The Antesonic Condition for the Explosion of Core-Collapse Supernovae

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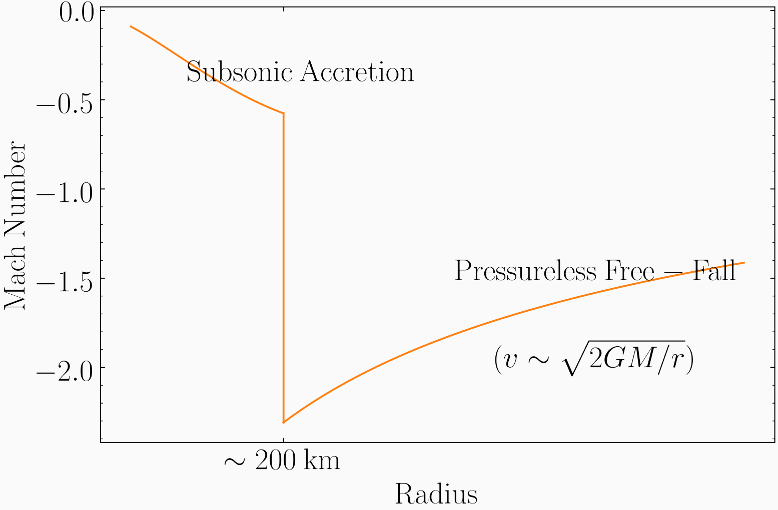
Motivations

- Goal: to understand the mechanism and circumstances of these events: how and why a dying star explodes
- This field typically relies on massive, high-fidelity simulations simulations to investigate this
- We approach from a different angle – we seek to understand explosion on a fundamental level, as a hydrodynamics problem, and determine what exactly separates the parameter space into successful and failed explosions

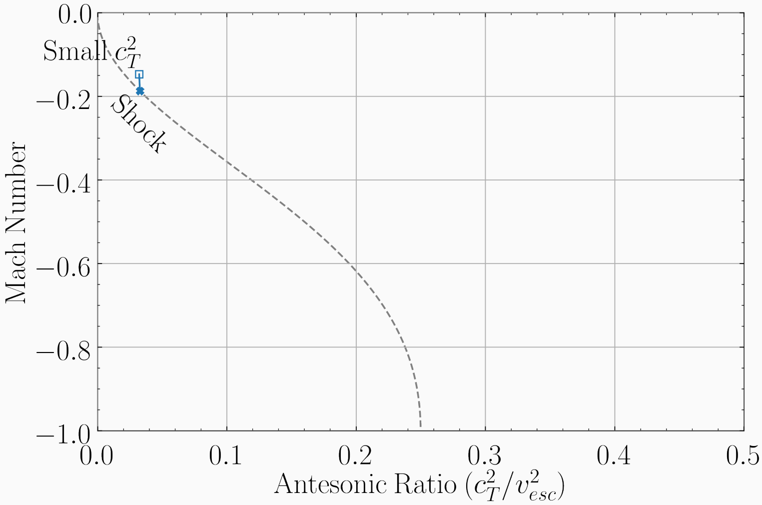
The Model Problem



Pejcha & Thompson 2012

- Pejcha & Thompson (2012) found that for a isothermal fluid in spherical symmetry, the Euler equations and shock-jump conditions could only be simultaneously satisfied in certain regions of parameter space.
- They parameterize this with the "antesonic ratio" c_T^2/v_{esc}^2
- For pressureless free-fall above the shock, the relevant condition is $\max(c_T^2/v_{esc}^2) \leq 3/16$

