Title: Weak interaction Physics in Large-Scale Core-Collapse

Date: Jun 21, 2011 09:30 AM

URL: http://pirsa.org/11060020

Abstract:

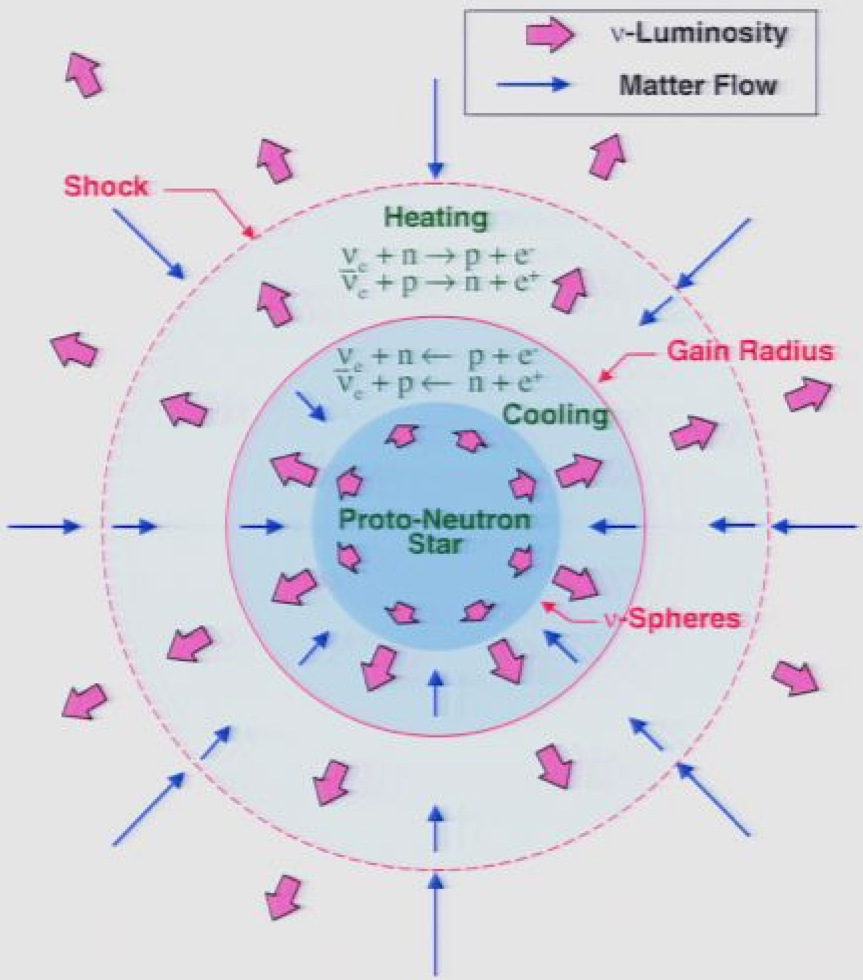
CHIMERA Collaboration

- Steve Bruenn, Pedro Marronetti (Florida Atlantic University)
- John Blondin (NC State University)
- Anthony Mezzacappa, Eirik Endeve, Raph Hix, Eric Lentz, Suzanne Parete-Koon (ORNL/UTK)
- Konstantin Yakunin (FAU), Reuben Budjiara, Austin Chertkow (UTK)

AGILE-Boltztran

- M. Liebendörfer, A. Mezzacappa
- E. Lentz
- T. Fischer and others in Basel

How is the supernova shock revived?



Known, Potentially Important Ingredients

- Gravity
- Neutrino Heating
- Convection
- Shock Instability (SASI)
- Nuclear Burning
- Rotation
- Magnetic Fields

Need 3D models with all of the above, treated with sufficient realism.

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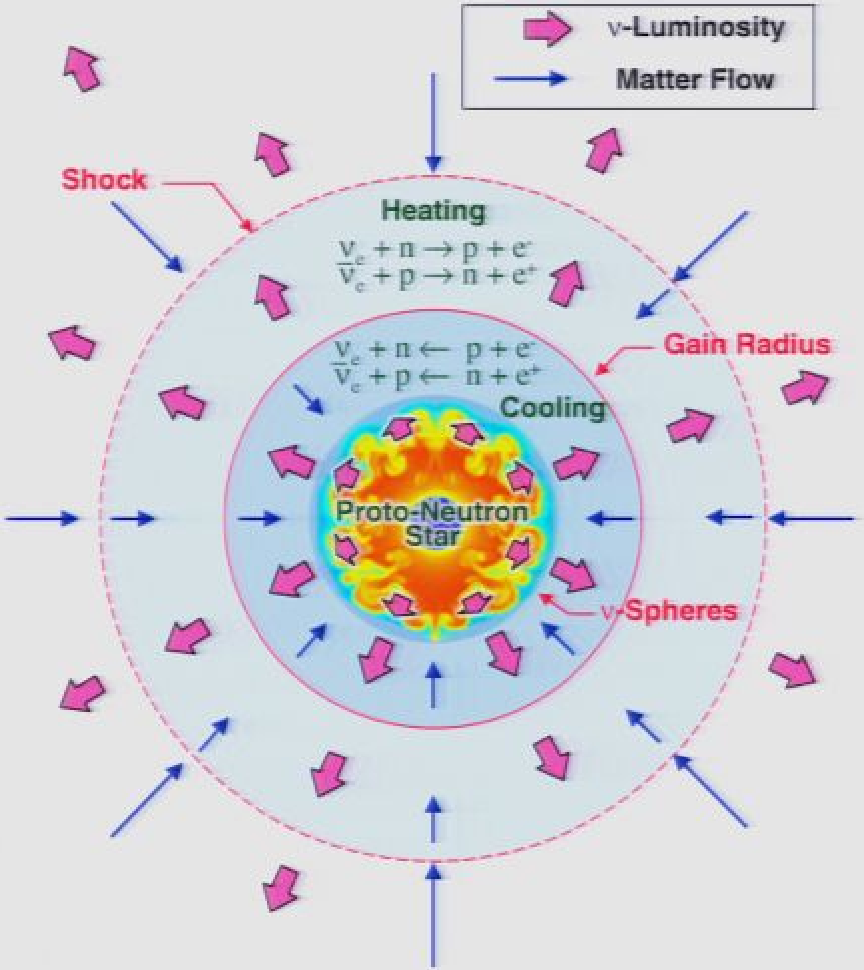

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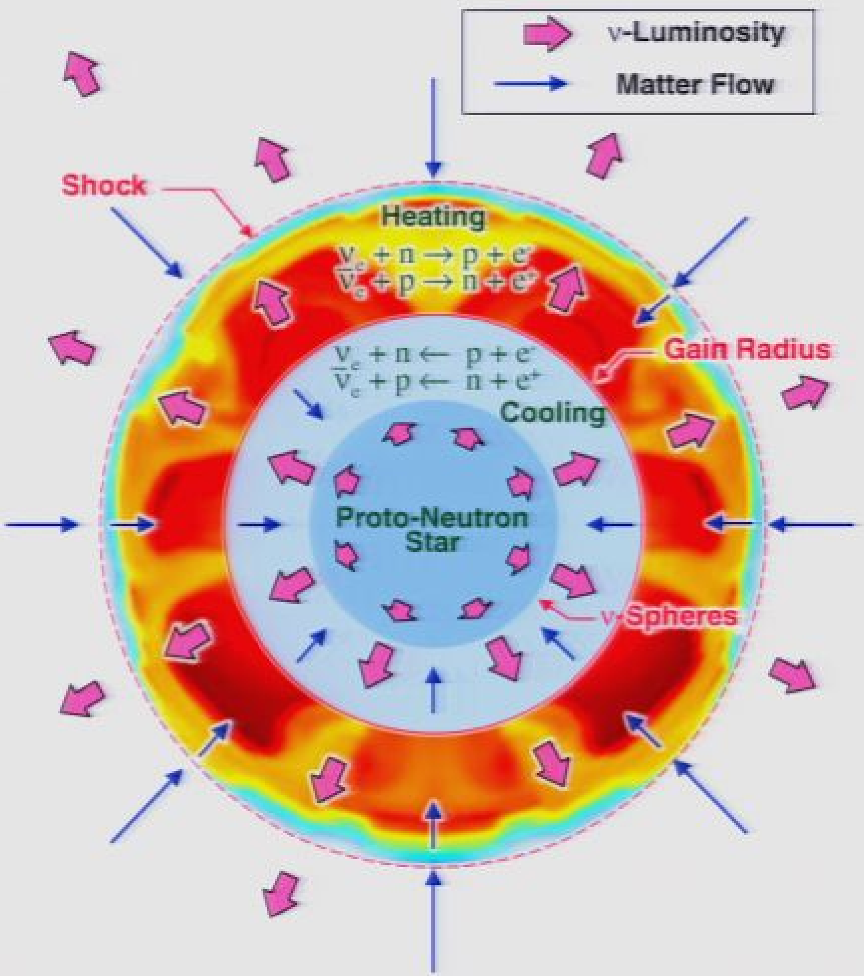

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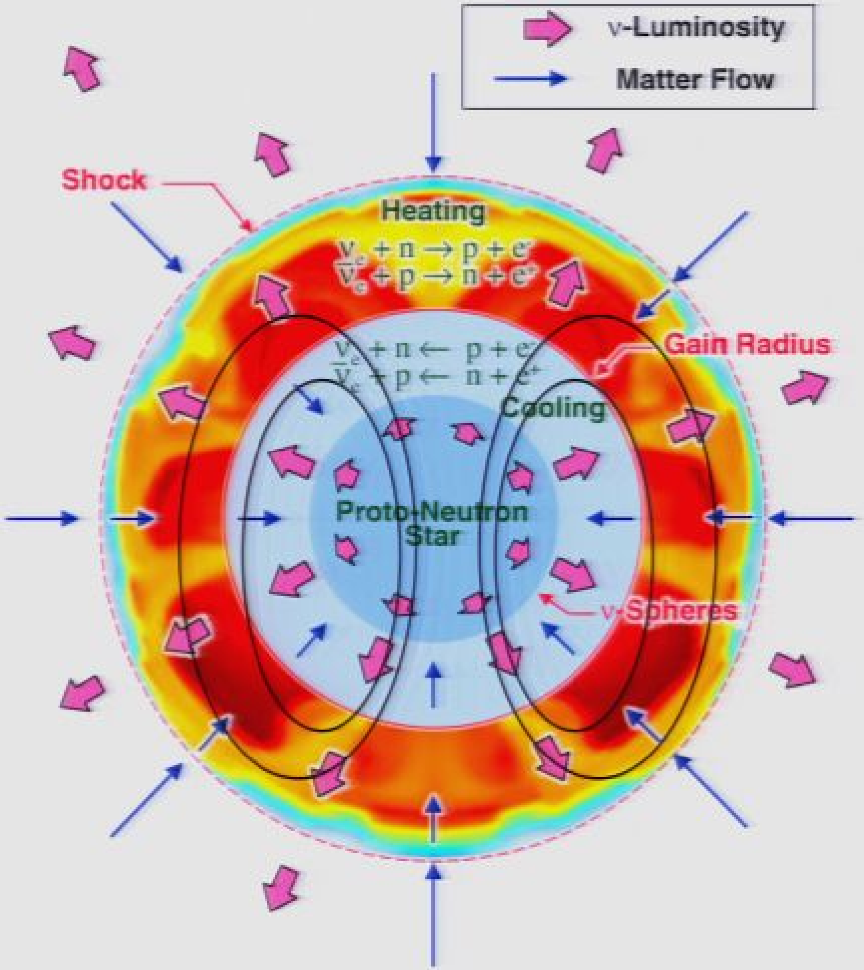

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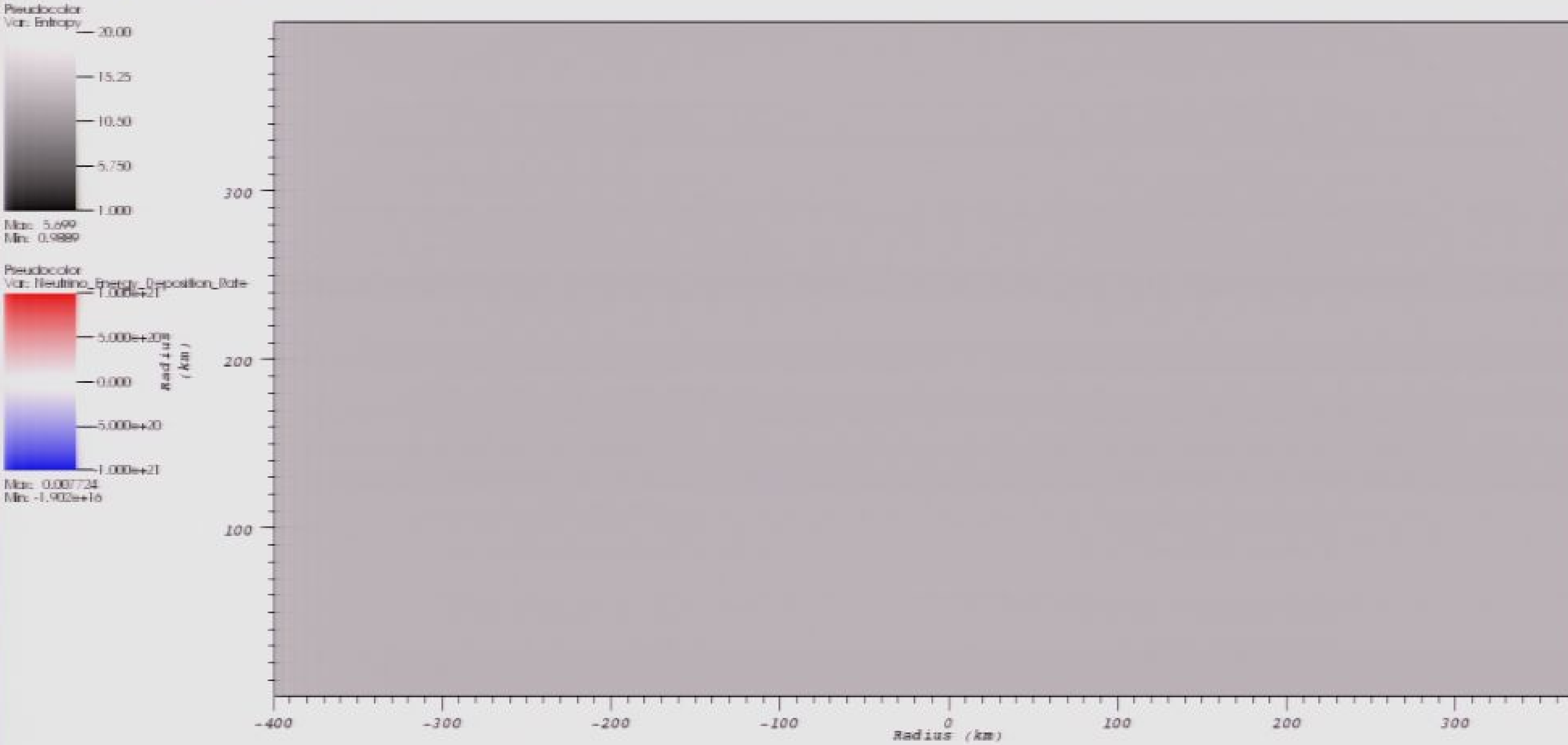
CHIMERA

- "RbR-Plus" MGFLD Neutrino Transport
  - O(v/c), GR time dilation and redshift, GR aberration (in flux limiter)
- 2D PPM Hydrodynamics
  - GR time dilation, effective gravitational potential,
  - adaptive radial grid
- Lattimer-Swesty EOS
- Nuclear (Alpha) Network
  - 14 alpha nuclei between helium and zinc
- 2D Effective Gravitational Potential
  - Marek et al. A&A, 445, 273 (2006)
- Neutrino Emissivities/Opacities
  - "Standard" + Elastic Scattering on Nucleons + Nucleon–Nucleon Bremsstrahlung

cf. Buras et al. *A&A*, **447**, 1049 (2003)

2D simulations

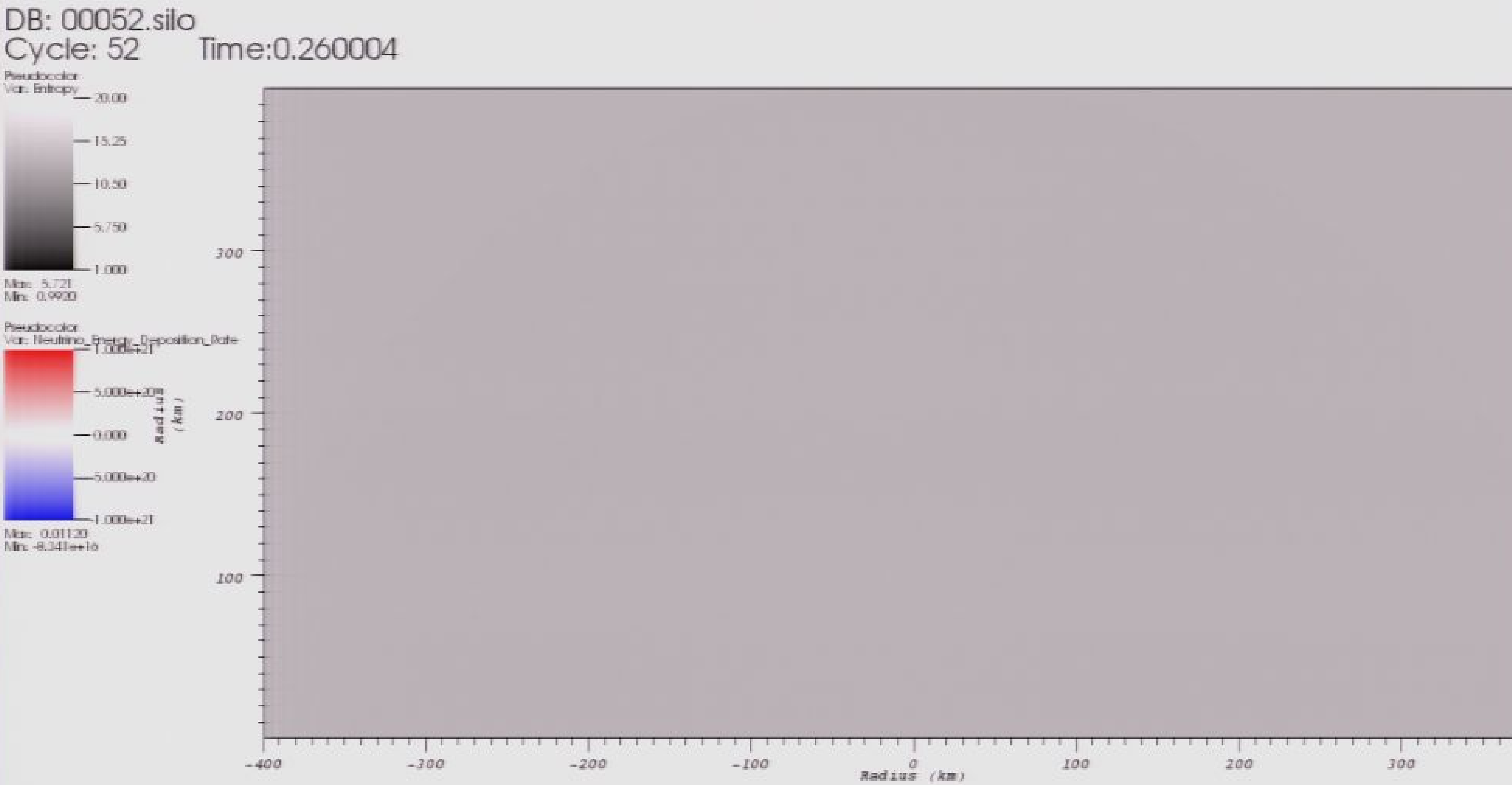
DB: 00021.silo
Cycle: 21 Time:0.105065



Entropy - semi-transparent grayscale

ν heating/cooling - red/blue colormap

2D simulations



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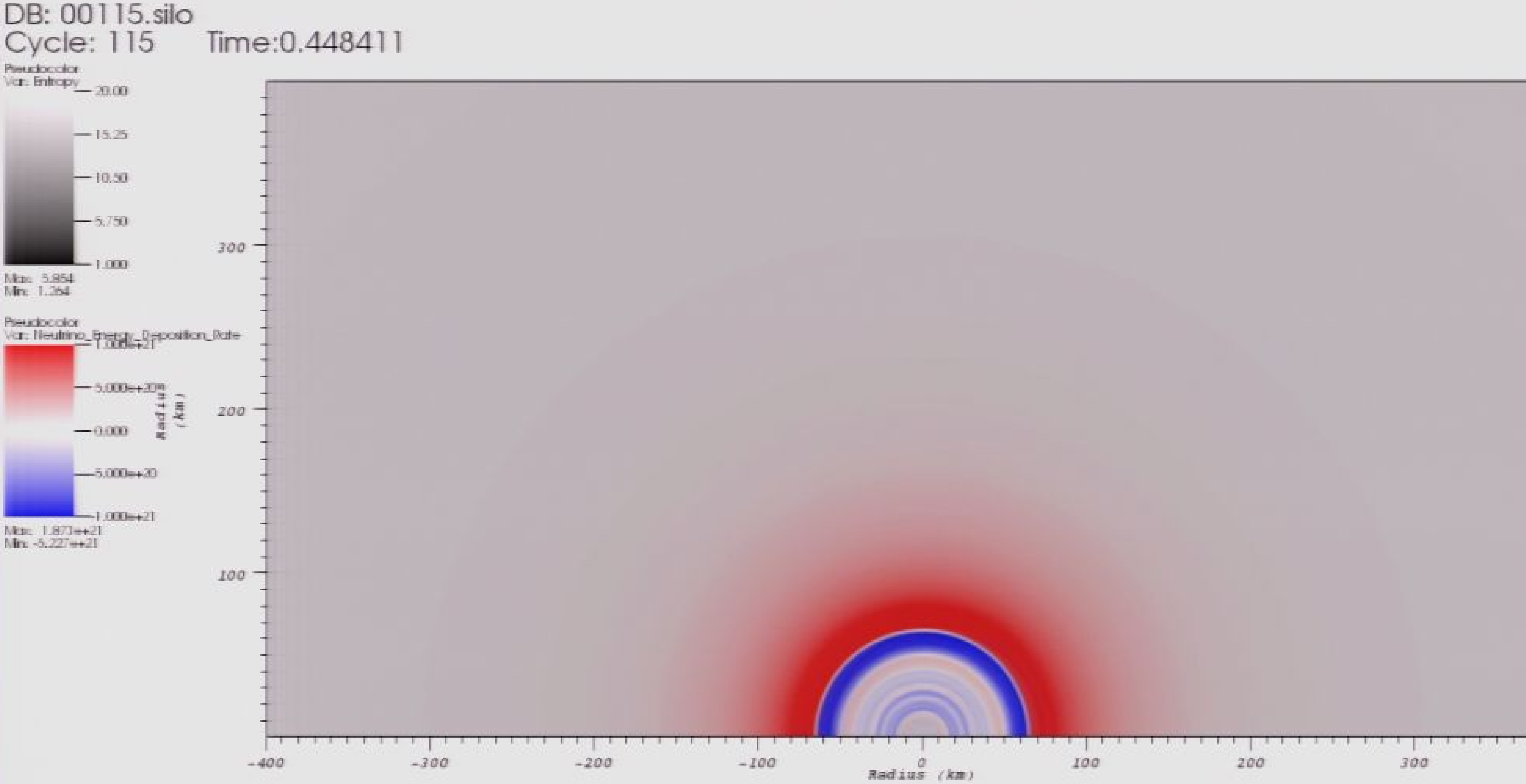

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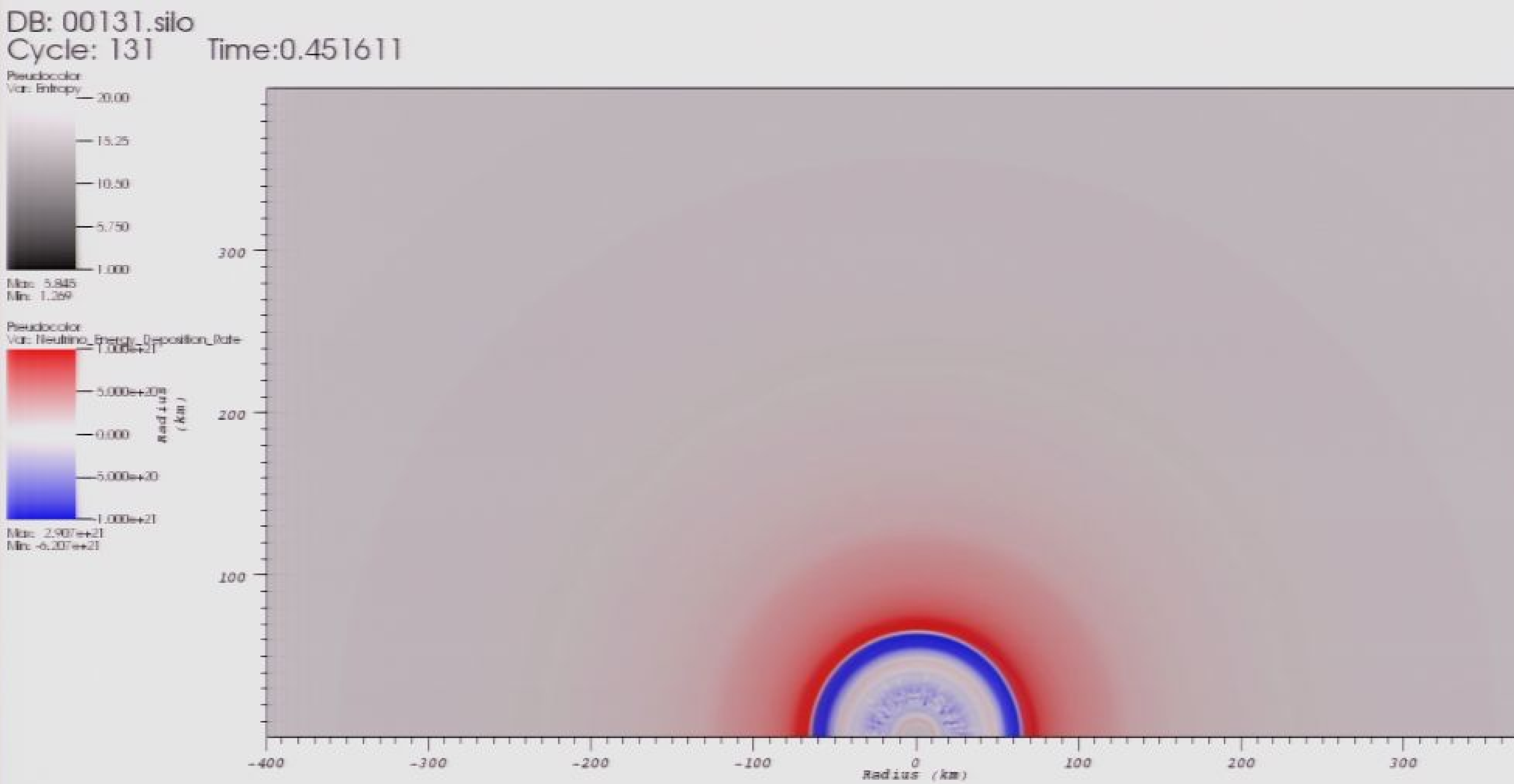

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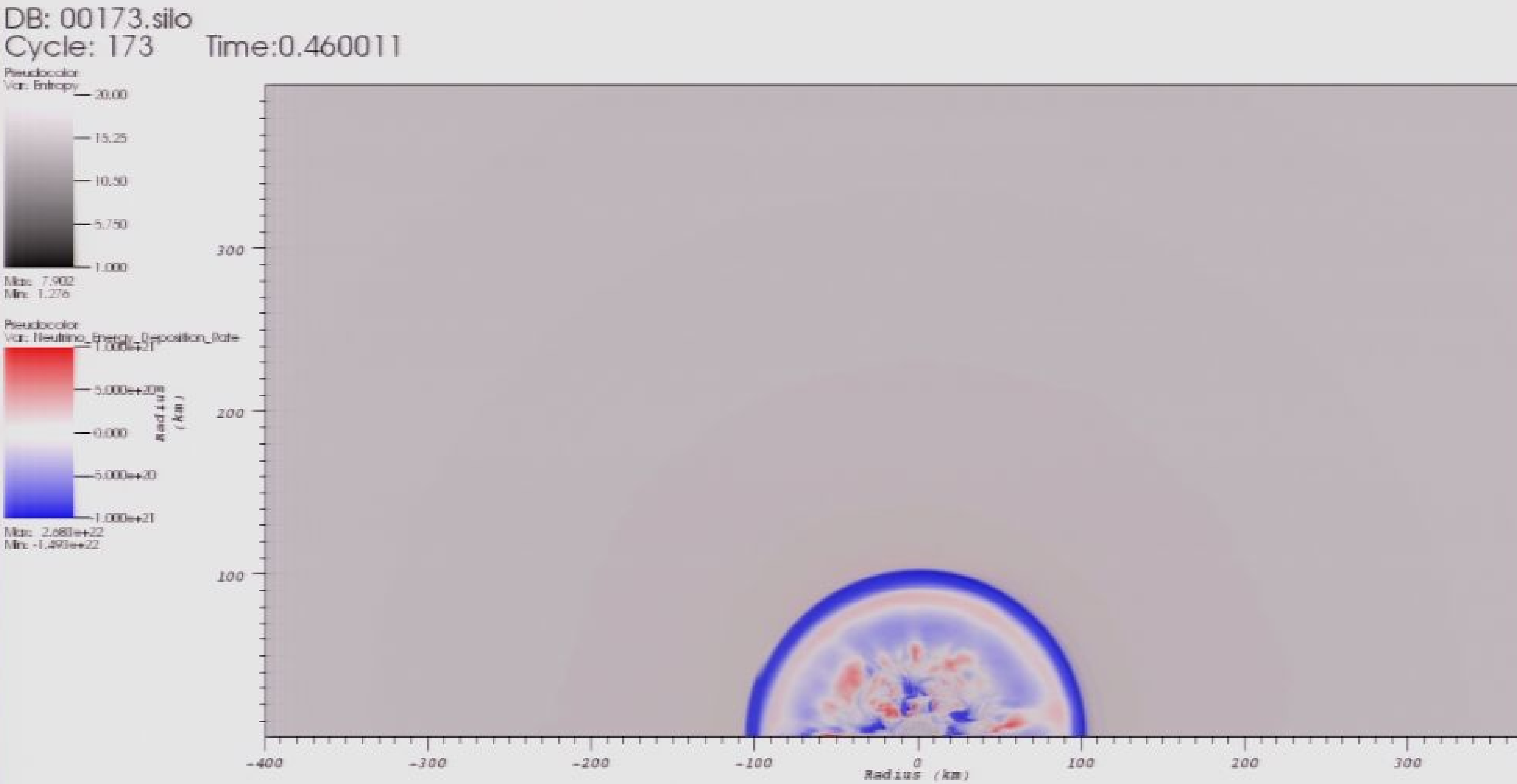

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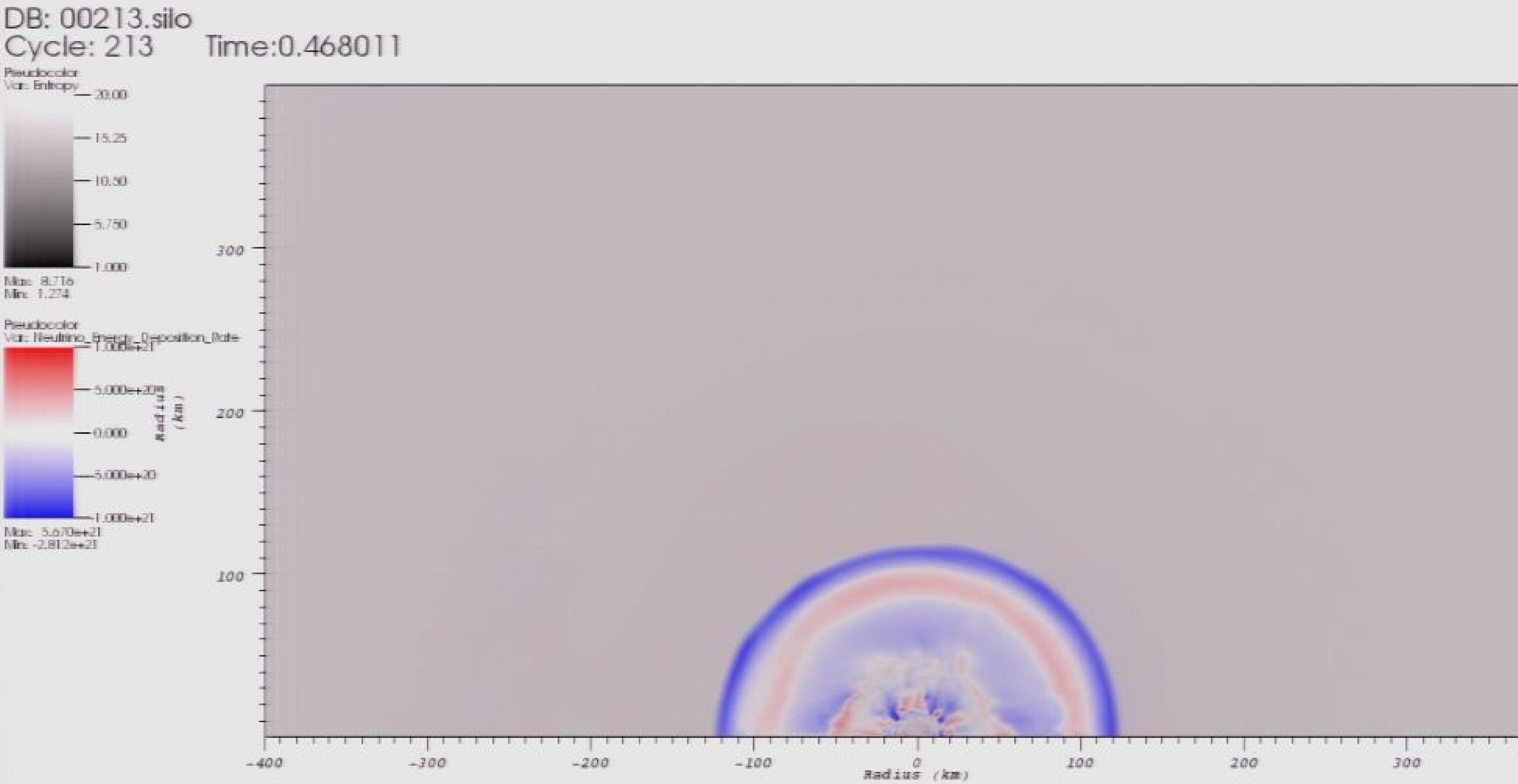

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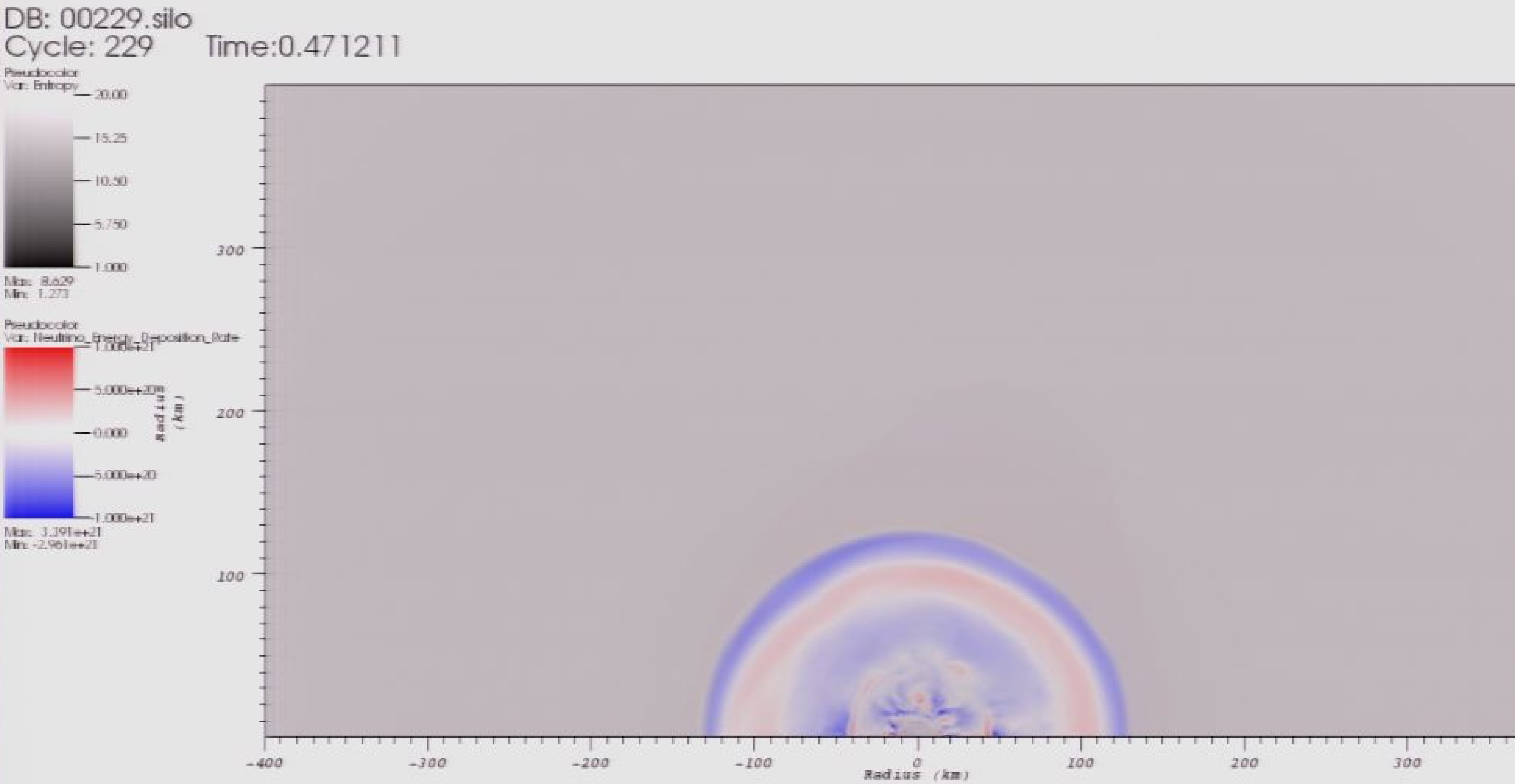

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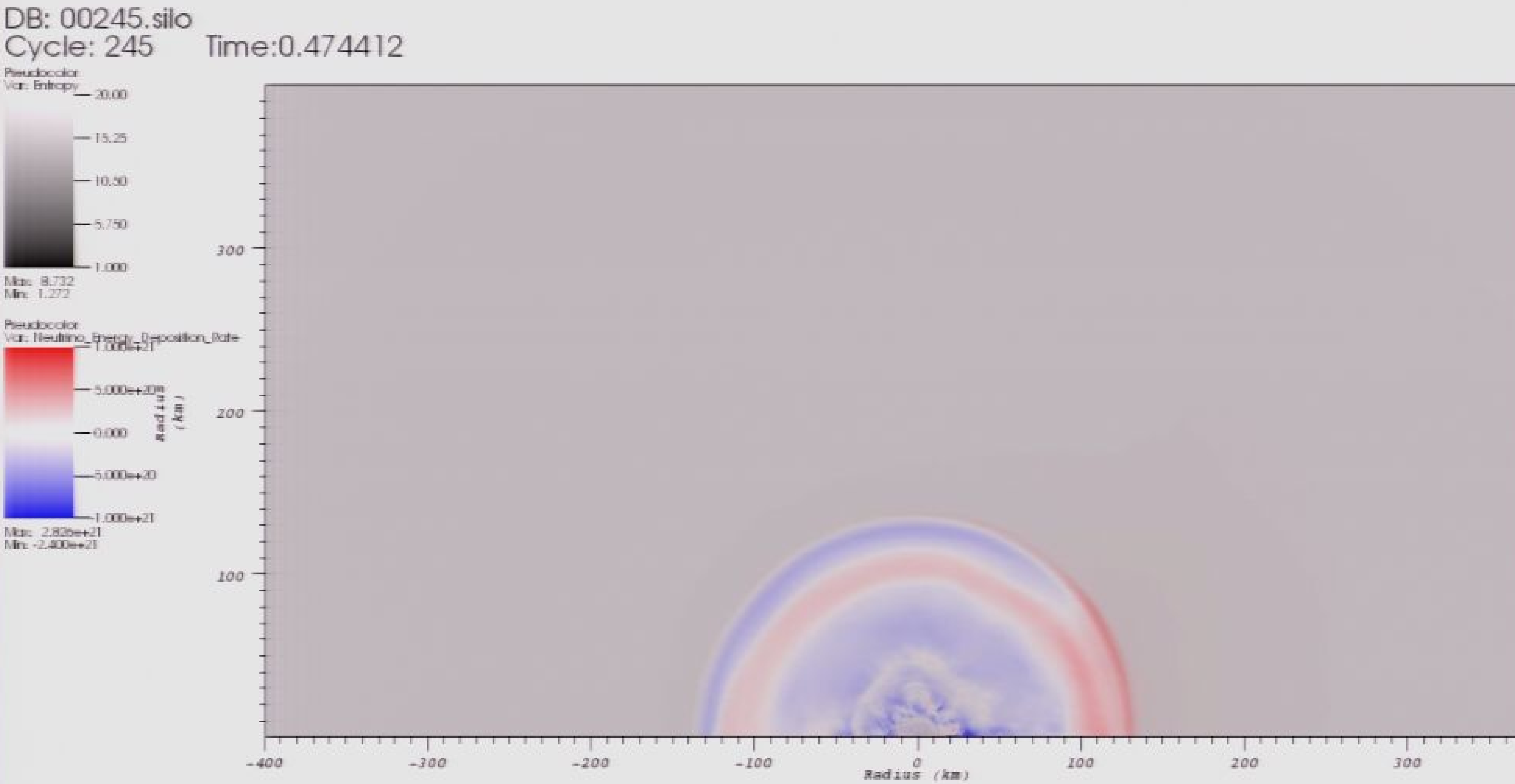

