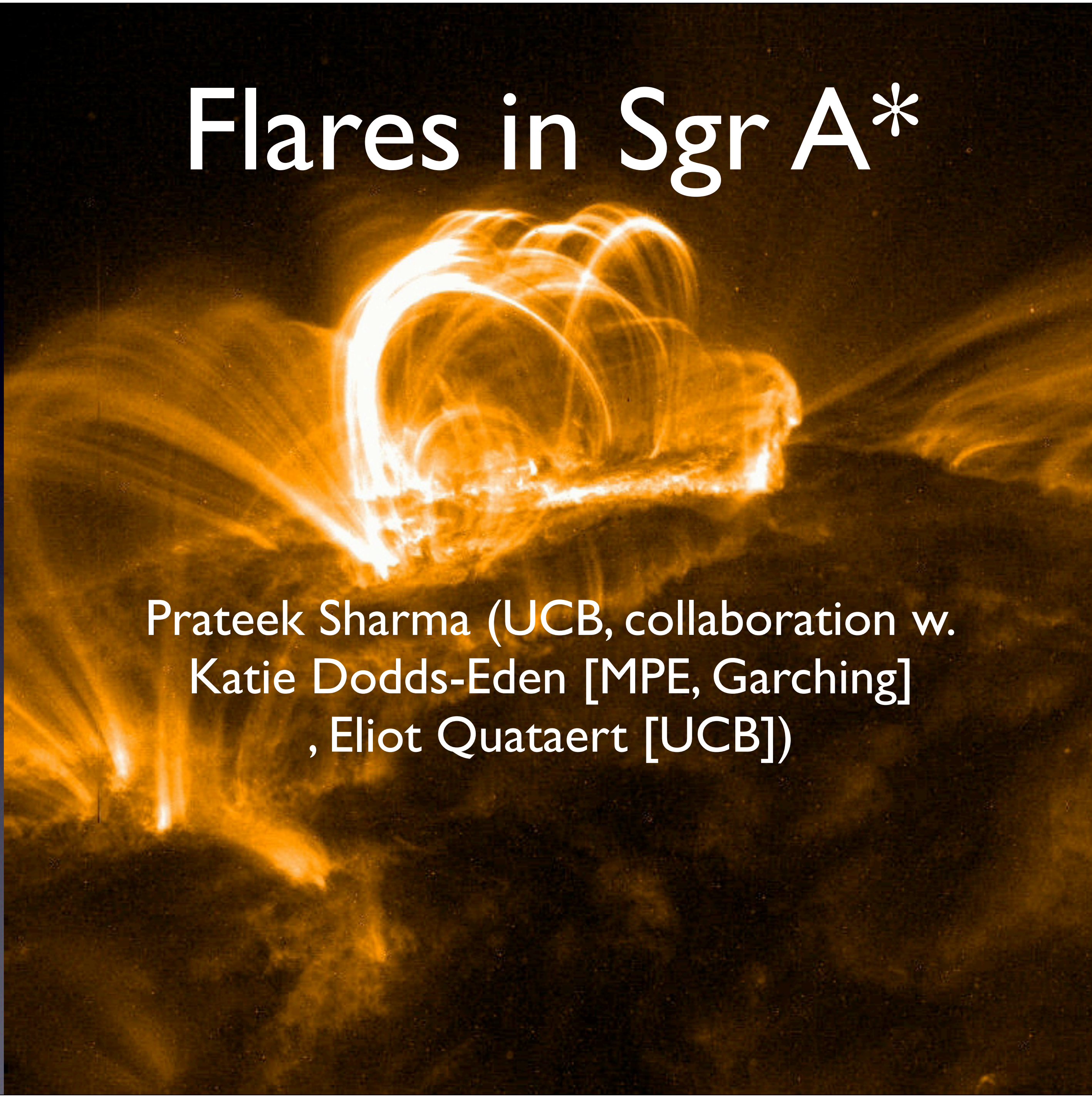
Flares in Sgr A*



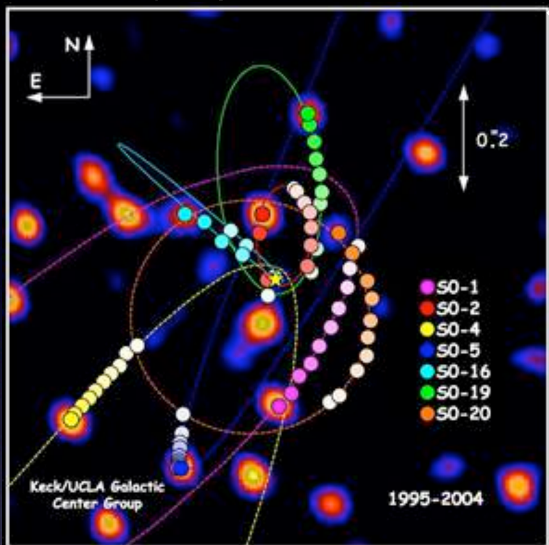
Prateek Sharma (UCB, collaboration w.
Katie Dodds-Eden [MPE, Garching]
, Eliot Quataert [UCB])

Flares in Astrophysics

- sudden jump in luminosity across λs
- unlike space physics: spatially unresolved; only spectra and lightcurves
- magnetic flares: low-mass stars, magnetars, ...
- focus on Sgr A*, the Galactic center BH

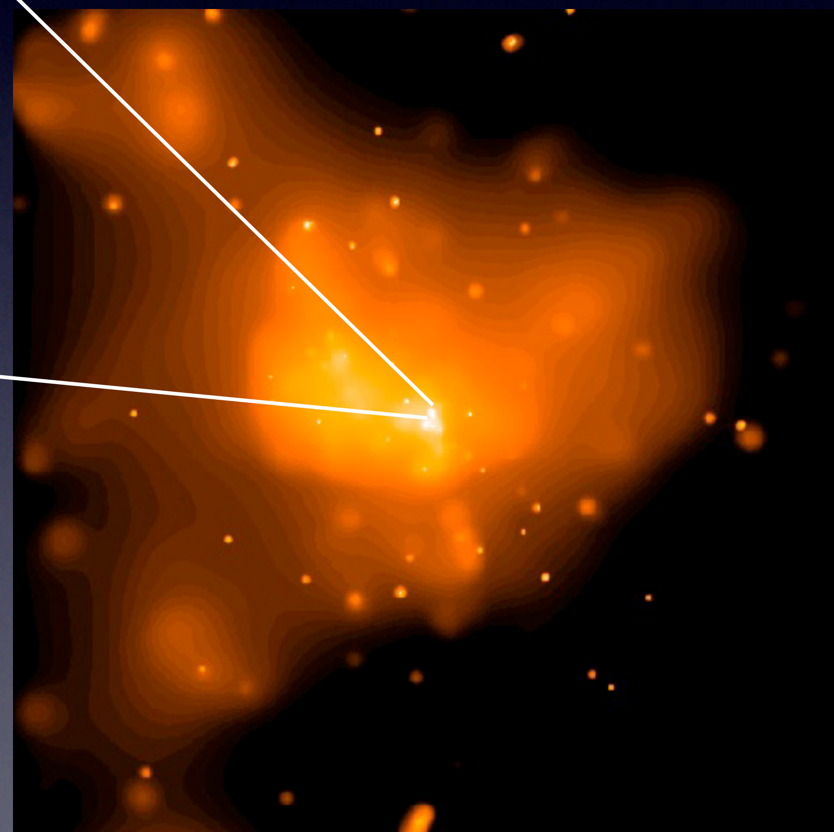
Sgr A*

[UCLA group, Genzel et al.]



0.05pc

Galactic supermassive BH ($4x10^6 M_{sun}$)

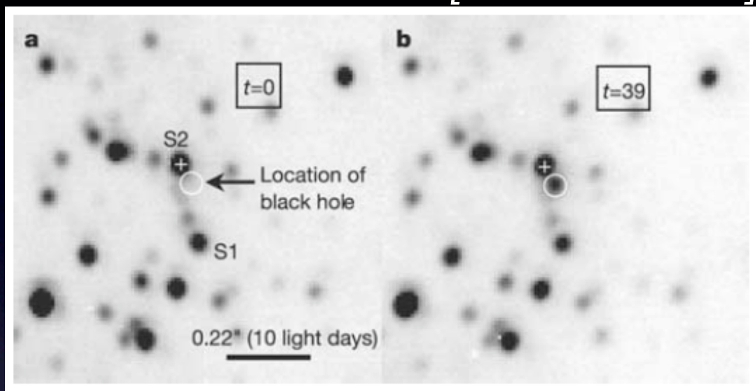


2.5pc

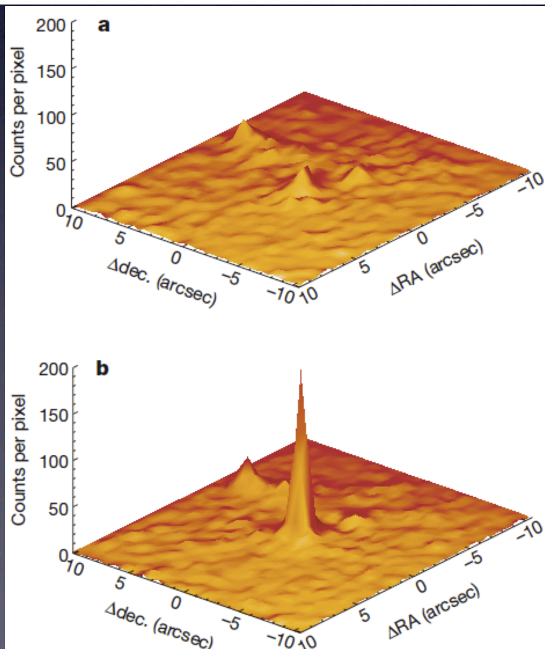
unremarkable in X-ray lum.
quiescent L ~ 10^{36} erg/s (radio dom.)
barely resolved by *Chandra*

