Collisional vs. Collisionless Processes

(an astrophysical perspective)

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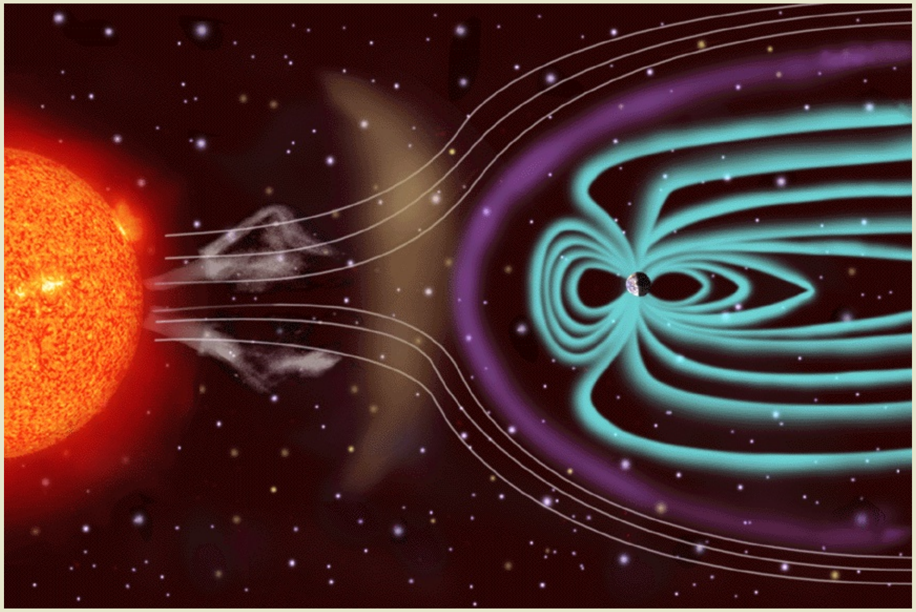
collision frequency:

$$\nu_{ei} = \frac{4\sqrt{\pi}}{3}\frac{e^2 q_i^2 n_e \ln\Lambda}{m_e m_i (v_e^2 + v_i^2)^{3/2}} \simeq 3\frac{n_e \ln\Lambda}{T_e^{3/2}}\ \mathrm{s}$$

- **solar wind**
- **shocks**
- **reconnection**
- **application to astrophysical accretion flows?**

