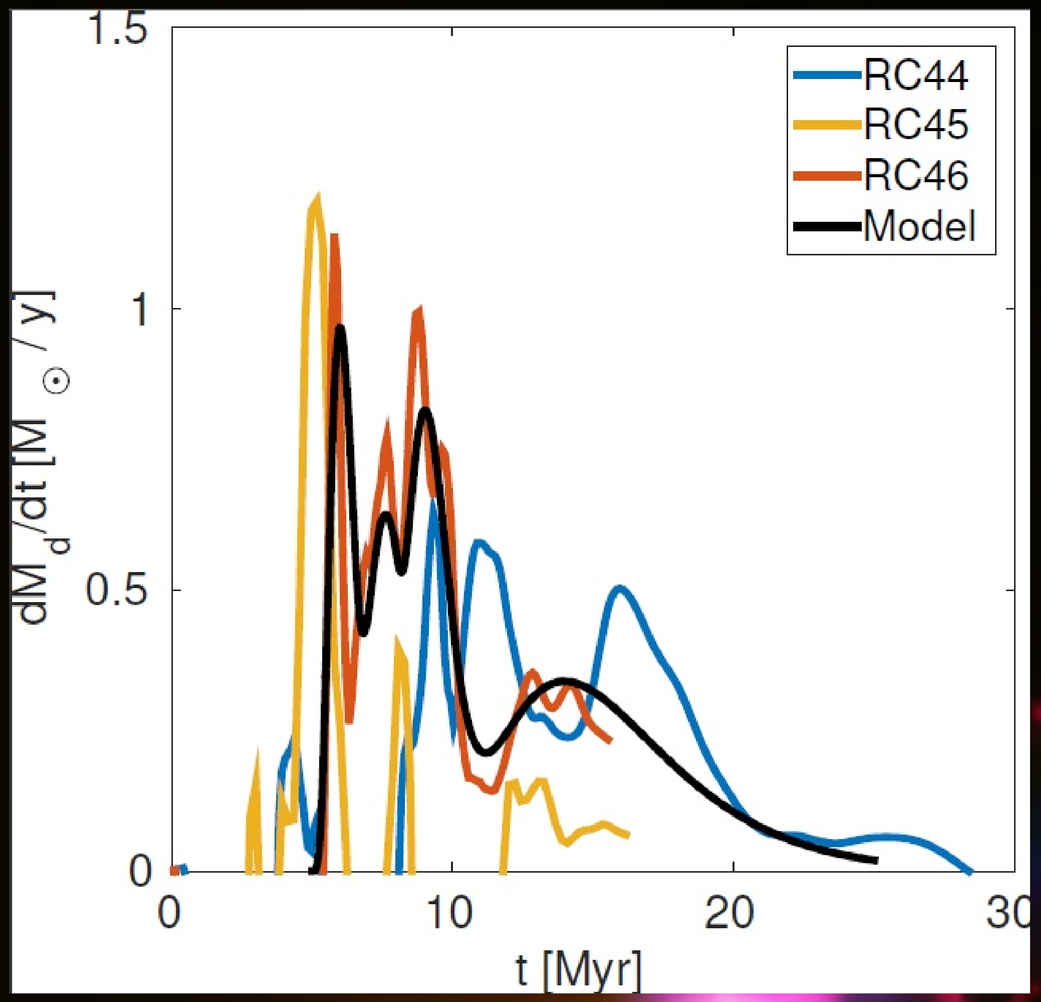

Black curve: template mass flow model

On the right plot the predicted change in $P_{jet} \propto \Sigma^{3/2}(\rho v_z)^{1/2}$

