Quiescent X-rays from Sgr A* accretion flow & constraints from 3D GRMHD + GR polarized rad. transfer

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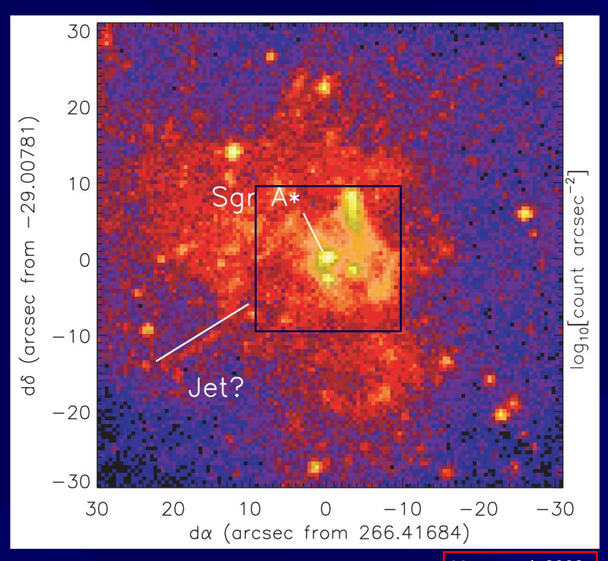
modeling X-rays

Black hole (BH) in the Galactic Center

$M = 4.3 \cdot 10^6 M_{Sun}$

Ghez, 2010, subm?

Hot gas produces extended emission + SSC process close to BH



Muno et al. 2008

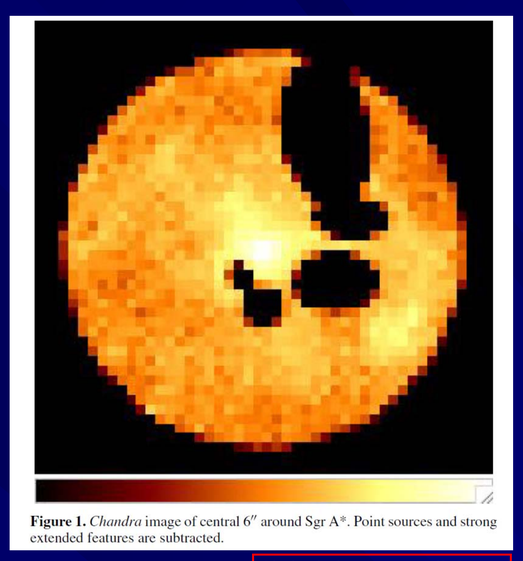
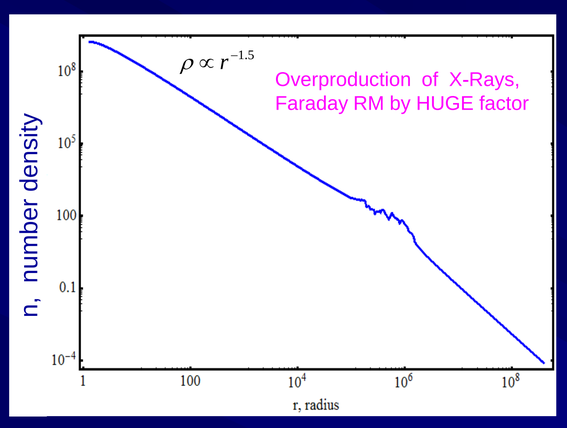


Figure 1. *Chandra* image of central 6′ around Sgr A*. Point sources and strong extended features are subtracted.

Shcherbakov, Baganoff, 2010

Black hole feedback is needed

Model w/o feedback cannot match observations



Overproduction of X-Rays, Faraday RM by HUGE factor

➡ Outflows ➡ No 1-st principle model

Blandford, Begelman 1999
Yuan et al. 2003

➡ Radiation feedback is negligible

the evidence of outflows from cometary shaped objects?

