General Relativistic Radiation MHD Simulations of Black Hole Accretion

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GR Radiation MHD Why do this?

- Long-standing questions in black hole astrophysics
  - Are radiation-pressure dominated accretion disks thermally unstable? (Pringle, Rees & Pacholczyk 1973)
  - Are radiation-pressure dominated accretion disks secularly unstable? (Lightman & Eardley 1974)
  - Can a disk sustain locally super-Eddington fluxes? (Begelman 2001)
  - How are the jets associated with black holes affected when the disk is radiation-pressure dominated?
- Building supermassive black holes
- Simulating quasi-stars

M87

Step 1: After-the-fact modeling

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  - Schnittman et al. (2006)
  - Noble et al. (2007); Mościbrodzka et al. (2009)
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  - Sgr A*
  - M87 (maybe)

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Credit: Jason Dexter

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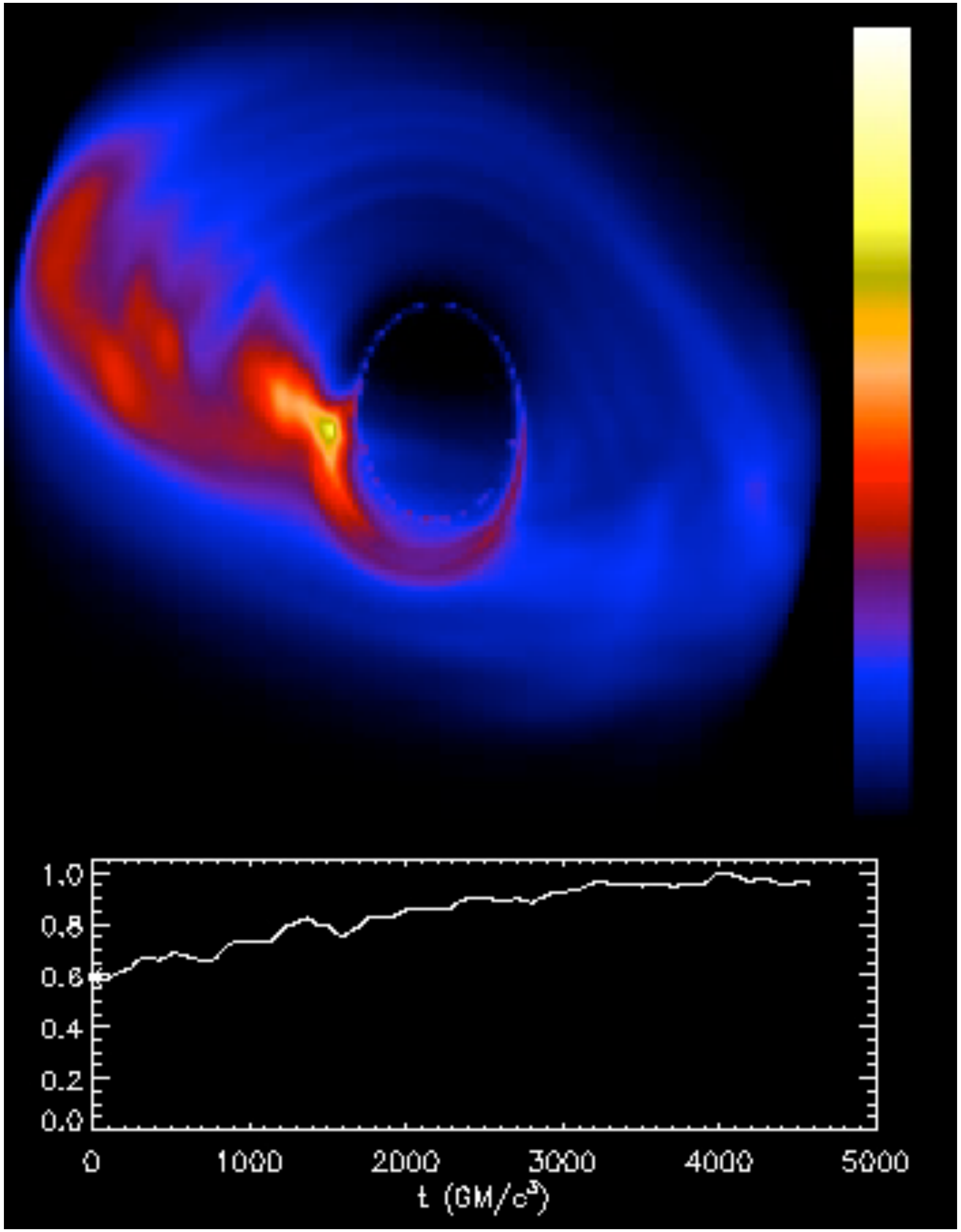
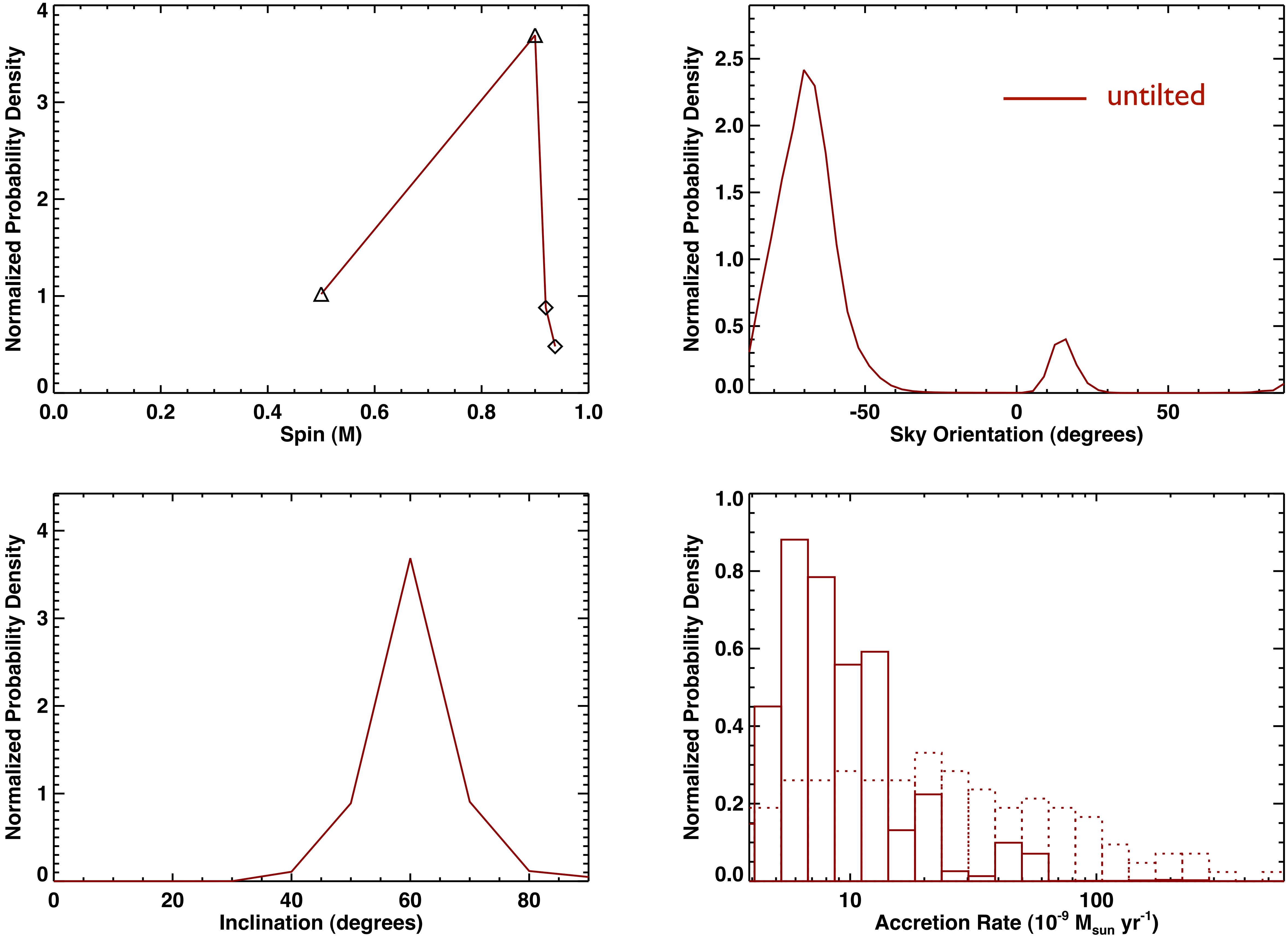