The solar wind

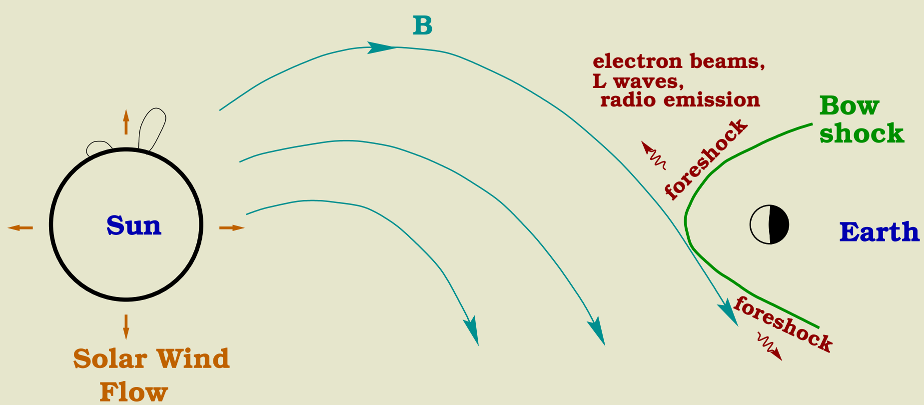


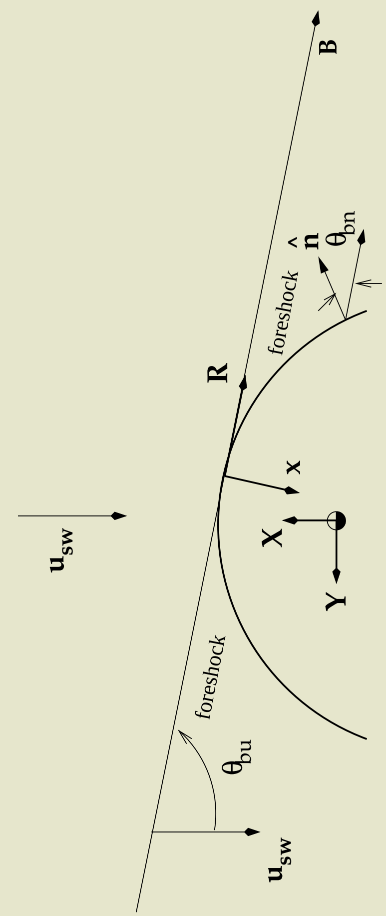
- highly collisionless
- T_e in fast solar wind increases outwards, with halo distbn of higher-E electrons
  $\Rightarrow$ heating/acceleration
- ion cyclotron waves? lower hybrid waves?
