Neutrino Oscillation Above a Black Hole Accretion Disk

Annie Malkus with Jim P. Kneller, Gail McLaughlin and Rebecca Surman

Malkus et al, arxiv:1207.6648

Accretion Disks

- Produce many neutrinos
- Play a role in . . .
  - Stellar Collapse
  - Mergers
  - Gamma Ray Bursts
  - Nucleosynthesis (r-Process?)

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A Neutrino Emitting Disk

Caballero et al., Phys.Rev.D80:123004,2009

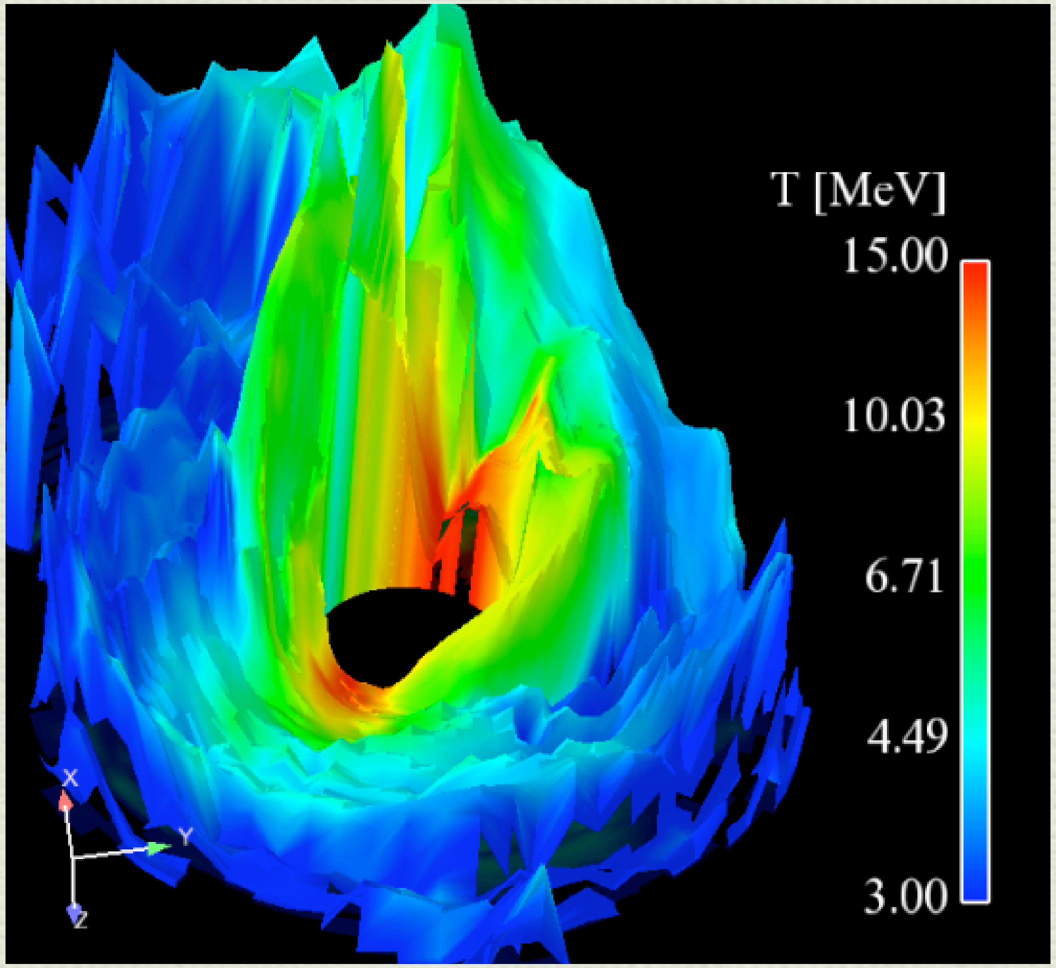
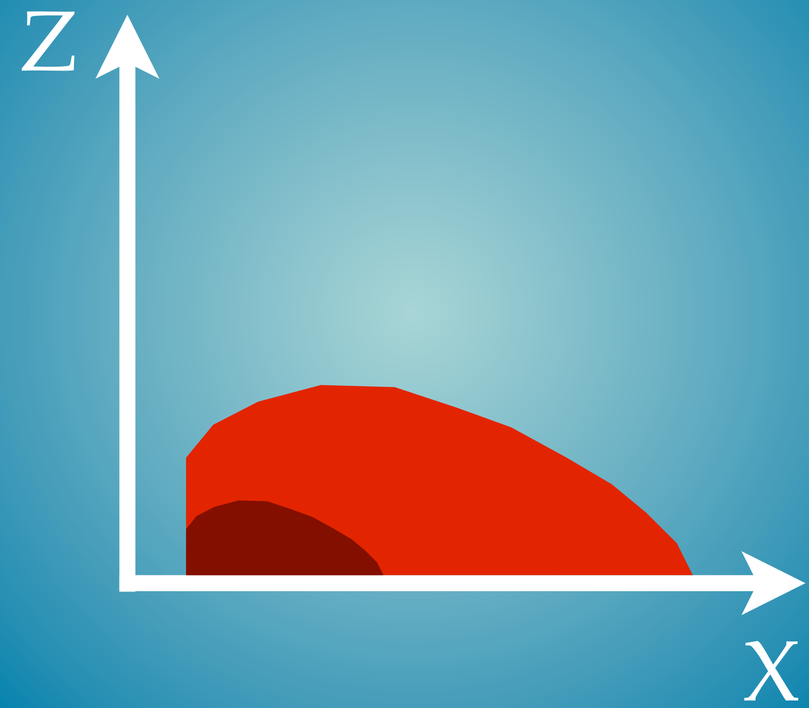
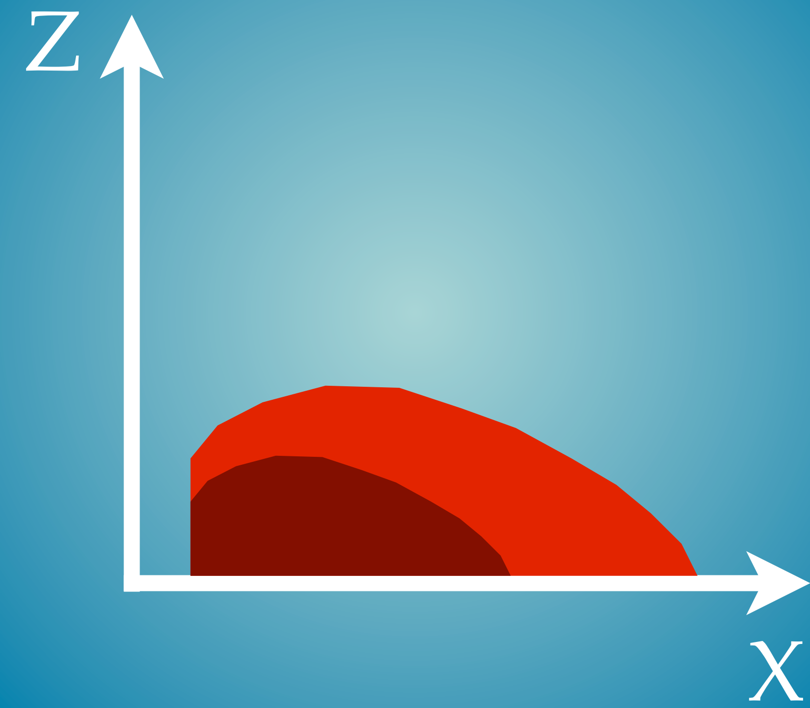


FIG. 3: (Color on line) Electron antineutrino surface seen at some inclination angle (see the x, y, z axis on the lower left corner). The height corresponds to h_ν as in Eq. 2. The color scale corresponds to the neutrino temperatures, also shown in Fig. 2. The black area in the center represents the boundary with the BH, $r = 2r_s$.