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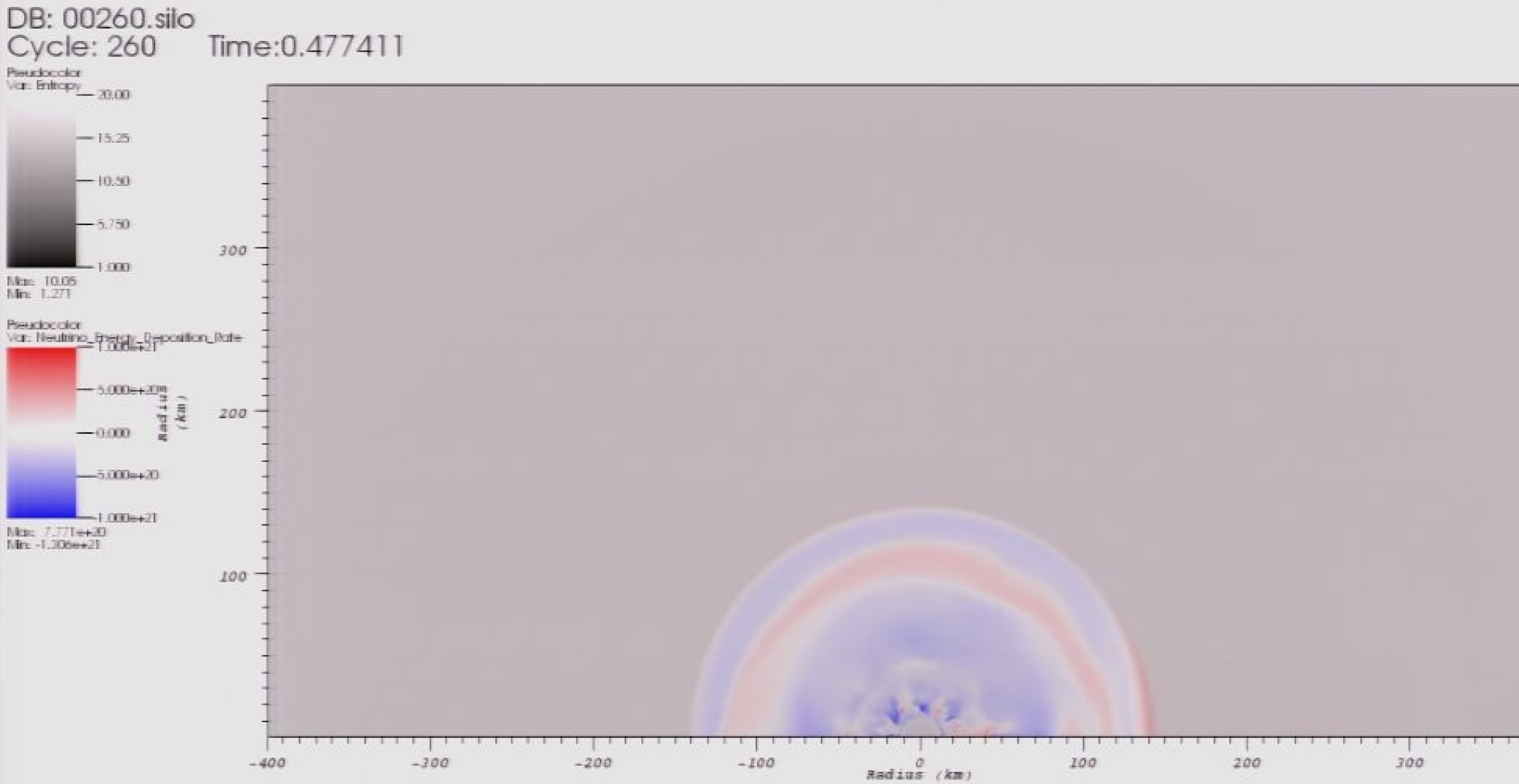

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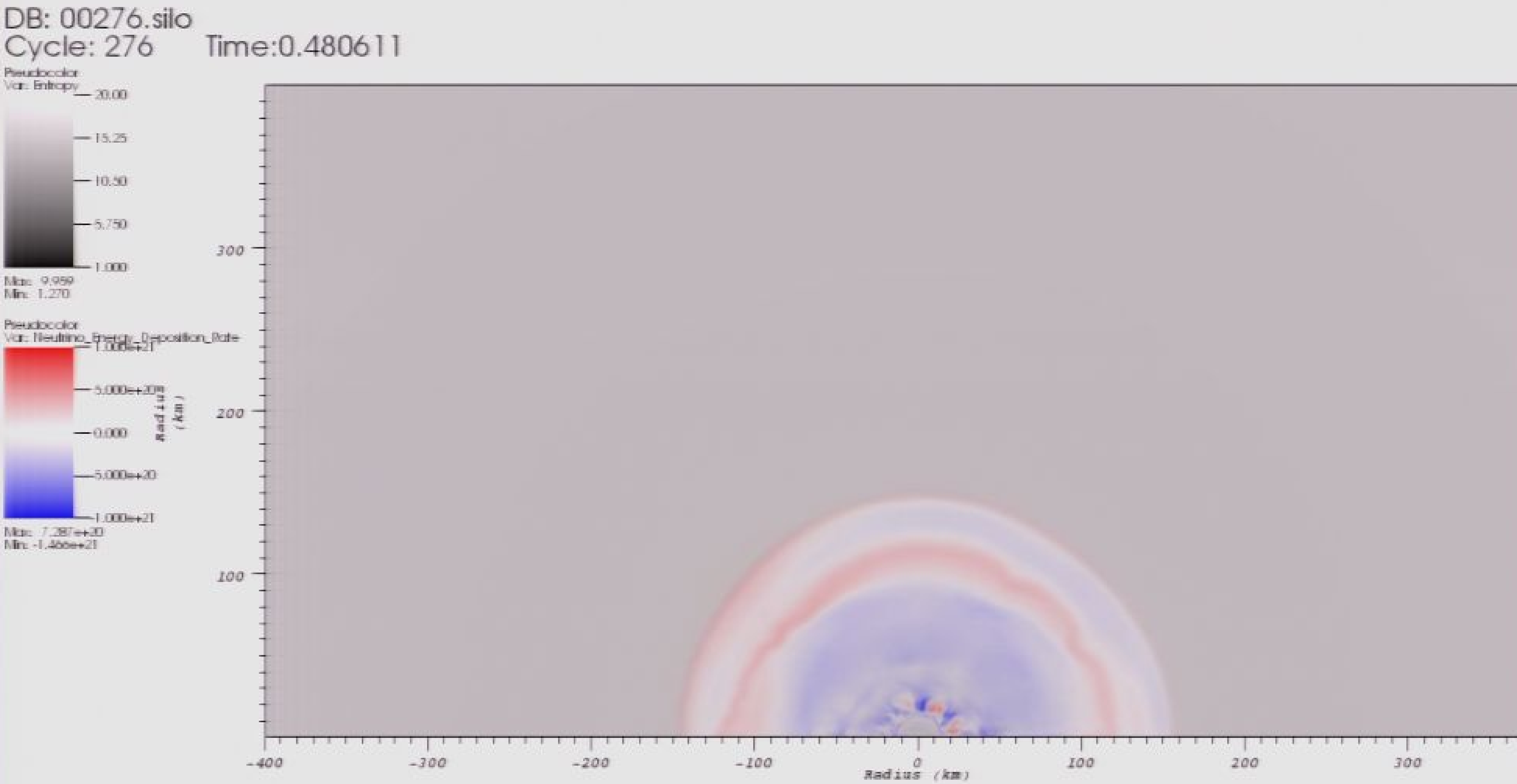

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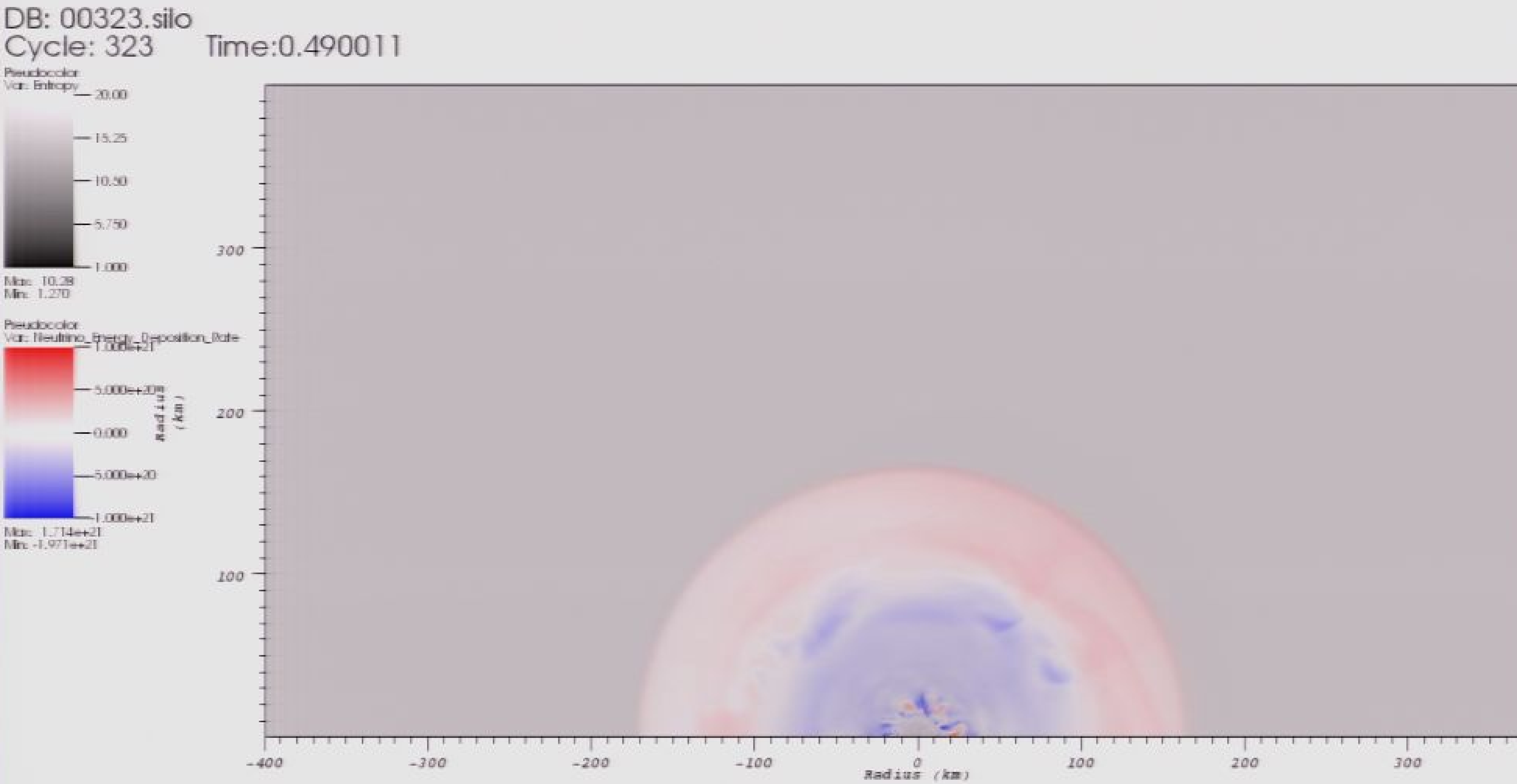

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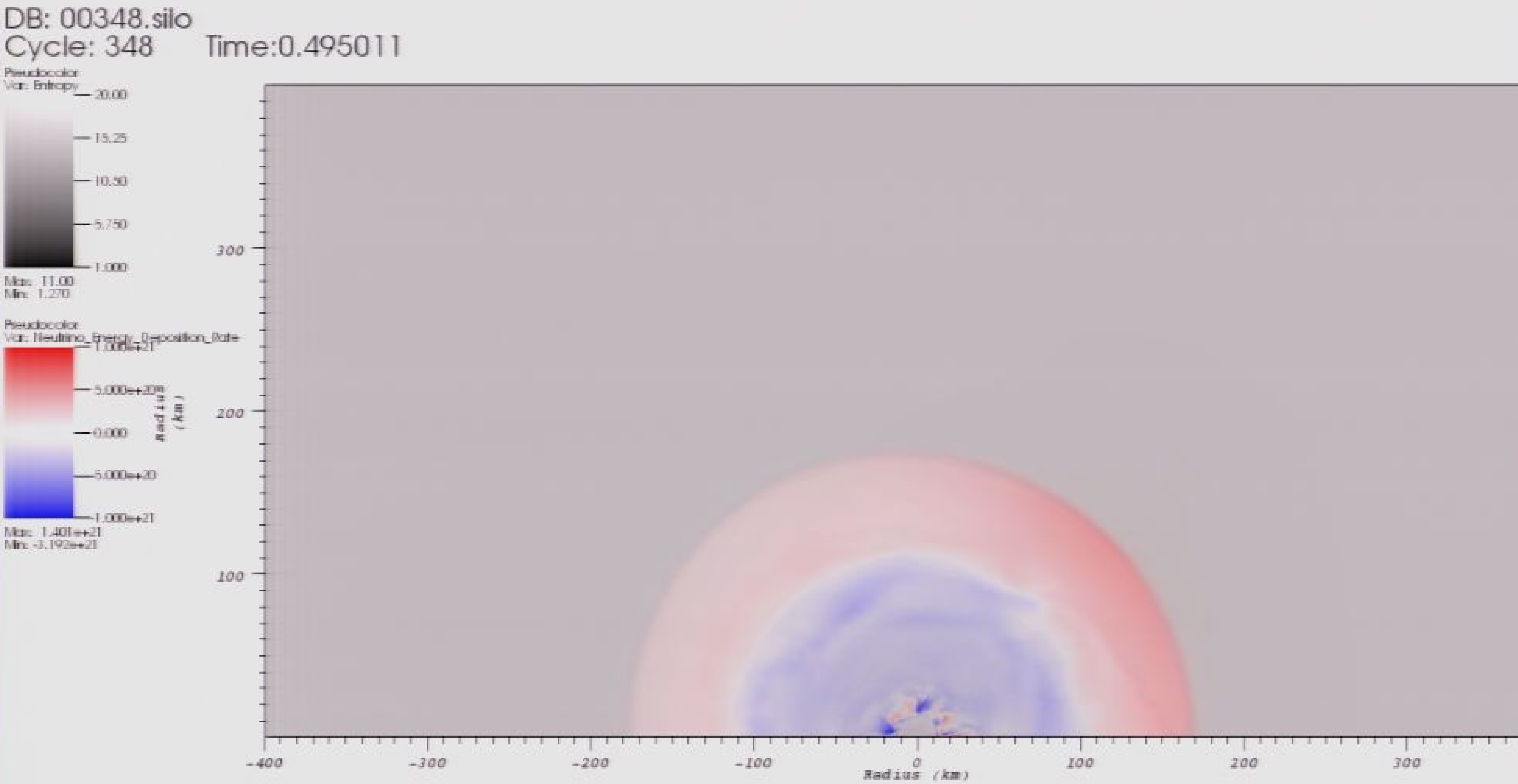

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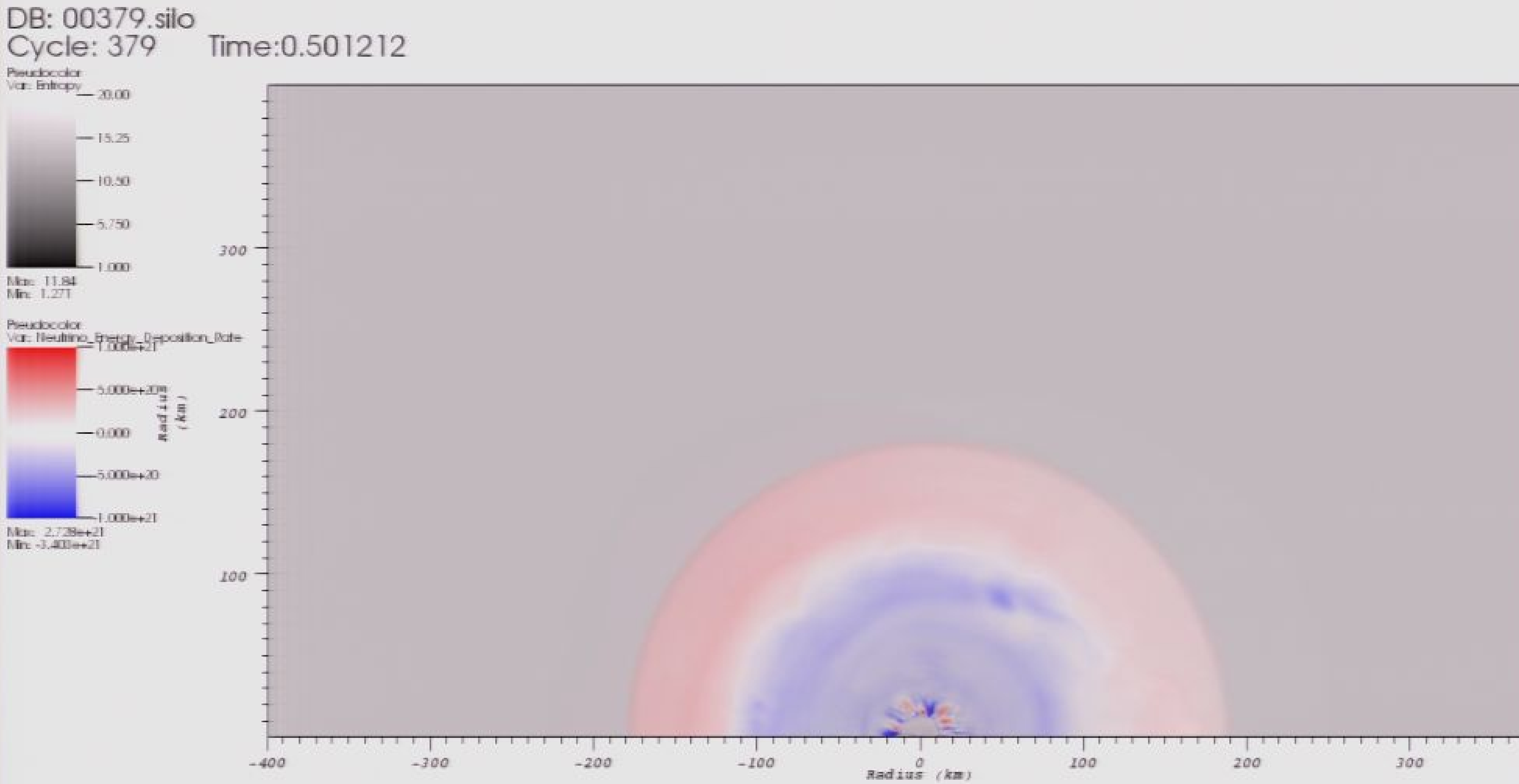

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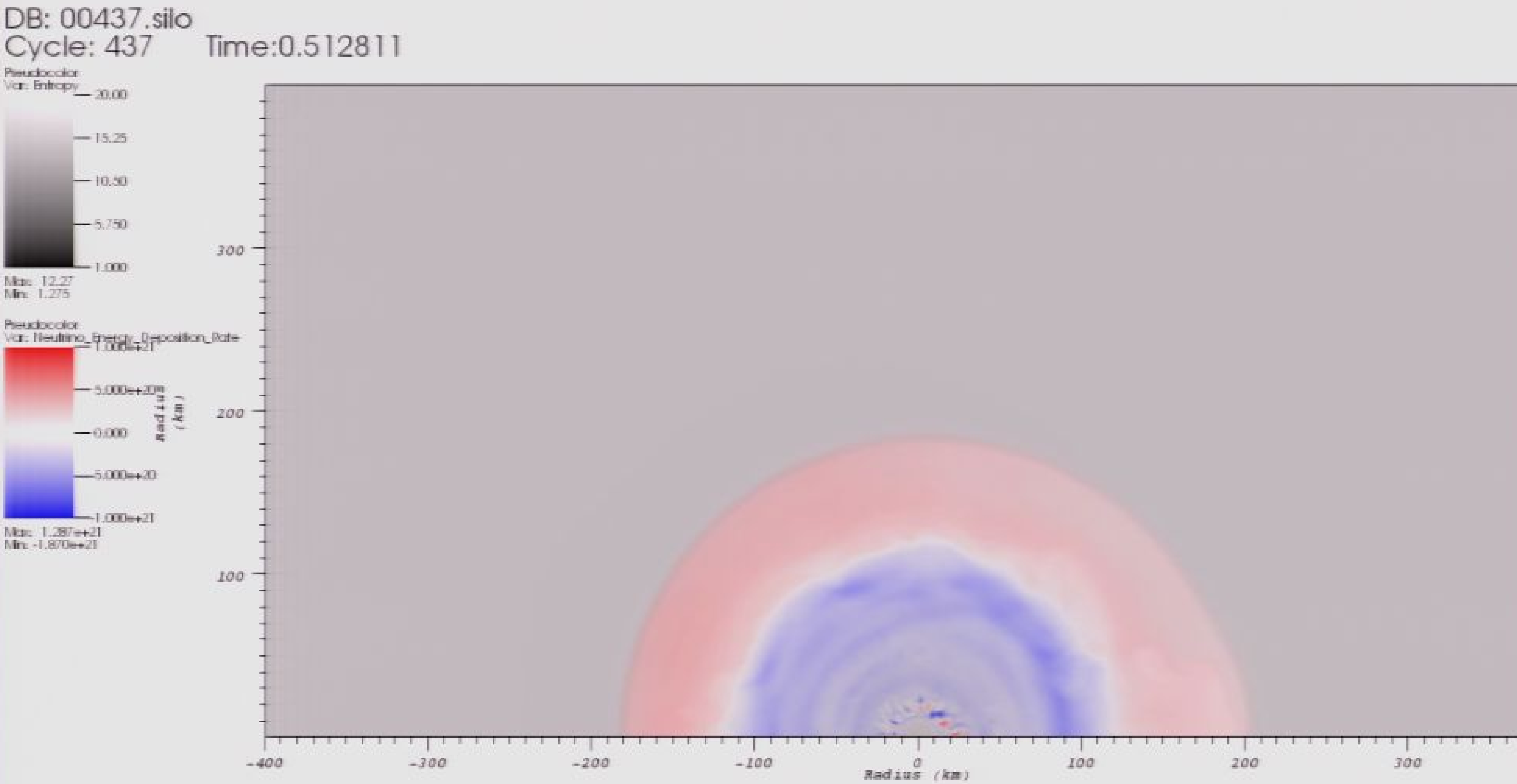

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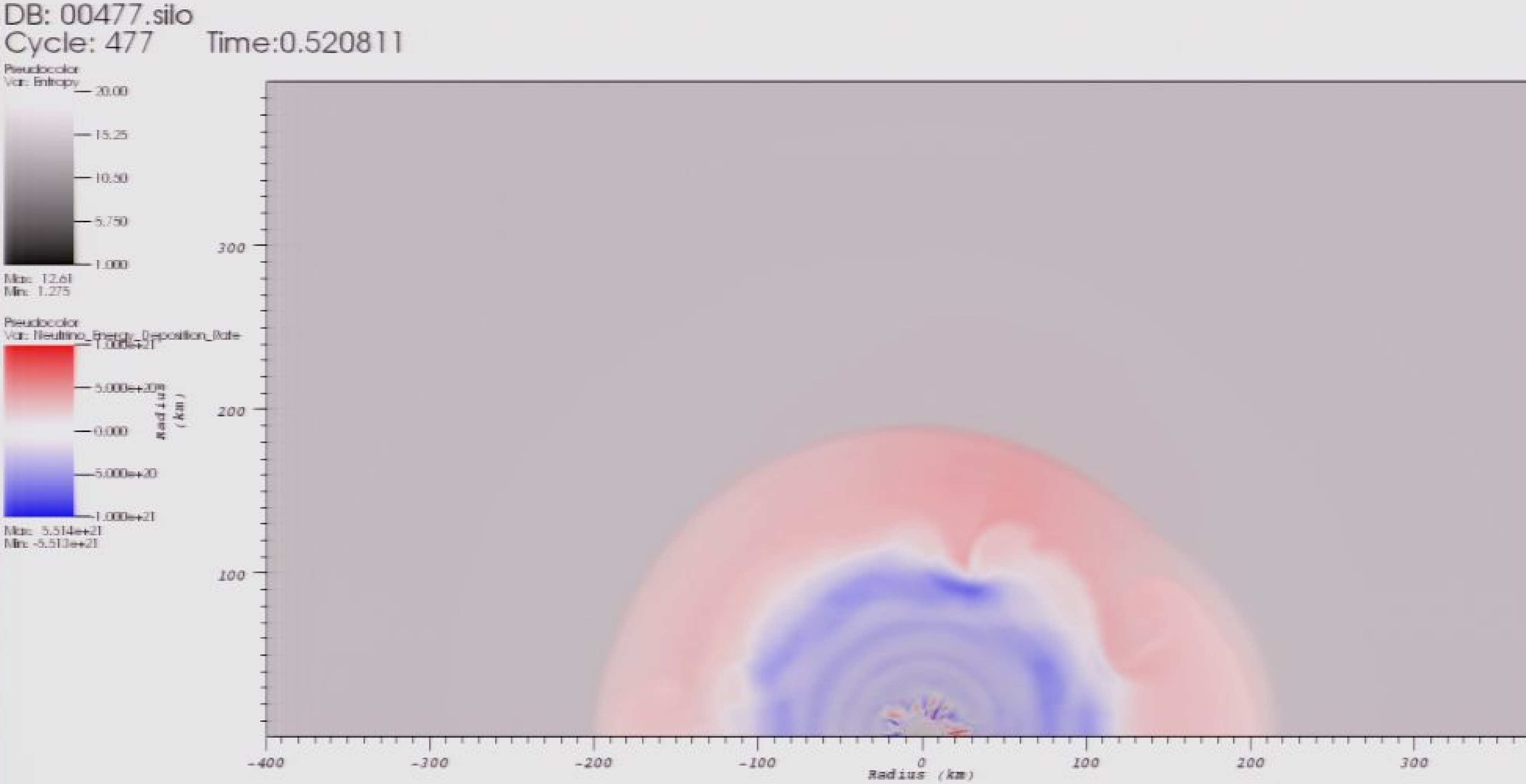

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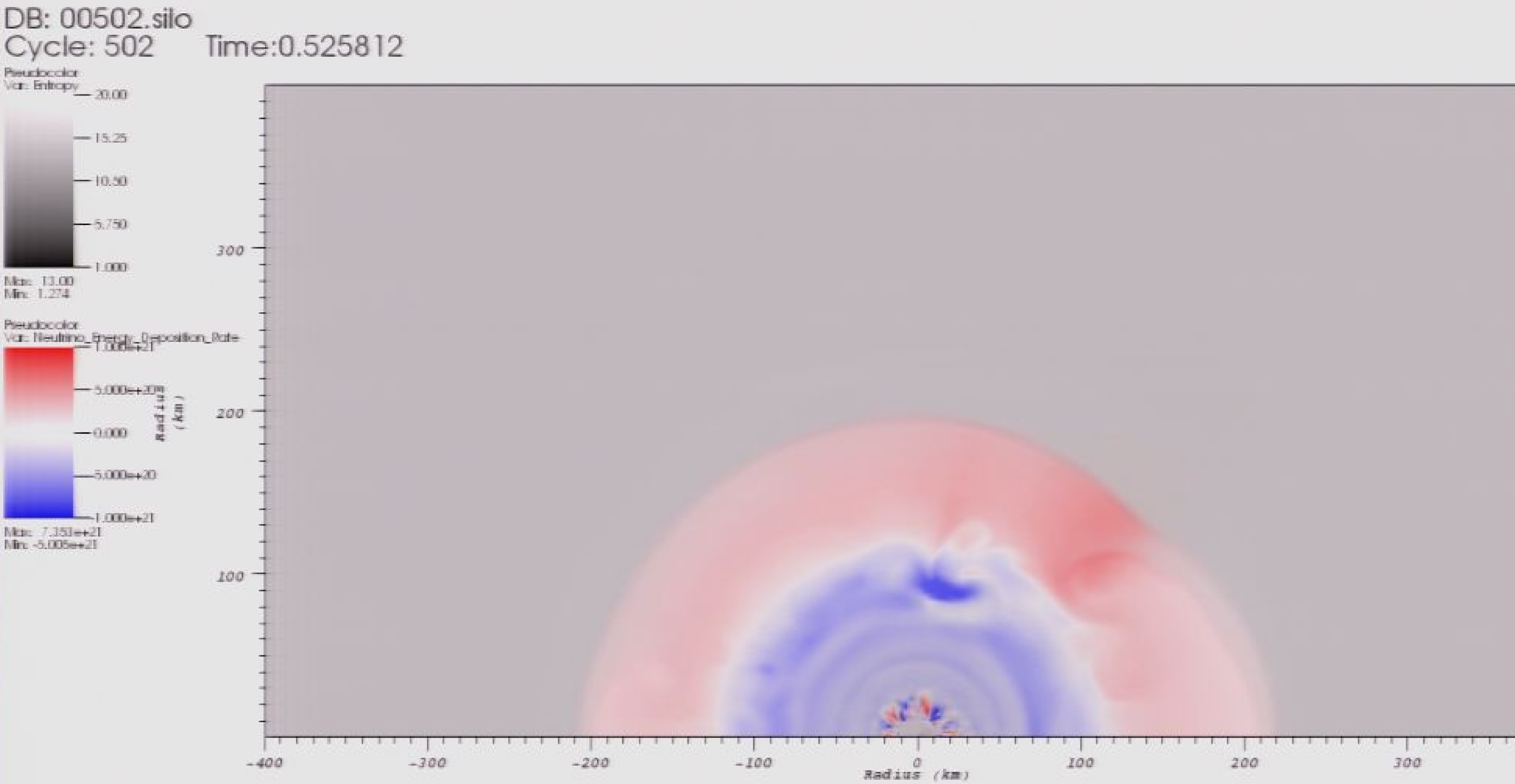

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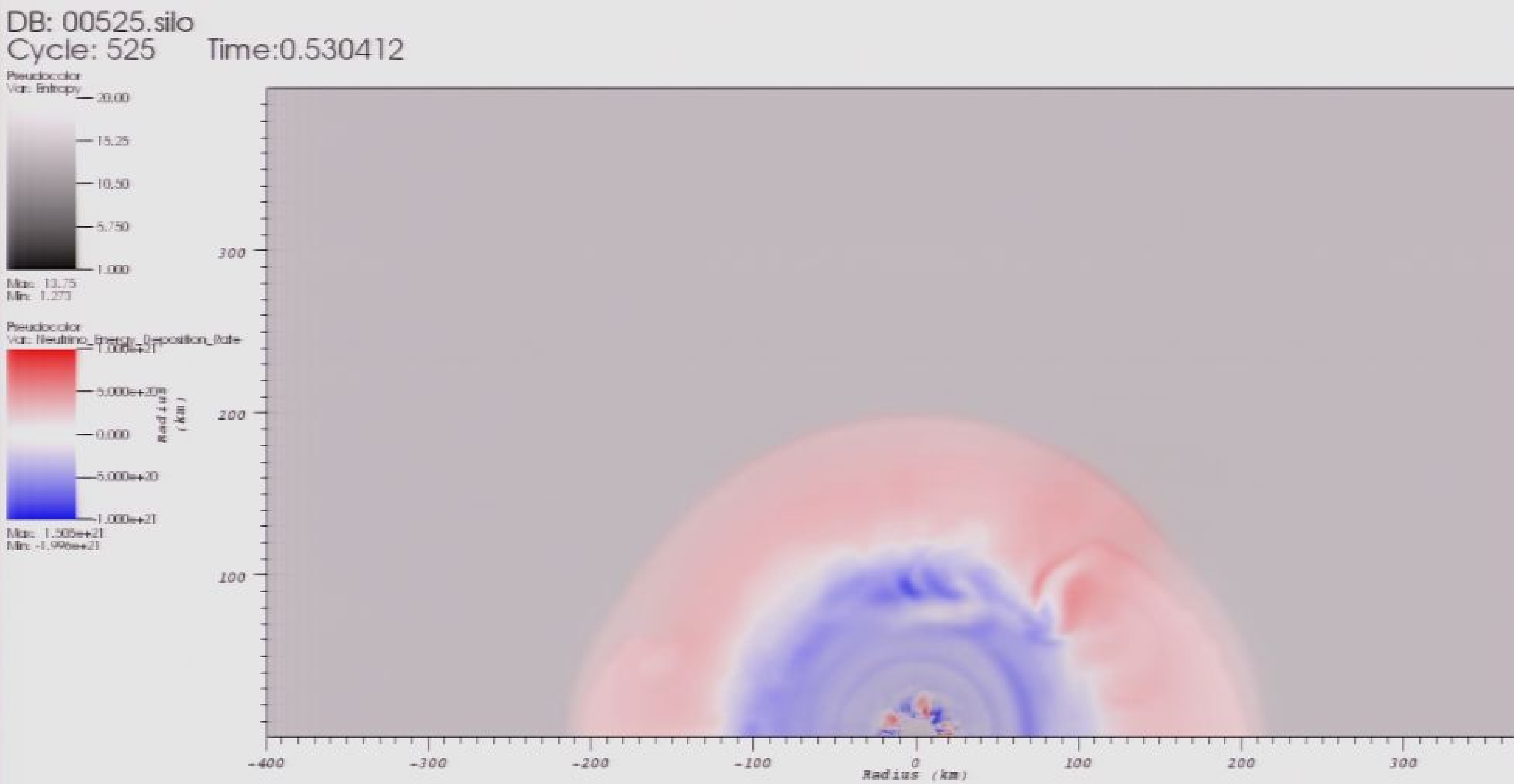

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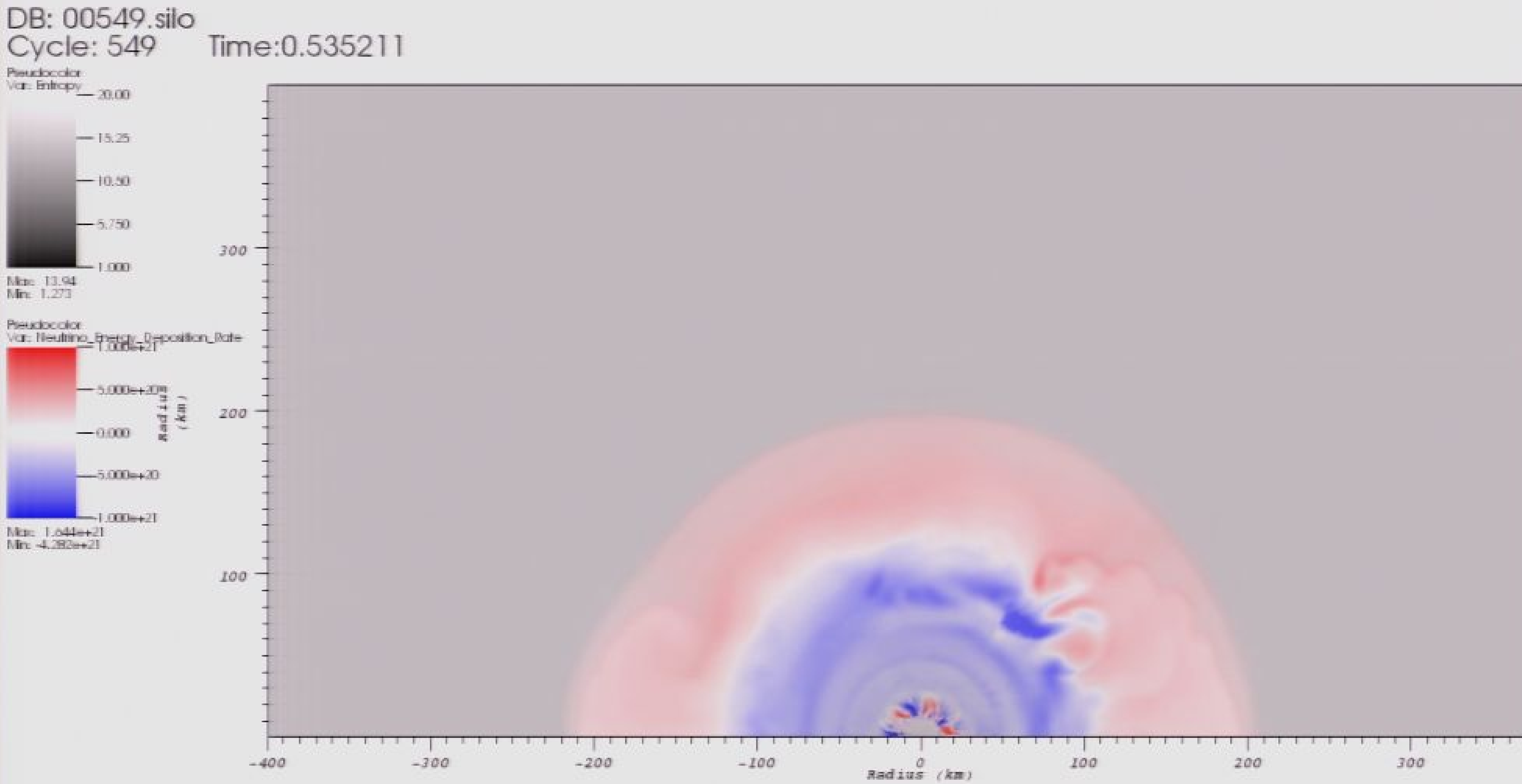

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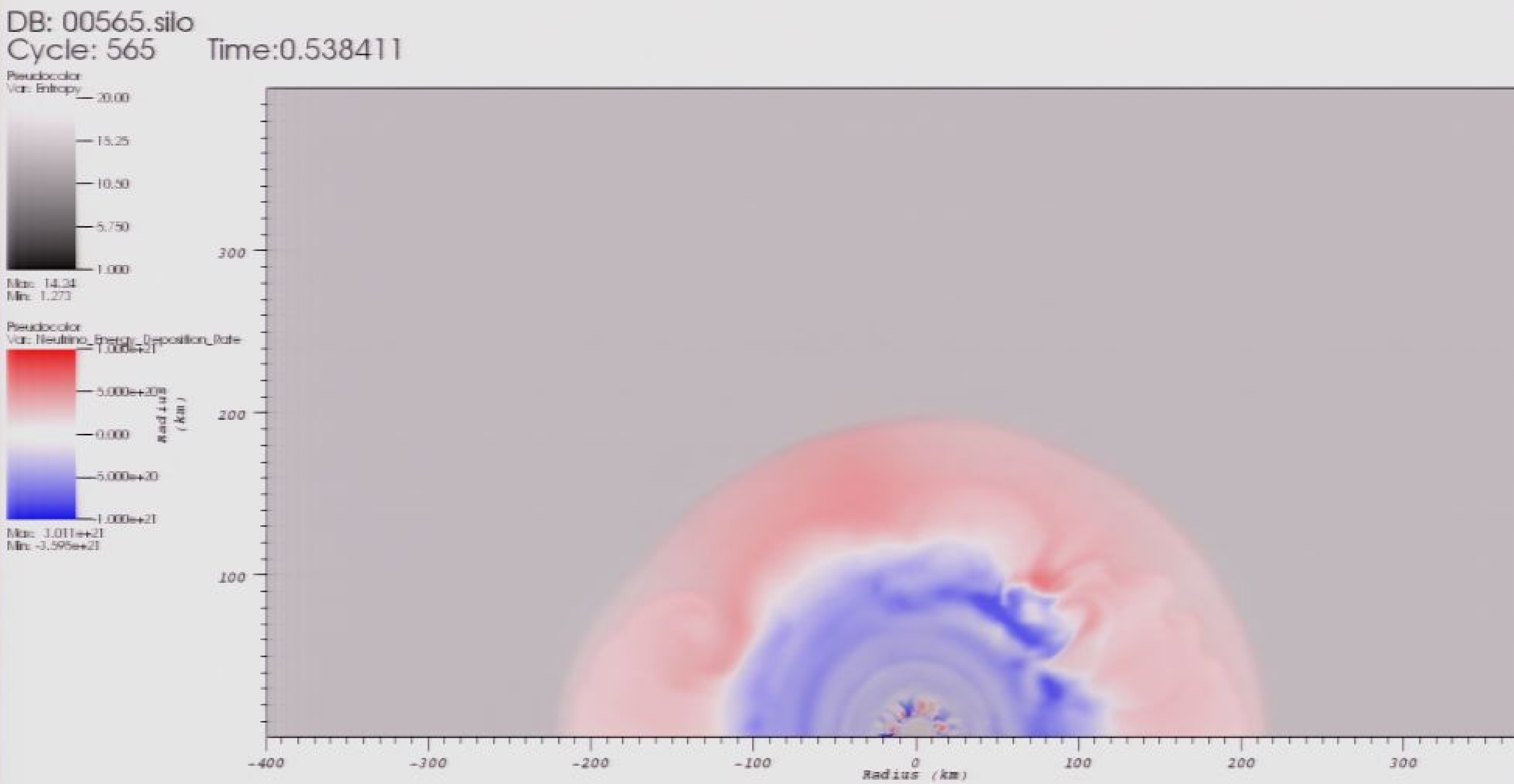