The Antesonic Condition



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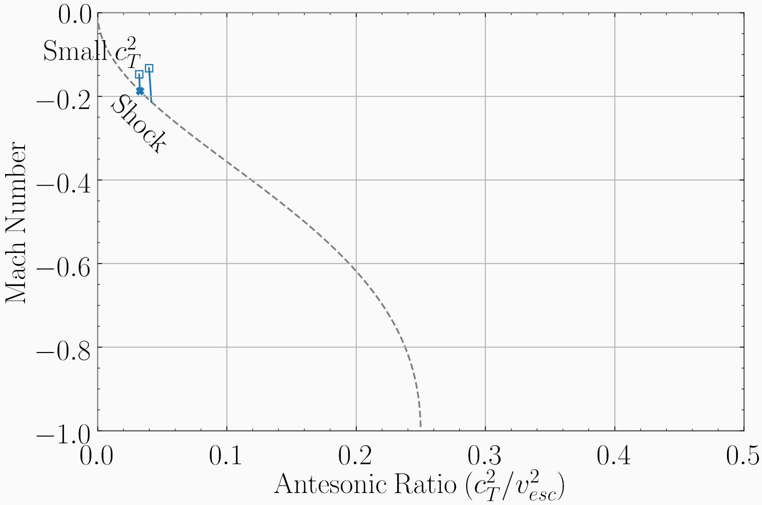

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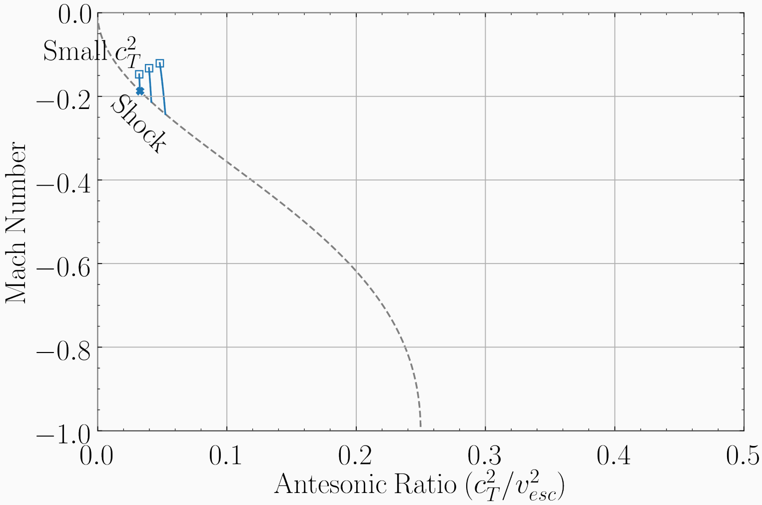

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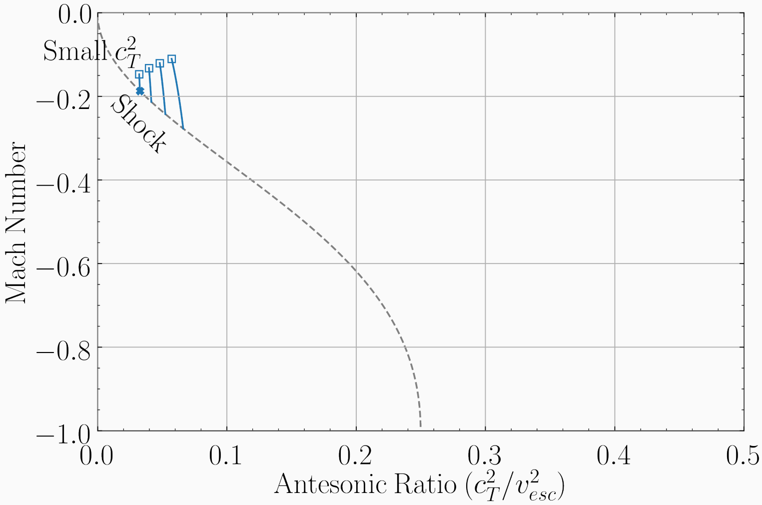