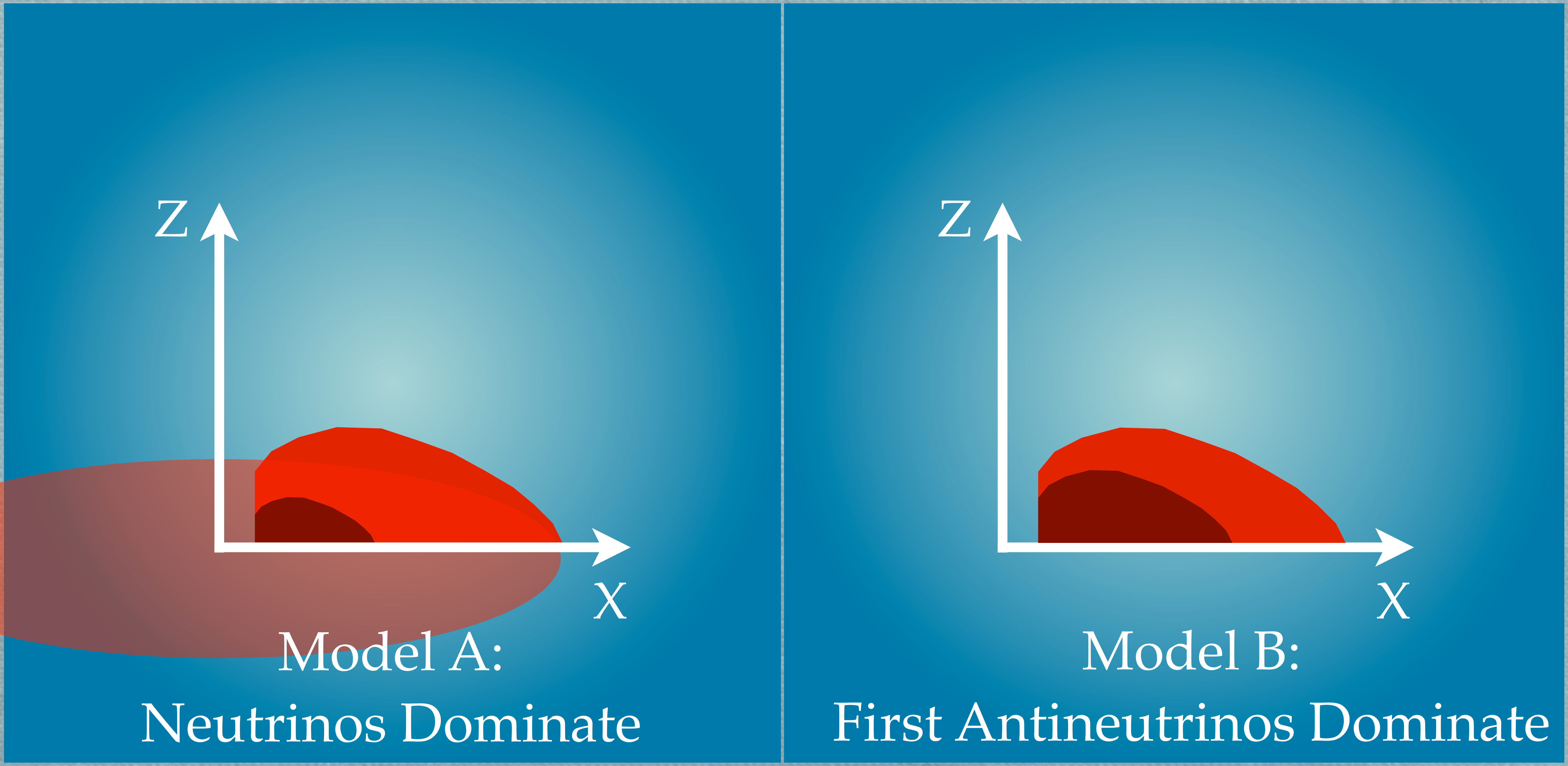


Model A:
Neutrinos Dominate



Model B:
First Antineutrinos Dominate

Models Relevant to Stellar Collapse



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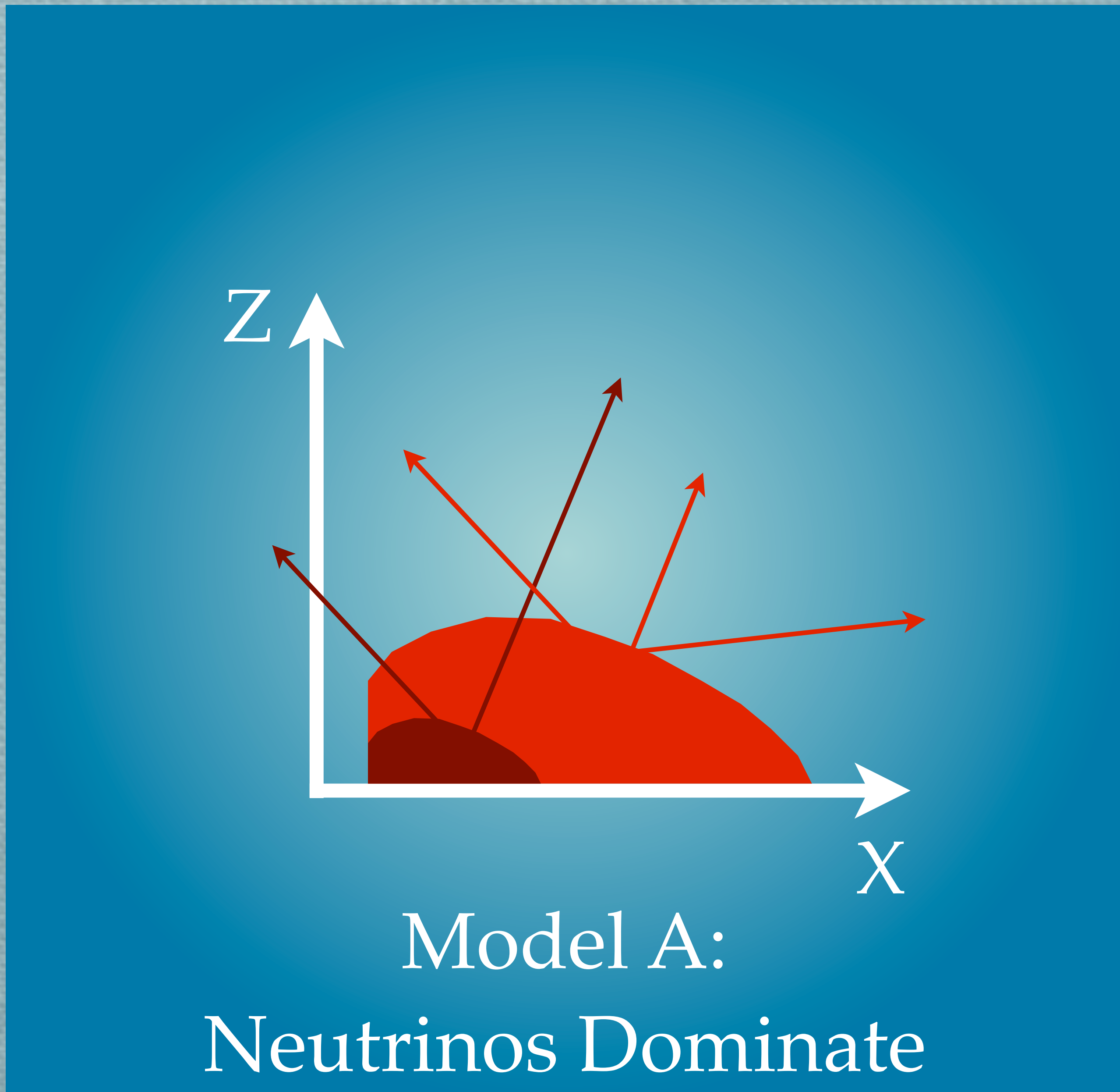

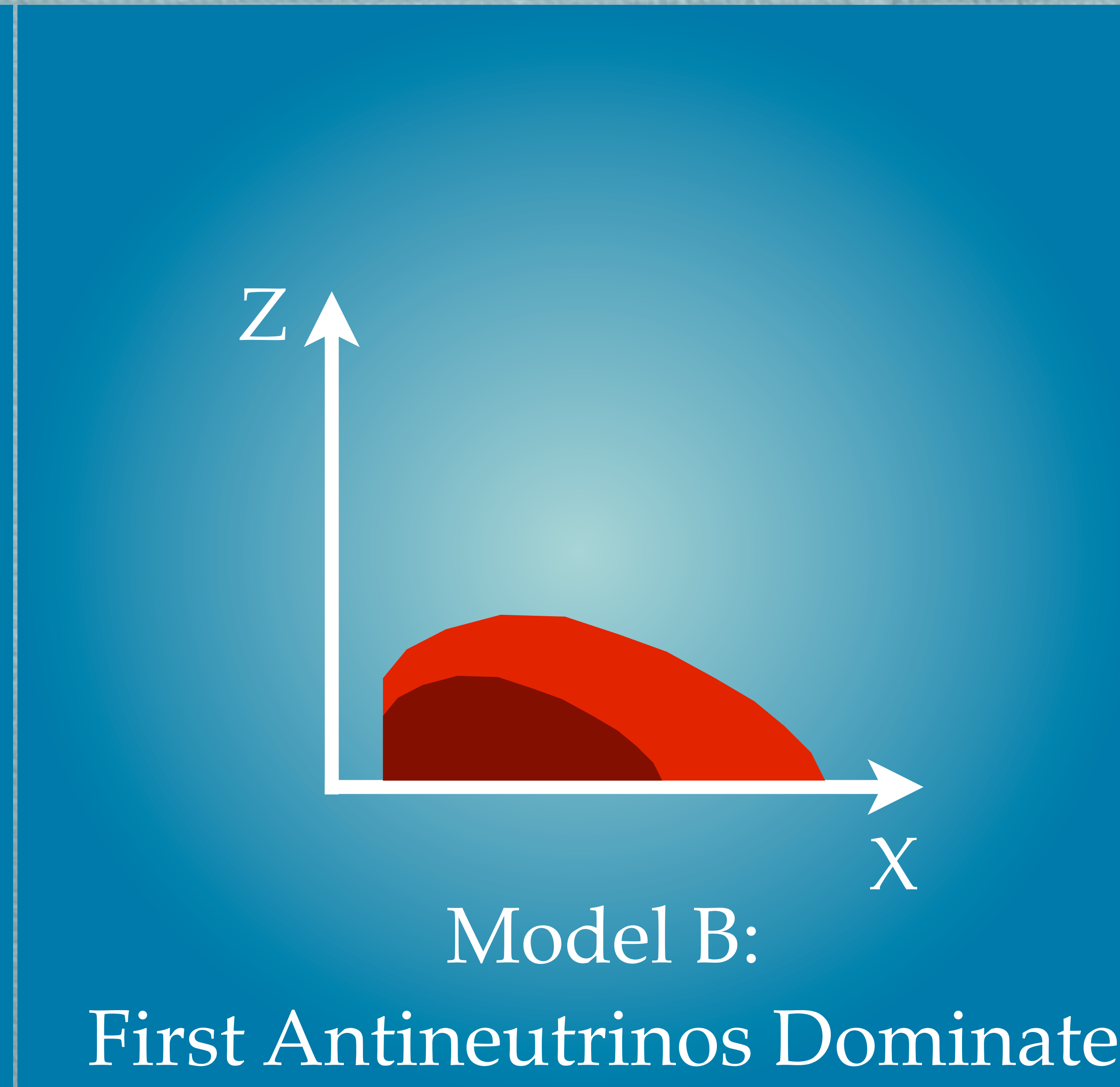

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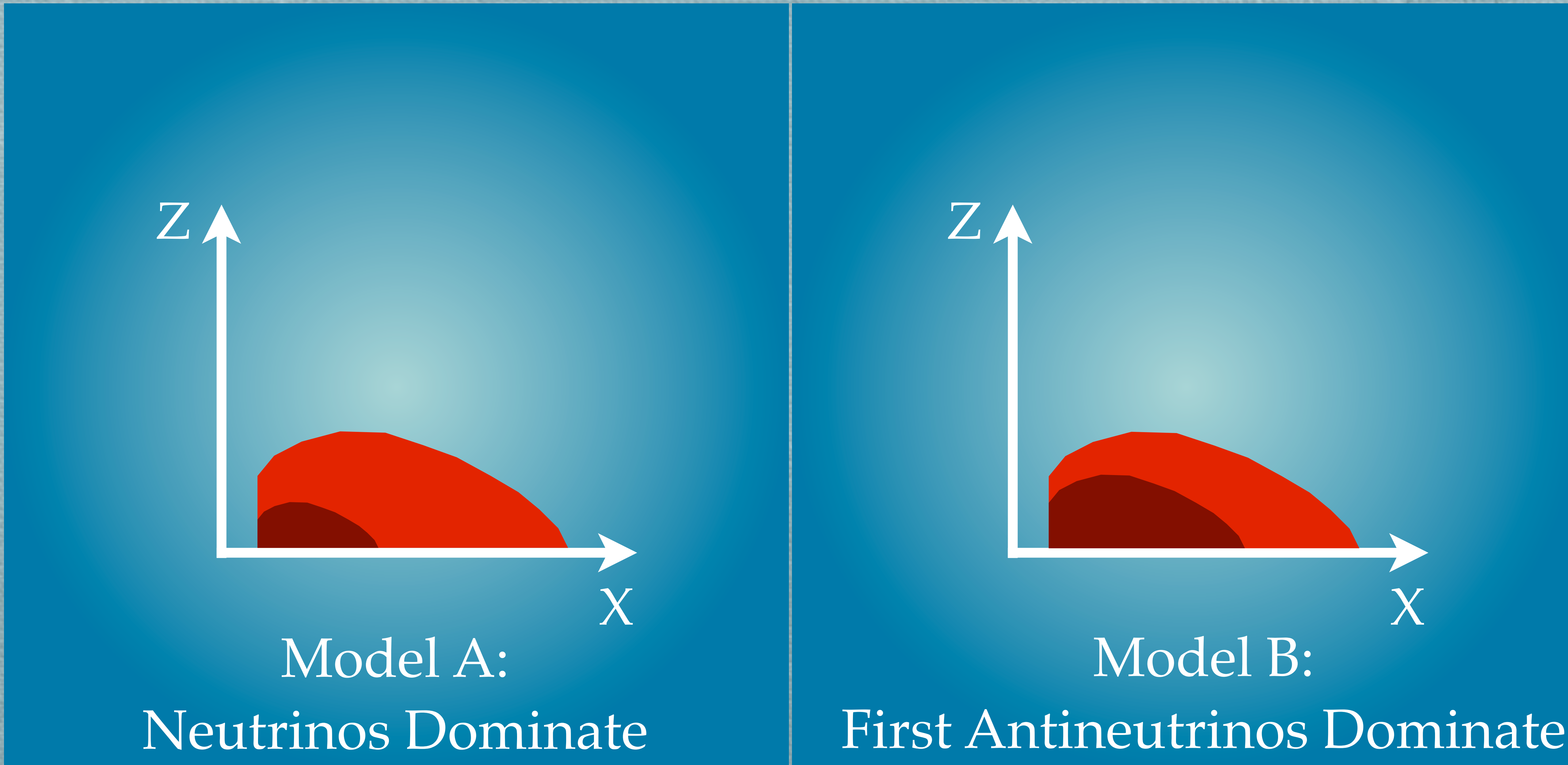

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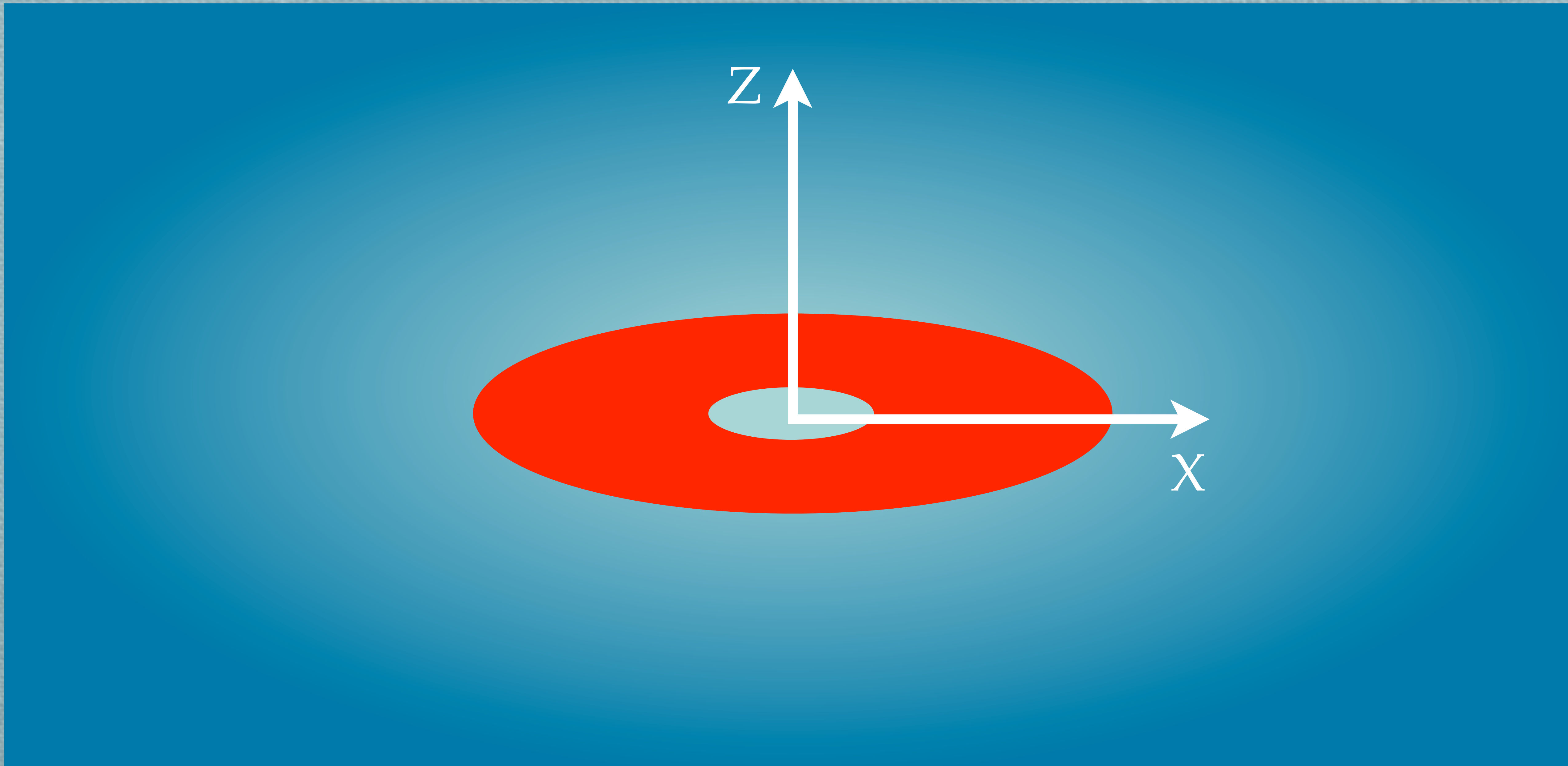
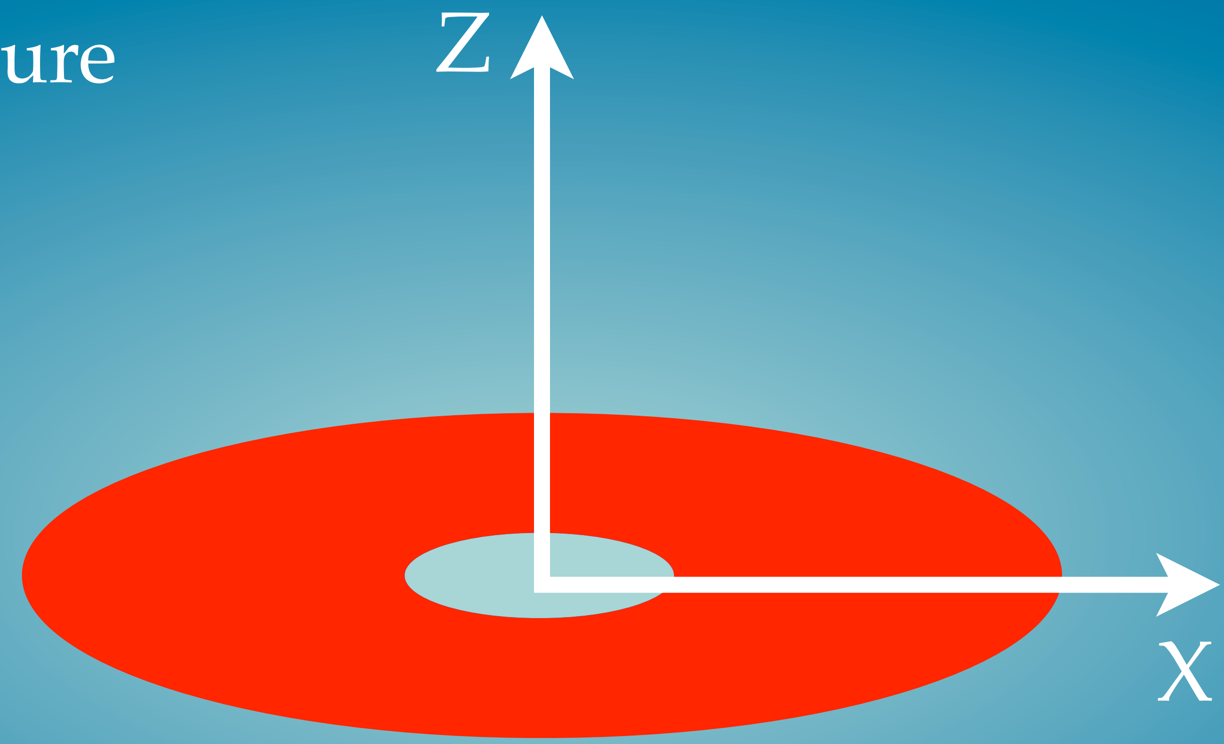