Flares from Sgr A*

IR *[Genzel et al. 2003]*

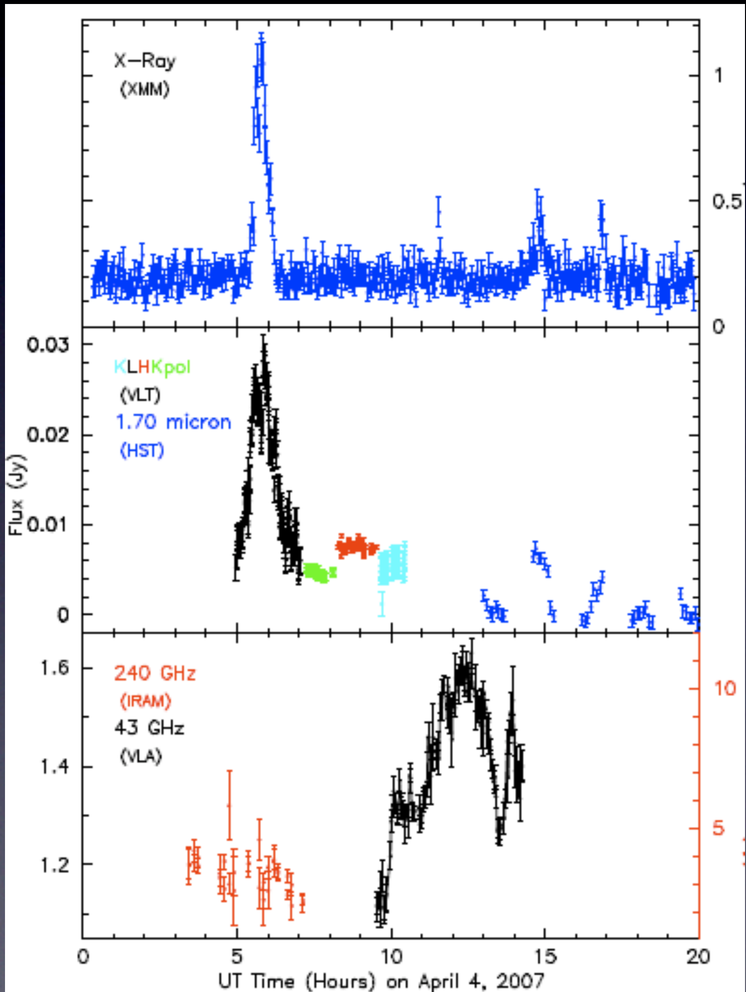


X-ray *[Baganoff et al. 2001]*



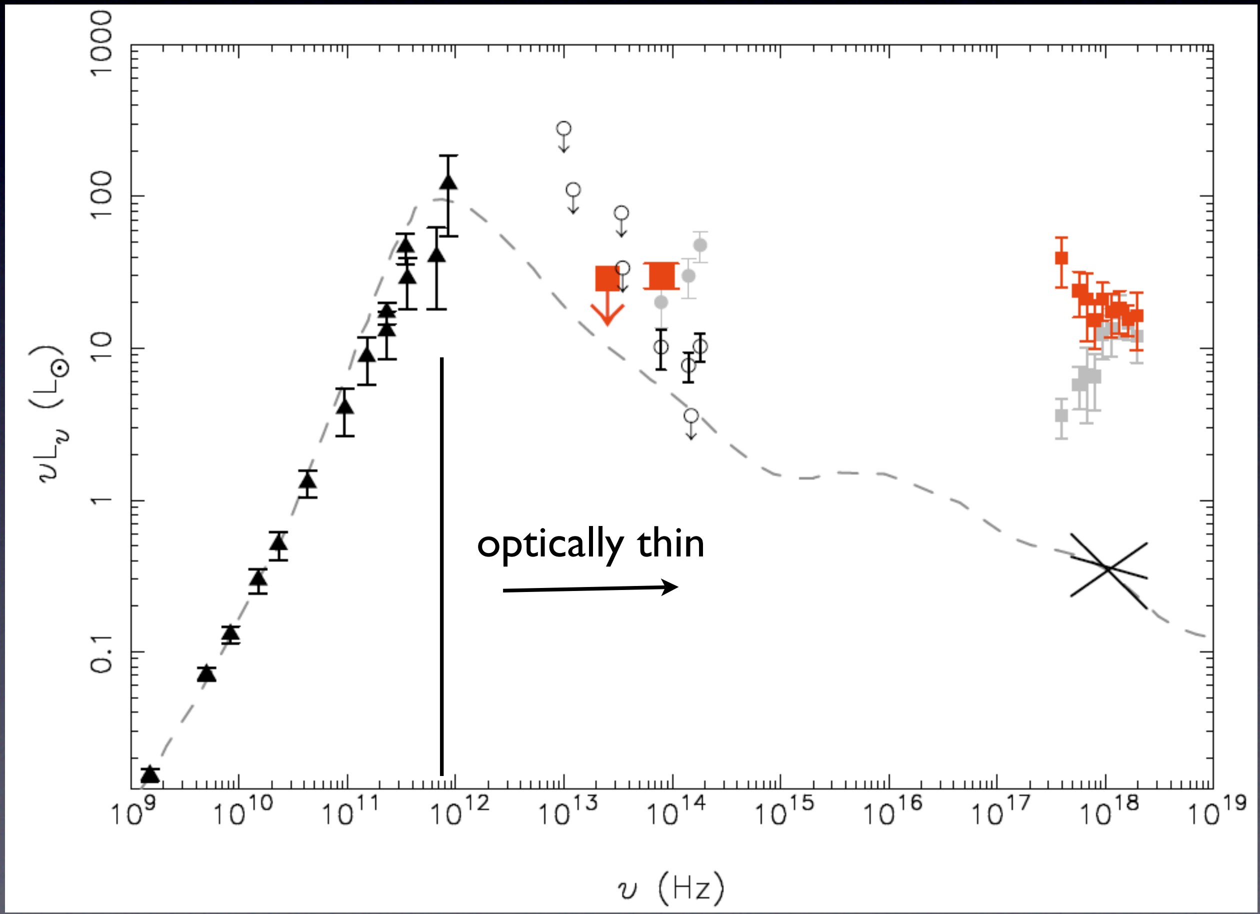
upto few/night
brighter rare

[Yusef-Zadeh et al. 2009]



Spectrum

[Dodds-Eden et al. 2009]

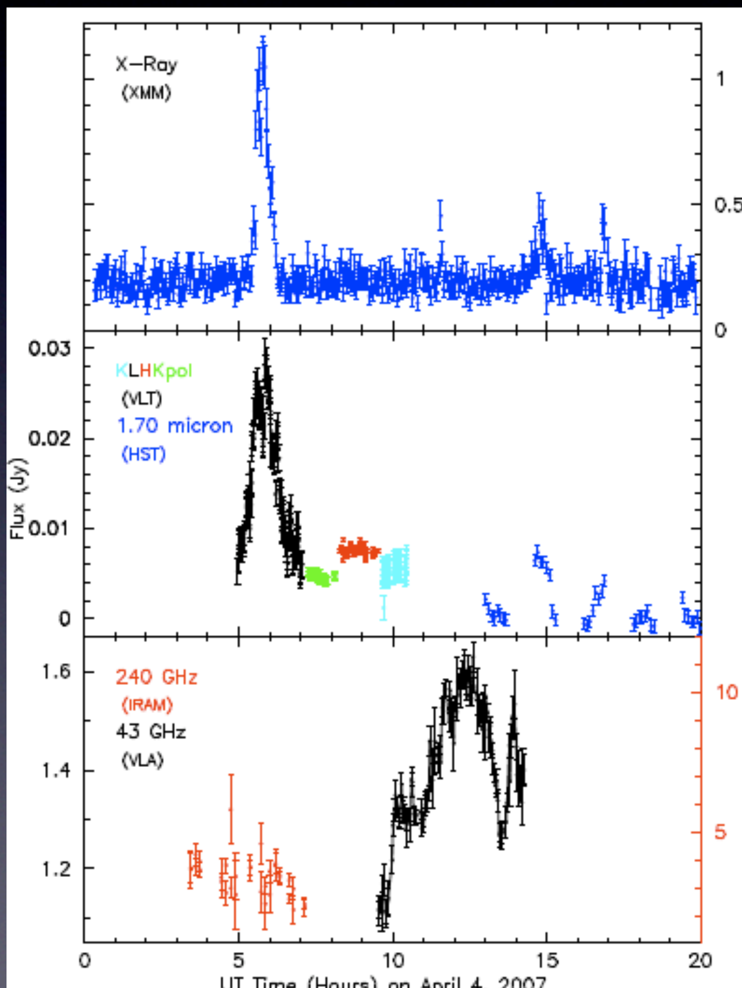


Generic Features

- IR flares most common; X-ray=>IR, not vice-versa
- only few simultaneous broad-band flares
- amplitude ↓ as ν ↓; highest amp. in X-ray, then IR, mm
- X-ray flare (20 min) $\leq$ IR (40 min) $\leq$ mm (few hrs)
- polarized IR (=>synchrotron), change in PA after peak