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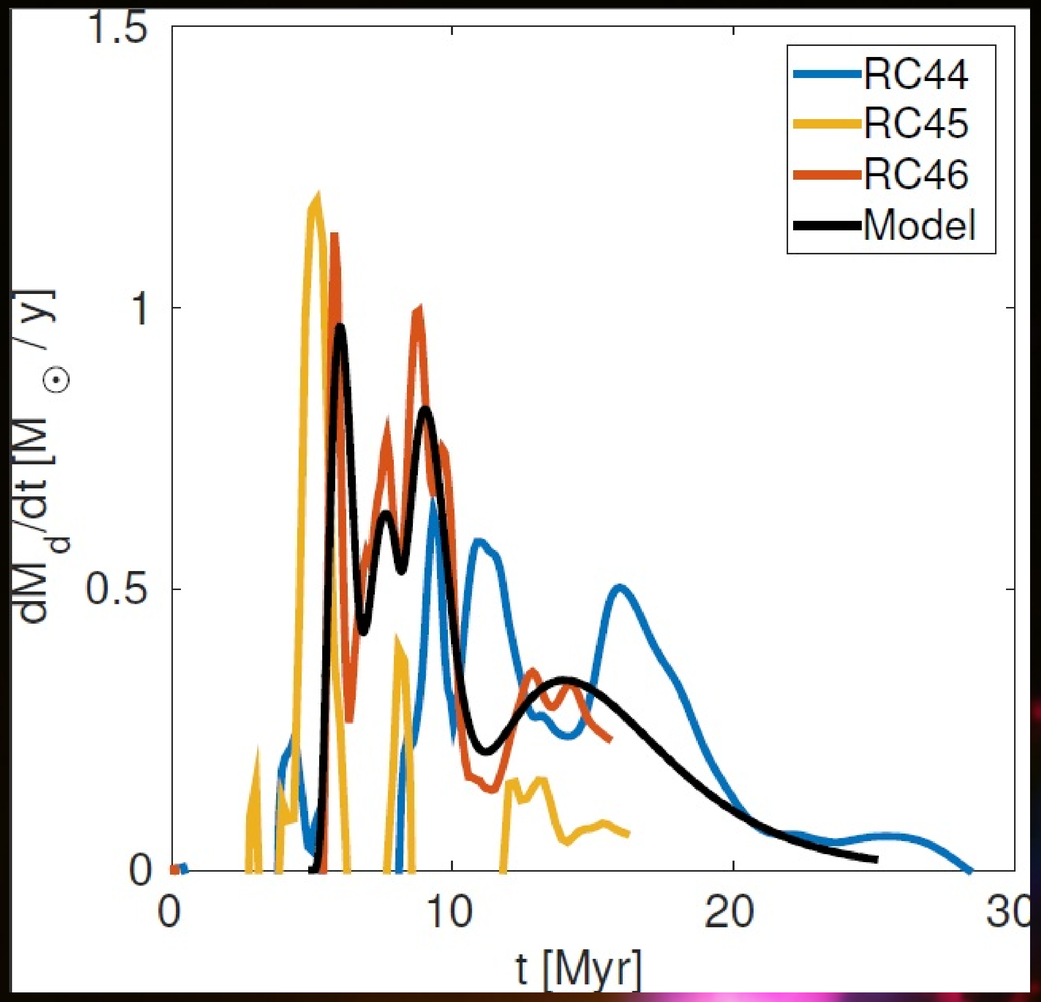