Muzic et al. 2010, subm

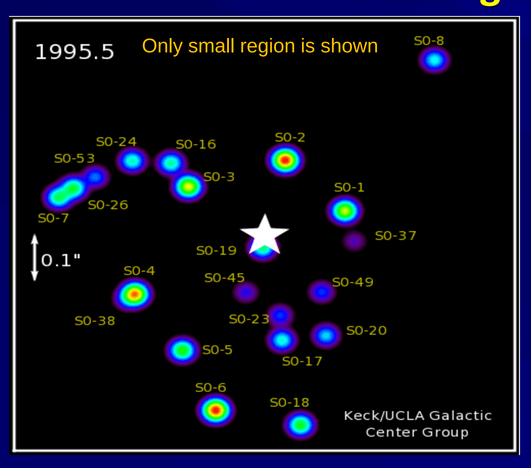
➡ Conduction Johnson, Quataert 2007

- ❖ electron conduction dominates convection etc.
- ❖ damped by a factor 3 to 5 in tangled magnetic field

Narayan, Medvedev 2001

❖ heat flux Q_e proportional to T_e gradient

Feeding by stellar winds



Stars emit wind at 300÷1200km/s
ejection rate $\sim 10^{-3} M_{Sun} / year$

Winds collide, heat the gas, provide seed magnetic field

Most of gas flows out, some accretes

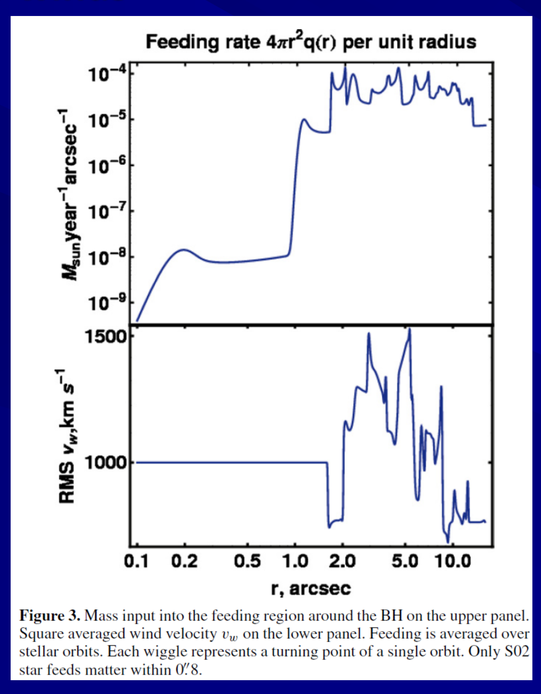


Figure 3. Mass input into the feeding region around the BH on the upper panel. Square averaged wind velocity v_w on the lower panel. Feeding is averaged over stellar orbits. Each wiggle represents a turning point of a single orbit. Only S02 star feeds matter within 0.″8.

Spherically symmetric accretion flows: minimal model with MHD turbulence

Shcherbakov 2008a

Inflow-outflow model with conduction and self-consistent feeding for Sgr A*

Shcherbakov Baganoff, 2010

Results

extended X-rays agree + SSC in quiescence

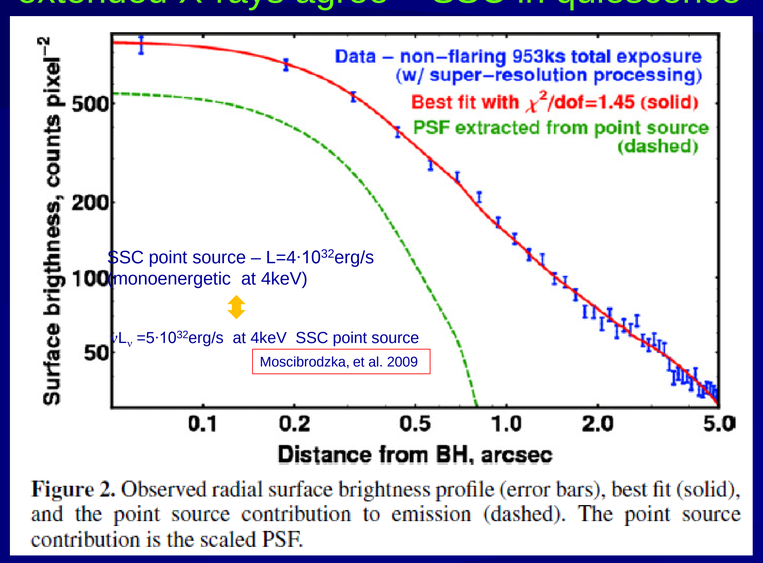
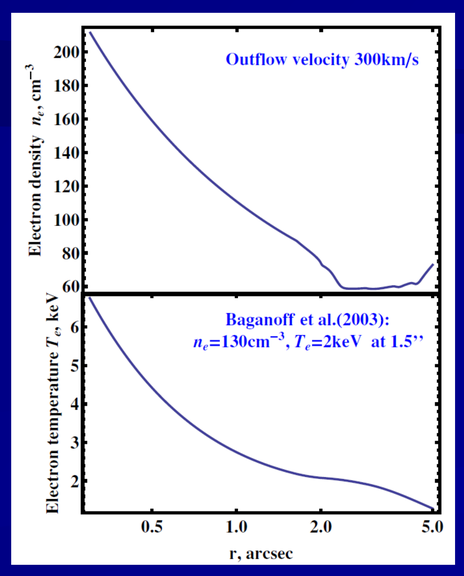