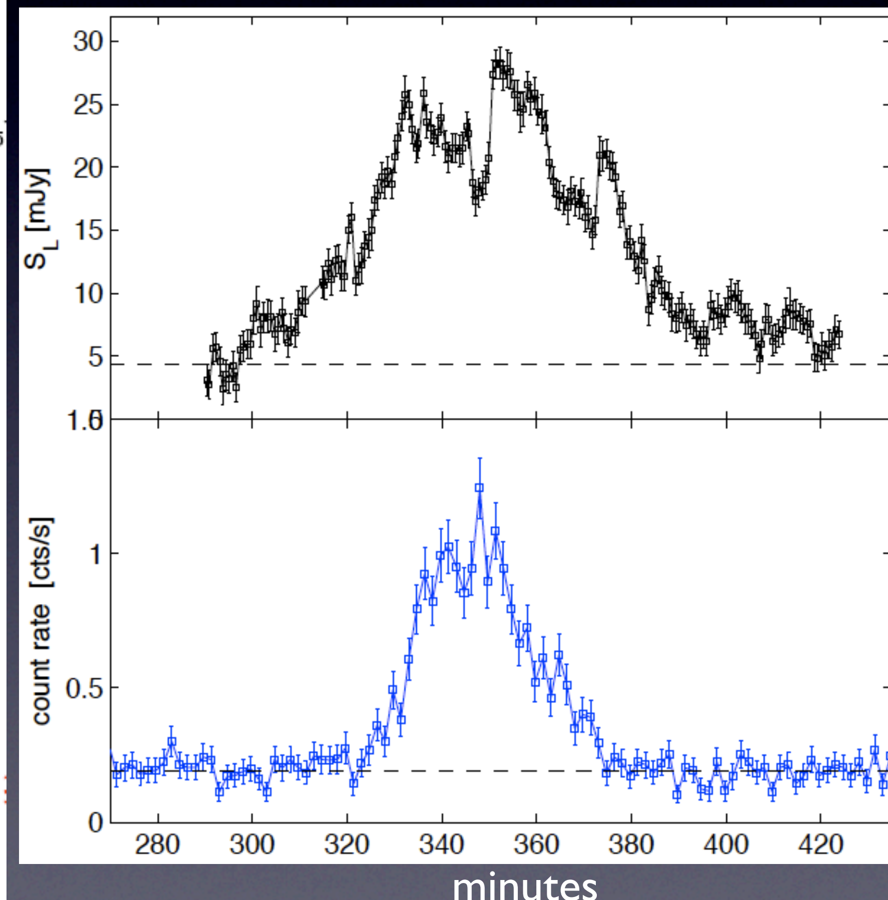
A multi-λ flare

[Yusef-Zadeh et al. 2009]



short Δt=>$R_F \leq R_S$

[Dodds-Eden et al. 2009]



Modeling

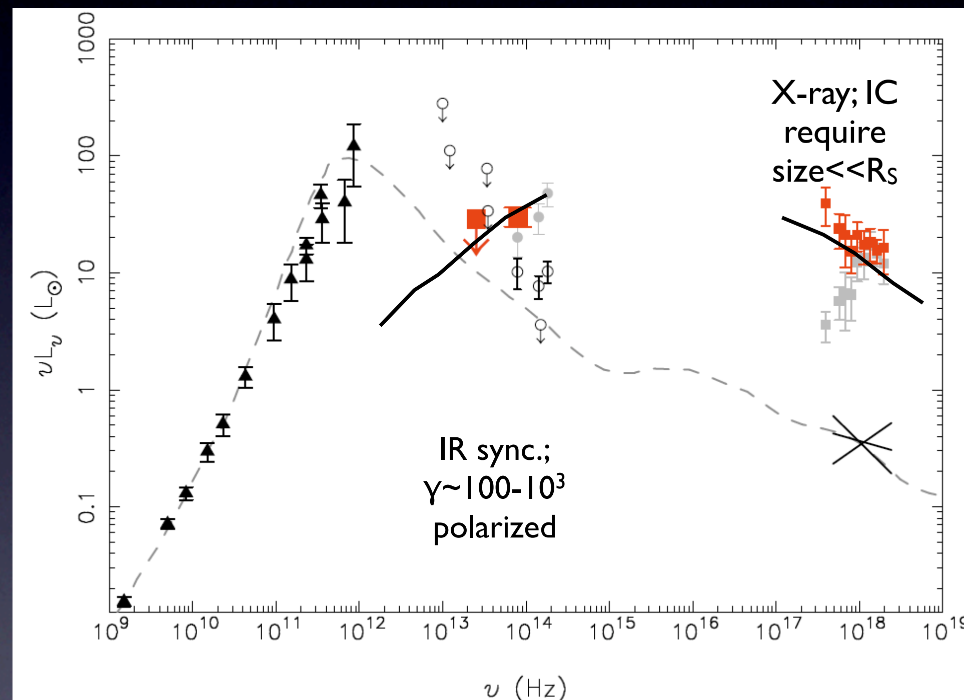
$$L_{\rm synch} \propto N\theta_E^2 B^2$$

$$L_{\rm IC} \propto N\theta_E^2 R_Q^{-2}$$

$$L_{\rm SSC} \propto N^2\theta_E^4 B^2 R_F^{-2}$$

$$\nu_{IC} = \gamma^2 \nu_{seed}$$

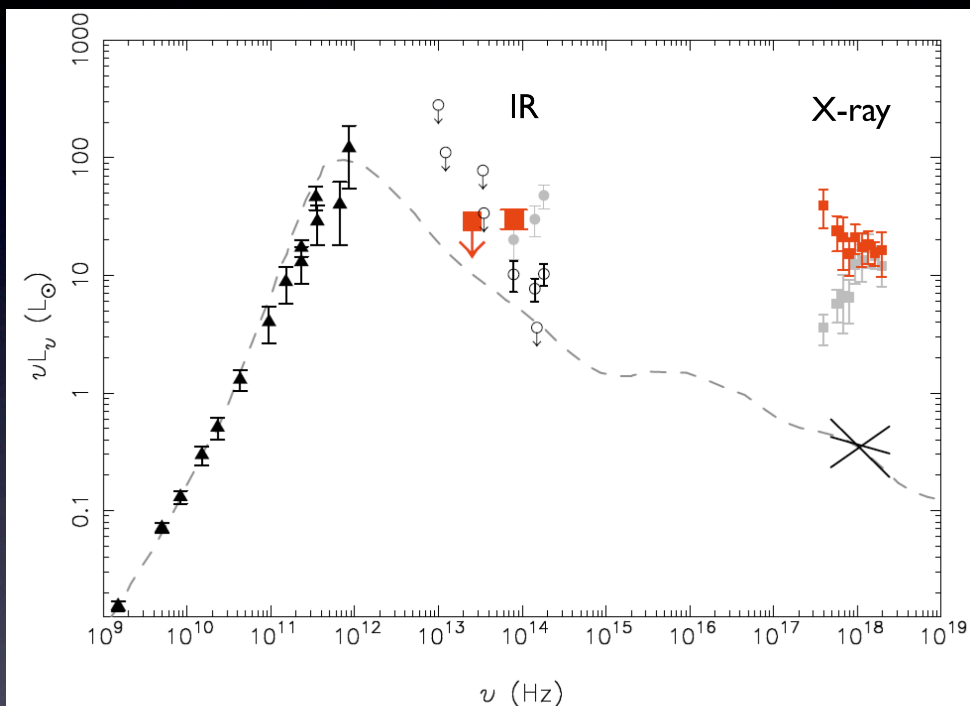
$$\nu_c = 4.2 \times 10^6 B\gamma^2$$



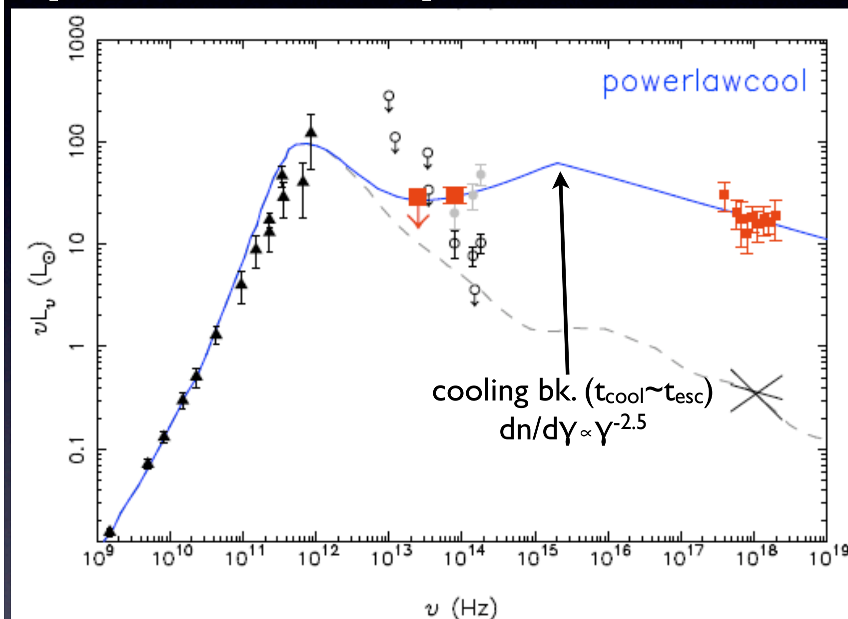
IC: R_Q too small (contradicts size mm.), << R_S
SSC: B too large

IC/SSC may apply for other flares where IR is softer and X-ray harder

Synchrotron+cooling



[Dodds-Eden et al. 2009]