  $\Rightarrow$ electron-ion coupling via wave-particle energy exchange

Planetary/interplanetary bow shocks

(c.f. Burgess session on Tues)

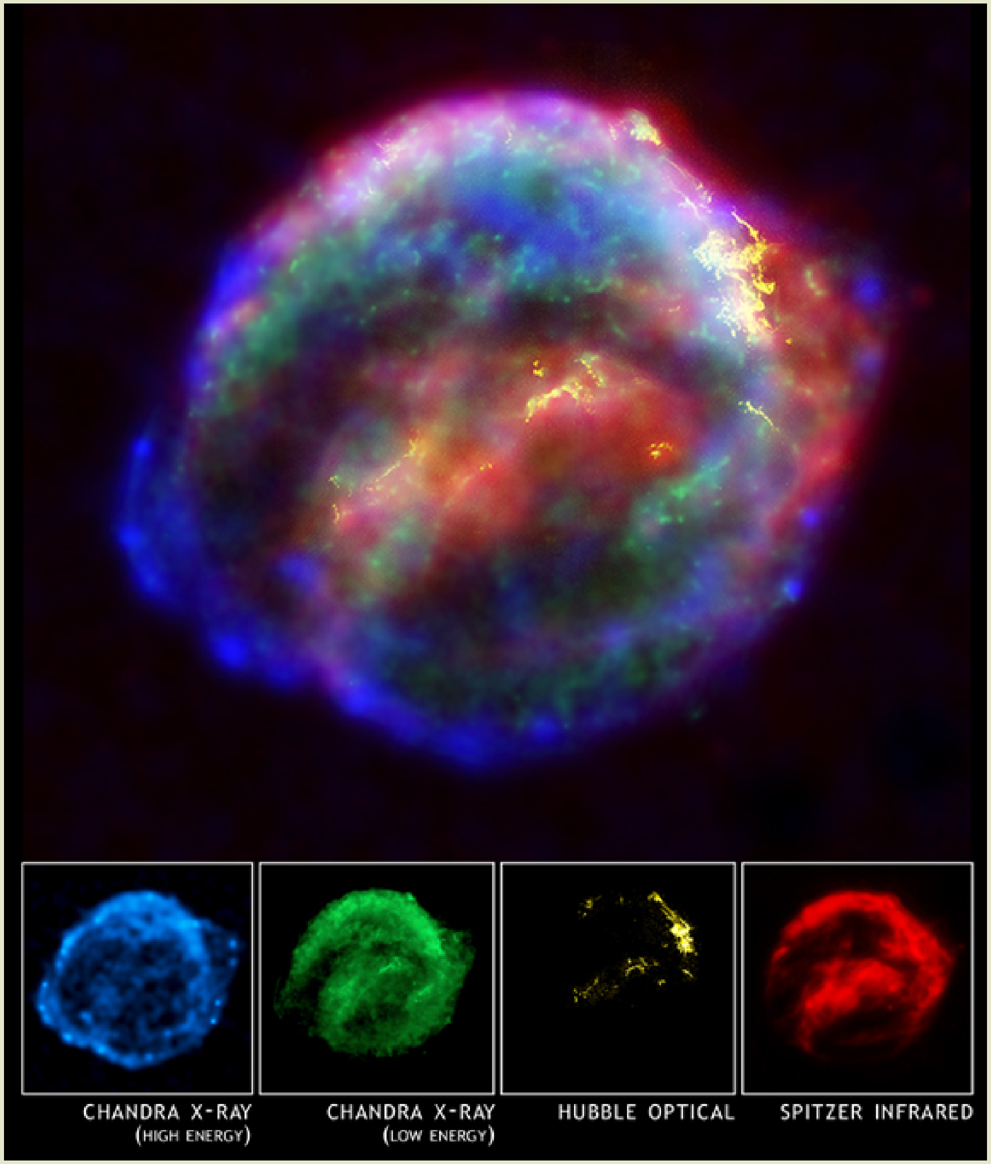
- **also collisionless**
- **electron heating/acceleration observed**