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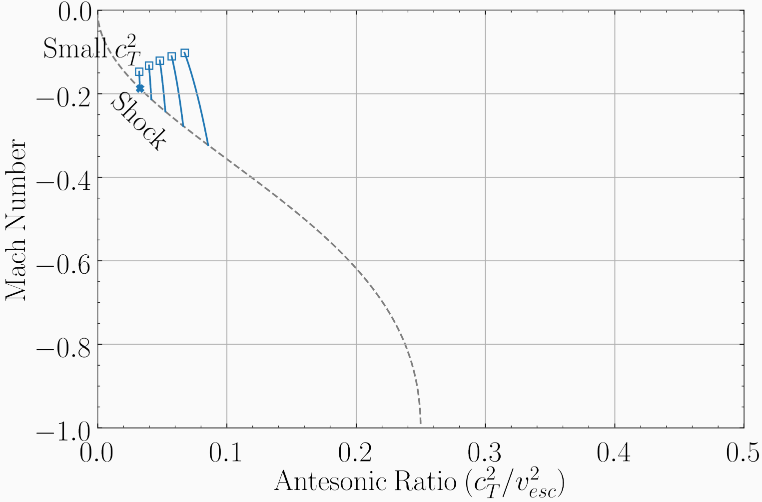

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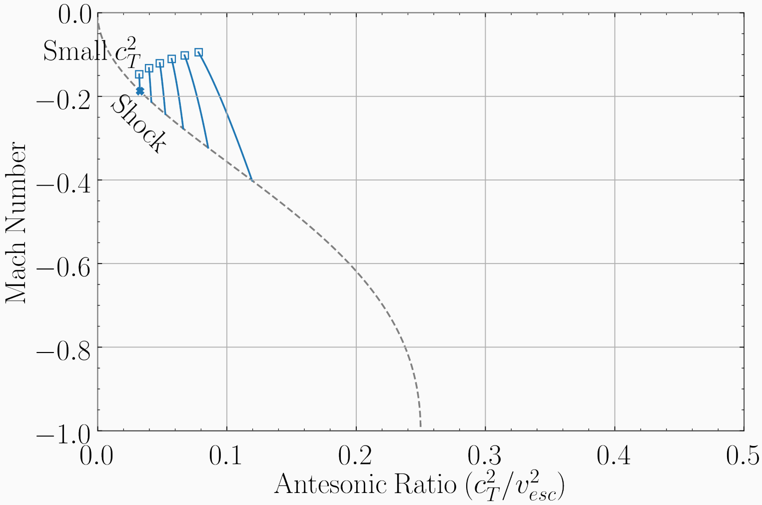
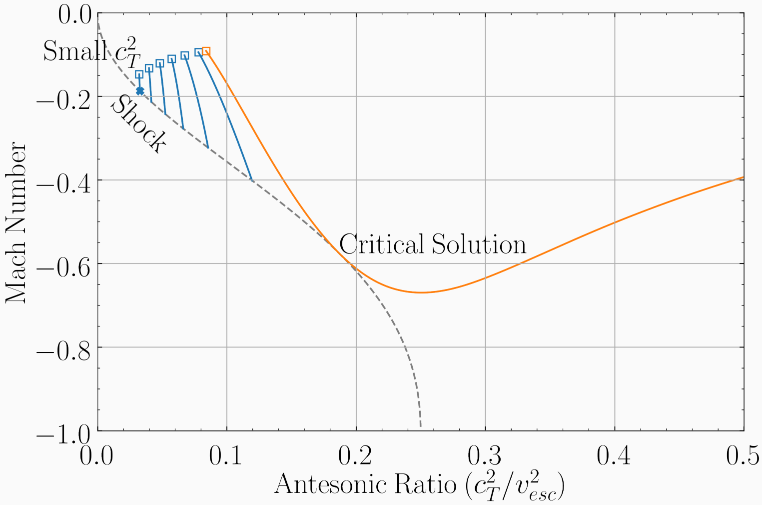
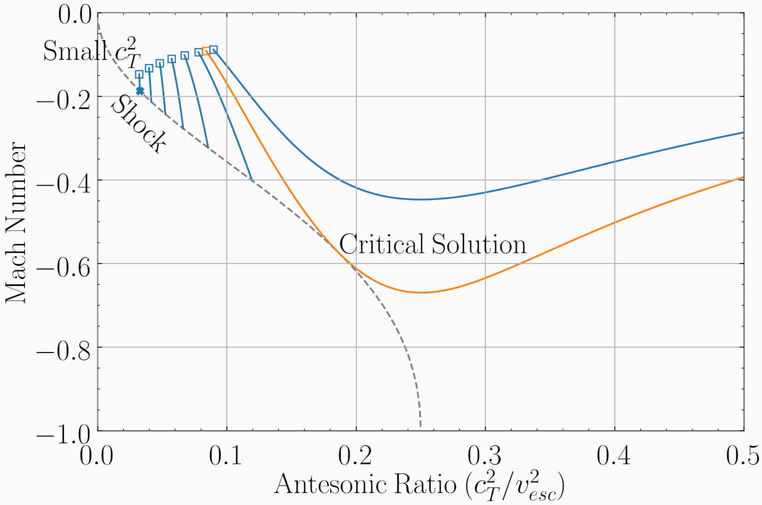




