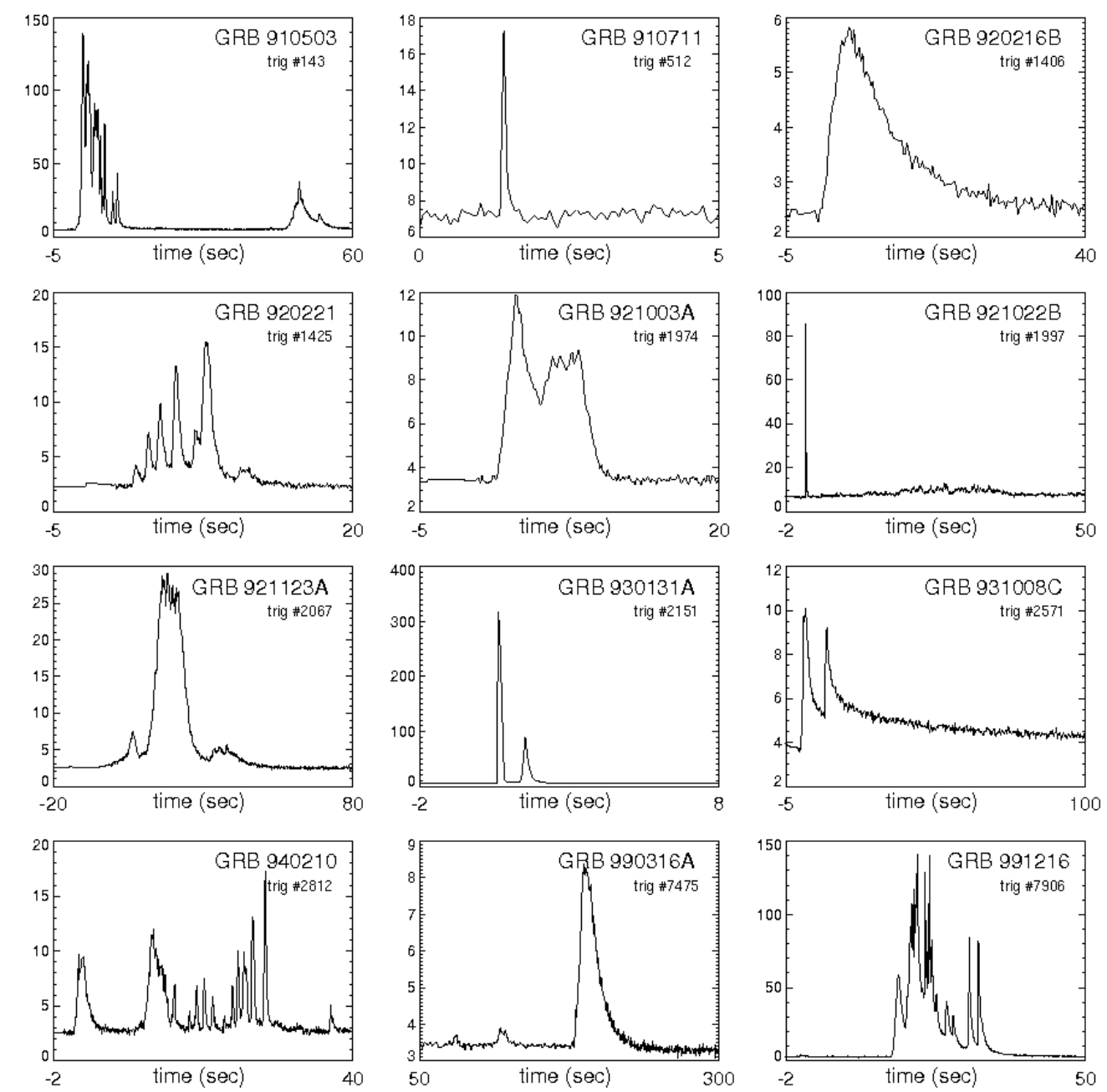


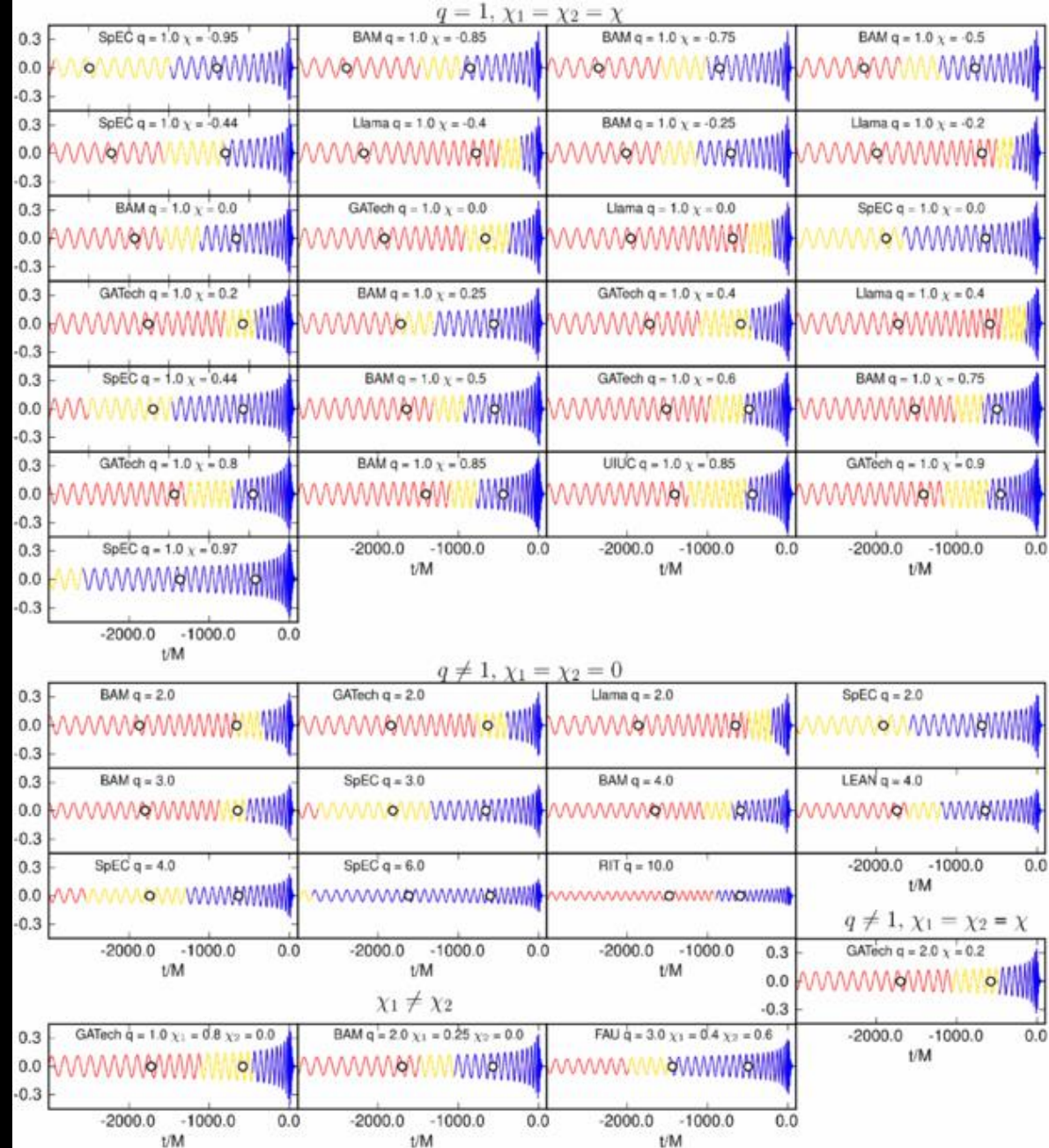
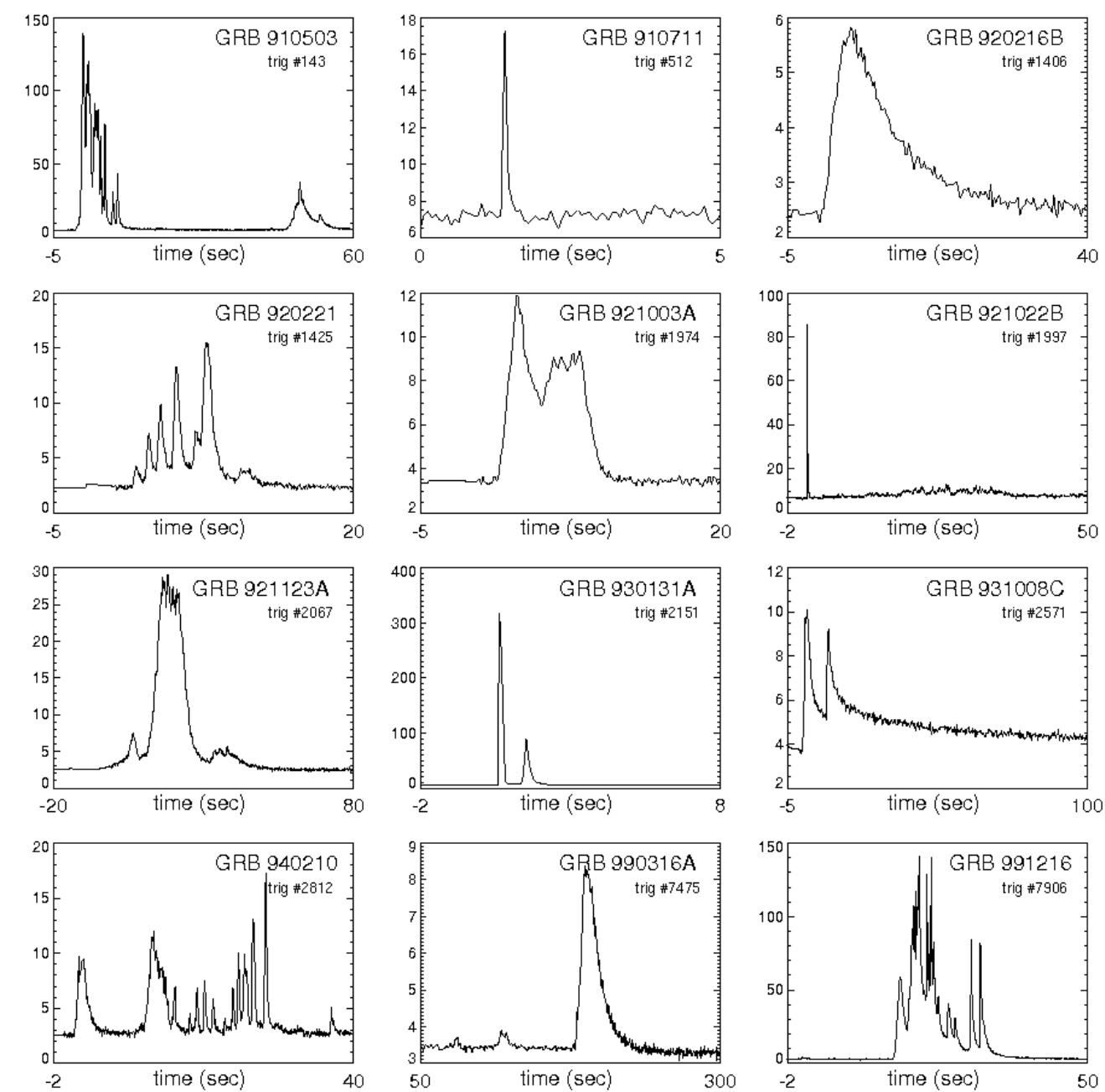
MONTE CARLO NEUTRINO TRANSPORT IN POST-MERGER DISKS