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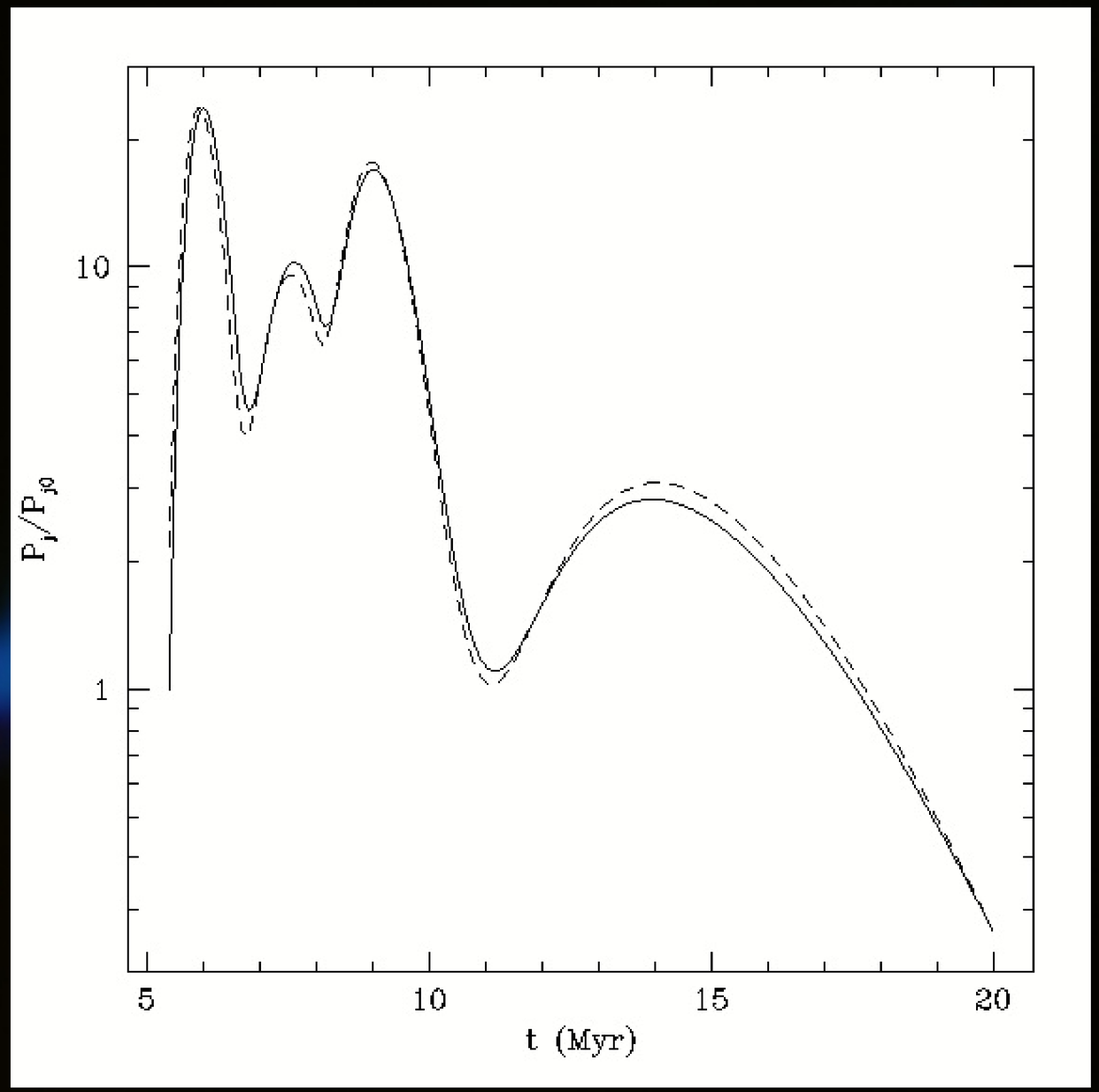

- P_{jet} enhanced by a factor ~ 10 on 15-20 Myrs.
- EUV ($\lambda \lesssim 1100$ Å) correlates with GHz synchr for RLQ

And now? So what??