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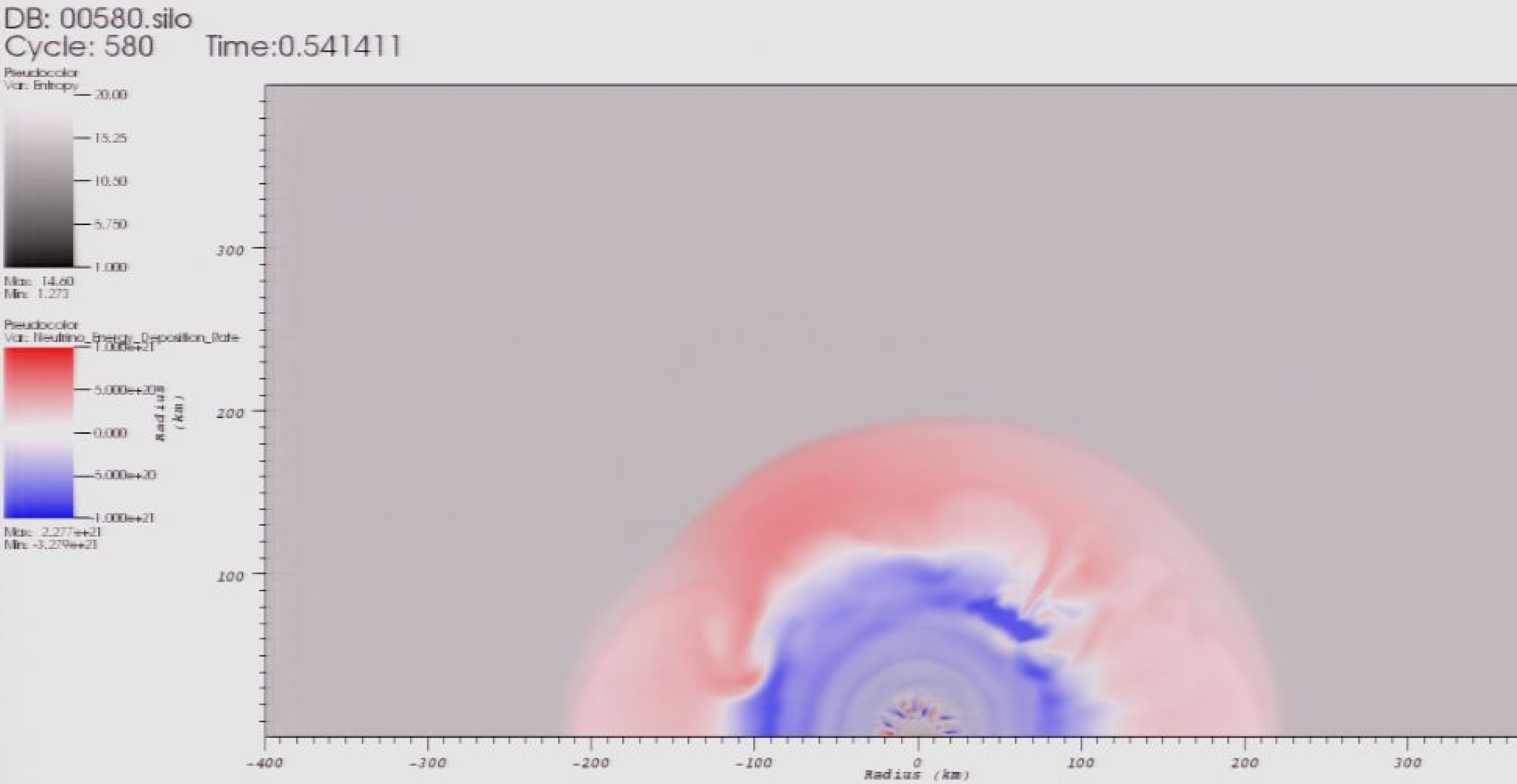

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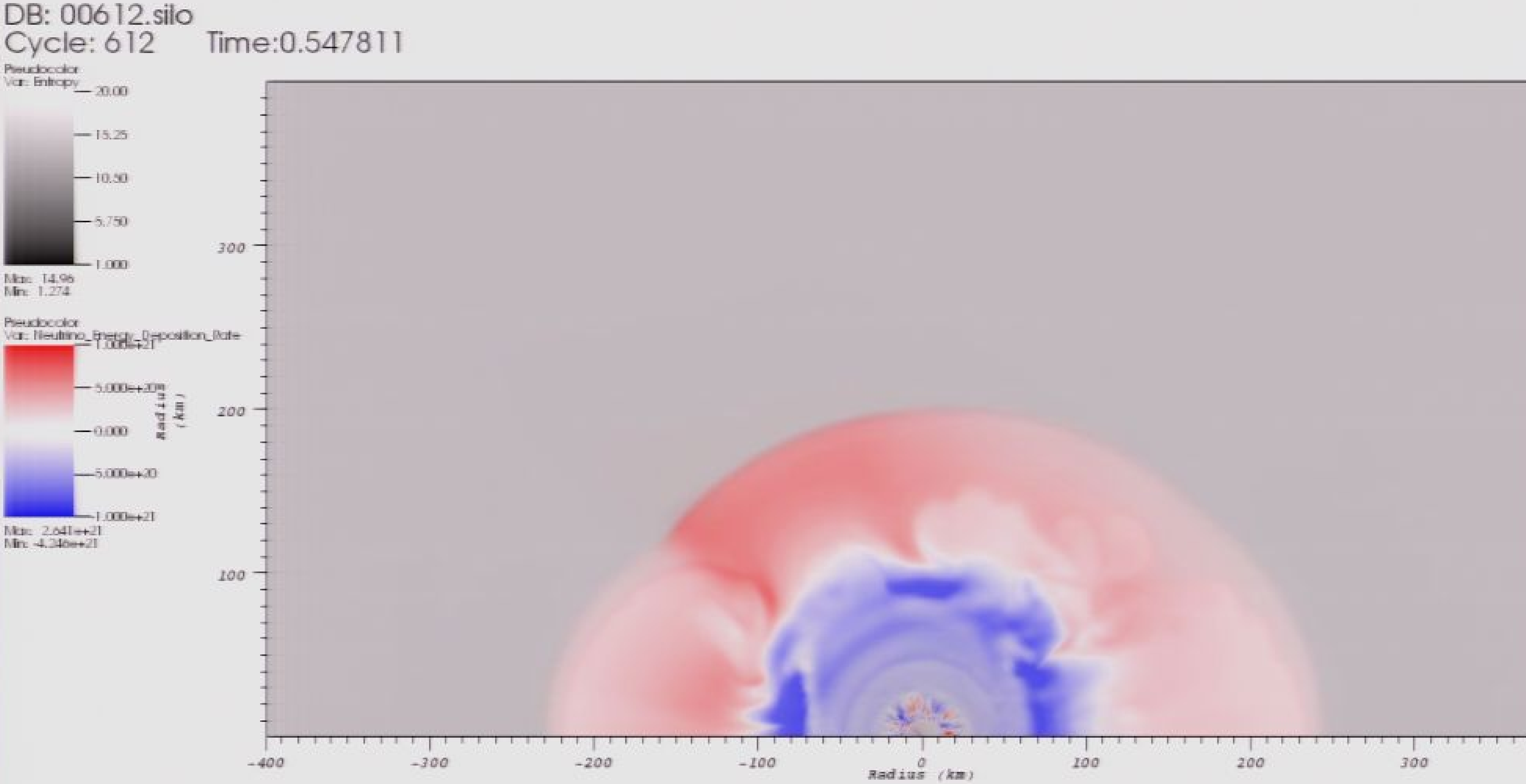

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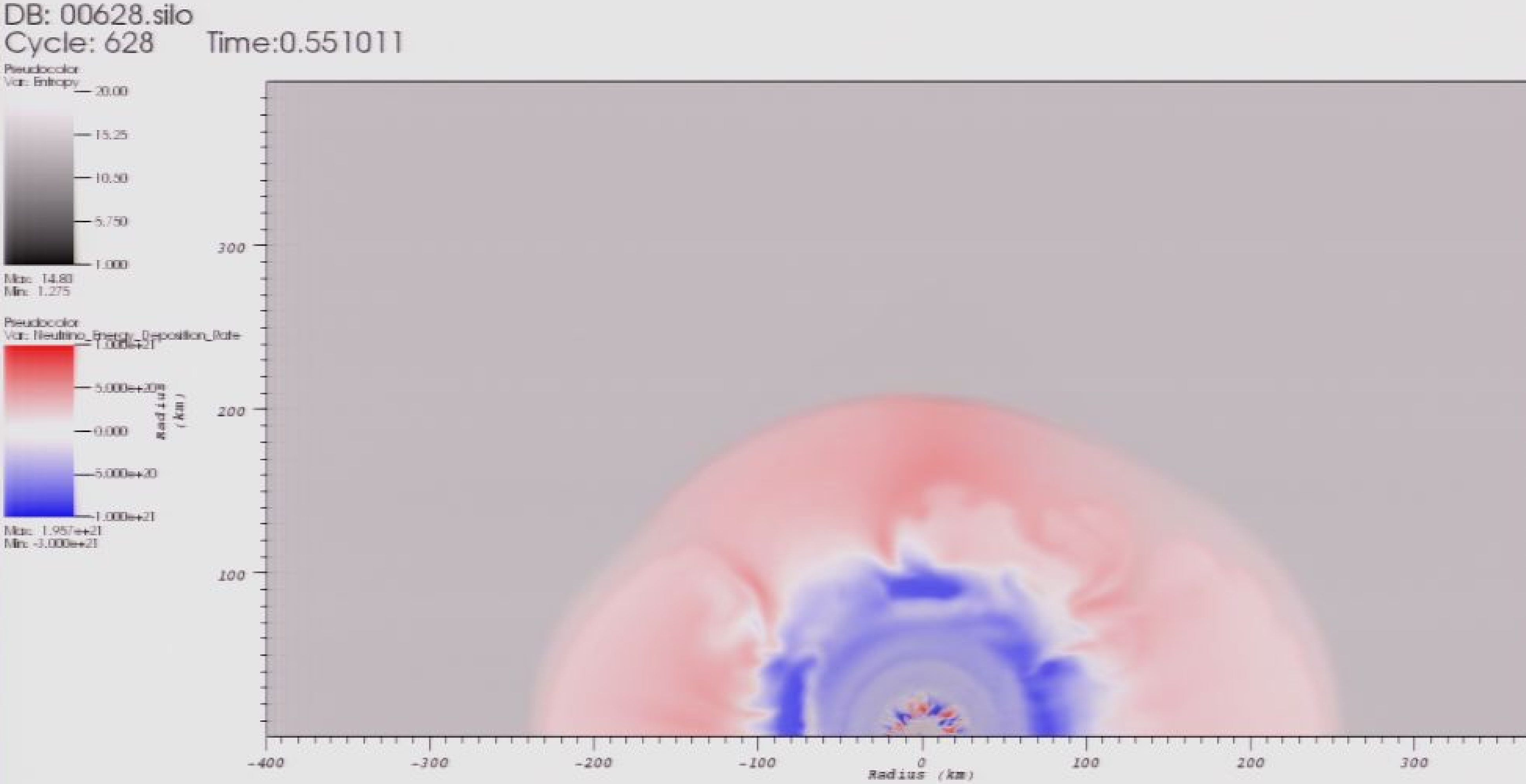

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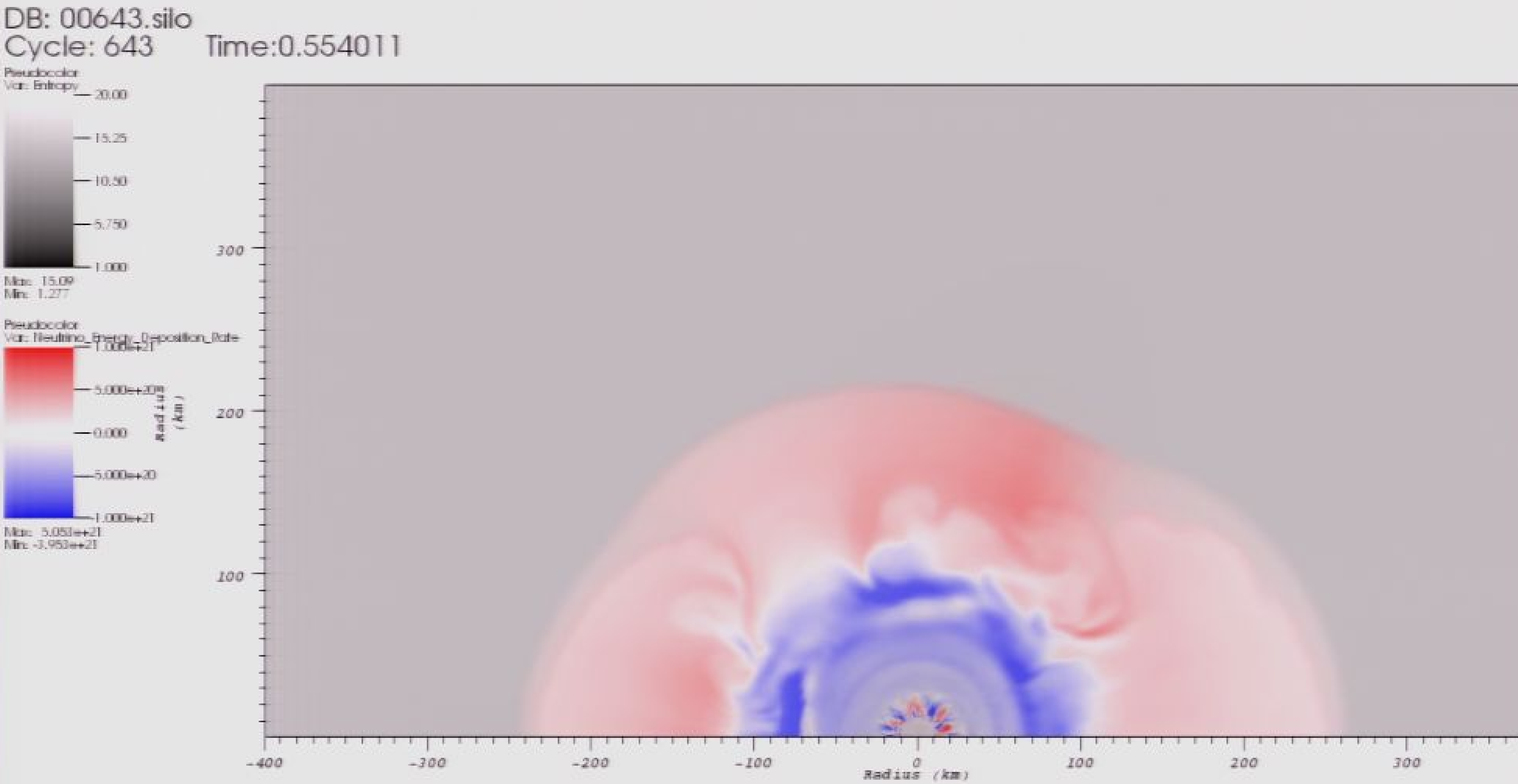

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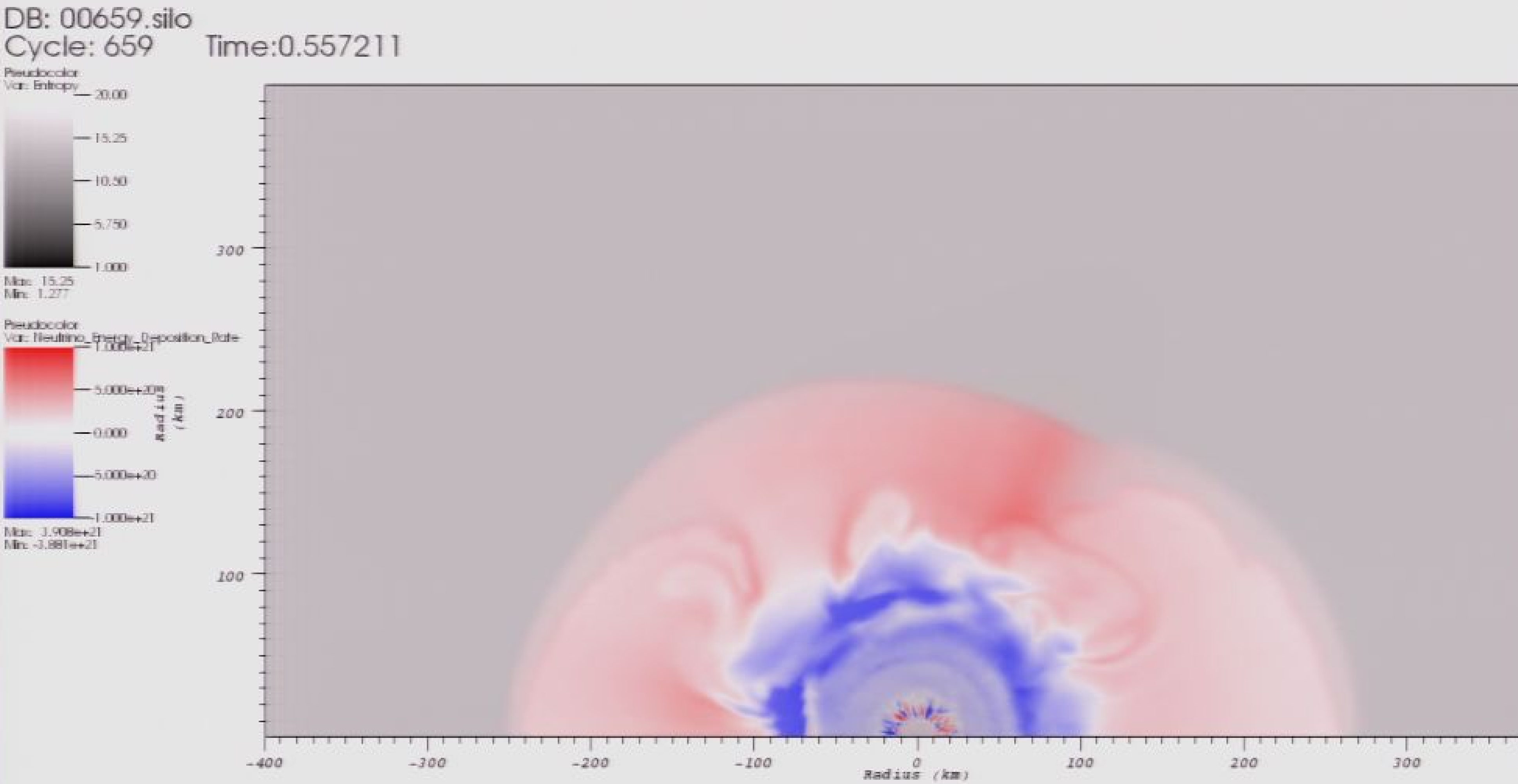

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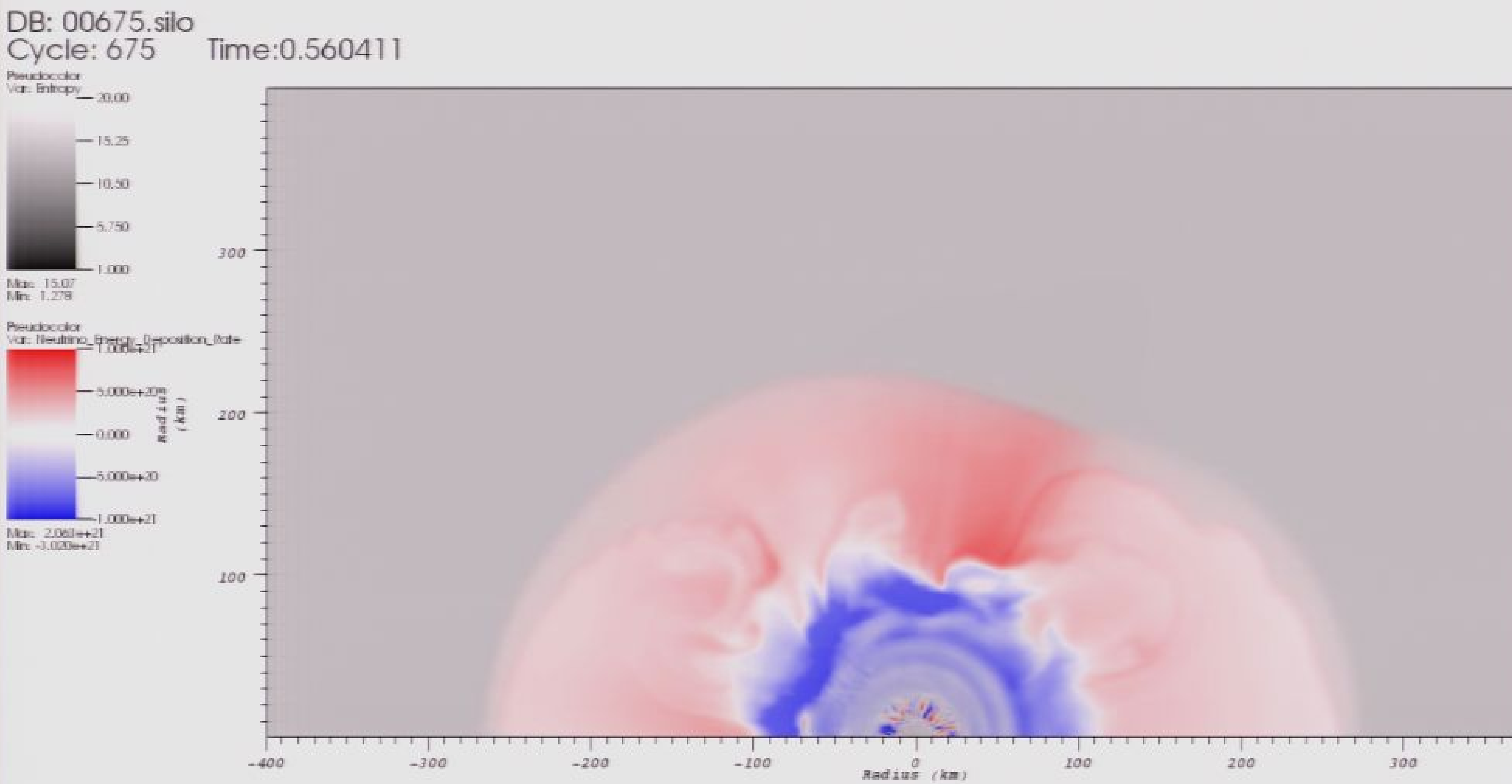

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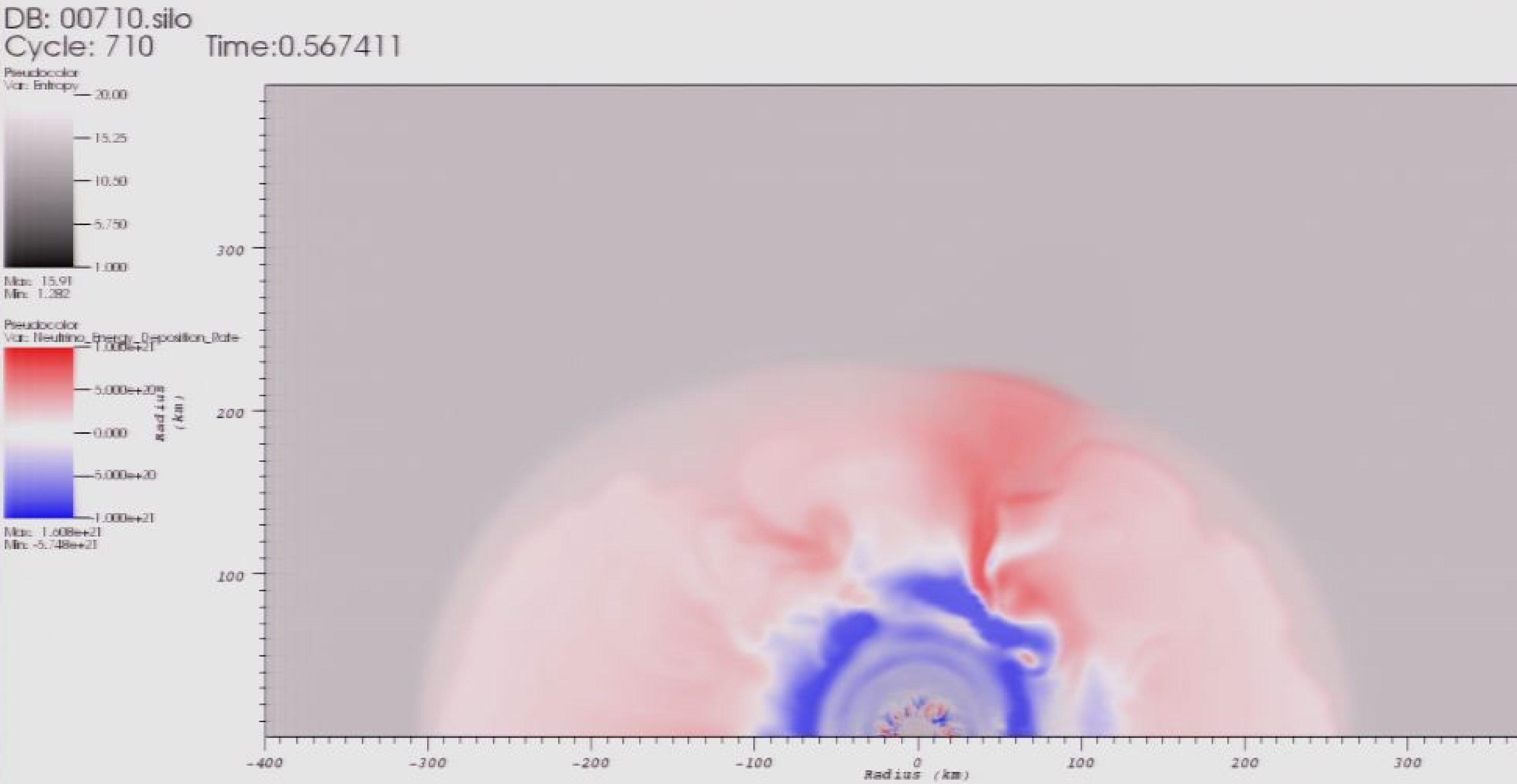

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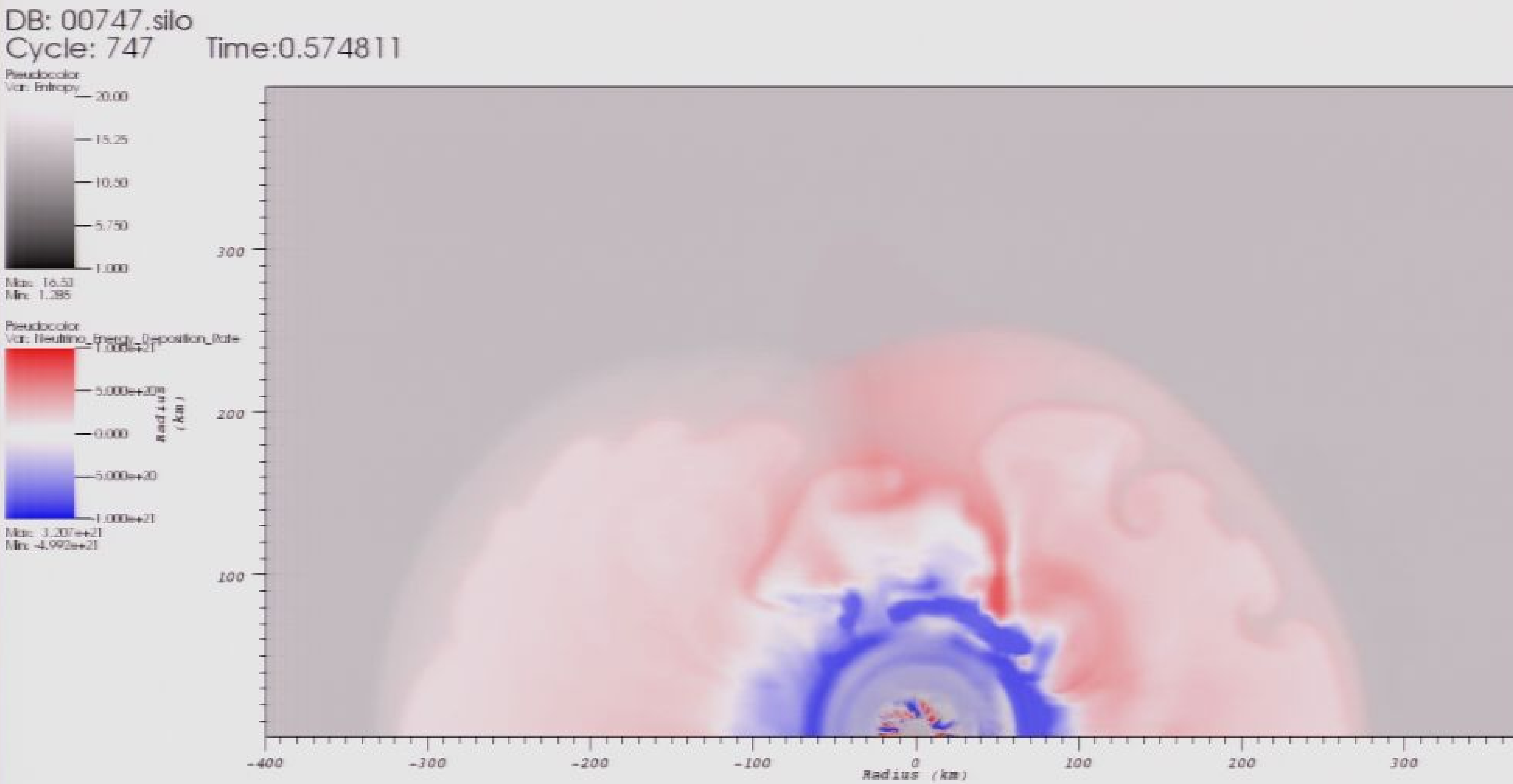

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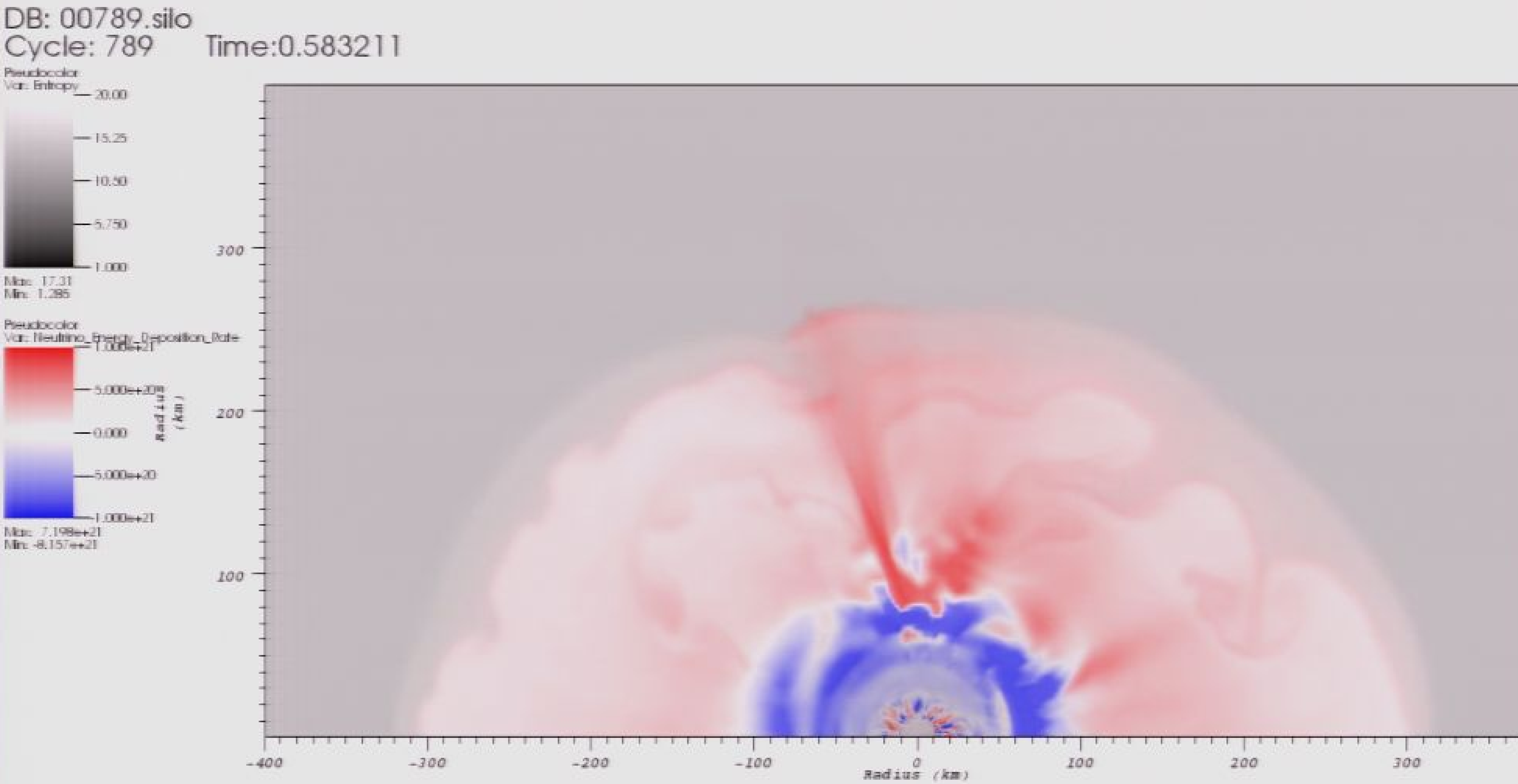

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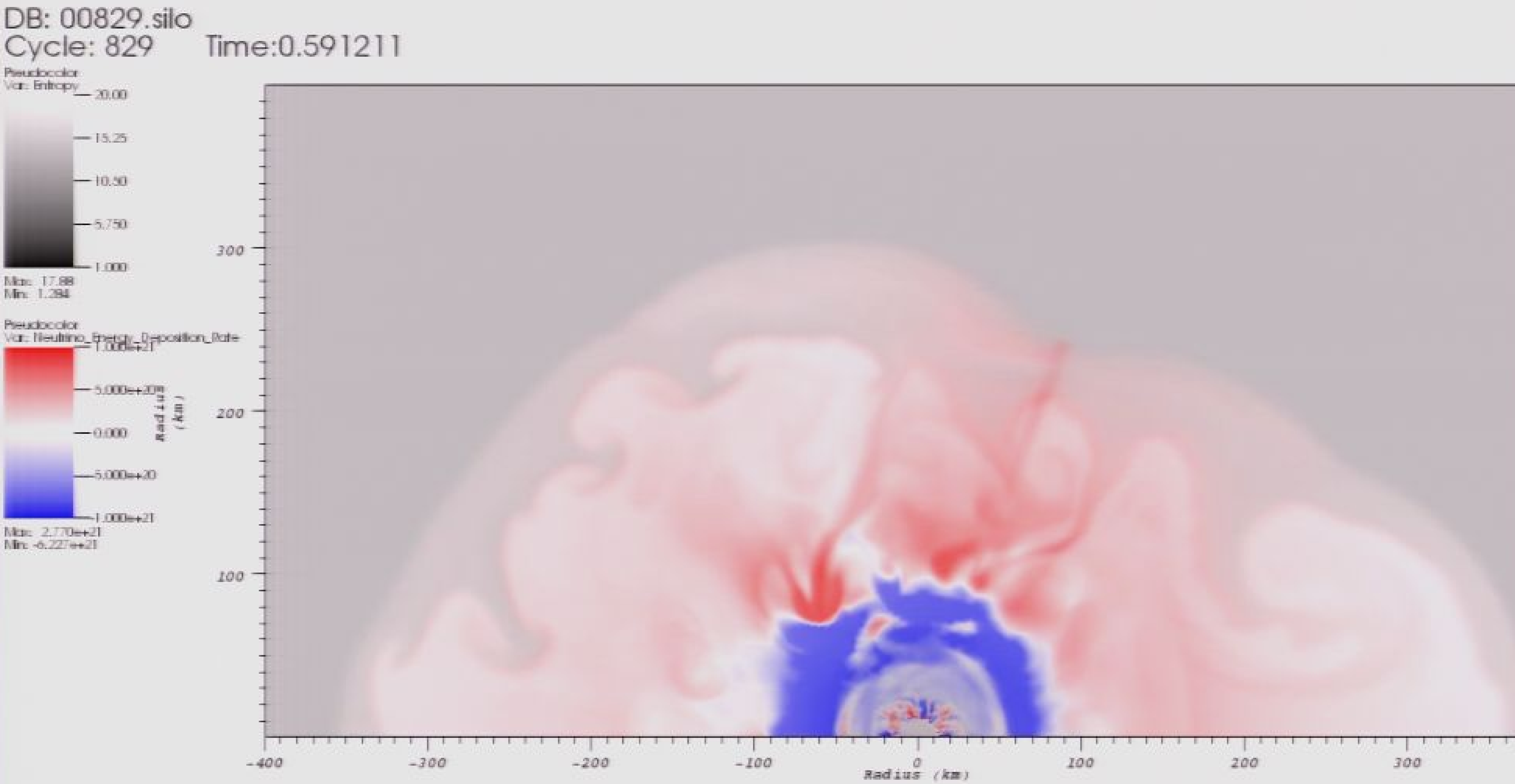

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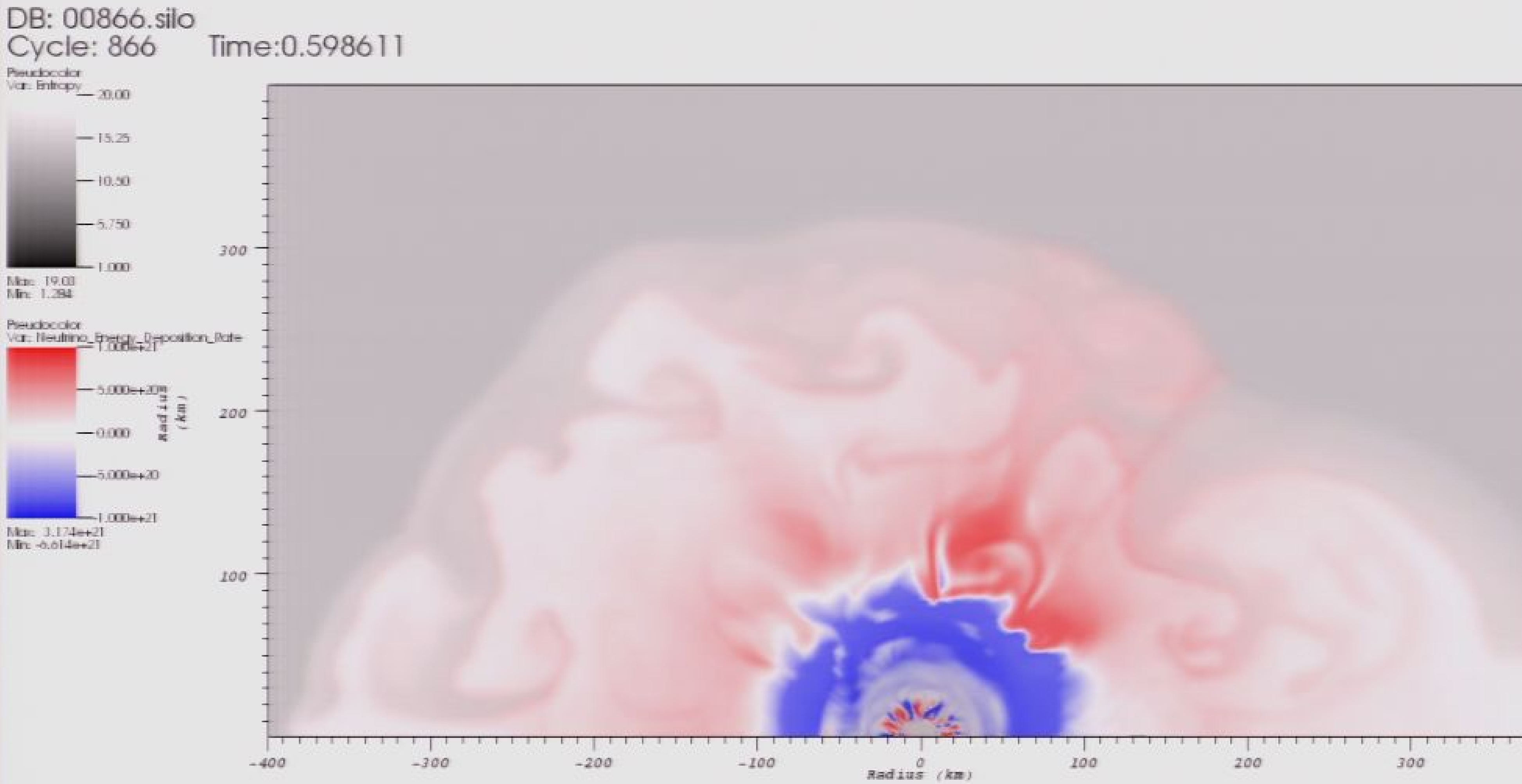