SHERWOOD RICHERS

DAN KASEN, EVAN O'CONNOR, RODRIGO FERNANDEZ, CHRISTIAN OTT

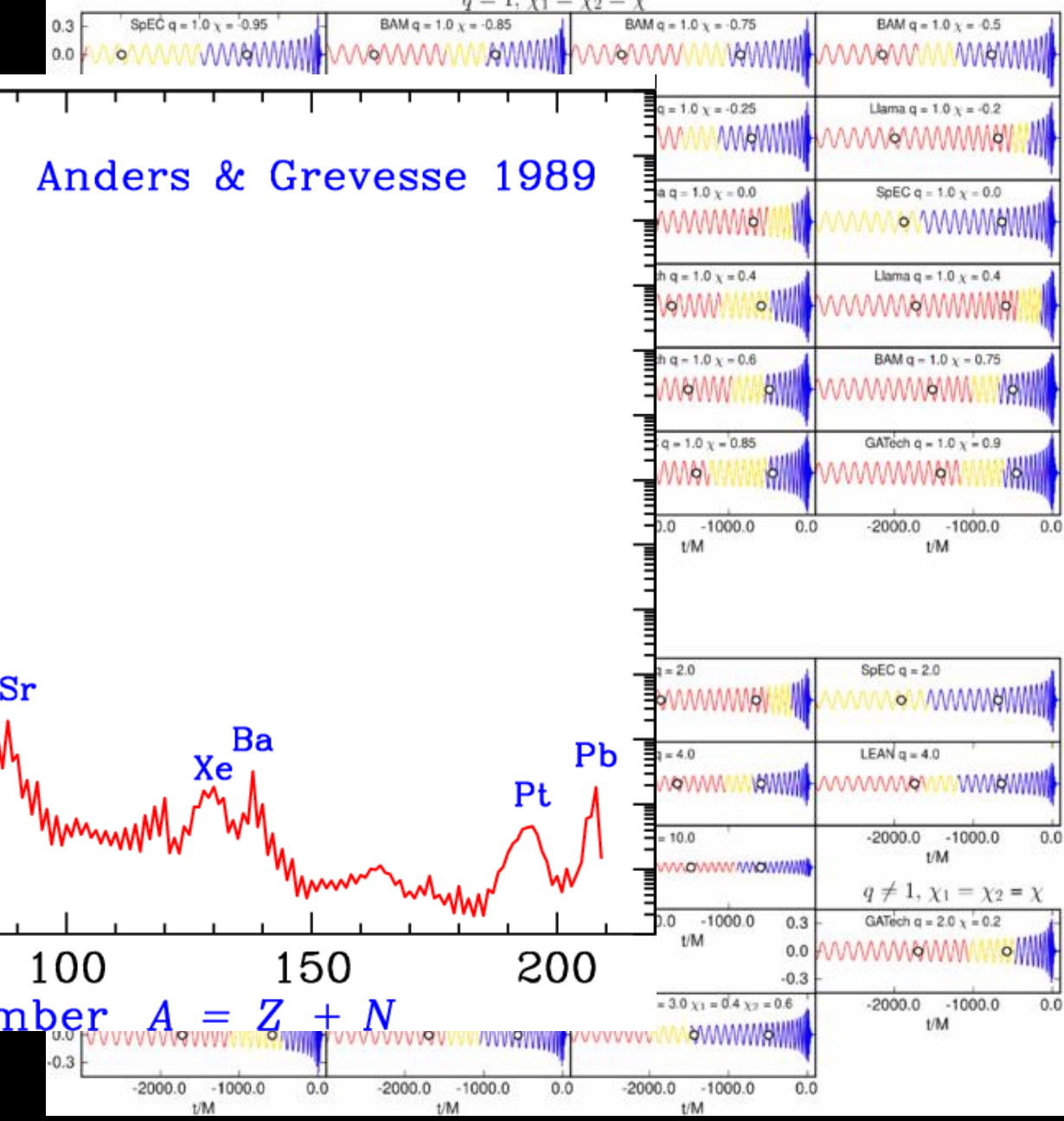
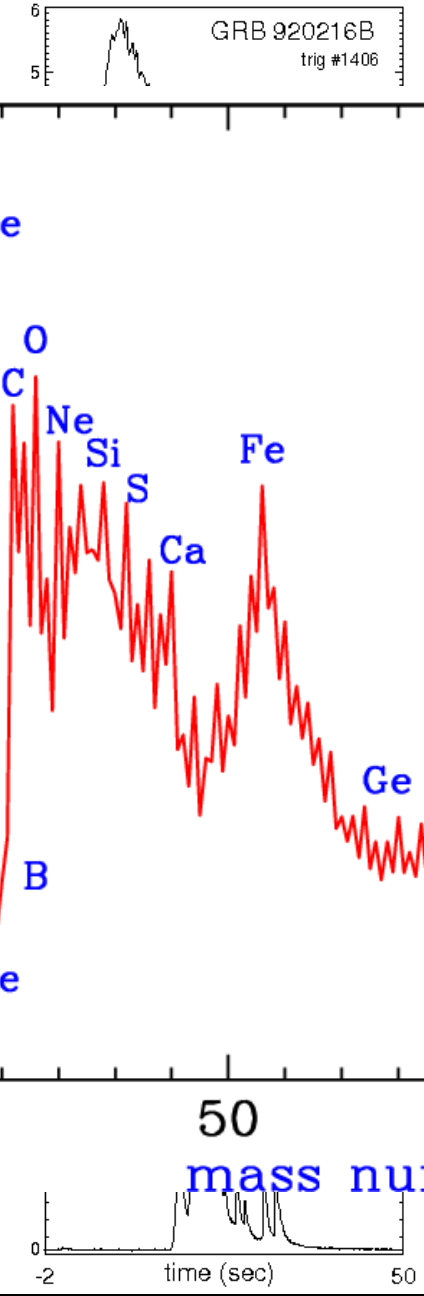
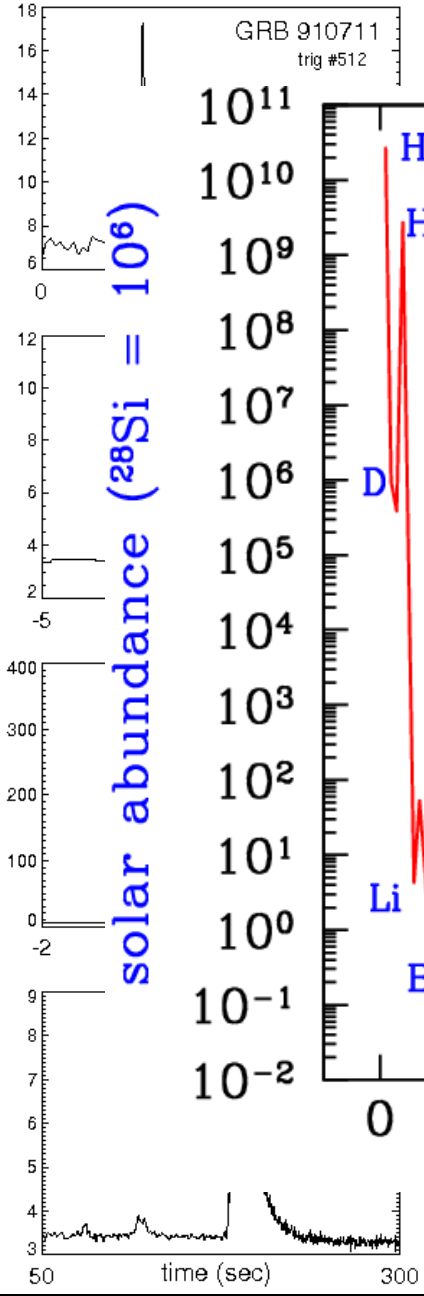
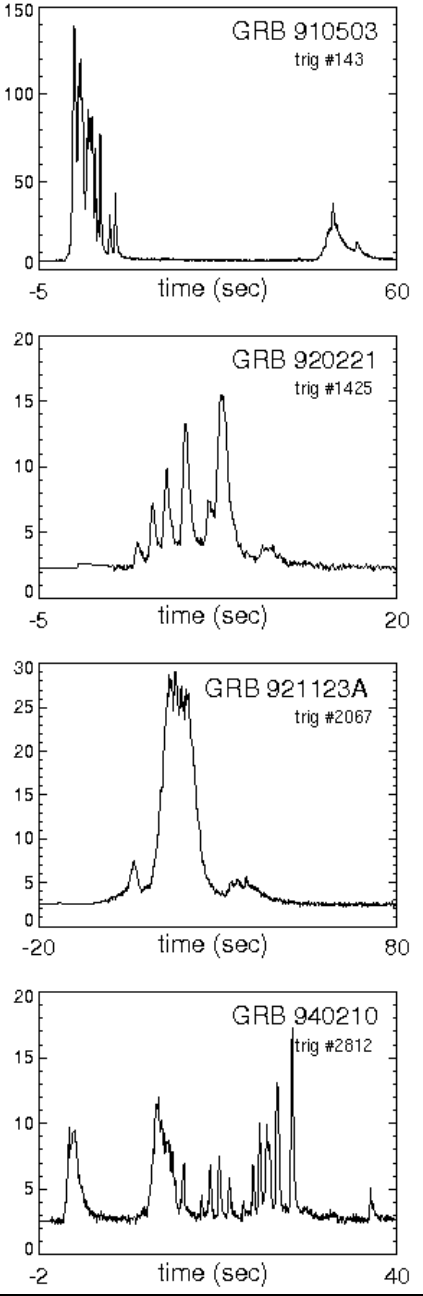


Daniel Perley



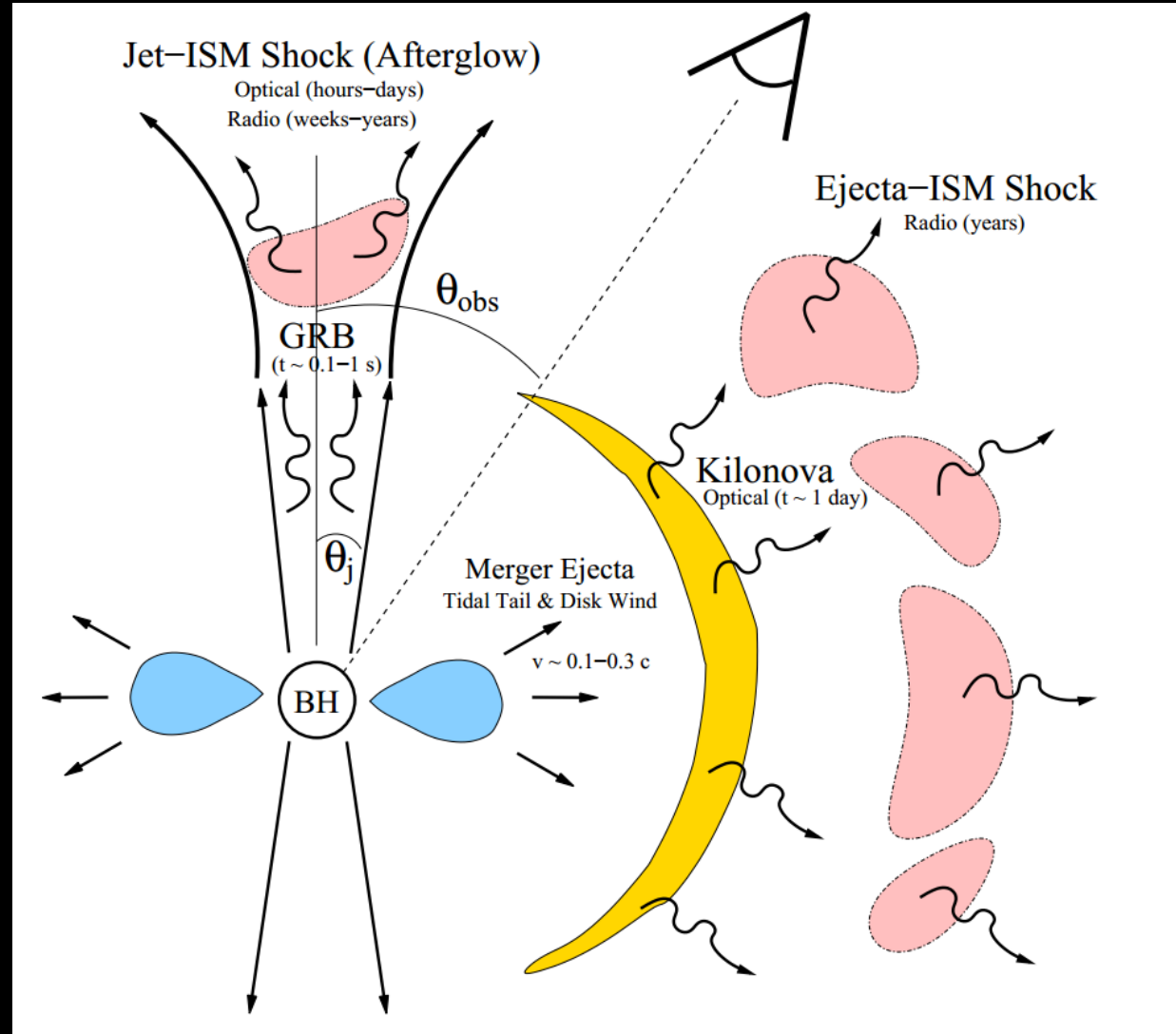
Daniel Perley

NINJA-2 Catalog



SHORT GRB

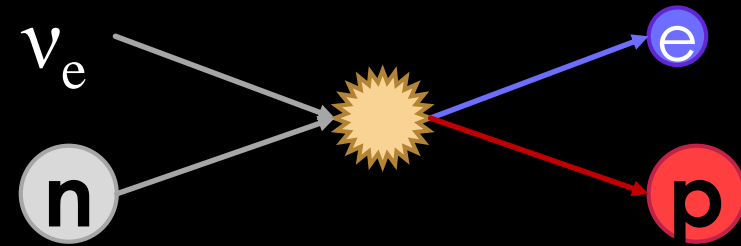
- MERGING COMPACT OBJECTS
(LEE & RAMIREZ-RUIZ 2007)
- COLLIMATED JET
 - $L_{iso} \approx 10^{53}$ ERG/S
(E.G. BLOOM+ 2003)
- DISK COOLS VIA NEUTRINOS
- $t_{diff} \ll t_{dyn}$



Metzger & Berger (2011)

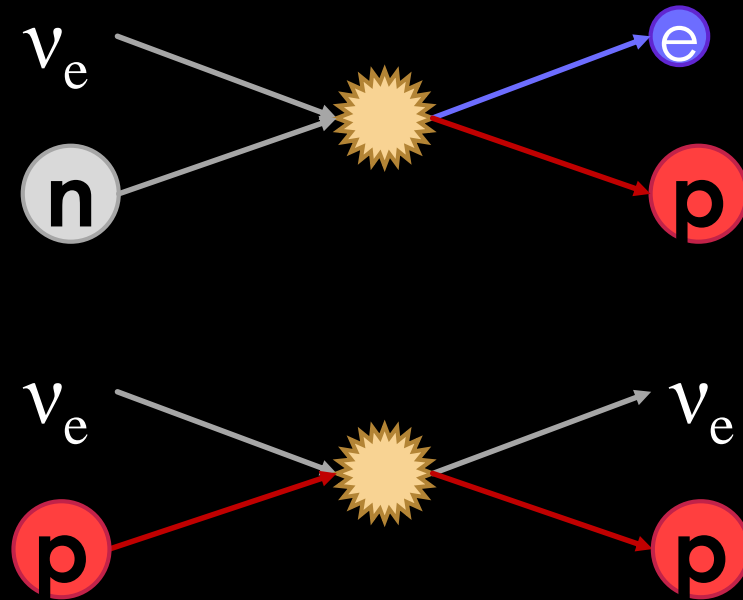
NEUTRINOS

- ABSORB/EMIT
 - DEPOSIT/EMIT ENERGY
 - CHANGE Y_E
- SCATTER
 - TRAP NEUTRINOS
 - REDISTRIBUTE ENERGY
- ANNIHILATE/EMIT
 - DEPOSIT/EMIT ENERGY



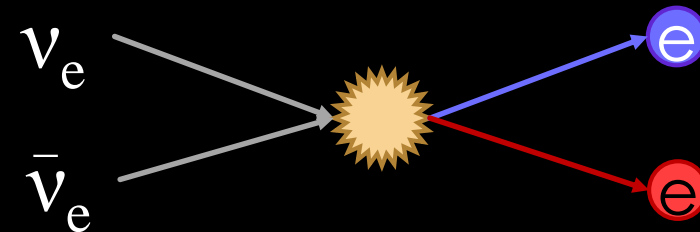
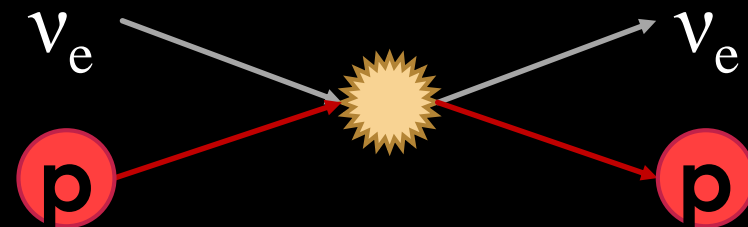
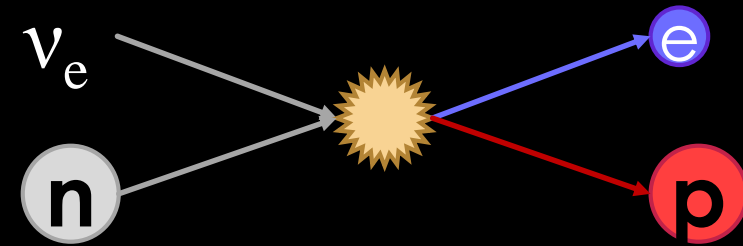
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NEUTRINOS

