Fire and Smoke: Probing Inflow and Outflow of Low Luminosity AGN with Millimeter Wavelength Polarimetry

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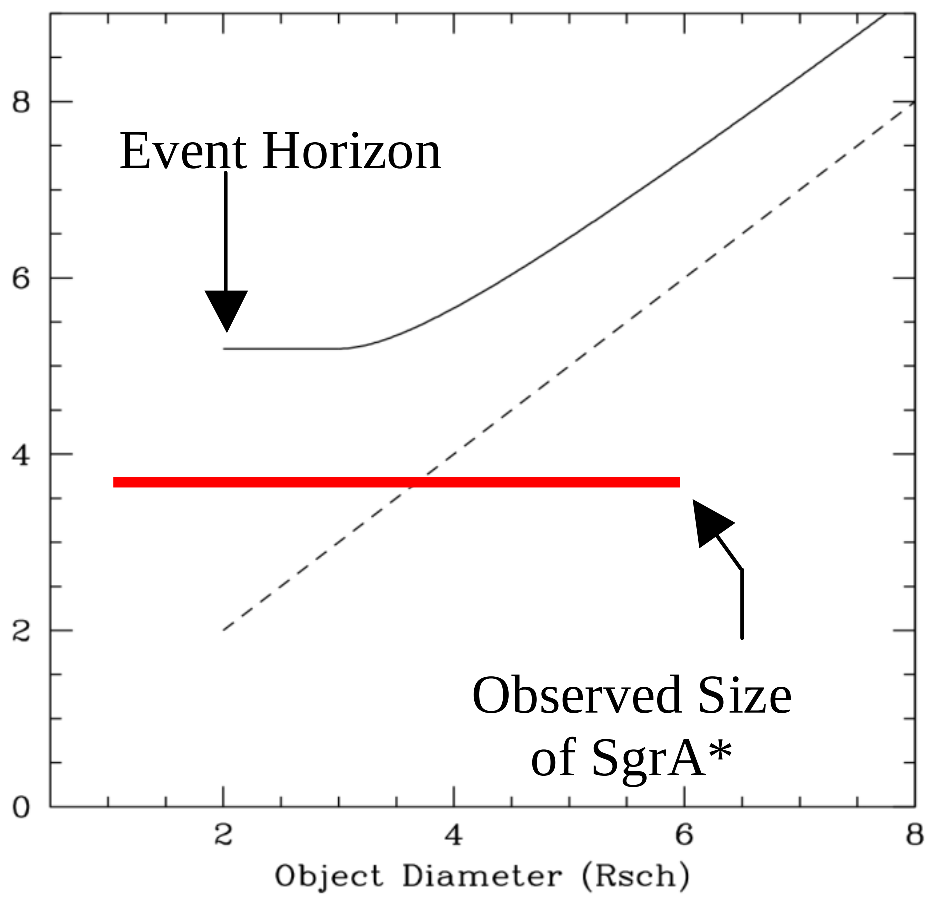
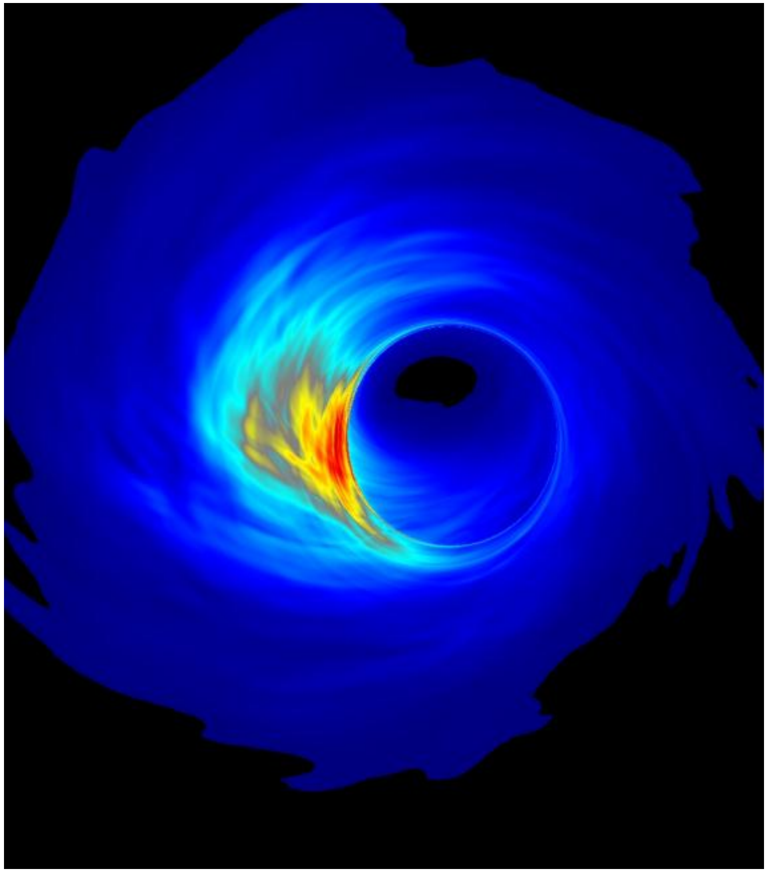
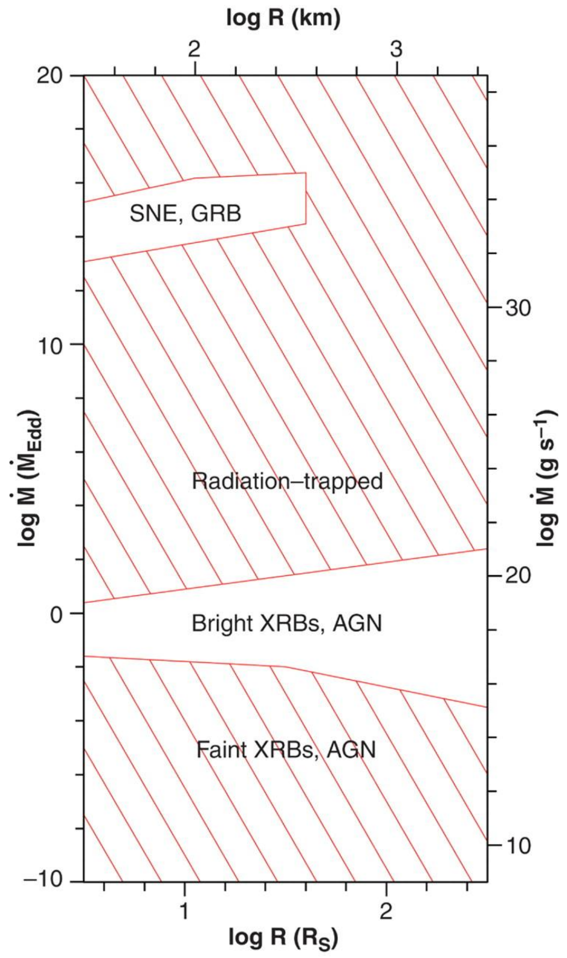
Sagittarius A*