Credit: Jason Dexter

GR Radiation MHD Constraining Sgr A*



(Dexter et al. 2010)

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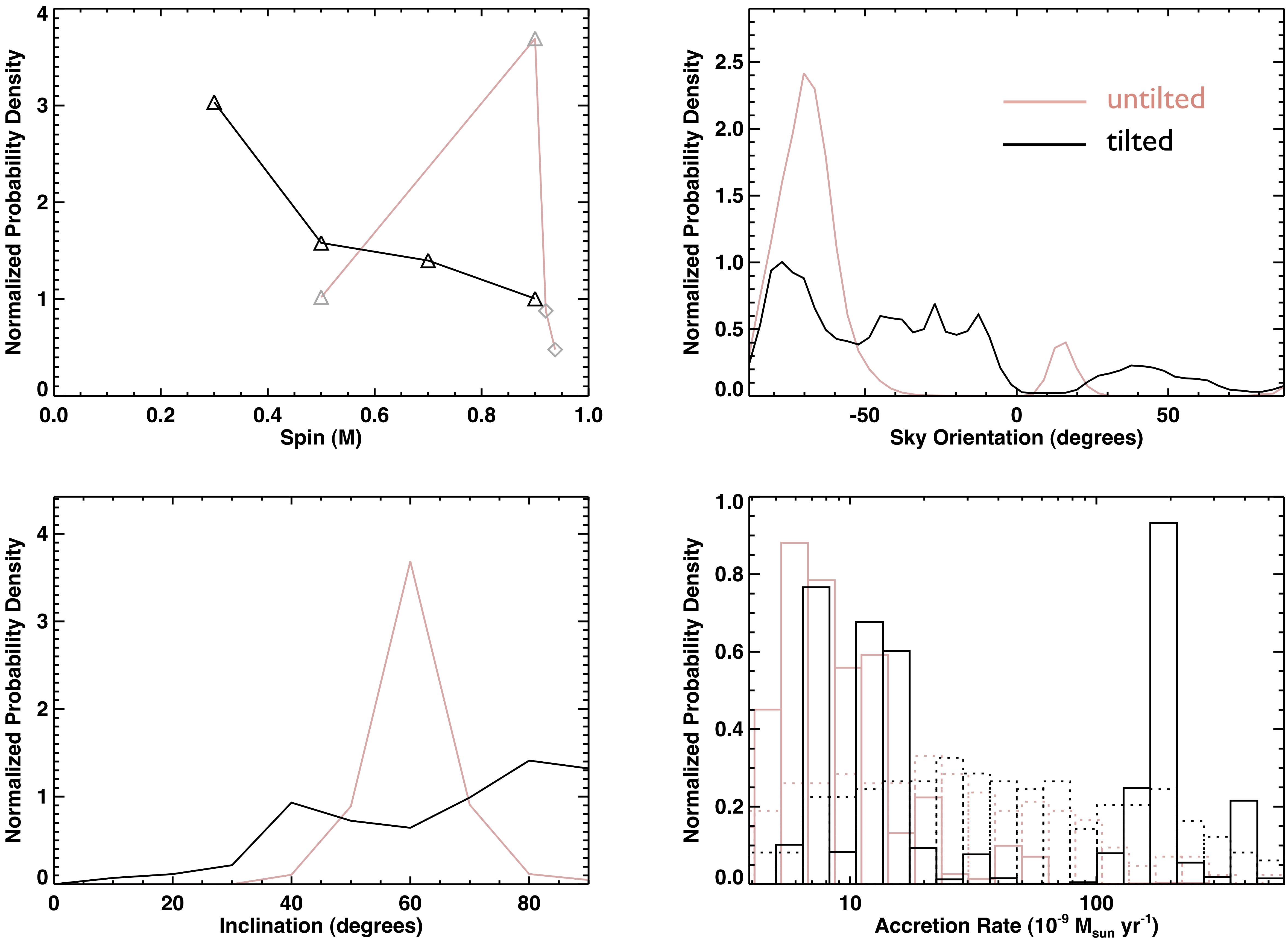

(Dexter & Fragile 2013)

Step 2: Optically-thin cooling

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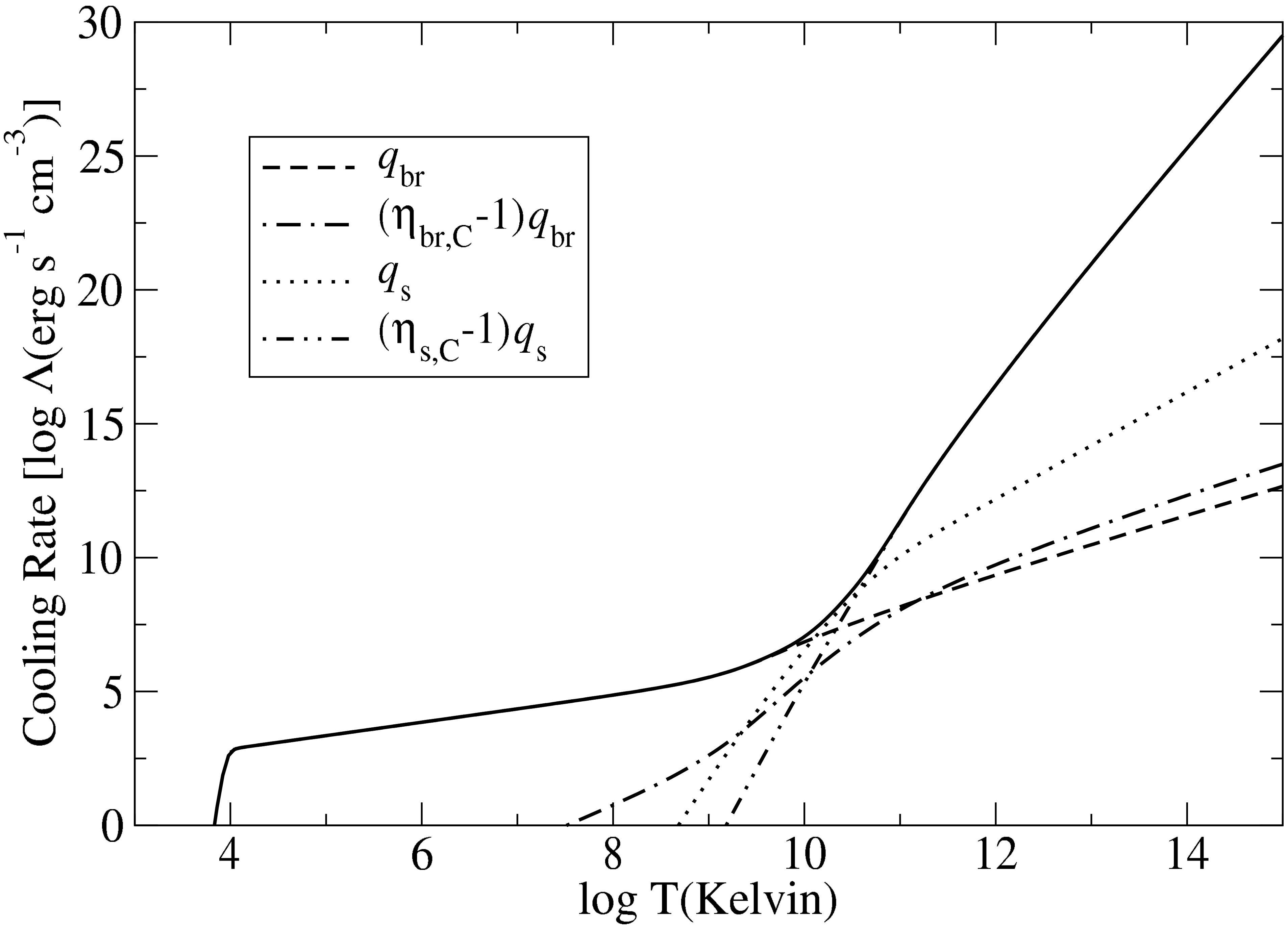
- Cooling simply enters as source term in energy and momentum equations

