2D HD simulations of SSC in a bimodal regime

(R. Wünsch, J. Palouš, G. Tenorio-Tagle, S. Silich)

Super star clusters:

- observed in variety of starburst galaxies at all redshifts (Ho , 1997)
- masses: $M_{\rm SC} \sim 10^5 - 10^7$ $M_\odot$
- radii: $R_{\rm SC} \sim 3 - 5$ pc
  $\rightarrow$ very compact
- age: < 500 Myr
- $L_{\rm mech} \sim 10^{40} - 10^{42}$ erg/s
- stellar winds and SN return $\sim 40\% M_{\rm SC}$ back into ISM

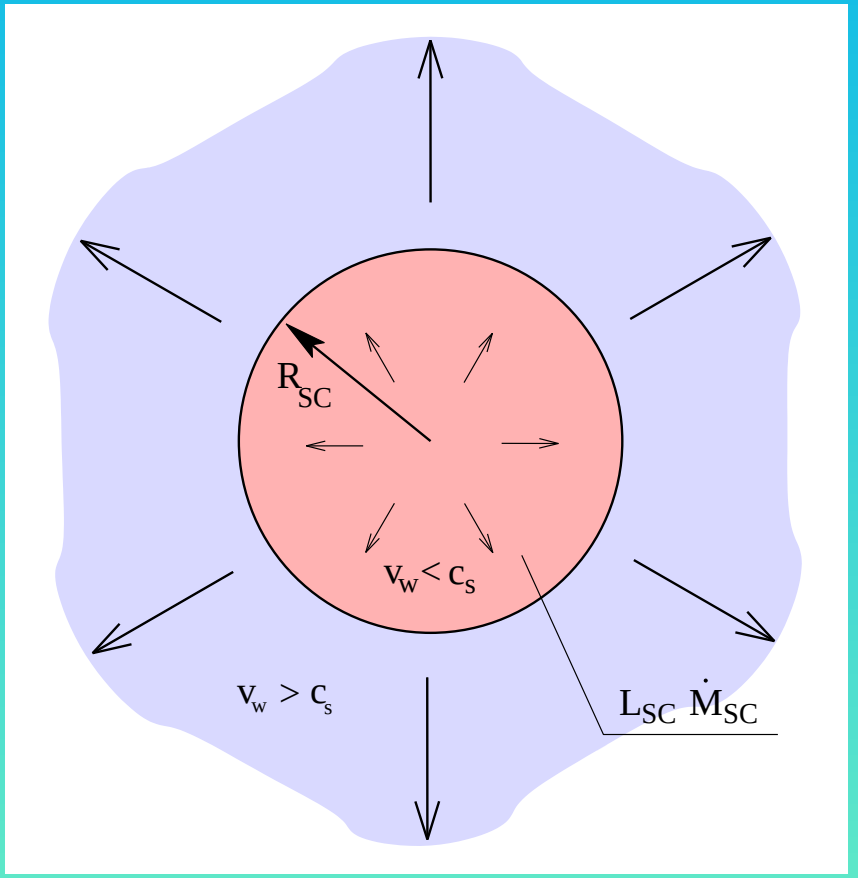
Physical model of SSC wind

- SW and SN energy thermalized (efficiency η)
- 4 parameters:

  η, $R_{\rm SC}$, $L_{\rm SC}$ and $\dot{M}_{\rm SC}$
- $L_{\rm SC}$ and $\dot{M}_{\rm SC}$ coupled:

