The (missing) link between Type Ia SNe and their SNRs

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with

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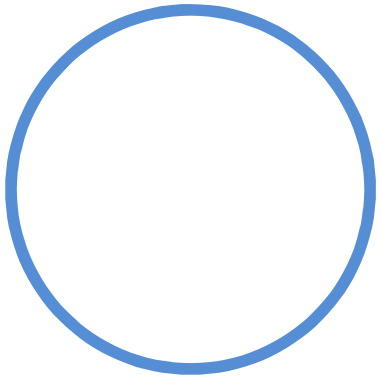
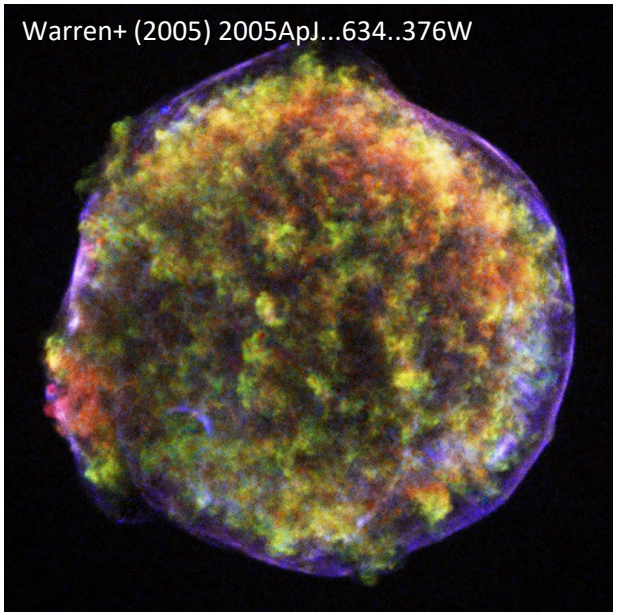
A hopefully non-controversial statement

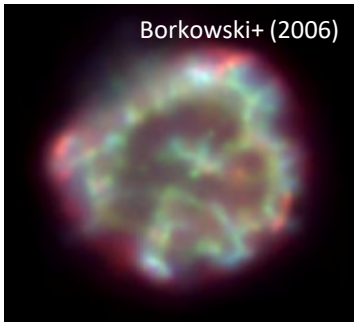
This is a perfect circle

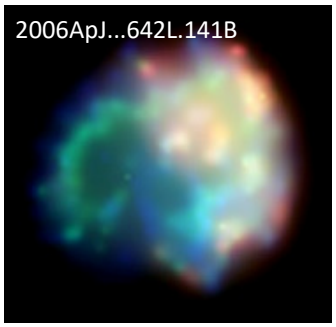


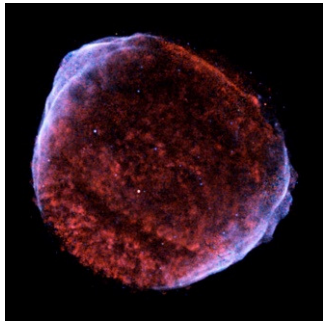
This is not

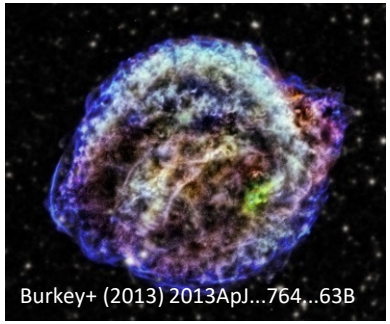


Neither are these

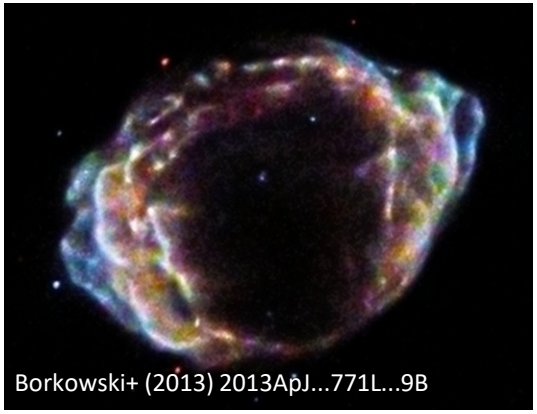








And especially not this

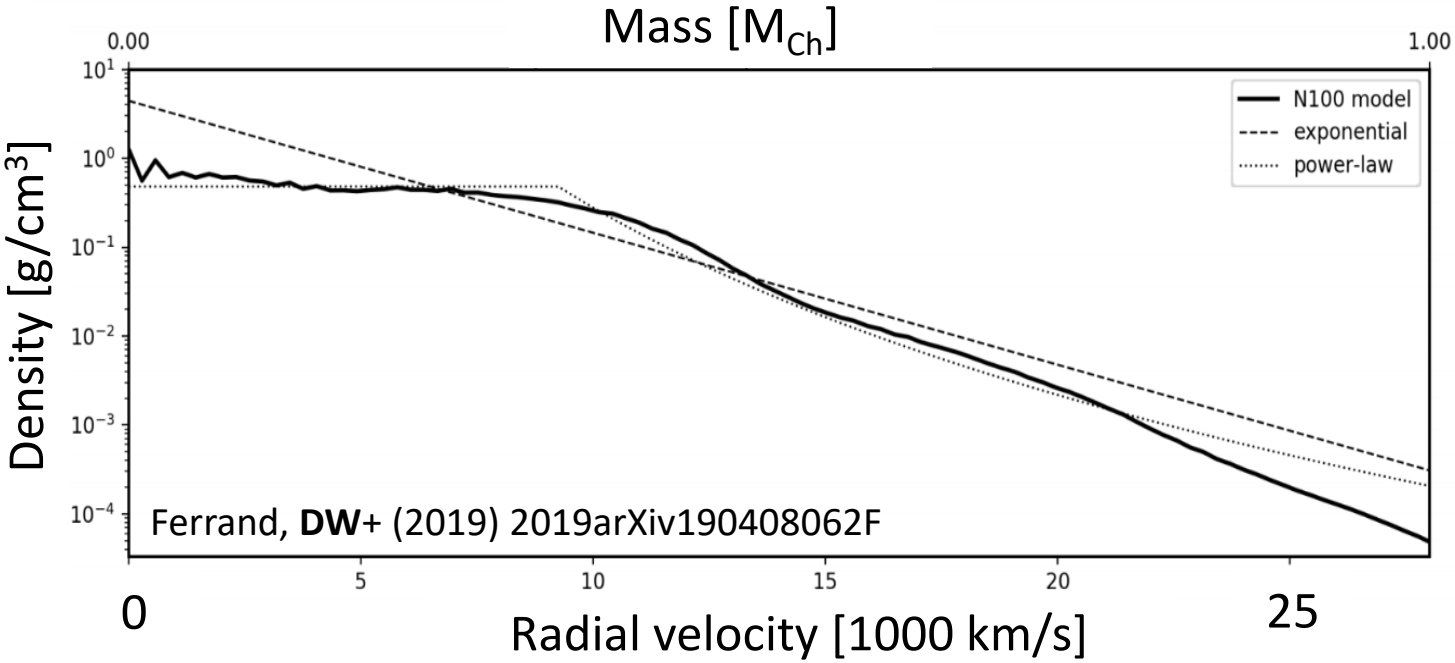


Reasons SNRs might not be spheres

- Inhomogeneous ejecta (Wang & Chevalier 2001; Orlando+ 2012; Warren & Blondin 2013; Williams+ 2017)
- Asymmetric CSM (Lu+ 2011; Williams+ 2011; Liu+ 2012; Fang+ 2018)

Reason ejecta might not be homogeneous

- The supernova
- SNR models all 1-D to start



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Reason ejecta might not be homogeneous