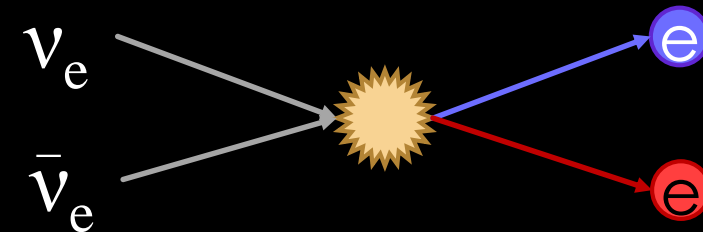
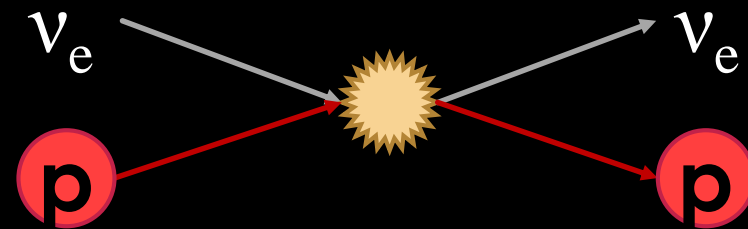
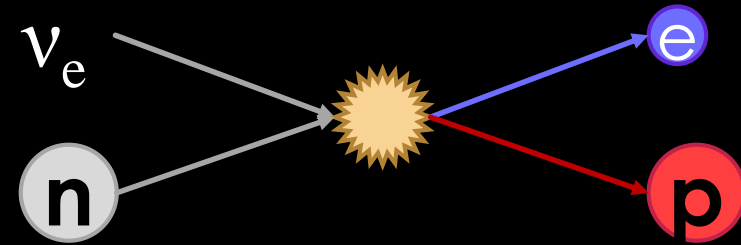
- ABSORB/EMIT
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NEUTRINOS

- ABSORB/EMIT
 - DEPOSIT/EMIT ENERGY
 - CHANGE Y_E
- SCATTER
 - TRAP NEUTRINOS
 - REDISTRIBUTE ENERGY
- ANNIHILATE/EMIT
 - DEPOSIT/EMIT ENERGY

{ignoring oscillations}



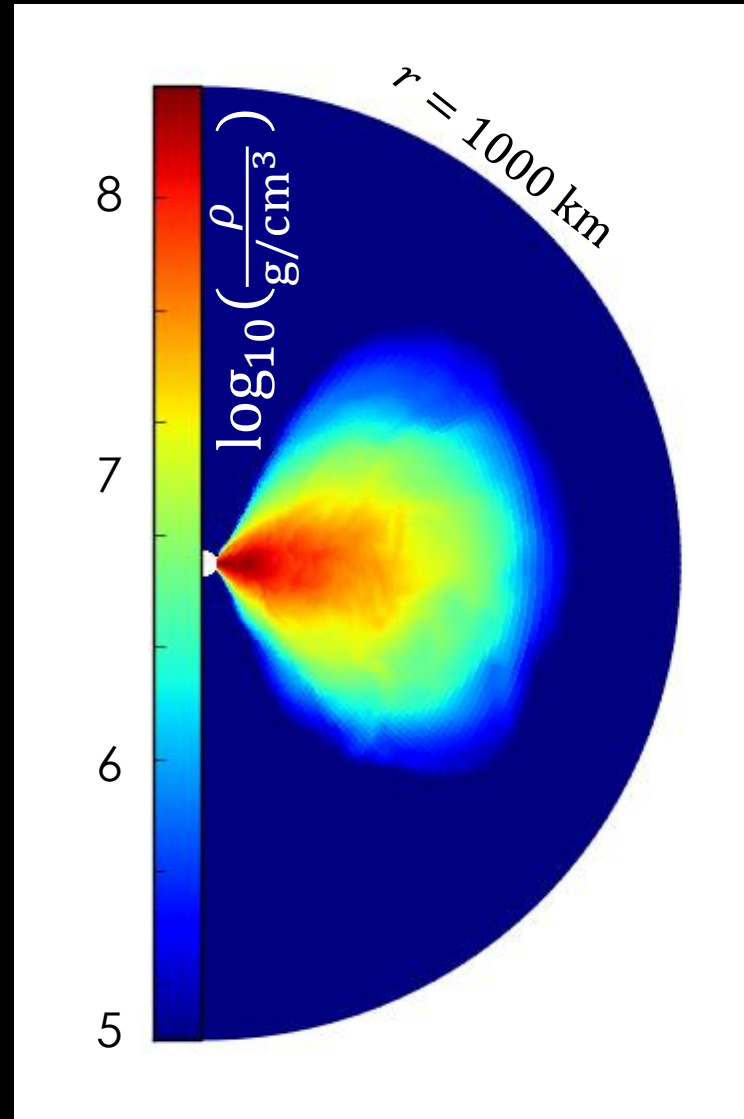
HOW TO MOVE NEUTRINOS

SEDONU + NULIB

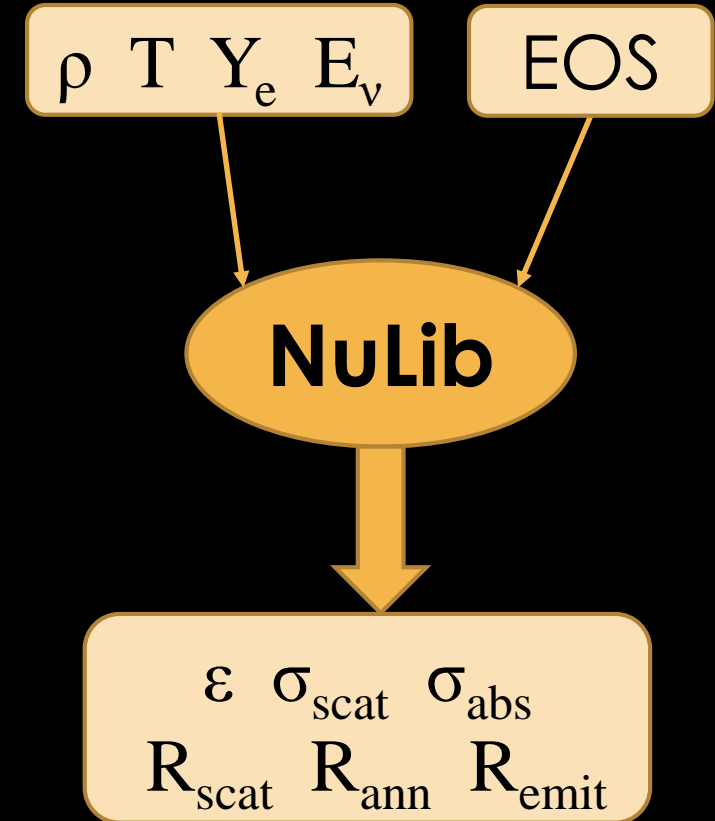
- 1) TAKE FLUID SNAPSHOT
- 2) EMIT
- 3) PROPAGATE
- 4) SCATTER AND ABSORB
- 5) CALCULATE:

- TIMESCALES
- ANNIHILATION RATES

Open-source!



data: Metzger & Fernandez (2014)

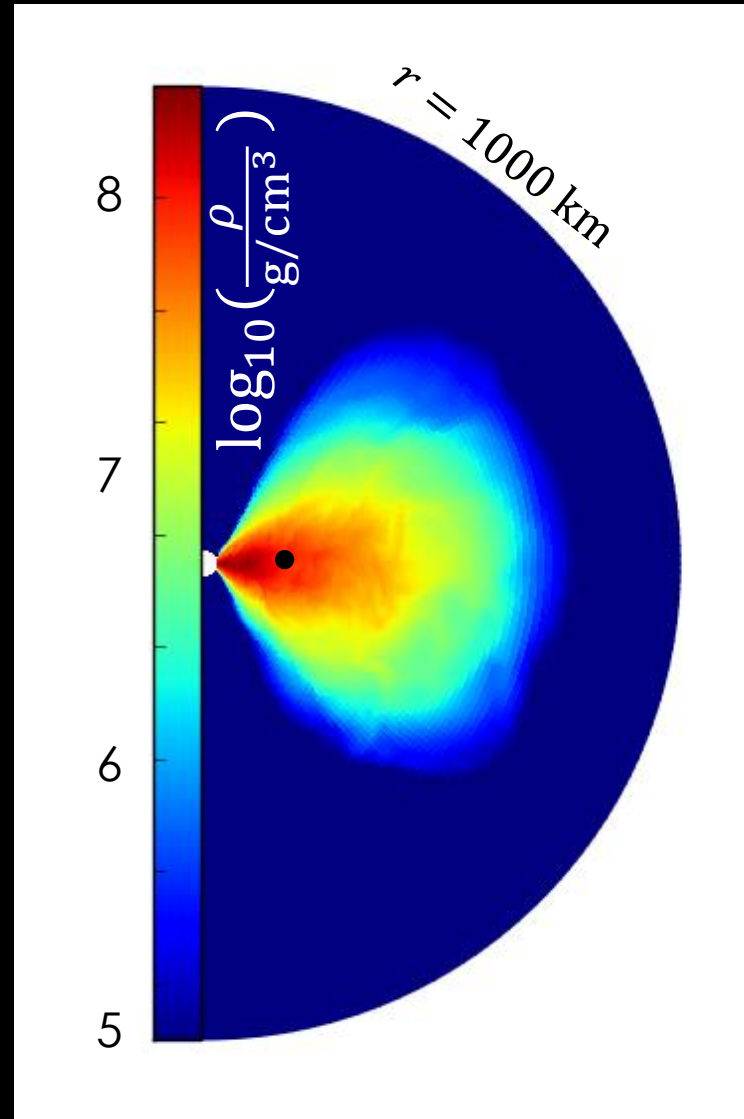


SEDONU + NULIB

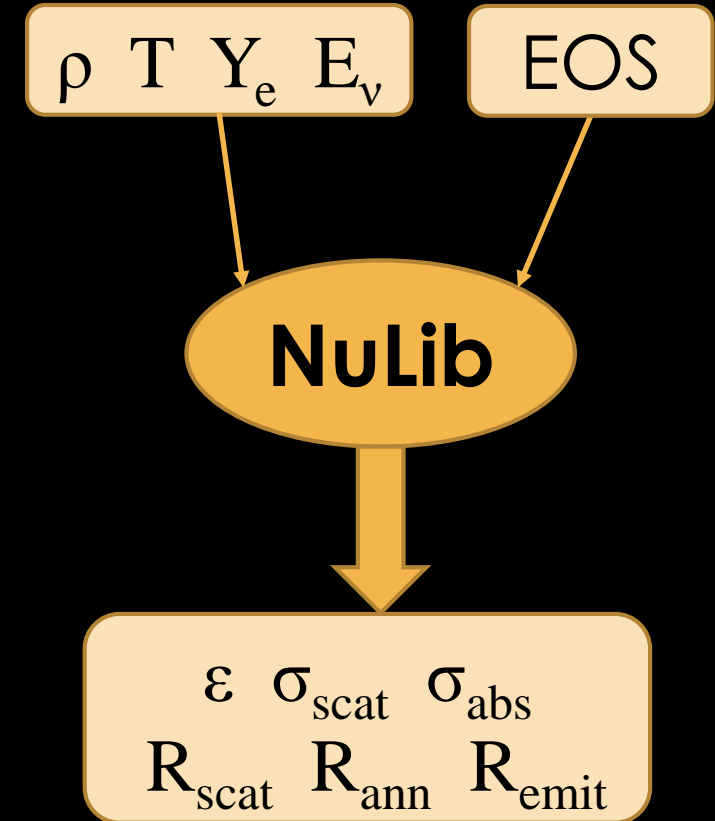
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Open-source!



data: Metzger & Fernandez (2014)

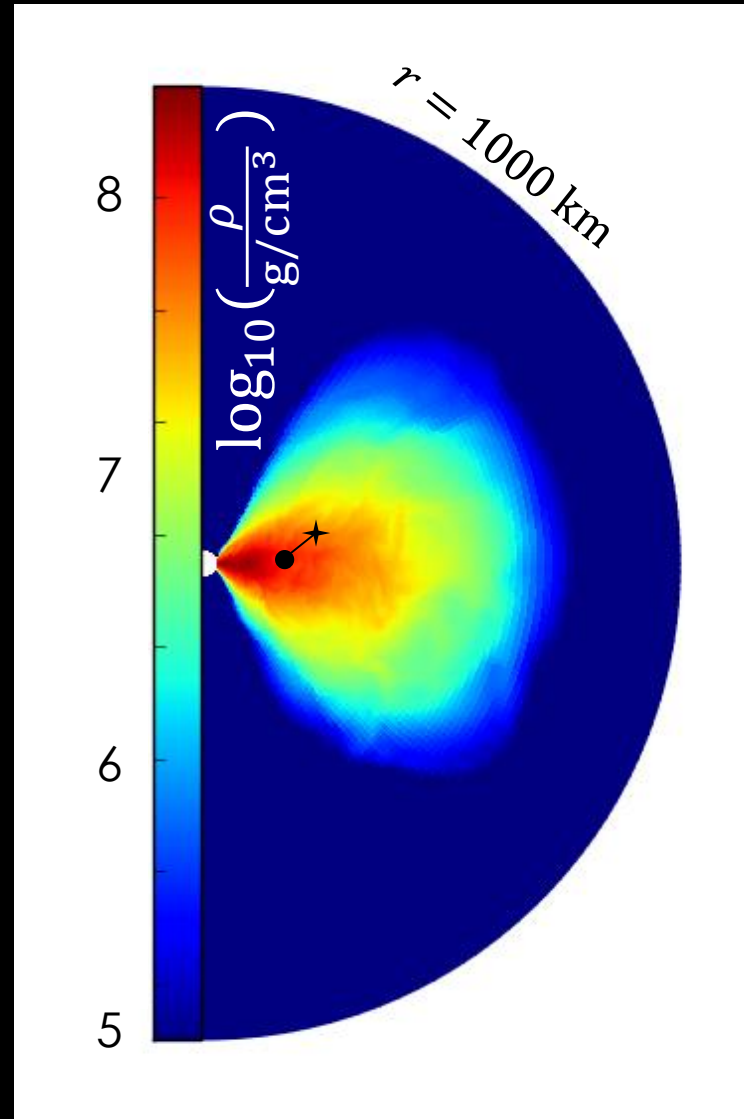


SEDONU + NULIB

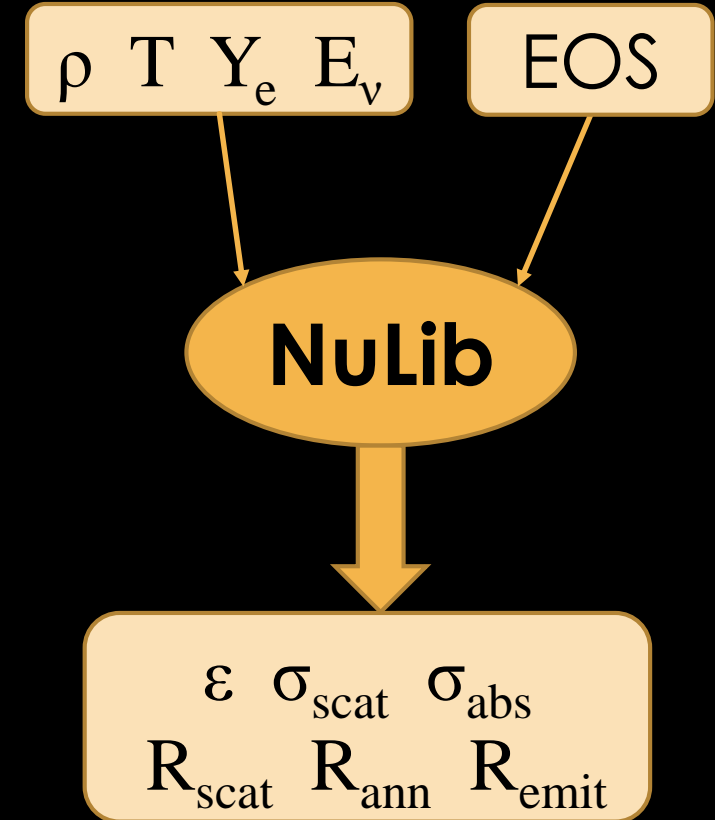
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Open-source!



