Electron and Proton Heating in Transrelativistic Magnetic Reconnection

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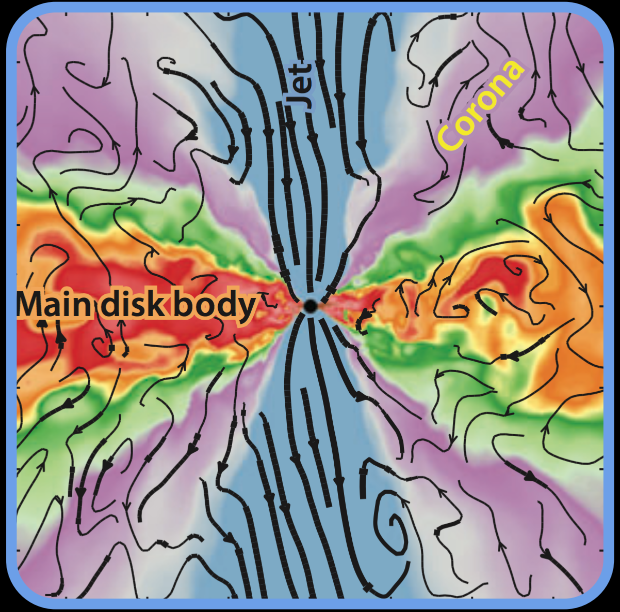
Michael E. Rowan[1], Lorenzo Sironi[2], and Ramesh Narayan[1] ([1]Harvard, [2]Columbia)

- Transrelativistic reconnection: $\sigma_w \equiv B_0^2/4\pi w \sim 0.1 - 1$ (w is enthalpy density)
  - Corona of Sgr A*
  - Microphysics: unresolved in MHD
  - Reconnection: important effect
  - Should Include to model EHT observations
- How much magnetic energy is dissipated to electrons, protons?
  - Particle in cell simulations: `TRISTAN-MP`
  - 2D in space, but track all 3 components of momentum
- Main focus: electron heating (rather than acceleration)
  - How does the energy partition vary with inflow parameters, in the transrelativistic regime?



Yuan + Narayan 2014

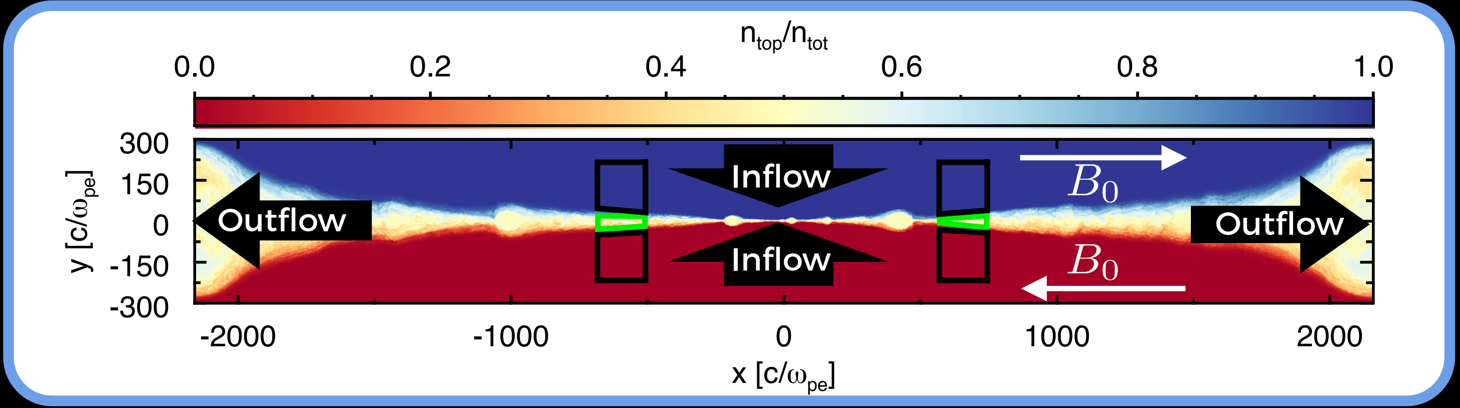
Beta (of the ions)	Sigma (magnetization)	Temperature ratio	Mass ratio
$\beta_i = \frac{n_i k_B T_i}{B^2/(8\pi)} = \frac{\text{thermal pressure}}{\text{magnetic pressure}}$	$\sigma_w = \frac{B^2/4\pi}{w} = \frac{\text{magnetic pressure}(\times 2)}{\text{enthalpy density}}$	$\frac{T_e}{T_i} = \frac{\text{electron temperature}}{\text{ion temperature}}$	$\frac{m_i}{m_e} = \frac{\text{Ion mass}}{\text{Electron mass}}$
0.01 - 2	0.1 - 10	0.1 - 1	10 - 1836