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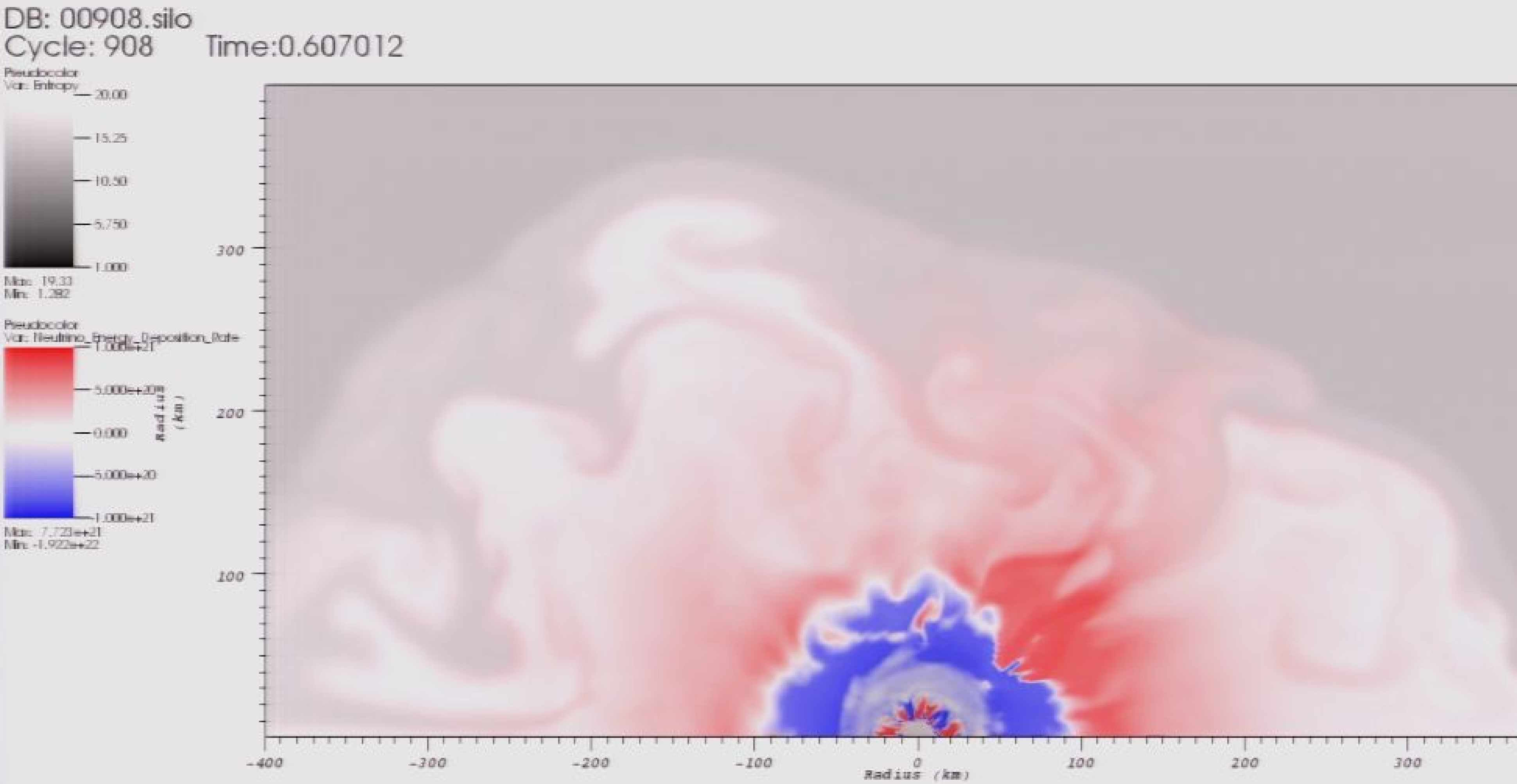

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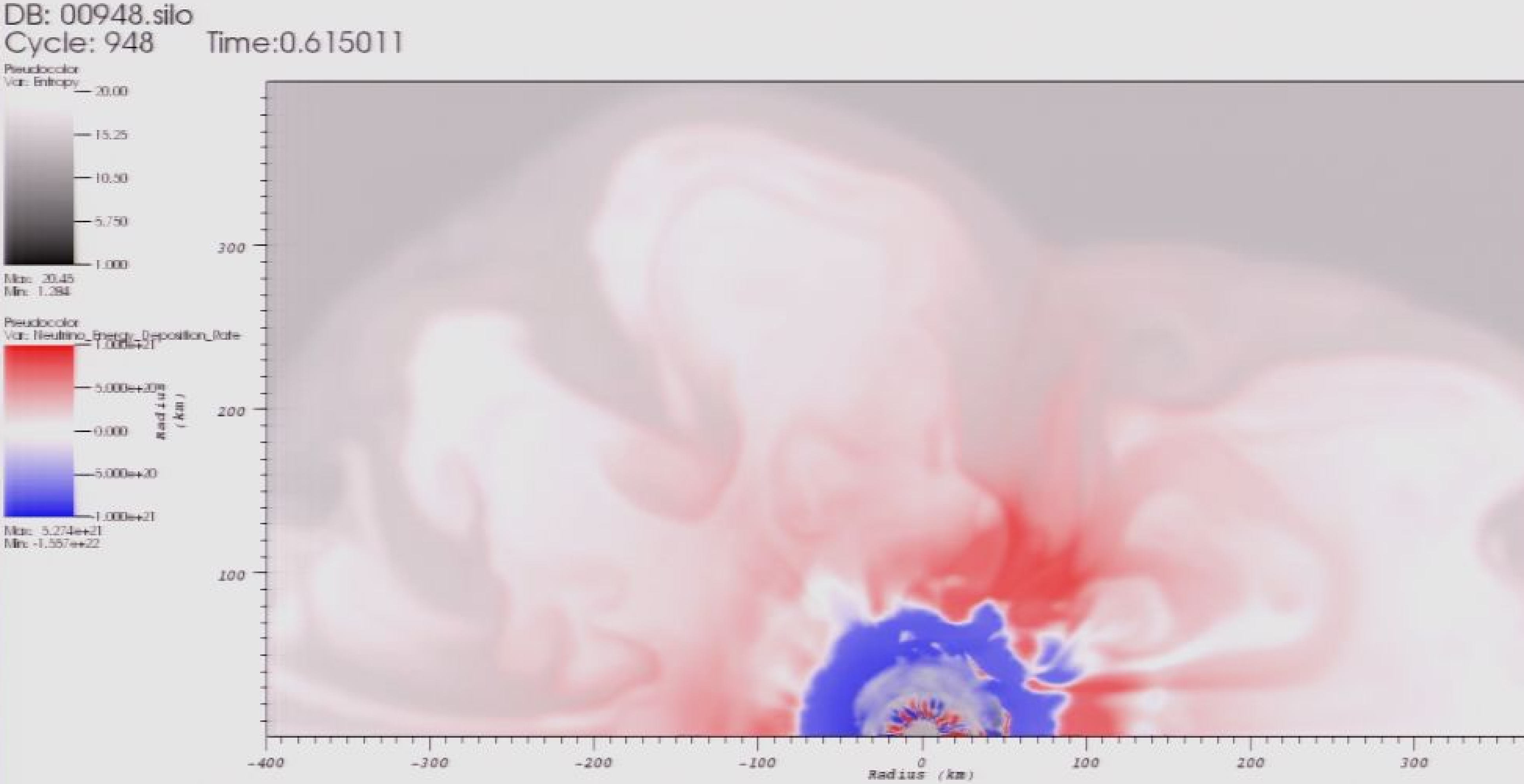

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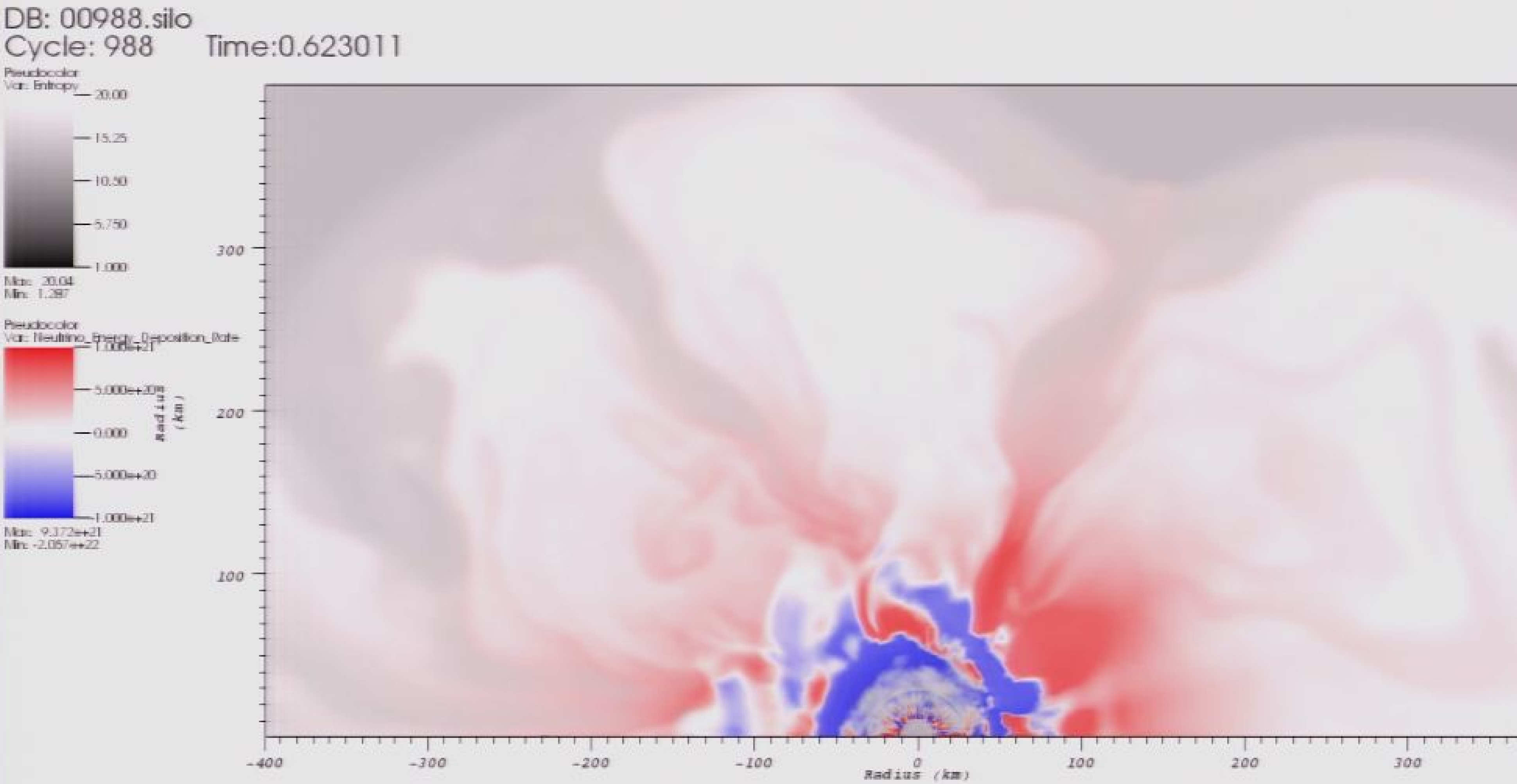

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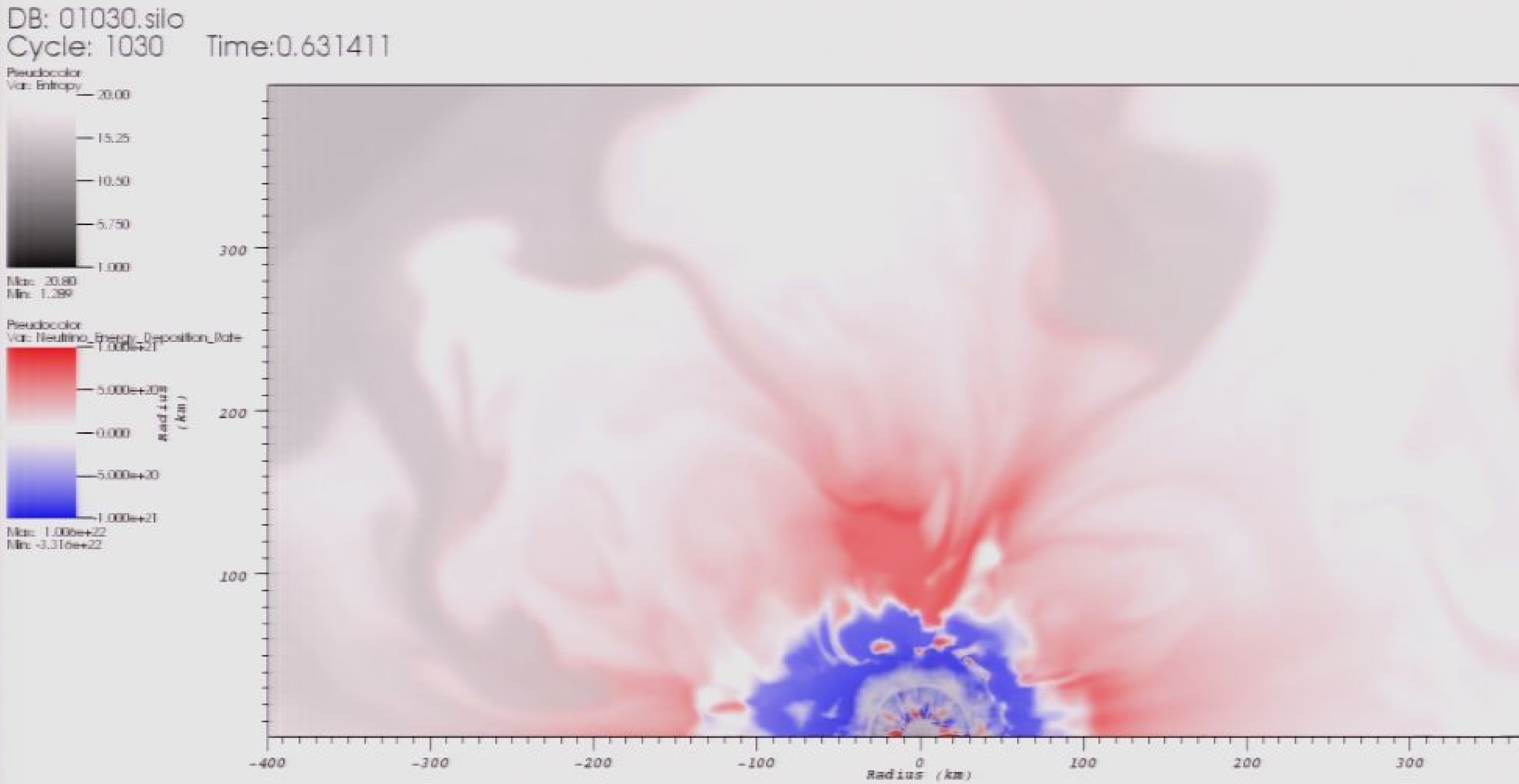

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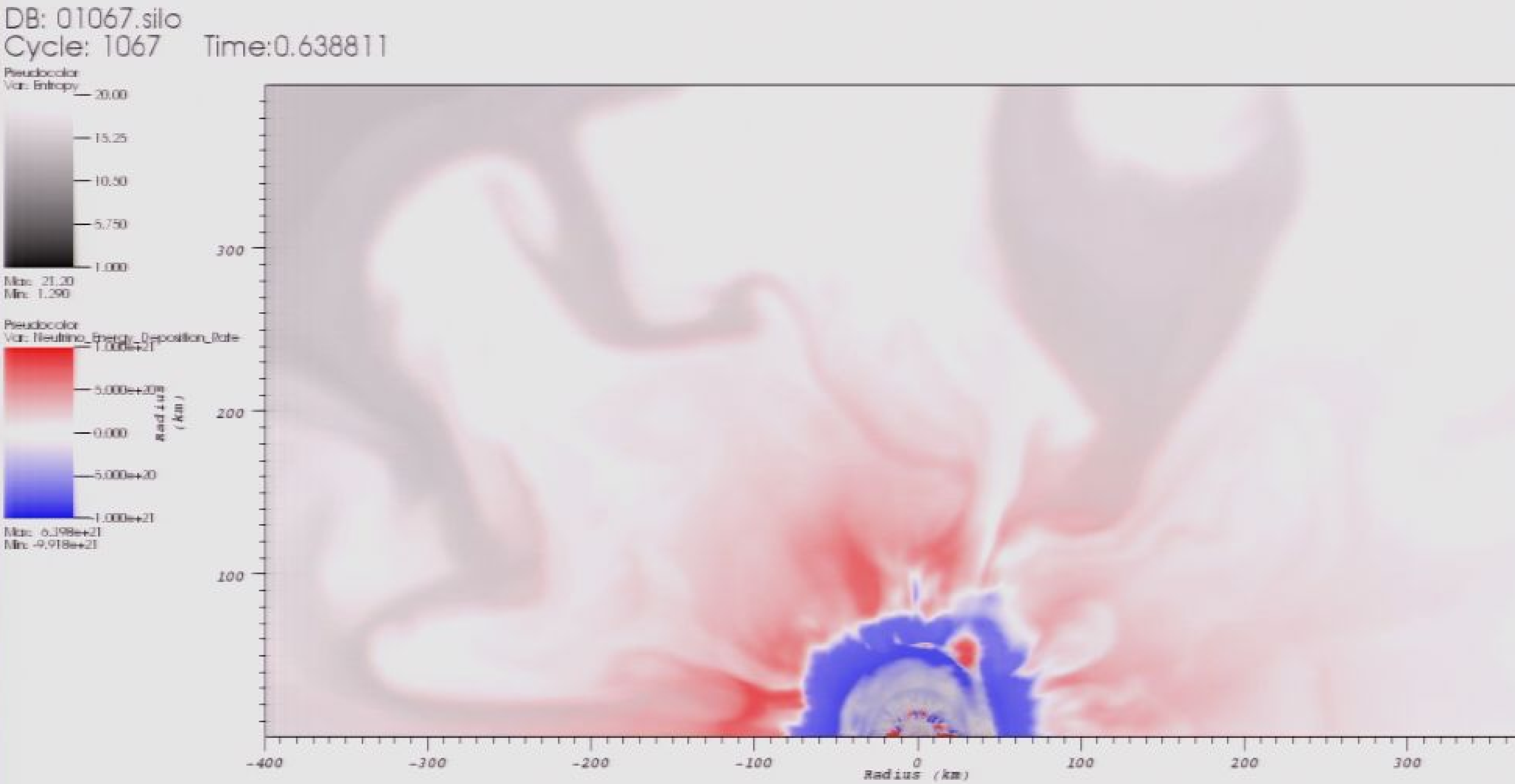

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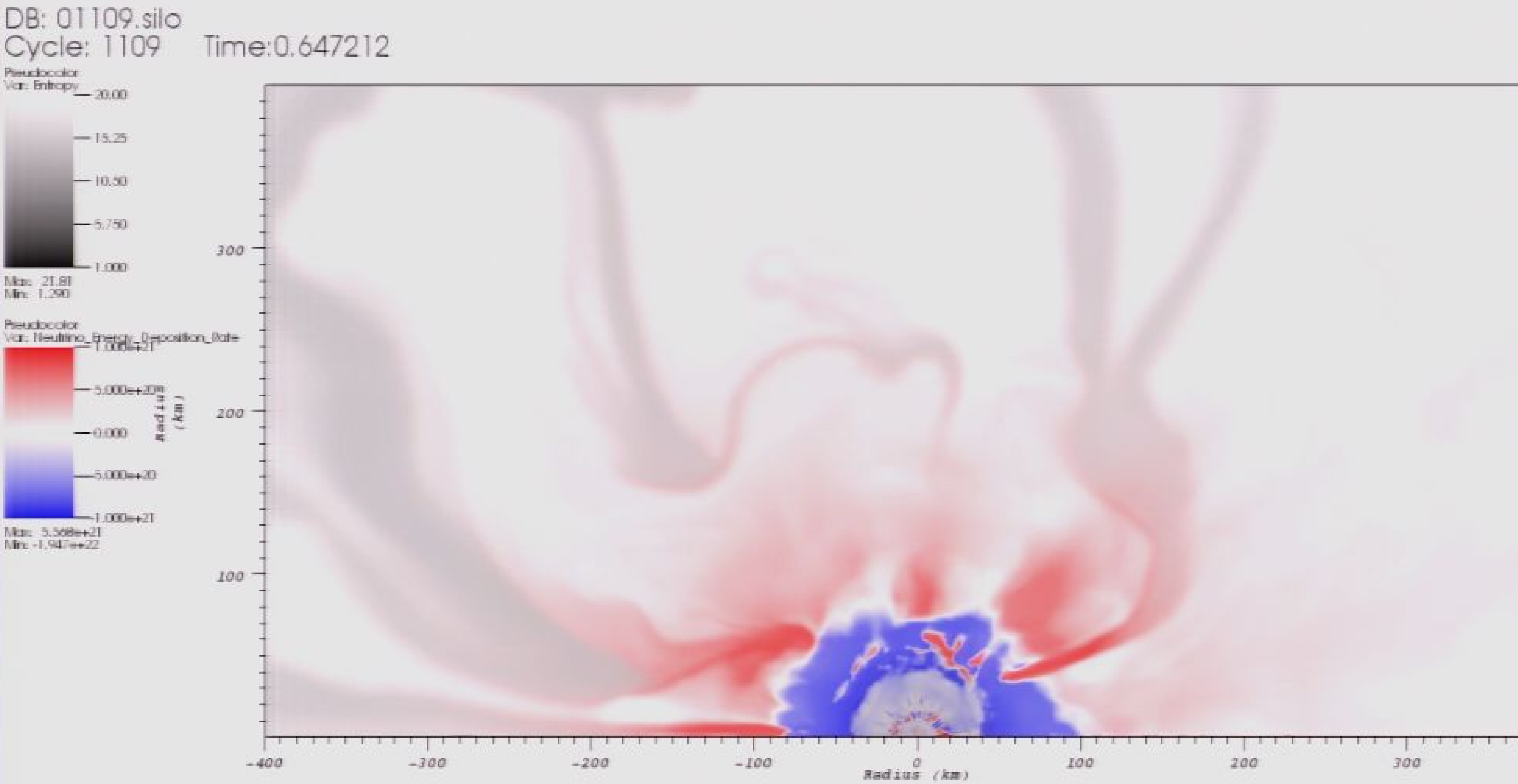

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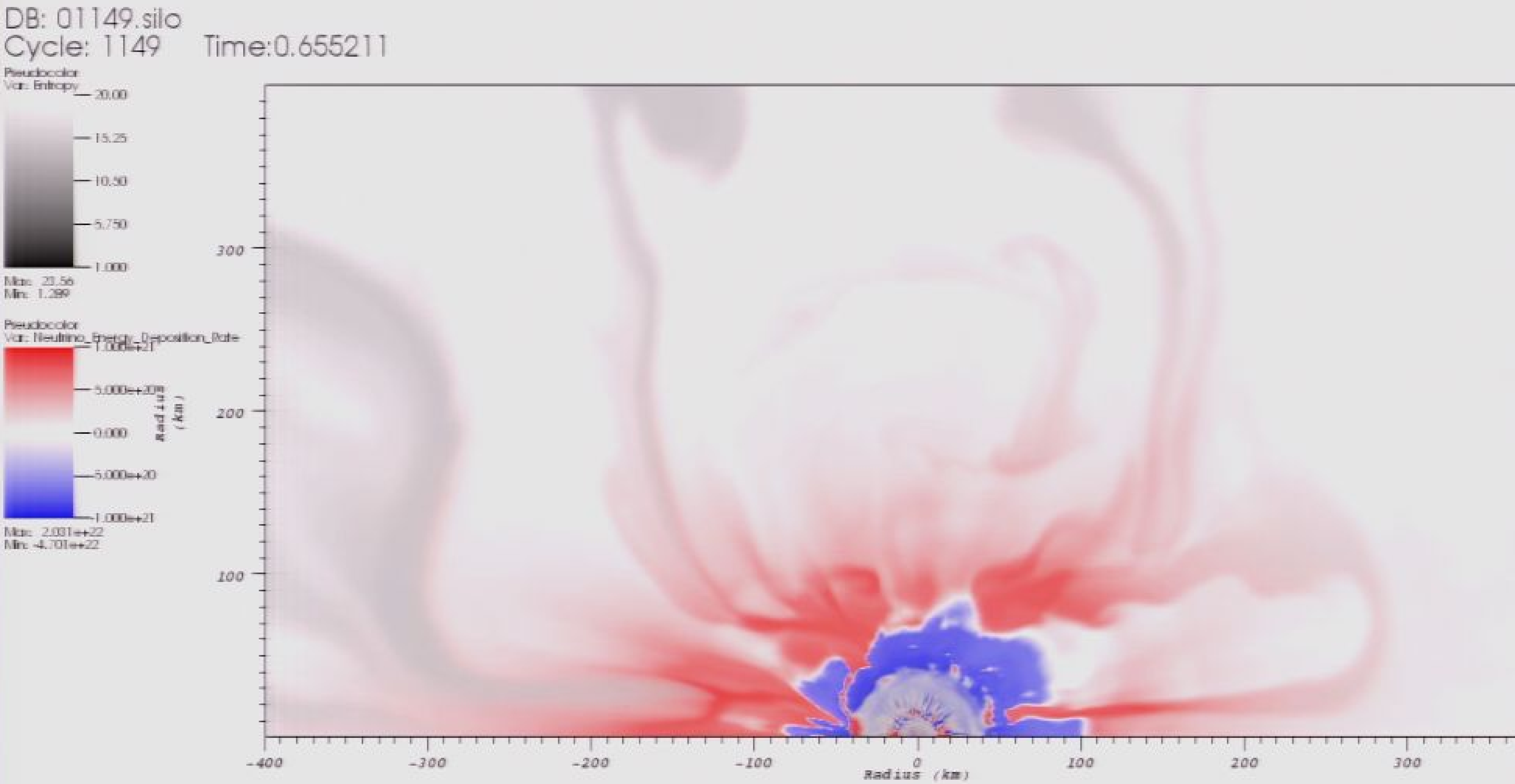

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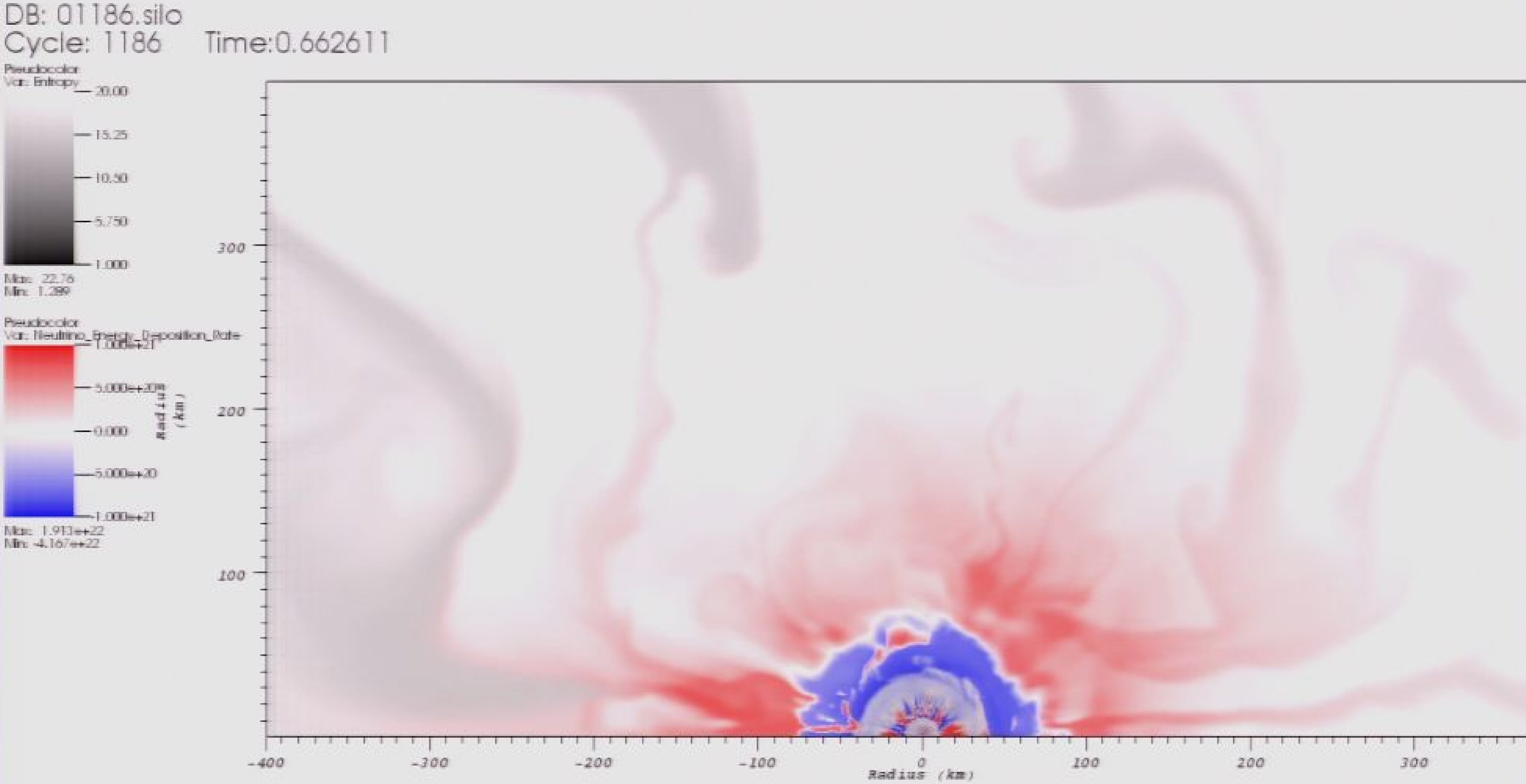

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Important Neutrino Emissivities/Opacities

★ $e^{-(+)} + p(n), A \leftrightarrow \nu_e(\bar{\nu}_e) + n(p), A'$

$e^+ + e^- \leftrightarrow \nu_{e,\mu,\tau} + \bar{\nu}_{e,\mu,\tau}$

Bruenn, *Ap.J. Suppl.* (1985)
- Nucleons treated as independent in nuclei
- No energy exchange in nucleonic scatterin

Langanke et al. PRL, **90**, 241102 (2003)
- Included correlations between nucleons in nuclei.

★ $\nu + n, p, A \rightarrow \nu + n, p, A$

$\nu + e^-, e^+ \rightarrow \nu + e^-, e^+$

Reddy, Prakash, and Lattimer, PRD, **58**, 013009 (199
Burrows and Sawyer, PRC, **59**, 510 (1999)
- (Small) Energy is exchanged due to nucleon rec
- Many such scatterings.

Janka et al. PRL, **76**, 2621 (1996)

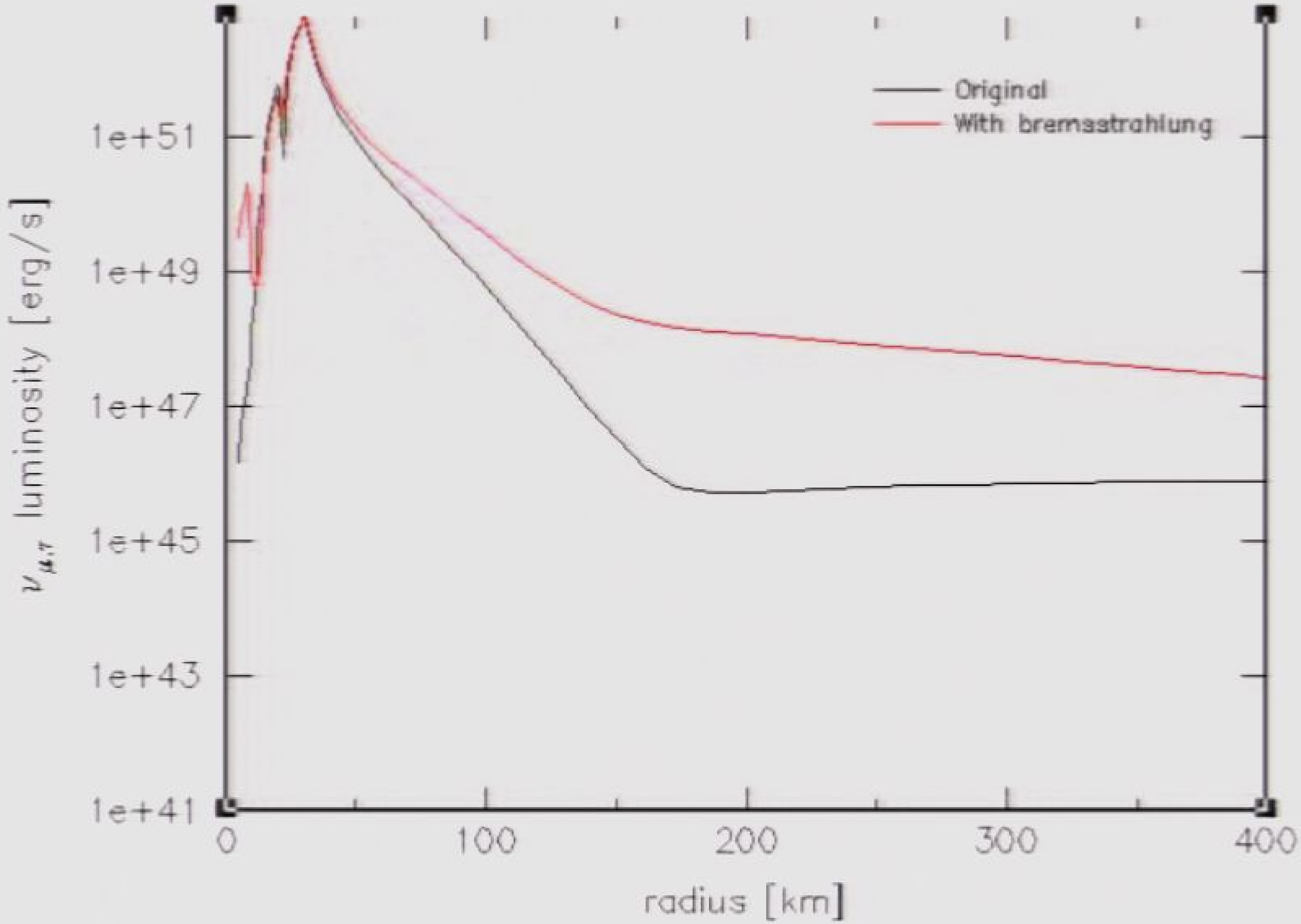
★ $N + N \leftrightarrow N + N + \nu_{e,\mu,\tau} + \bar{\nu}_{e,\mu,\tau}$

$\nu_e + \bar{\nu}_e \leftrightarrow \nu_{\mu,\tau} + \bar{\nu}_{\mu,\tau}$

Hannestadt and Raffelt, *Ap.J.* **507**, 339 (1998)
Hanhart, Phillips, and Reddy, *Phys. Lett. B*, **499**, 9 (20
Thompson et al., *Phys.Rev.***C62**, 035802 (2000)
- New source of neutrino-antineutrino pairs.