$$v_{a,\infty} = \sqrt{\frac{2L_{\rm SC}}{\dot{M}_{\rm SC}}}$$

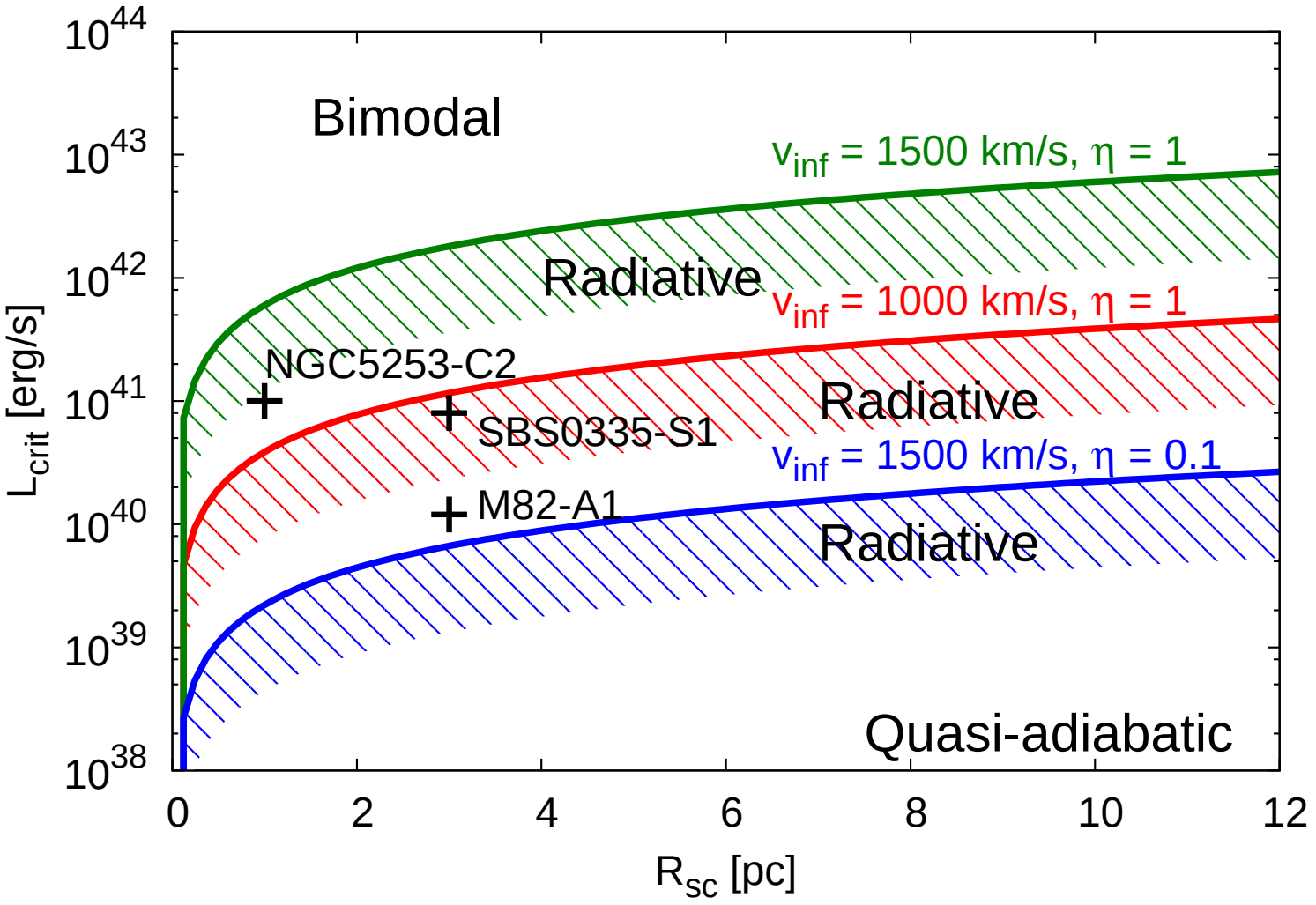
  if a stellar population assumed



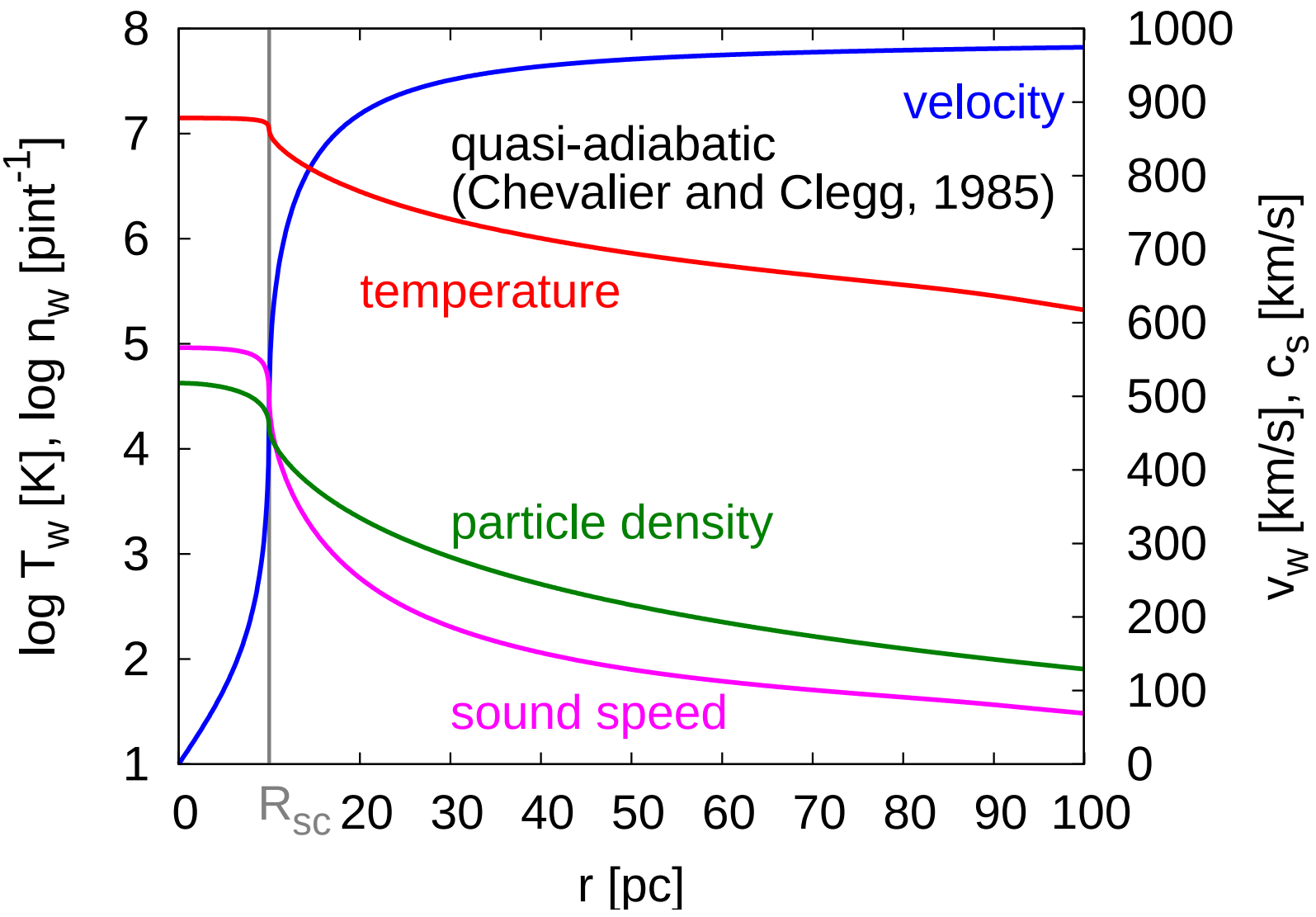
- Catastrophic cooling: (Silich et al., 2004)
  energy input rate: $L_{\rm SC} \propto M_{\rm SC}$
  cooling rate: $\frac{de}{dt}\big|_{\rm cool} \propto \rho^2 \propto \dot{M}_{\rm SC}^2 \propto M_{\rm SC}^2$