data: Metzger & Fernandez (2014)

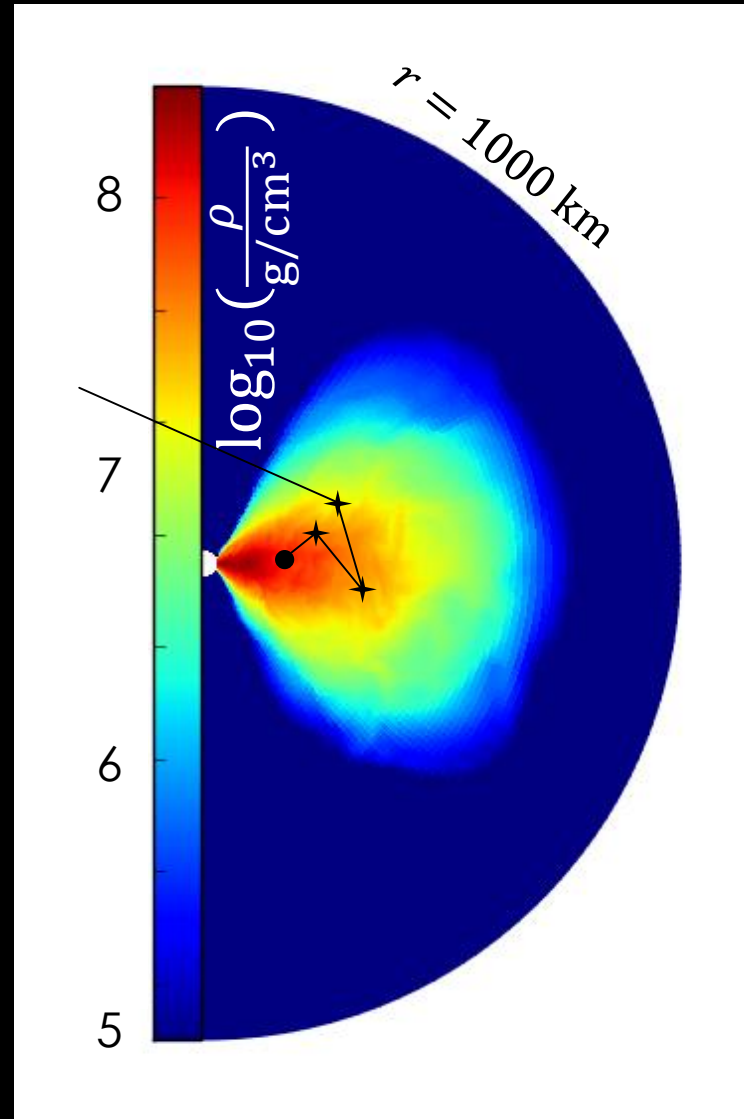


SEDONU + NULIB

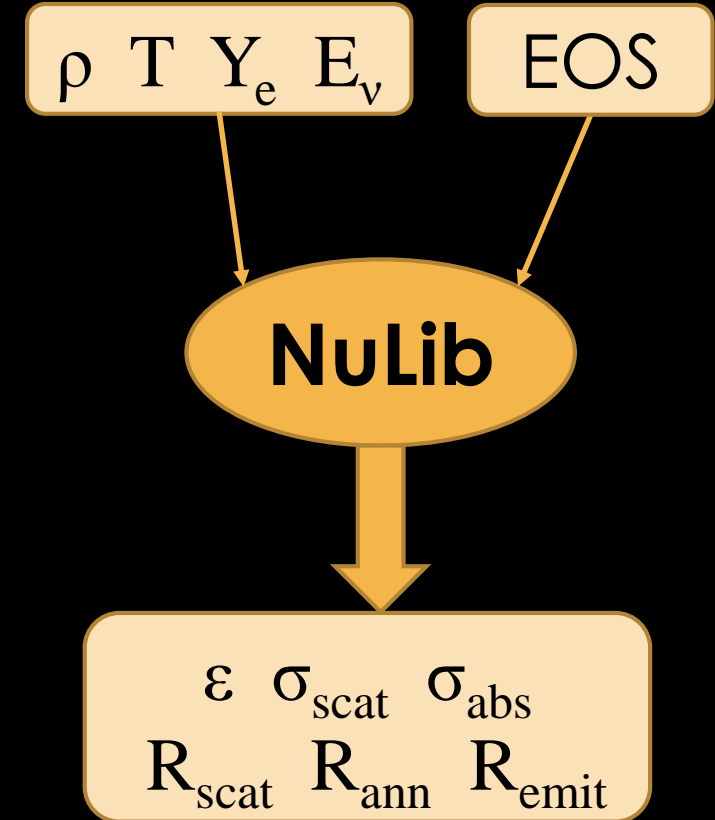
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Open-source!



data: Metzger & Fernandez (2014)

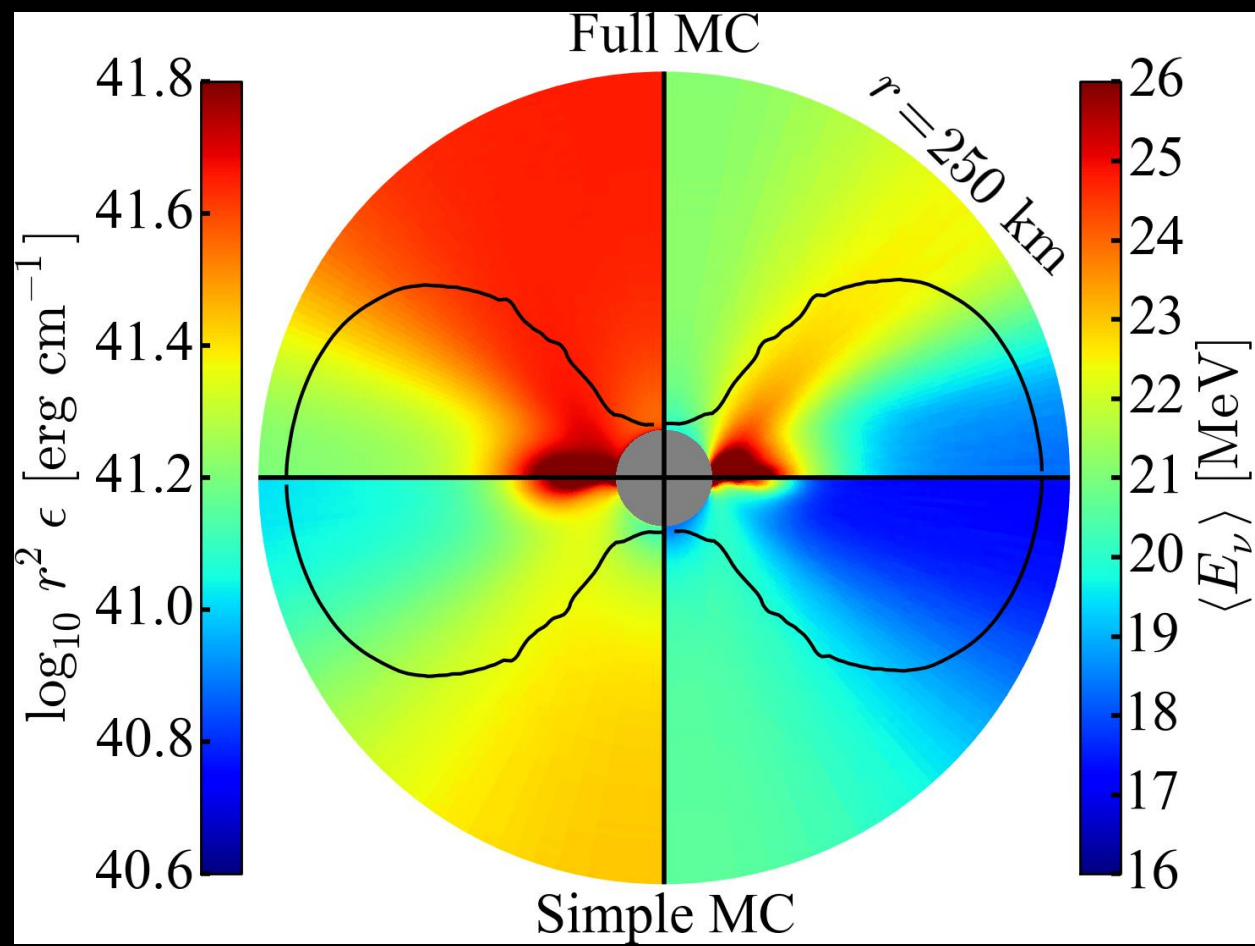
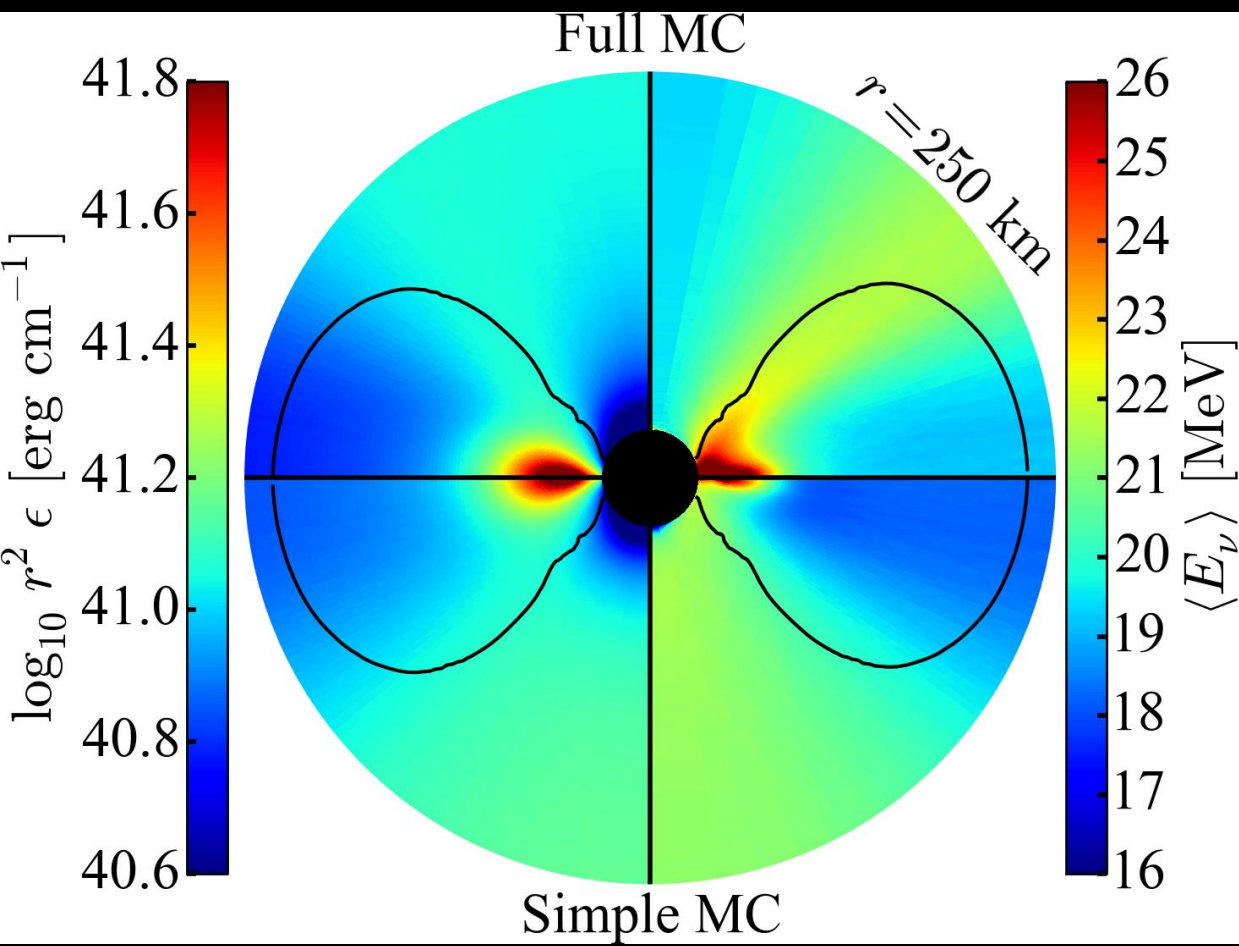


HOW DO NEUTRINOS LOOK?