What We Don't Know Yet

- Why is Sgr A* so underluminous?
  - $L \sim 10^{-10} L_{Edd}$
- Models degenerate
  - *Inflow, outflow, jets, nonthermal emission*
- How does Sgr A* relate to other AGN?
- Fundamental gravity

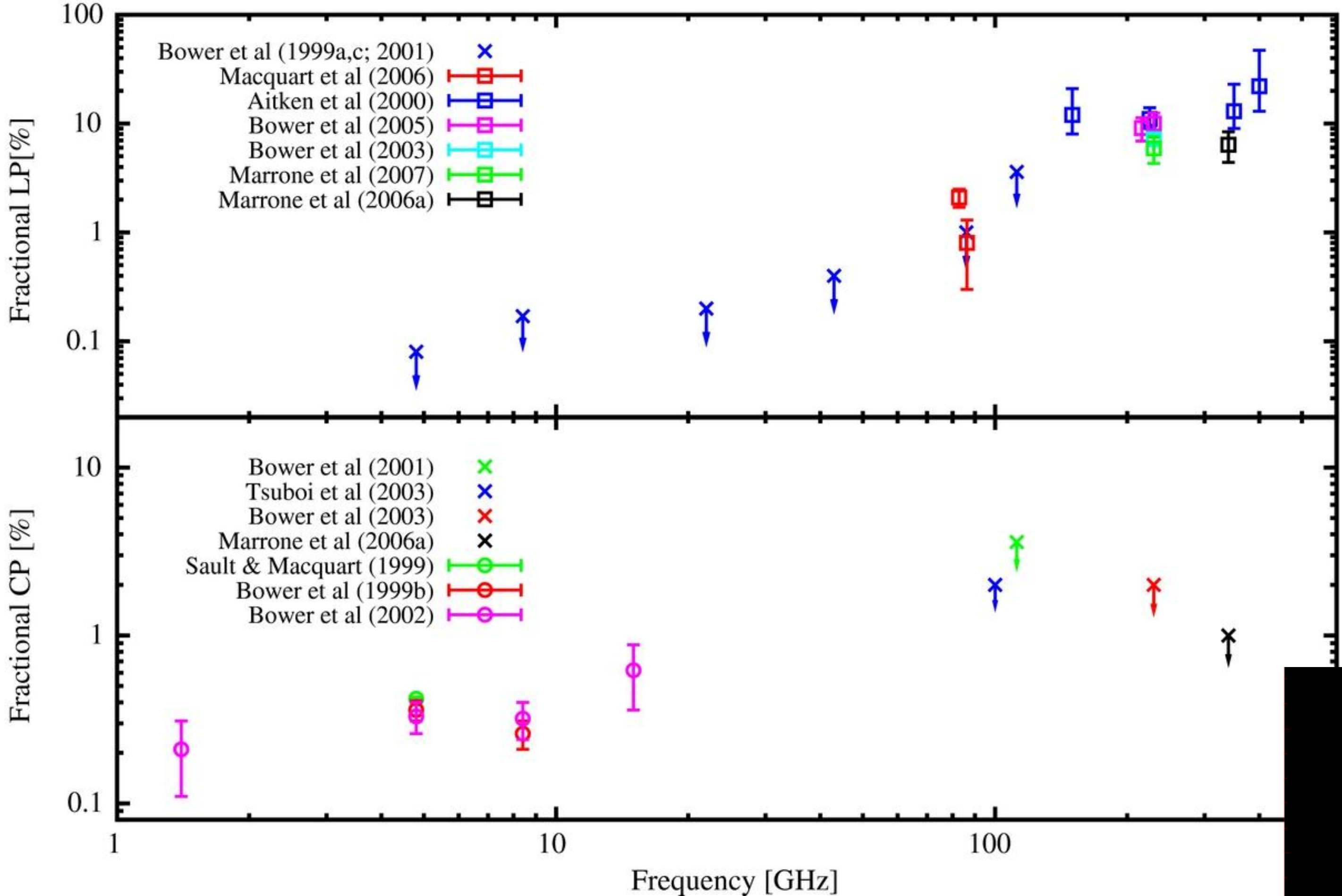


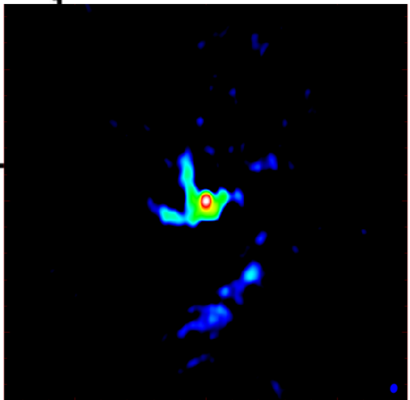
Narayan & Quataert 2005

Sagittarius A* Polarimetry

- Transition in LP fraction @~100 GHz
- RM = -5 x 10^5 rad m^{-2}
- RM stable $\tau > 10$ years
- Variation of intrinsic LP angle on short timescales
- CP from 1.4 to 345 GHz
- CP stable $\tau > 30$ years