bremsstrahlung
synchrotron
inverse Compton

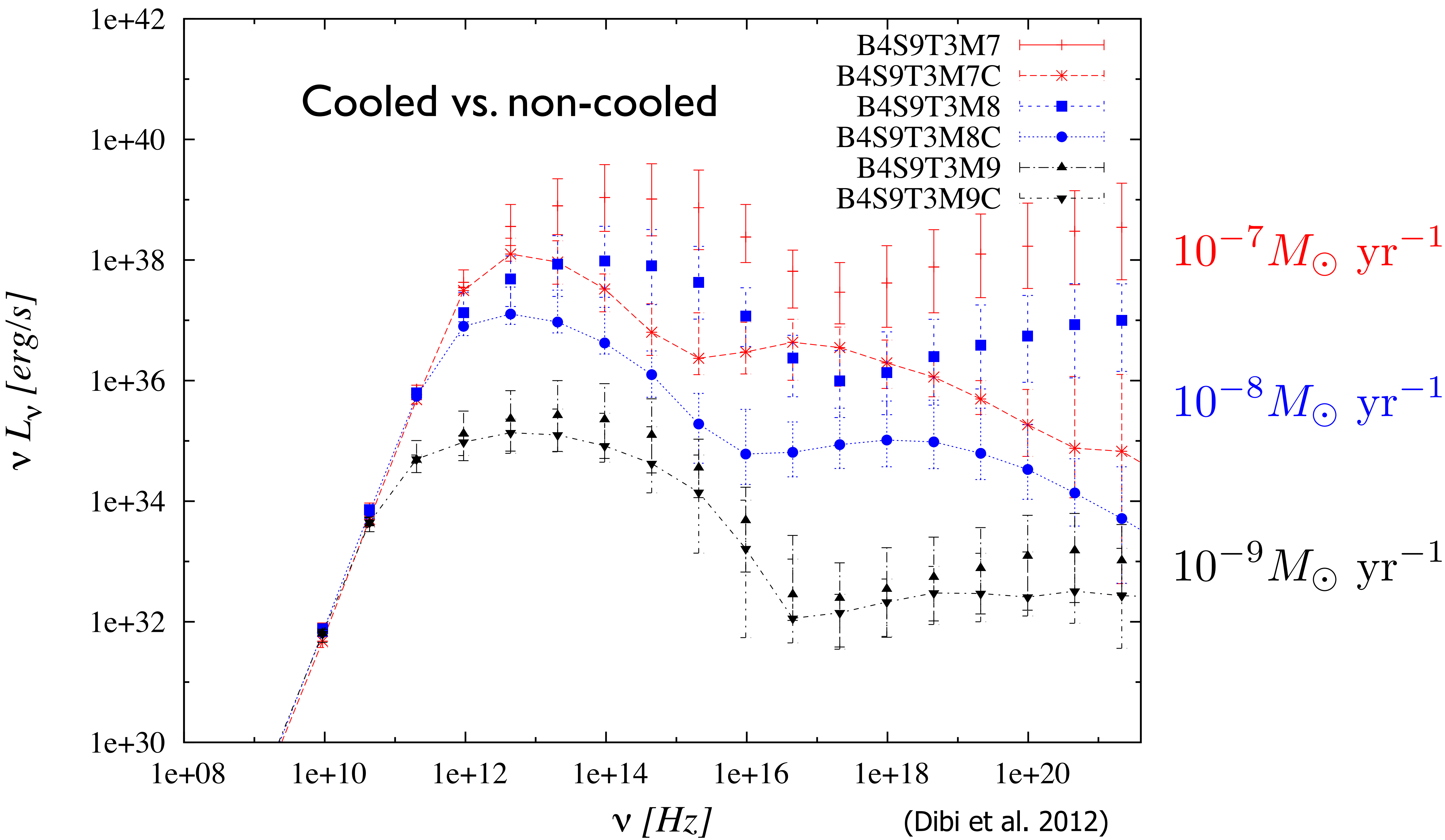
$$\Lambda(\rho, T, B^2, H)$$



(Fragile & Meier 2009)

GR Radiation MHD Step 2: Optically-thin cooling

- Is "after-the-fact" radiative treatment adequate for Sgr A*?
  - Dibi et al. (2012); Drappeau et al. (2013)



(Dibi et al. 2012)

Step 3: Optically-thick GR rad-MHD

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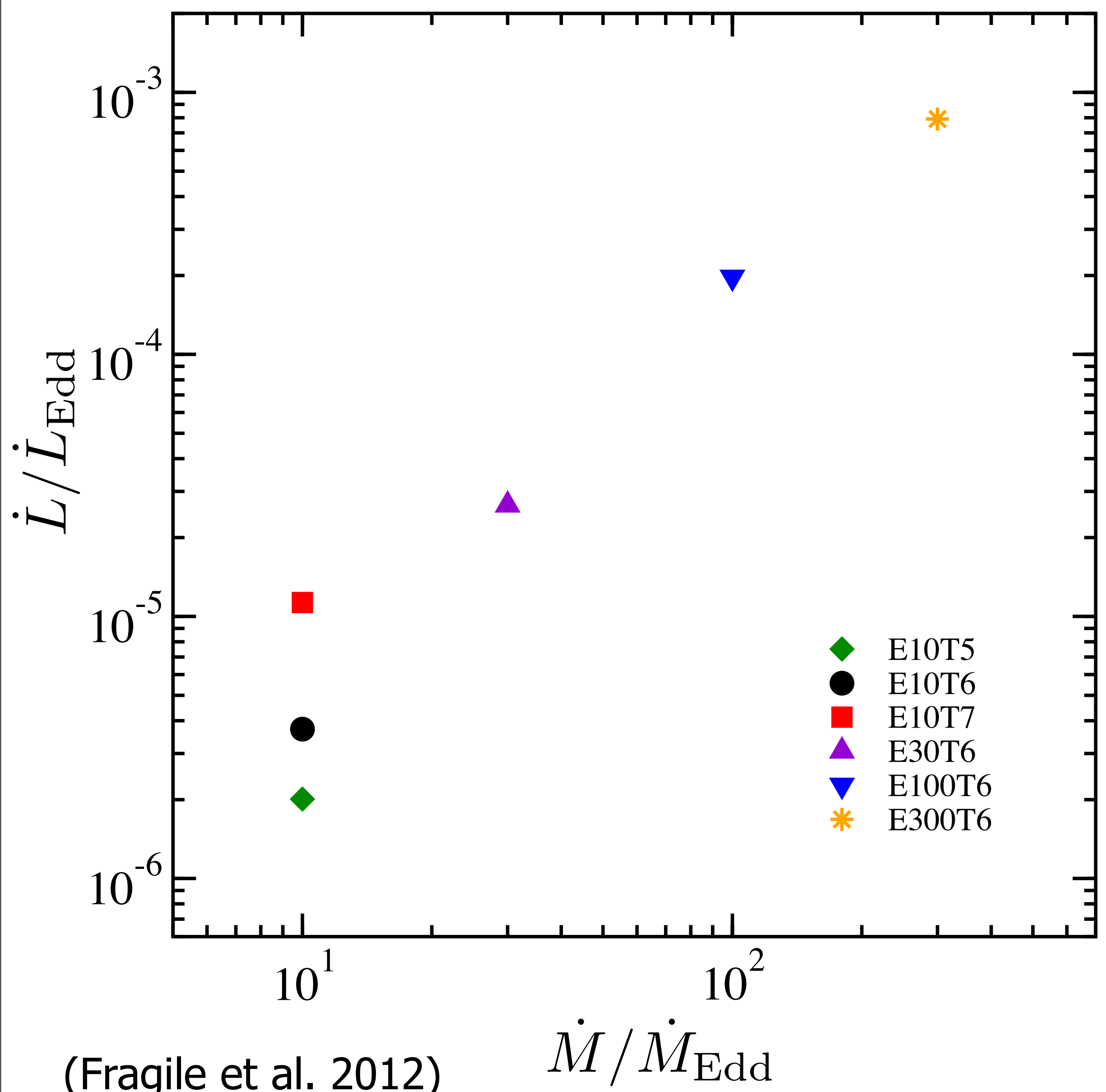
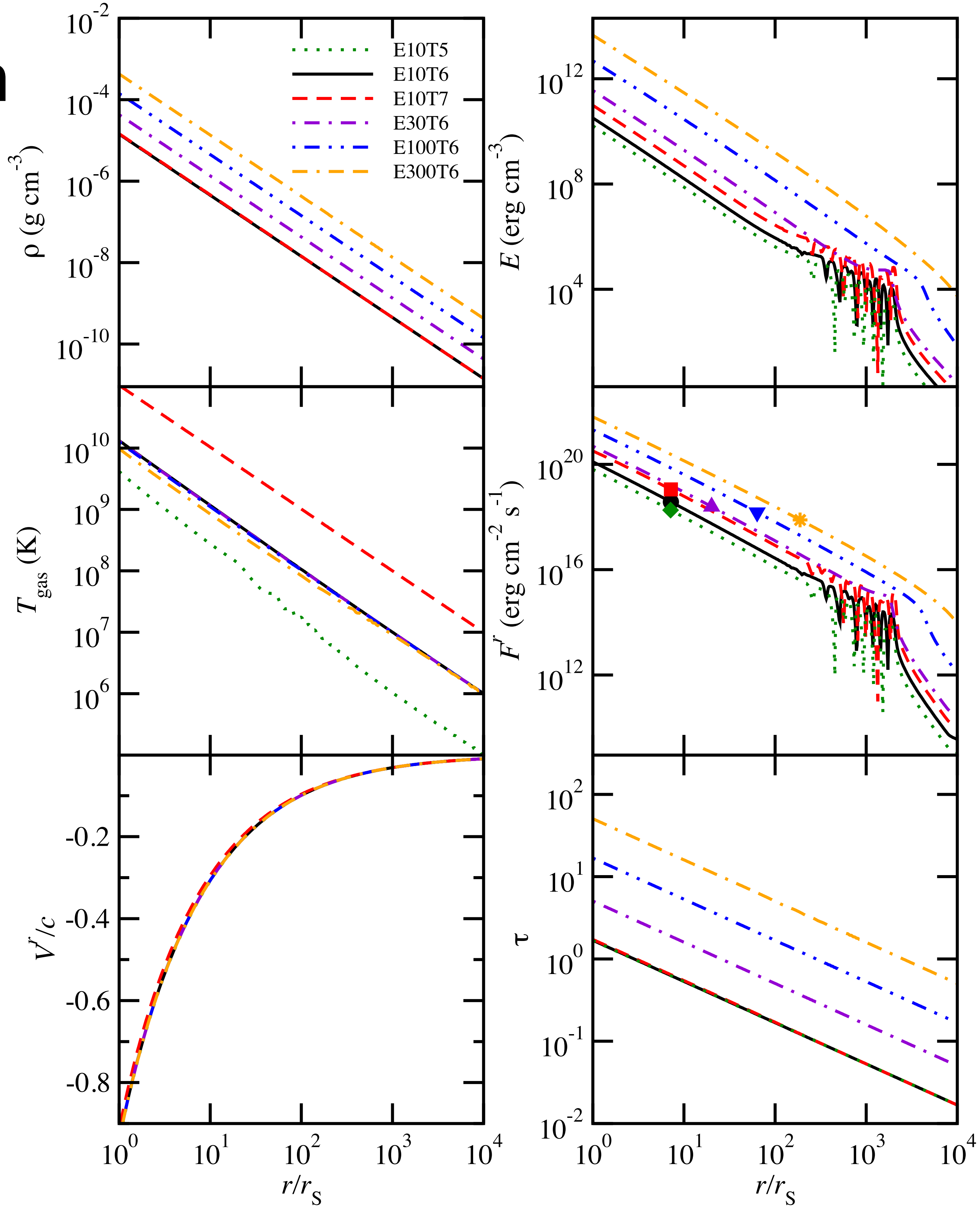
- Bondi inflow with radiation
  - Spherical accretion above Eddington limit