ASYMMETRIC NEUTRINO RADIATION

BH

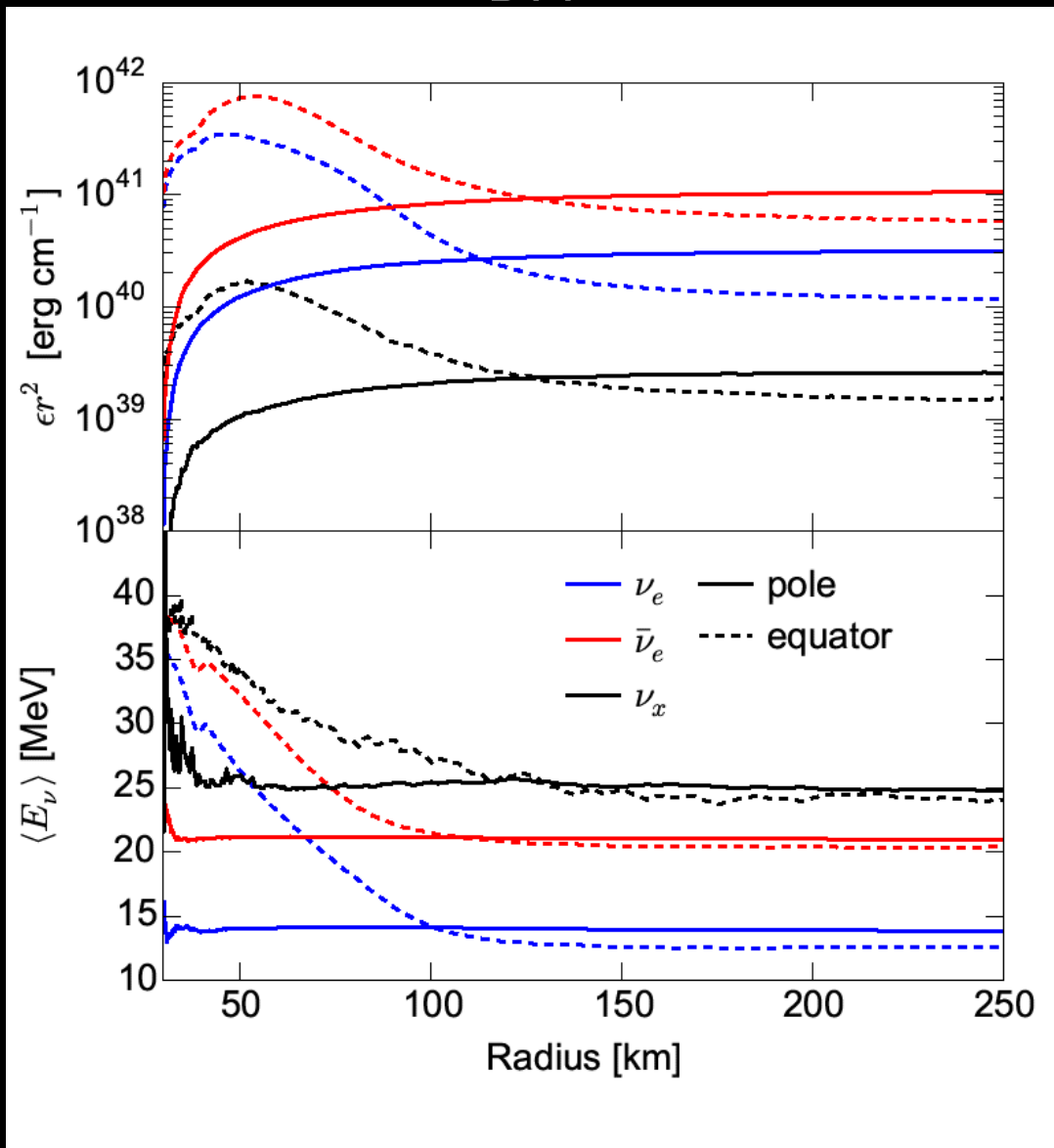
HMNS



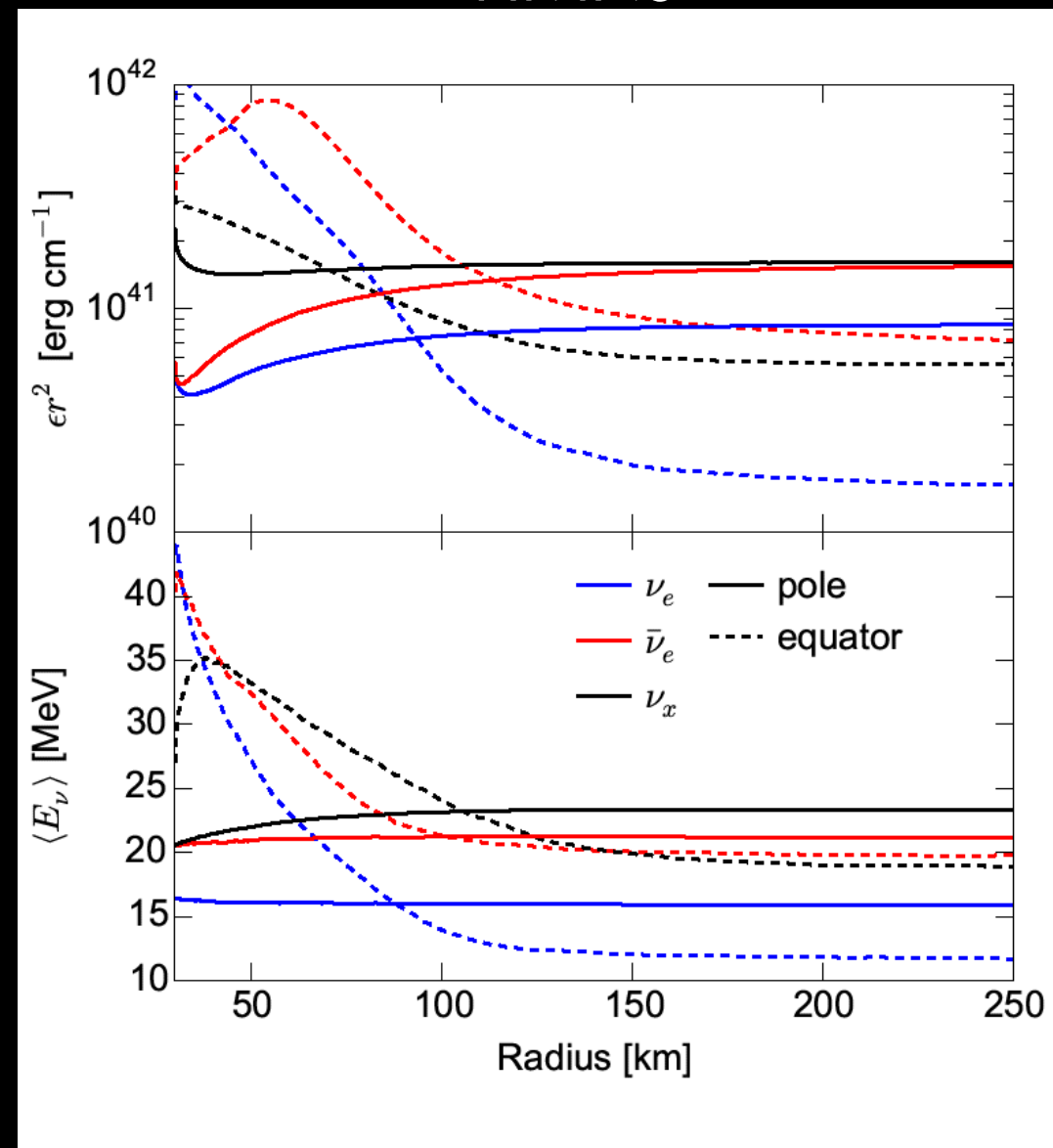
Special relativity beams and hardens neutrinos

ASYMMETRIC NEUTRINO RADIATION

BH

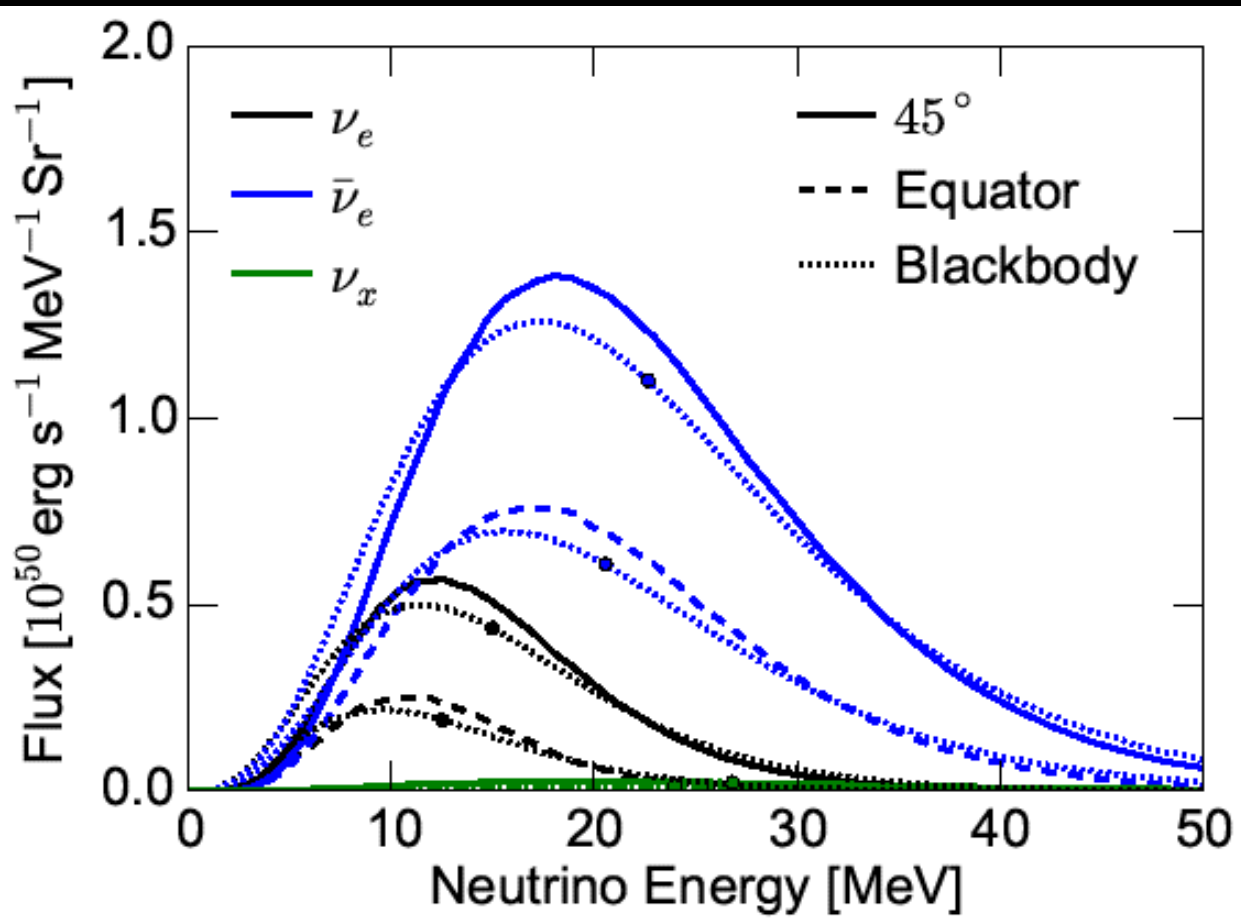


HMNS

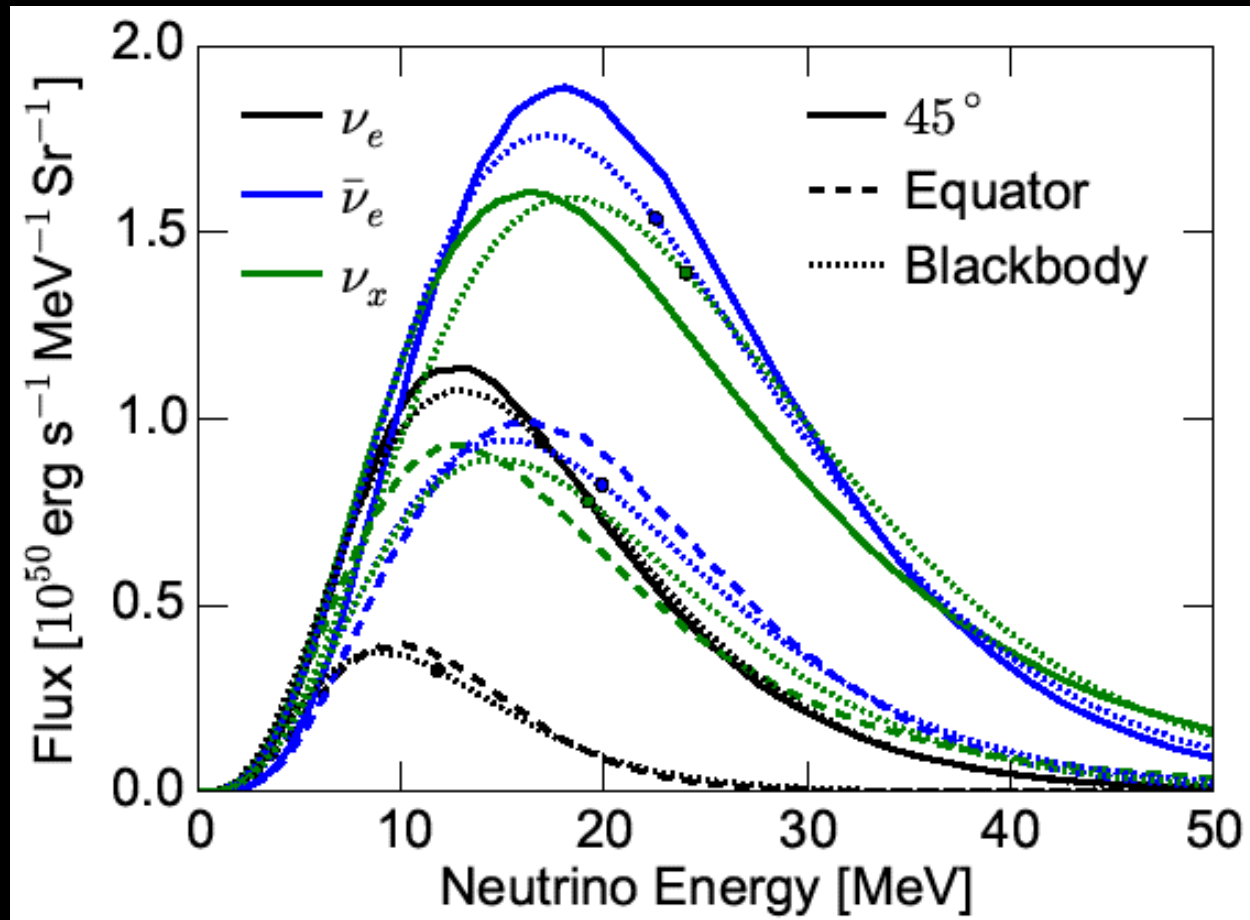


SPECTRA

BH



HMNS



Escape spectra are not quite blackbody.