Figure 2. Observed radial surface brightness profile (error bars), best fit (solid), and the point source contribution to emission (dashed). The point source contribution is the scaled PSF.



accretion rate = $6 \cdot 10^{-8} M_{Sun}$/yr – <1% of the naïve model estimate, but agrees w/ sub-mm modeling

fitting sub-mm + polarized

Electron temperature near BH $T_e \sim 3 \cdot 10^{10}$ K

Sharma, Quataert, Hammett, Stone, 2007

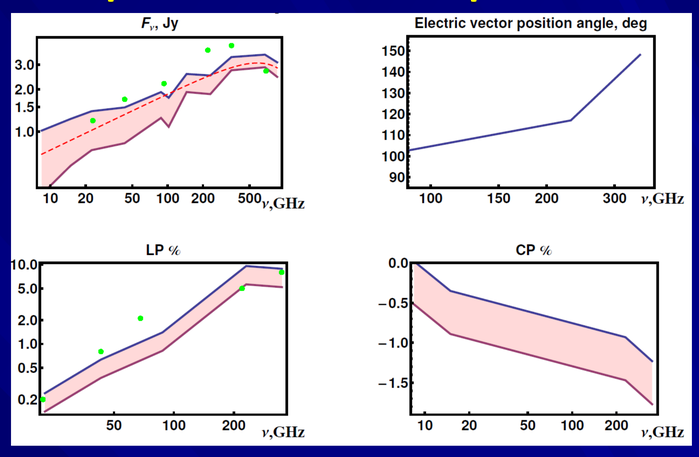
$\theta_e = \frac{kT_e}{m_e c^2} = 5 \Rightarrow$ Transrelativistic electrons (that's where all the problems come from)

Polarized observation provide more information + GR allows to determine spin ➡ General relativistic polarized radiative transfer: the interface between dynamics and observations — Shcherbakov, Huang 2010, subm.

Faraday conversion is crucial in calculation of circular polarization (V) ➡ Propagation effects in magnetized transrelativistic plasmas — Shcherbakov 2008b

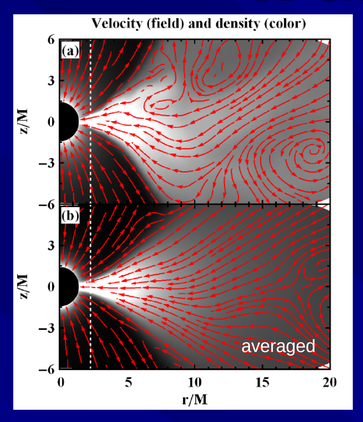
Applications of the above + results for spin, accretion flow parameters ➡ Constraining the accretion flow in Sgr A* by GR dynamical and radiative modeling — Shcherbakov, Penna, McKinney, 2010, in prep.

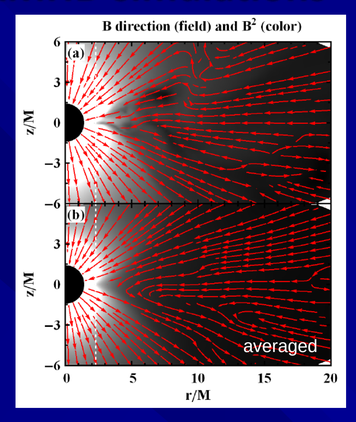
Compilation of sub-mm polarized observations

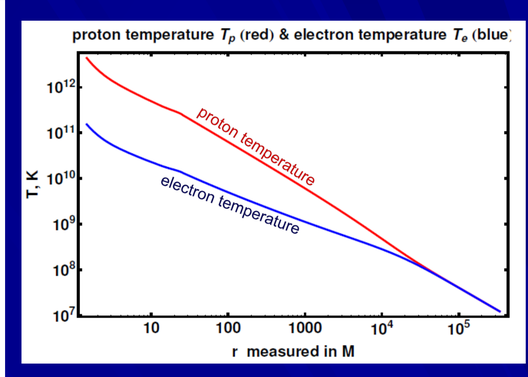


29 papers incorporated:
- ❑ median within errors is shaded
- ❑ CP by SMA (Moran et al.)
- ❑ dots show old compilation