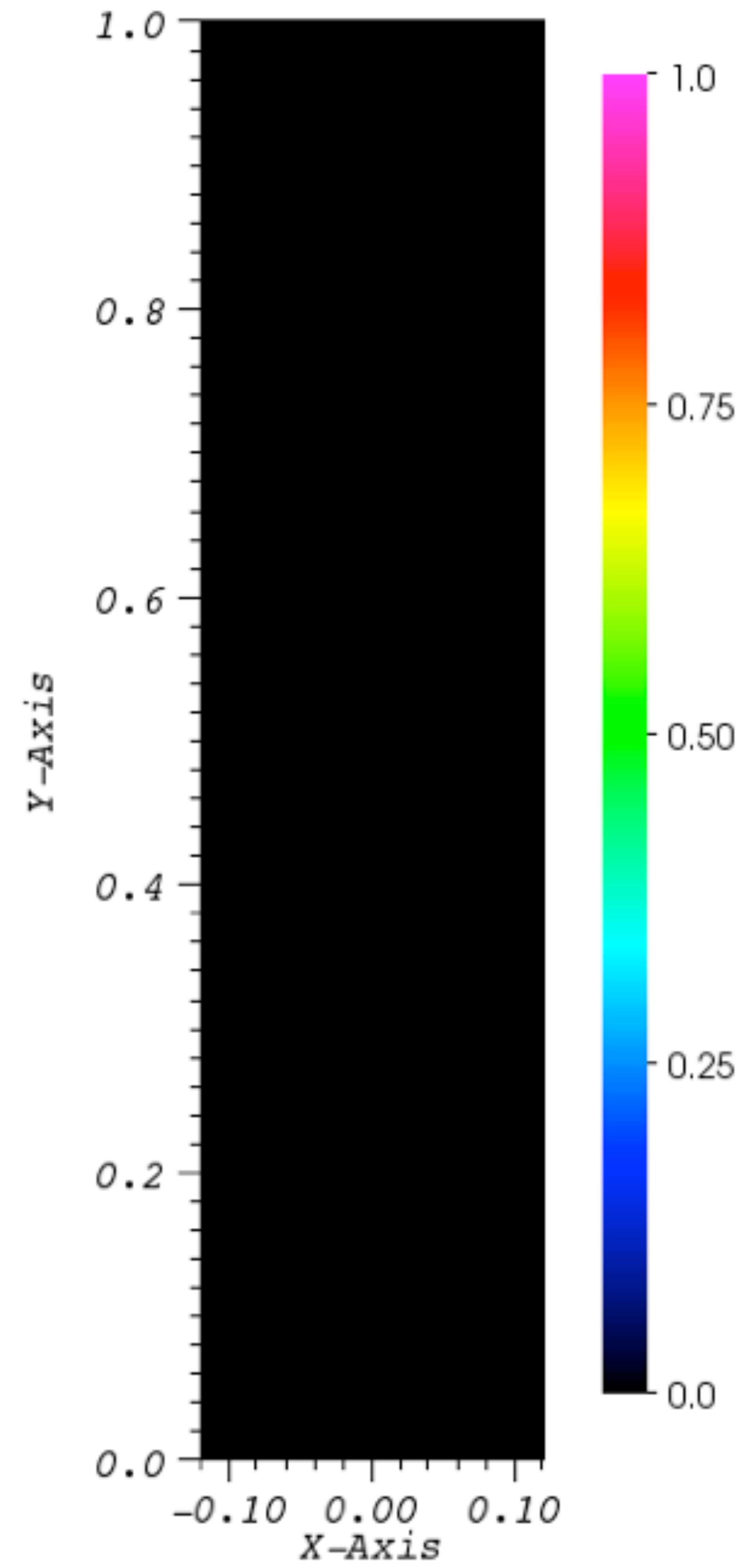


(Fragile et al. 2012)



Step 3: Optically-thick GR rad-MHD

- Drawbacks of method:



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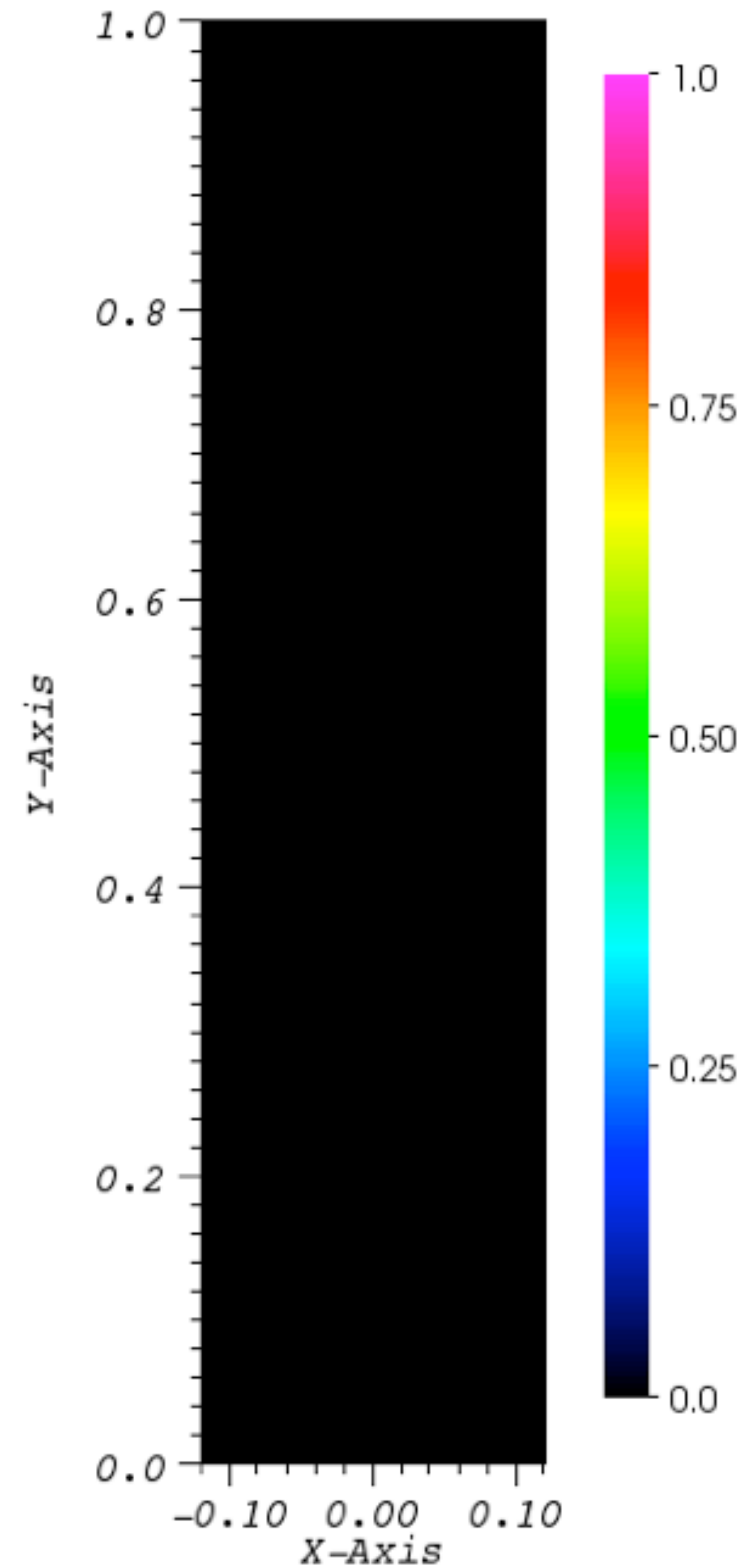

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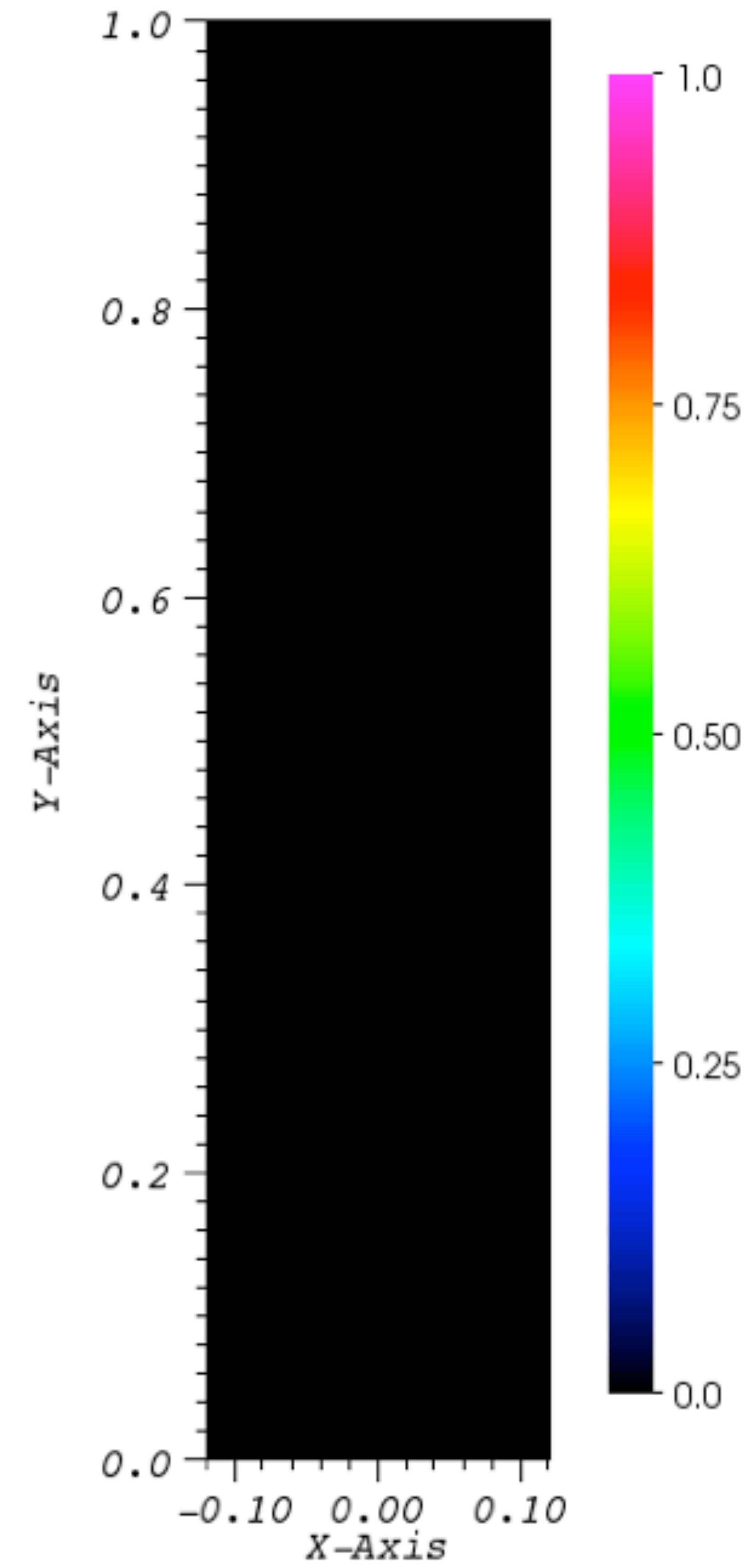