Polarization Fraction of Sgr A*





Munoz et al 2011

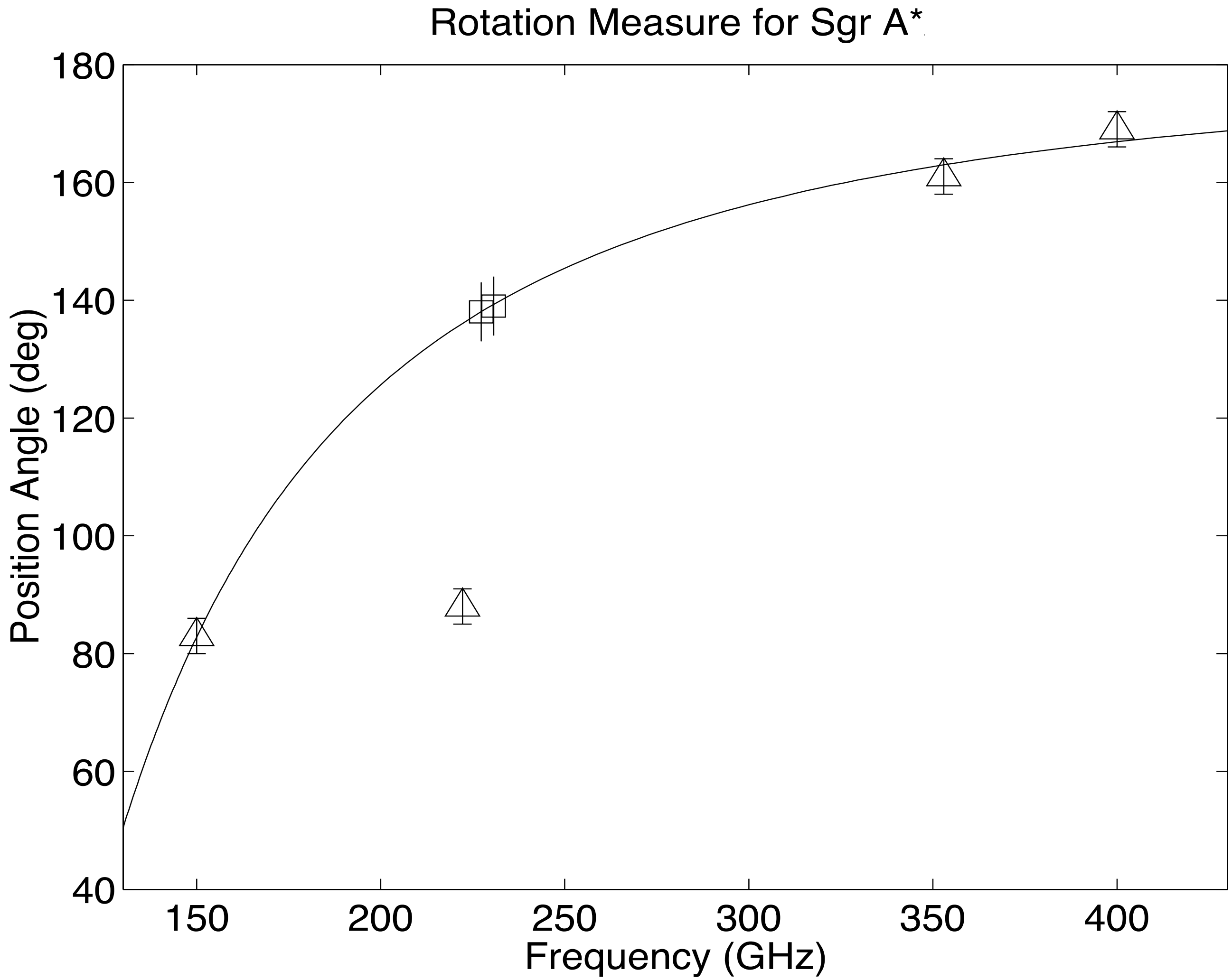
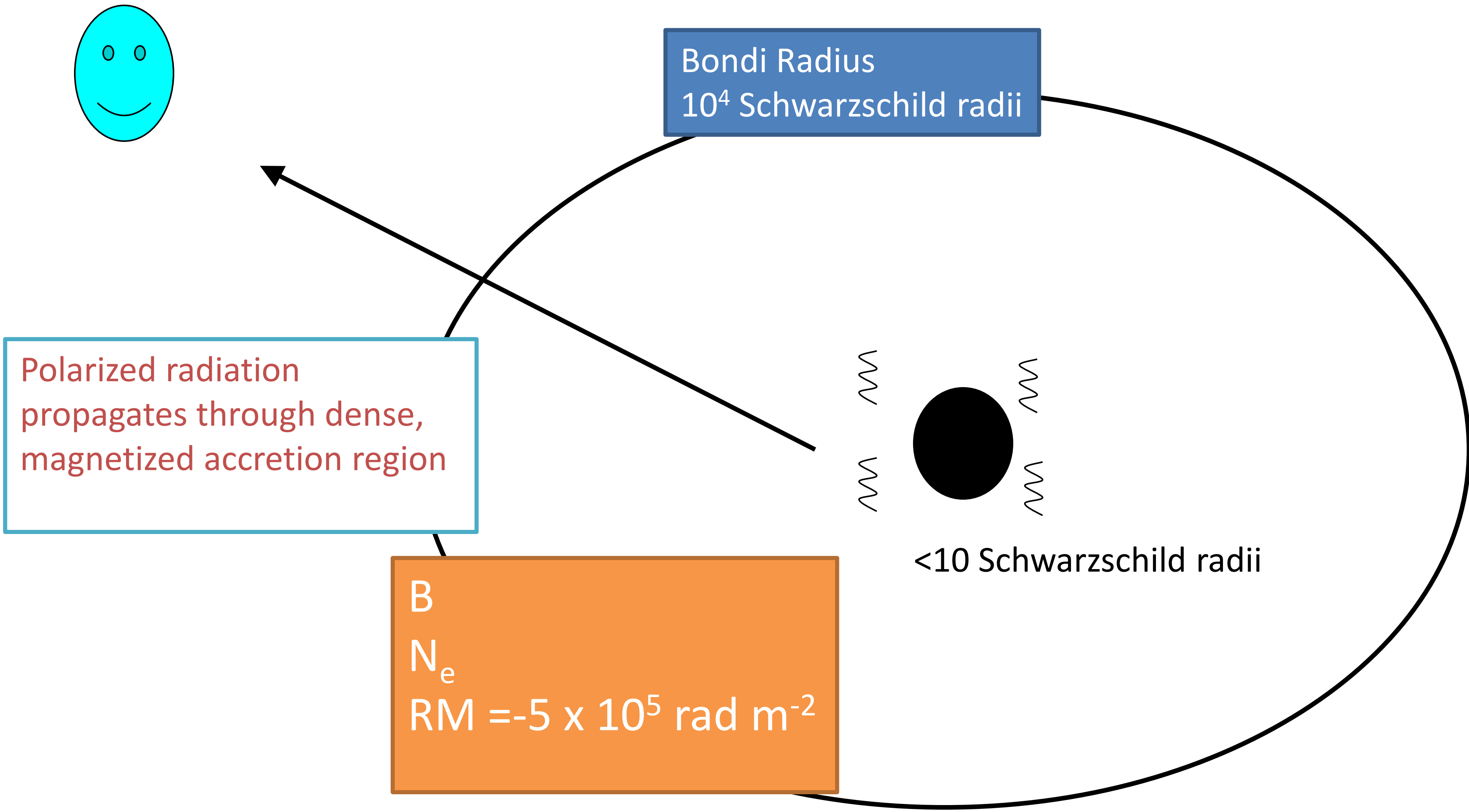