Buras et al. *Ap.J.*, **587**, 320 (2003)

NN bremsstrahlung (AGILE-Boltztran)



onset of bounce ------> ~50 ms post-bounce

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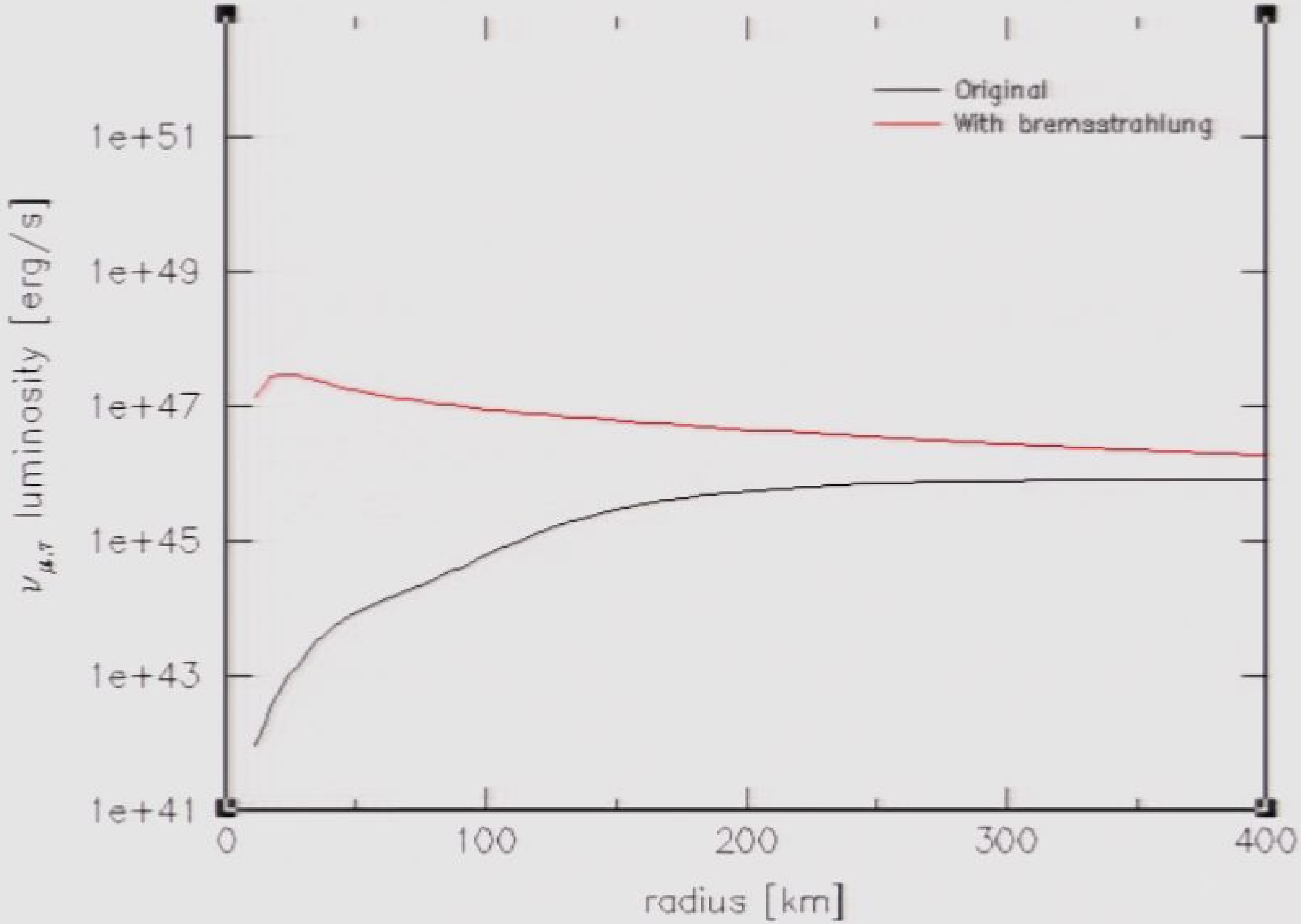

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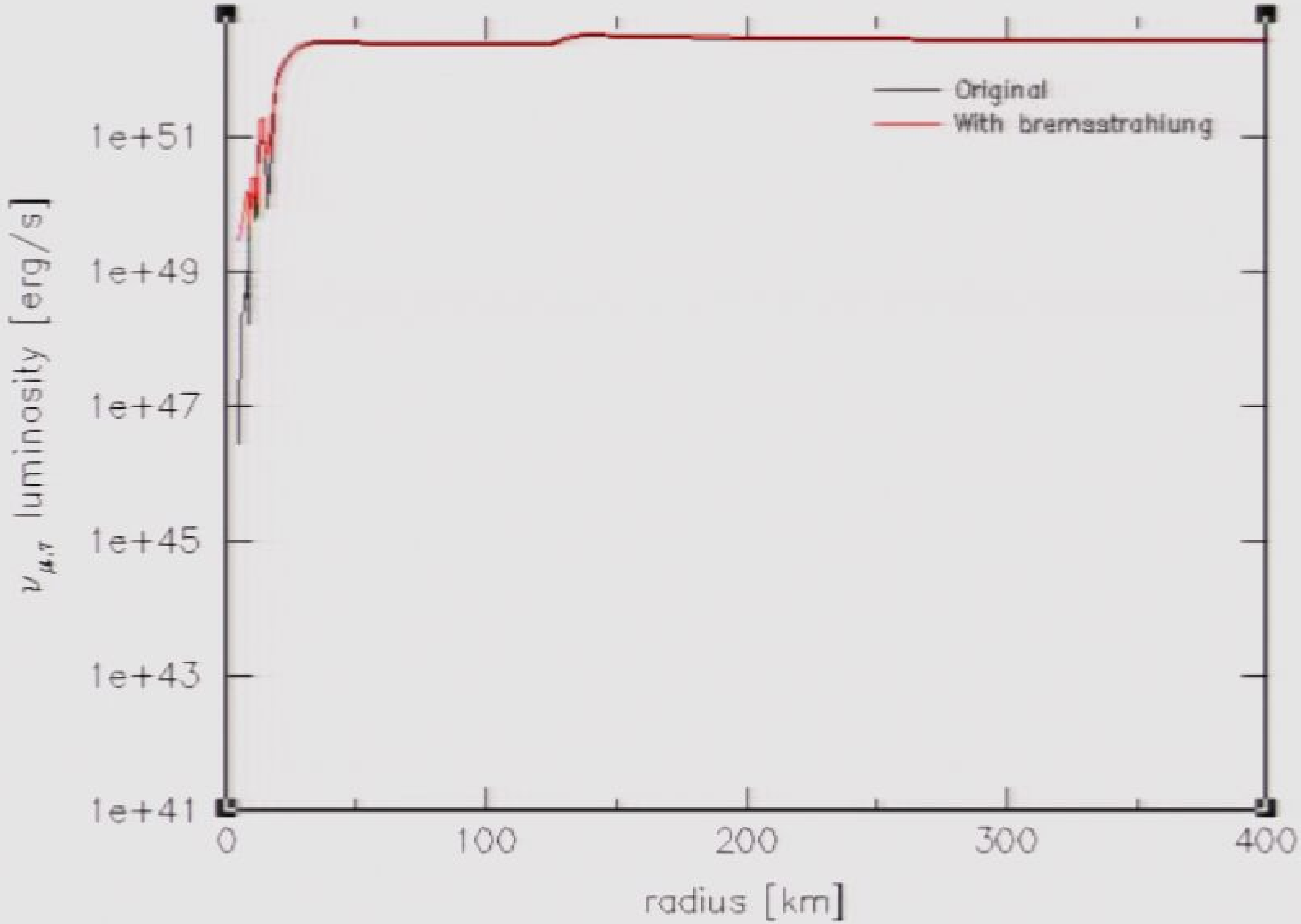

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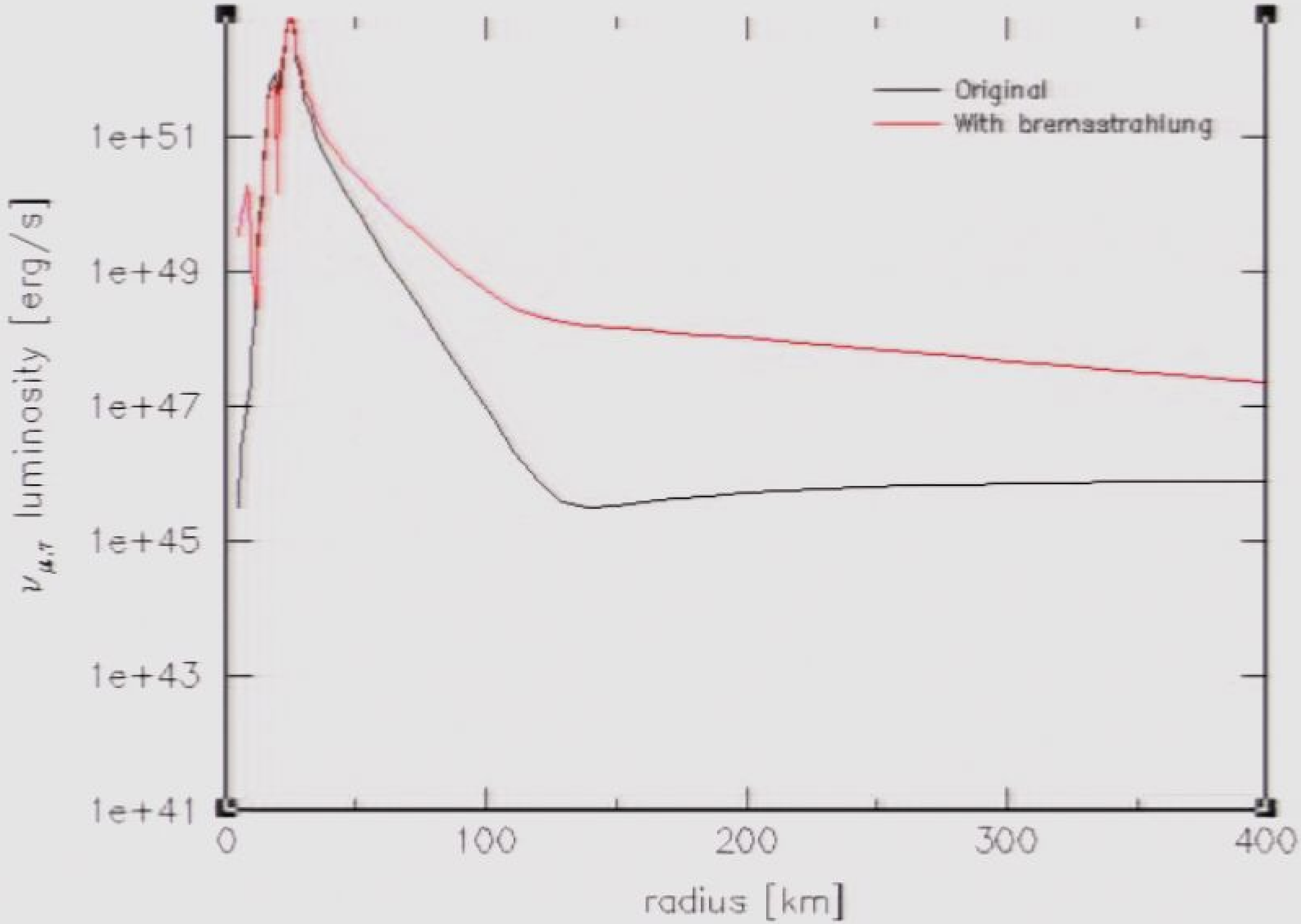

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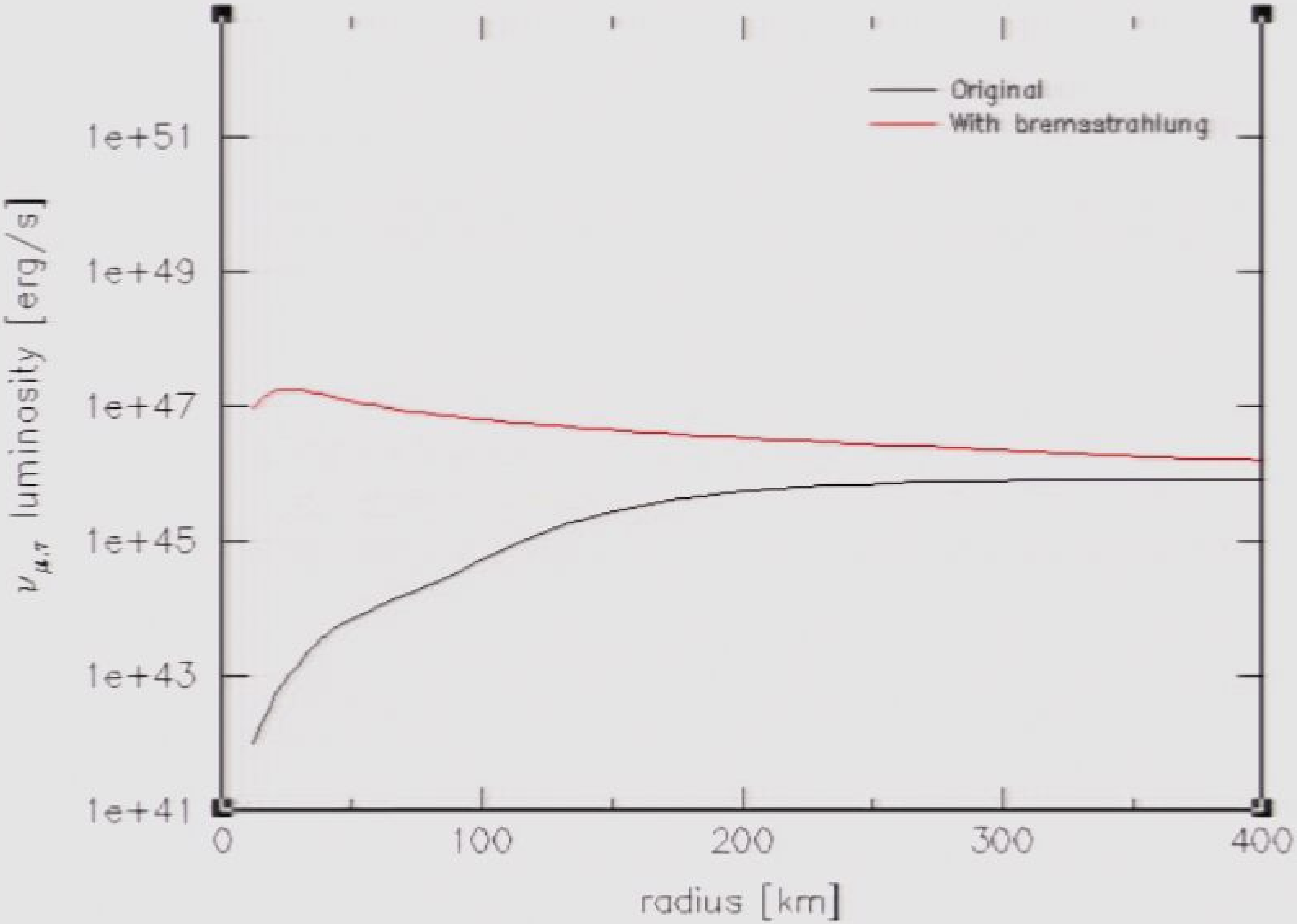

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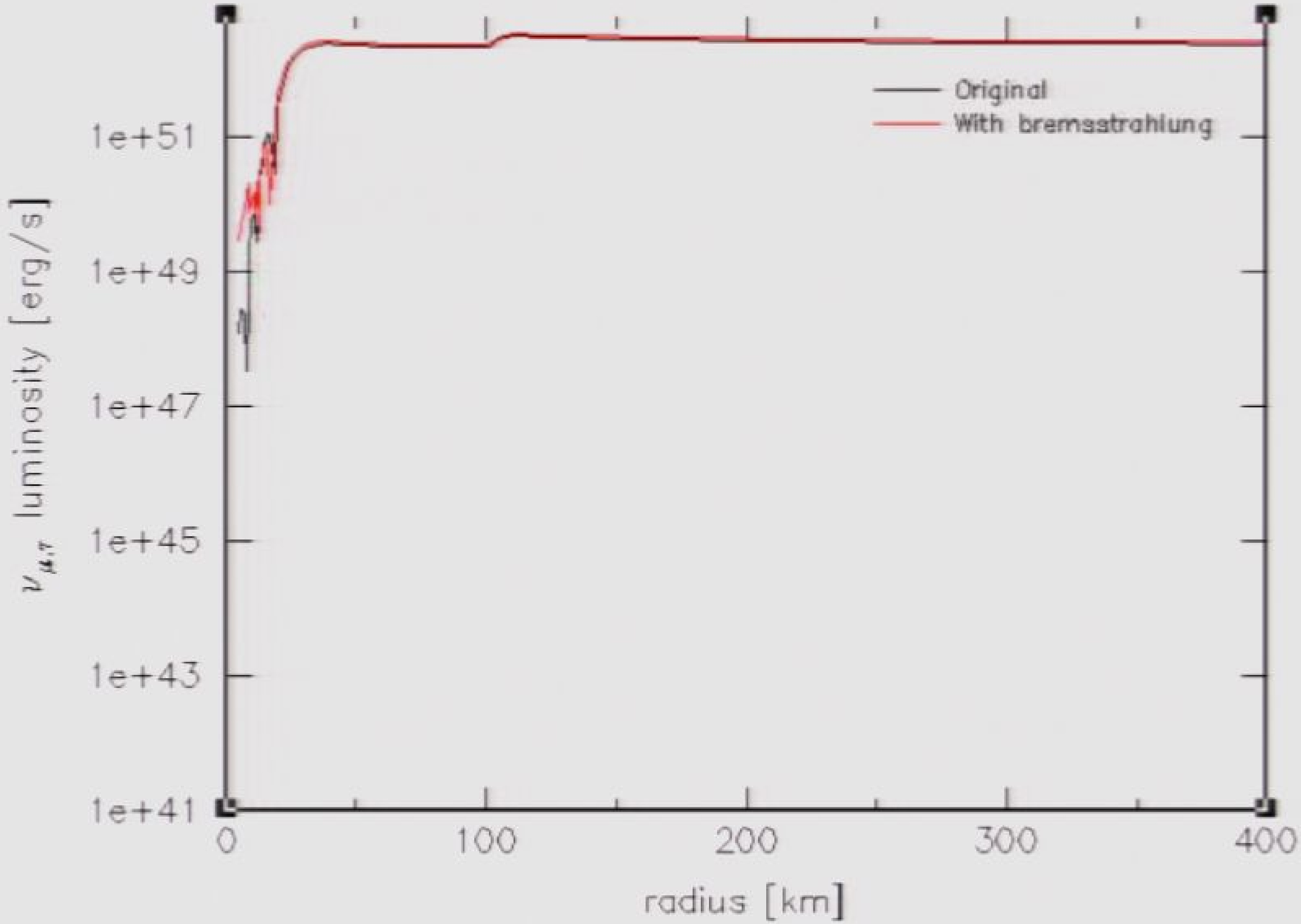

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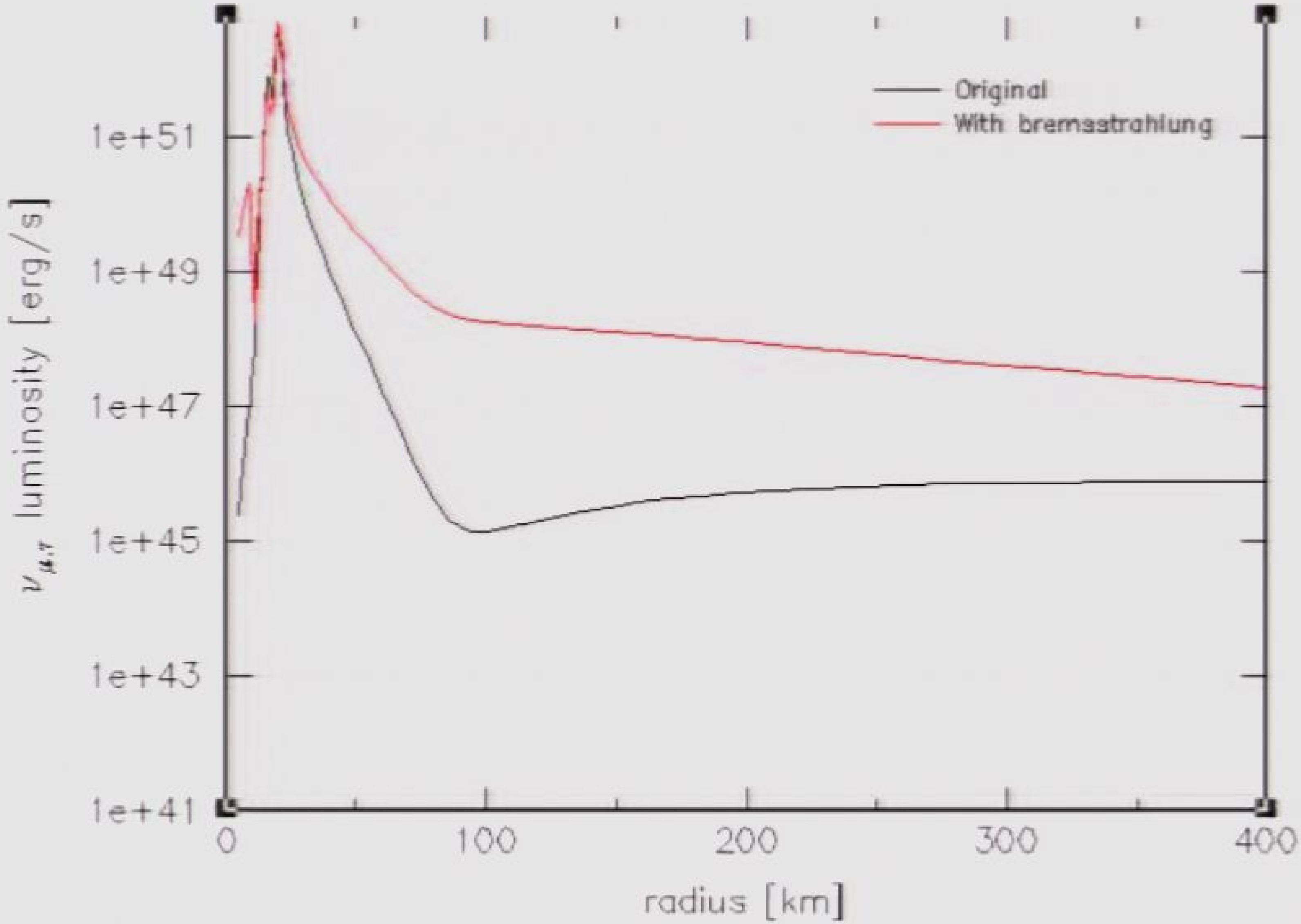

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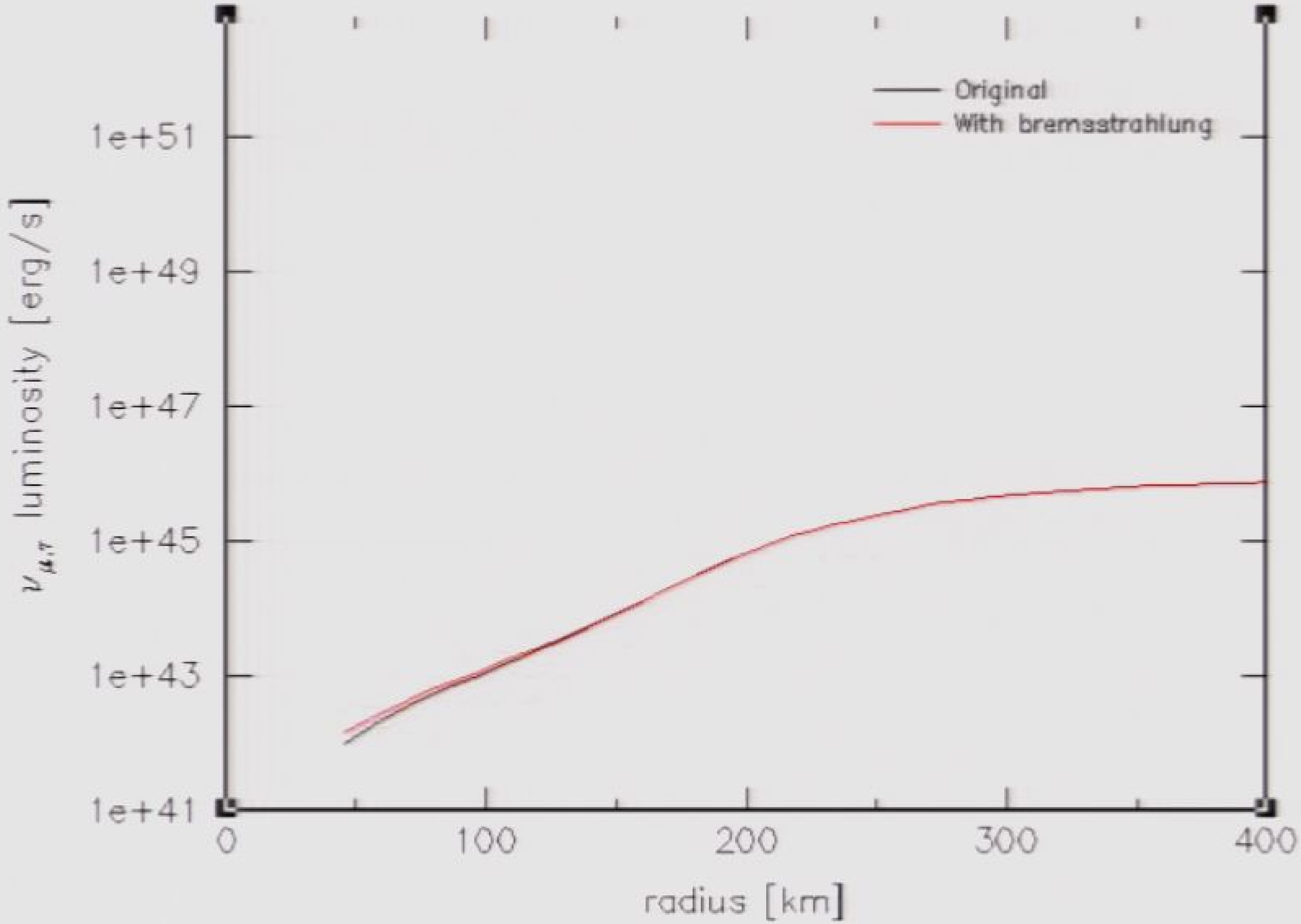

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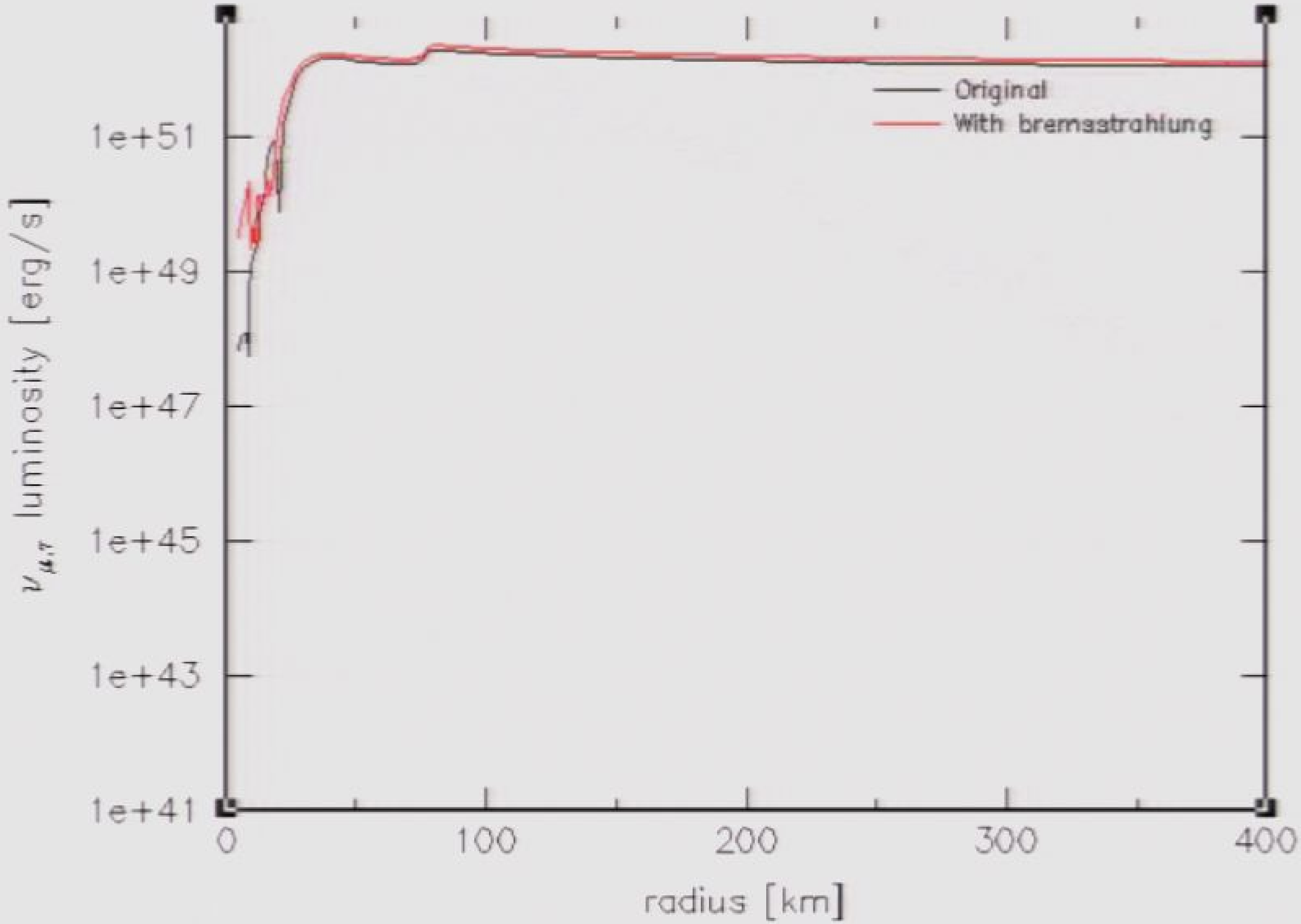

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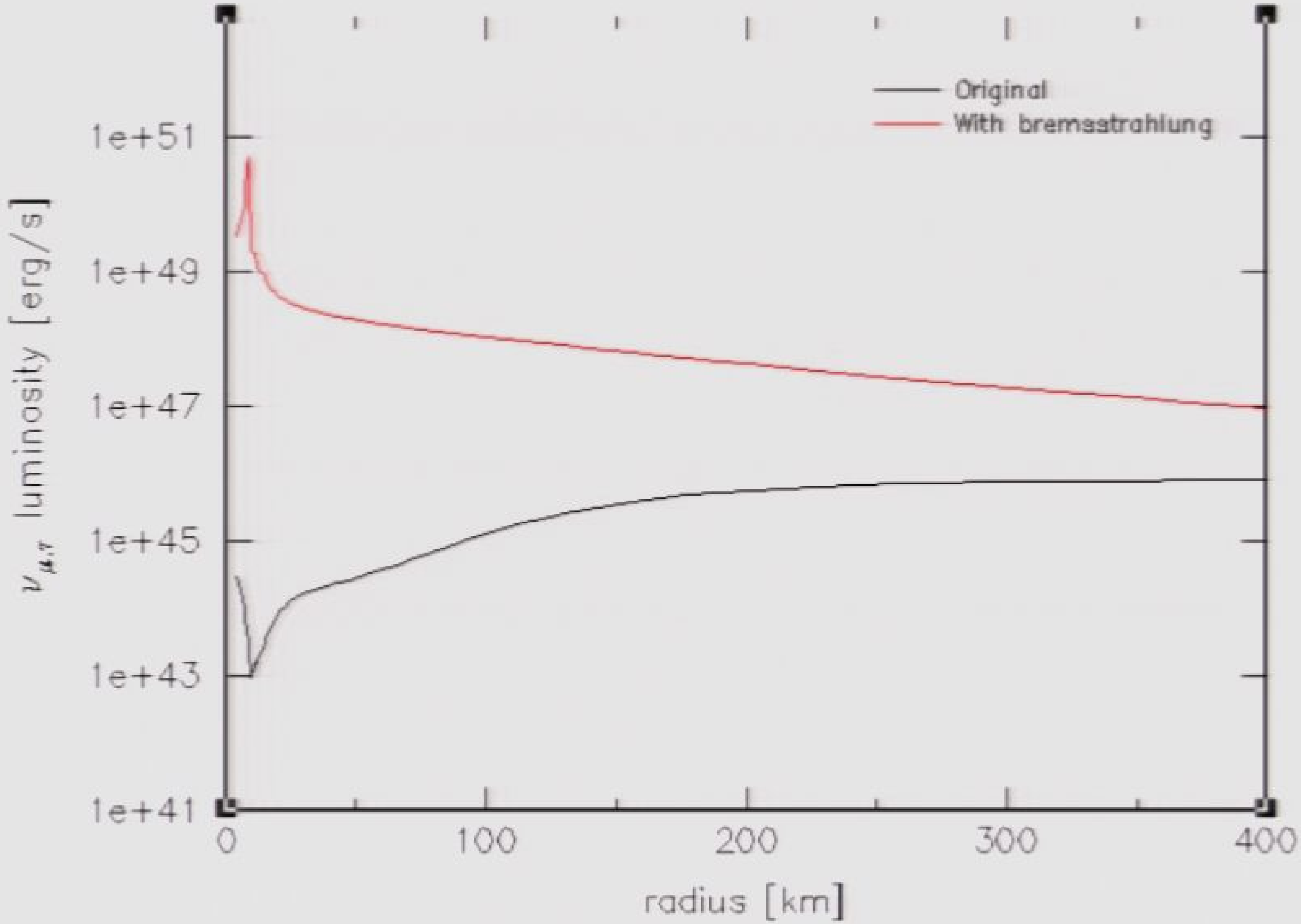

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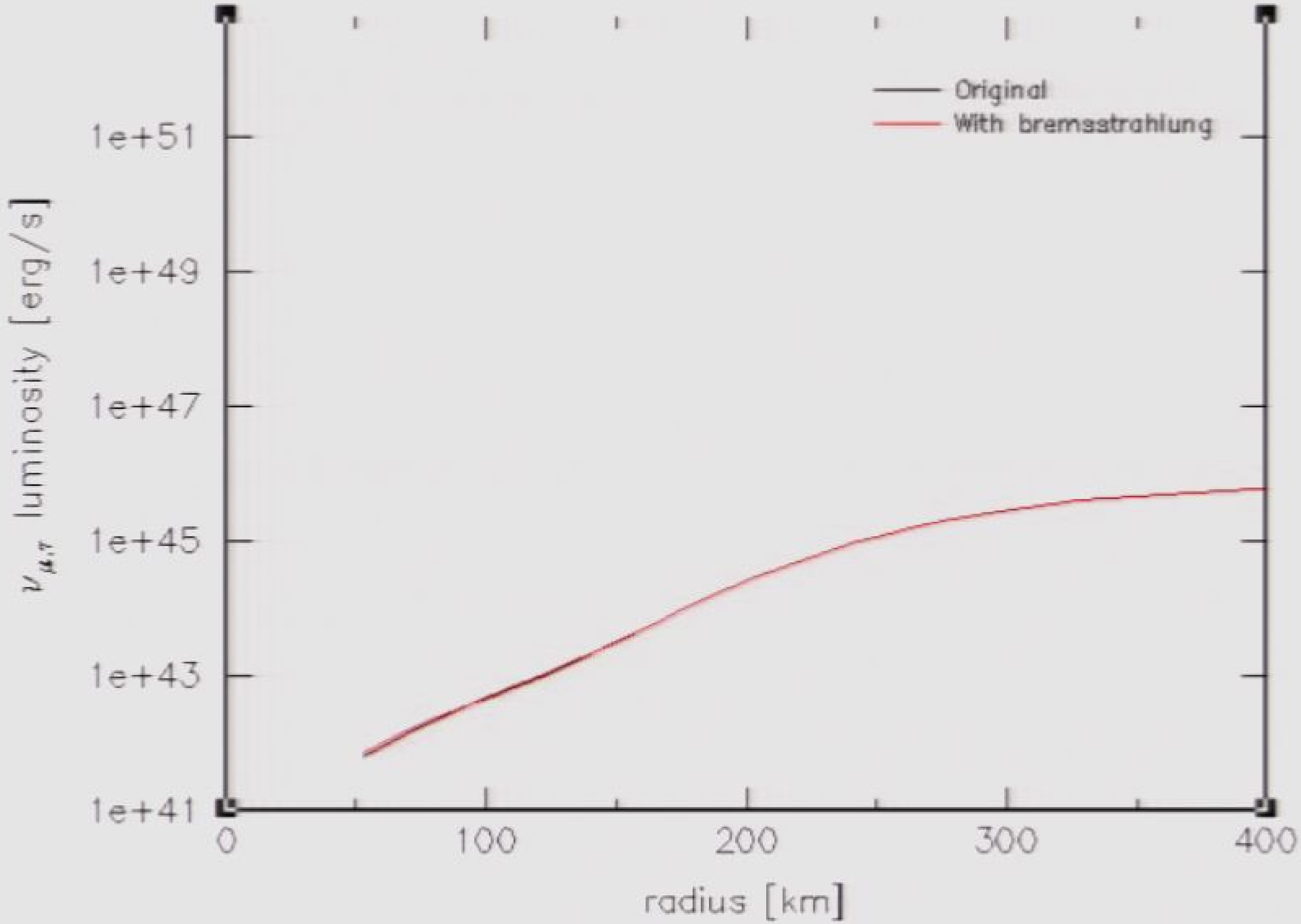

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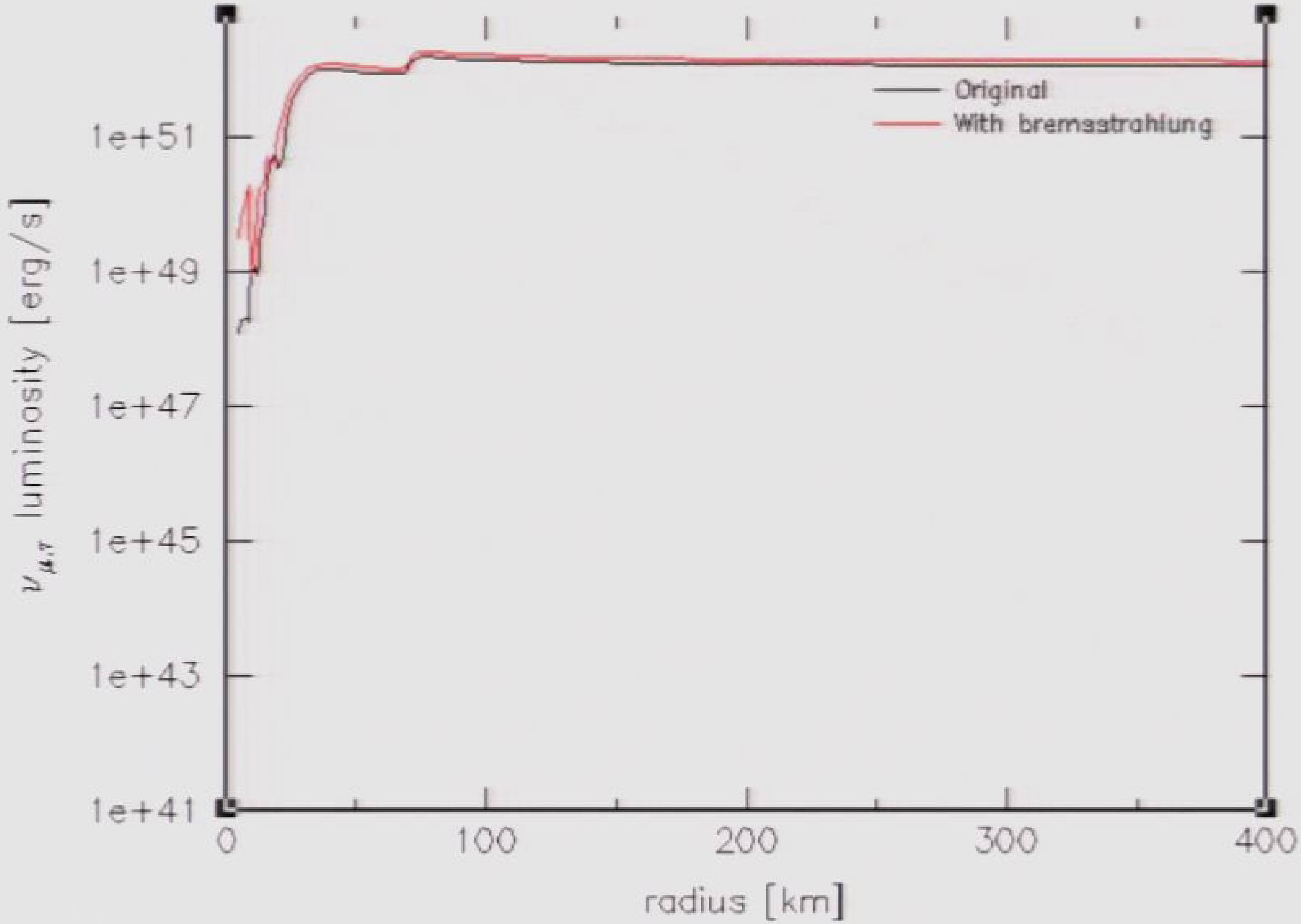

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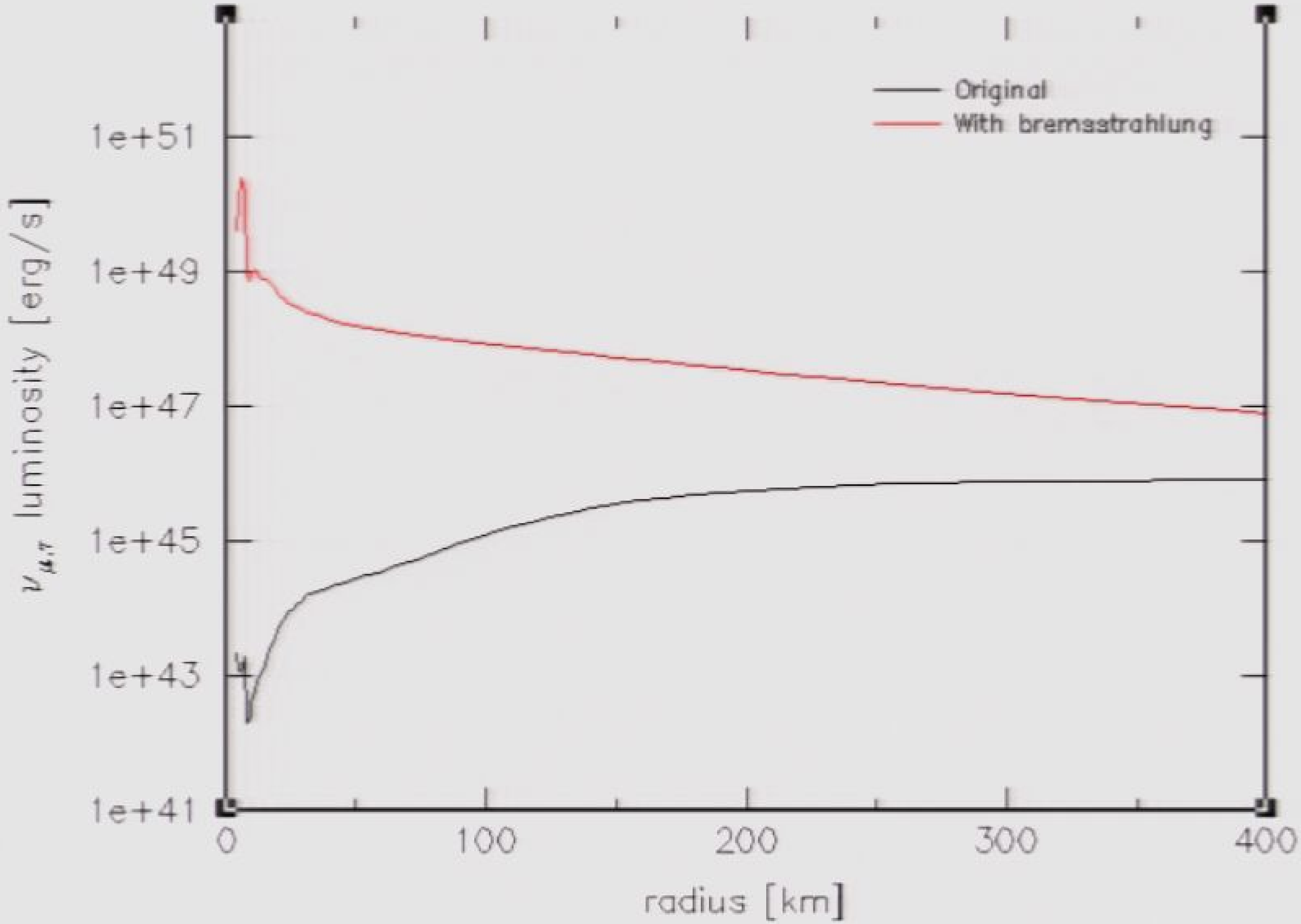