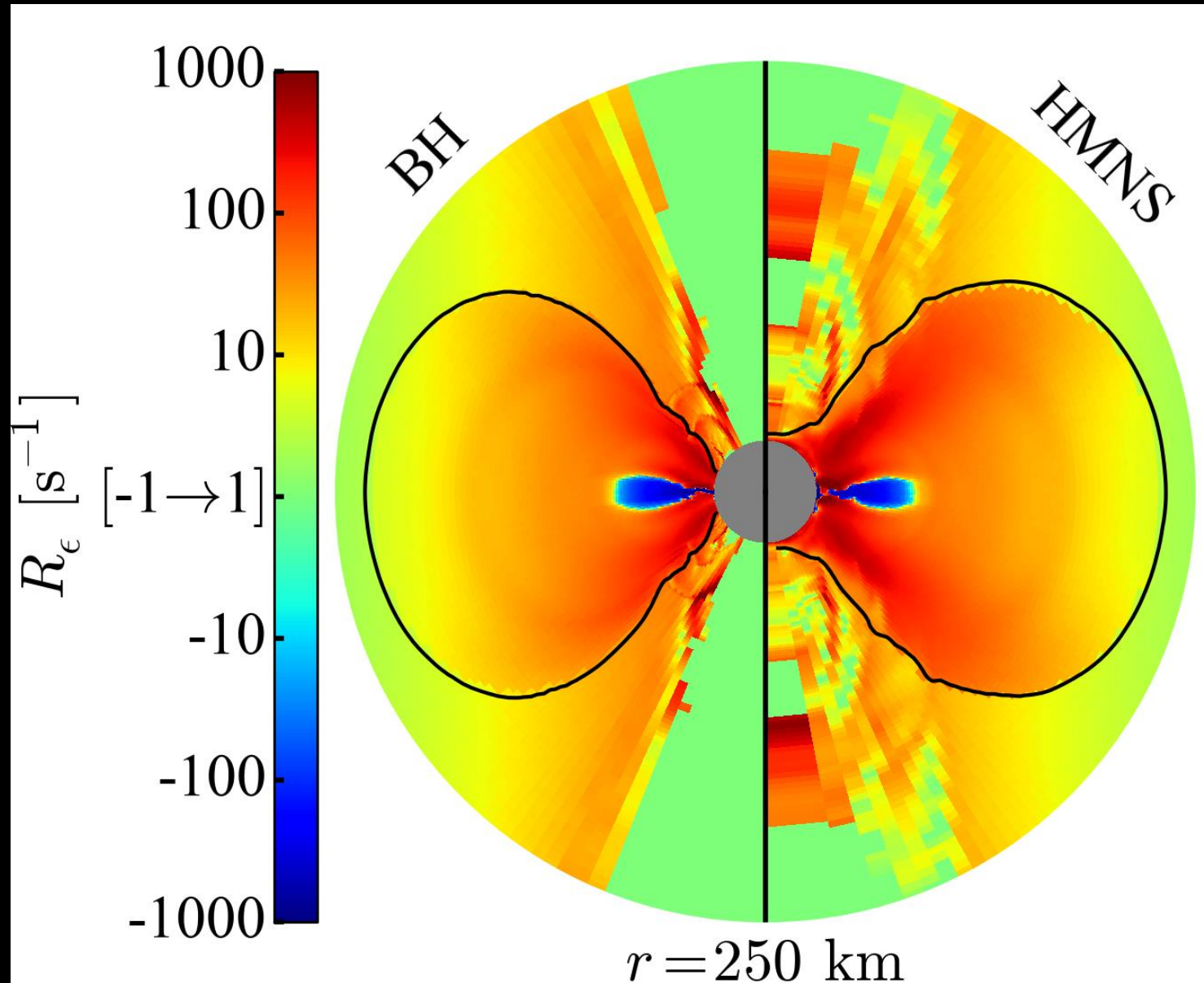
WHAT DO NEUTRINOS DO?

HEATING/COOLING RATE

$$R_\epsilon = \frac{1}{\epsilon} \frac{d\epsilon}{dt}$$

Neutrinos cool equator

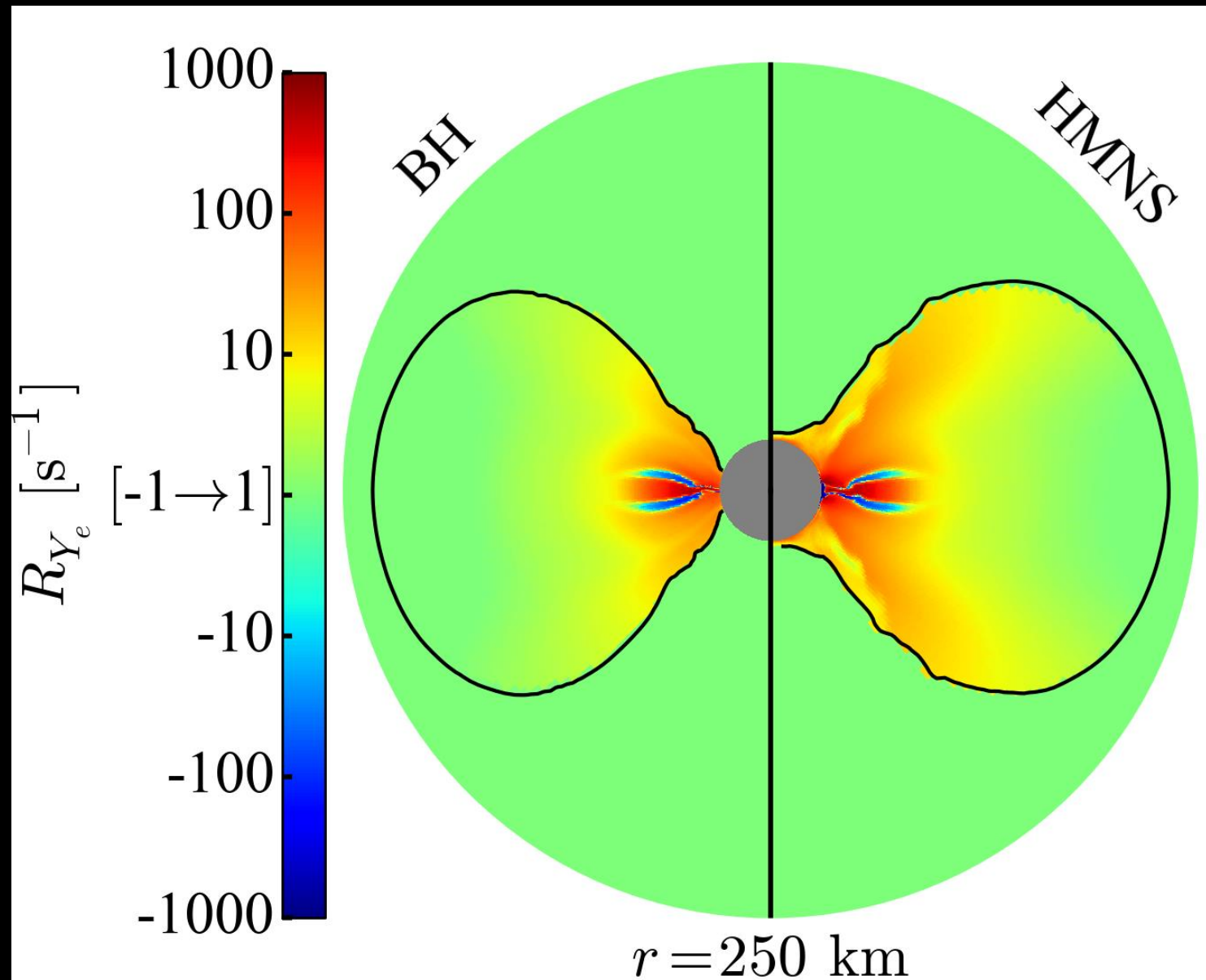
And heat above disk



LEPTONIZATION RATE

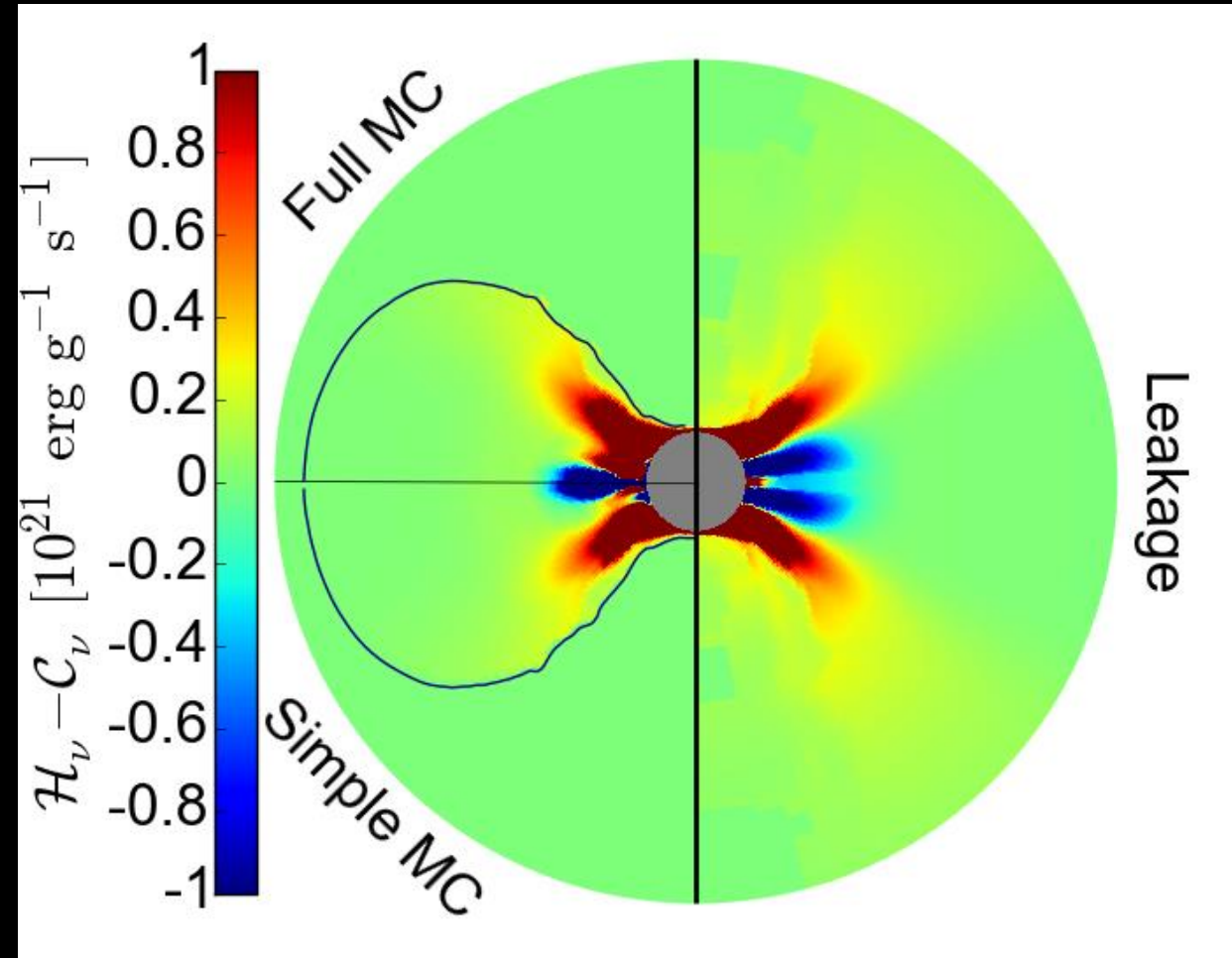
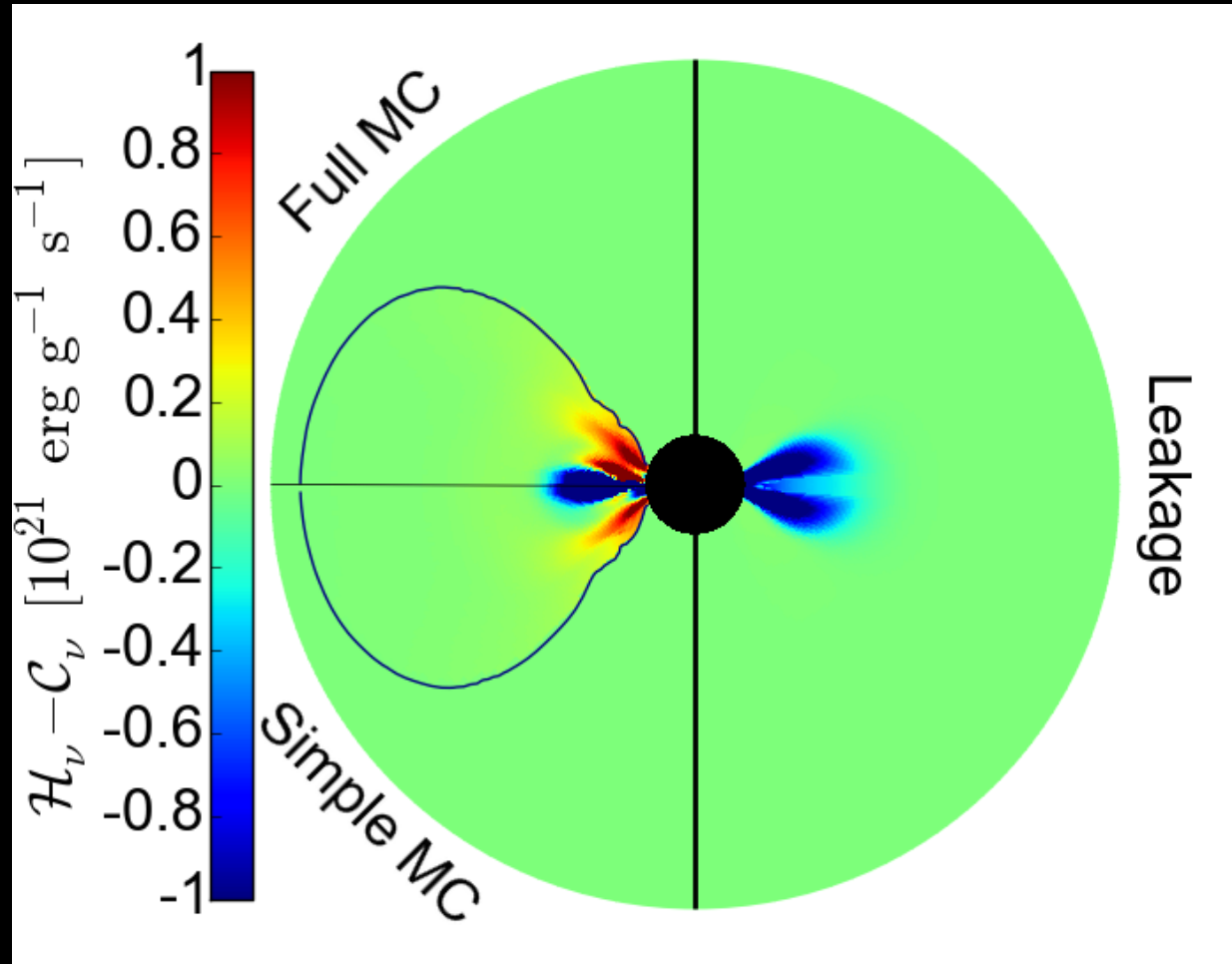
$$R_{Y_e} = \frac{dY_e}{dt}$$