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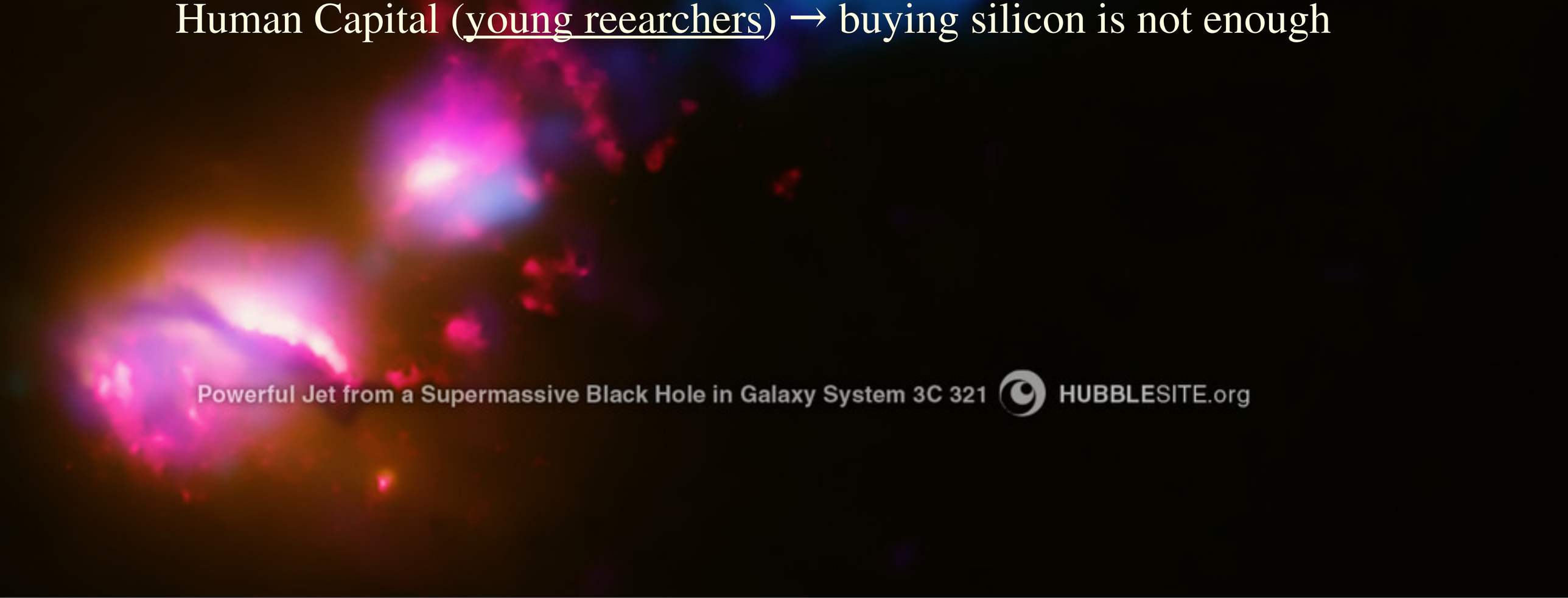