Critical luminosity

- stationary solution for $L < L_{\rm crit}(R_{\rm SC}, v_{a,\infty}, \eta)$



Quasi-adiabatic and radiative solution



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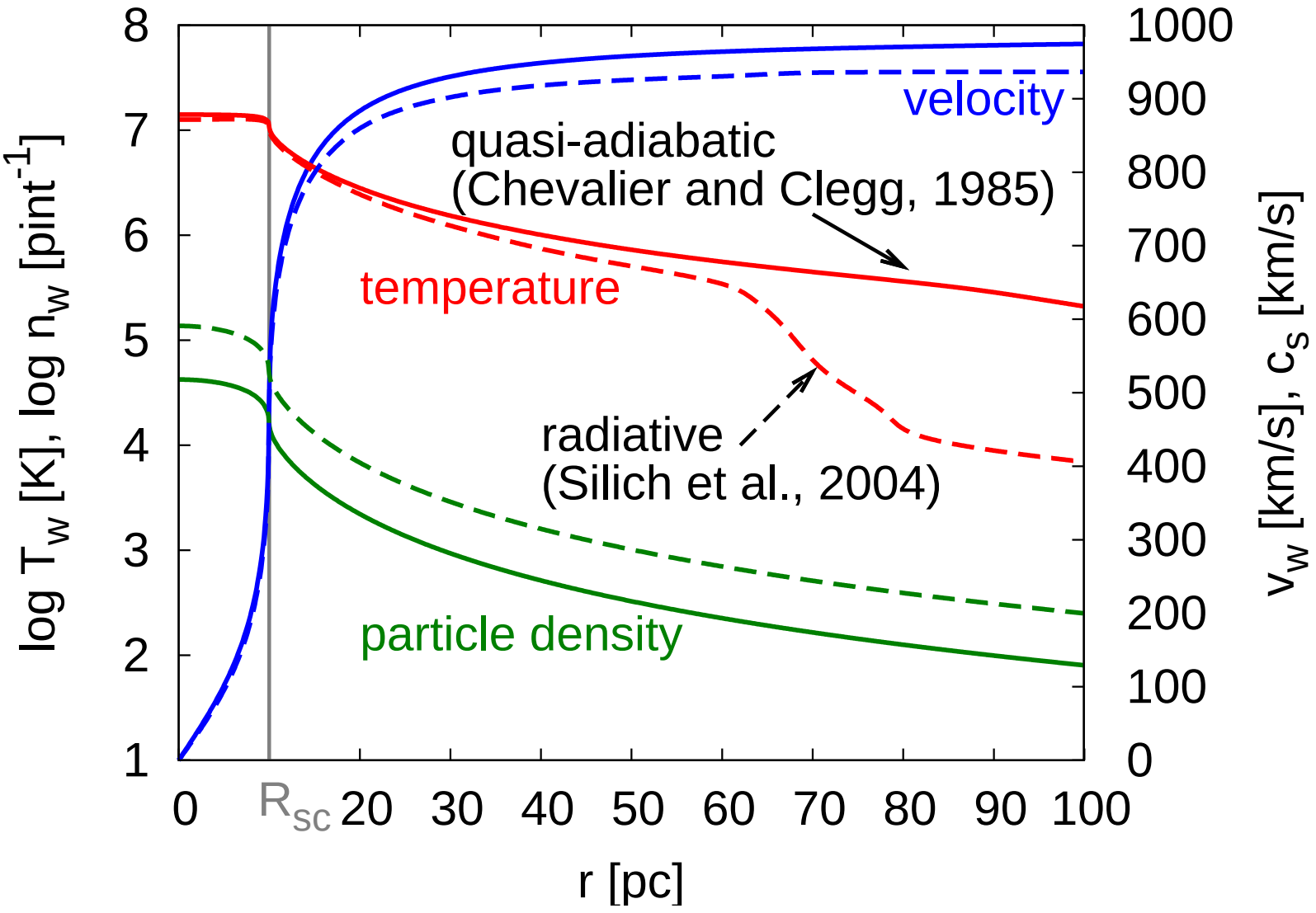
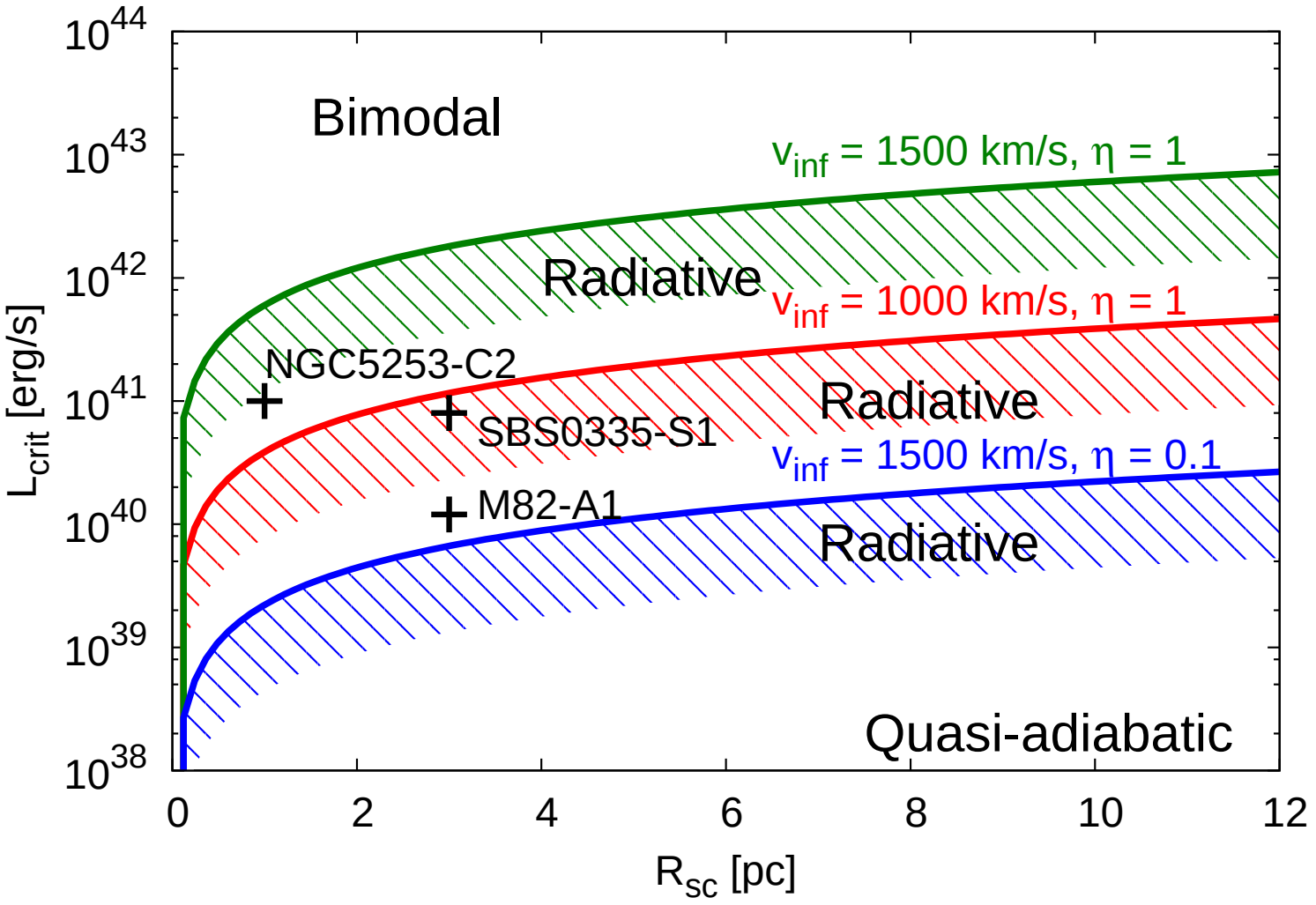