Supernova shocks

- collisionless, high-M
- evidence for electron heating *and* acceleration from X-ray bremsstrahlung and radio synchrotron spectra



Reconnection

(c.f. Owen session on Tues)

In situ evidence of magnetic reconnection in turbulent plasma

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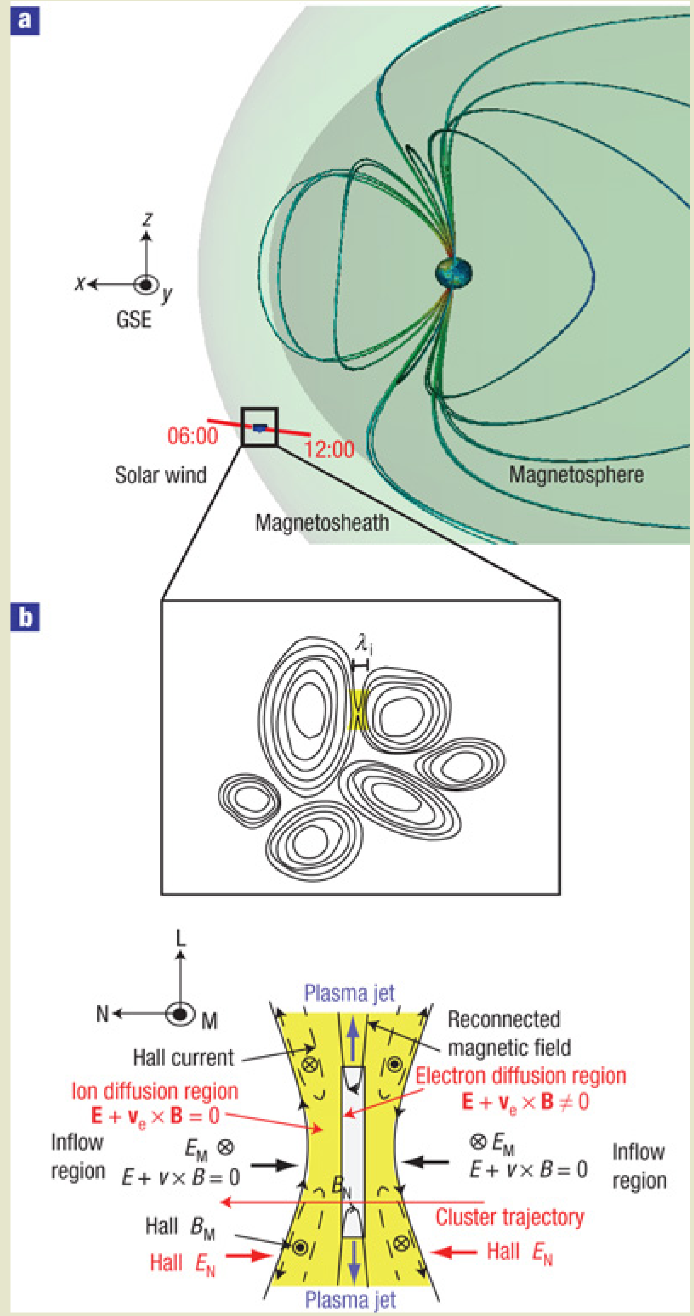
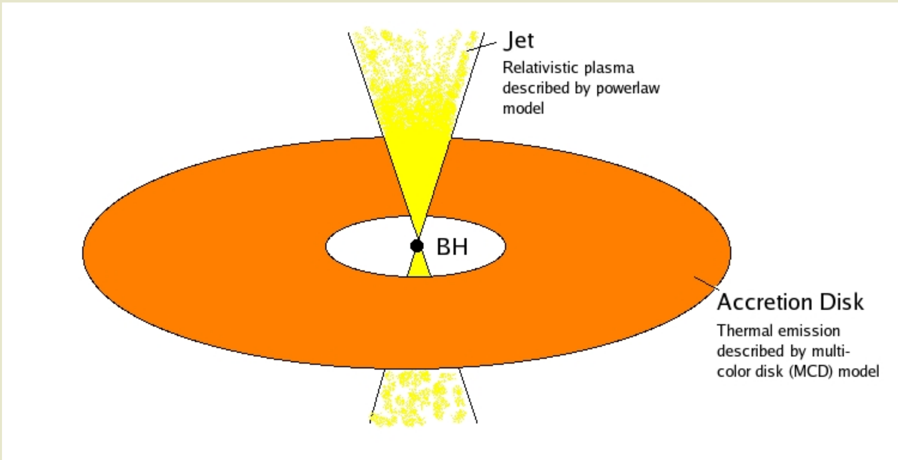
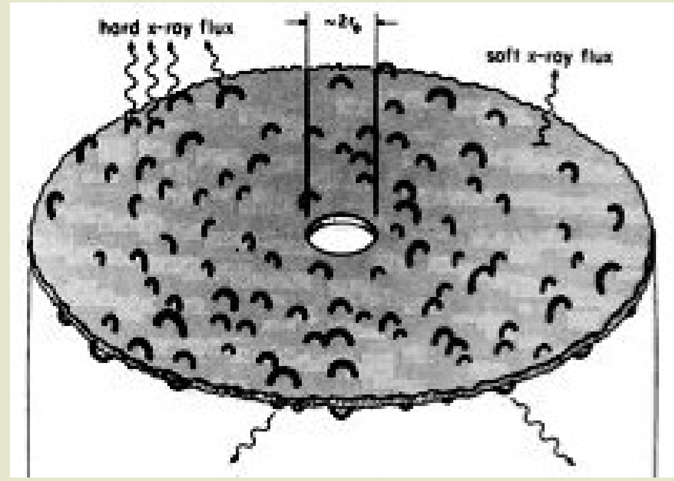