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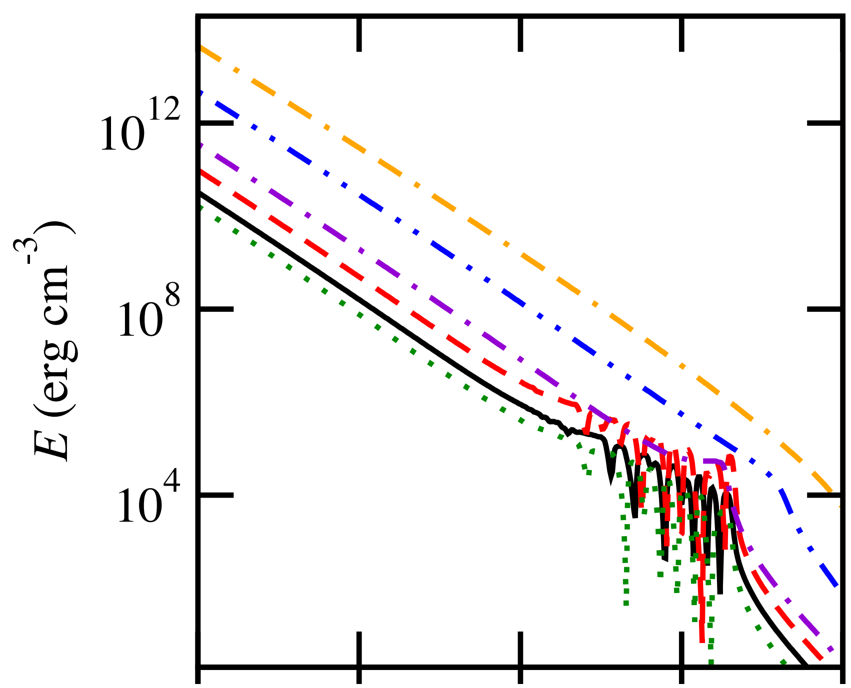
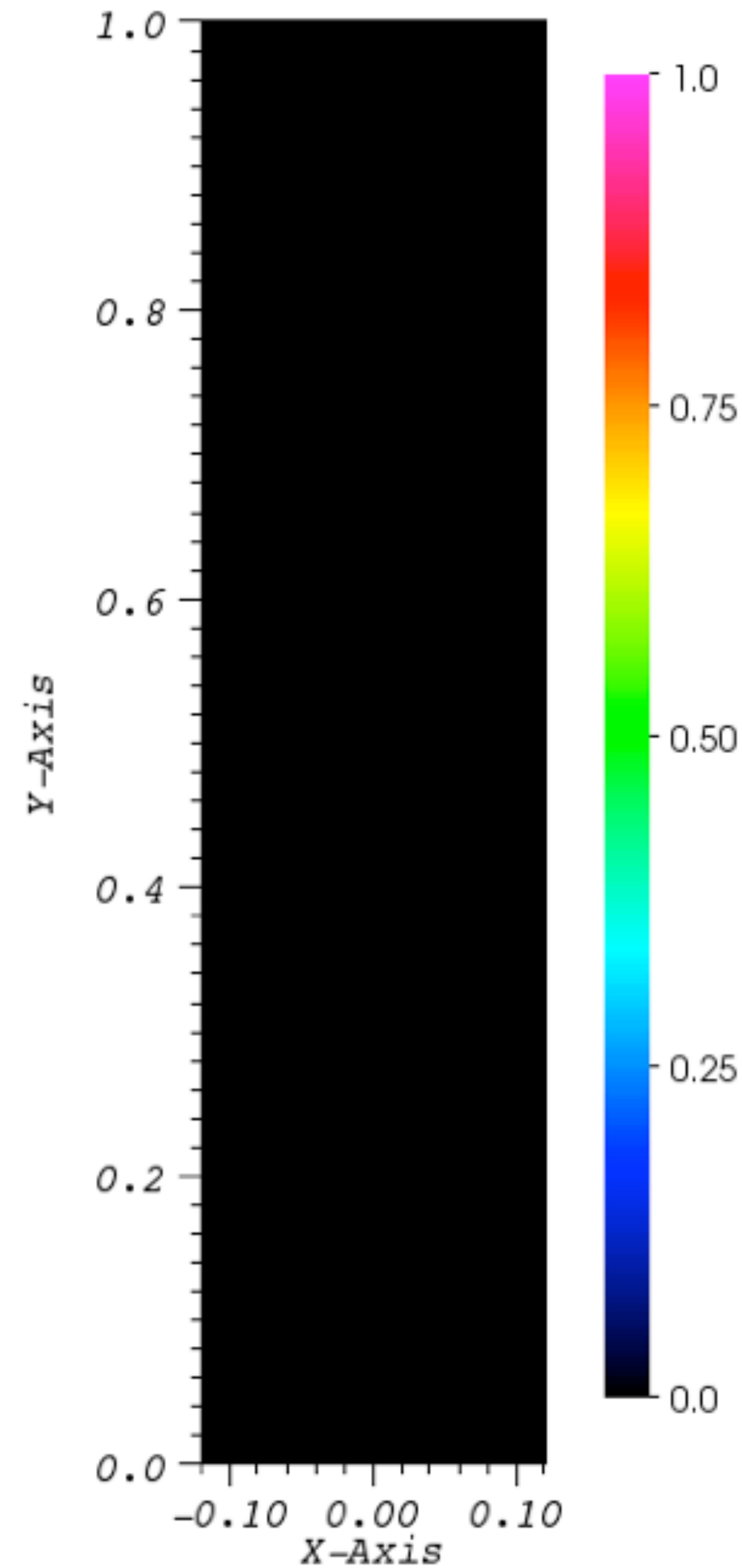
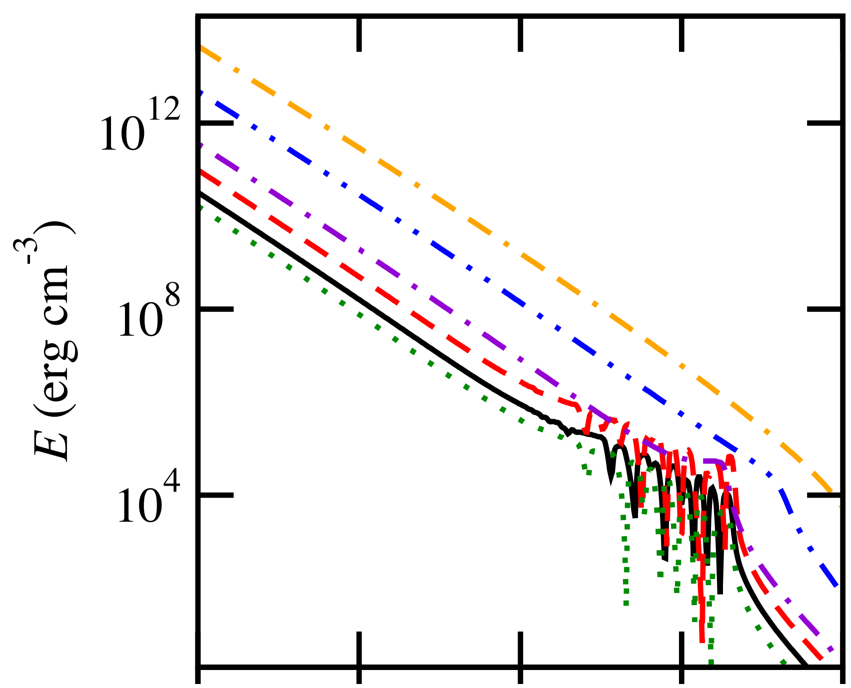
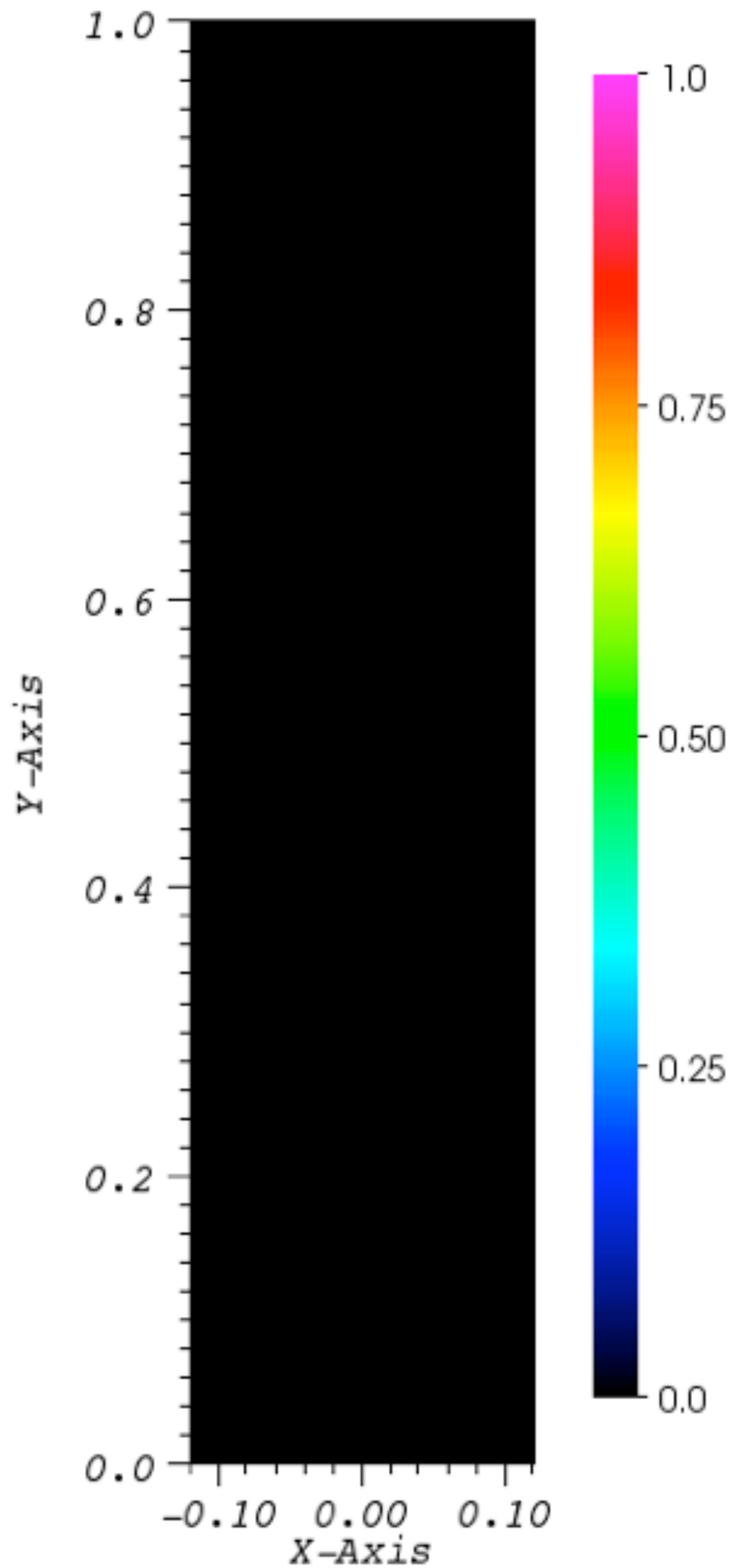