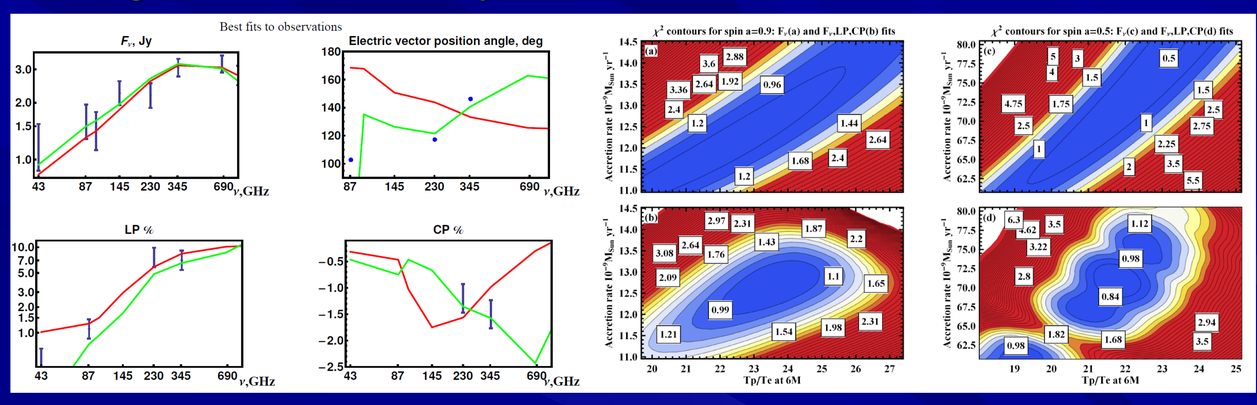
3D GRMHD simulations + extensions





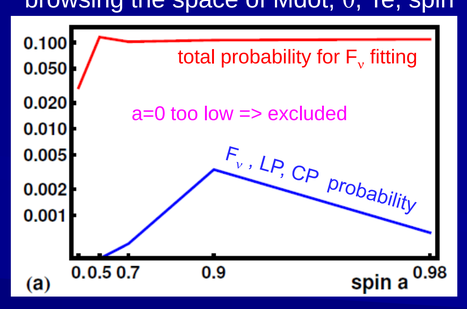


Fitting sub-mm with GR polarized radiative transfer – two models



Constraining the parameters

browsing the space of Mdot, θ, Te, spin



90% confidence intervals

$\theta = 59^\circ \pm 9^\circ$ inclination angle

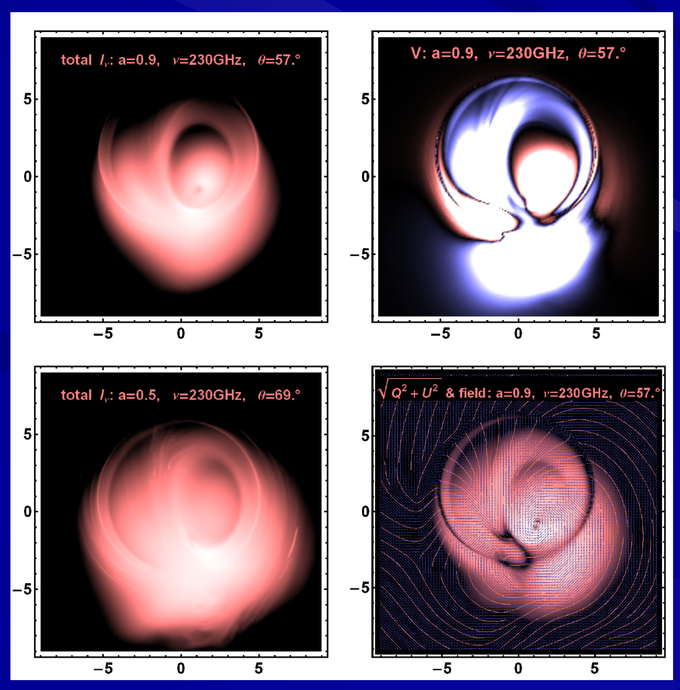
$T_e = 3.4^{+1.2}_{-0.9} \times 10^{10}$ K at 6M

$\mathrm{PA} = 96^\circ \pm 20^\circ$ spin position angle

jet PA is ≈ 120° -- consistent?

spin a=0.9 – preferred

Polarized images



Exciting results on variability: QPOs and flares
Ask me to show you a movie!