- The supernova
- SNR models all 1-D to start
- But supernovae are decidedly not

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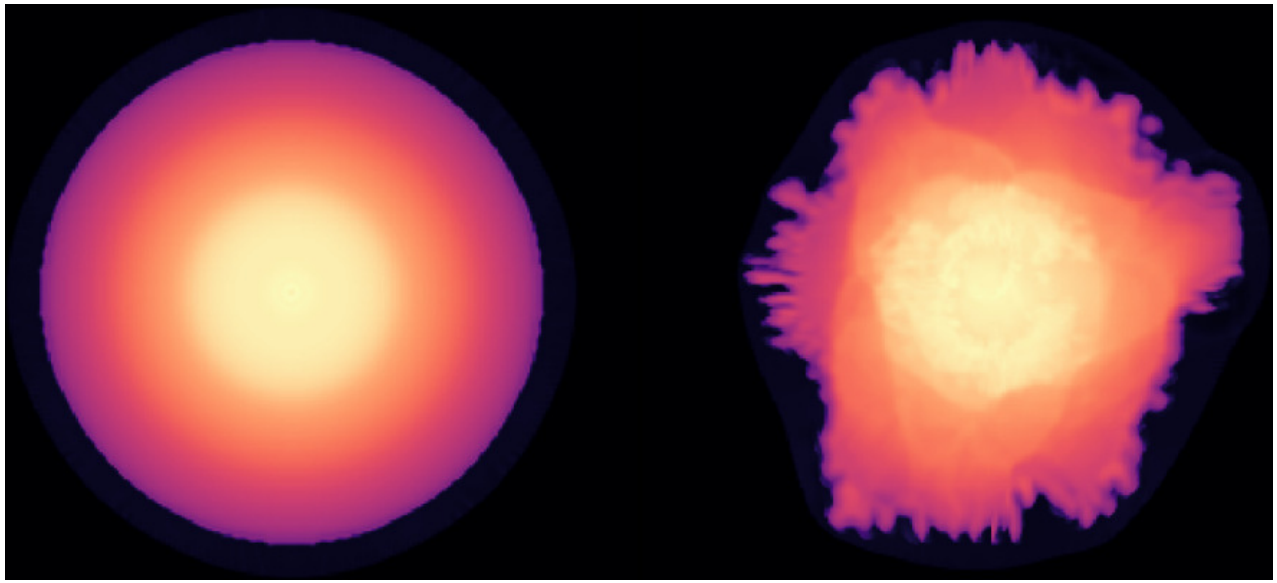
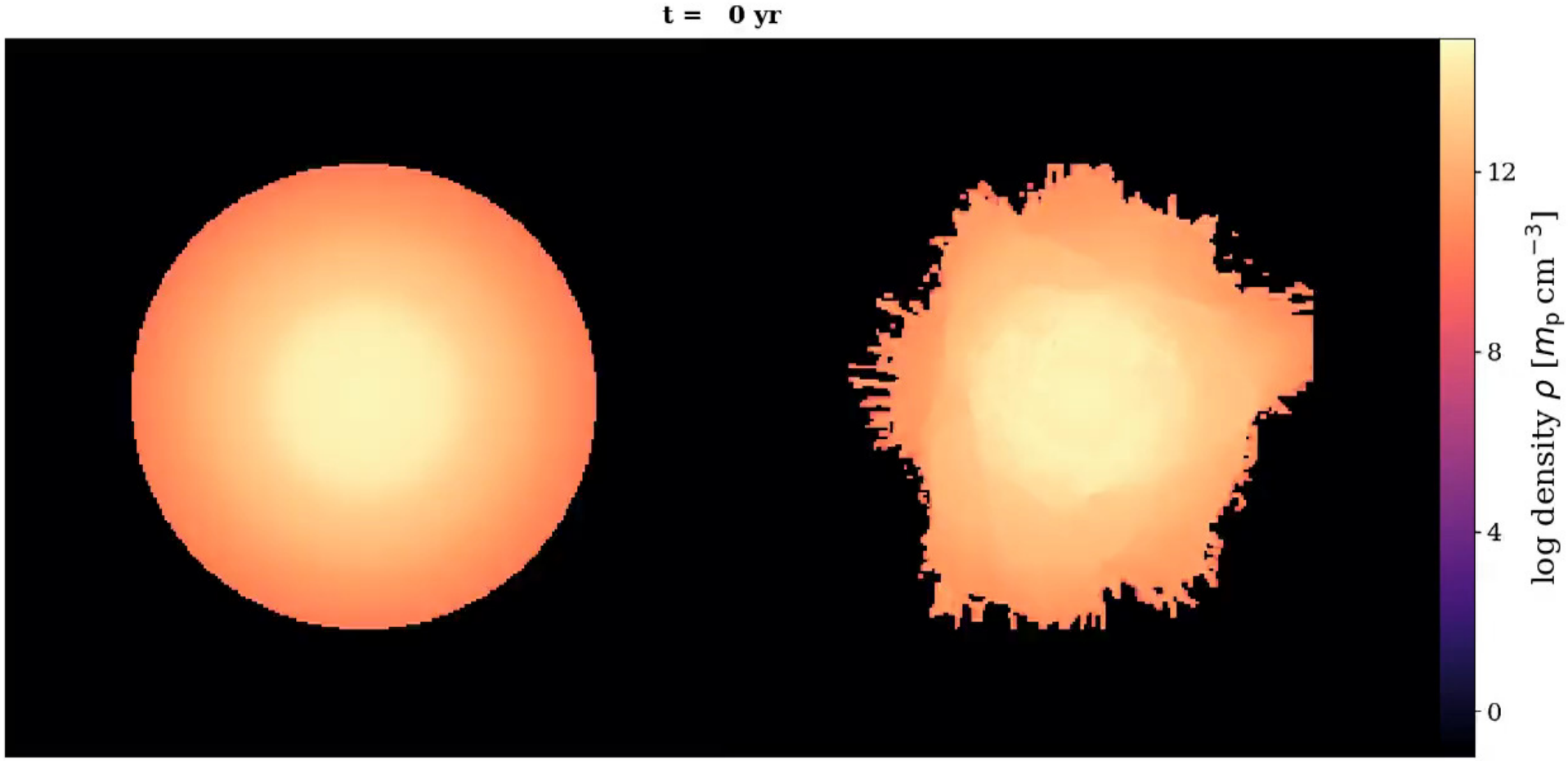


Starting an SNR simulation with the SN

- Effects of 1-D initial conditions vs 3-D initial conditions?
- How long does “memory” of SN persist into SNR evolution?