Neutrinos raise
Electron fraction



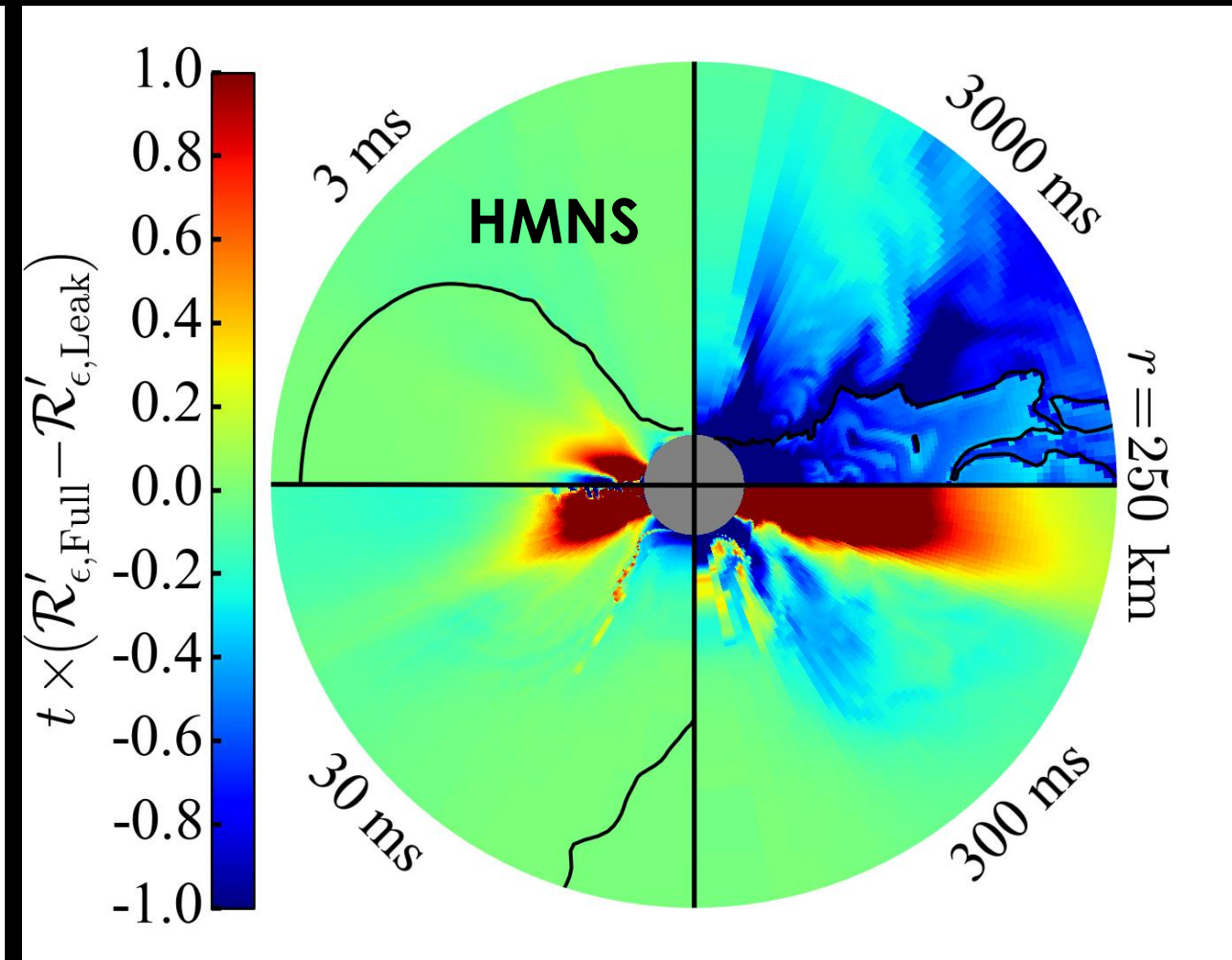
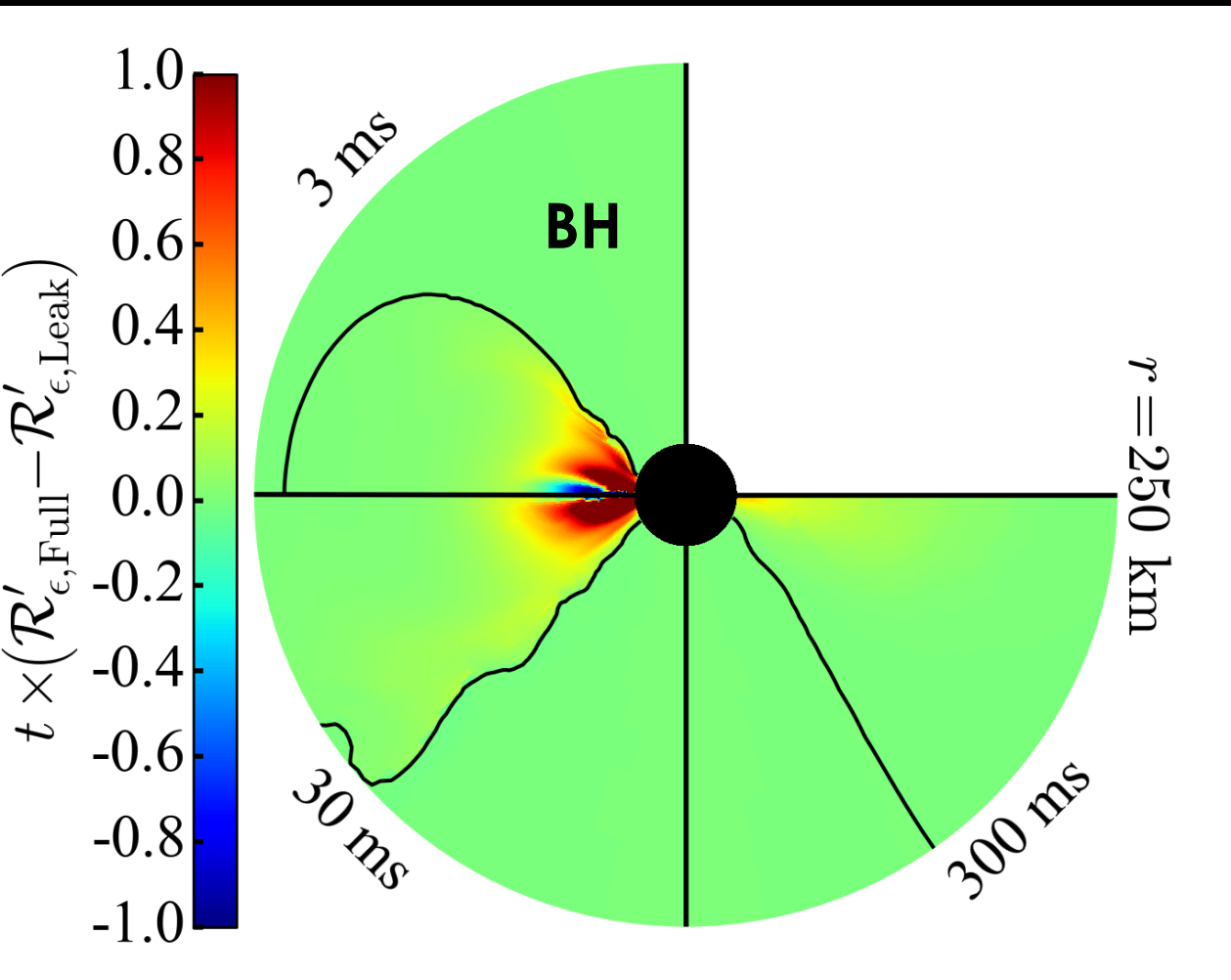
DOES LEAKAGE SUCK?

COMPARISON TO LEAKAGE



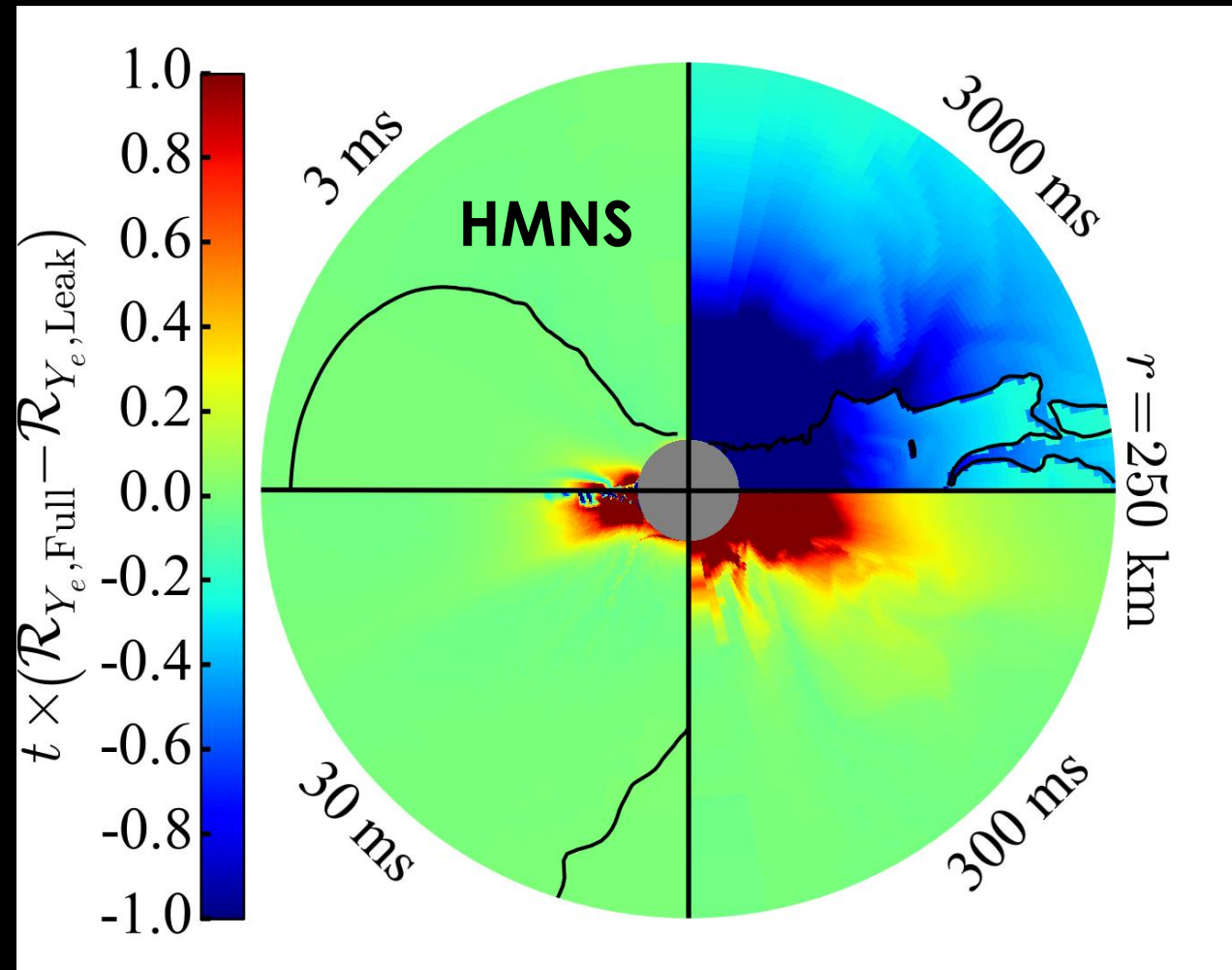
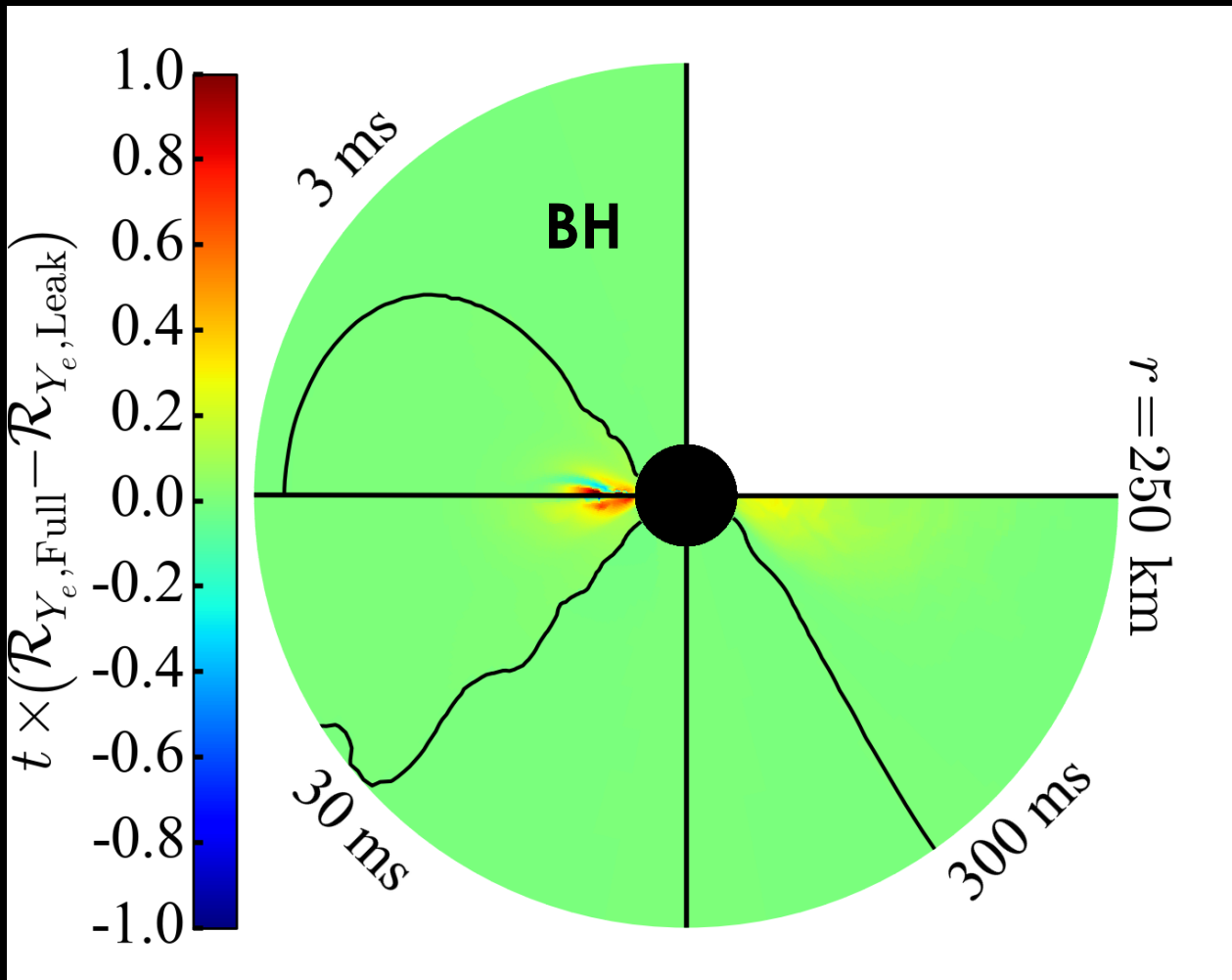
10^{20} erg/g binding energy \rightarrow stronger outflows