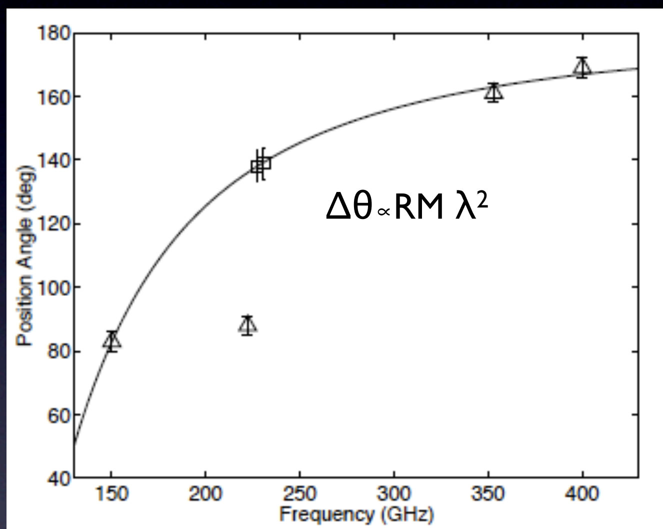


B~30G from Faraday RM constrains
agree w. global MHD sims.
constrains on peaks of IR/X-ray spec.=>
optically thin synchrotron from IR to X-ray

$$\tau_{cool} = 8 \left(\frac{B}{30\ \mathrm{G}}\right)^{-3/2} \left(\frac{\nu}{10^{14}\ \mathrm{Hz}}\right)^{-1/2} \ \mathrm{min}$$

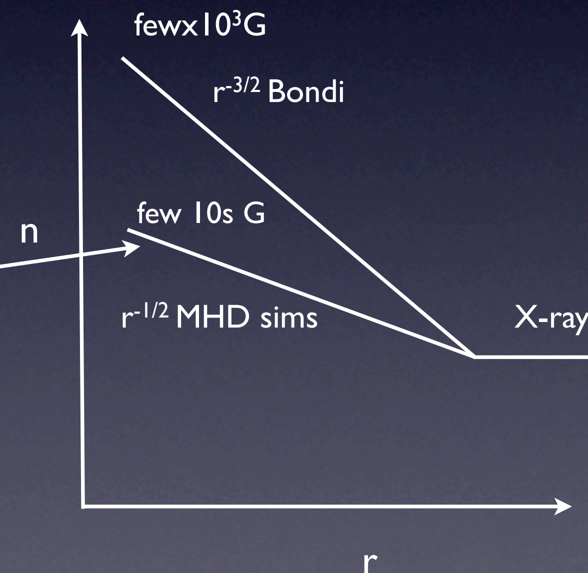
Faraday RM

[Bower et al. 2003; Marrone et al. 2007]

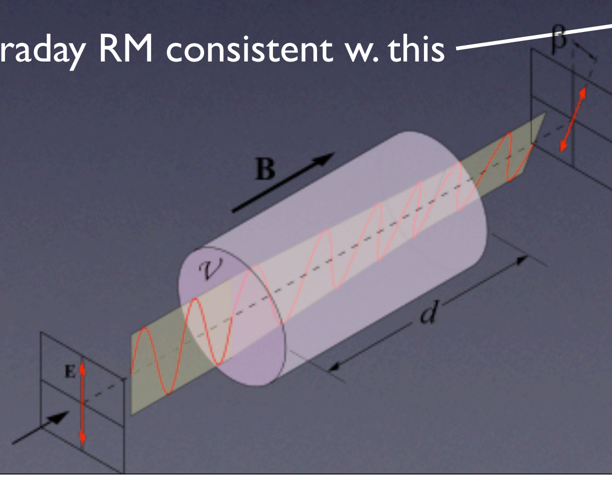


RM ($\propto \int nB_{||}ds$) $\approx 6\times10^5$ rad/m^2; steady in time

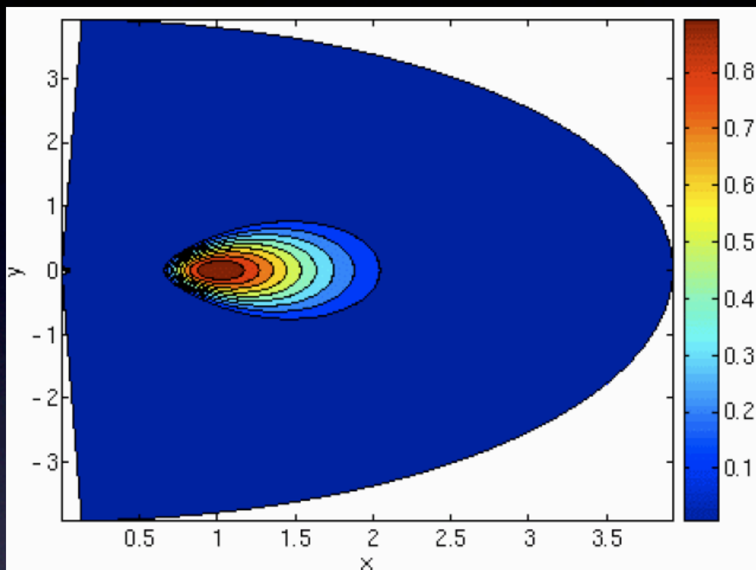
assuming $B \sim (nT)^{1/2}$, $RM \sim n^{3/2}$; measuring RM constrains n_{in}



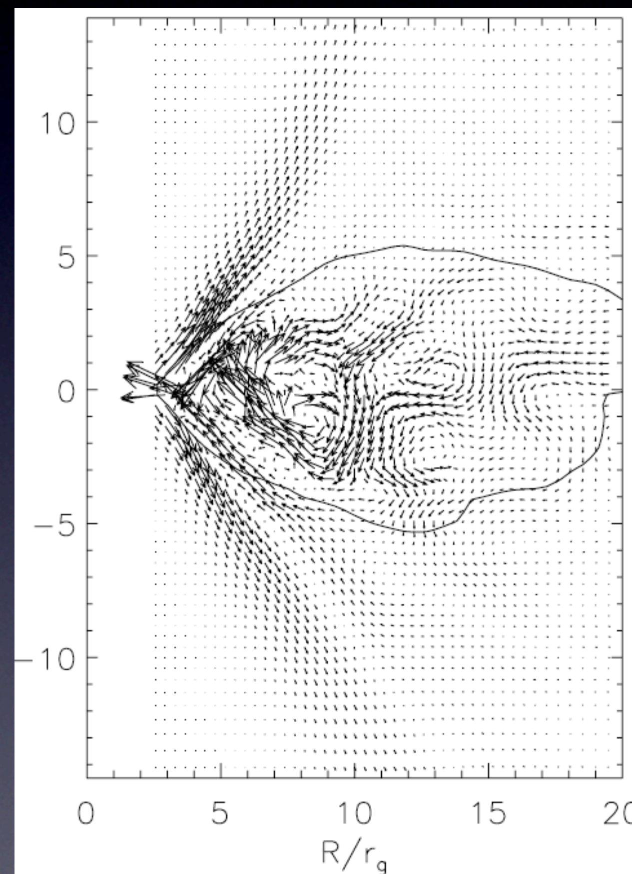
Faraday RM consistent w. this

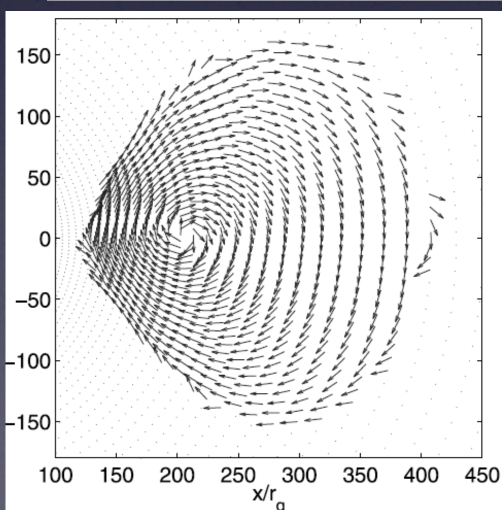


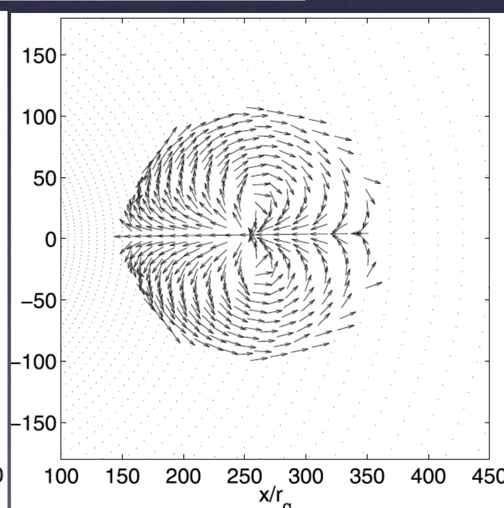
Hot Accretion sims.