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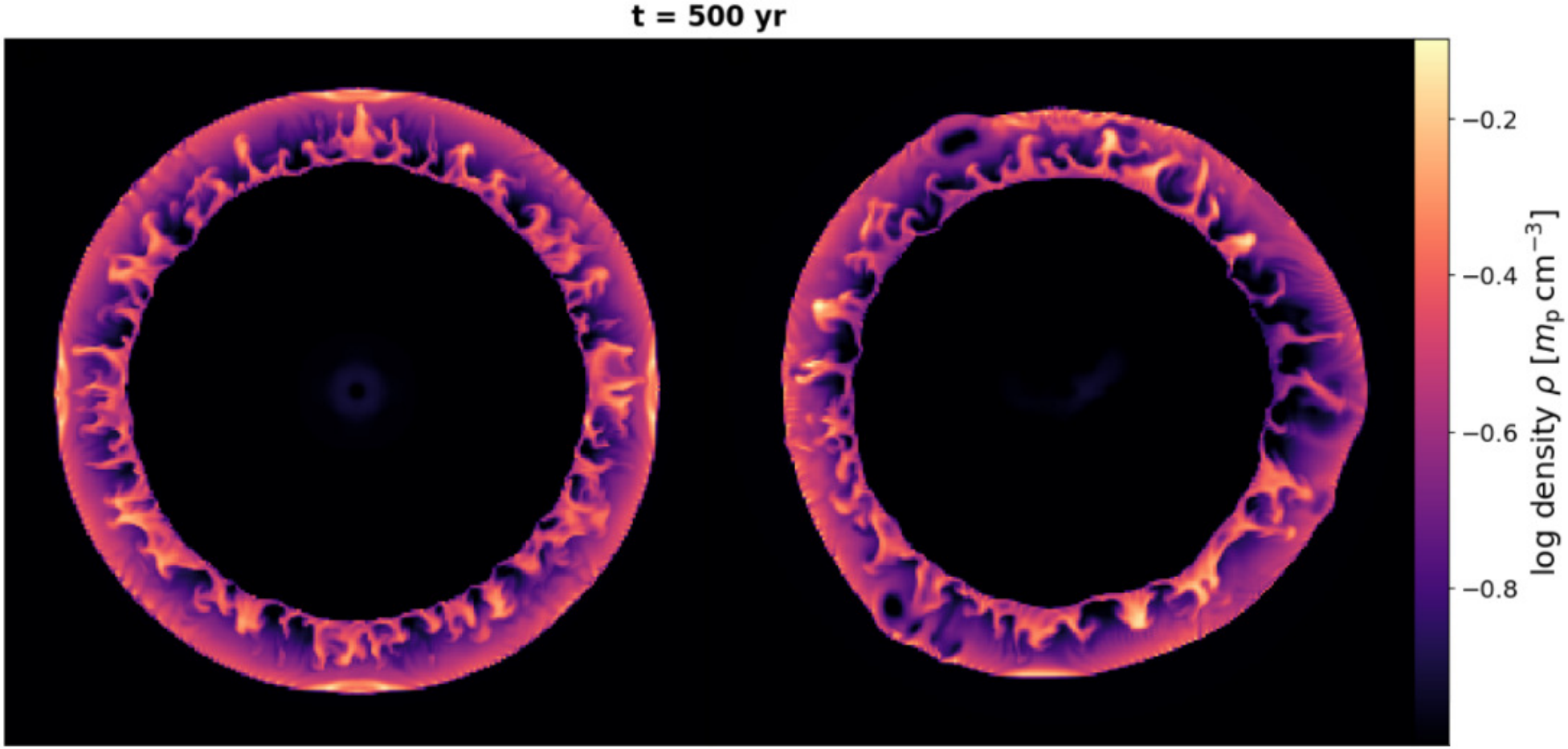

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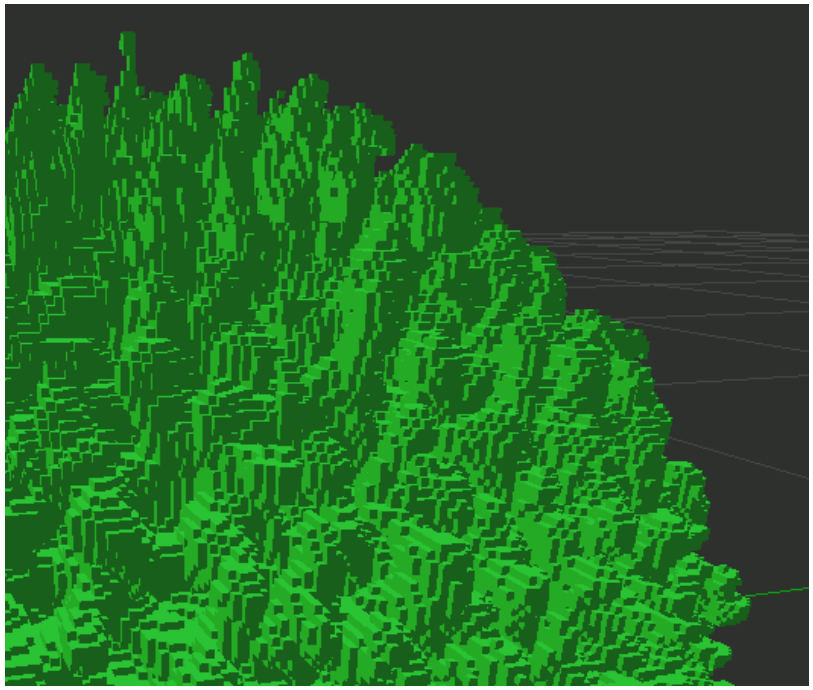
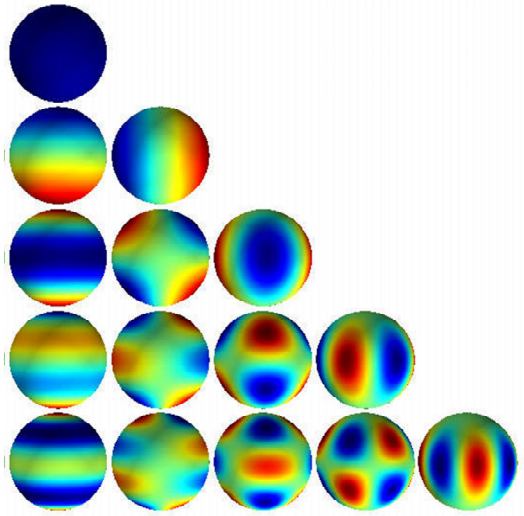
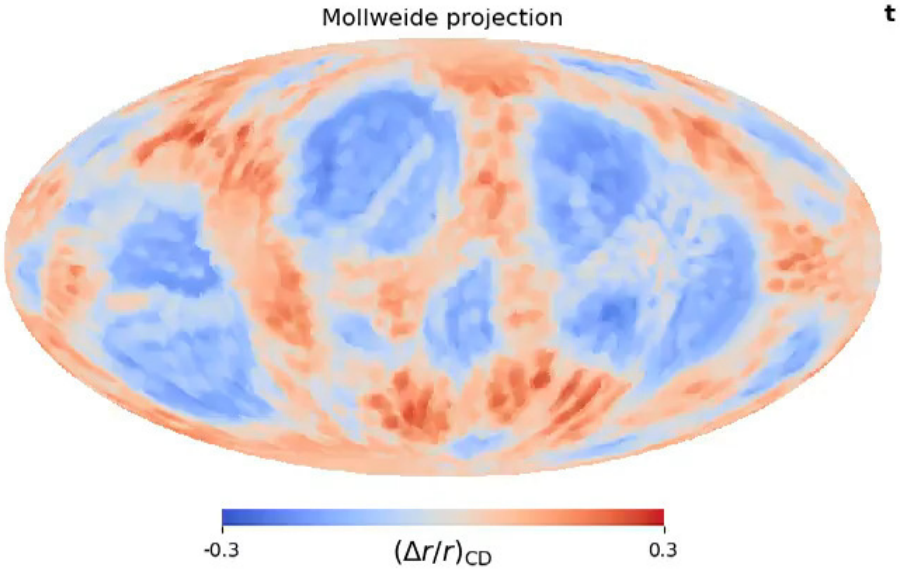
1-D vs 3-D initial conditions

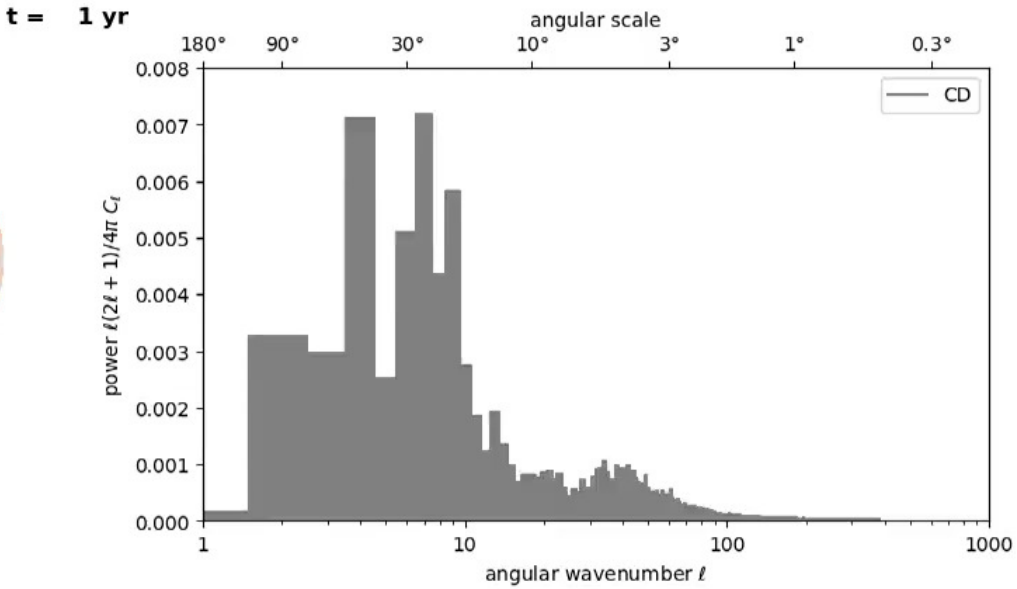
- Find forward shock (FS), contact discontinuity (CD) and reverse shock (RS) as continuous surfaces
- Cast radial rays through each interface to project radius on a sphere (HEALPix for tessellation)
- Plot interfaces in Mollweide projection
- Compute angular power spectrum for interfaces