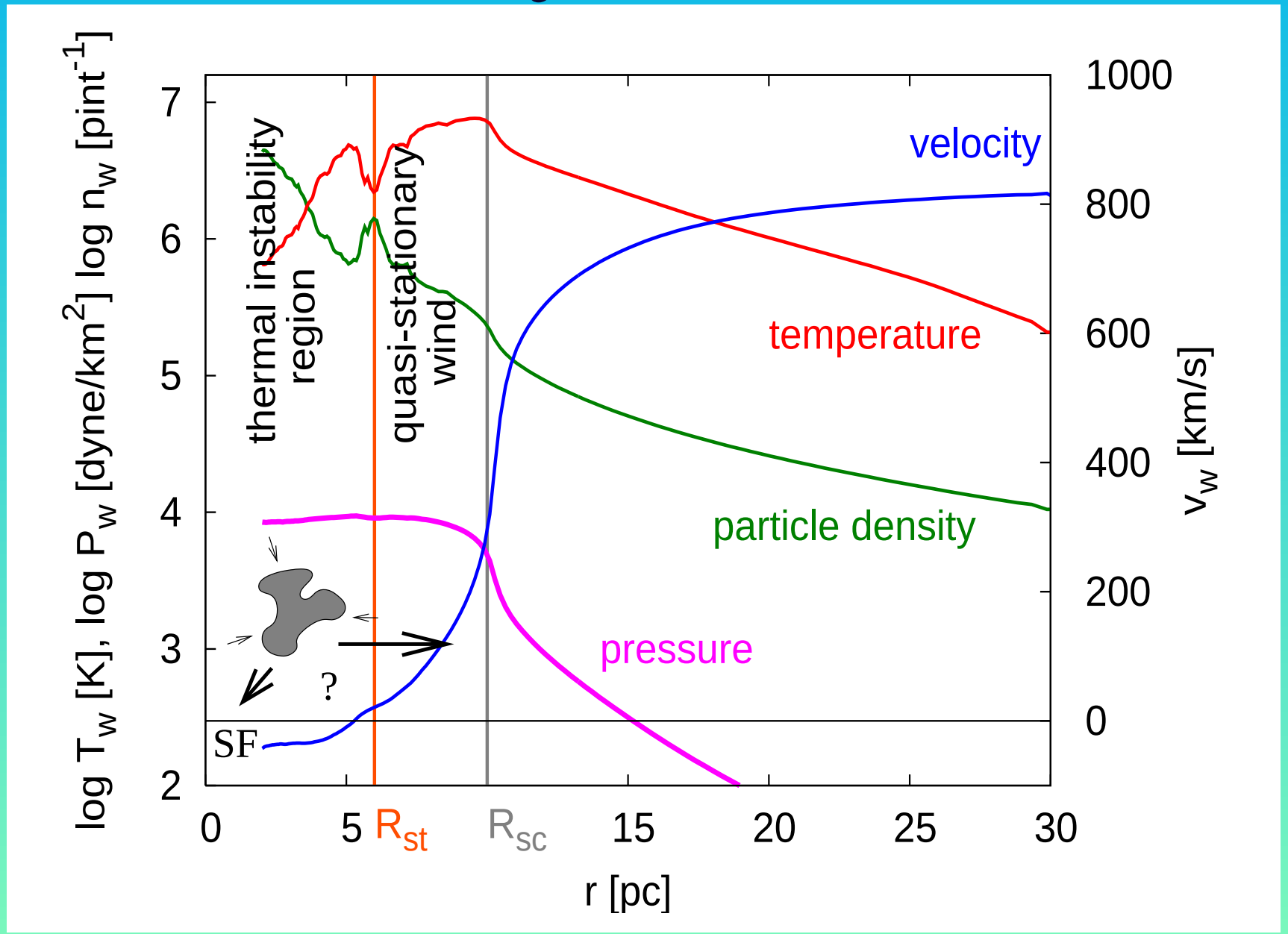
Critical luminosity

- bimodal solution for $L > L_{\rm crit}(R_{\rm