[Hawley & Balbus 2002]



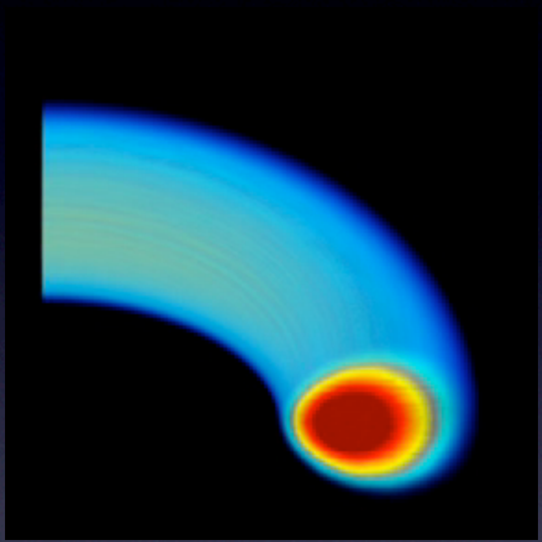


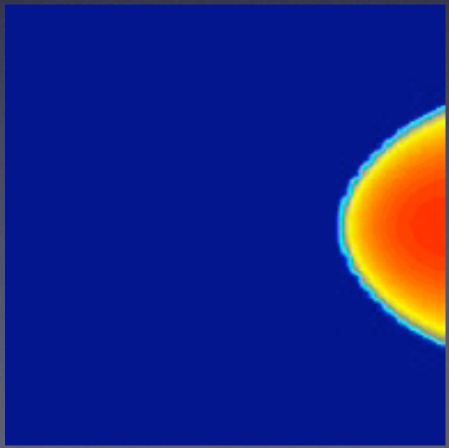


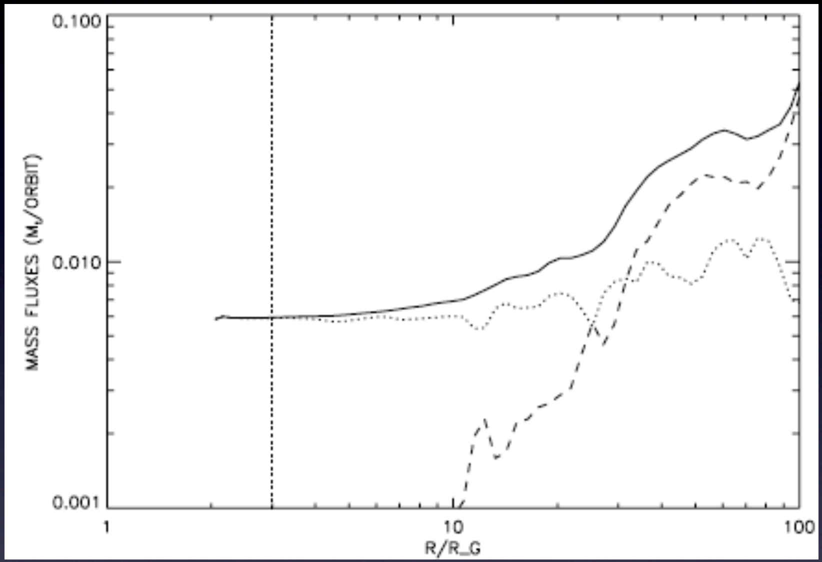
MHD turbulence & transport

MHD simulations

[movies by John Hawley]





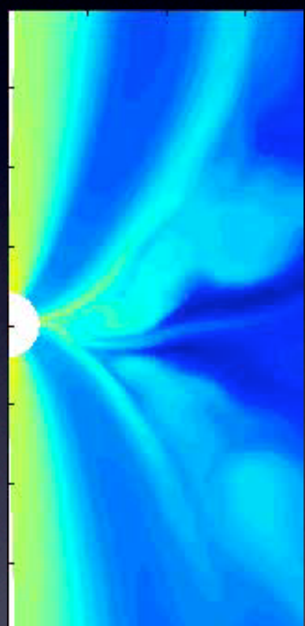


accretion very efficient E~0.1mc^2; fusion~0.007mc^2
behind most energetic events in the universe:
GRBs, quasars,AGN,XRBs,...

RIAFs: only a small fraction of mass falls in!
$L=\eta\dot{M}c^2$; low luminosity by 10^5
accretion energy goes to ions=>η<<1

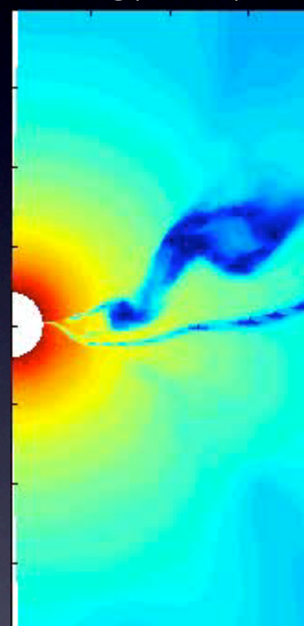
Flares in MHD sims?

Log(T)



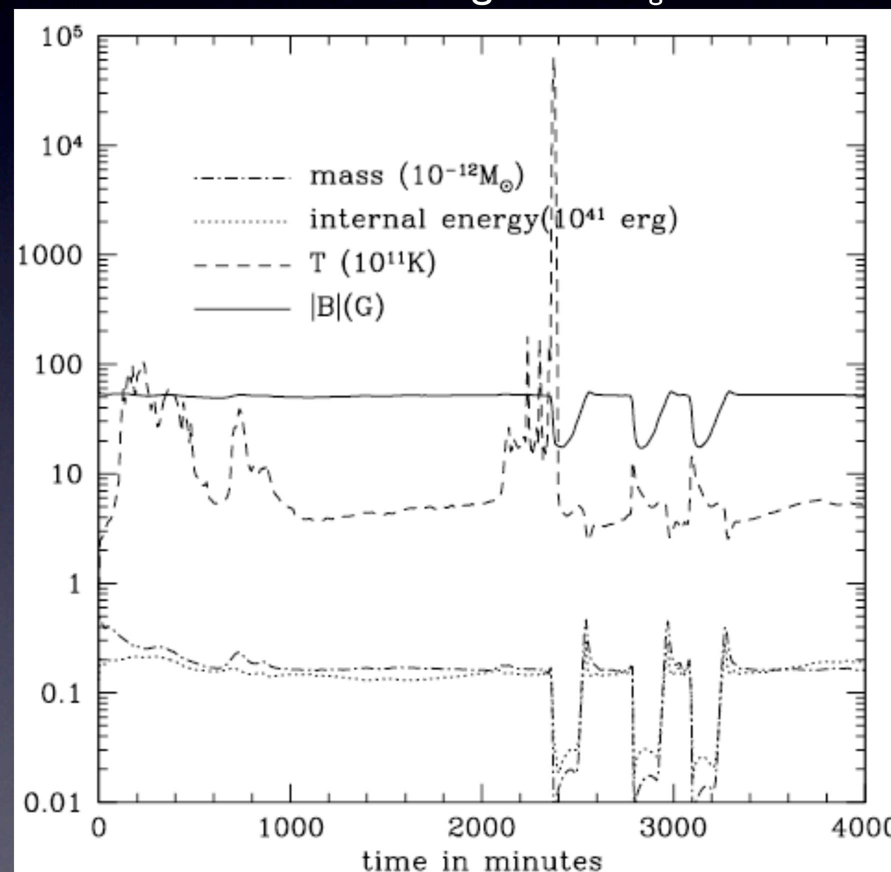
20r_g

Log($B^2/8\pi$)



20r_g

volume avg. over 6r_g

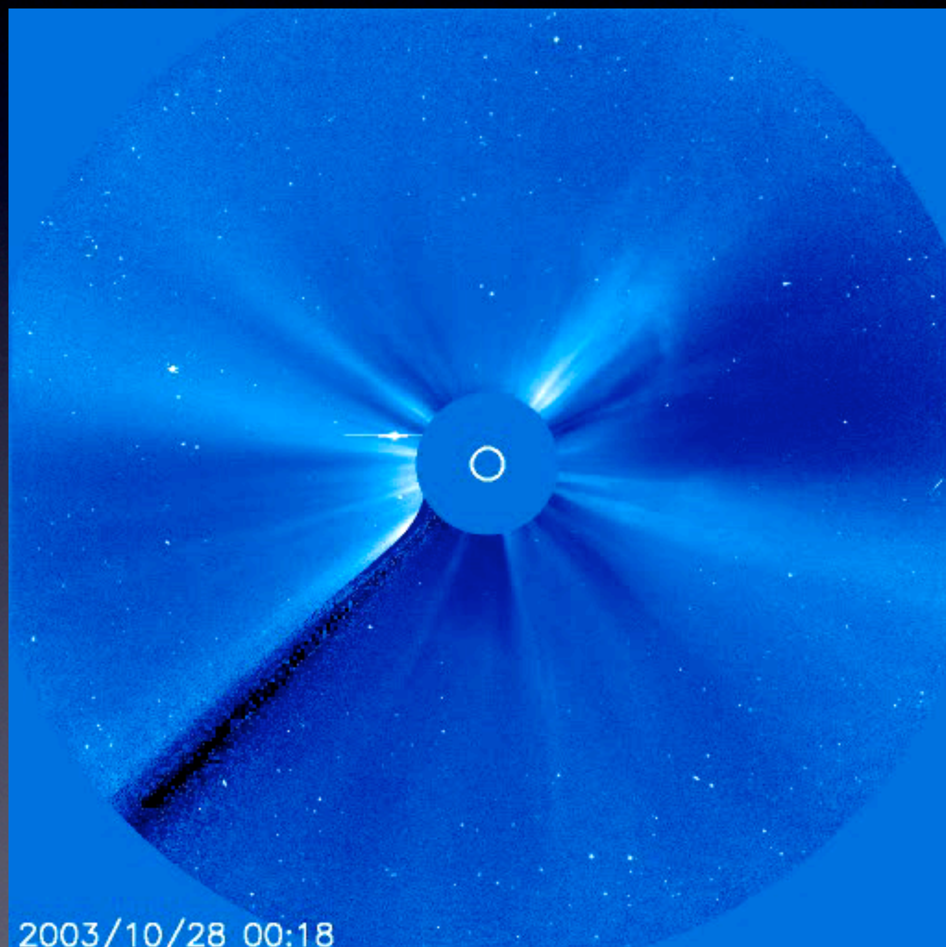


single initial loop, current sheet at equator

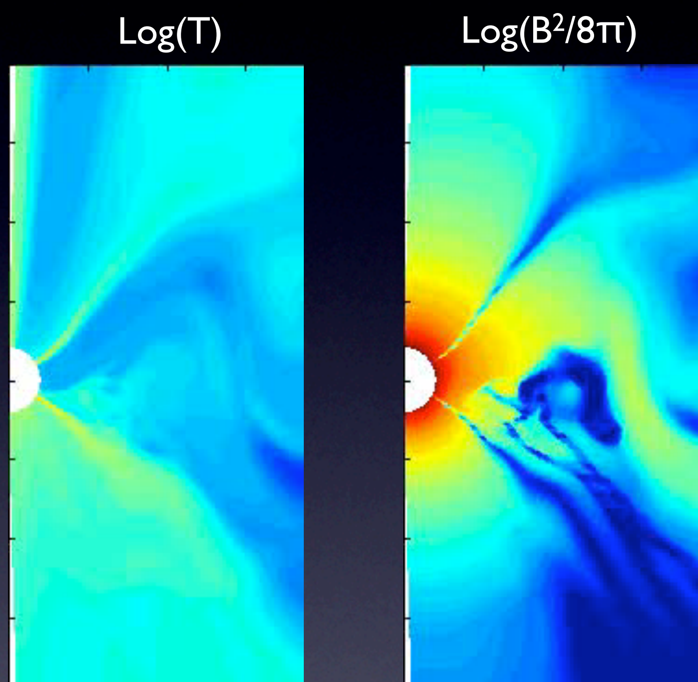
must look at short time (sampled at 8 min.), small volume