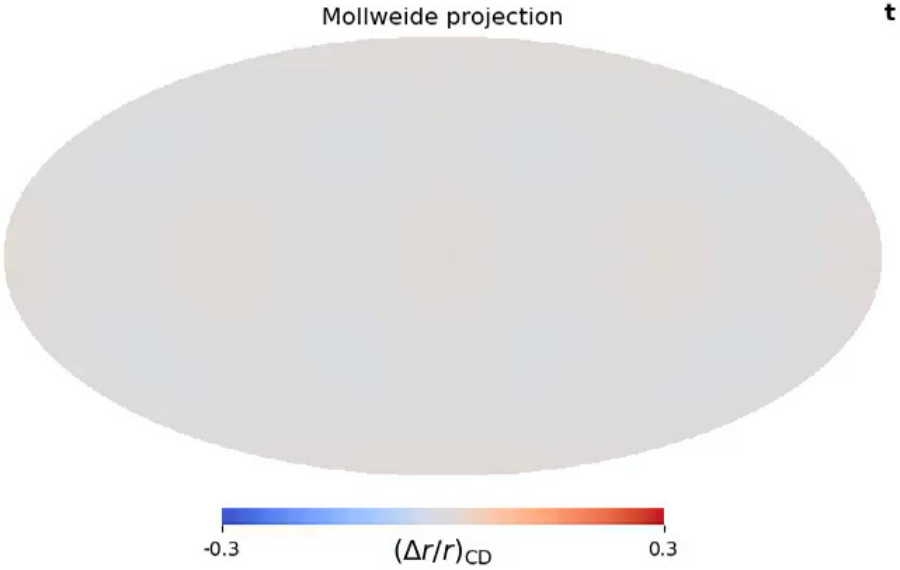


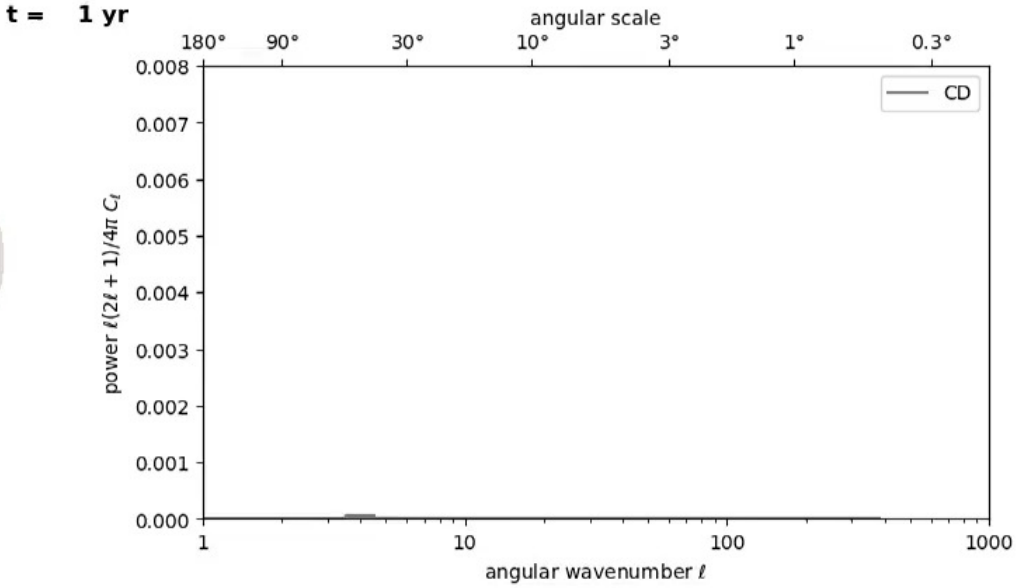


1-D vs 3-D initial conditions









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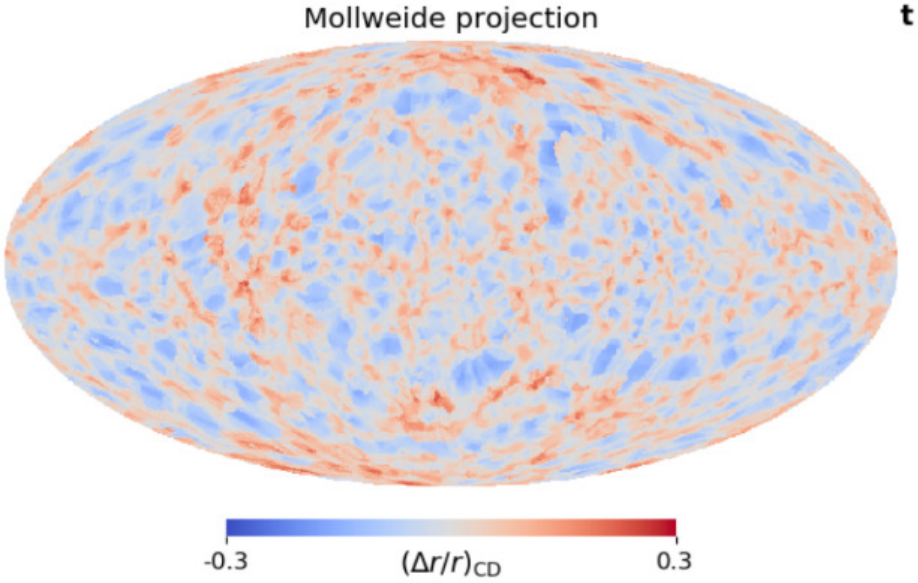