SC}, v_{a,\infty}, \eta)$



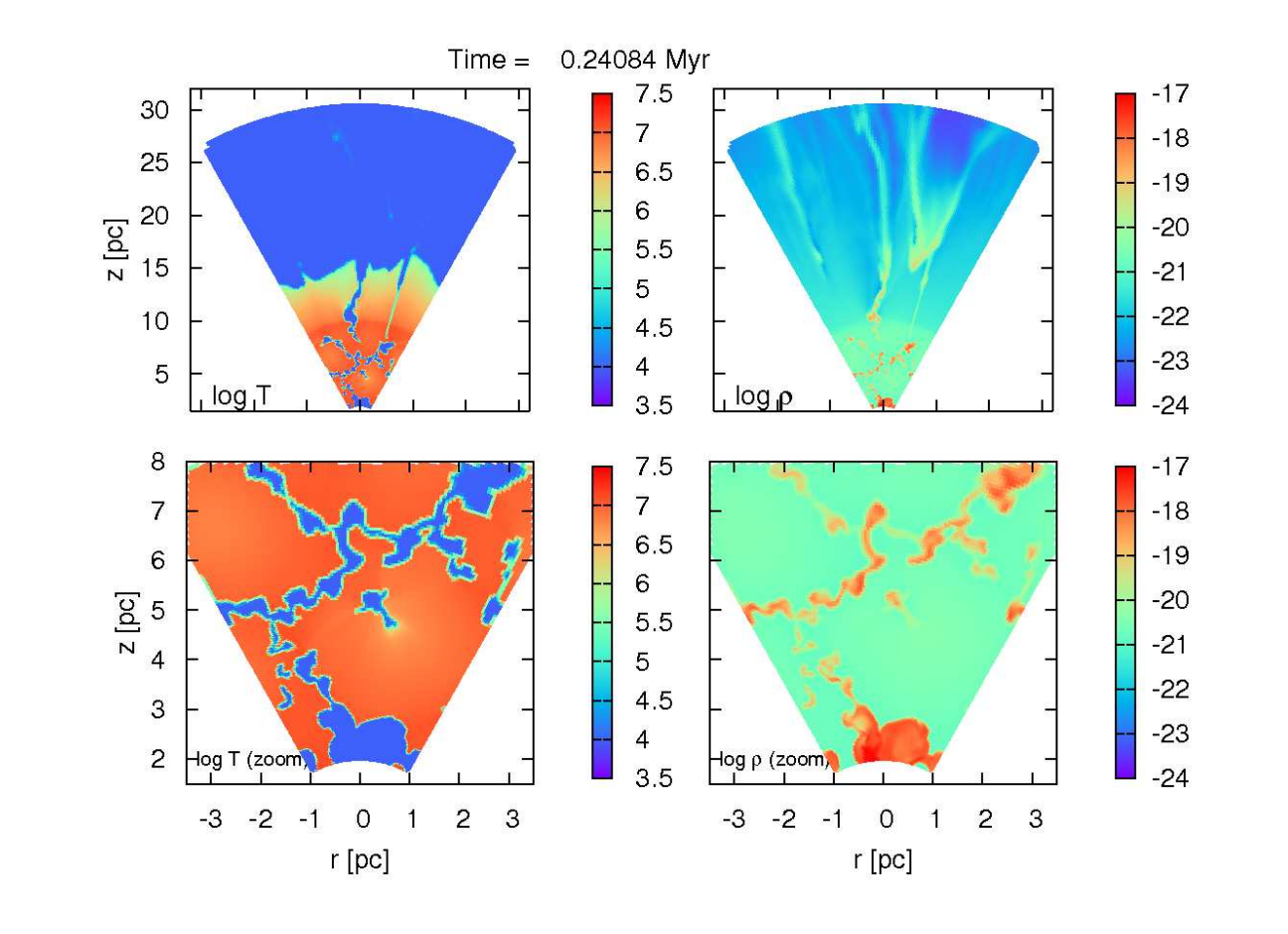
Bimodal solution

Tenorio-Tagle et al. (2007)