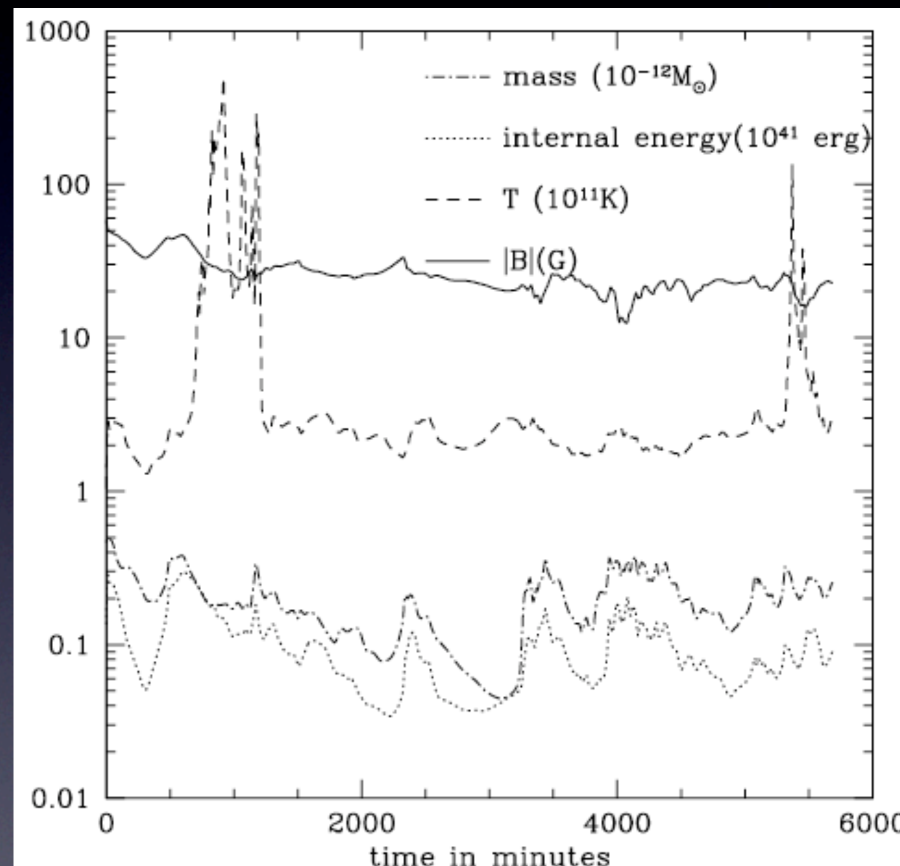
CME?

[SOHO]



Initial B-geometry

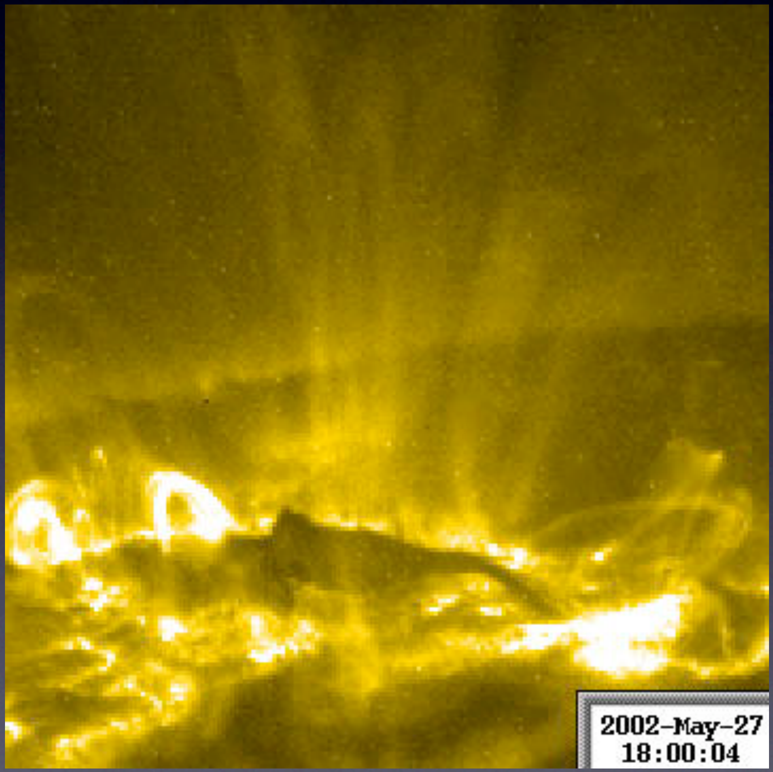




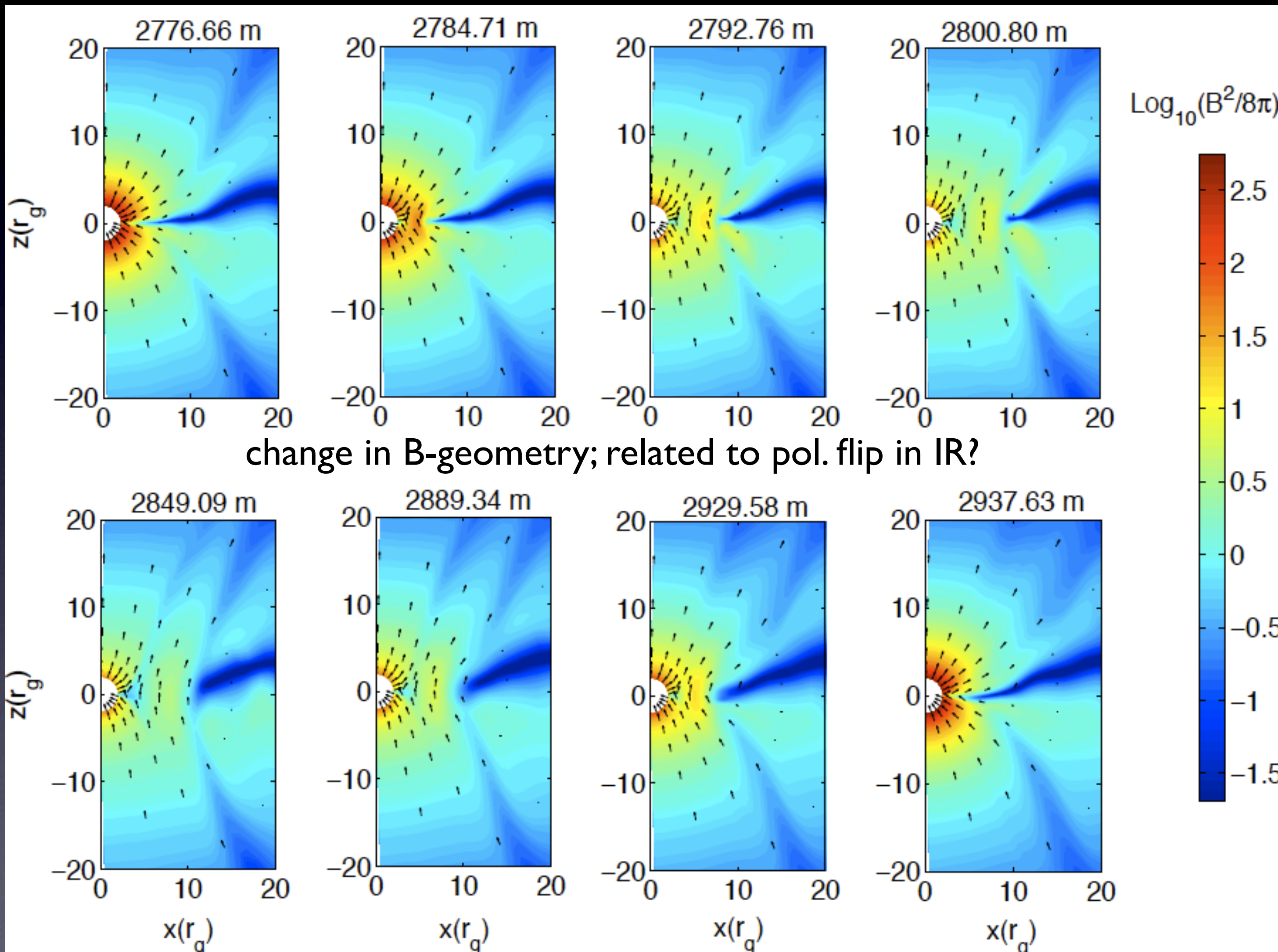
two initial loops, current sheets above/below equator
much more turbulent, thicker disk
less dramatic flares, still related to drop in B & rise in T

Variety in flares

[TRACE]