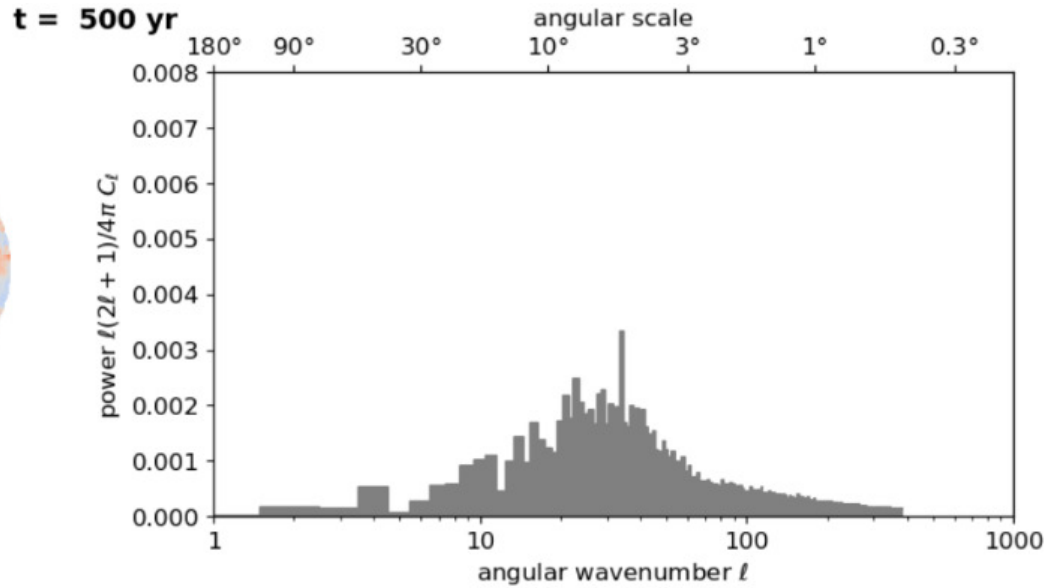

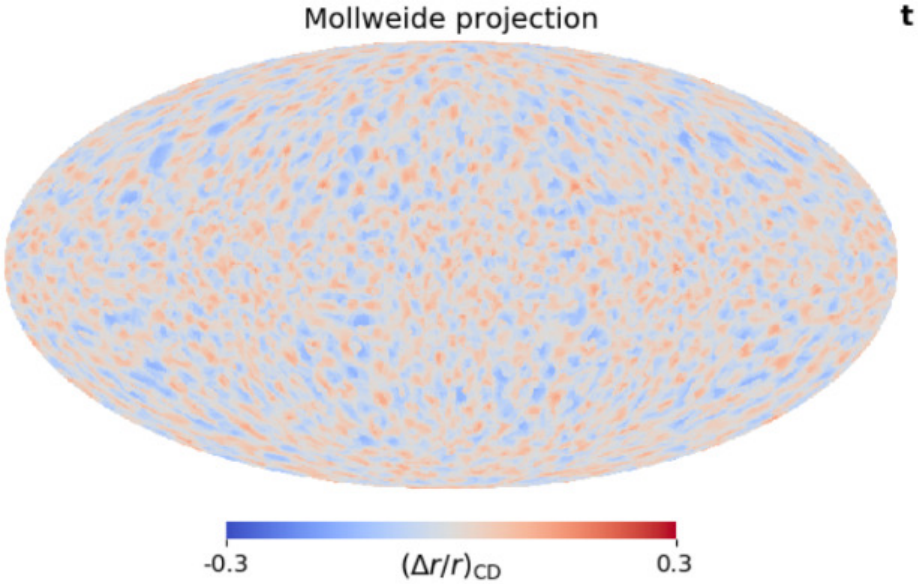

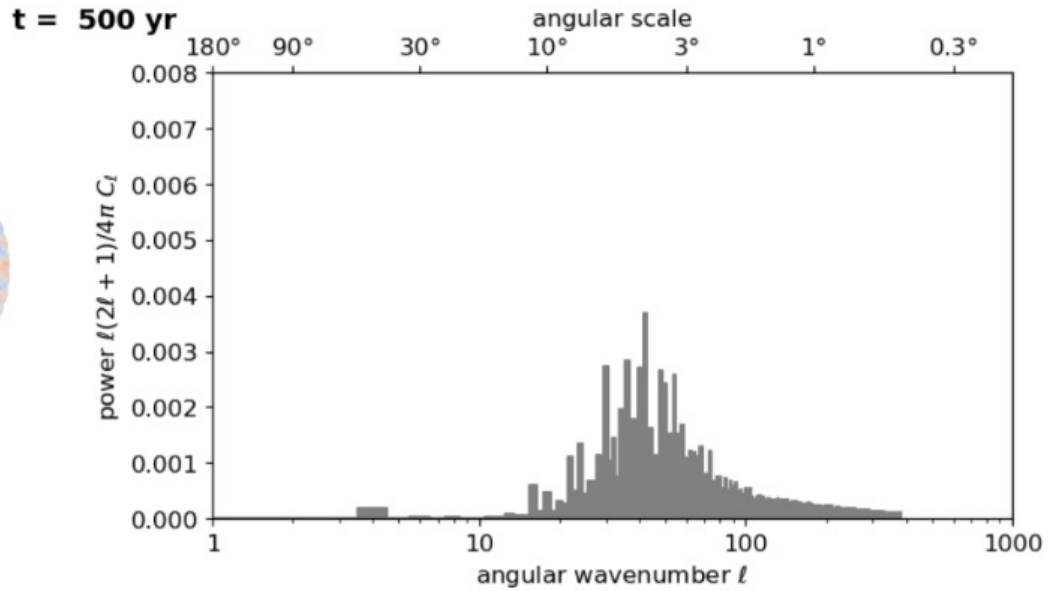

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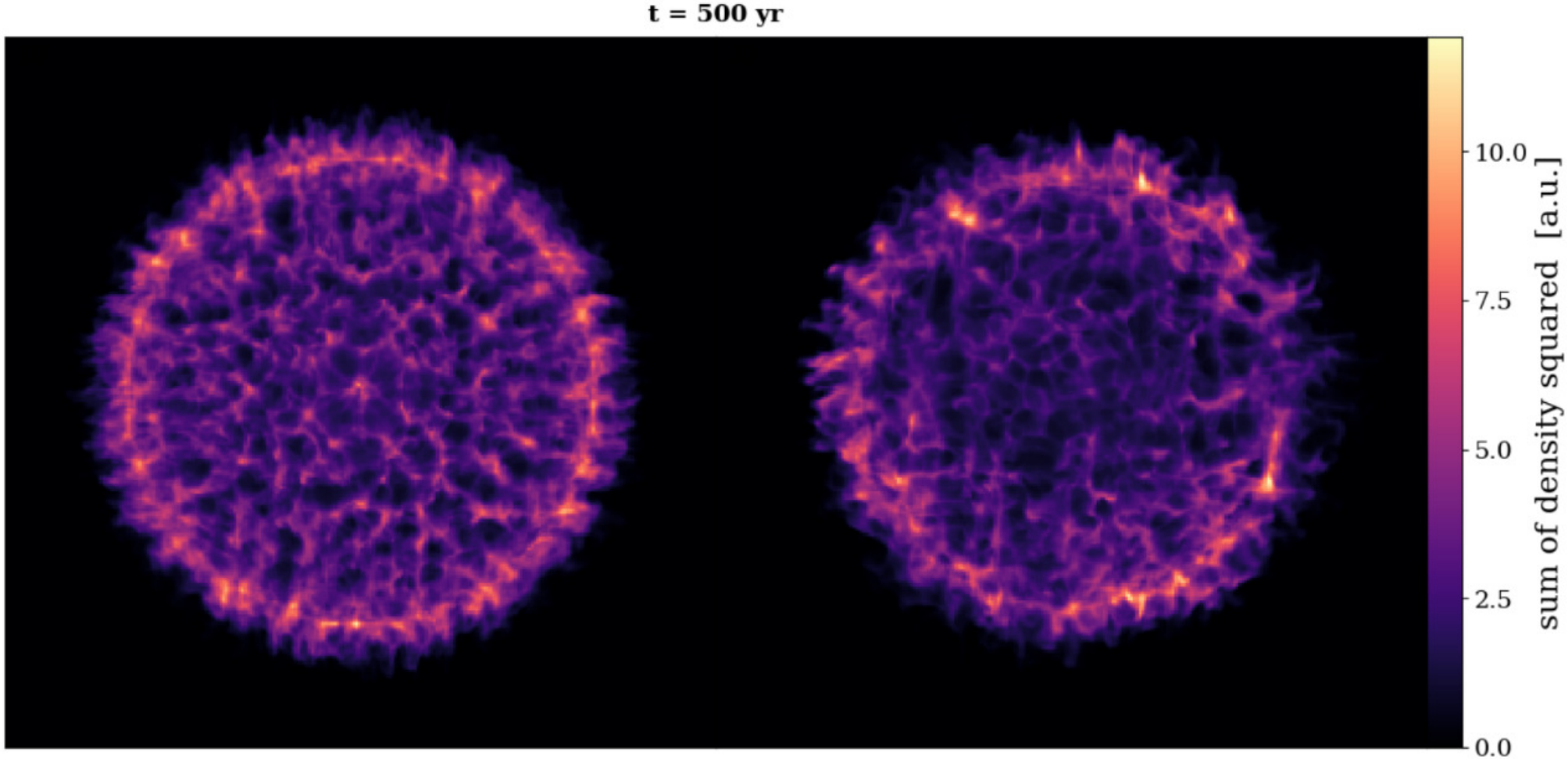
1-D vs 3-D initial conditions

- Power at low wavenumber easily noticeable in projection (c.f. “genus statistic” of Sato+ 2019)