Realizing the Qualitative Picture

capturing the important features

- Single Temperature



Realizing the Qualitative Picture

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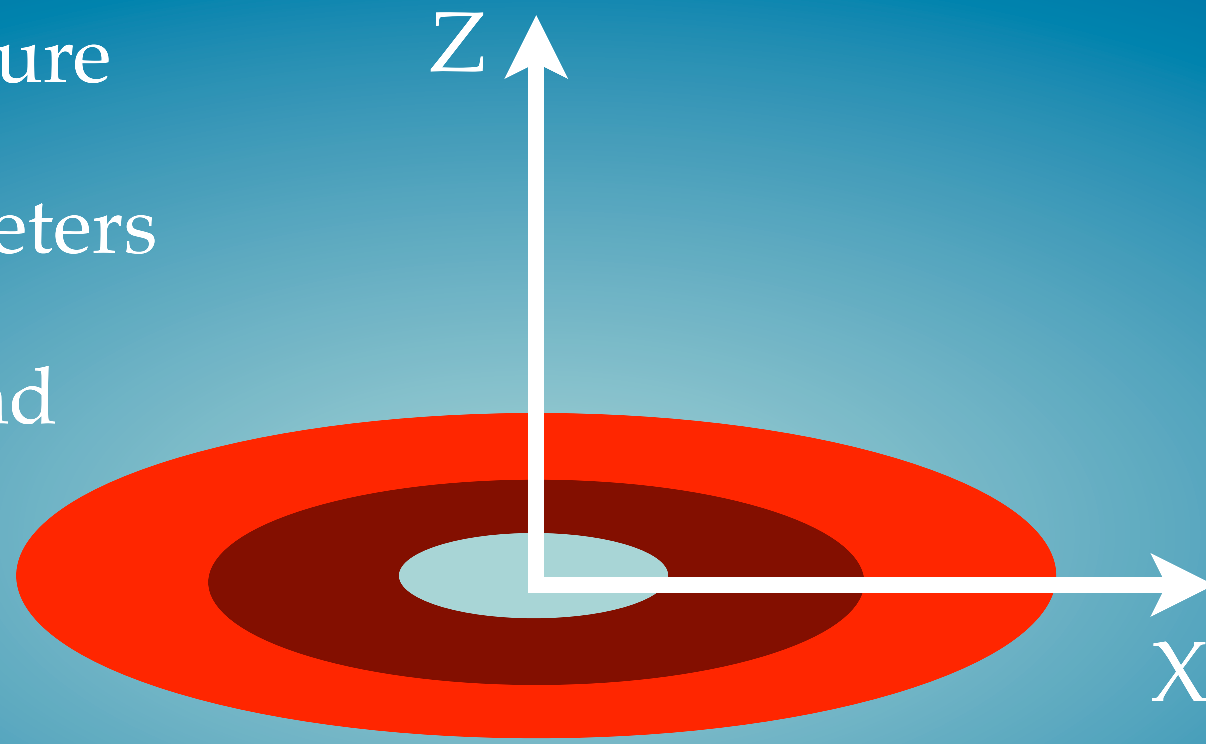
- Single Temperature
- Different Parameters for Neutrinos and Antineutrinos

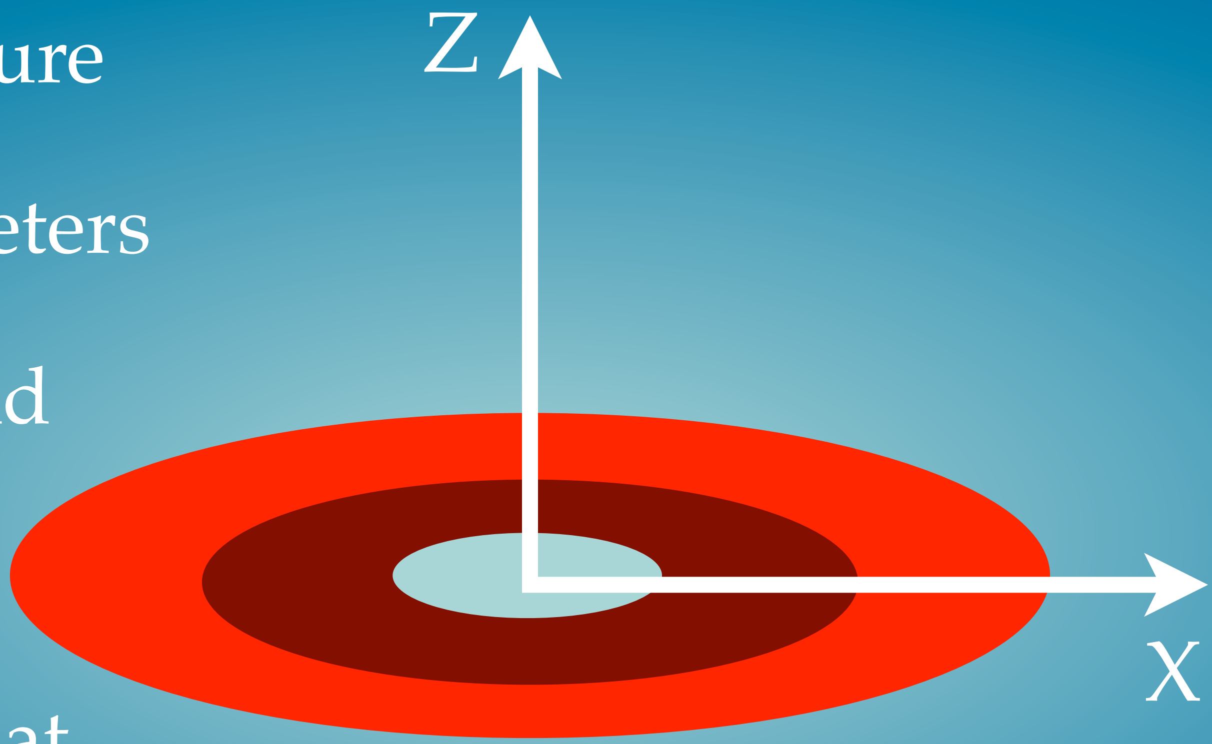


Realizing the Qualitative Picture

capturing the important features

Dasgupta et al., Phys.Rev. D78 (2008) 033014

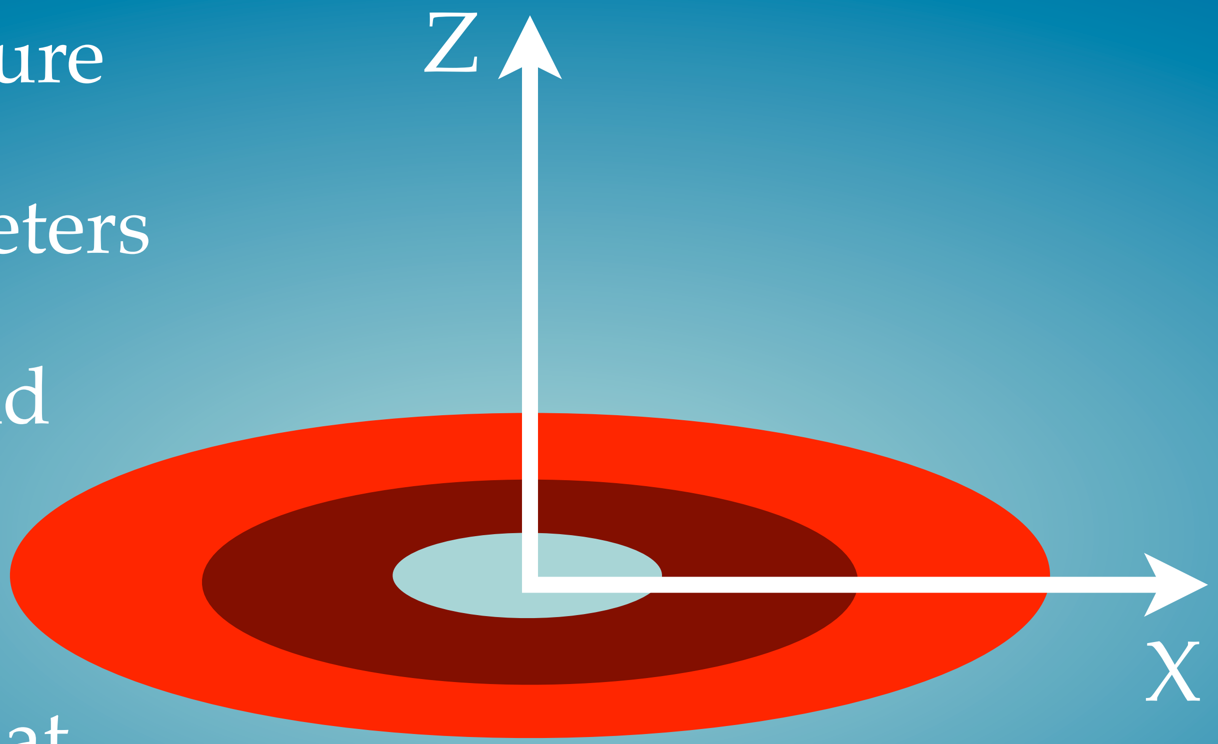
- Single Temperature
- Different Parameters for Neutrinos and Antineutrinos
- Geometrically Flat



Realizing the Qualitative Picture

capturing the important features

- Single Temperature
- Different Parameters for Neutrinos and Antineutrinos
- Geometrically Flat
- Hole in the Center