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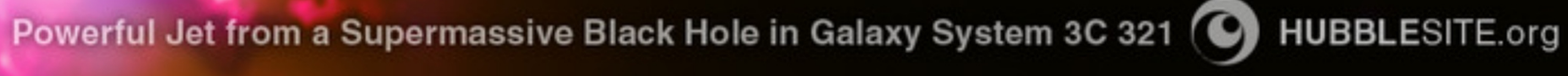
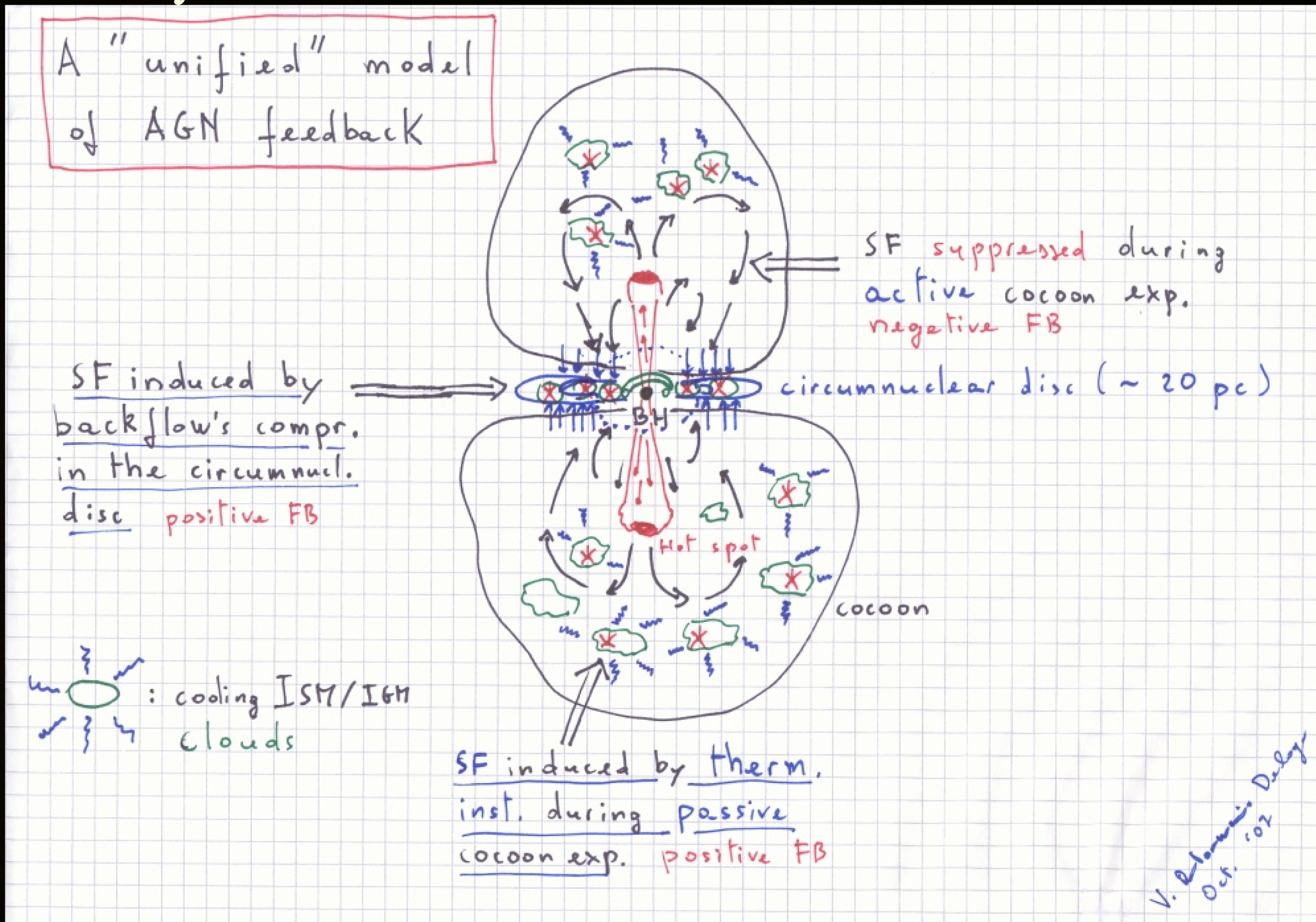
- Tighter interaction with the Numerical Analysis and Computational Physics communities → credible physical targets and language



My "unified" mechanical AGN feedback model



Black Holes-galaxies co-evolution
Physical Models

- Jet's feedback - Jet's production, SMBH accretion: highly decoupled in spatial scales, <u>but</u> strongly coupled energetically (GRMHD - Tchekhovskoy, Sądowski, McKinney..., theory: Paczinsky, Abramowicz, Narayan, Lasota)
- Positive feedback: outflows at $z \gtrsim 1$ (Maiolino, Lehnert) - is it <u>cosmologically</u> significant? Can it boost sognificantly the SFR?
- SMBH physics: directly accessible through GWs→ BHs' growth history and SF history

- Backflow: low L_z accreting gas from large (SF) to AU (BH) accretion scales, connection between

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