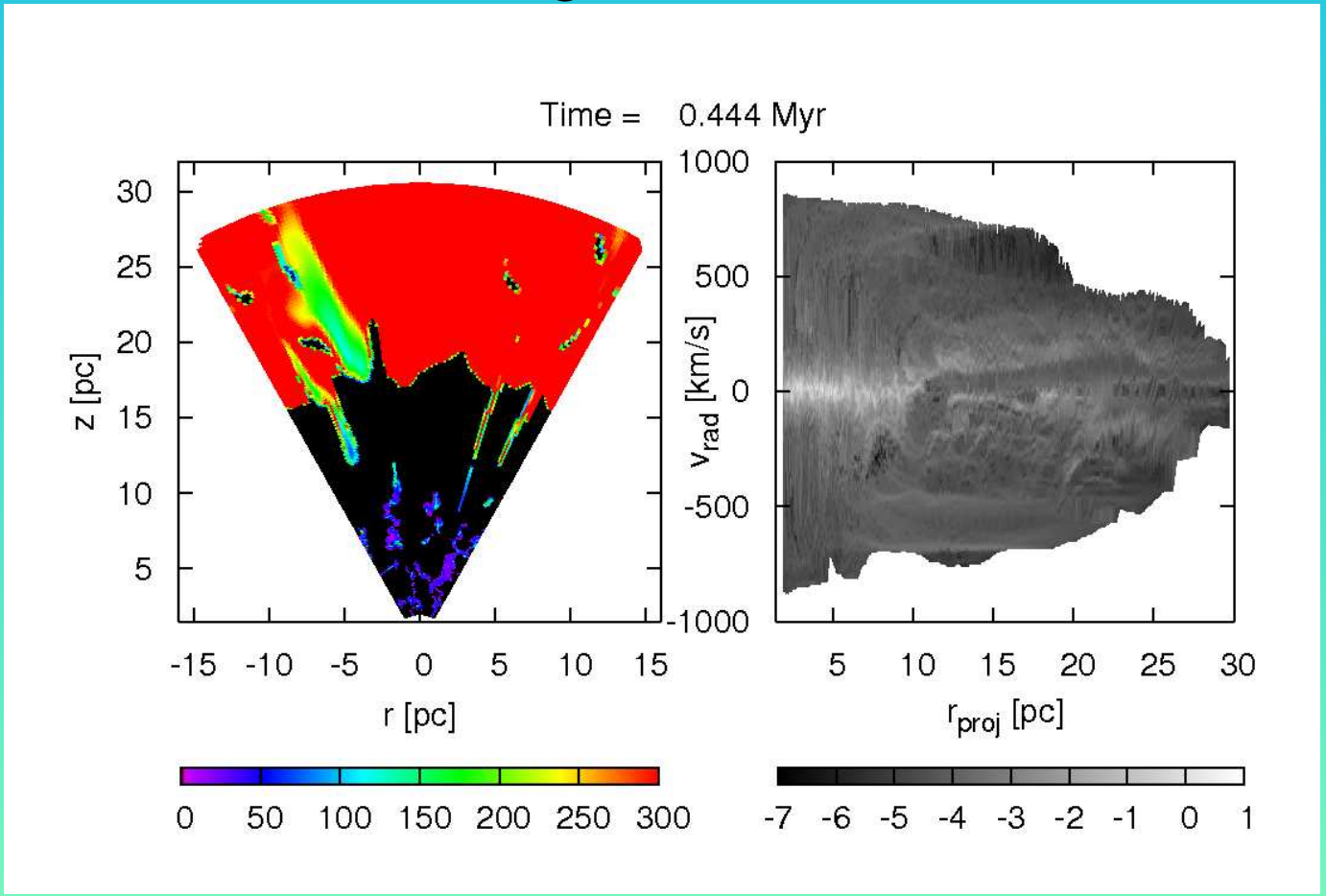
Numerical simulations

- ZEUS, 2D spherical coords, radially scaled, 1 radian
- new cooling (both global time-step control and substeps)
- $R_{\rm SC} = 10$ pc, $L_{\rm SC} = 10^{43}$ erg/s $v_{a,\infty} = 1000$ km/s, $T_{\rm min} = 10^4$ K



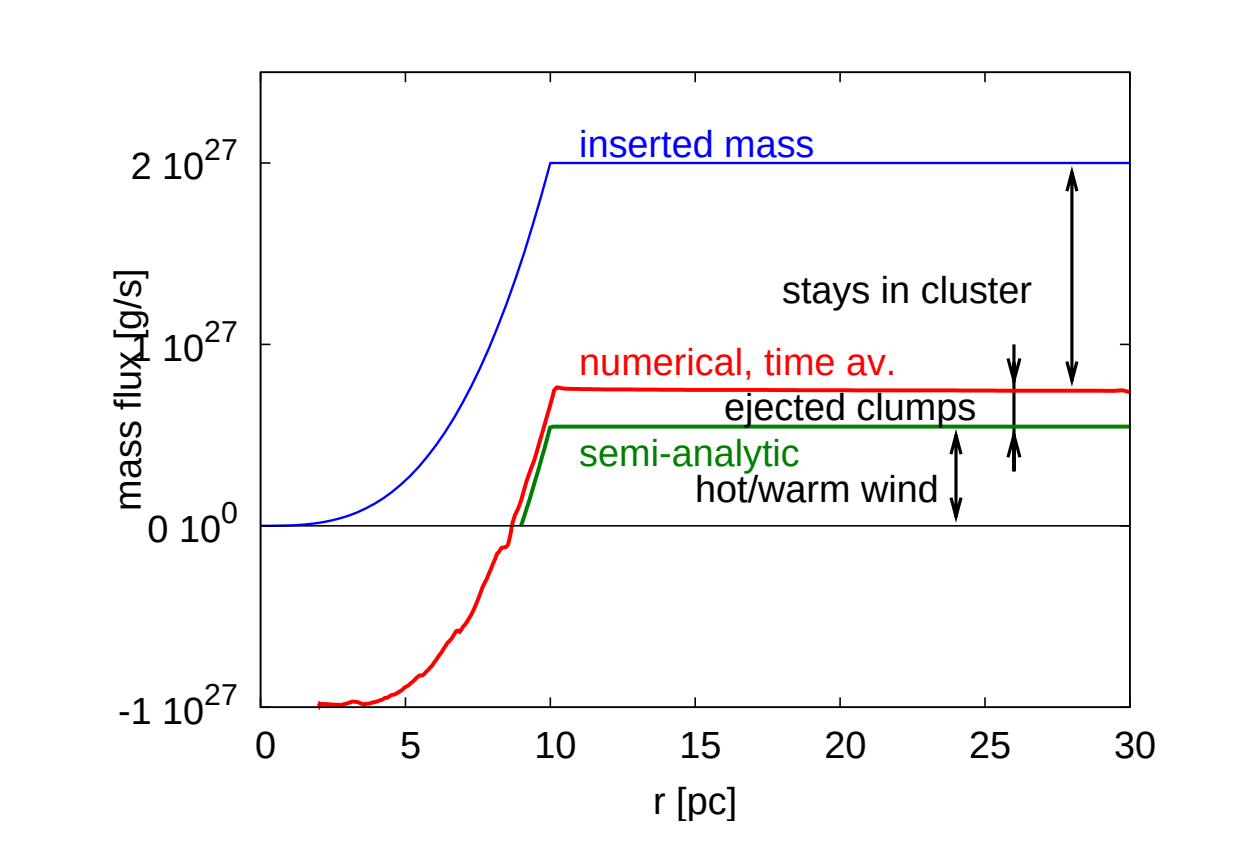
Velocity and "line profile"