- Here, we focus on antiparallel reconnection (no guide field)

- Characterize heating via dimensionless ratio (as in Drake et al. 2014)

$$M_{Te} = \frac{k_B T_{e,out} - k_B T_{e,in}}{B^2/4\pi n}$$

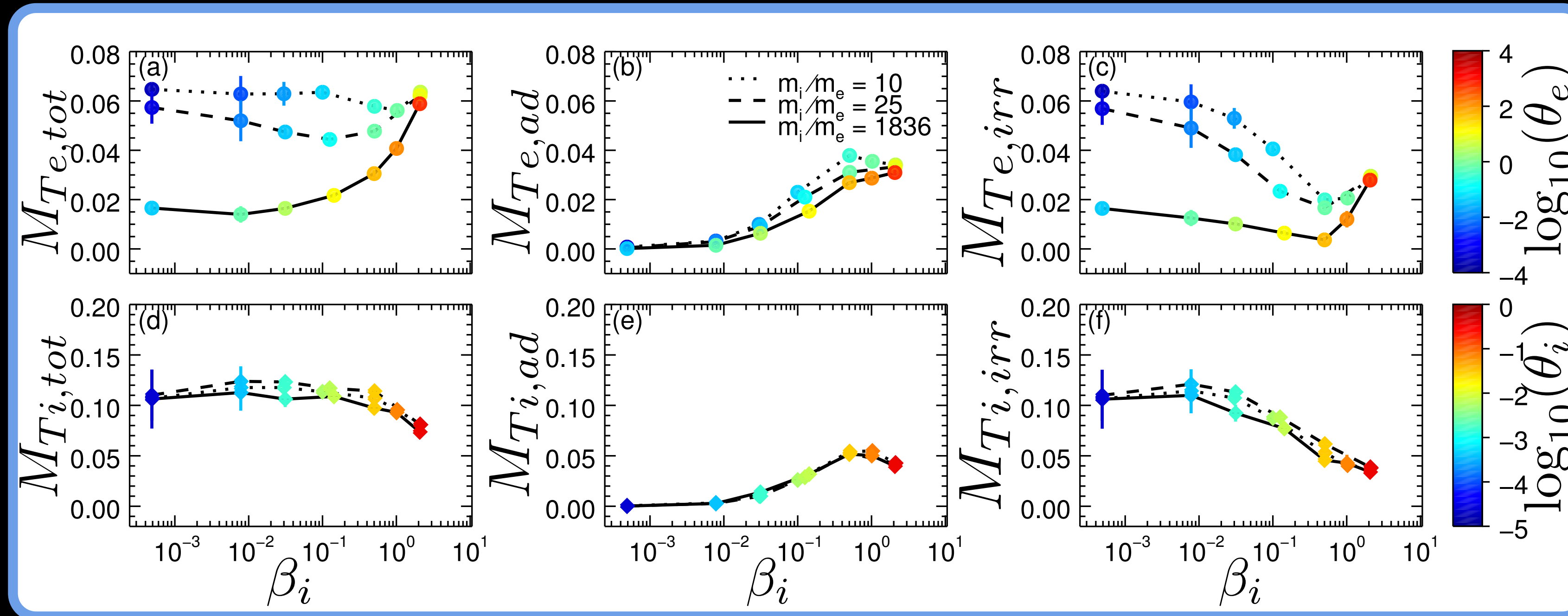
- We further separate heating into irreversible and adiabatic components