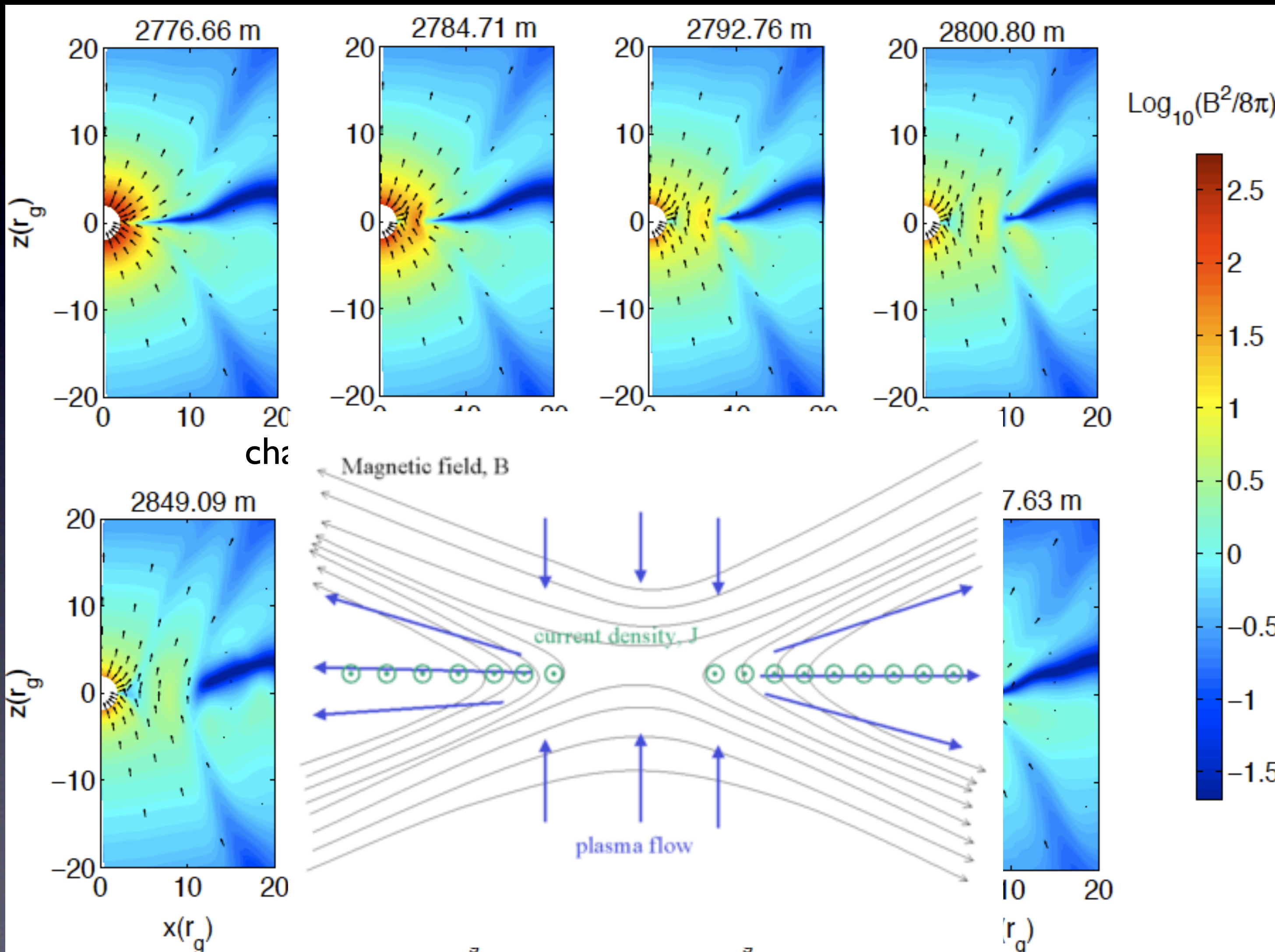


really Reconnection?



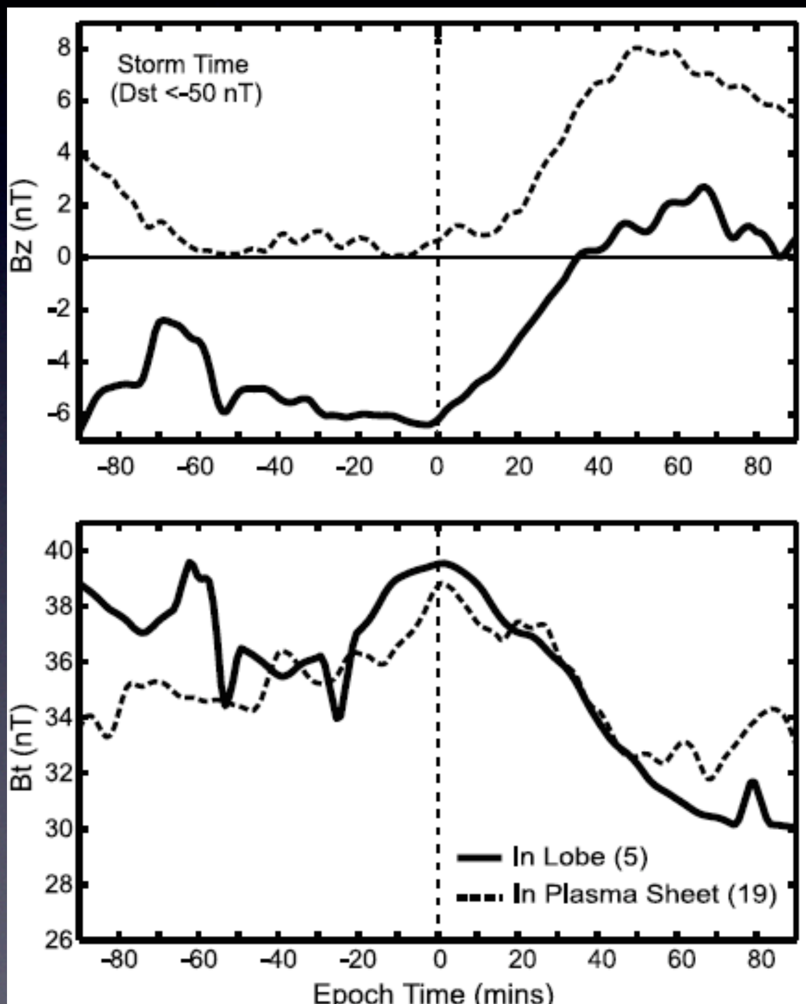
change in B-geometry; related to pol. flip in IR?

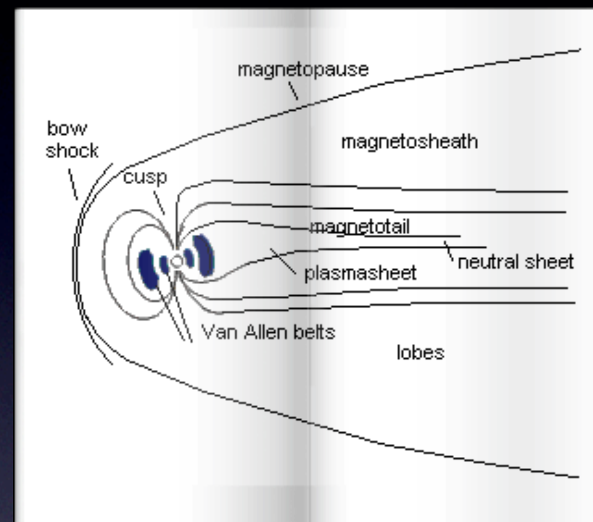
really Reconnection?



Tail reconnection

[McPherron & Hsu]

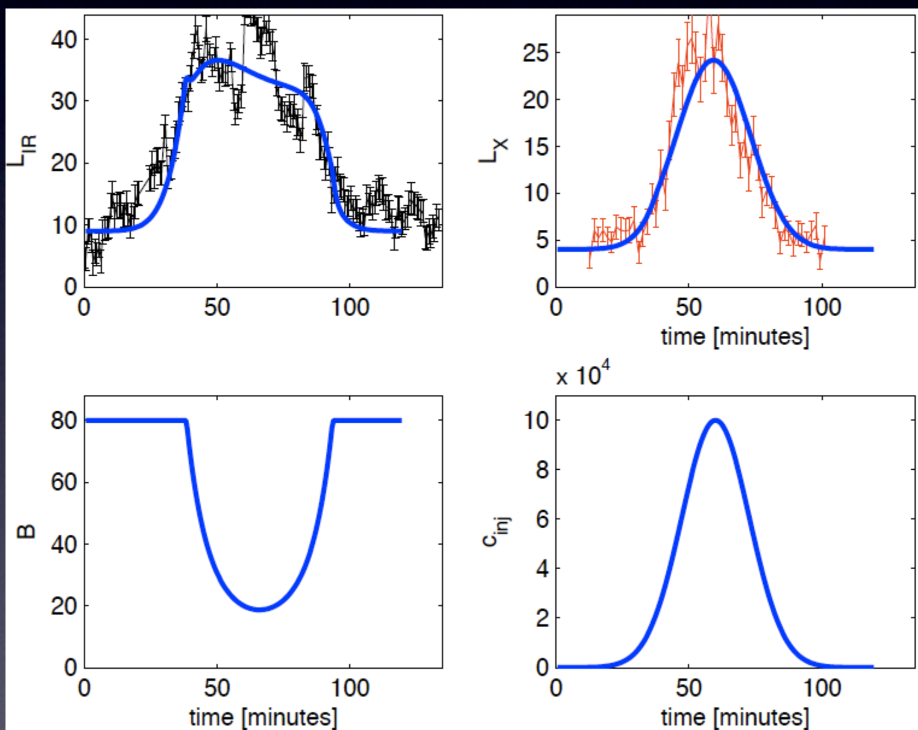




energy stored in B, suddenly released
change in B-geometry (B_z)
almost like the accretion flare!

