Flares in Sgr A*

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Sgr A* 

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

unremarkable in X-ray lum.
quiescent L \sim 10^{36} \text{ erg/s (radio dom.)}
barely resolved by Chandra
Flares from Sgr A*

IR [Genzel et al. 2003]

[Yusef-Zadeh et al. 2009]

X-ray [Baganoff et al. 2001]

upto few/night brighter rare
Spectrum

[ Dodds-Eden et al. 2009 ]

optically thin
Generic Features

- IR flares most common; X-ray $\Rightarrow$ IR, not vice-versa
- only few simultaneous broad-band flares
- amplitude $\downarrow$ as $\nu$ $\downarrow$; 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
Hot Accretion sims.

[Hawley & Balbus 2002]

MHD turbulence & transport
Flares in MHD sims?

Log(T)

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

volume avg. over 6$r_g$

single initial loop, current sheet at equator
must look at short time (sampled at 8 min.), small volume
two initial loops, current sheets above/below equator
much more turbulent, thicker disk
less dramatic flares, still related to drop in $B$ & rise in $T$
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!
A multi-λ flare

[Yusef-Zadeh et al. 2009]

short $\Delta t \Rightarrow R_F \leq R_S$

[Dodds-Eden et al. 2009]
Modeling

\[ L_{\text{synch}} \propto N \theta_E^2 B^2 \]
\[ L_{\text{IC}} \propto N \theta_E^2 R_Q^{-2} \]
\[ L_{\text{SSC}} \propto N^2 \theta_E^4 B^2 R_F^{-2} \]

\[ \nu_{\text{IC}} = \gamma^2 \nu_{\text{seed}} \]
\[ \nu_c = 4.2 \times 10^6 B \gamma^2 \]

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

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

\[ \tau_{\text{cool}} = 8 \left( \frac{B}{30 \text{ G}} \right)^{-3/2} \left( \frac{\nu}{10^{14} \text{ Hz}} \right)^{-1/2} \text{ min} \]
Time-dependent model

- Synchrotron cooling
- Adiabatic cooling
- Self absorption
- All effects

Graph showing time evolution with $t_{inj}$, $t_{inj} + t_{cool}$, and $t_{exp}$, with flux at different frequencies (X-ray, 1.70 micron, 240 GHz, 43 GHz) over UT Time (Hours) on April 4, 2007.
Time-dependent model

\[ L_X (t_{\text{inj}} + t_{\text{cool}}) \]

- \( L_X \) (XMM)
- \( L_{\text{IR}} \) (VLT)
- \( L_{\text{Sol}} \) (HST)

\[ S_\nu \text{ @ 43 GHz} \]

- \( S_\nu \) (IRAM)
- \( S_\nu \) (VLA)

\[ \text{Flux (uJy)} \]

- \( 240 \text{ GHz} \) (IRAM)
- \( 43 \text{ GHz} \) (VLA)

\[ \text{UT Time (Hours) on April 4, 2007} \]
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 blue IR or IC/SSC needed?
  • polarization, Faraday rotation during flares
  • X-ray, IR cleaner than radio/sub-mm (turbulent fluctuations, association w. X-ray, IR flares?)