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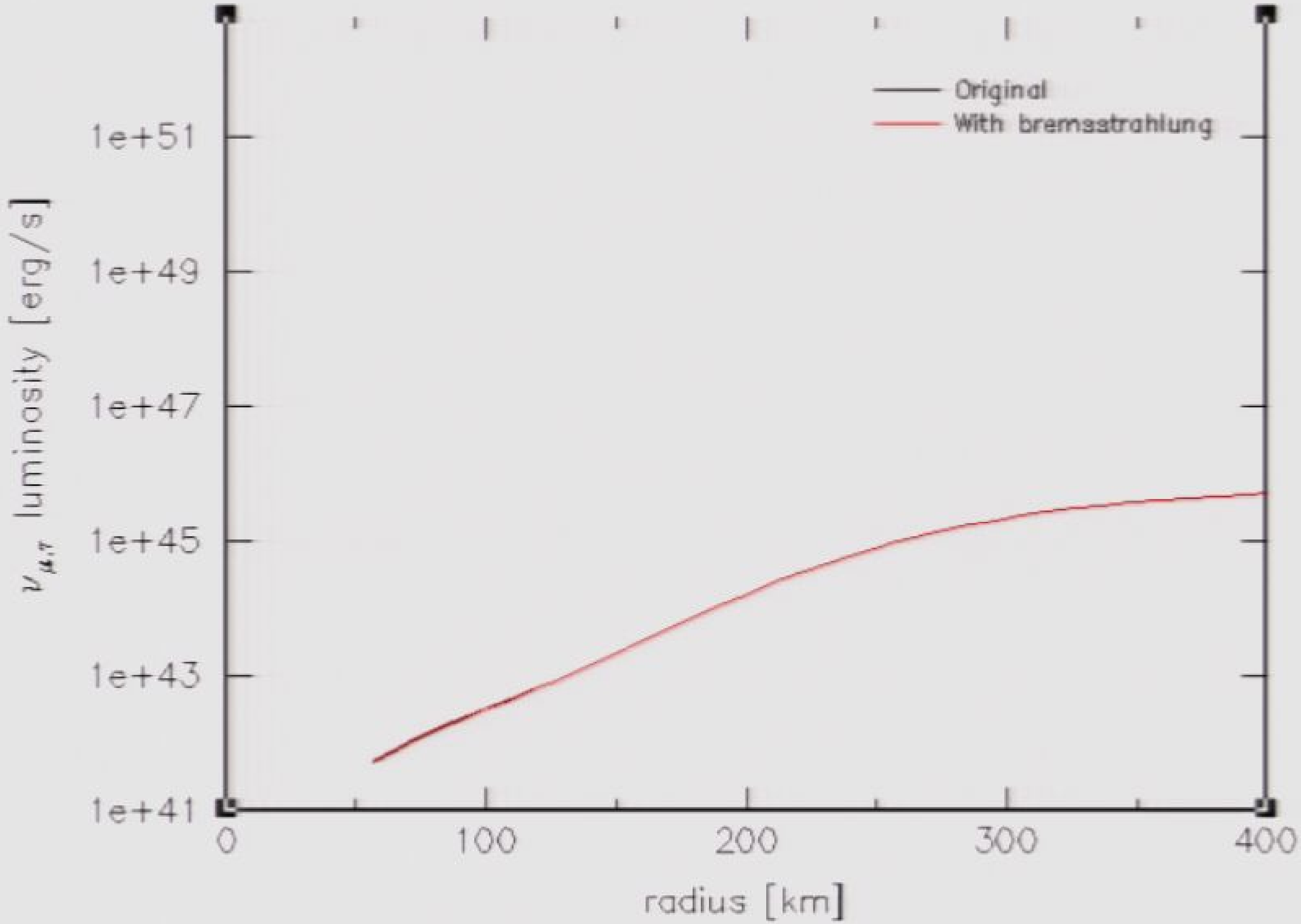

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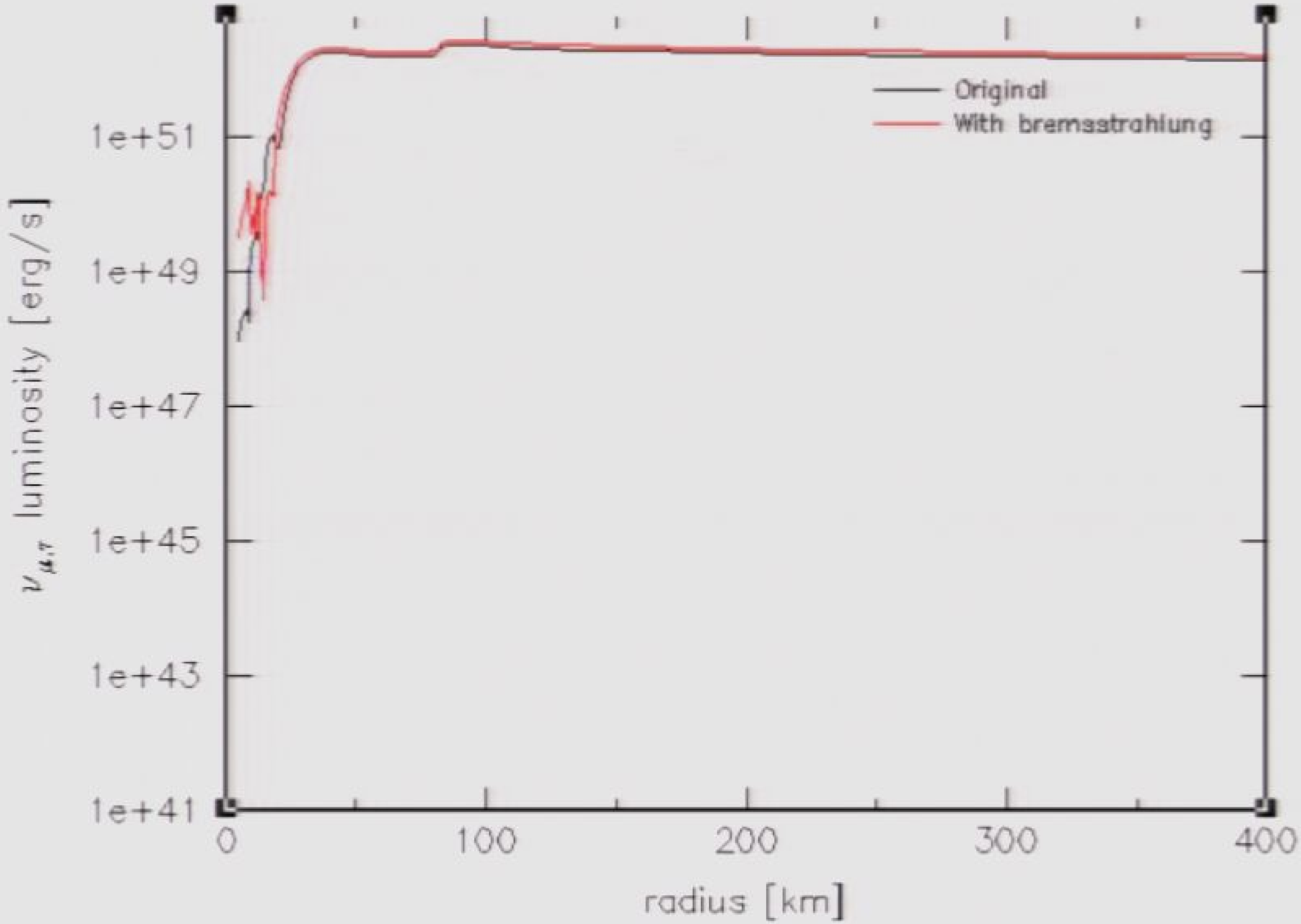

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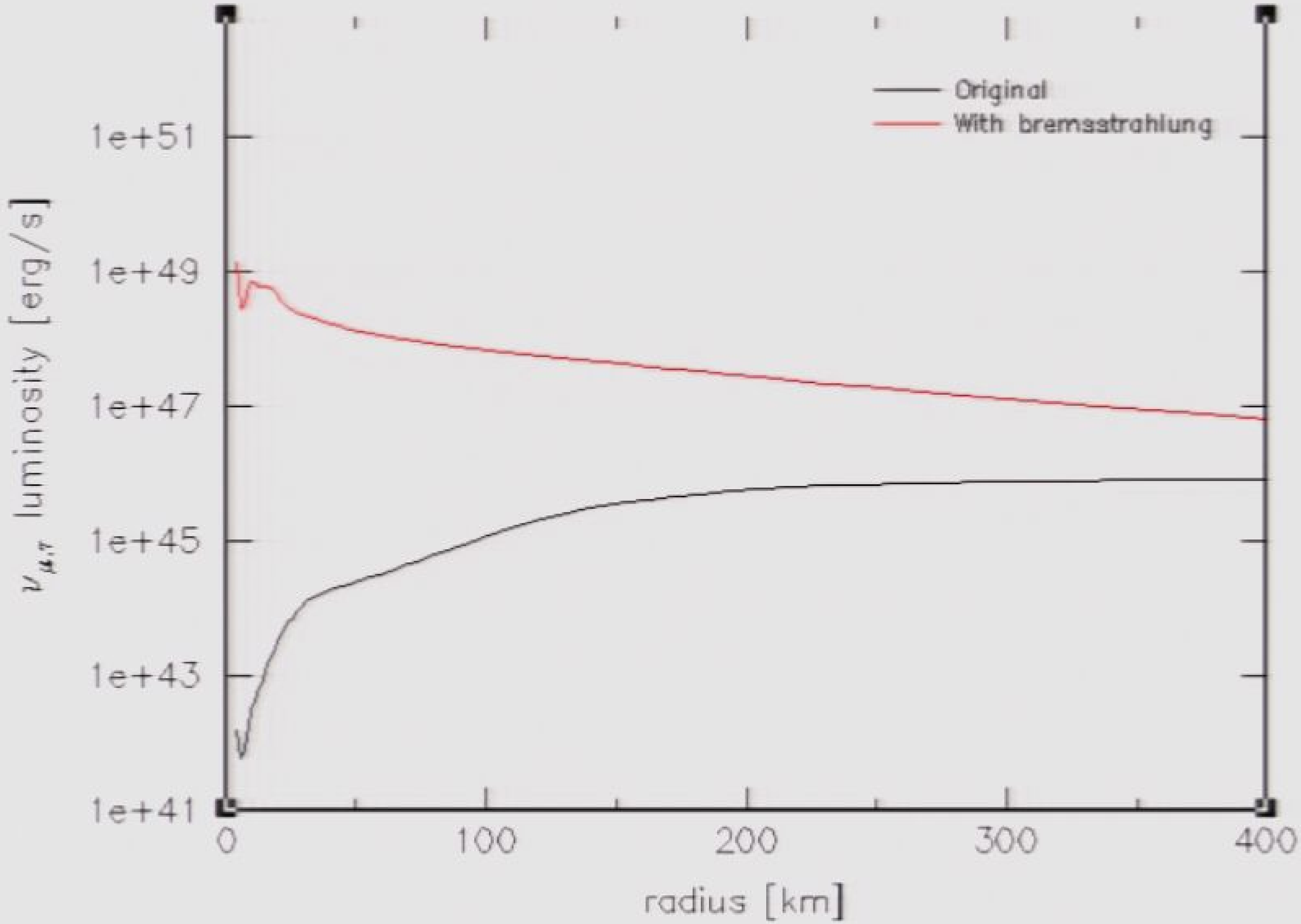

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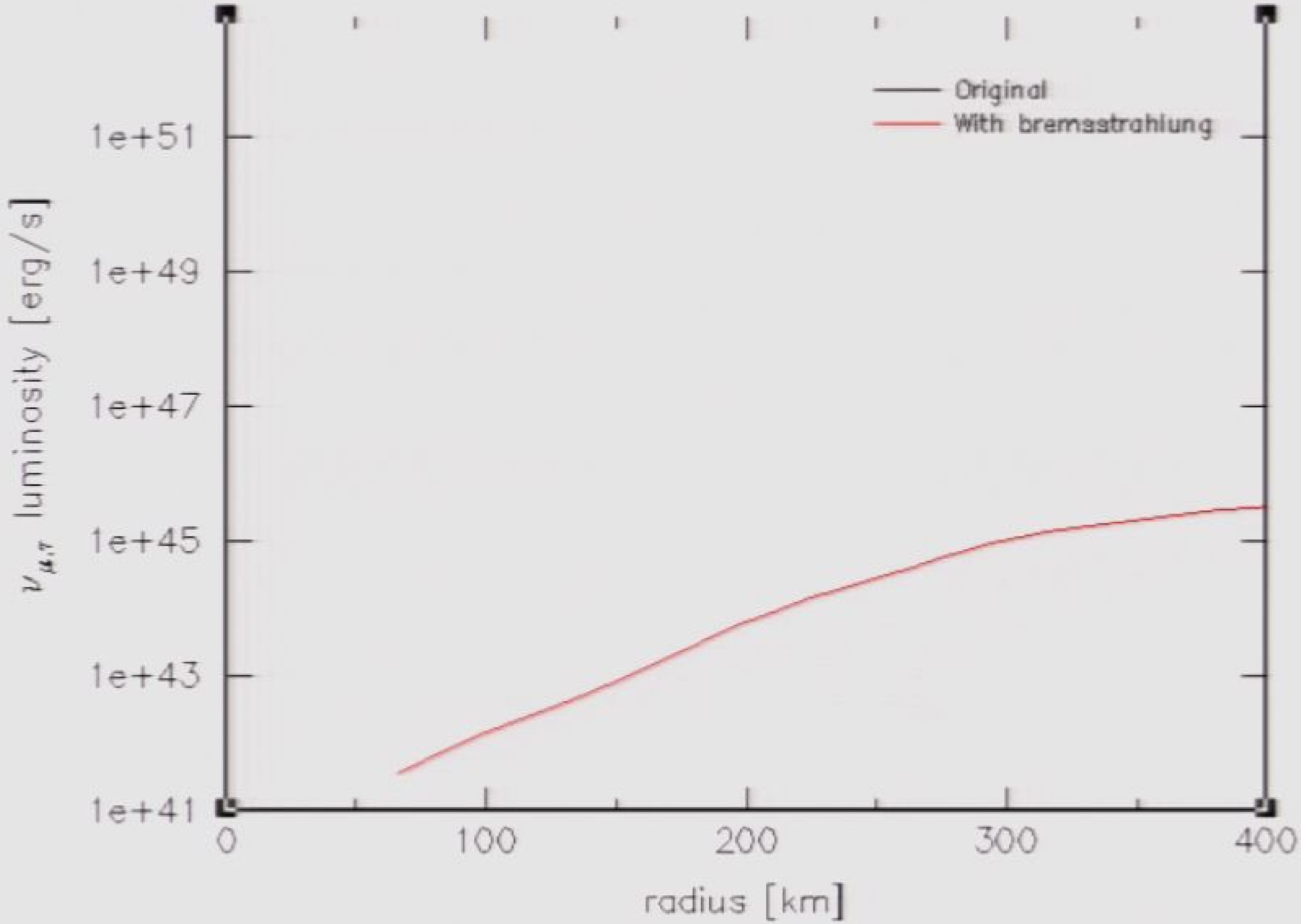

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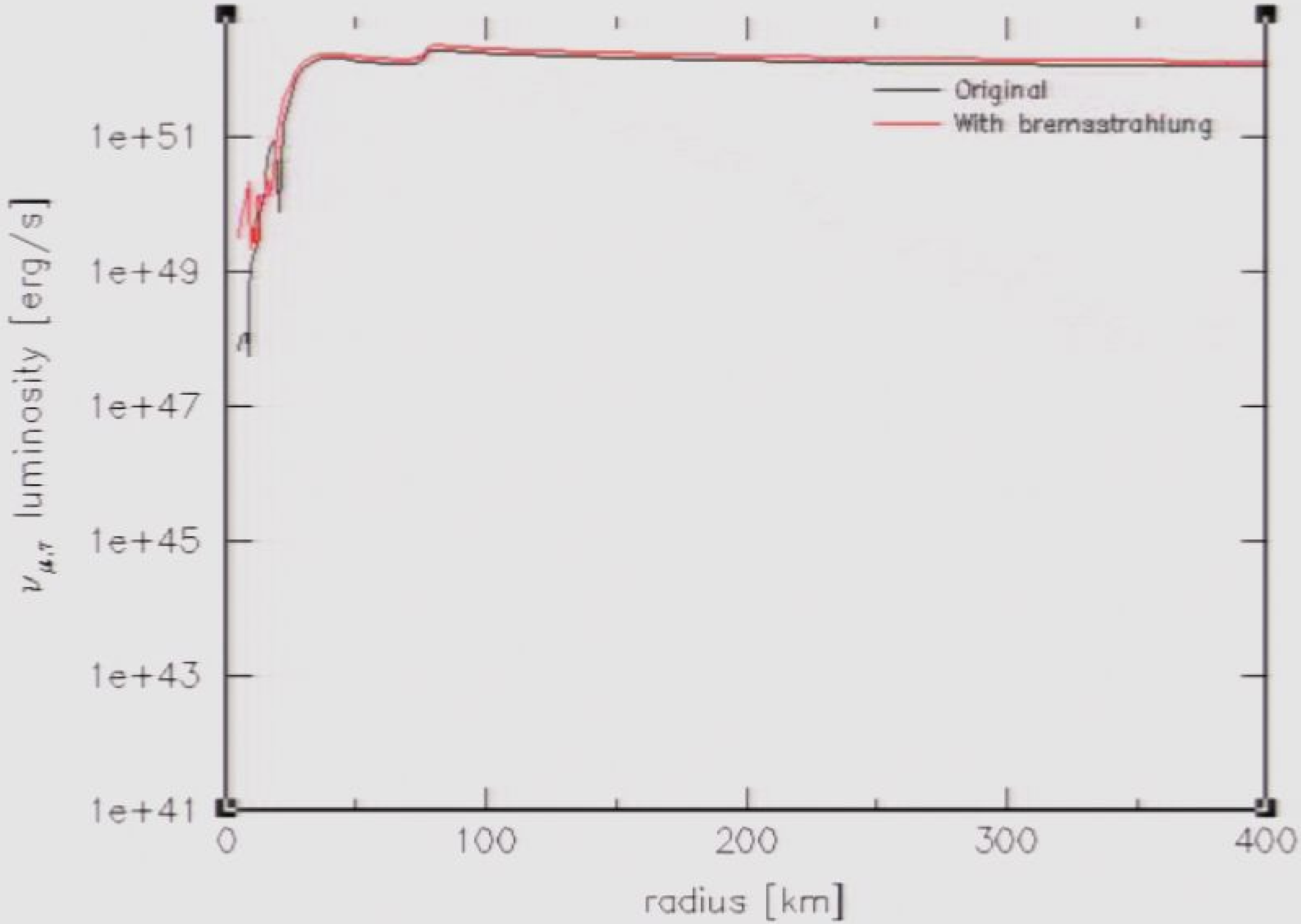

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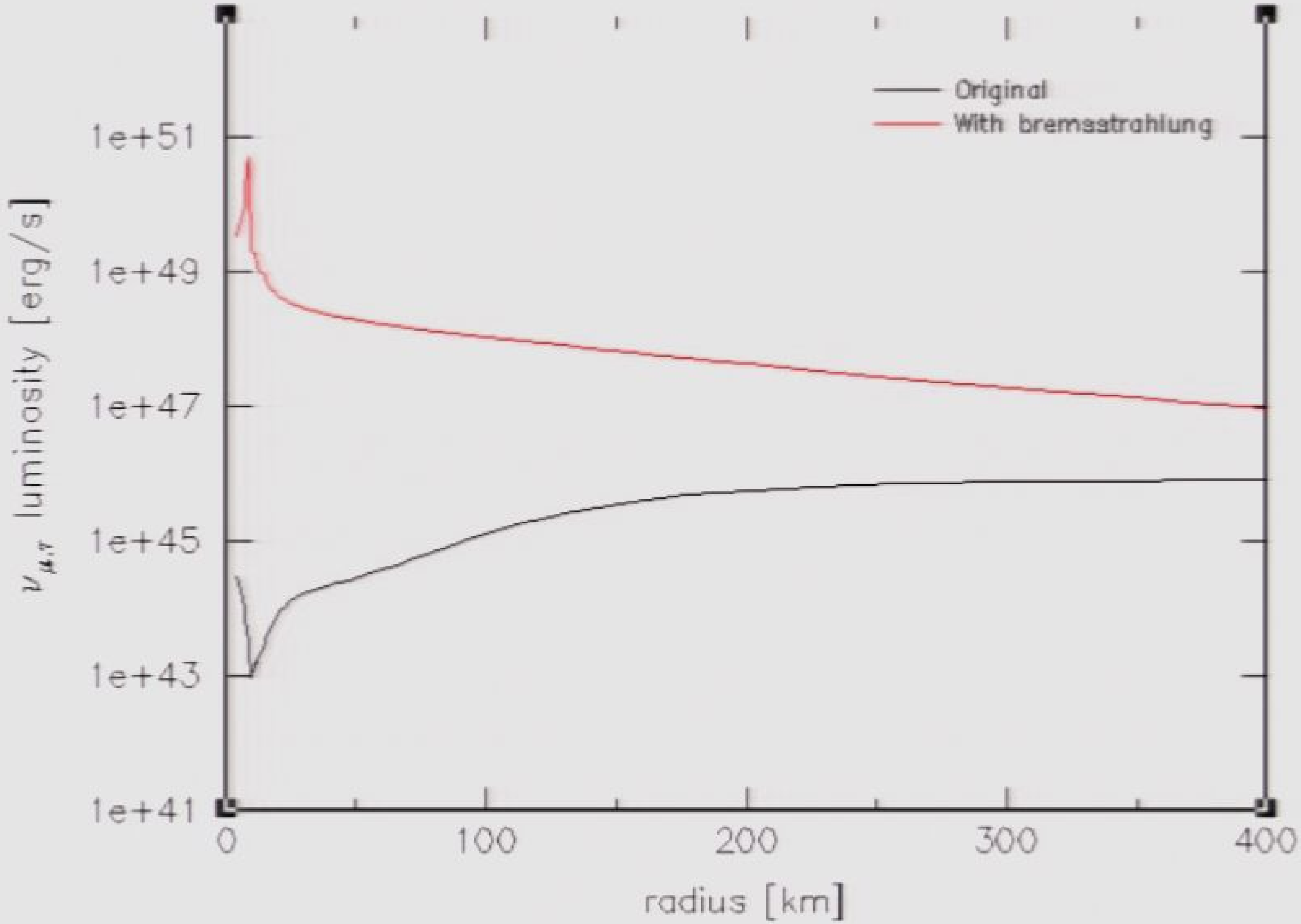

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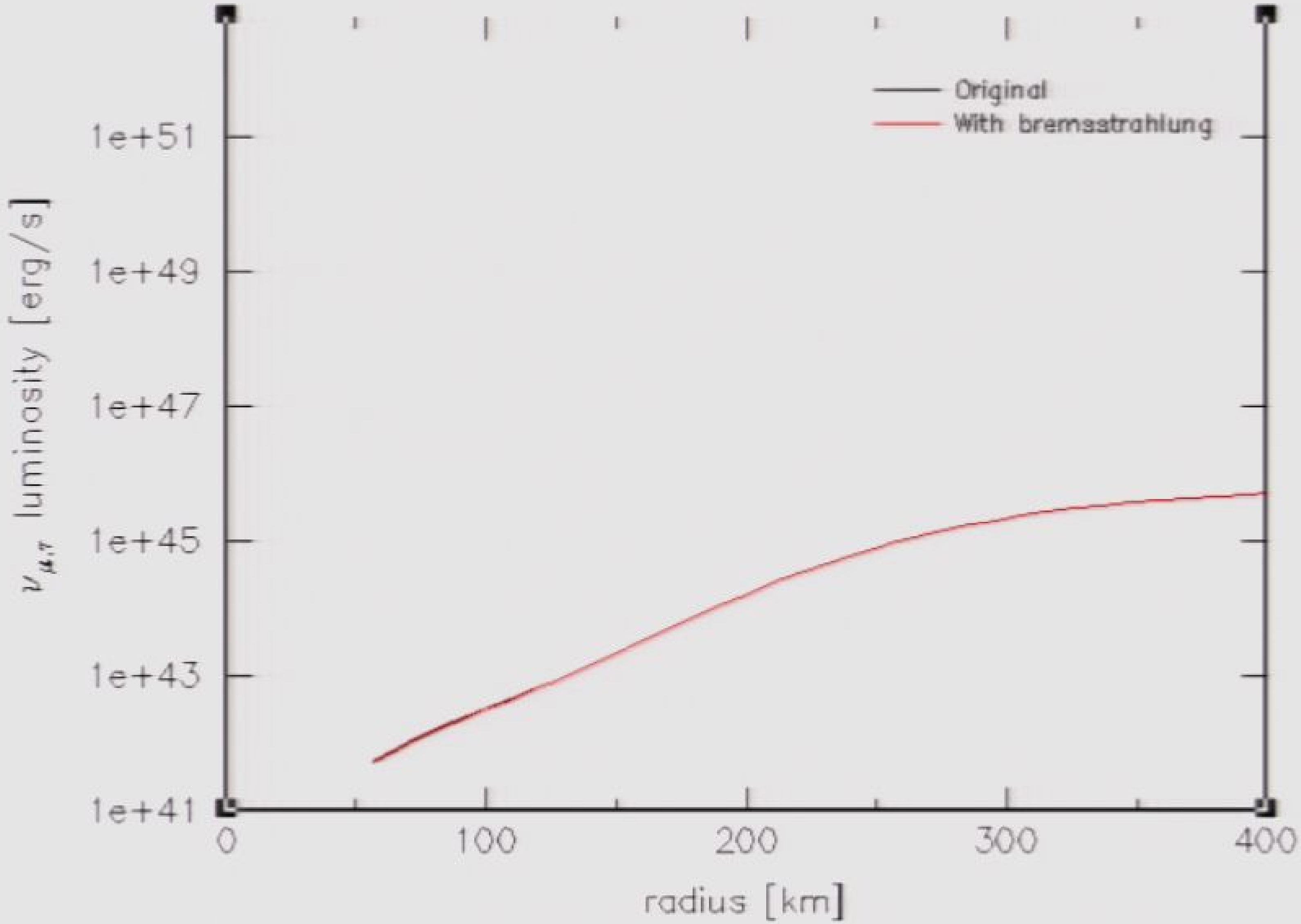

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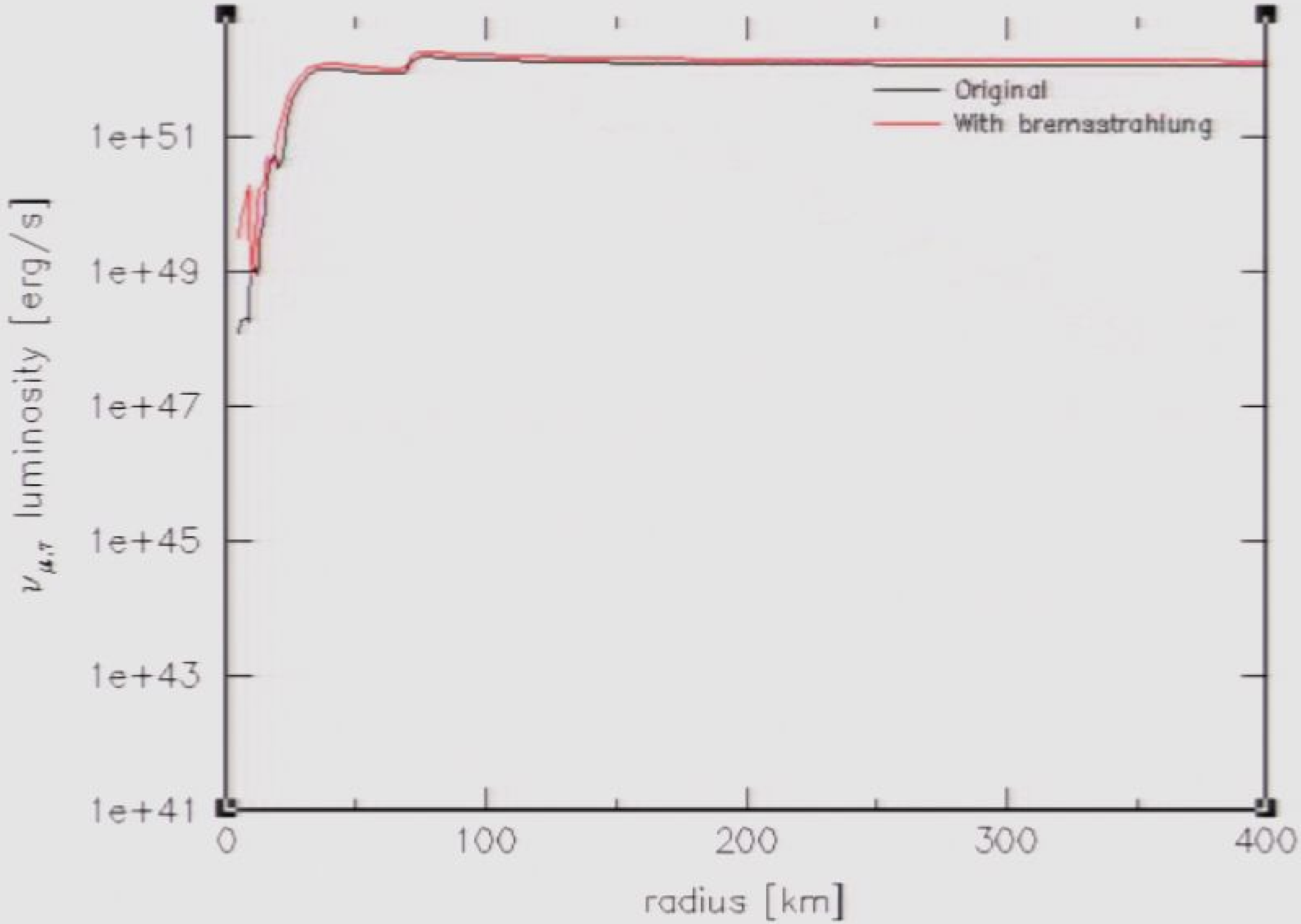

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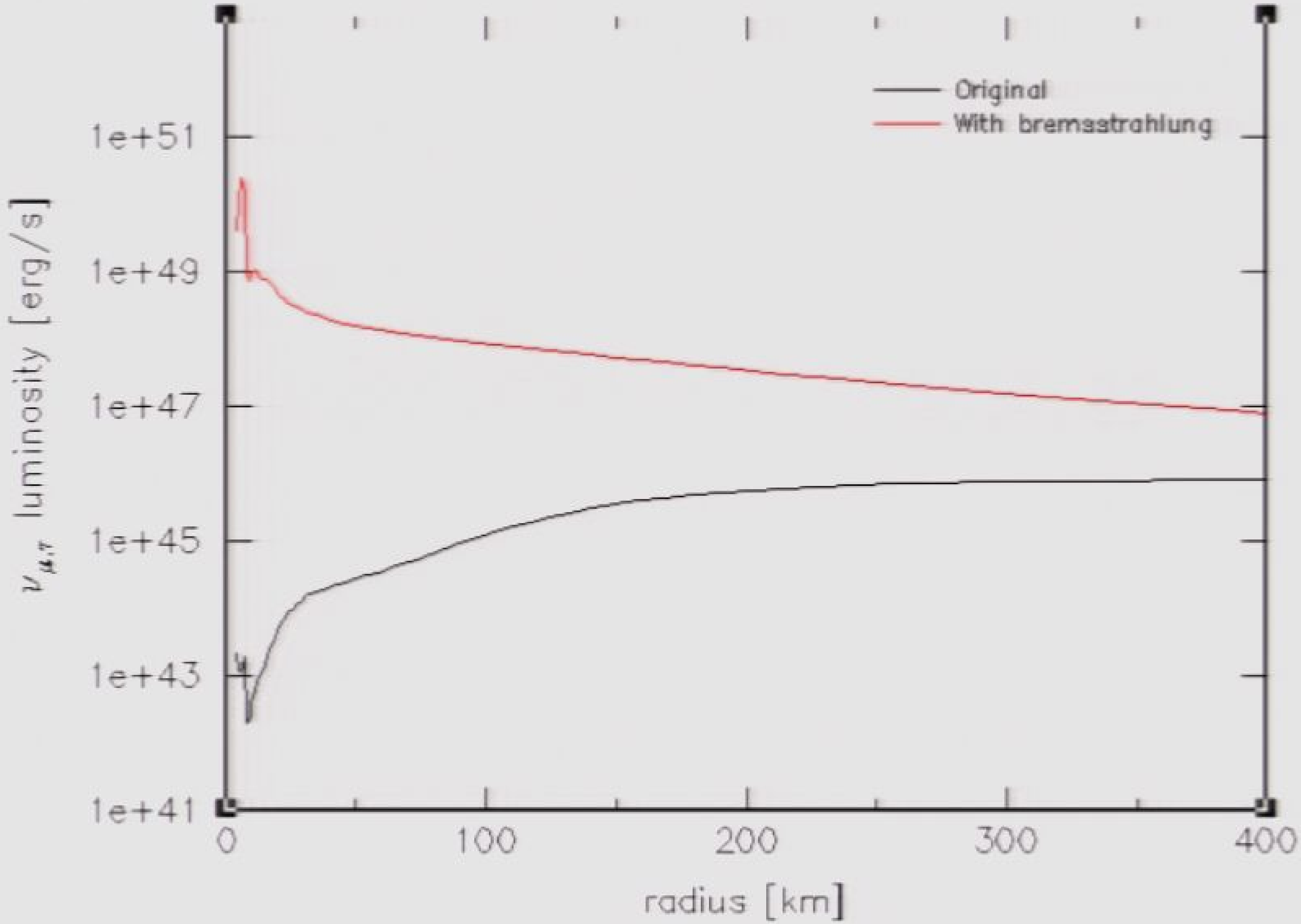

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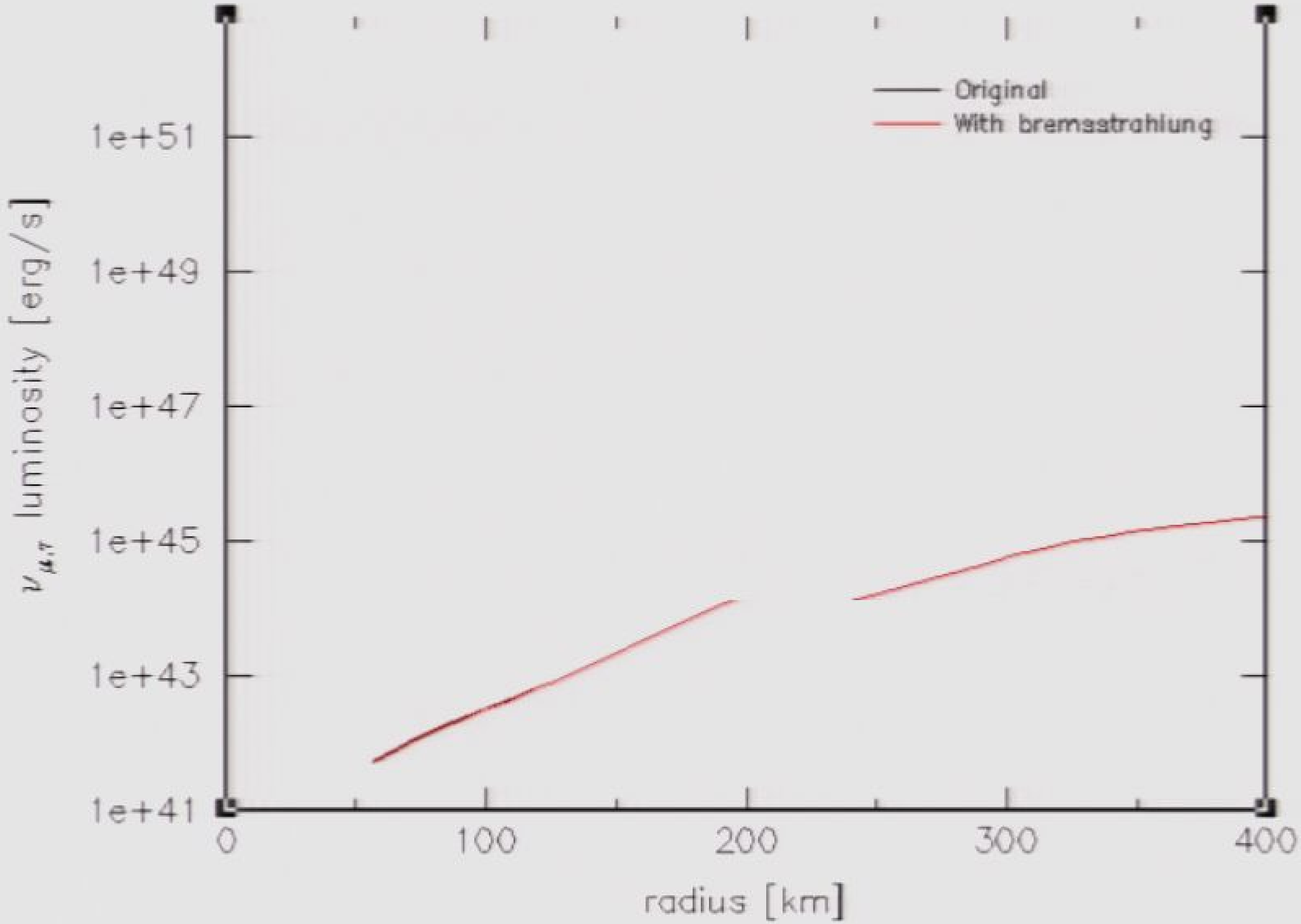

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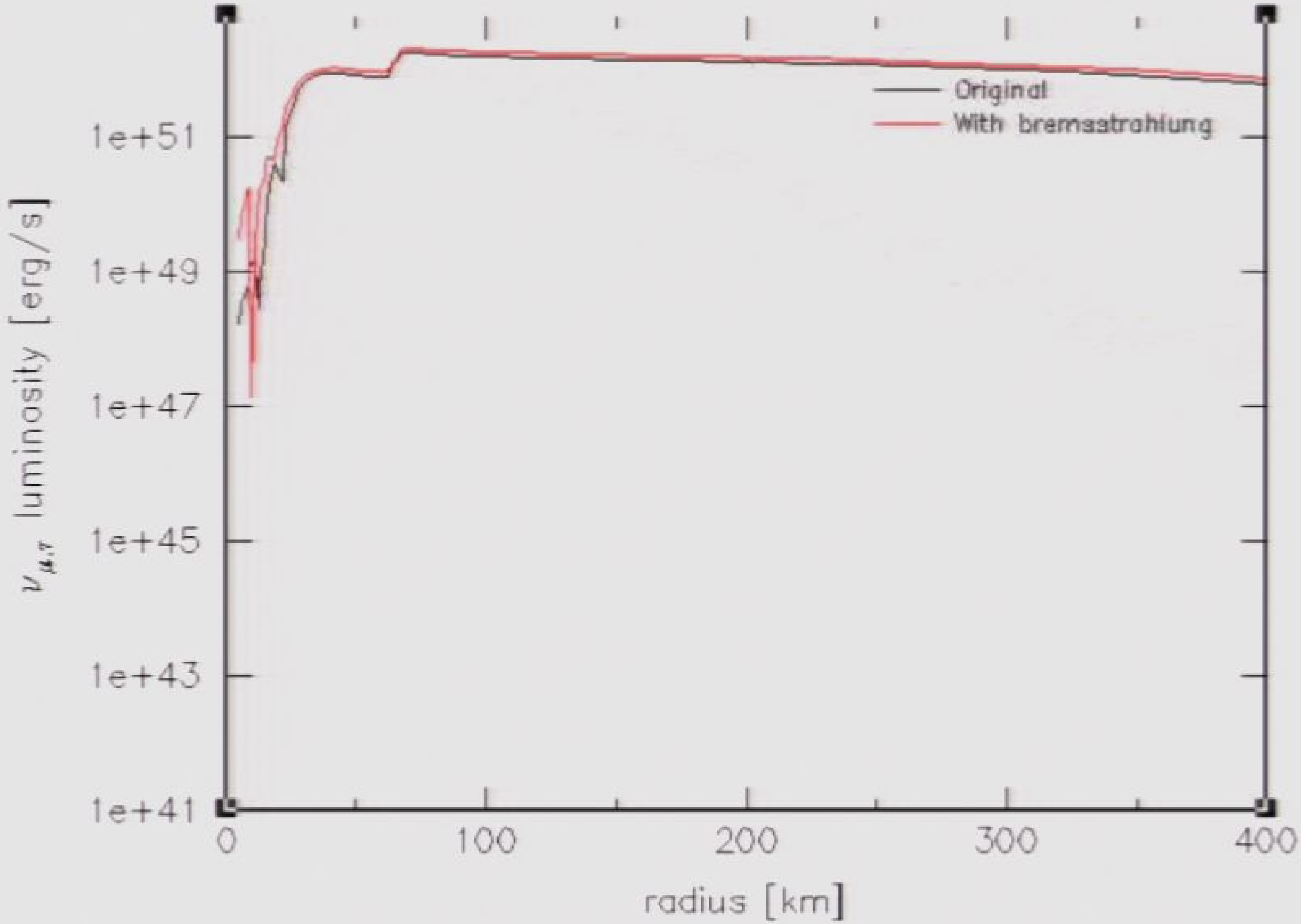