Realizing the Qualitative Picture

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- Single Temperature
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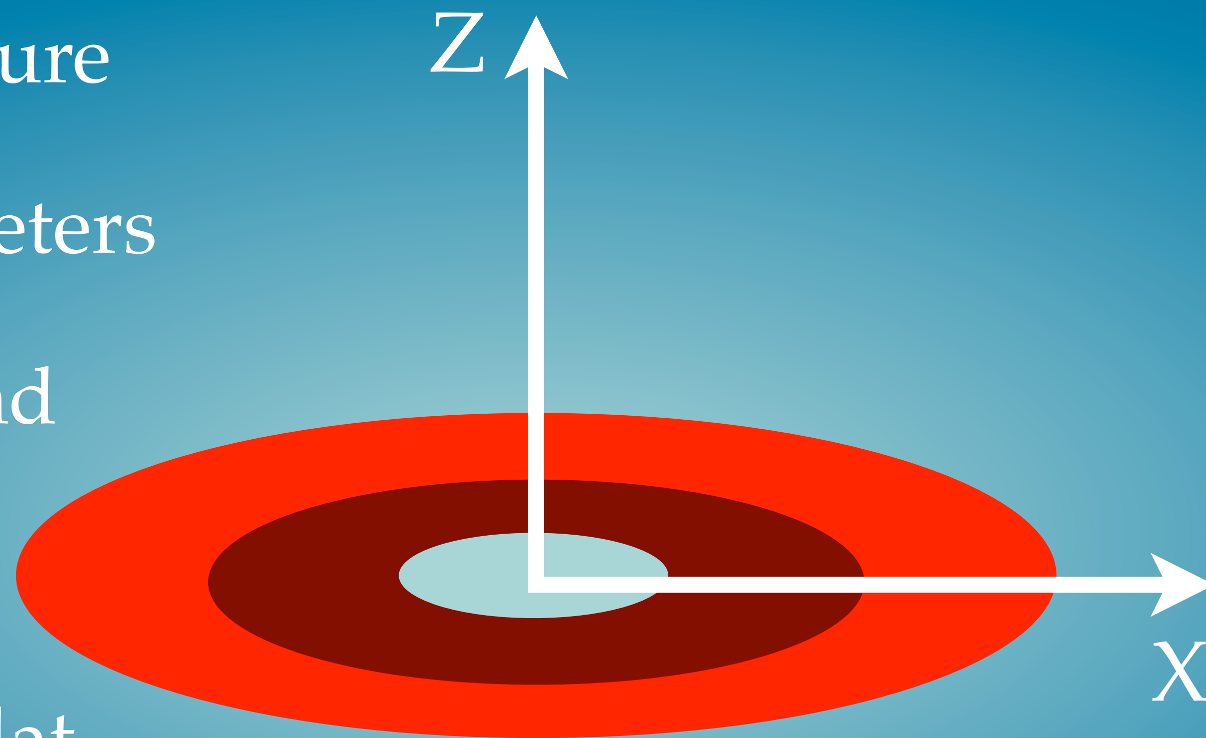
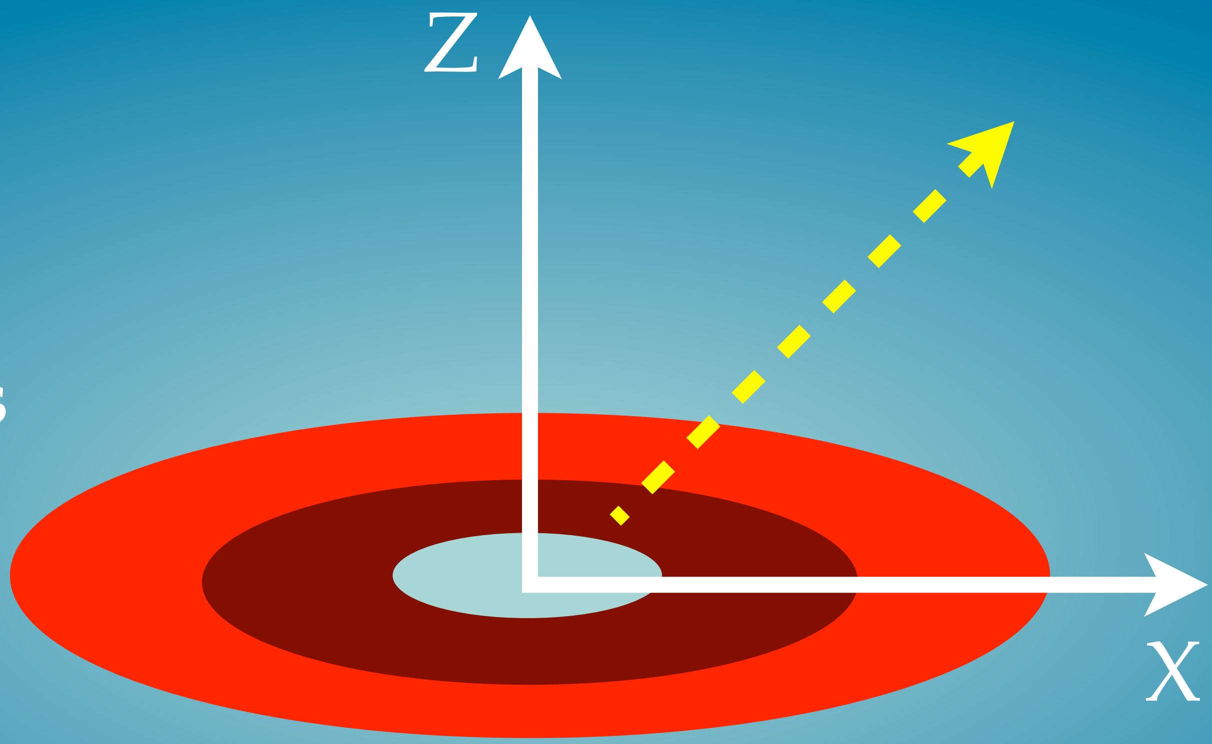
- Geometrically Flat
- Hole in the Center
- Fermi-Dirac



Realizing the Qualitative Picture

capturing the important features

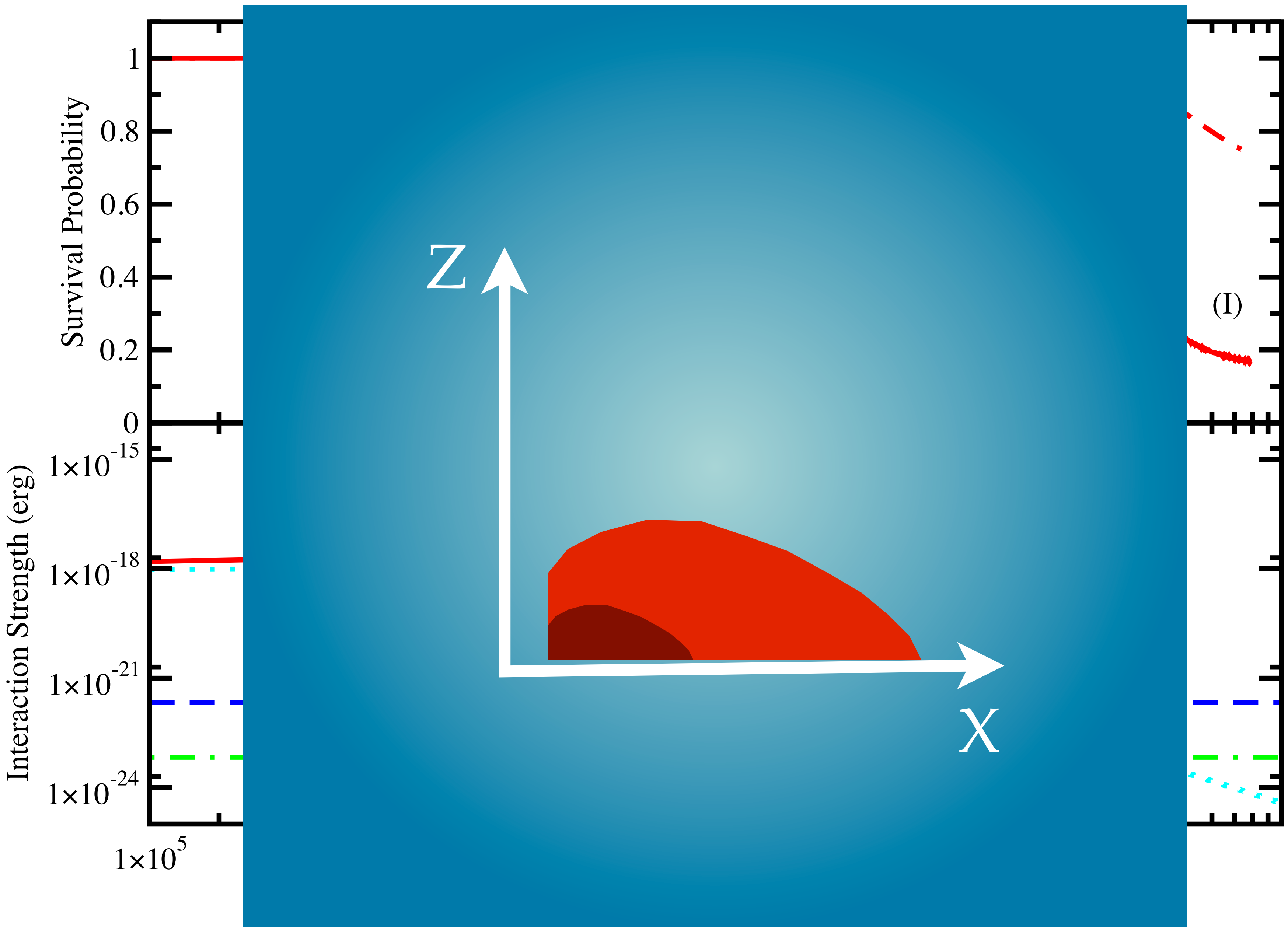
- Single Angle
- One Trajectory
- Both Hierarchies
- Three Flavor