0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0.0
0.1
0.2
0.3
0.4
0.5
Small c_T^2
Shock
Critical Solution
Mach Number
Antesonic Ratio (c_T^2/v_{esc}^2)

The Antesonic Condition



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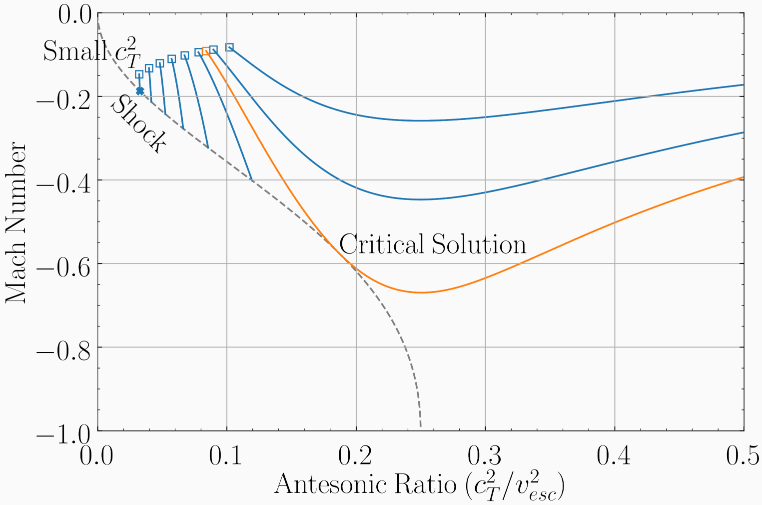

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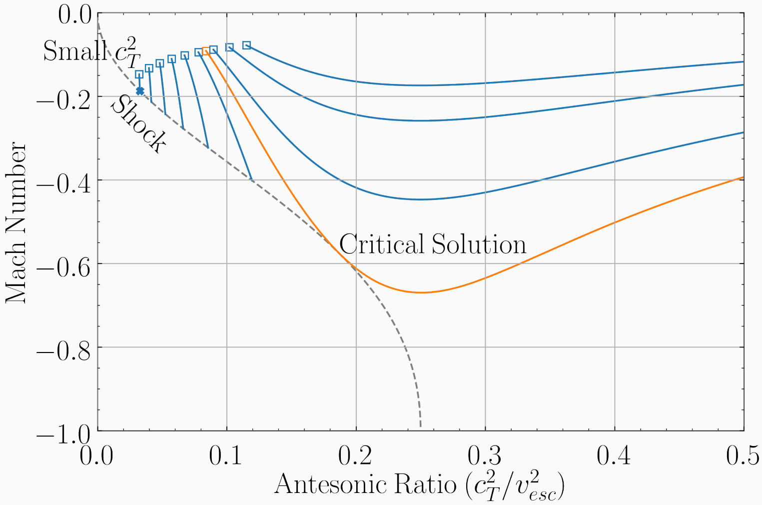