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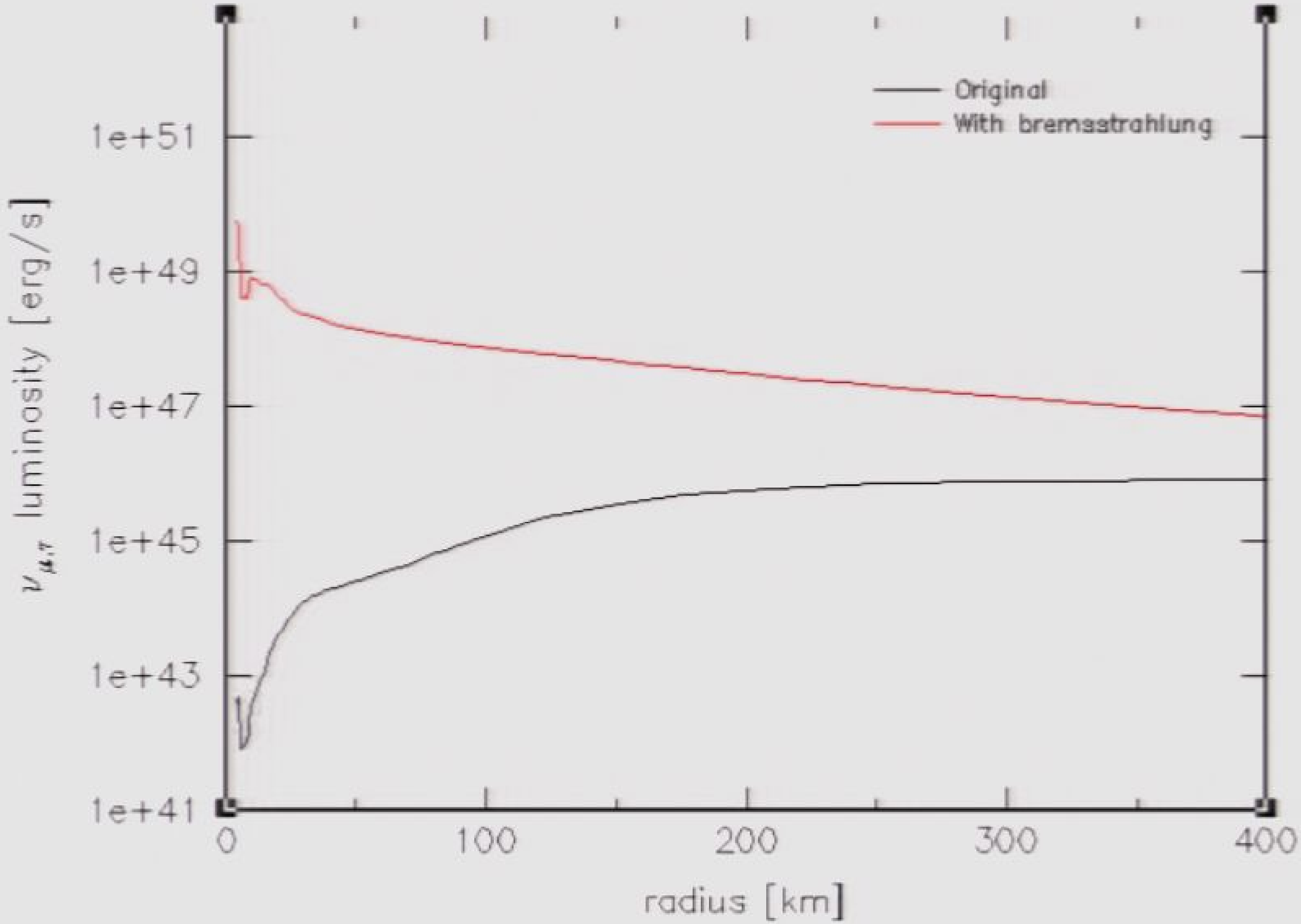

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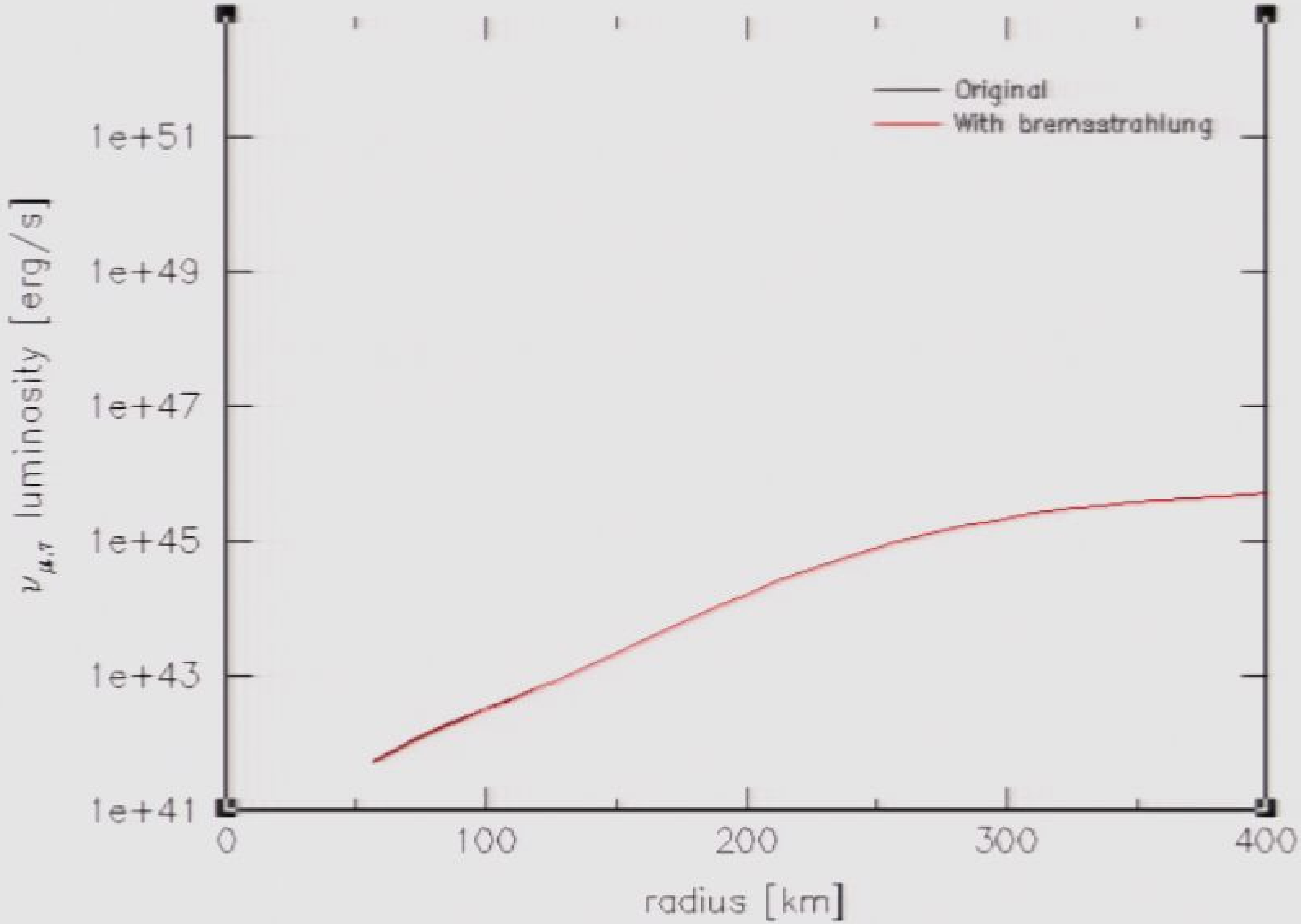

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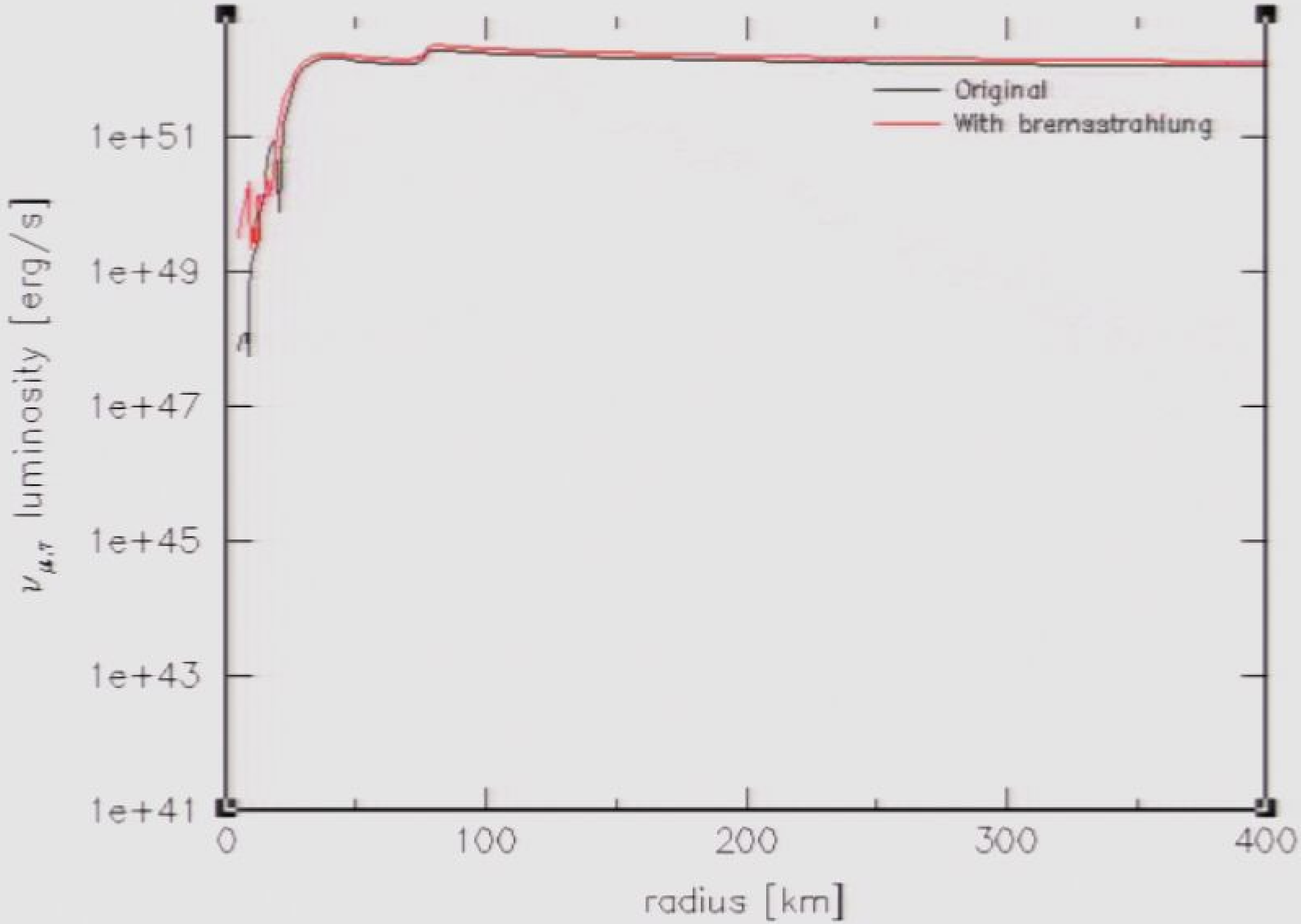

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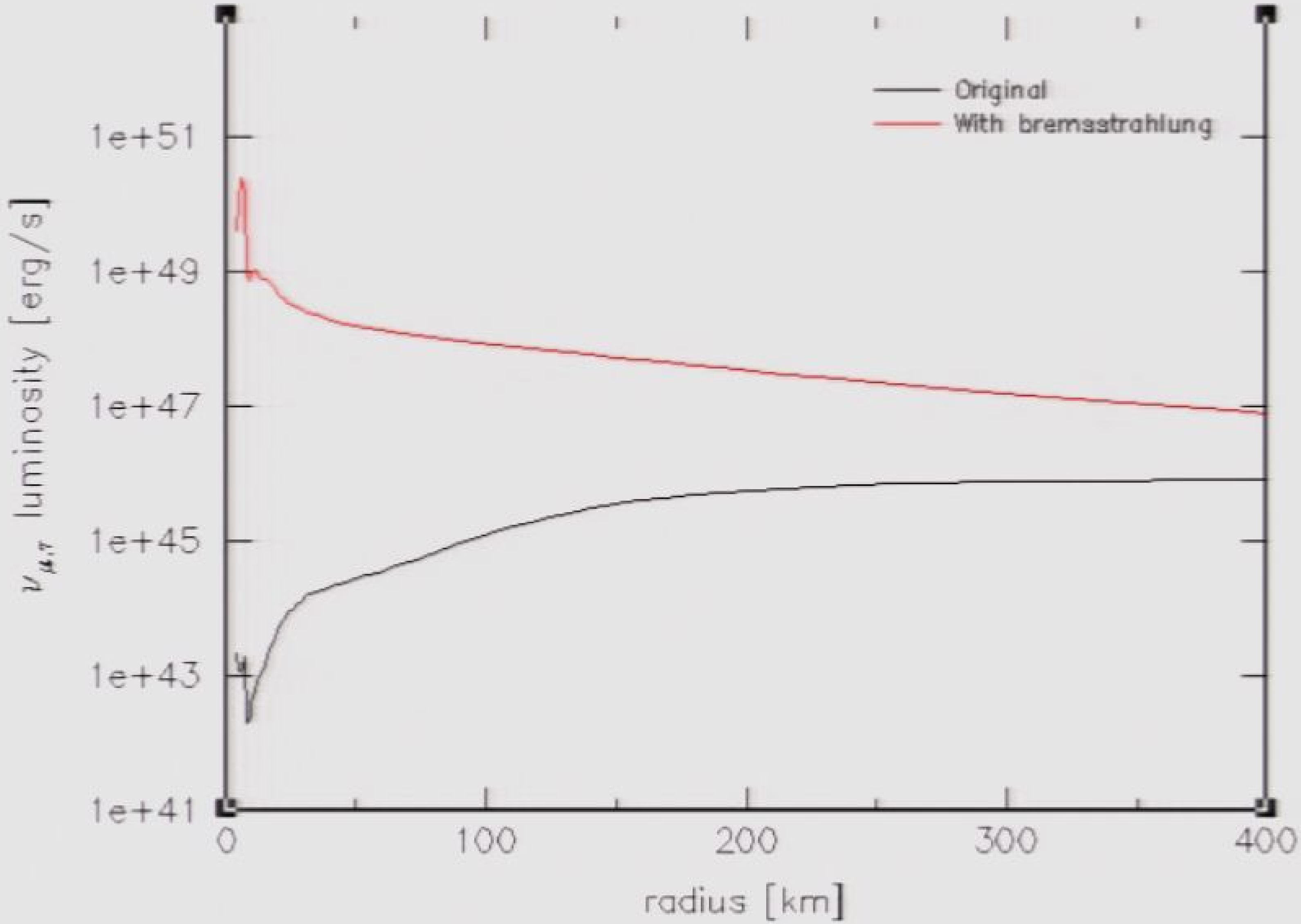

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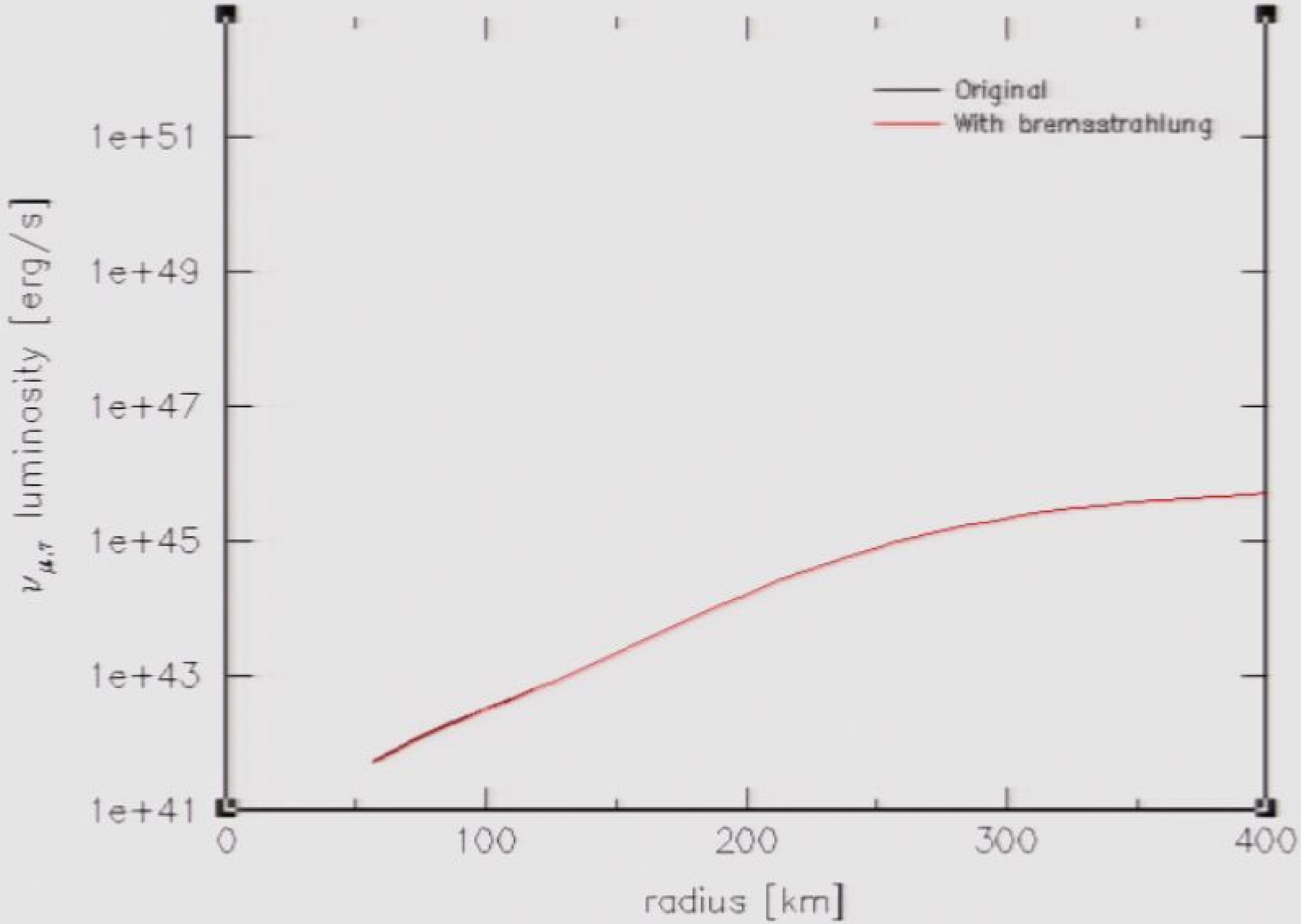

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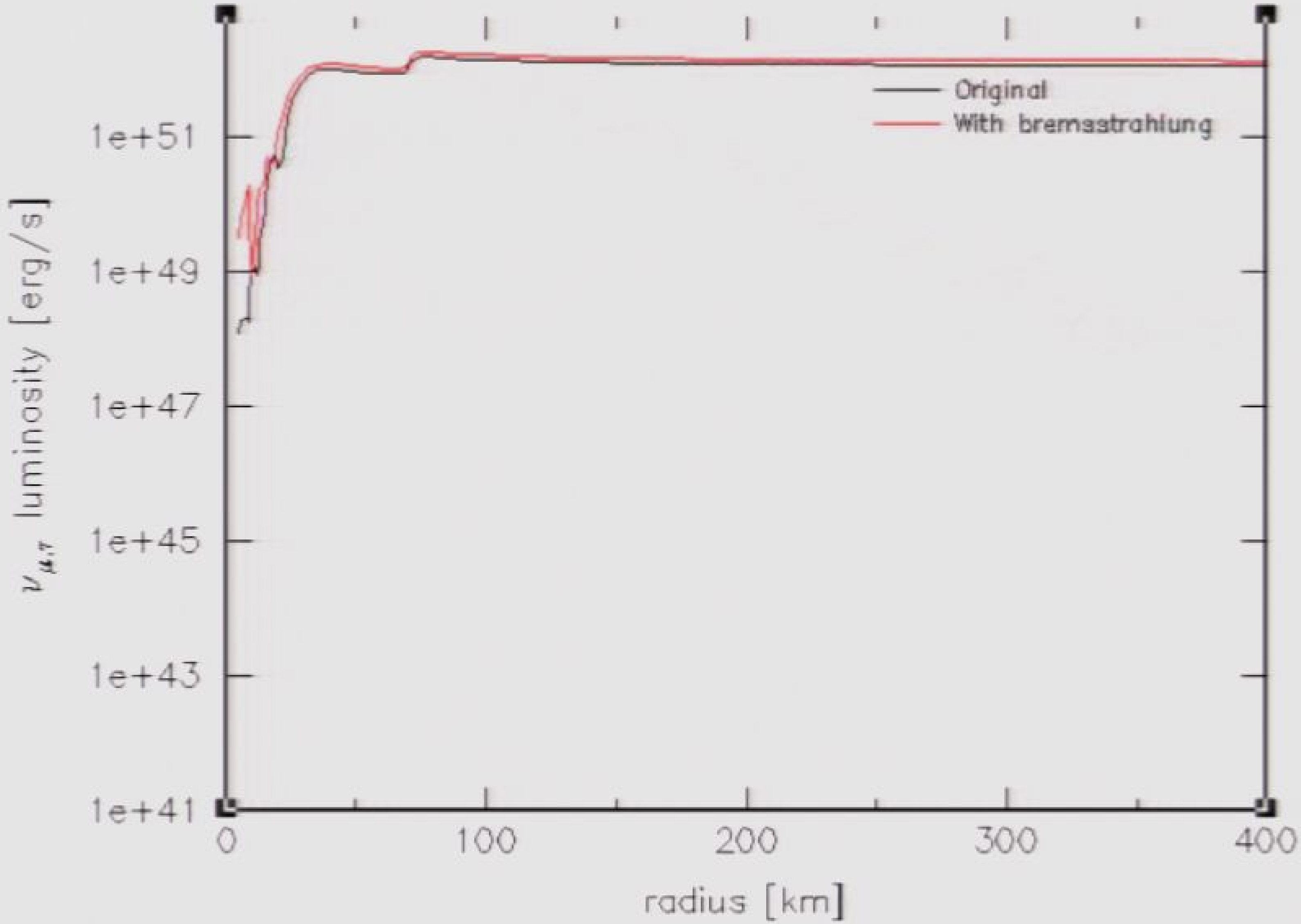

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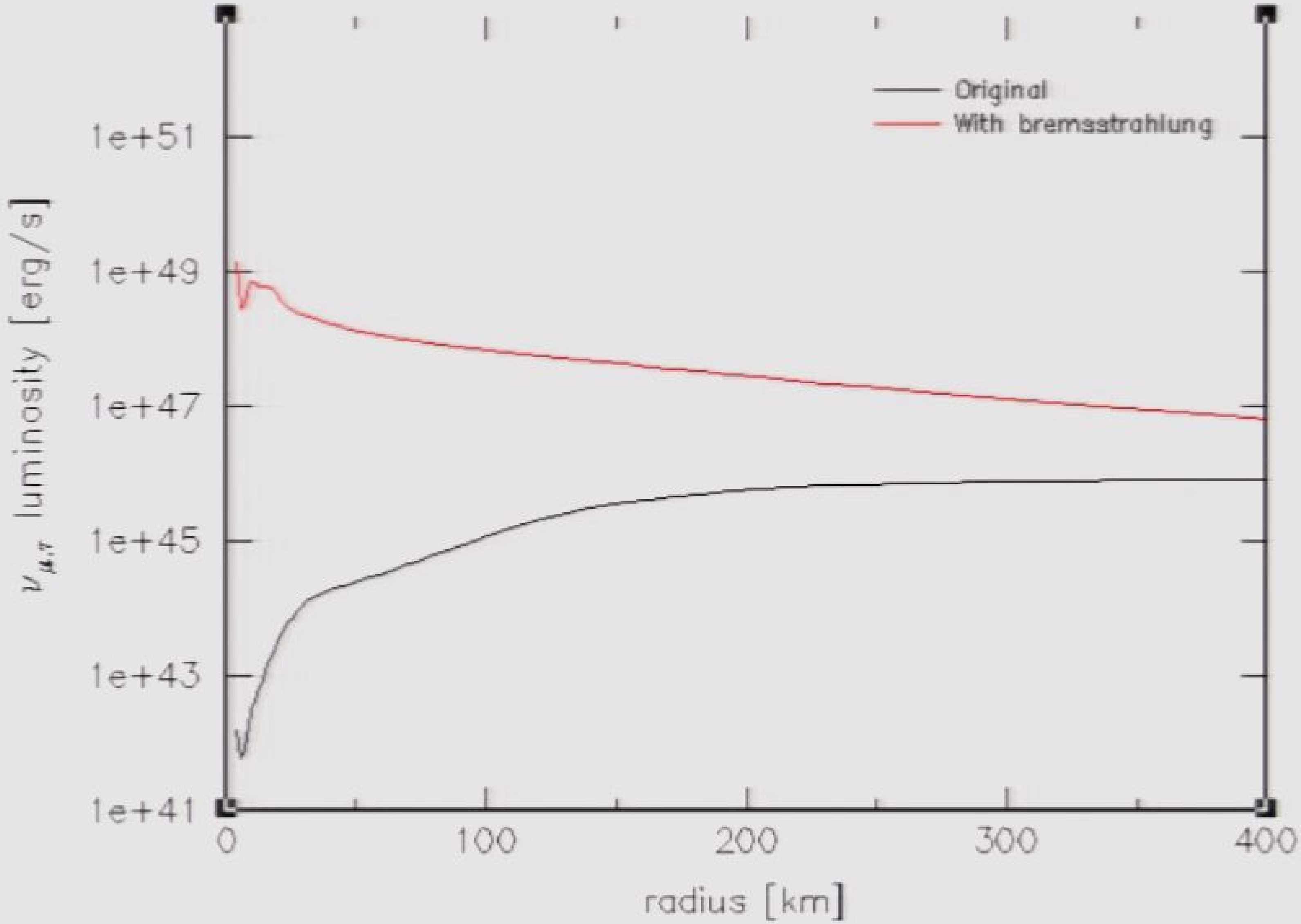

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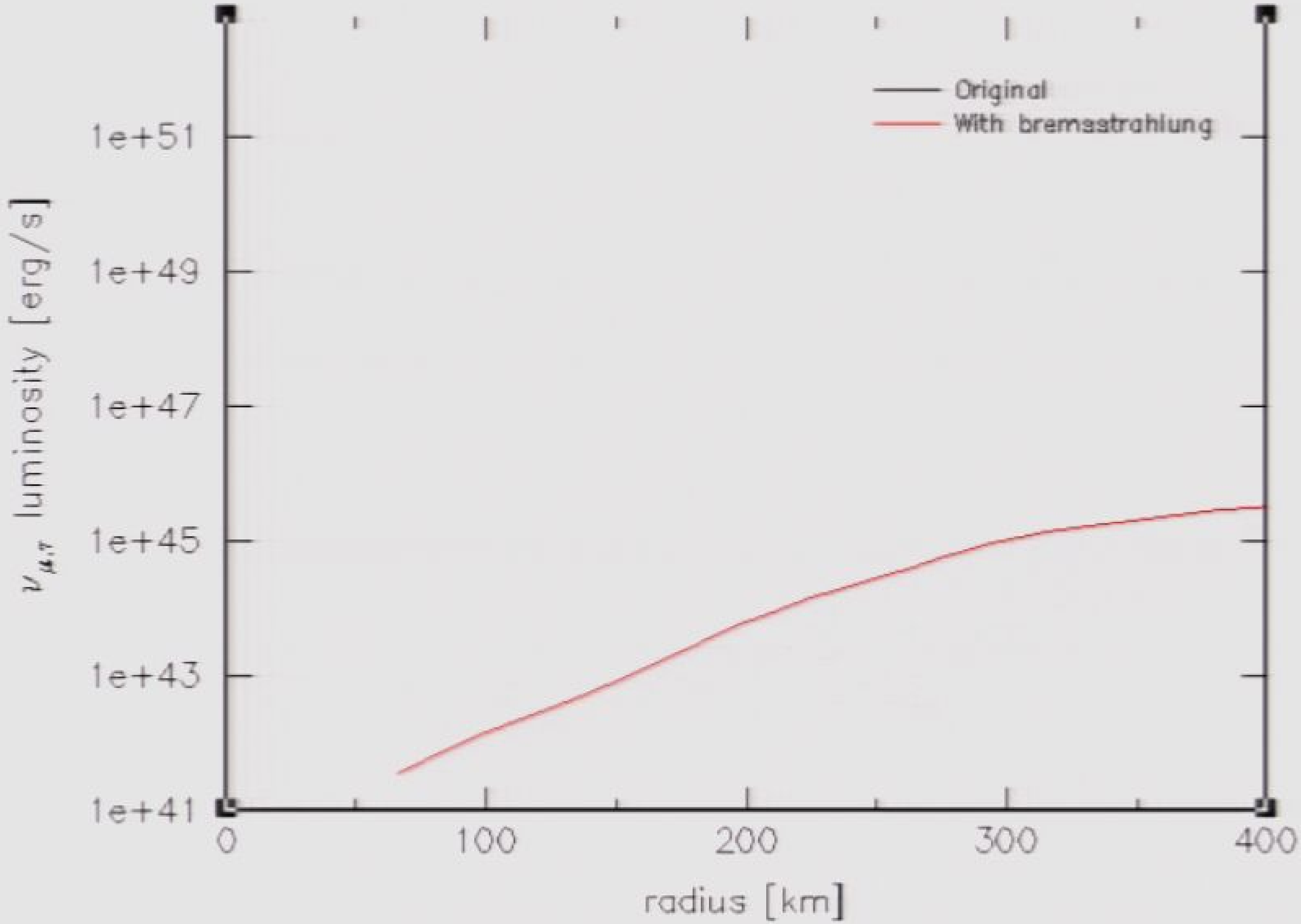

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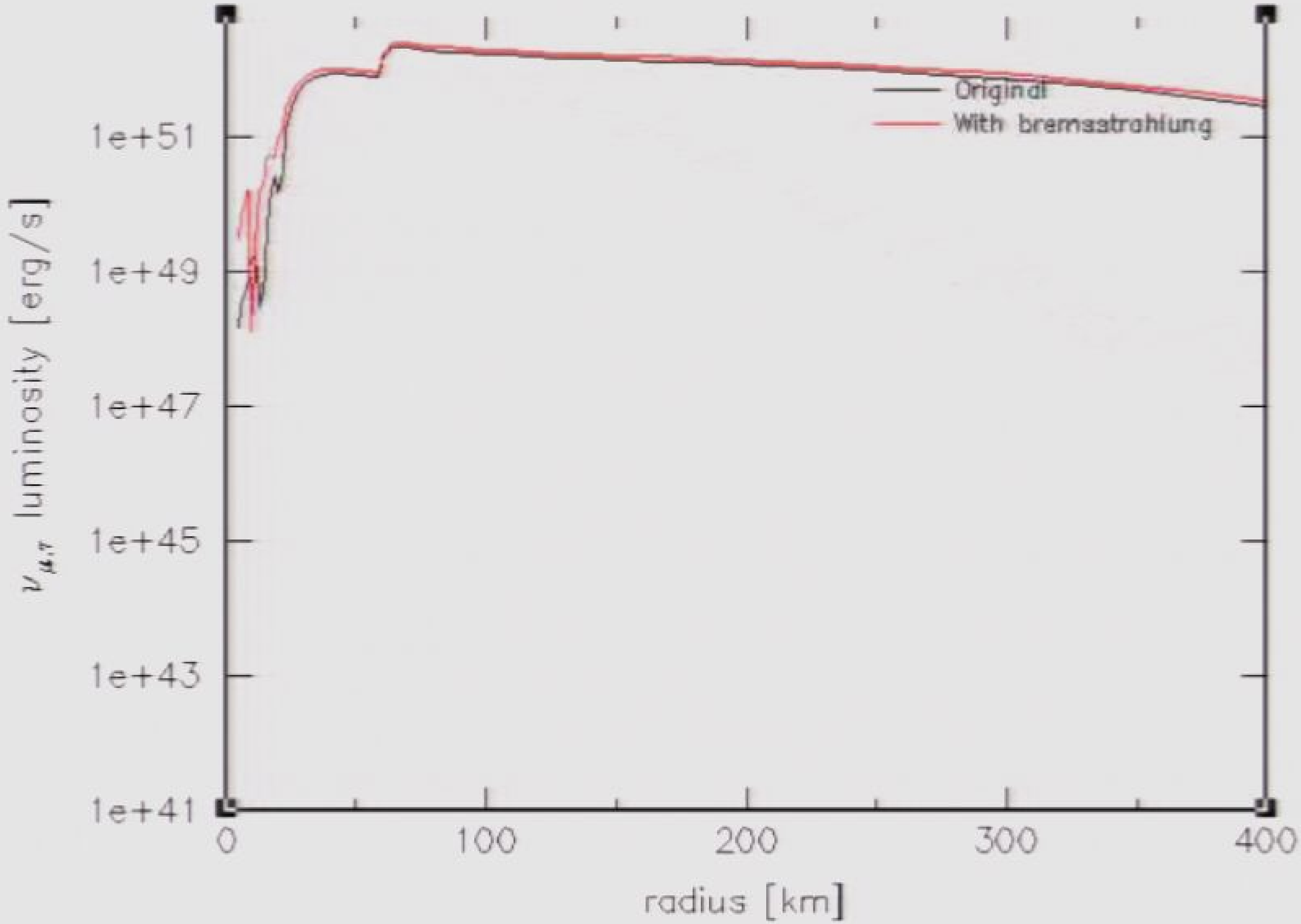

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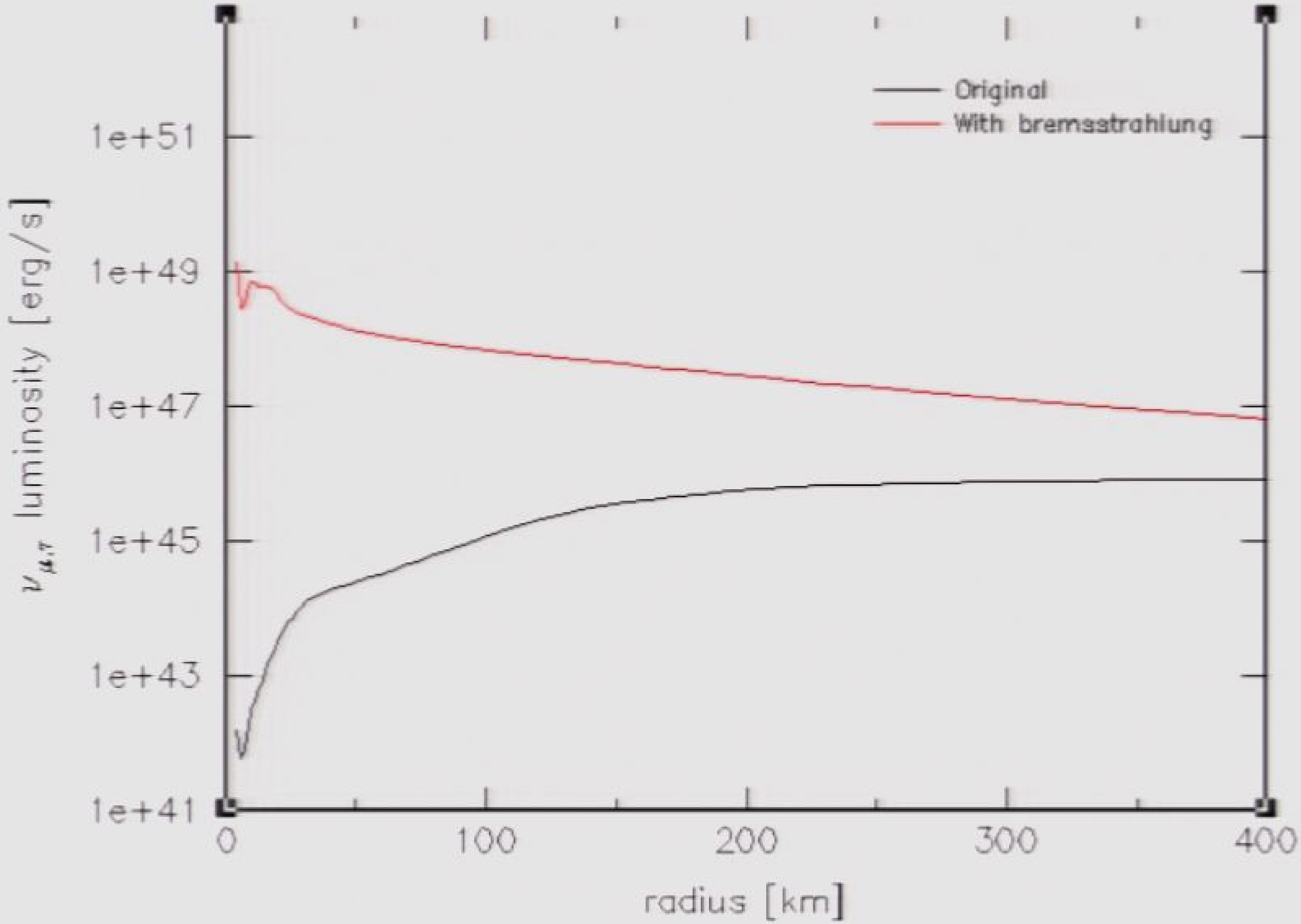