Realizing the Qualitative Picture

capturing the important features

Malkus et al, arxiv:1207.6648

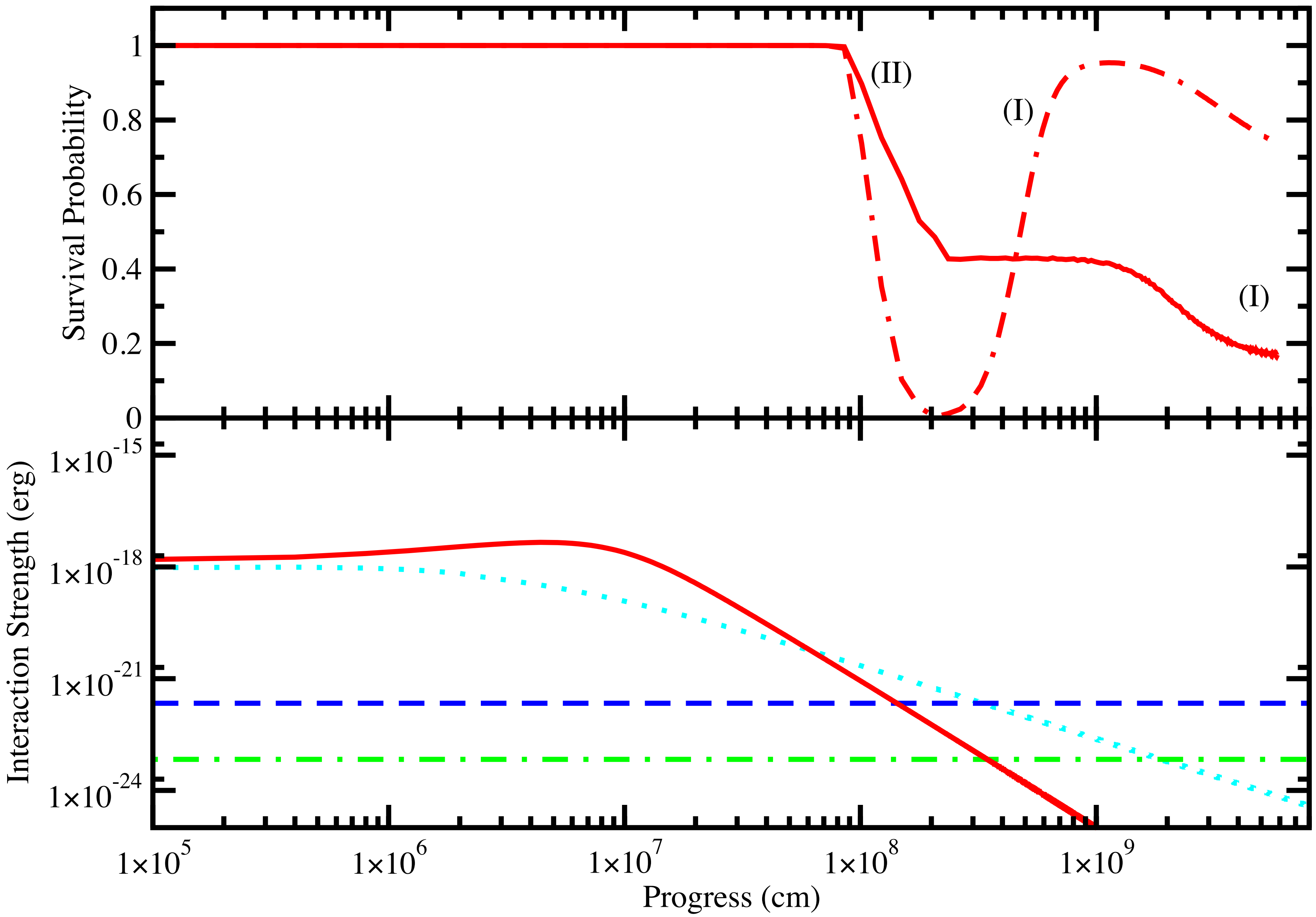


Normal Hierarchy

(I) MSW
(II) Bipolar

Model A

Malkus et al,
arxiv:1207.6648



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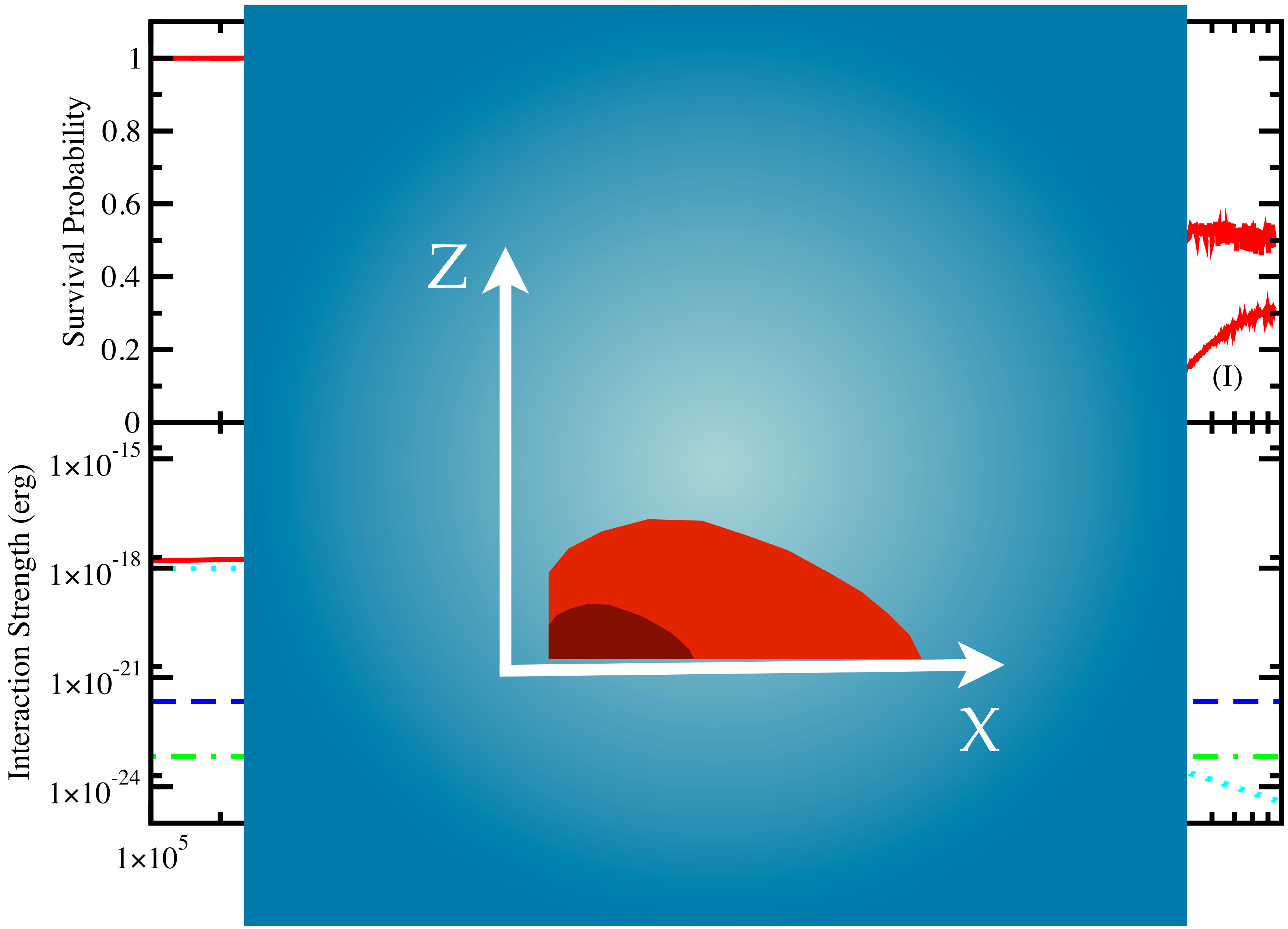

Inverted Hierarchy

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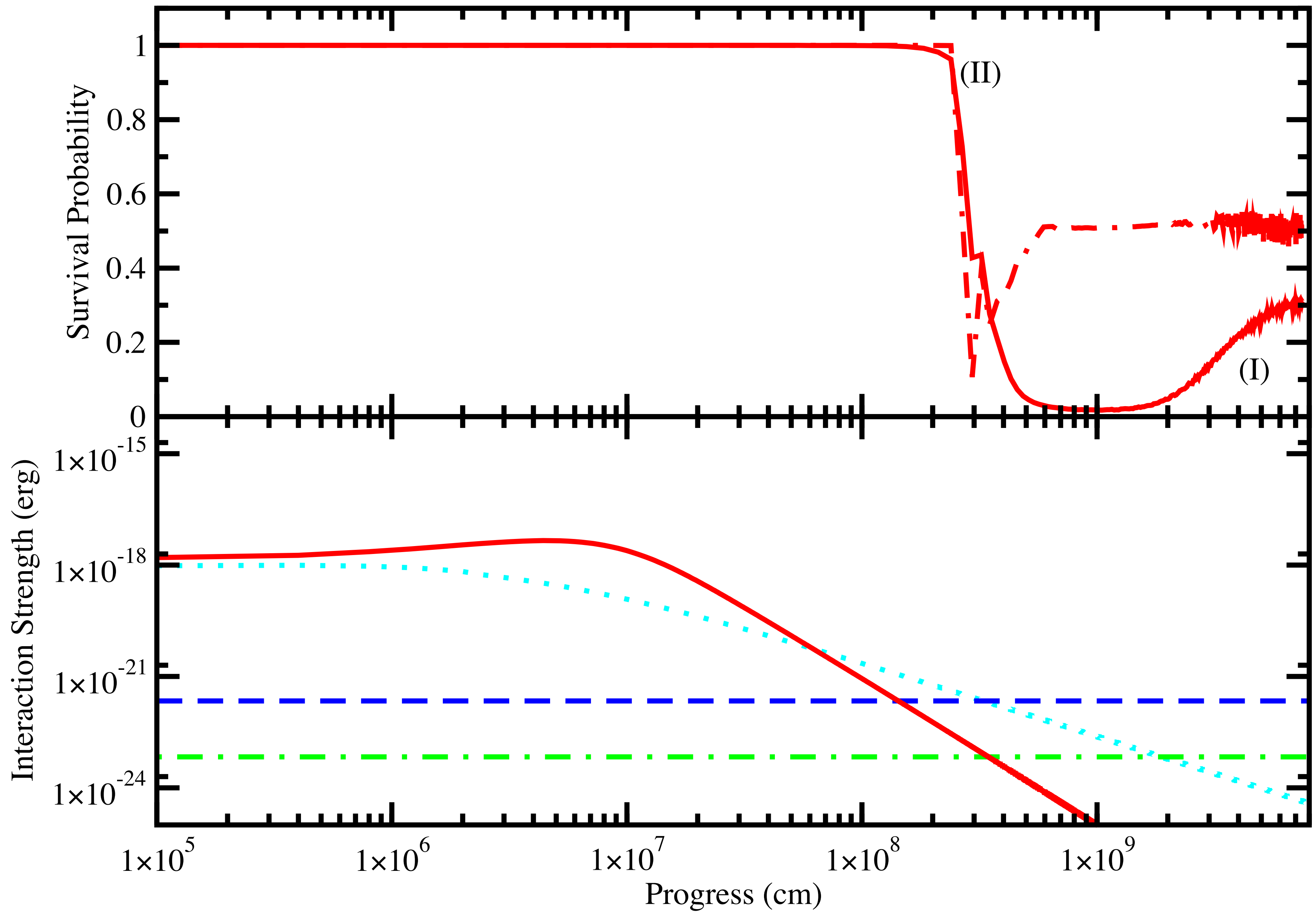
Malkus et al, arxiv:1207.6648



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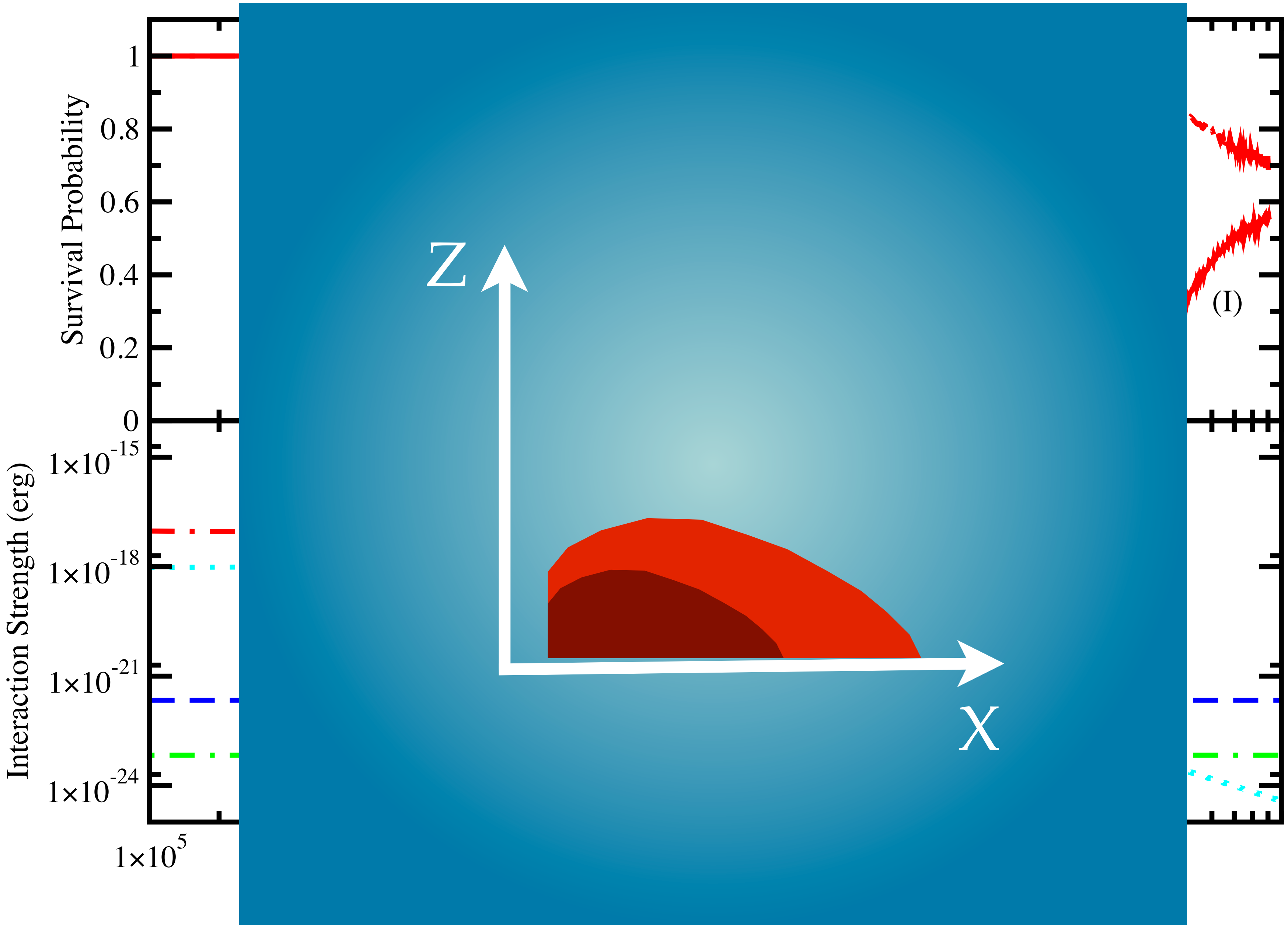
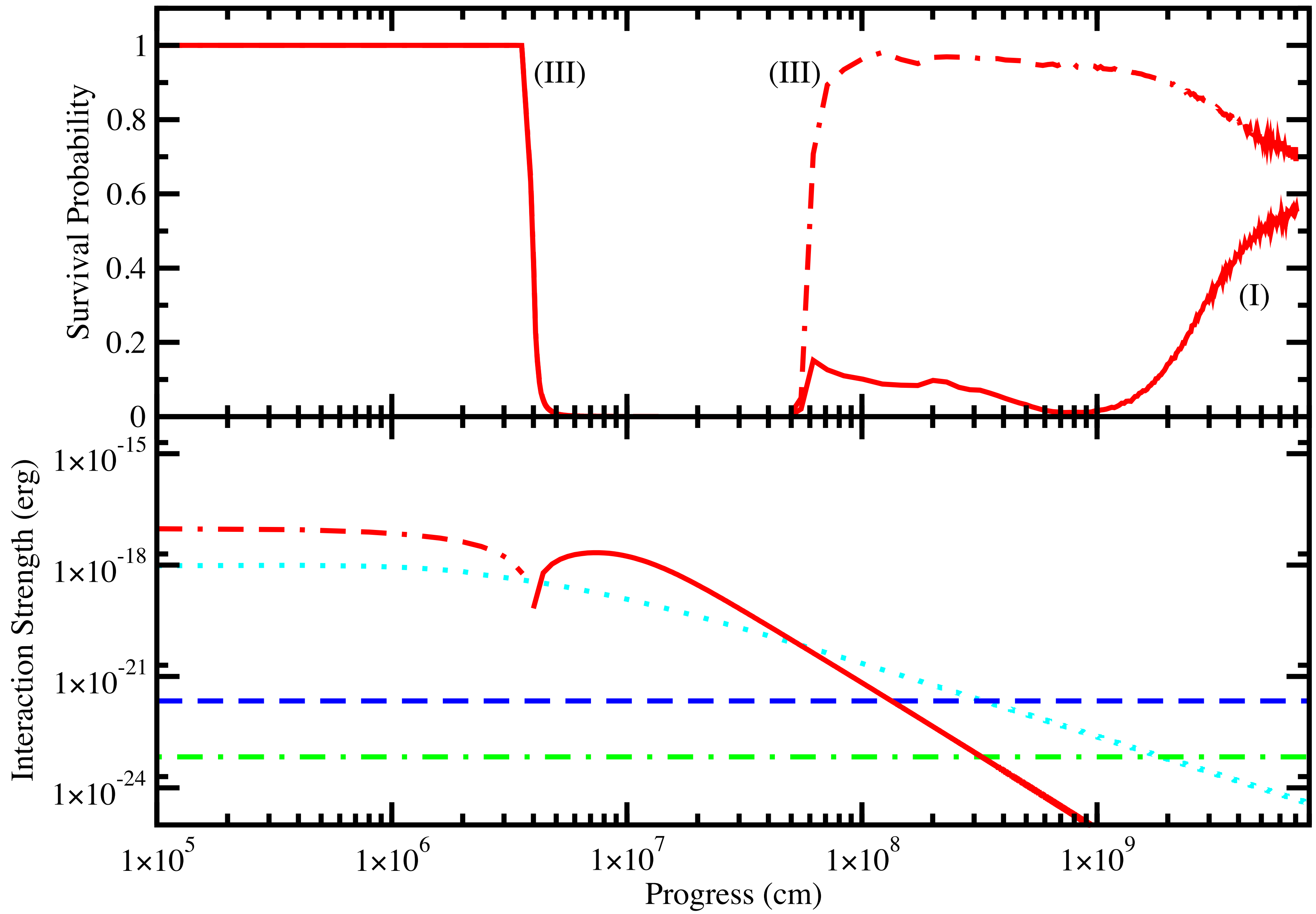