Total | **Adiabatic** | **Irreversible**

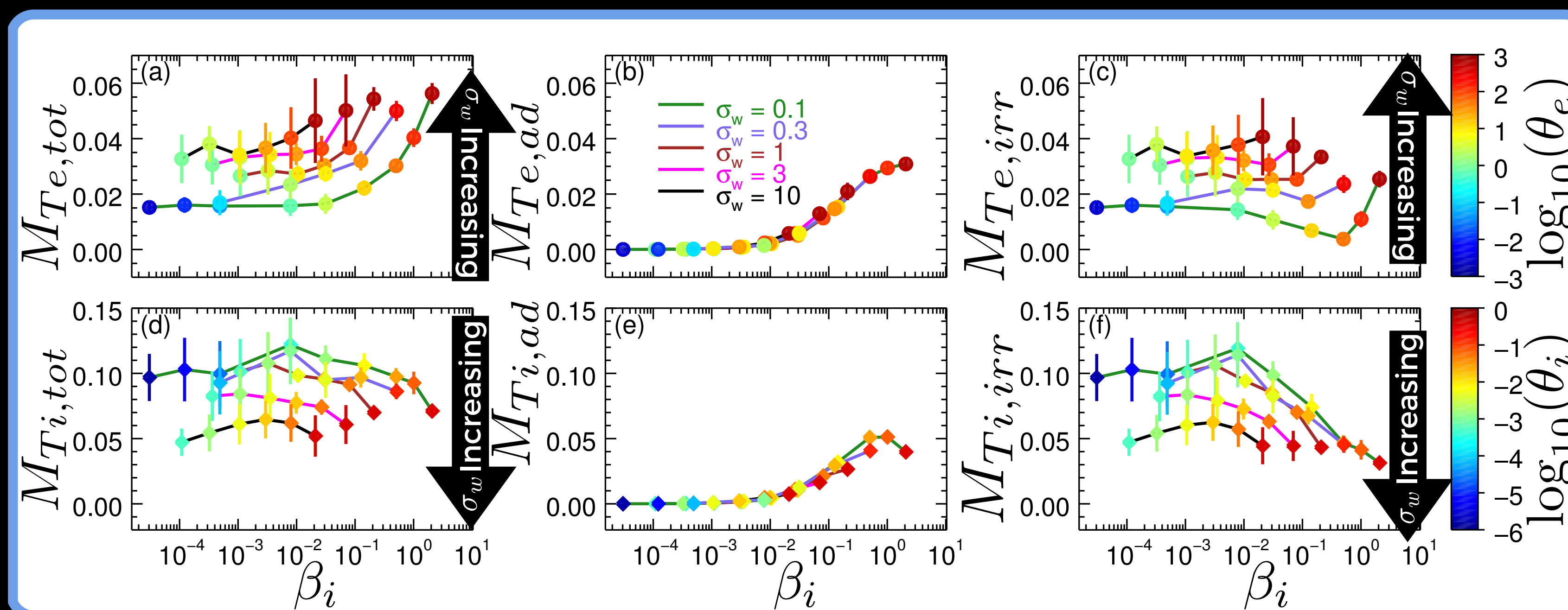
Mass ratio

- At low β_i, electron heating depends on mass ratio, m_i/m_e
- Mass ratio ranges from 10 - 1836



Magnetization

- vary σ_w from 0.1 - 10
- Here, $m_i/m_e = 1836$ and $T_e/T_i = 1$
- At high β_i, total electron heating attains a value of $M_{Te,tot} \approx 0.05 \approx M_{Ti,tot}$
- σ_w dependent plateau at low β_i, with higher magnetizations giving larger heating efficiency



Energy equipartition

- Achieve by increasing β_i (at fixed σ_w), or by increasing σ_w (at fixed β_i)
- In either case, ratio of ion to elec. skin-depth→1 in the downstream
- In panels (a) and (b), points indicate simulations, lines are fit: $q_{ue,fit} = 0.5 \exp\left[-(1-\beta_i/\beta_{i,max})^{3.3}/(1+1.2\sigma_w^{0.7})\right]$, where $\beta_{i,max} = 1/4\sigma_w$