- Left: magnitude of velocity of 10^4 K gas
- Right: column density (projected radius, radial velocity)
- 2 components of outflowing warm material

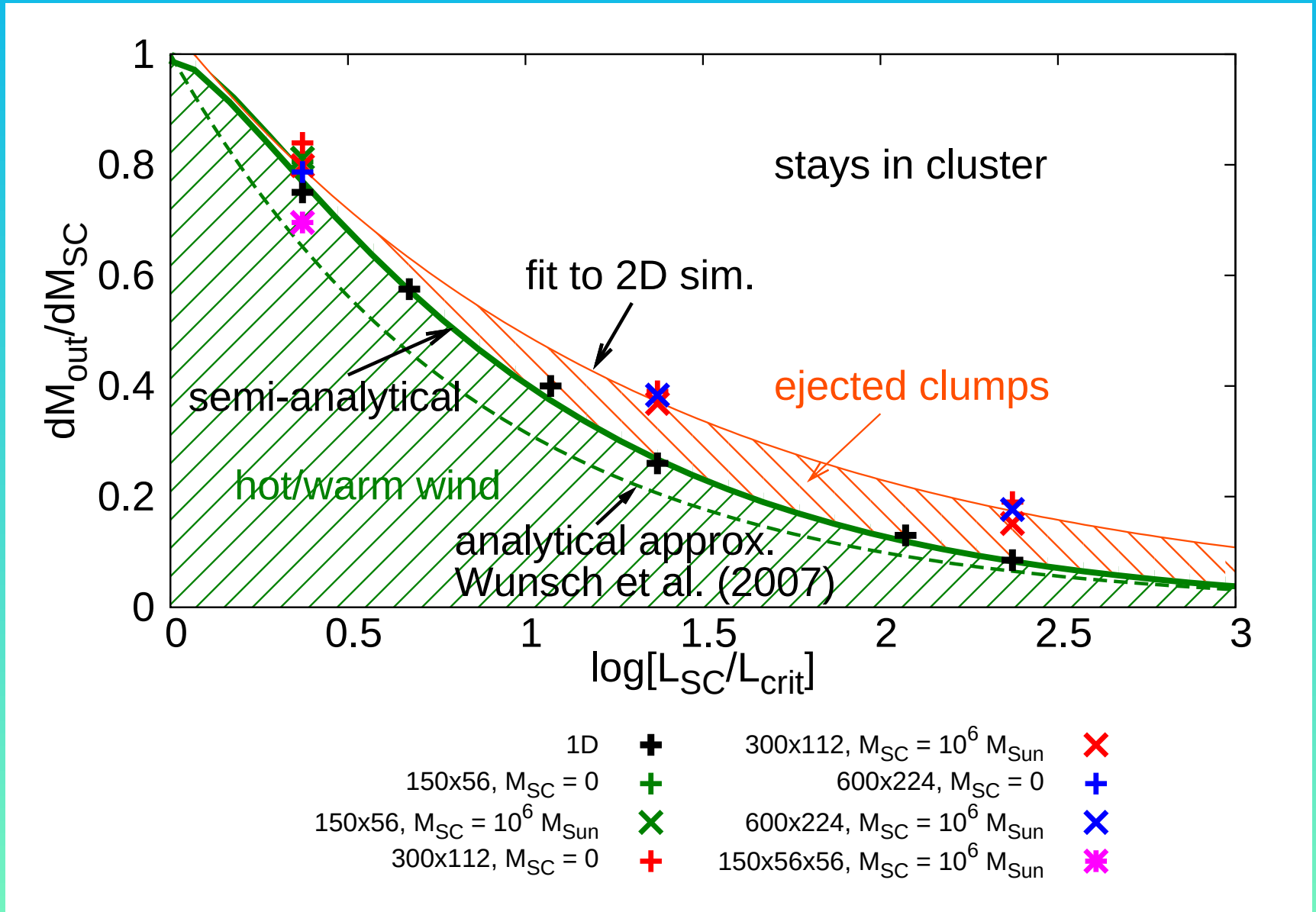


Mass flux as function of radius

- semi-anl: includes hot/warm wind only
- numerical: includes both hot/warm wind and clumps
- substantial amount of mass stays inside cluster
  $\rightarrow$ eventually available for SF



Outflow from the cluster for different models



Conclusions

- 2D simulations confirm bimodal behaviour: outer part of cluster produces the quasi-stationary wind, thermal instability forms dense warm clumps in the inner region
- warm 10^4 K outflow from the cluster consits of two components: originally hot wind that cools down and ejected clumps formed in the central region
- ejected clumps carry only small amount of inserted mass (10% or less), most of mass inserted below R_{st} stays in the cluster

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References

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