Normal Hierarchy

Model B

(I) MSW
(II) Bipolar
(III) Neutrino-Matter

Malkus et al, arxiv:1207.6648



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Malkus et al,
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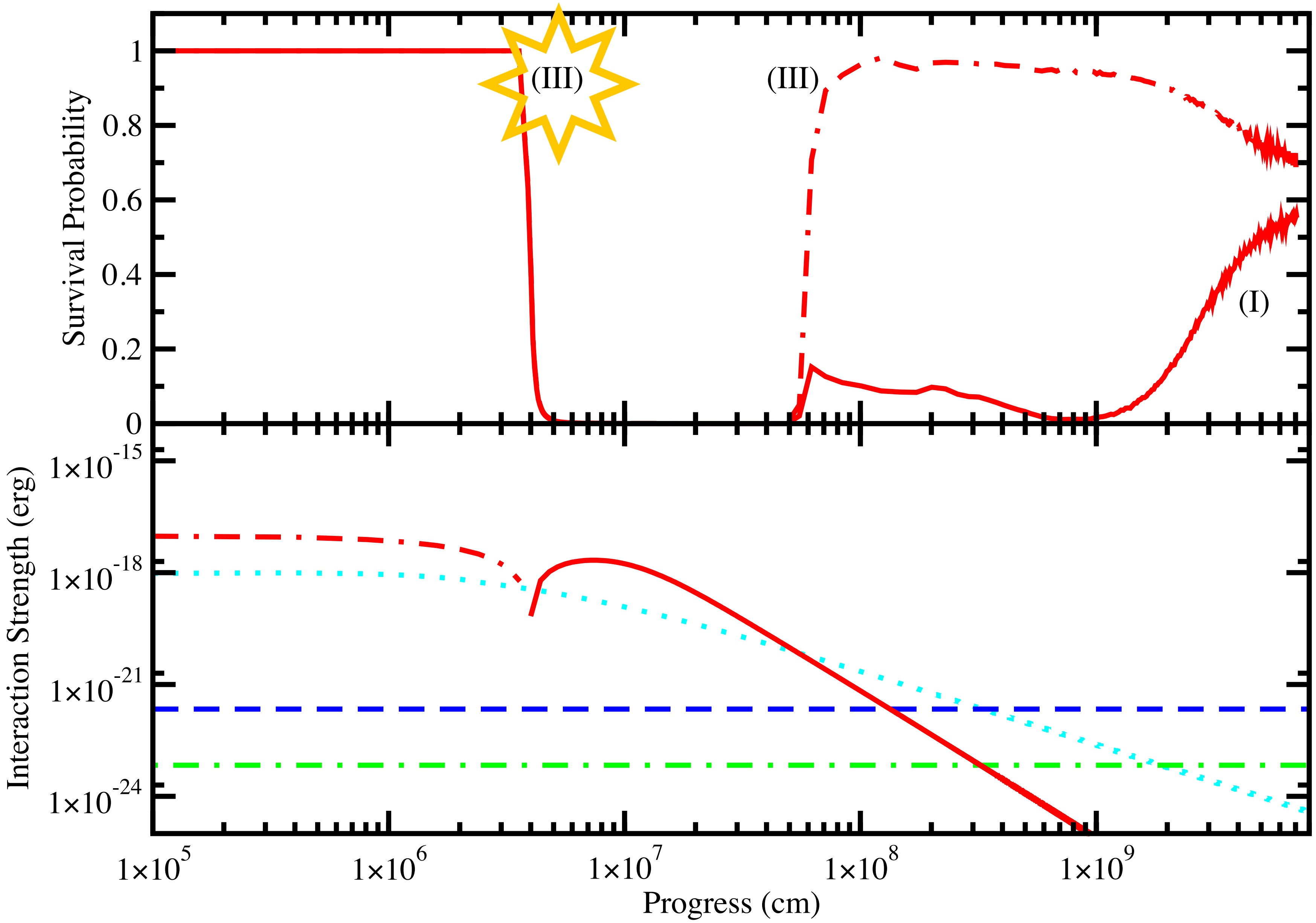

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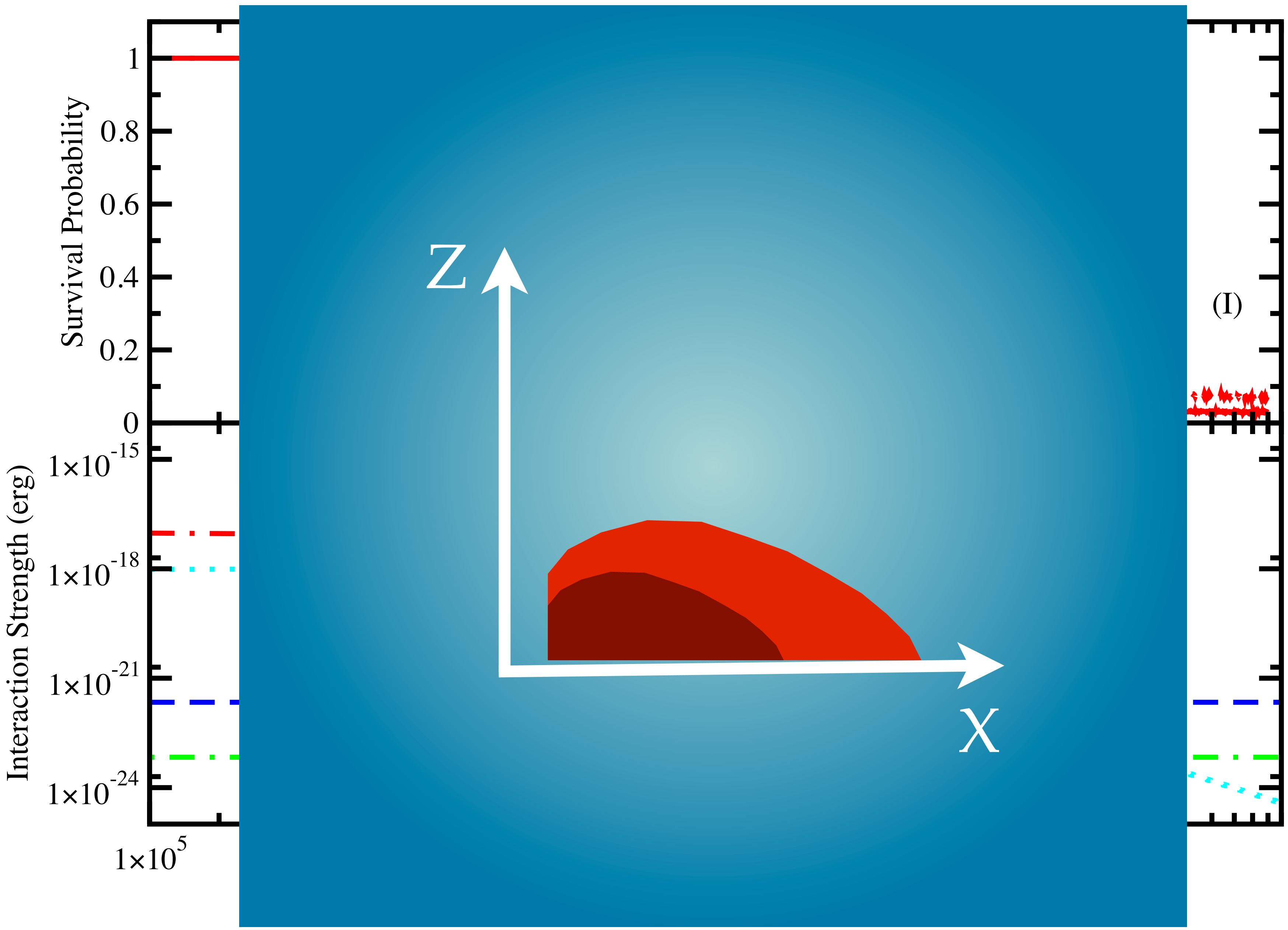

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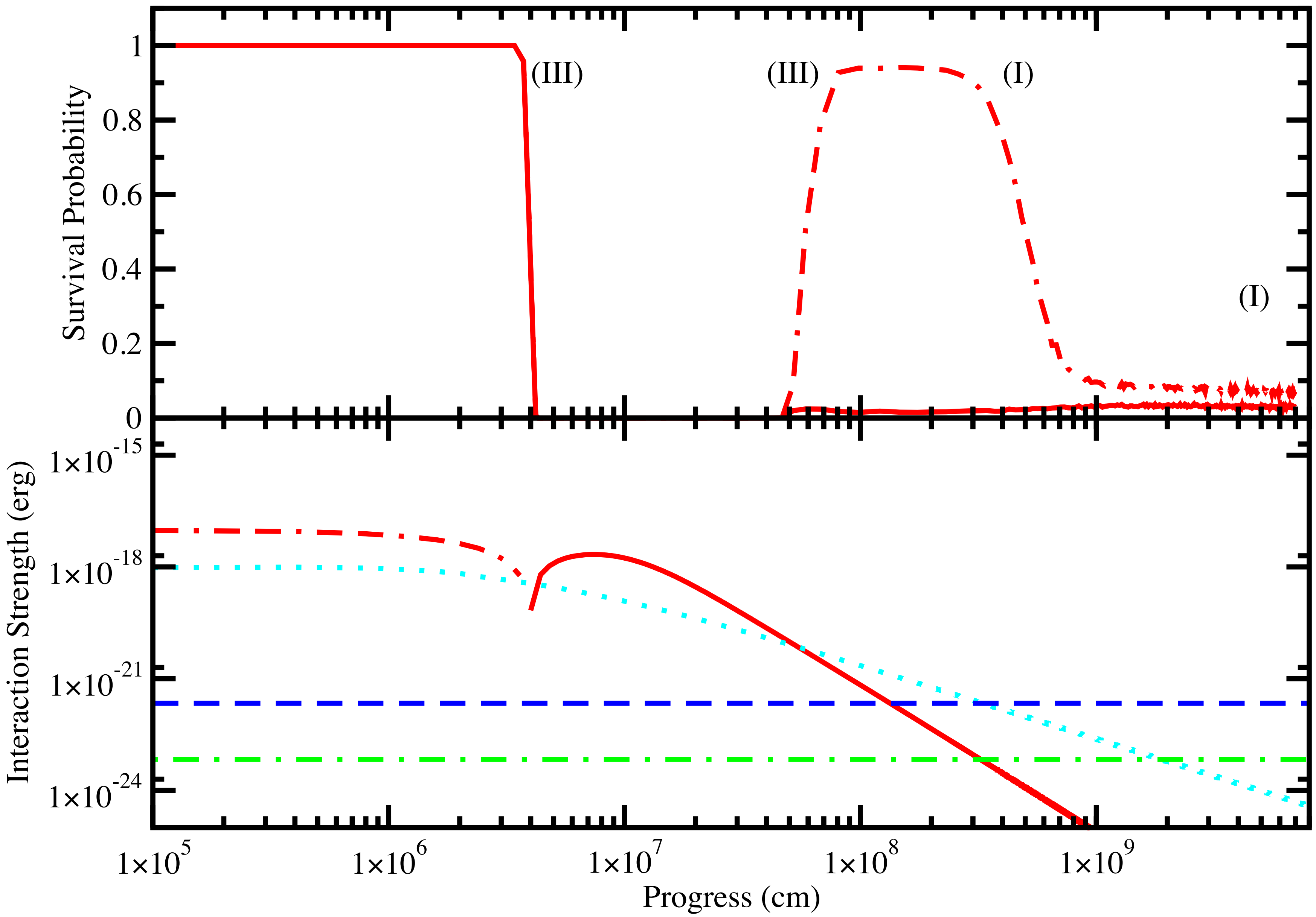