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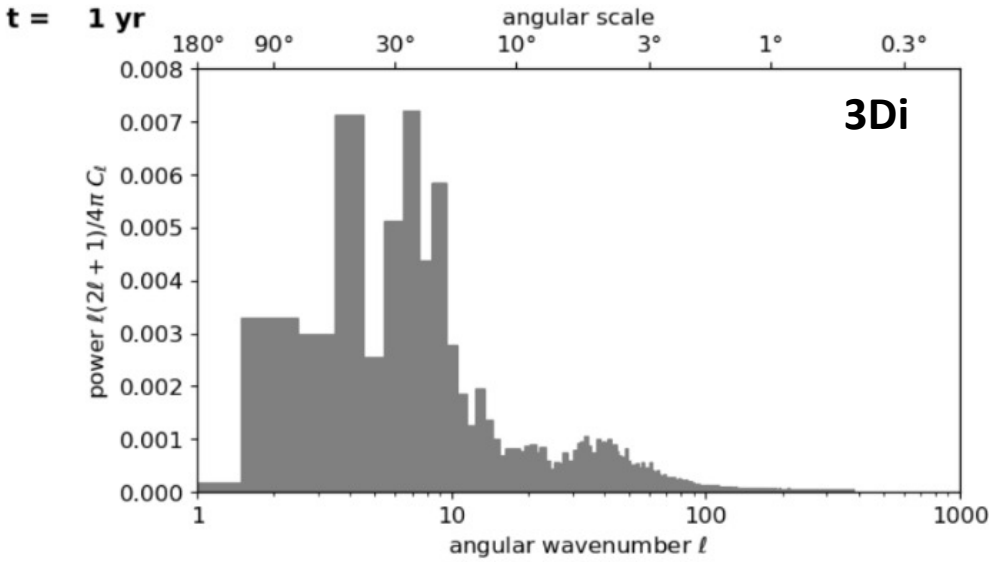
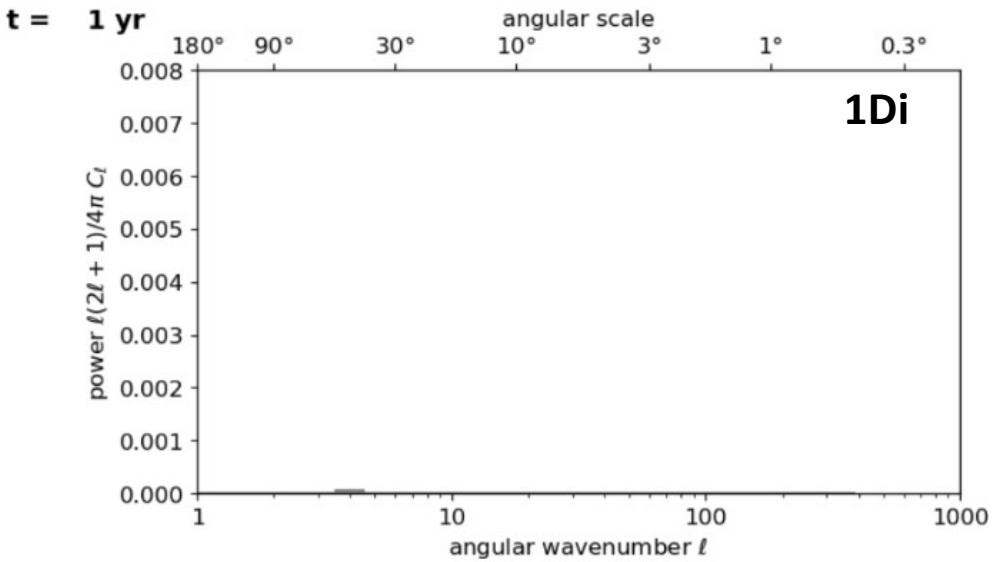
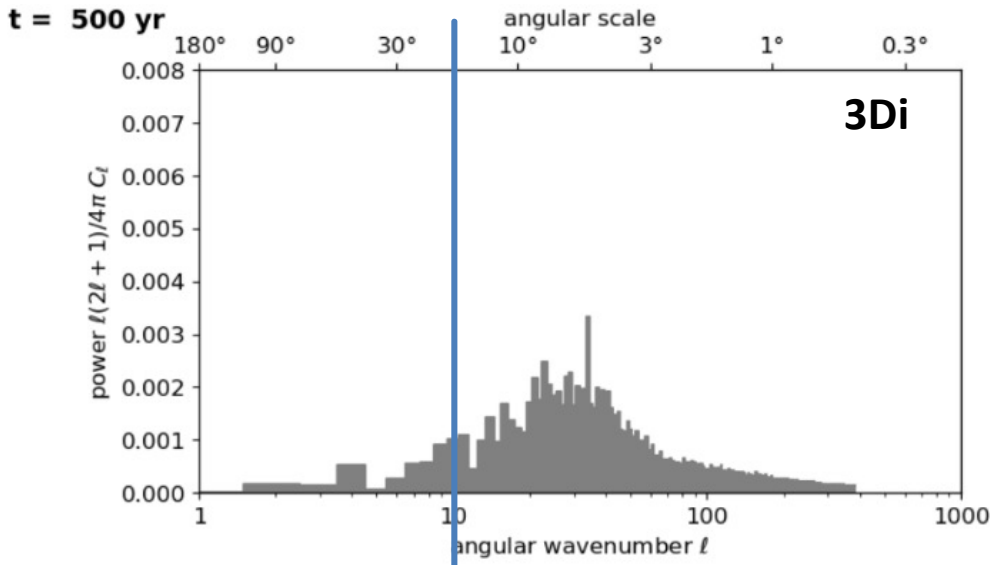
SNR memory of the SN