COMPARISON TO LEAKAGE



MC neutrinos escape more easily

COMPARISON TO LEAKAGE



MC neutrinos escape more easily

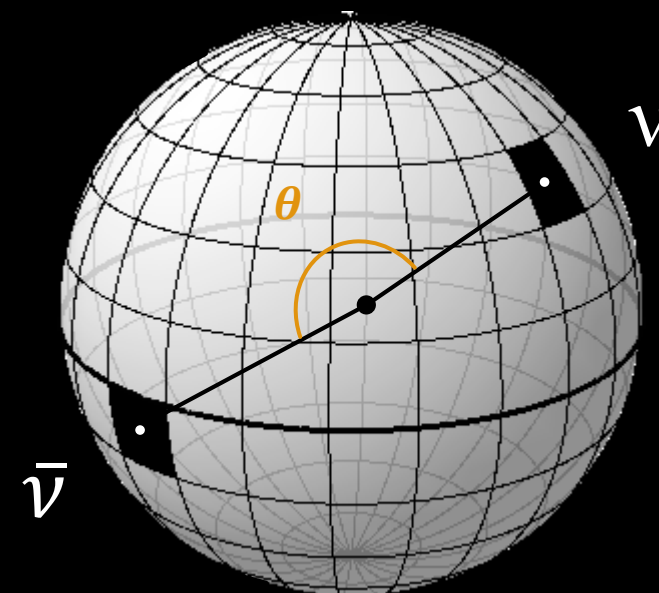
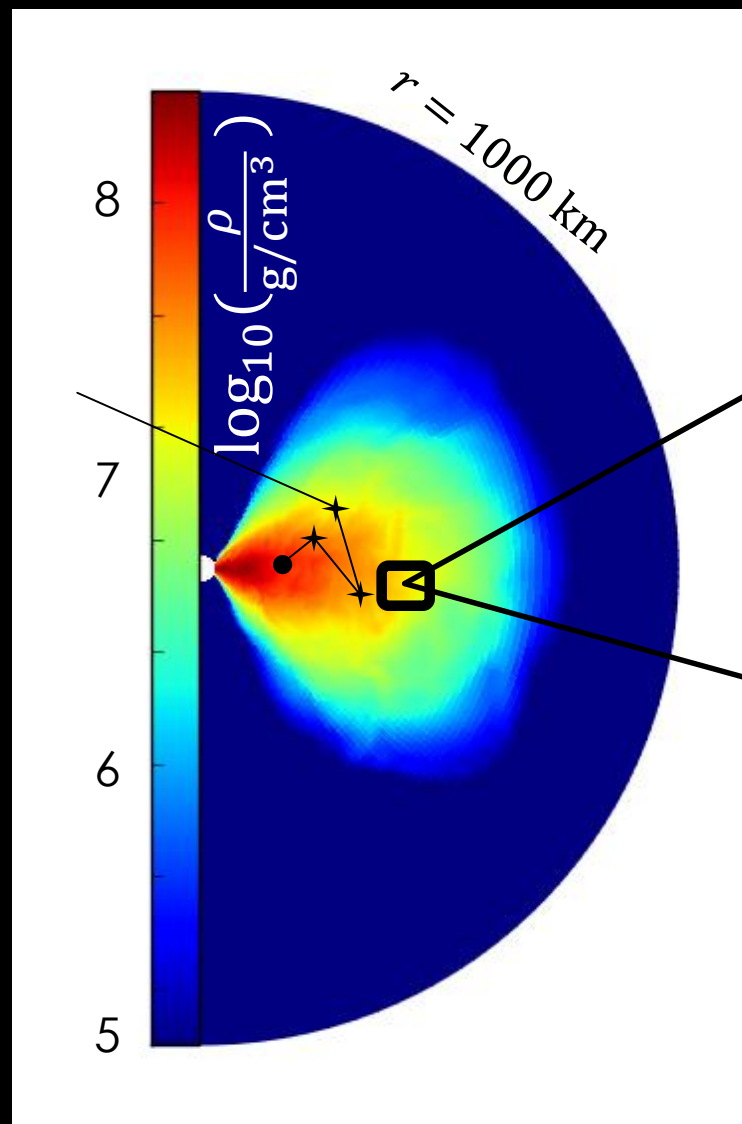
CAN NEUTRINOS POWER A
JET?

ANNIHILATION

- STRONG ANGULAR DEPENDENCE
- ALL SPECIES PARTICIPATE

$$dQ^+ \sim I\bar{I} (E + \bar{E})(1 - \cos \theta)^2 dE d\bar{E} d\Omega d\bar{\Omega}$$

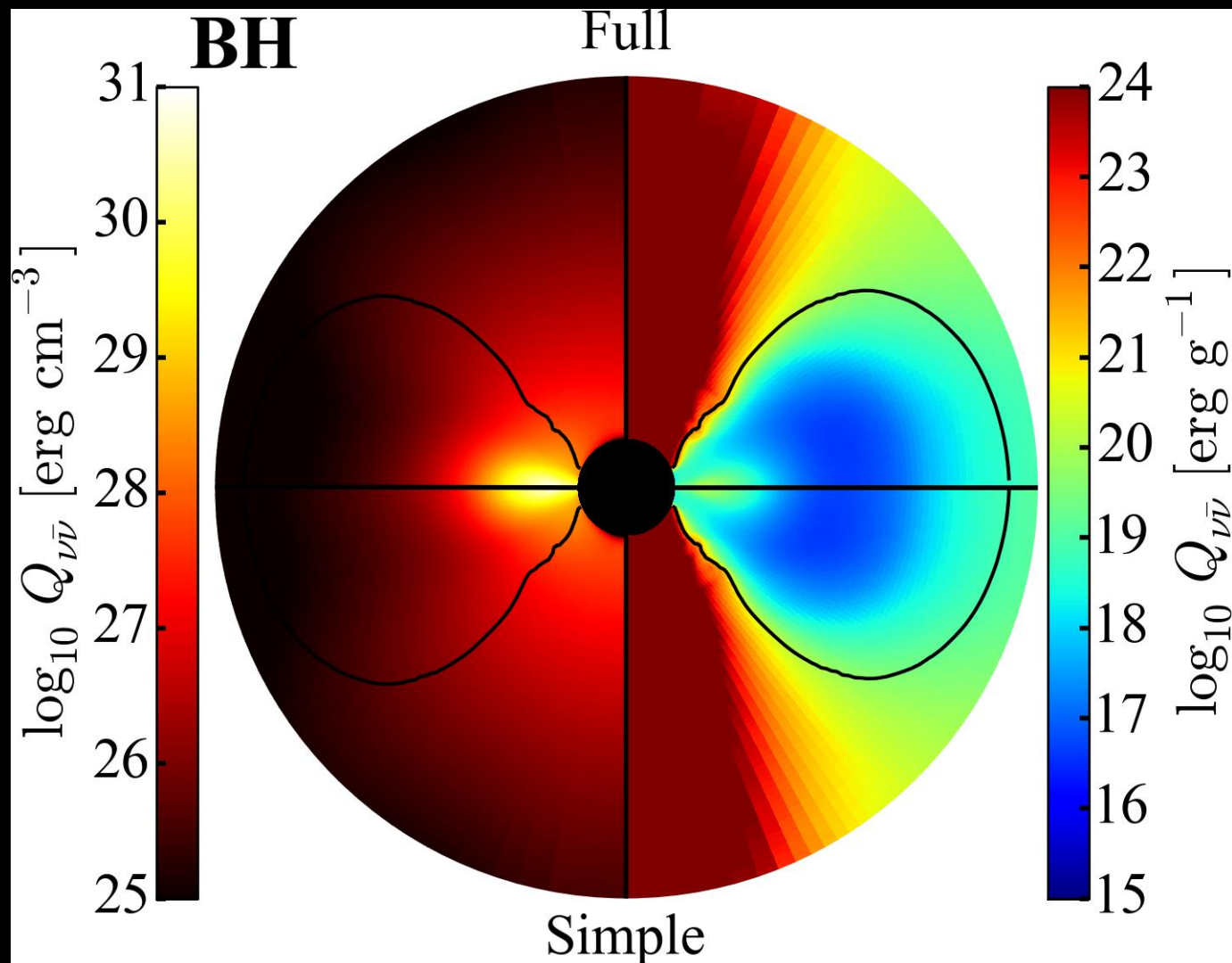
Ruffert et al. (1997)



data: Metzger & Fernandez (2014)

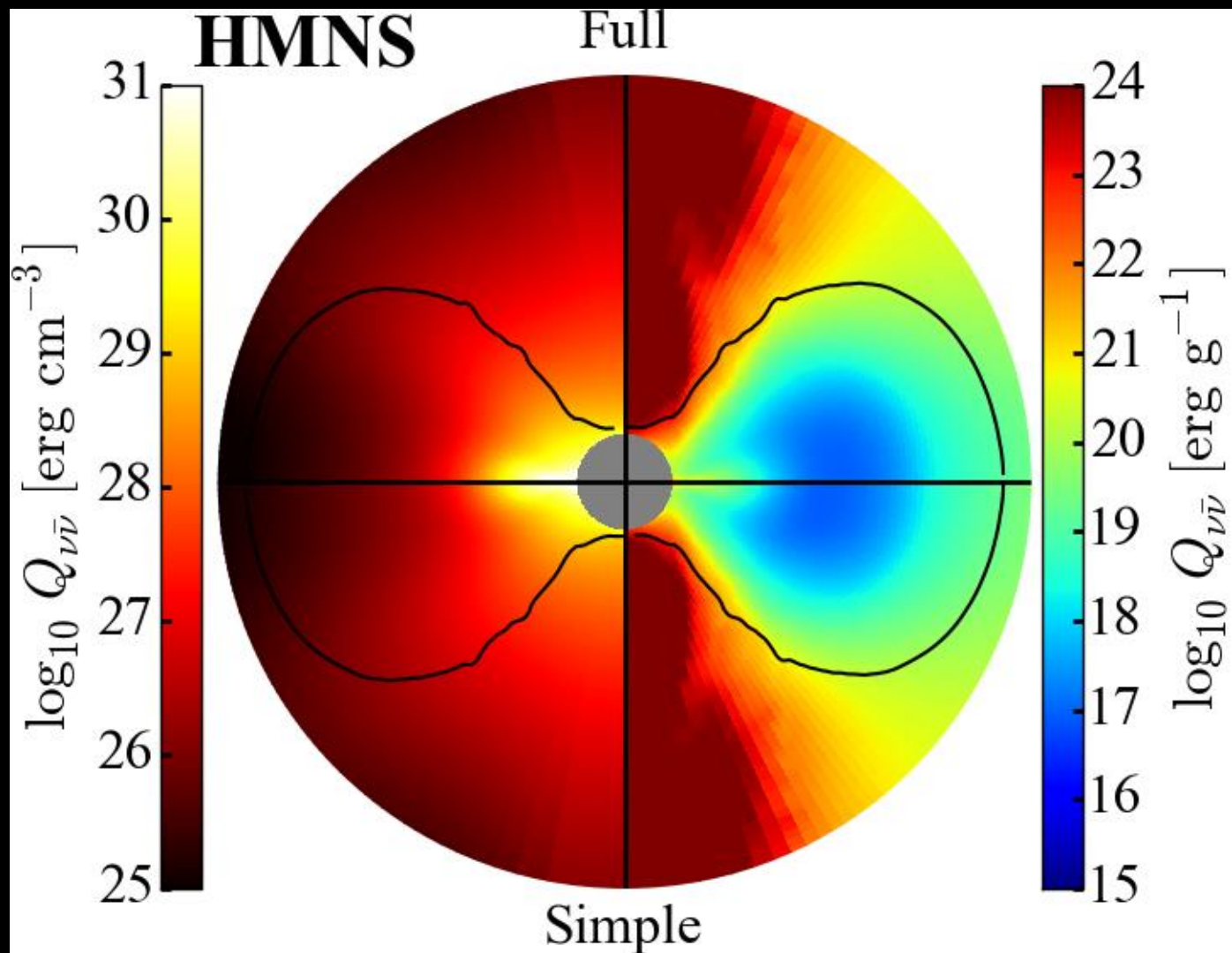
ANNIHILATION

- LARGE POLAR SPECIFIC HEATING
 - 3×10^{46} ERG IN BH JET
 - $10^{48} - 10^{50}$ ERG REQUIRED
(LEE & RAMIREZ-RUIZ 2007)
- JET IS UNLIKELY



ANNIHILATION

- LARGE POLAR SPECIFIC HEATING
 - 3×10^{46} ERG IN BH JET
 - 2×10^{48} ERG IN HMNS JET
 - $10^{48} - 10^{50}$ ERG REQUIRED
(LEE & RAMIREZ-RUIZ 2007)
- JET IS UNLIKELY



CONCLUSIONS

- ANNIHILATION CANNOT DRIVE JET (PROBABLY)
- LEAKAGE LACKS SPECTRAL AND ANGULAR EFFECTS
- MC → FASTER COOLING AND LEPTONIZATION
- **CAVEAT:** NON-EQUILIBRIUM

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- MC → FASTER COOLING AND LEPTONIZATION
- **CAVEAT:** NON-EQUILIBRIUM

SELF-PROMOTION

- SEE THE PAPER!
 - **ARXIV:1507.03606**
- SEE THE CODE!
 - **BITBUCKET.ORG/SRICHERS/SEDONU**
- SEE THE PERSON!
 - **TAPIR.CALTECH.EDU/~SRICHERS**