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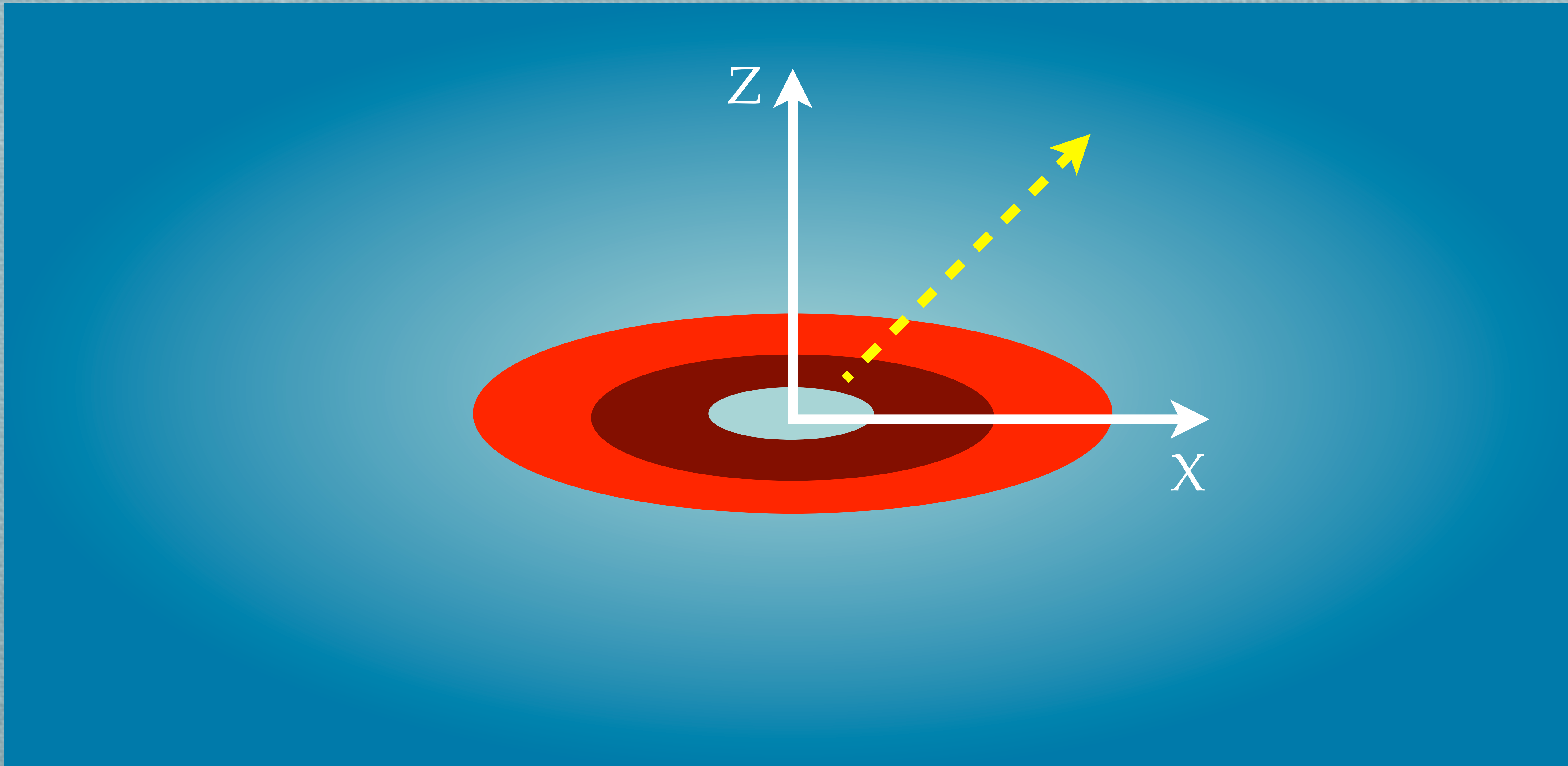
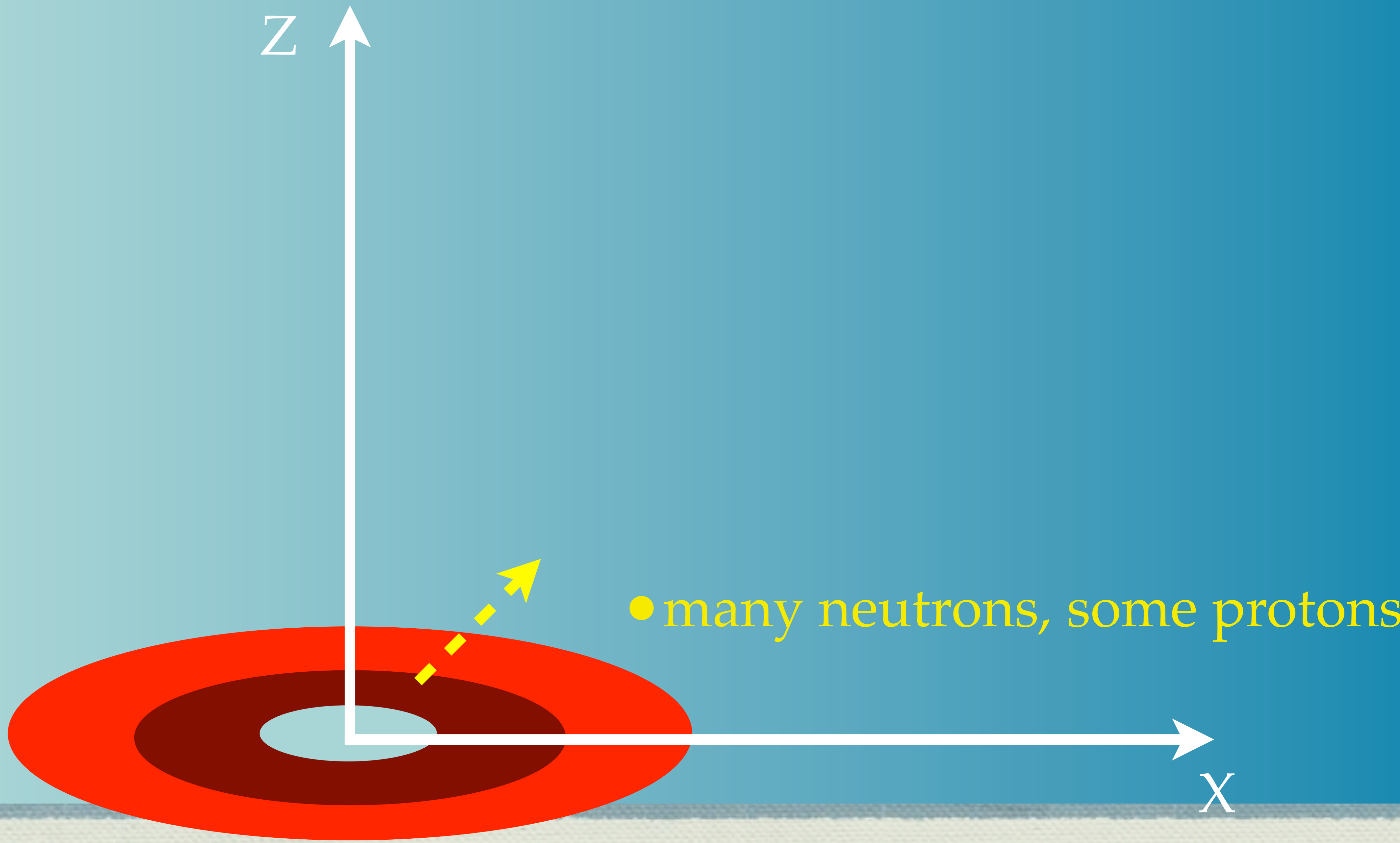


Nucleosynthesis Along the Trajectory

where are the neutrons?



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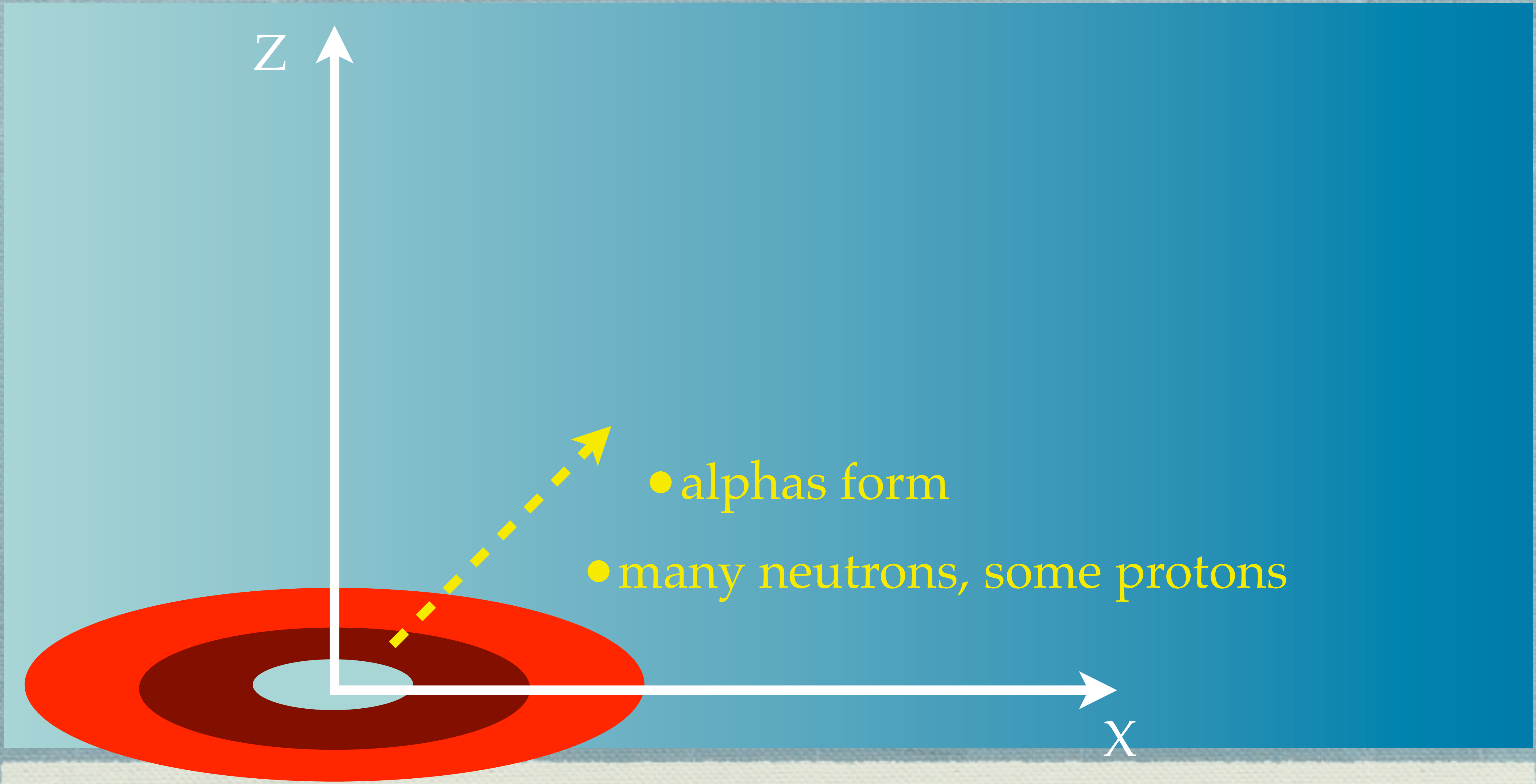

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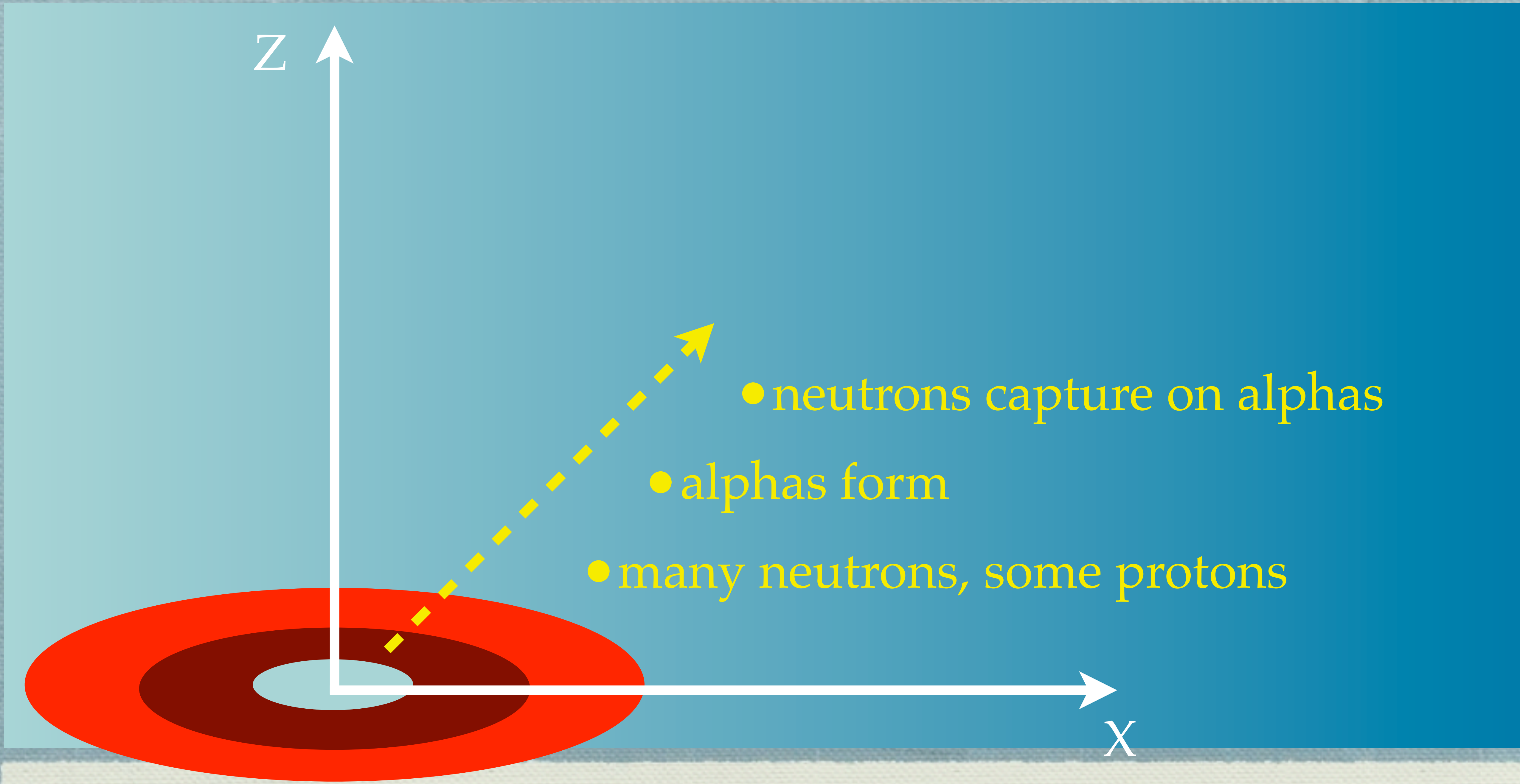