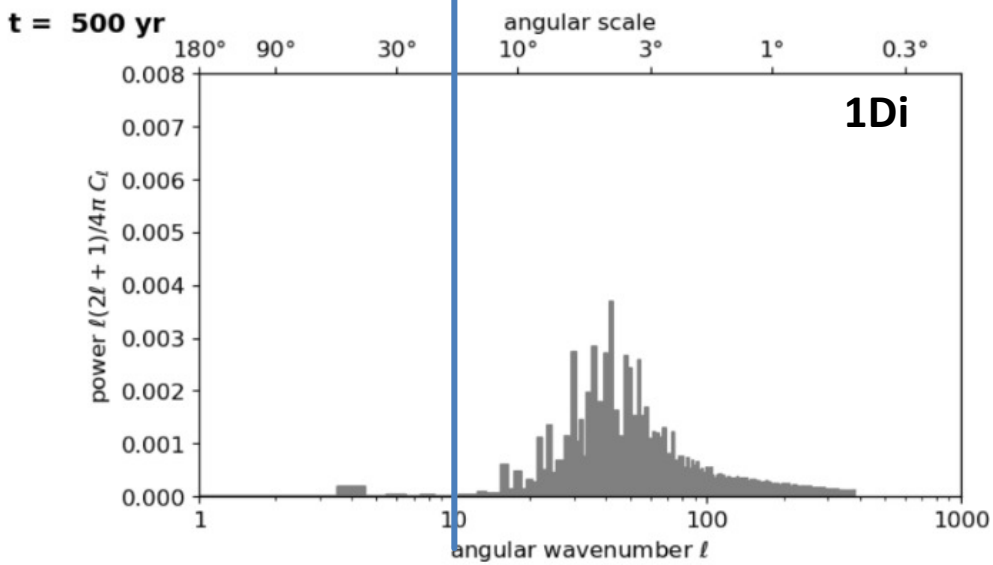
CD power at 1 yr





CD power at 500 yrs





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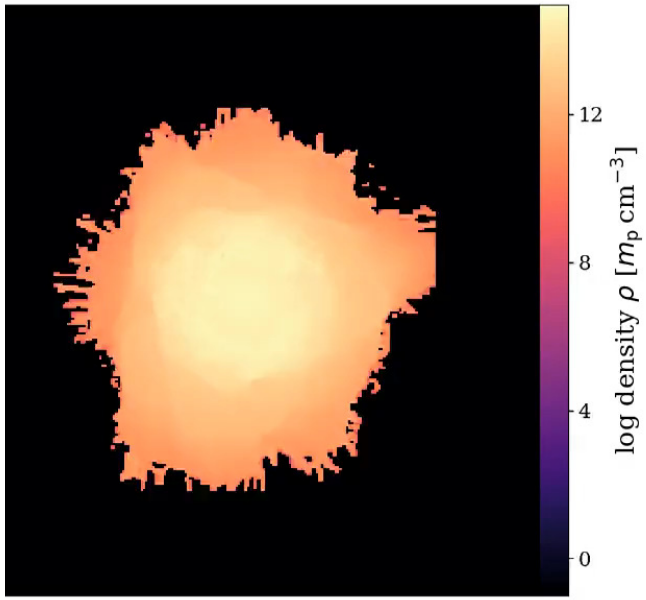
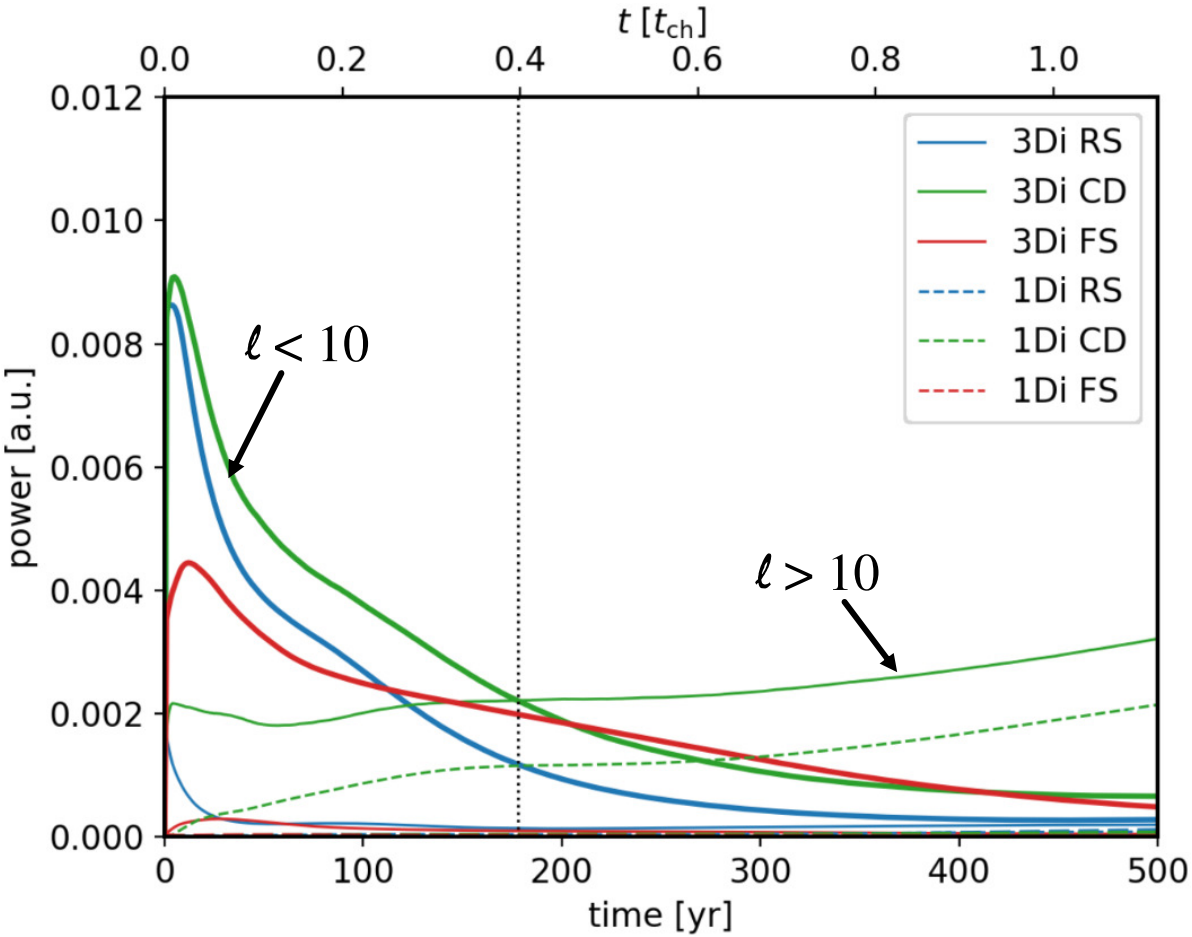
SNR memory of the SN

- Remnants circularize & lose power at low ℓ
- Development of RT instability creates power at large ℓ





- By ≈175 years, SNR power dominates SN power ➔ SN transitions to SNR

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Summary

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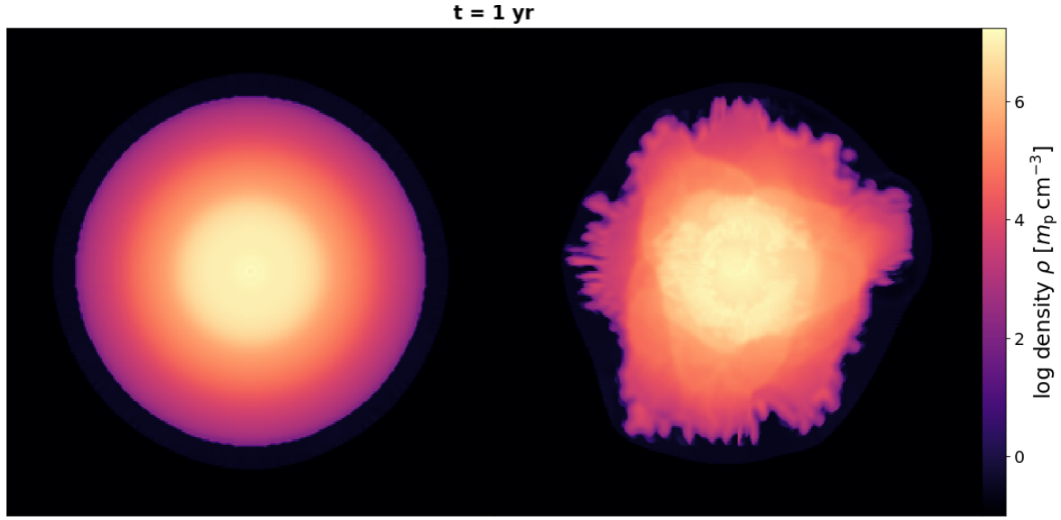
- Simulations of SNe are not spherically symmetric



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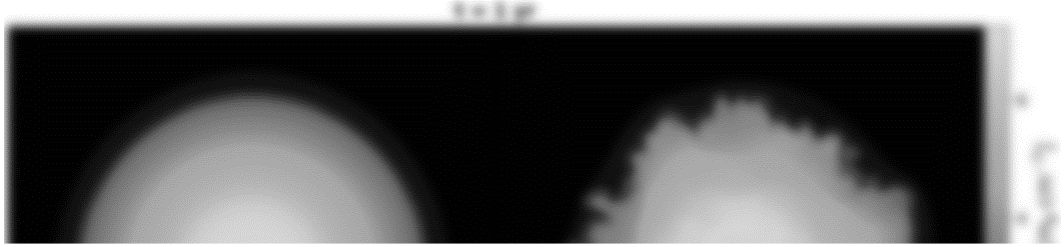
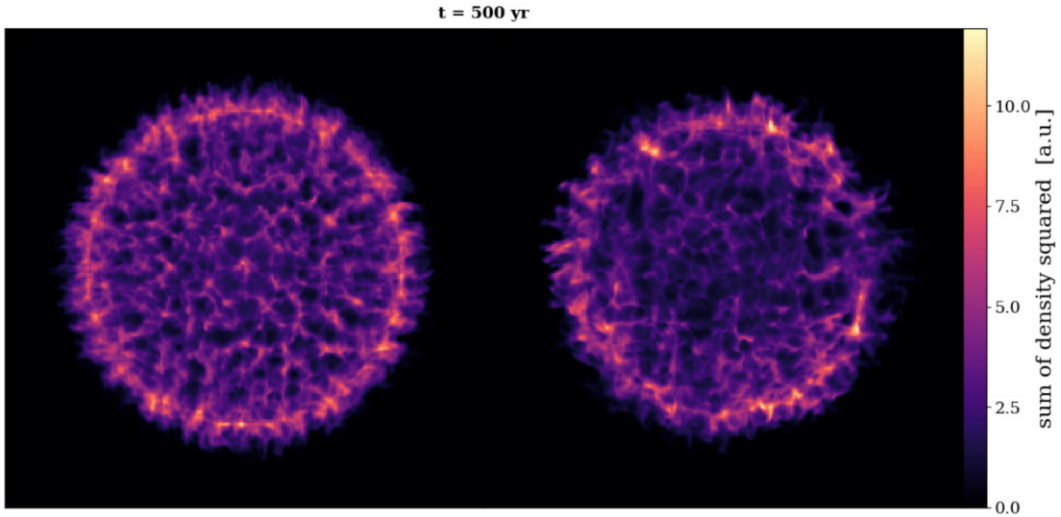