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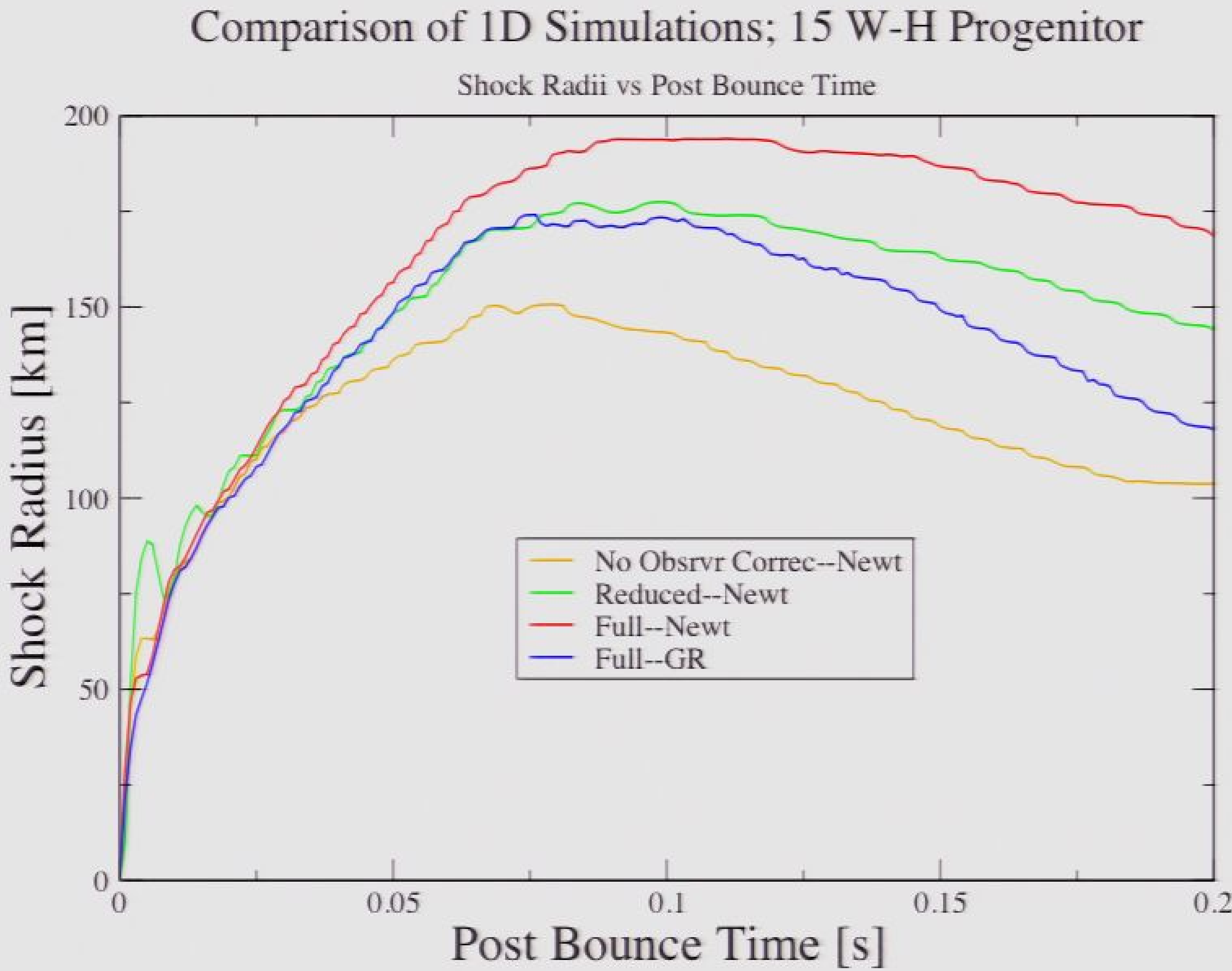
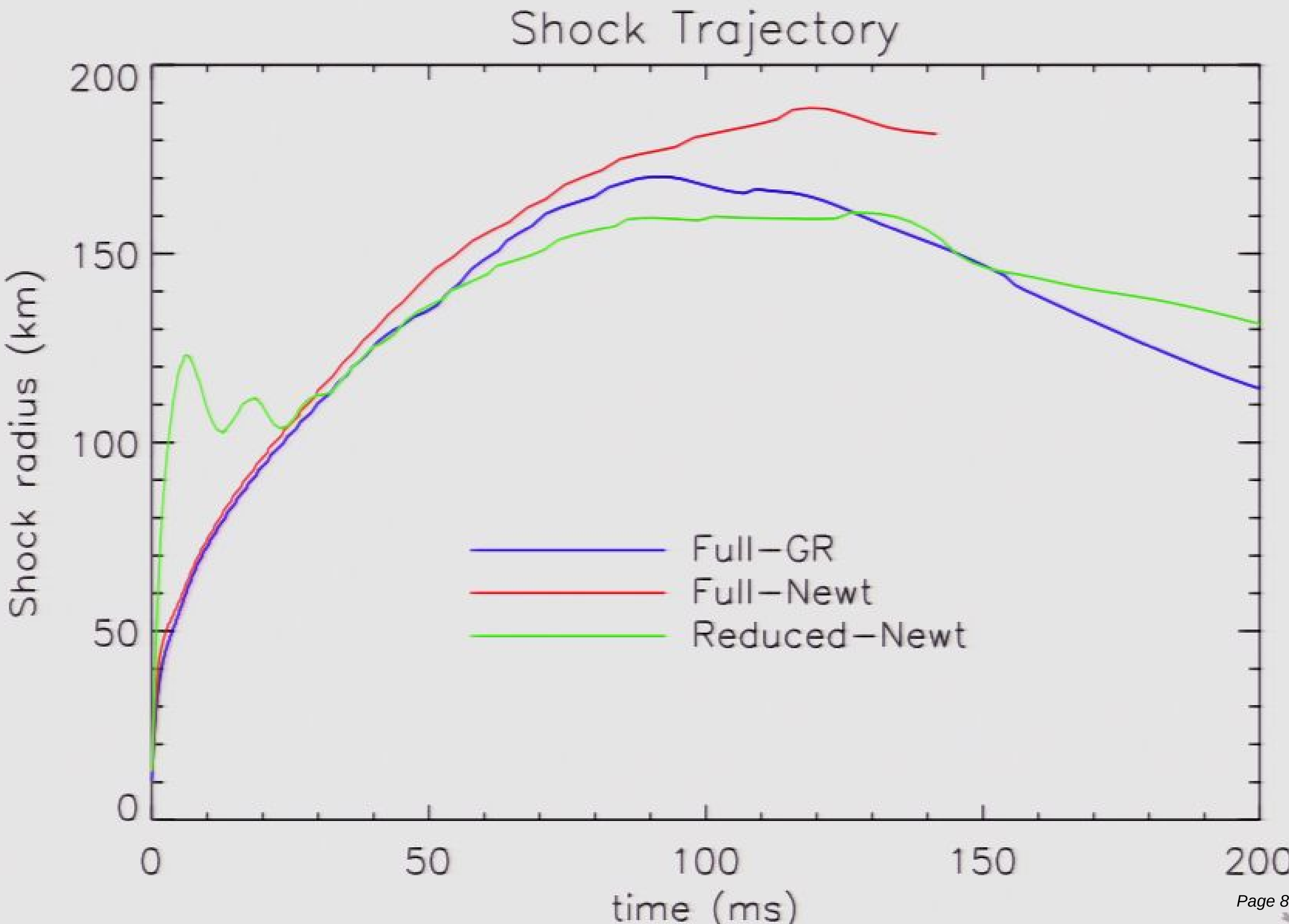
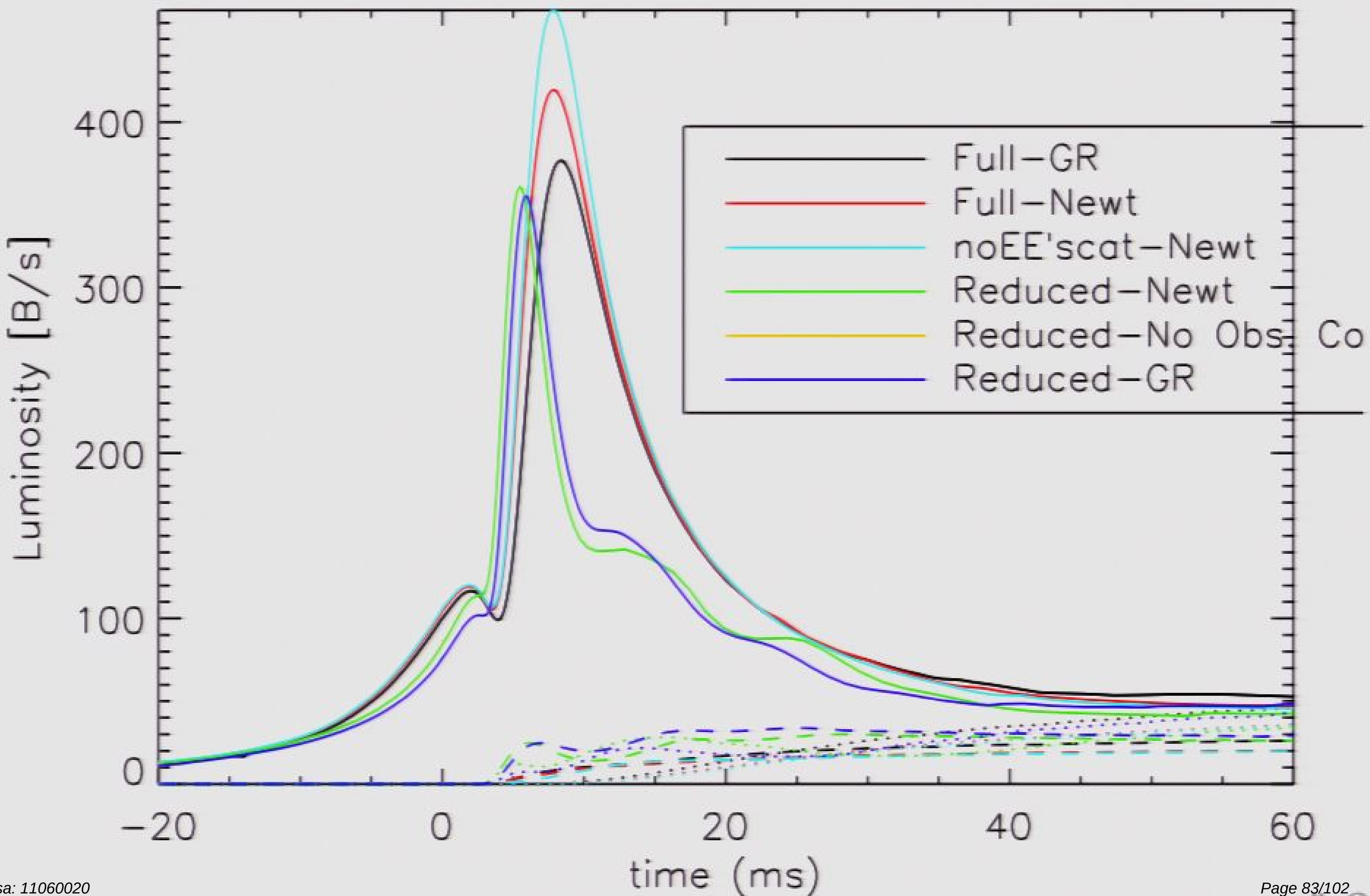
CHIMERA 1D simulations



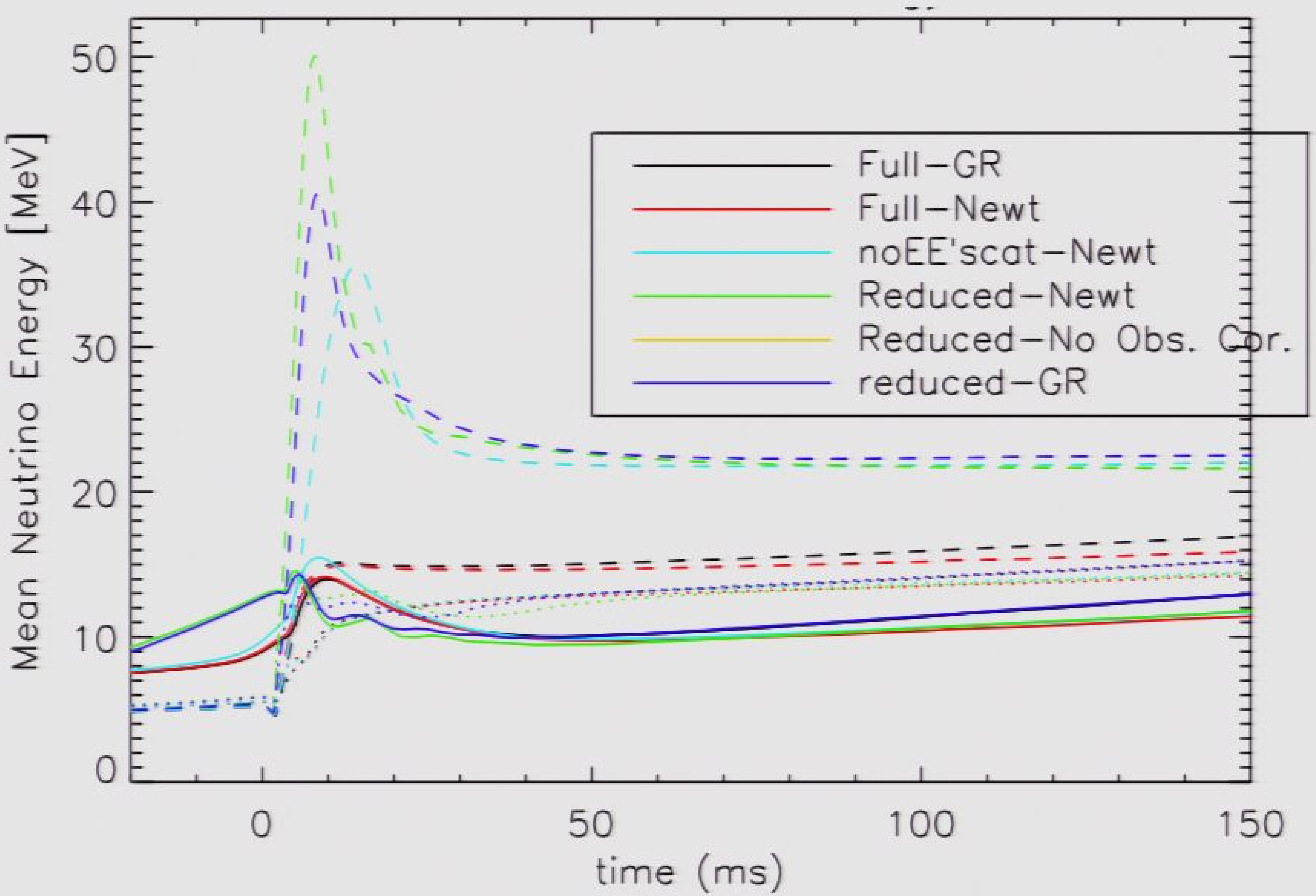
AGILE-Boltztran



AGILE-Boltztran neutrino luminosity



AGILE-Boltztran neutrino energies



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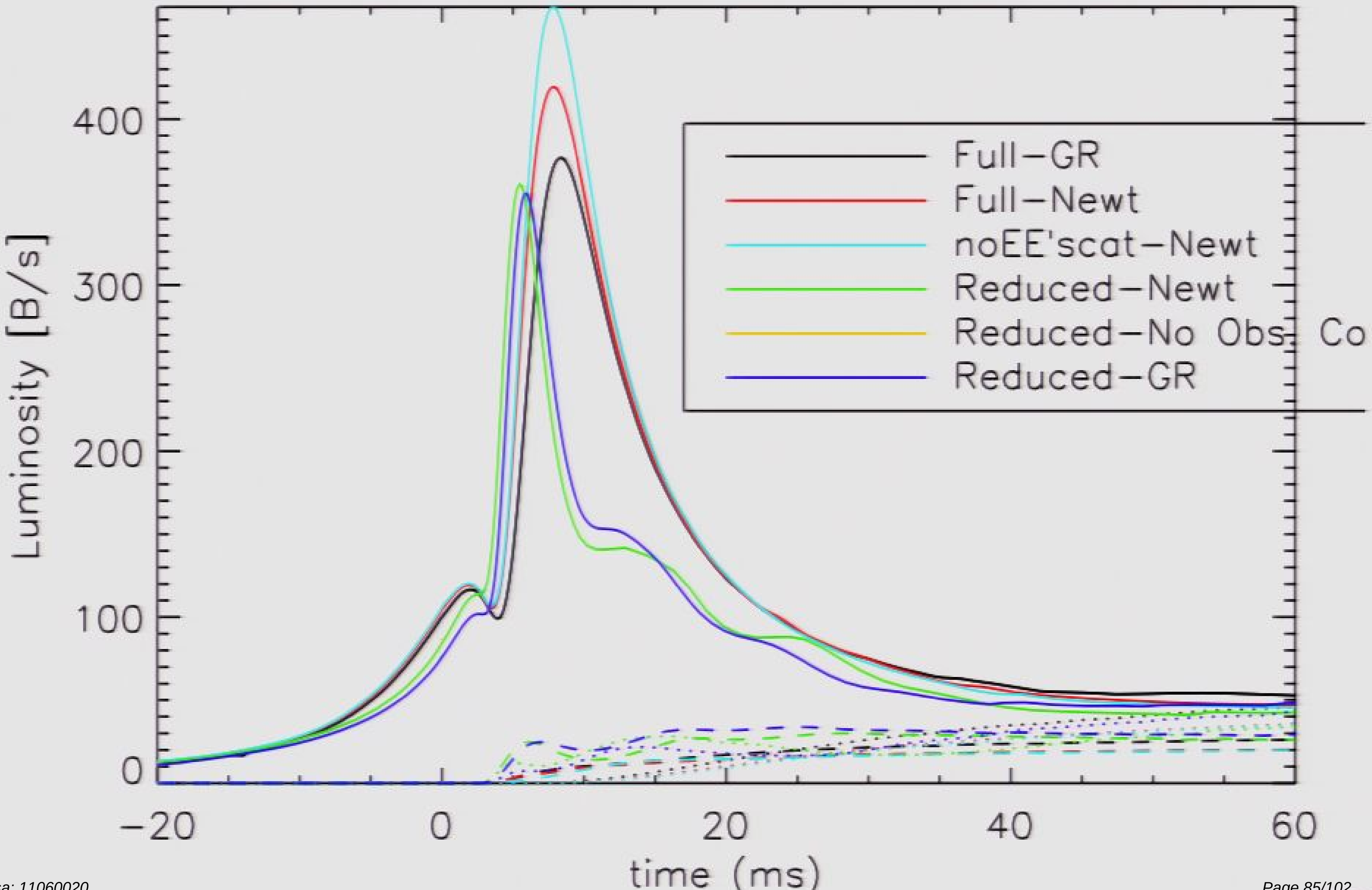
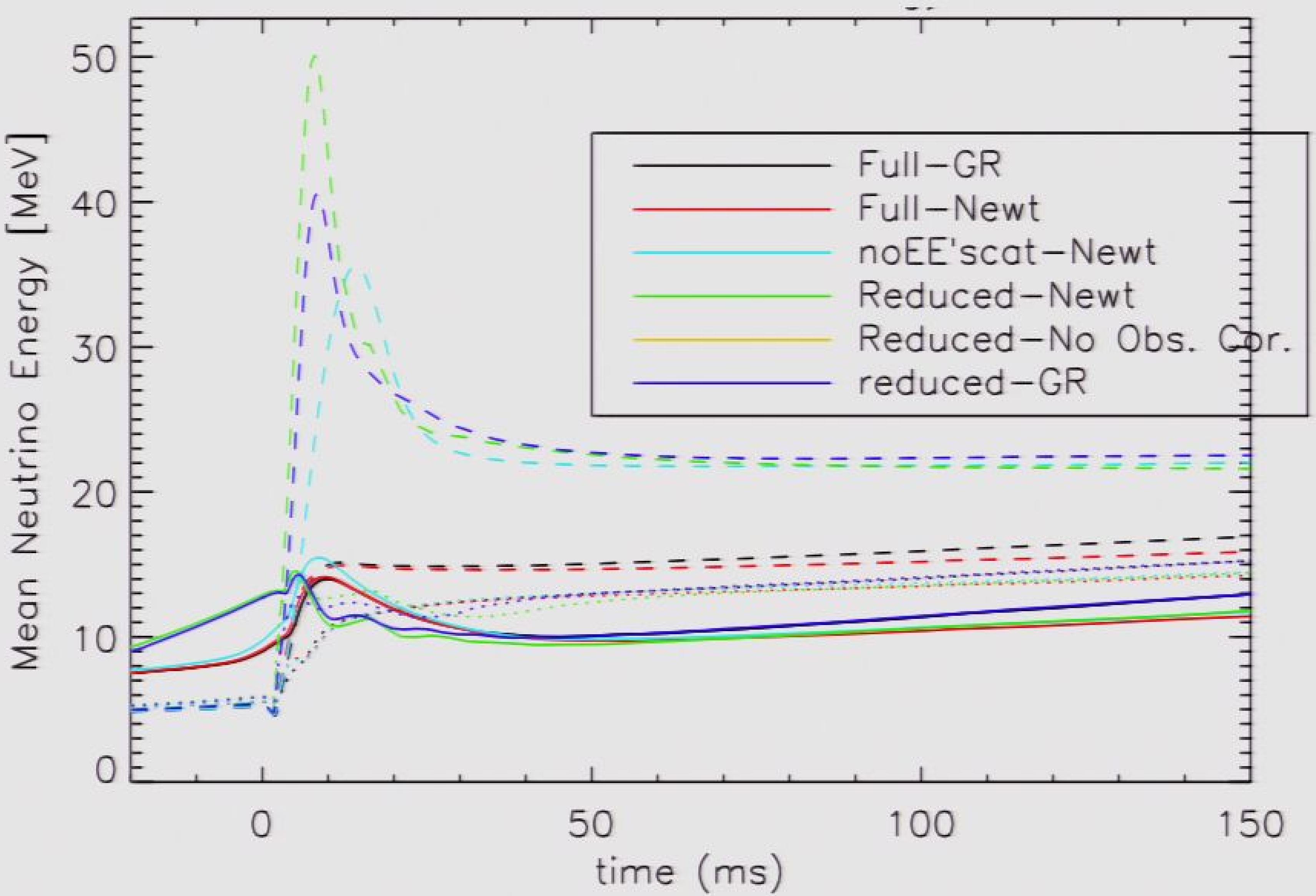
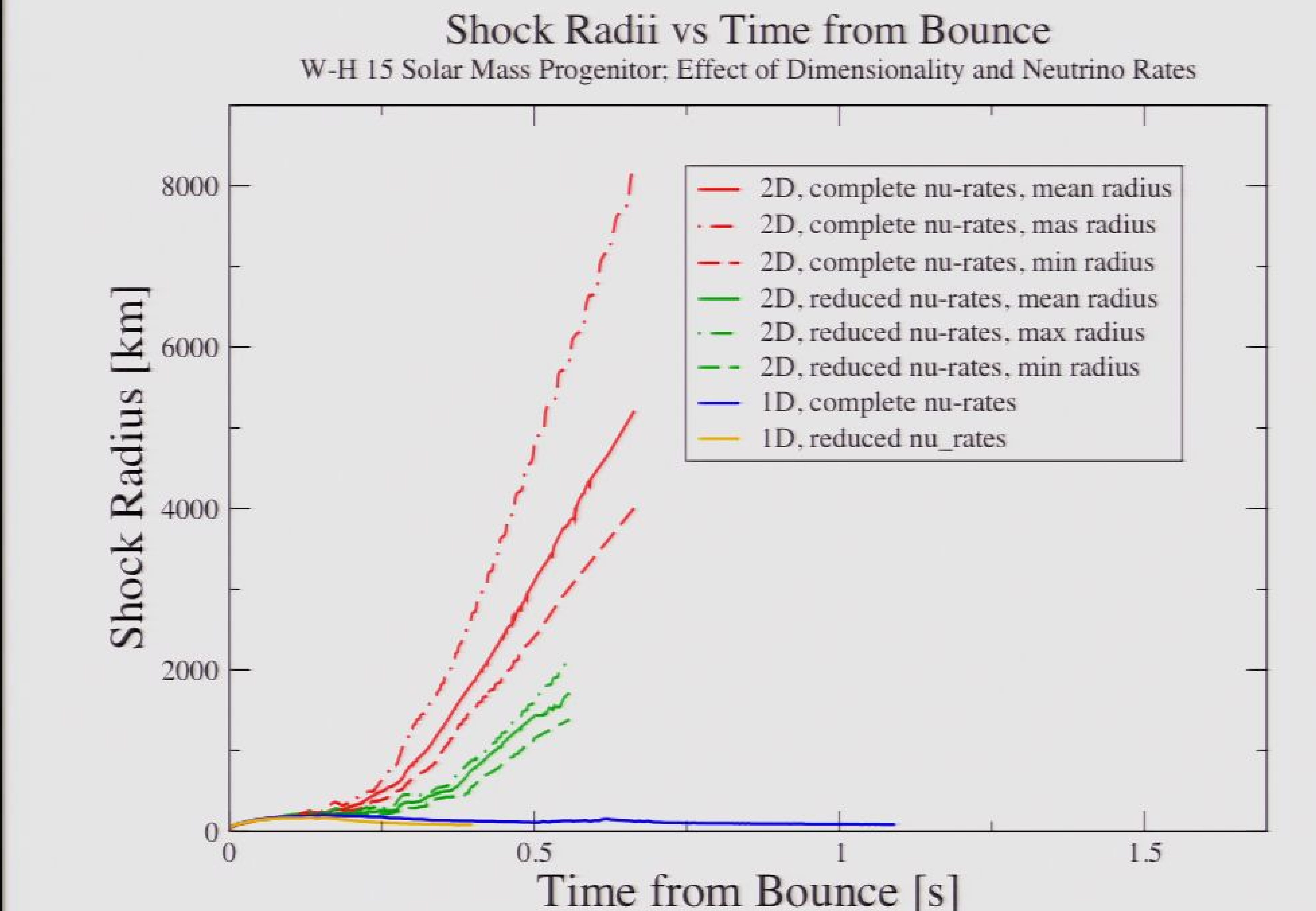


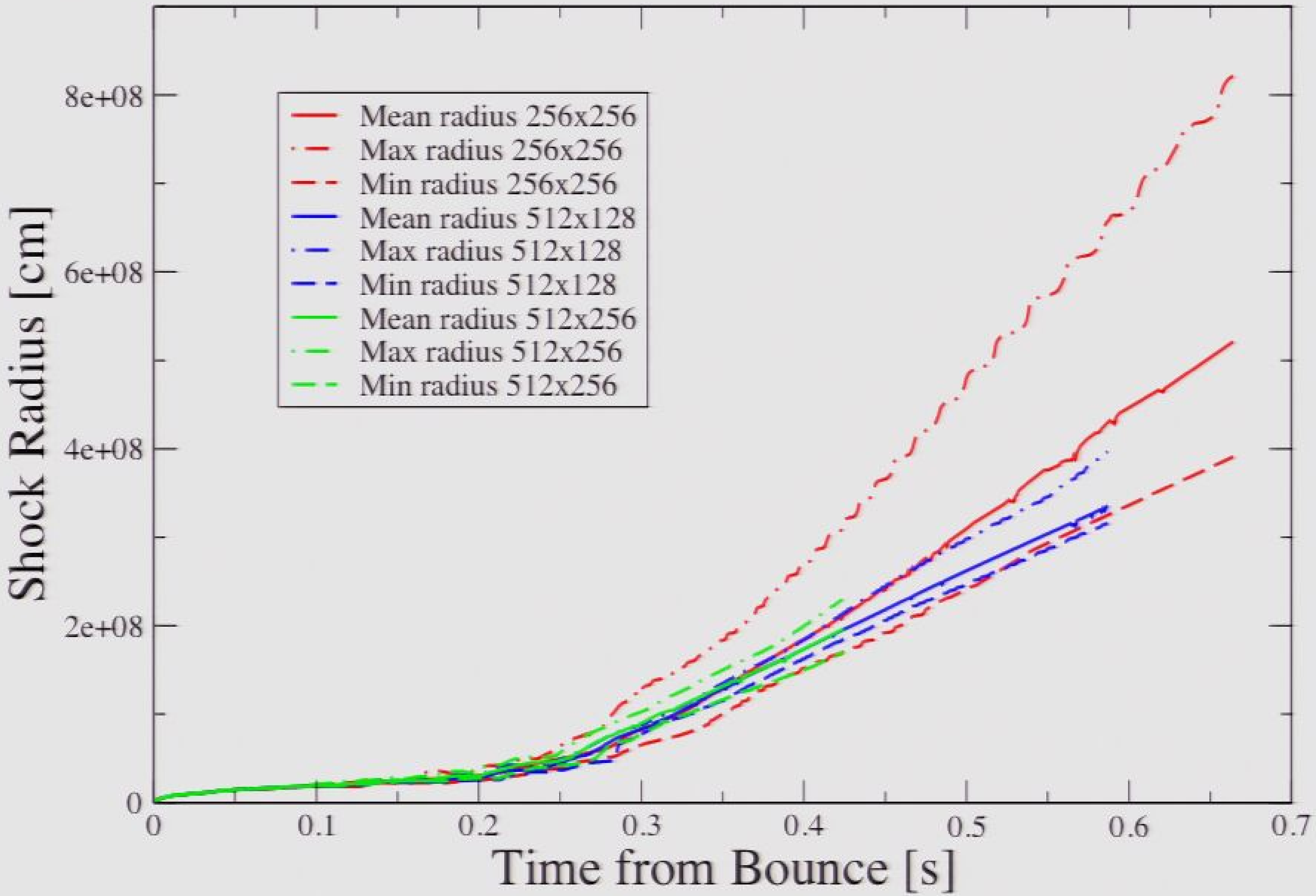
AGILE-Boltztran neutrino energies





Shock Radii vs Time from Bounce
W-H 15 Solar Mass Progenitor; Effect of Dimensionality and Neutrino Rates
2D, complete nu-rates, mean radius
2D, complete nu-rates, mas radius
2D, complete nu-rates, min radius
2D, reduced nu-rates, mean radius
2D, reduced nu-rates, max radius
2D, reduced nu-rates, min radius
1D, complete nu-rates
1D, reduced nu_rates
Shock Radius [km]
0
2000
4000
6000
8000
0
0.5
1
1.5
Time from Bounce [s]

Impact of resolution



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WeakLib

- 4 flavors x 20 E groups x 4 kinematic 'types' x 16^2 angles (at worst)
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- ---> ~ 40GB
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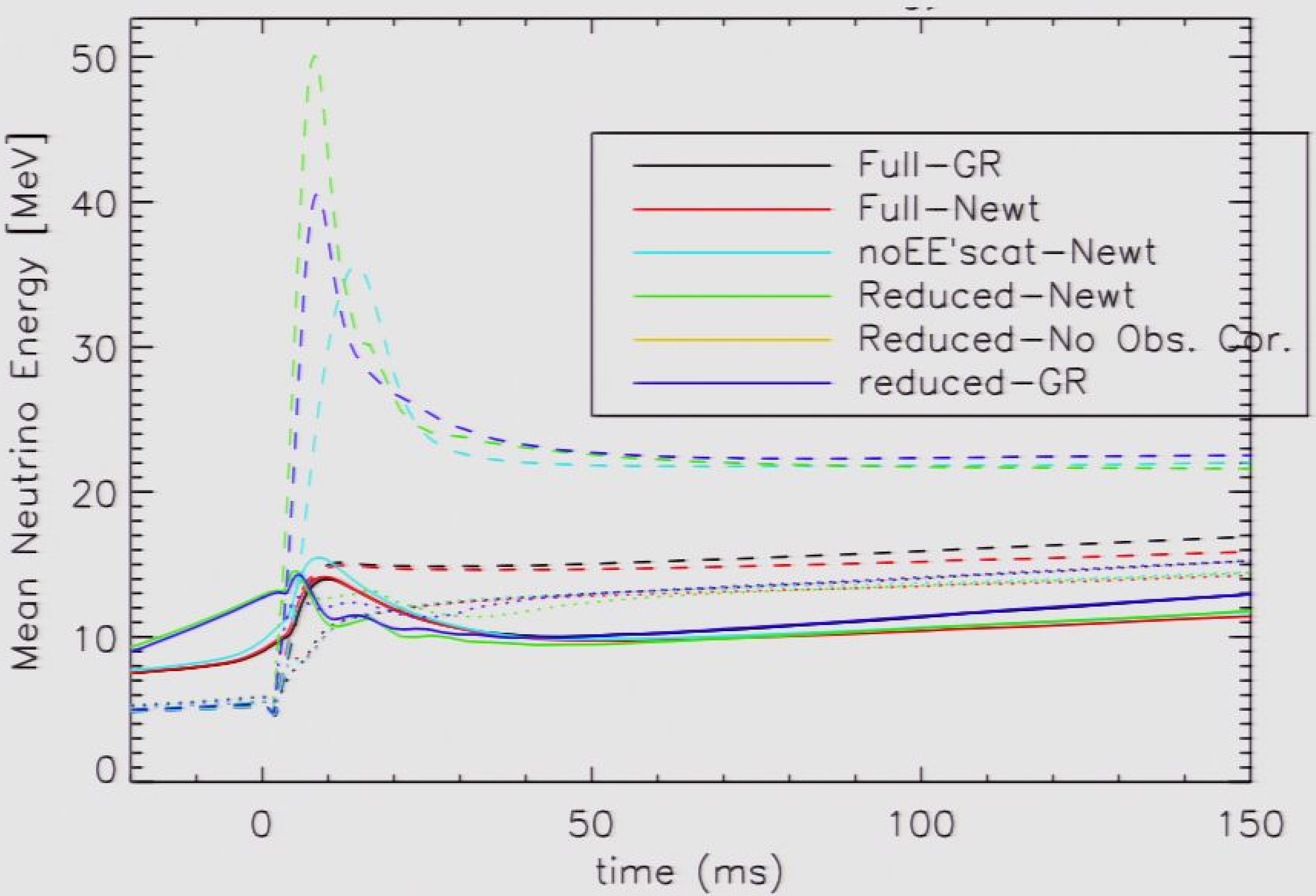
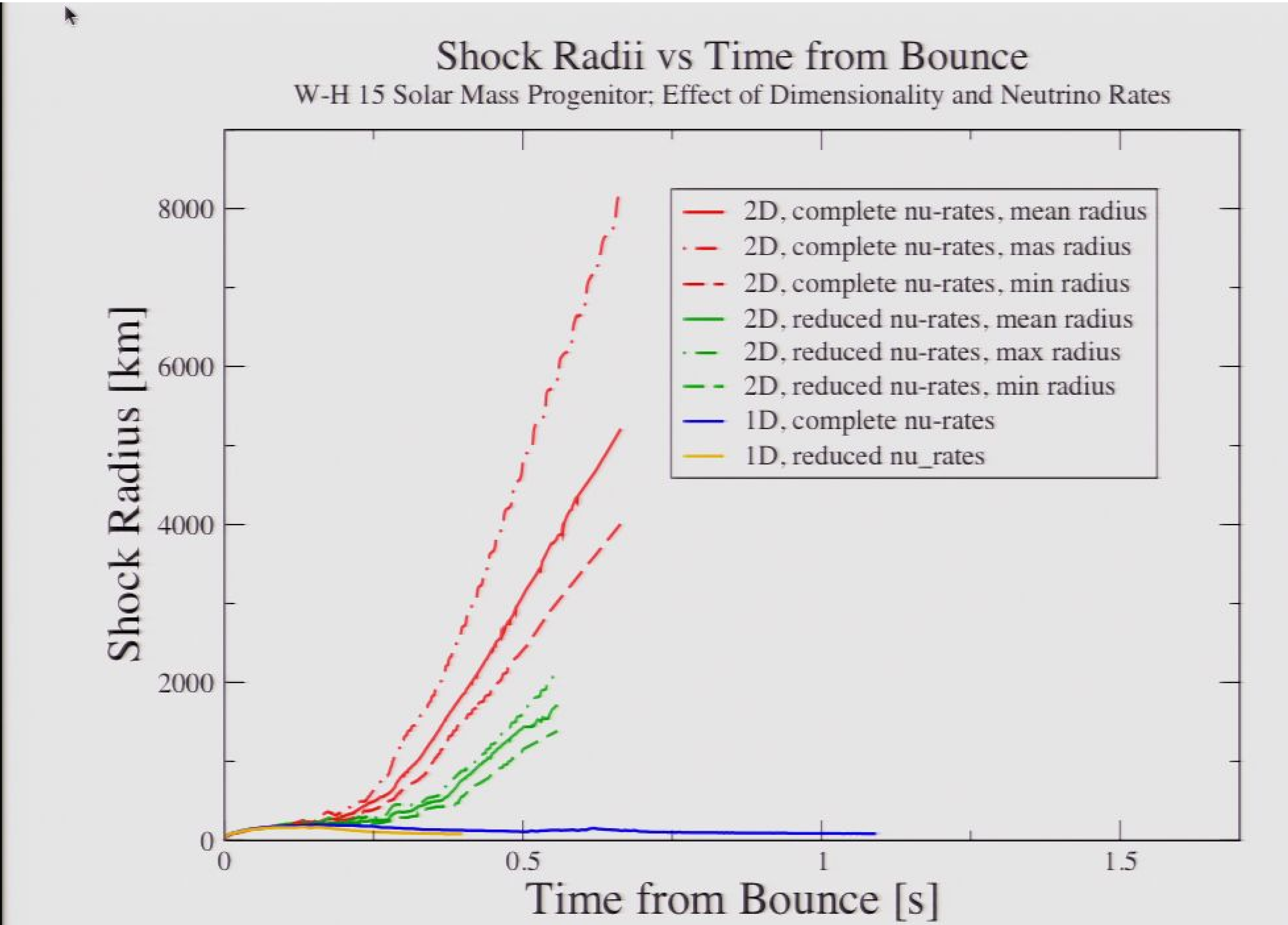
Summary

Microphysics	• Energy-transferring neutrino interactions have a profound effect on shock dynamics. • Charged and neutral current interactions on nuclei (and larger, correlated structures) need better implementations and integration with EoS.
in	
Computational	• Near-future (like, NOW!), large-scale (and smaller scale as well) computational platforms will not lend themselves to, e.g., increased spatial resolution, but will be able to deliver better physical fidelity if microphysics is parallelized at the node level. • EoS+neutrino interaction tables are small enough to be distributed across a modest number of cluster nodes.
Relativistic	Incorporating GR gravity into core-collapse simulations is roughly as important as incorporating energy-transferring weak interaction physics for shock dynamics.
Astrophysics	Regardless of dynamic effect, known physics that can impact observables must be included for simulations to successfully confront observations.

AGILE-Boltztran neutrino energies





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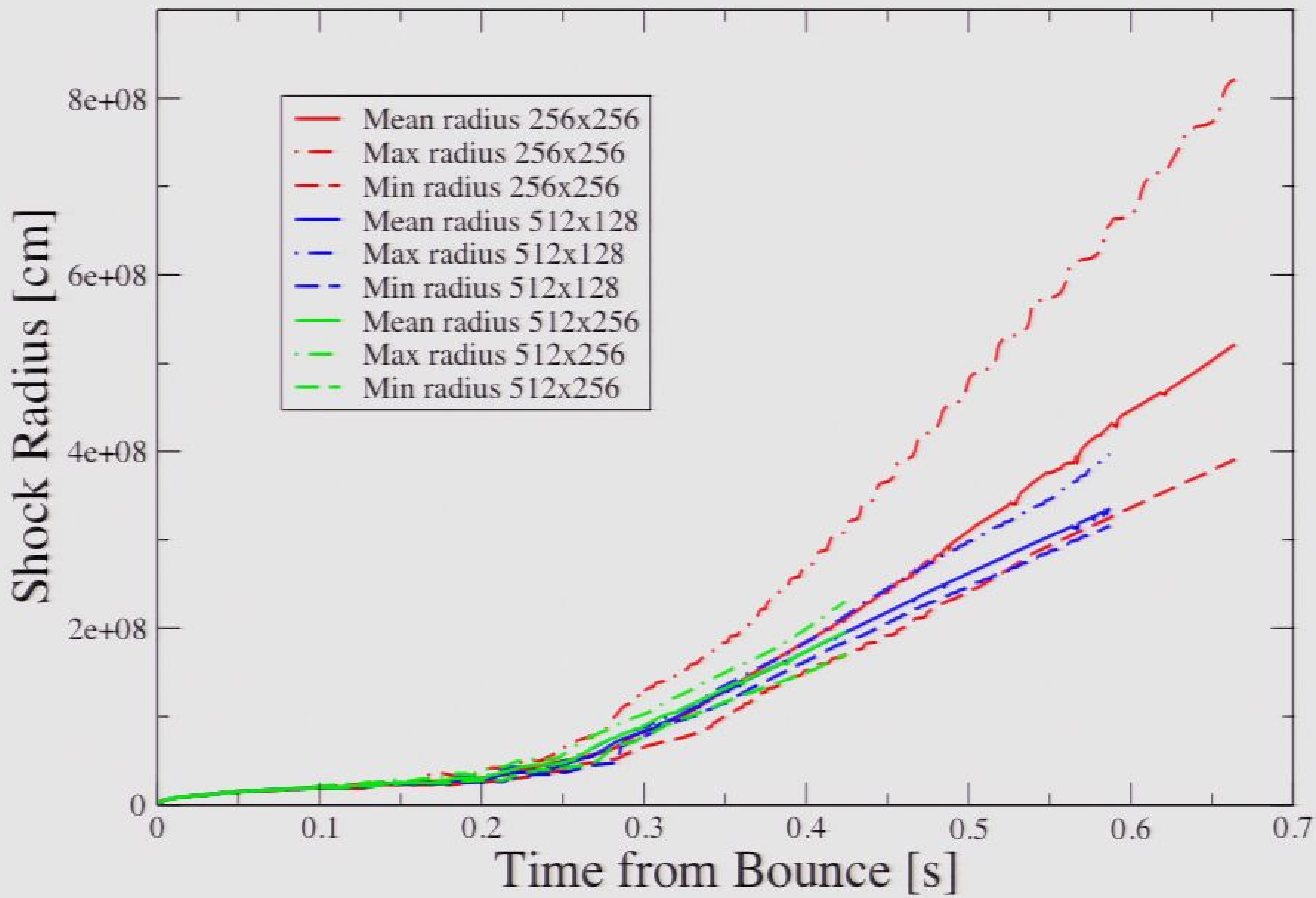

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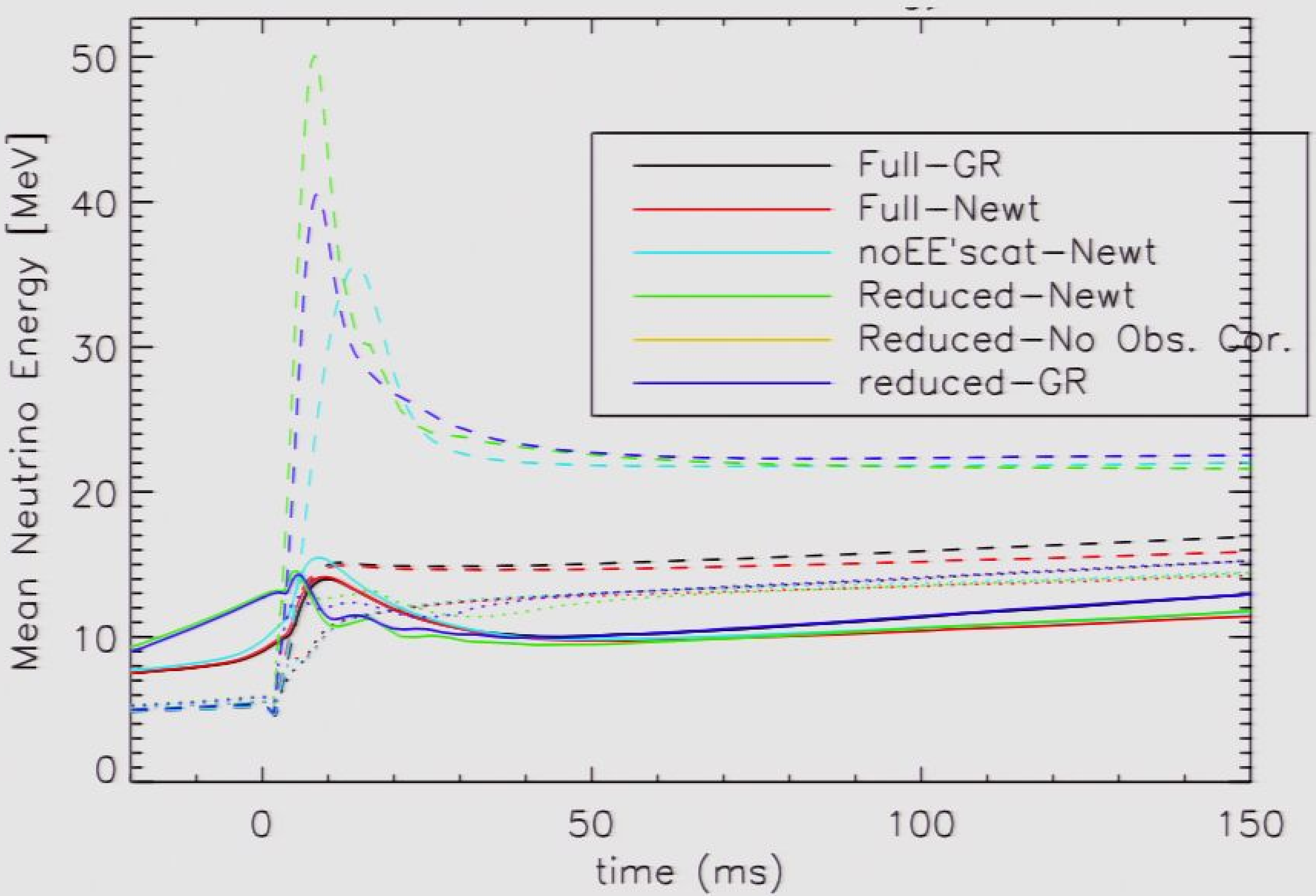

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