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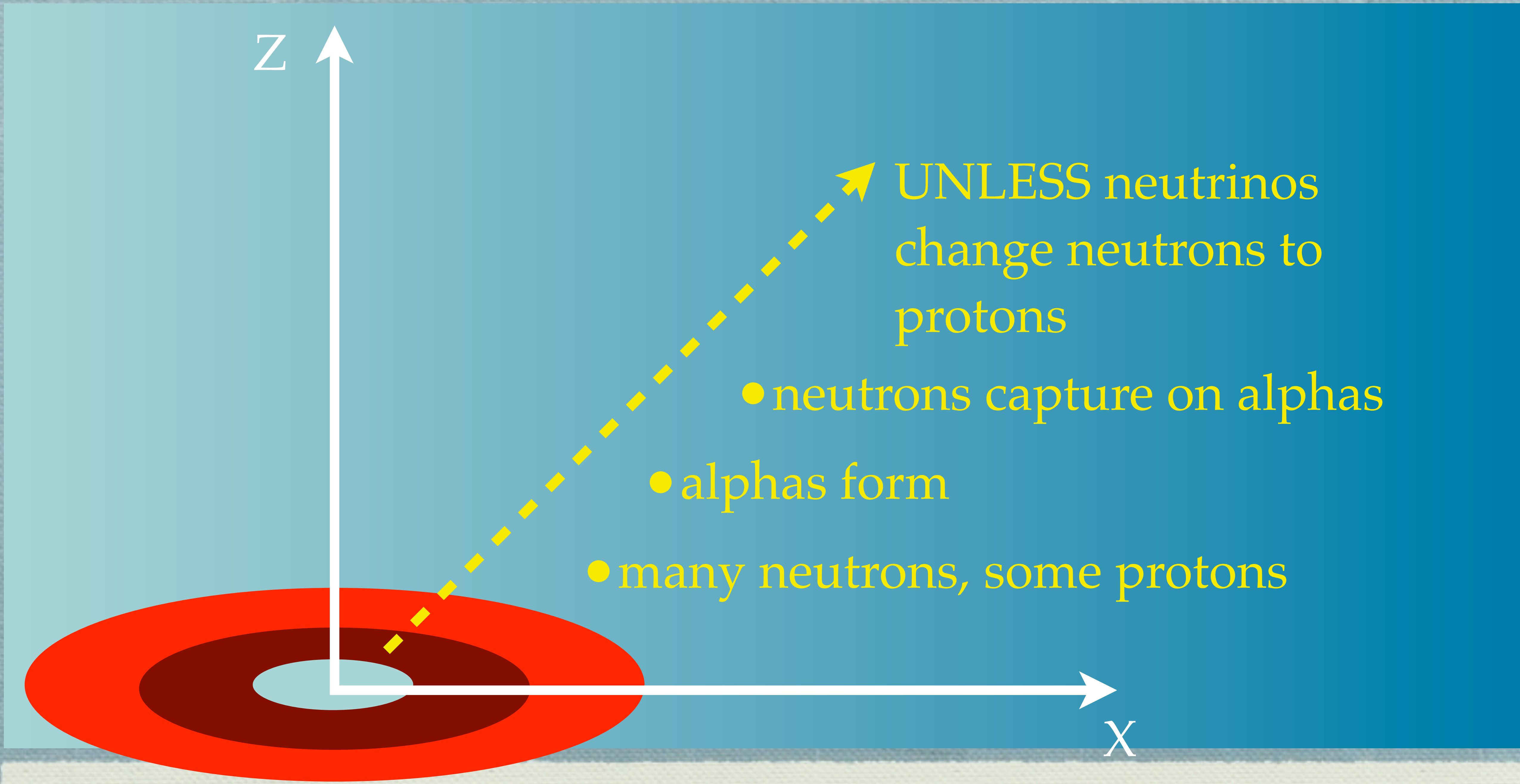

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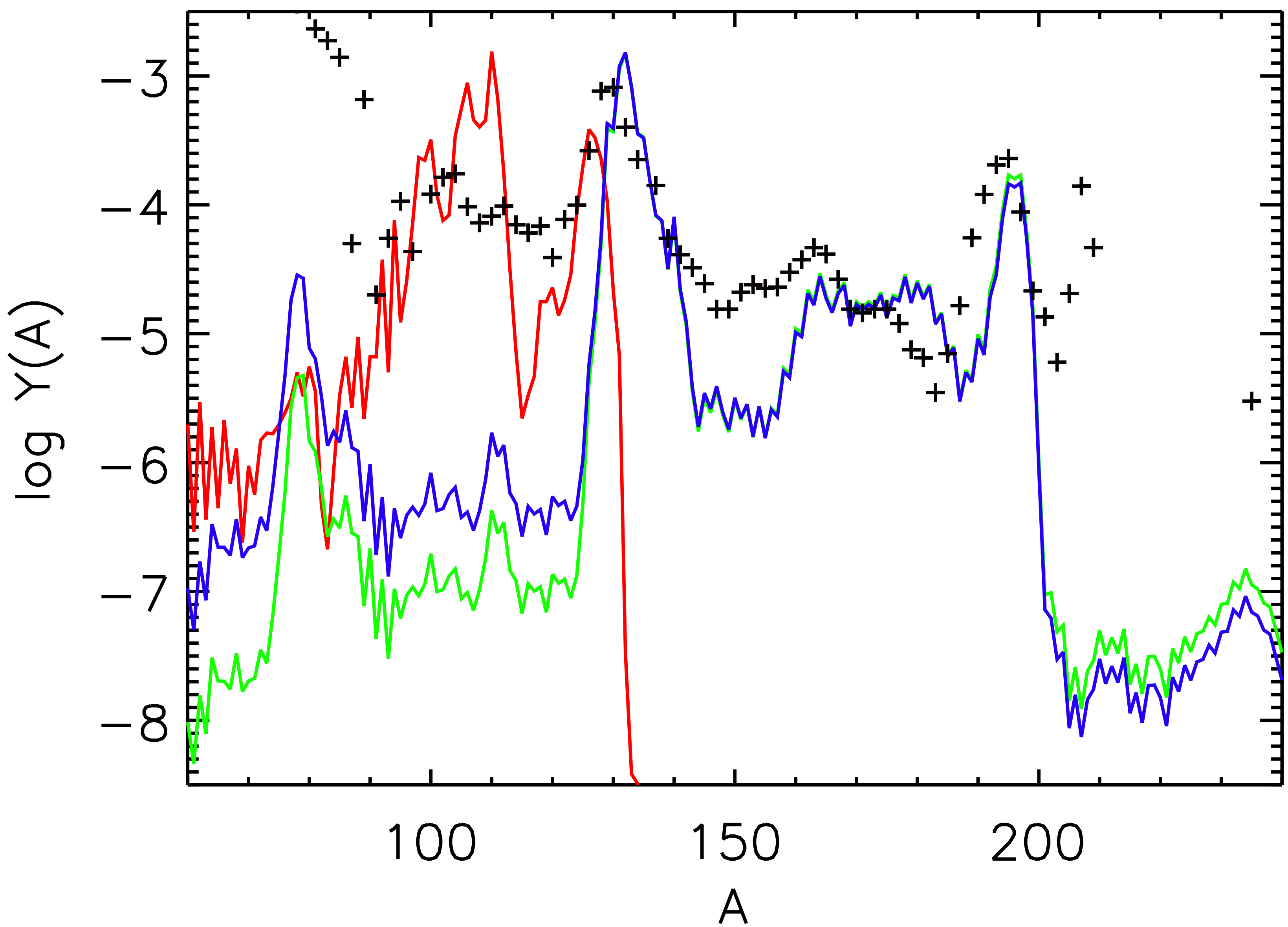
Malkus et al,
arxiv:1207.6648

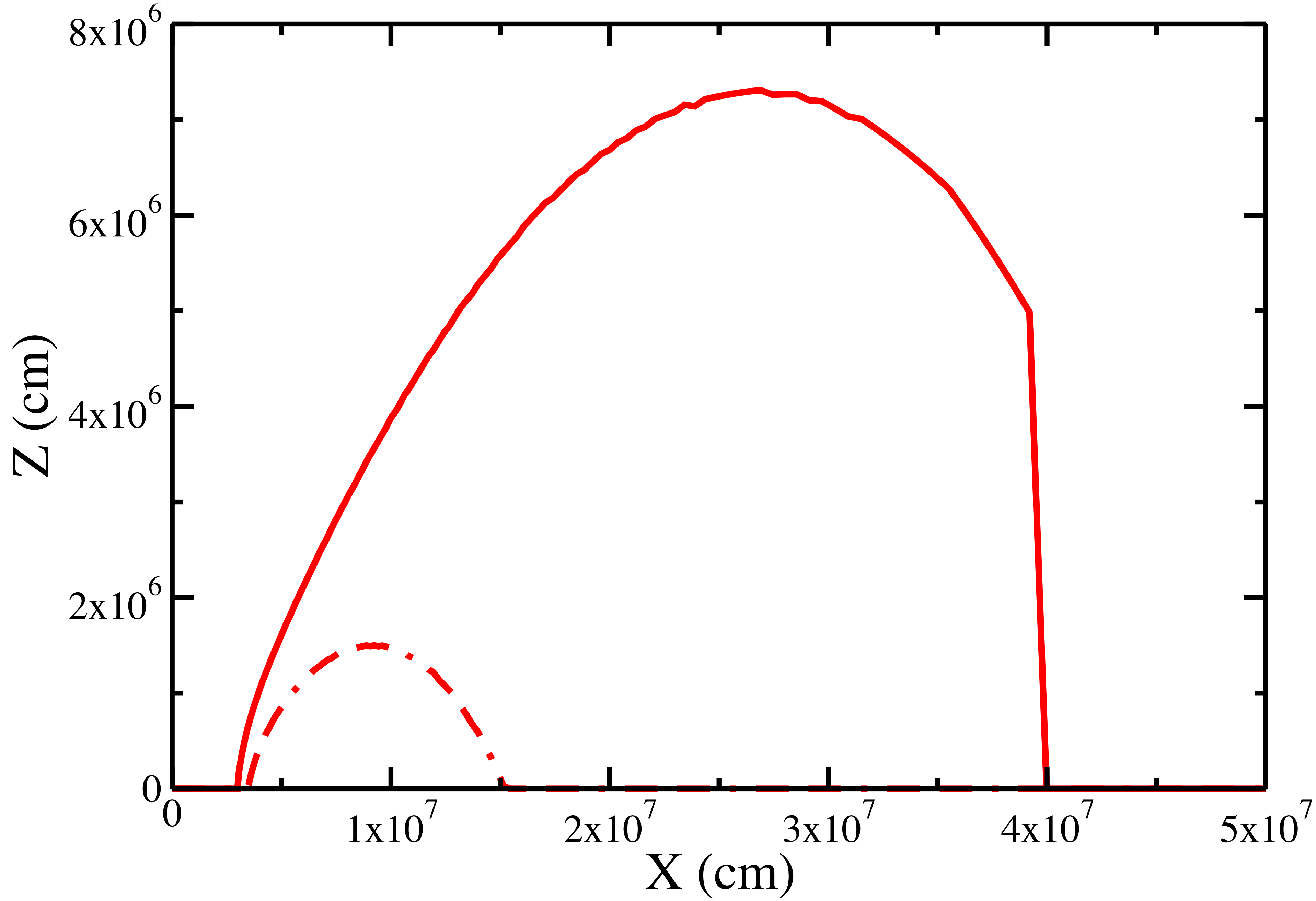


No Oscillation
Normal Hierarchy Oscillation
Neutrino Interactions Switched Off

r-Process

Conclusions and Comments

- Unique geometry of disks lends itself to varied neutrino oscillations
- Includes a new type of oscillation occurring when neutrino self-interactions cancel the matter term.
- The neutrino oscillations can have an impact on r-process



Decoupling Surface Heights