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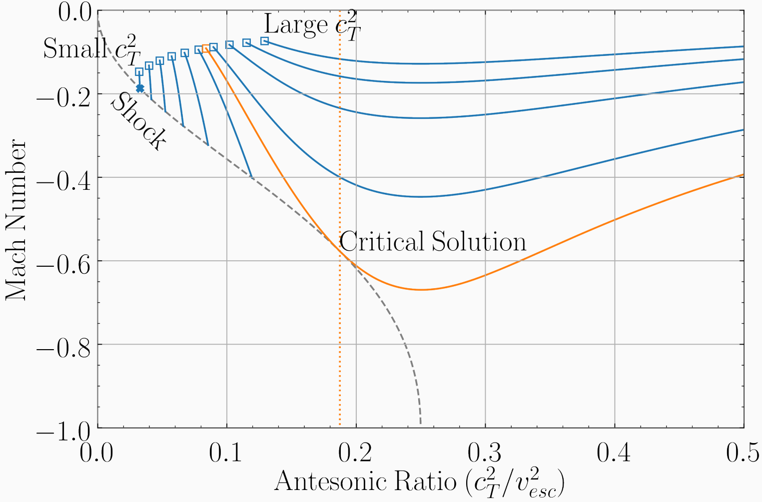

Critical Curve

- We adopt a polytropic equation of state ($P = K\rho^{\Gamma}$) and evolve our models in time using the FLASH code
- Beginning with stable solutions, we decrease the mass accretion rate until we reach explosion
- From this, we construct a critical curve that separates stable solutions from exploding ones.

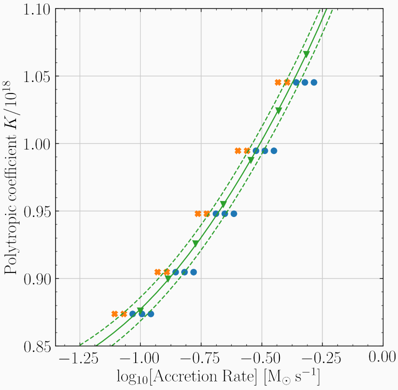

Figure 1: Raives et al 2018

Resolution

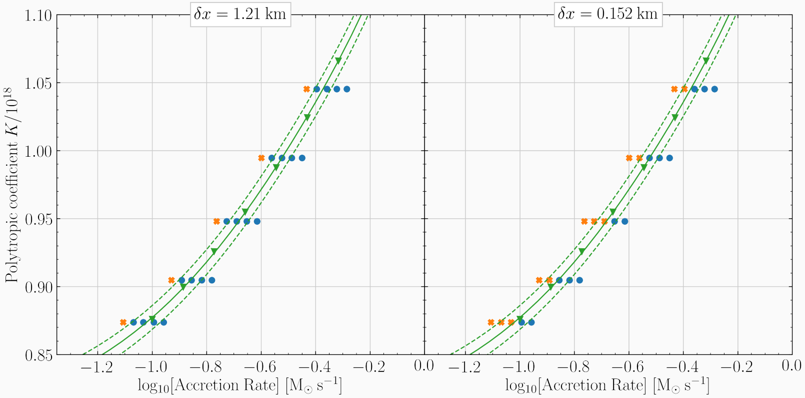

Figure 2: Raives et al 2018

The Wind

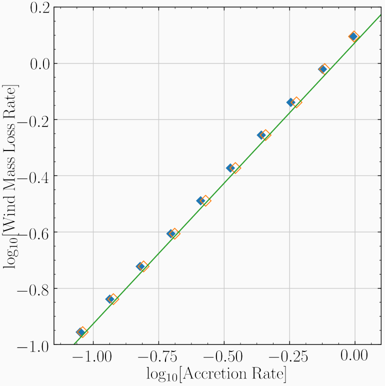

Figure 3: Raives et al 2018

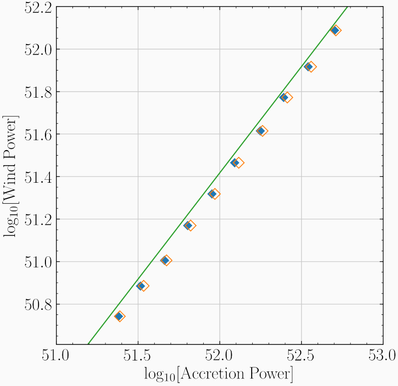

Figure 4: Raives et al 2018

Conclusions

- We extend the antesonic condition first formulated by Pejcha & Thompson (2012) to time-dependent models with a polytropic EOS
- We find that high resolution is necessary to capture the full nature of the critical condition for explosion
- There exists an important physical connection between the post-explosion wind and pre-explosion accretion flow.

Questions