- Using SN as initial conditions causes detectable differences to SNR ➔ possible to work backwards and infer SN mechanism?



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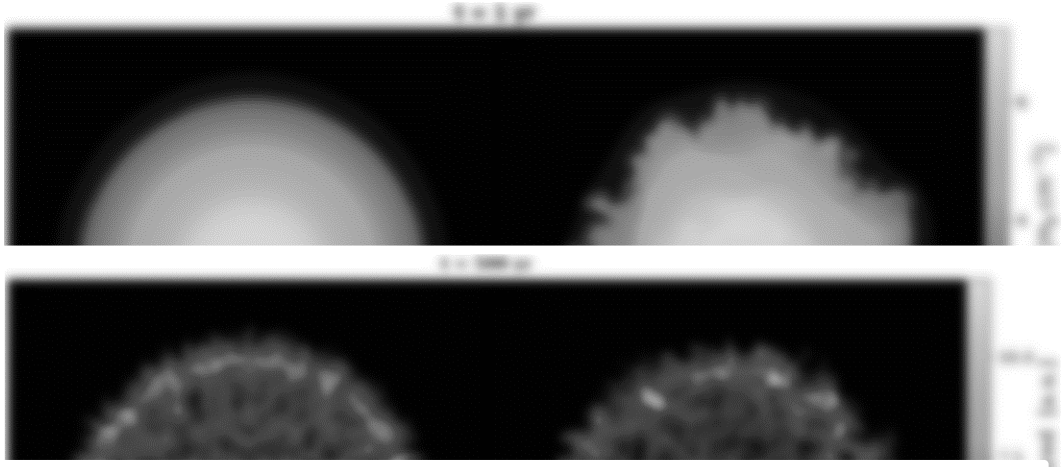
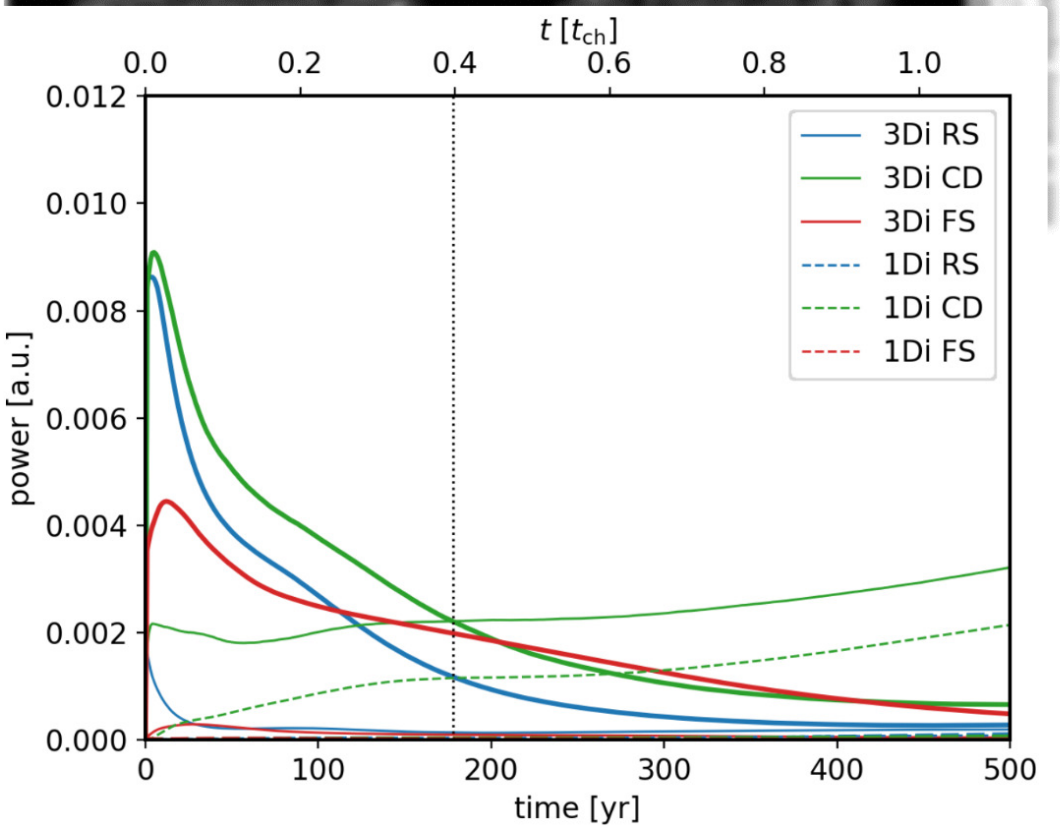
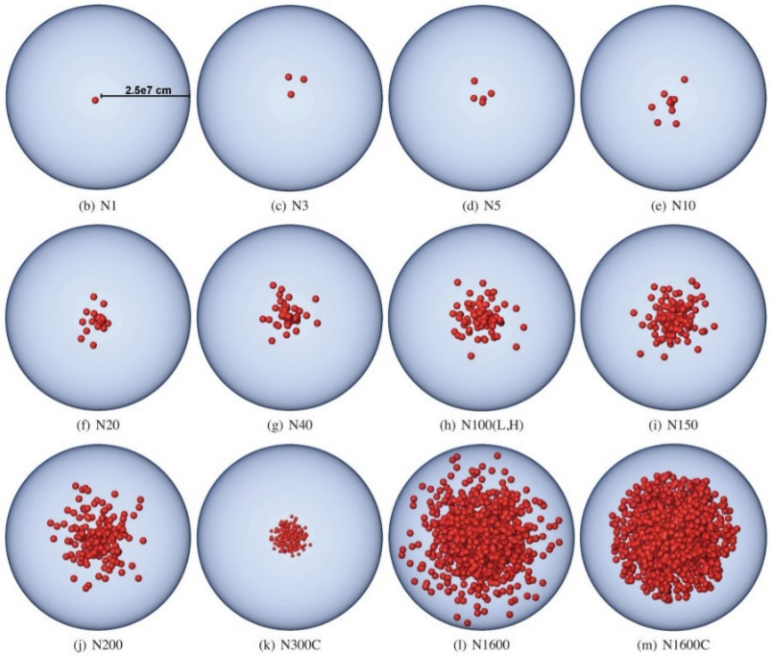
- Simulations of SNe are not spherically symmetric
- Using SN as initial conditions causes detectable differences to SNR ➔ possible to work backwards and infer SN mechanism?
- Imprint of SN in SNR can be detected long after ejecta morphology dominated by interaction with ISM





Perspectives

- Compute thermal emission for accurate predictions of observations
- Analyze our projected images quantitatively (e.g. genus statistic of Sato+ 2019)
- Run more models (single degenerate? double degenerate?)
- Eventually work to diagnose explosion model based on appearance of SNR
- We will evolve your favorite SN model. Just ask!



Seitenzahl+ (2013) 2013MNRAS.429.1156S

One last plug for VR