- Drawbacks of method:
  - Eddington closure does not preserve shadows
  - Method becomes unstable in optically thin regions
  - Radiation source term can be extremely stiff
    - prohibitively small time stepping required by explicit integration





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Bending of light ray
by black hole

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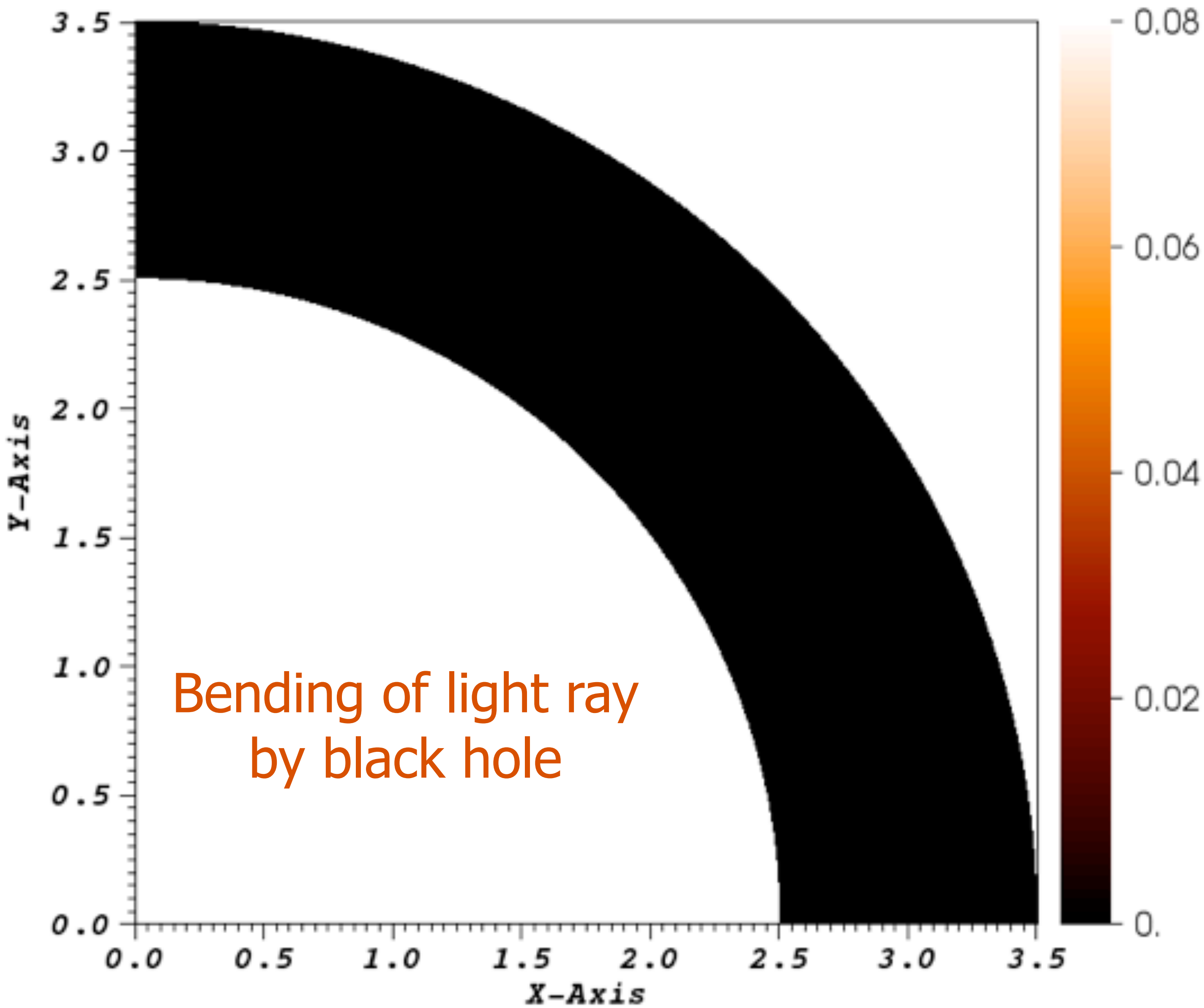