- **collisionless**
- **observed in terrestrial magnetotail, magnetosheath**
- **heating and acceleration of both ions and electrons detected in turbulent reconnection**

Accretion disks

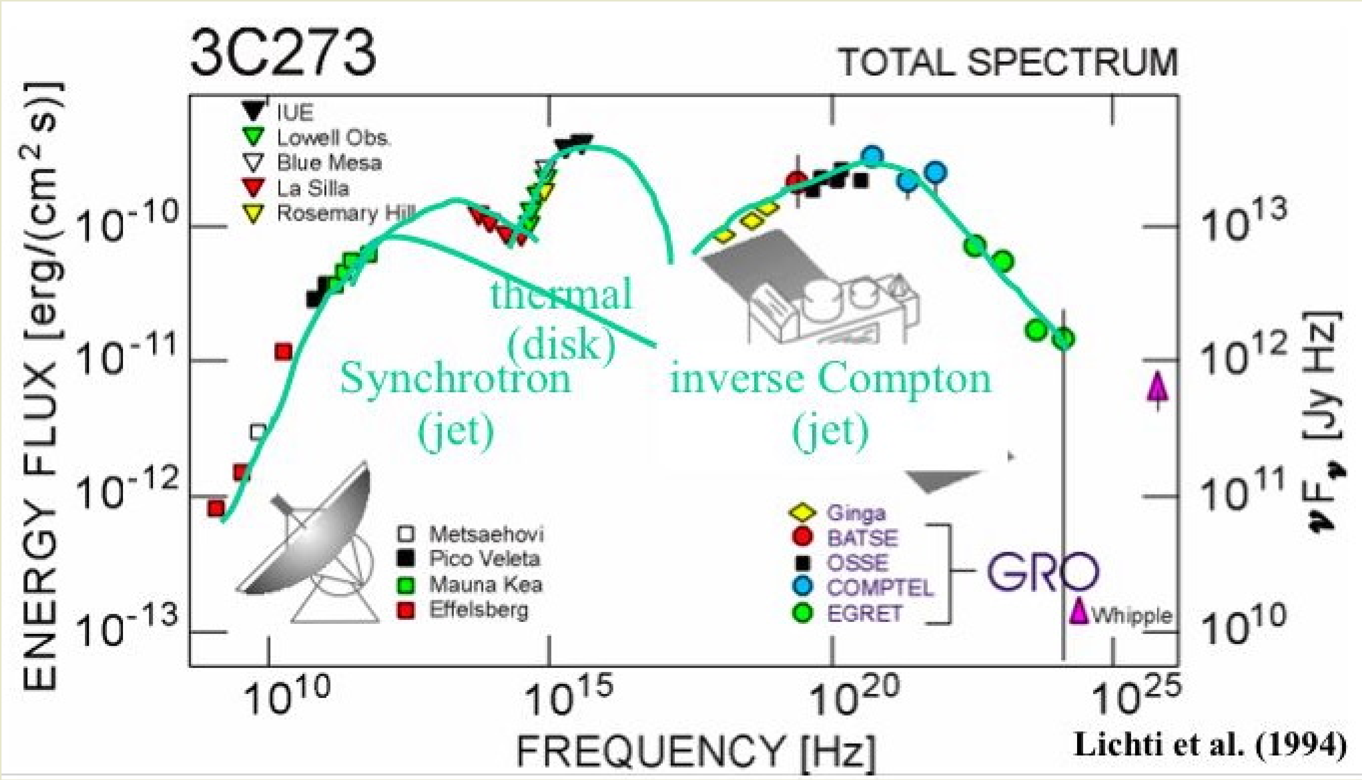




Standard model:

- **constant mass inflow:** $\dot{M}_{\mathrm{a}} = 2\pi r(-v_r) \int \rho dz$
- **Keplerian rotation:** $\Omega = (GM/r^3)^{1/2}$
- **collisional, but viscosity inefficient at angular momentum transport**
- **turbulent MHD stresses generated by magnetorotational instability –** $W_{r\phi} = \langle B_r B_\phi \rangle / 4\pi$ **can transport angular momentum:** $\dot{M}_{\mathrm{a}} \sim -(2\pi/\Omega) \int W_{r\phi} dz$
- **radiatively efficient: gravitational binding energy radiated locally** $\Rightarrow$ **geometrically thin (**$h \ll r$**)**

- **internal energy conservation:** $F(r) \sim 3GM\dot{M}_{\rm a}/8\pi r^3$
- **X-rays generated in a diffuse, magnetized corona ⇔ solar corona**
- **relativistic jets probably accretion powered, Poynting-flux dominated**



Low-$\dot{M}_{\mathrm{a}}$ systems:

- **collisionless ($t_{ei} > t_{\mathrm{inflow}} = r/v_r$)**
- **turbulent**
- **geometrically thick, 2-temperature plasma: $T_i \simeq 10^{12}\,\mathrm{K}$, $T_e \simeq 10^{10}\,\mathrm{K}$**

Critical assumption: electron-ion thermal coupling via wave-particle processes negligible $\Rightarrow$ ion pressure supports a "fat torus" geometry and internal energy is advected into the black hole rather than radiated away by electrons

Unresolved issue: to what extent can wave-particle processes couple the electrons and ions and which are the most relevant microprocesses?