Lightcurve/spectra

[courtsey Dodds-Eden]



$$\tau_{cool} = 8 \left(\frac{B}{30\ \mathrm{G}}\right)^{-3/2} \left(\frac{\nu}{10^{14}\ \mathrm{Hz}}\right)^{-1/2} \mathrm{min}$$

one-zone model $n_e(\gamma,t)$; adiabatic, cooling losses

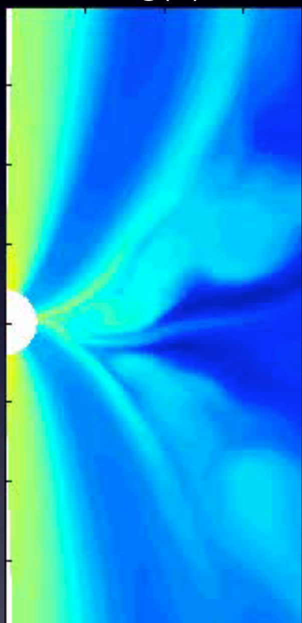
X-ray traces particle injection; IR affected by cooling

reduction in B sufficient to energize flare e^-s (eff~0.002)

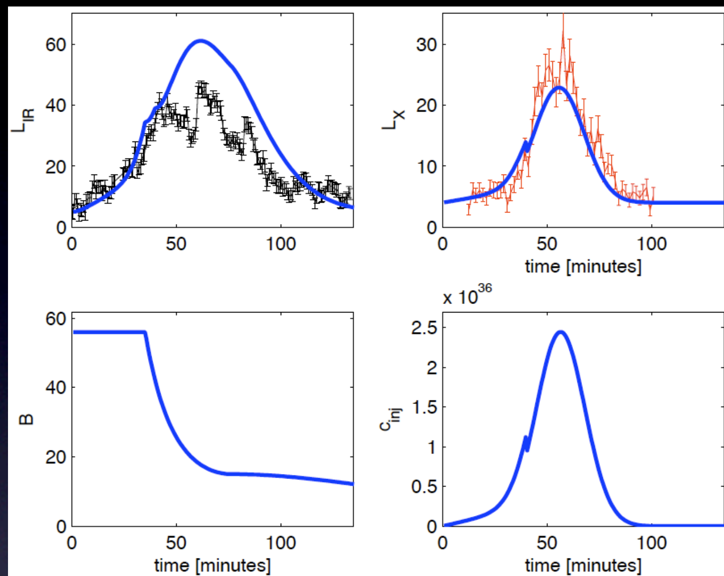
Radio flare

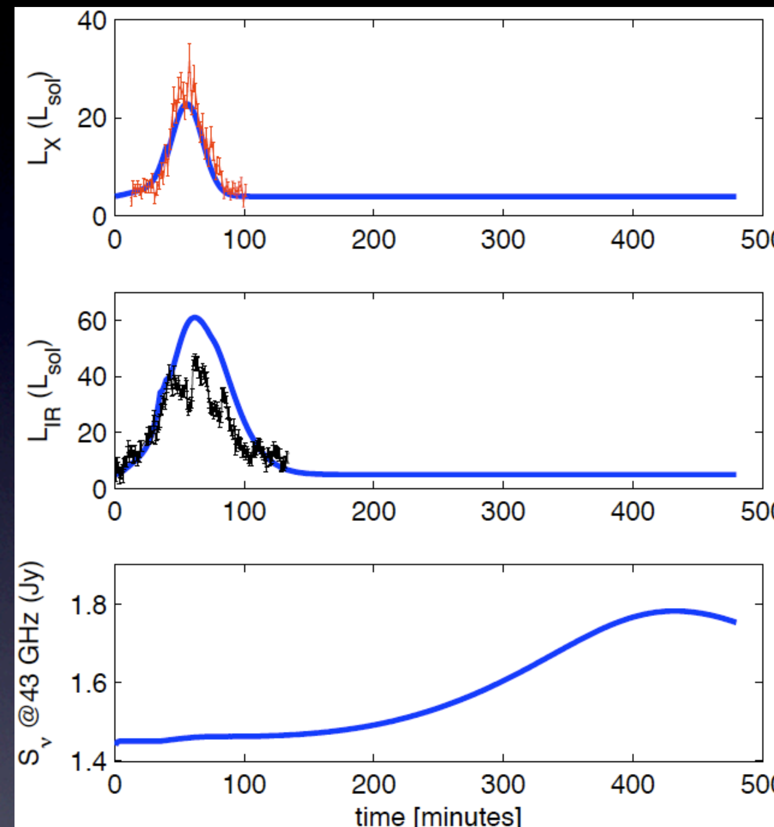
[in progress]

Log(T)



$20r_g$



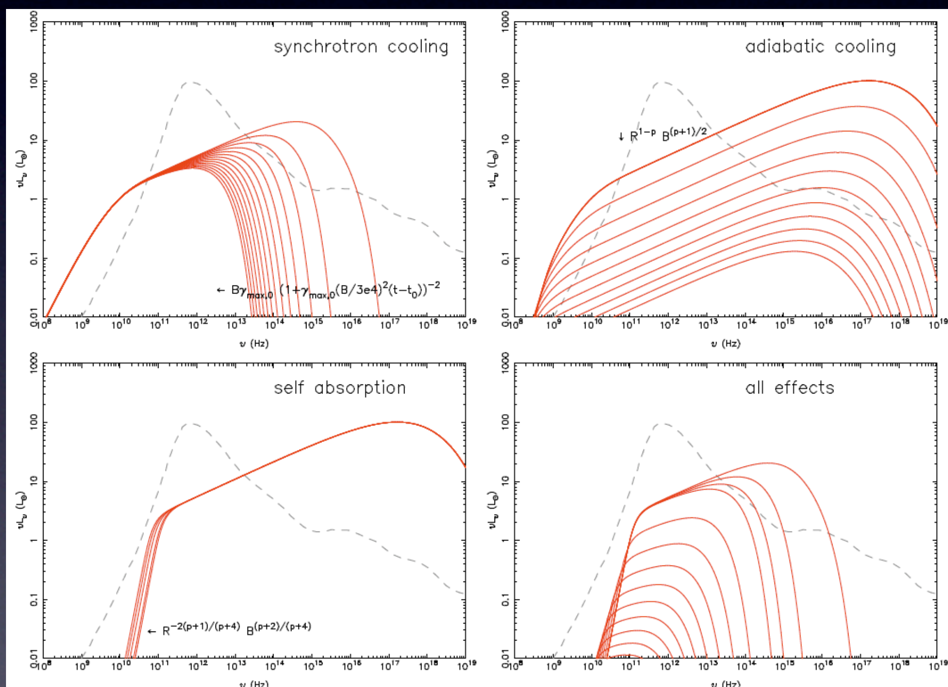


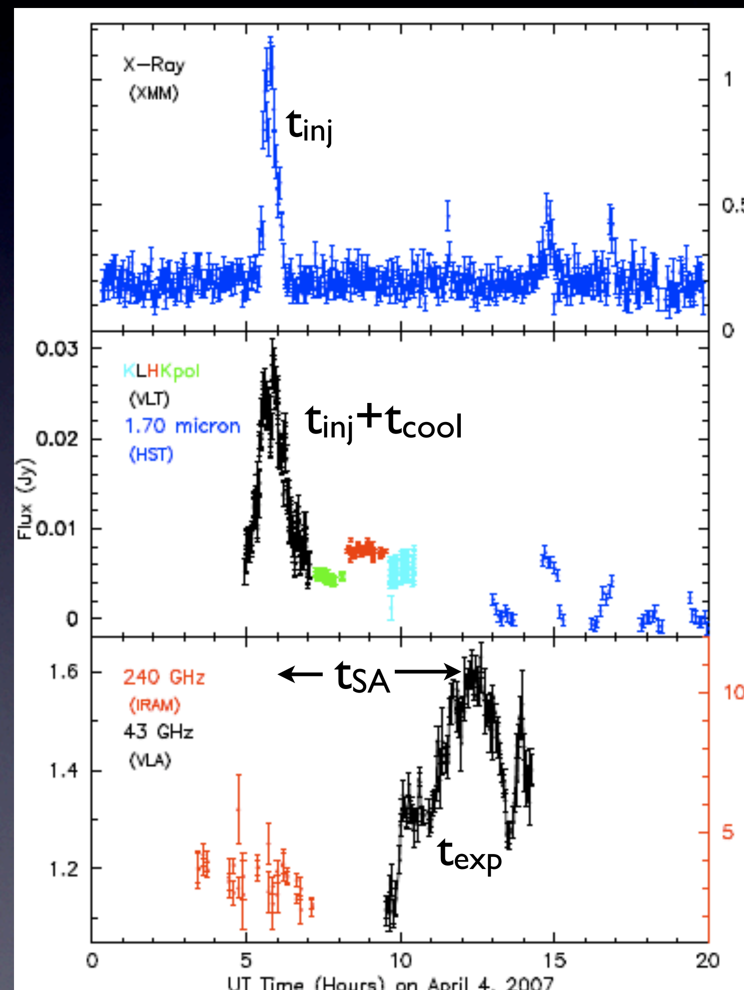
blob expands & become optically thin; delay inc. w. λ

quiescent flow optically thick @43GHz; turbulent fluc. in $\dot{M}$ look like flare

higher freq. flares are cleaner because optically thin

Time-dependent model





Future

- Modeling:
  - GRMHD flares in 3-D; resistivity??
  - better radiation transfer; GR, inclination/spin effects
  - effect of initial B-field configurations
- Observations:
  - time resolved spectra of bigger flares
  - better statistics; is sync. soft X-ray hard IR or IC/SSC needed?
  - polarization, Faraday rotation during flares
- Connections w. space physics!

Thank You!