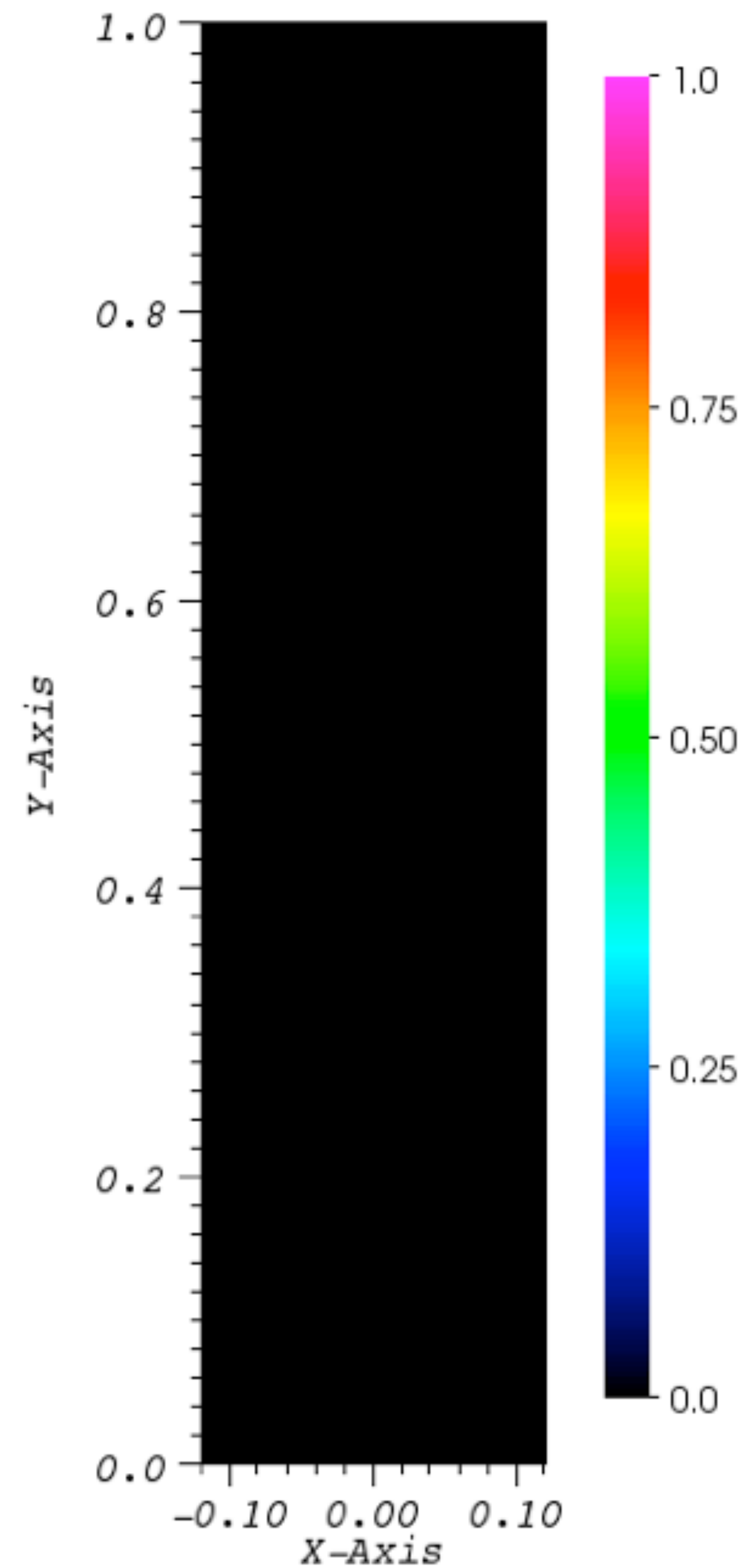

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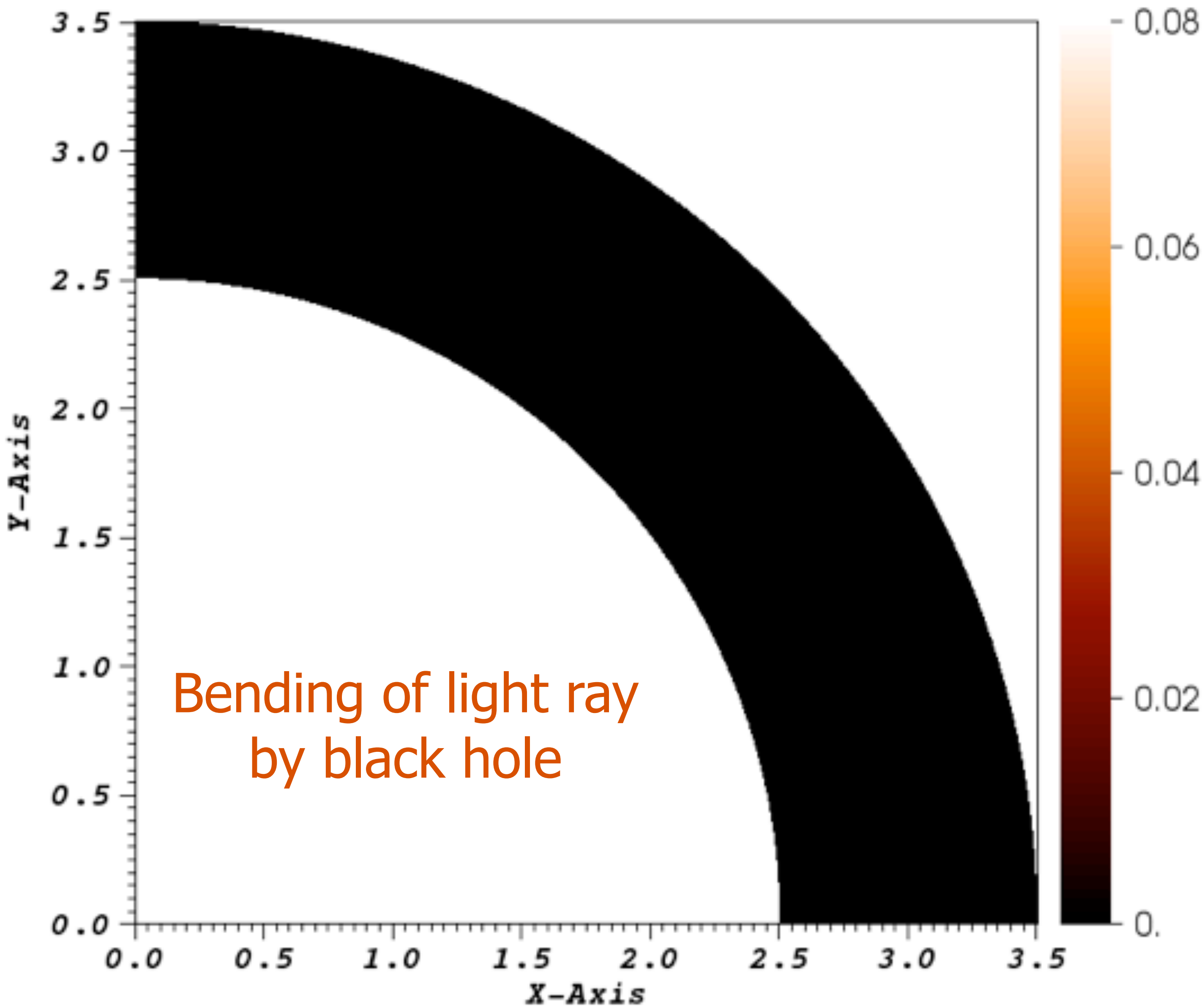

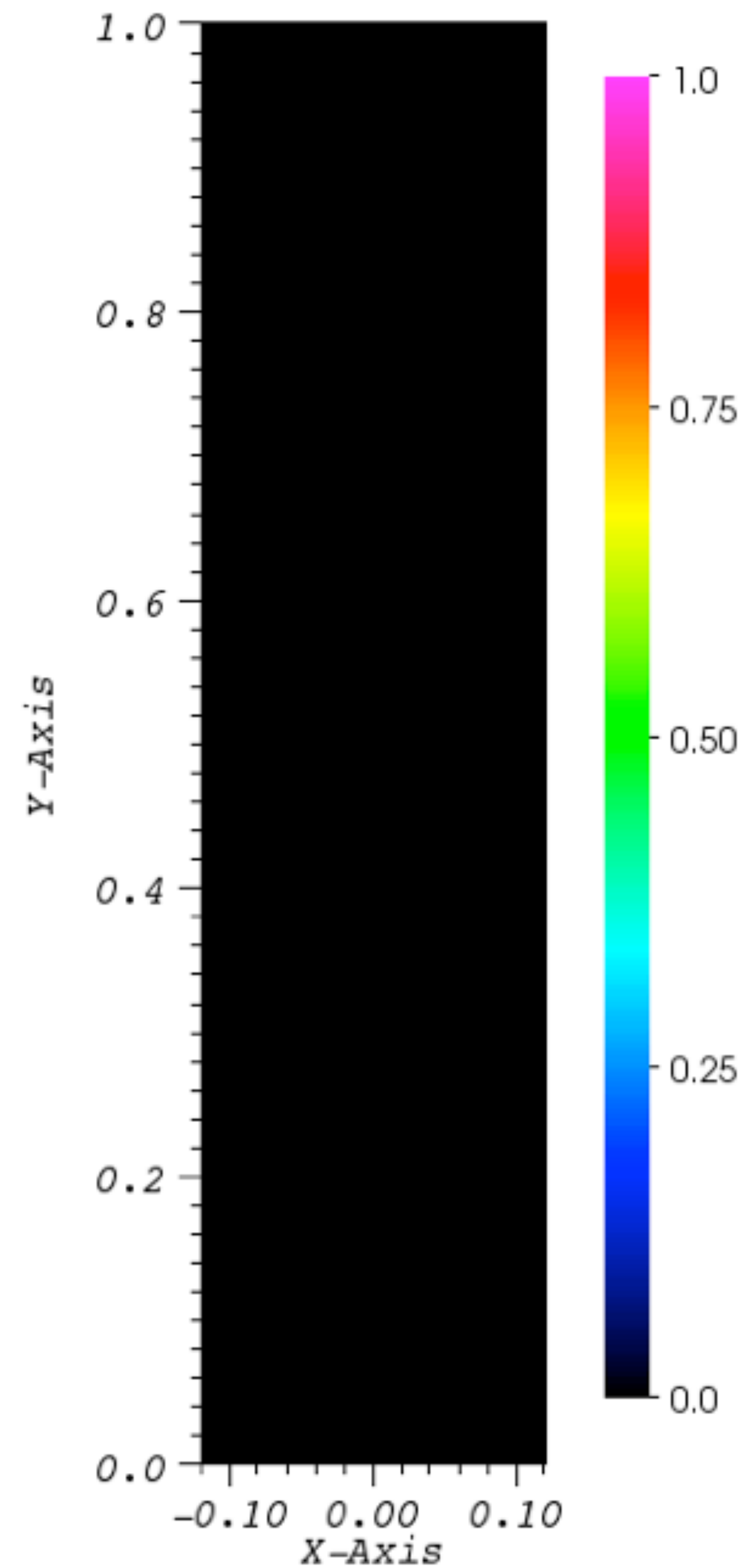

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- Thank you
  - KITP
  - program organizers
  - sponsors