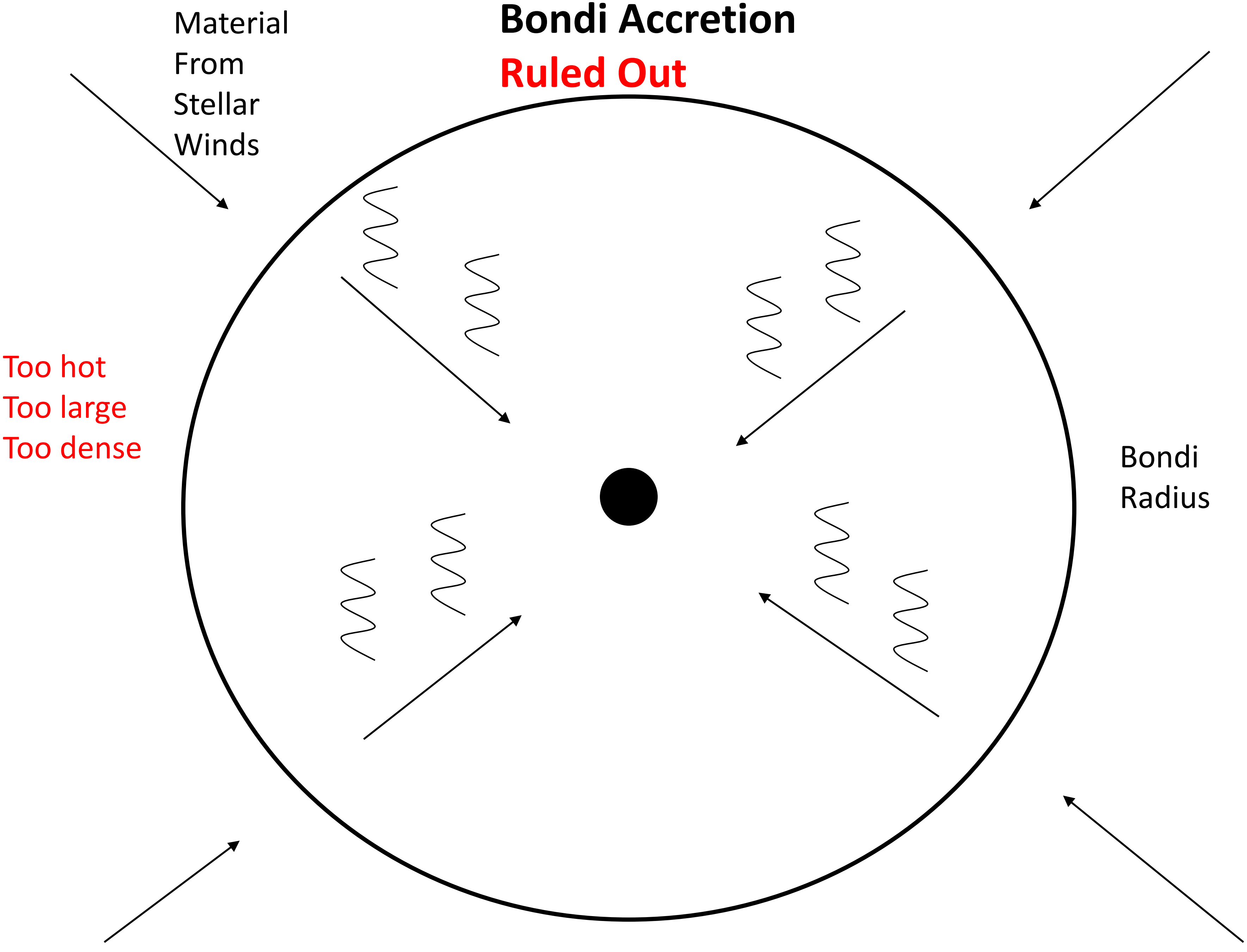
Fig. 2.— Position angle as a function of frequency. Triangles are the A00 data. Squares are the BIMA data. The solid line is a fit for the RM excluding the A00 230 GHz result. The best fit is $-4.3 \pm 0.1 \times 10^5$ rad m^{-2} with a zero-wavelength position angle of 181 ± 2 degrees.

Bower et al 2003


Bondi Radius
10^4 Schwarzschild radii
Polarized radiation propagates through dense, magnetized accretion region
<10 Schwarzschild radii
B
N_e
RM =-5 x 10^5 rad m^{-2}

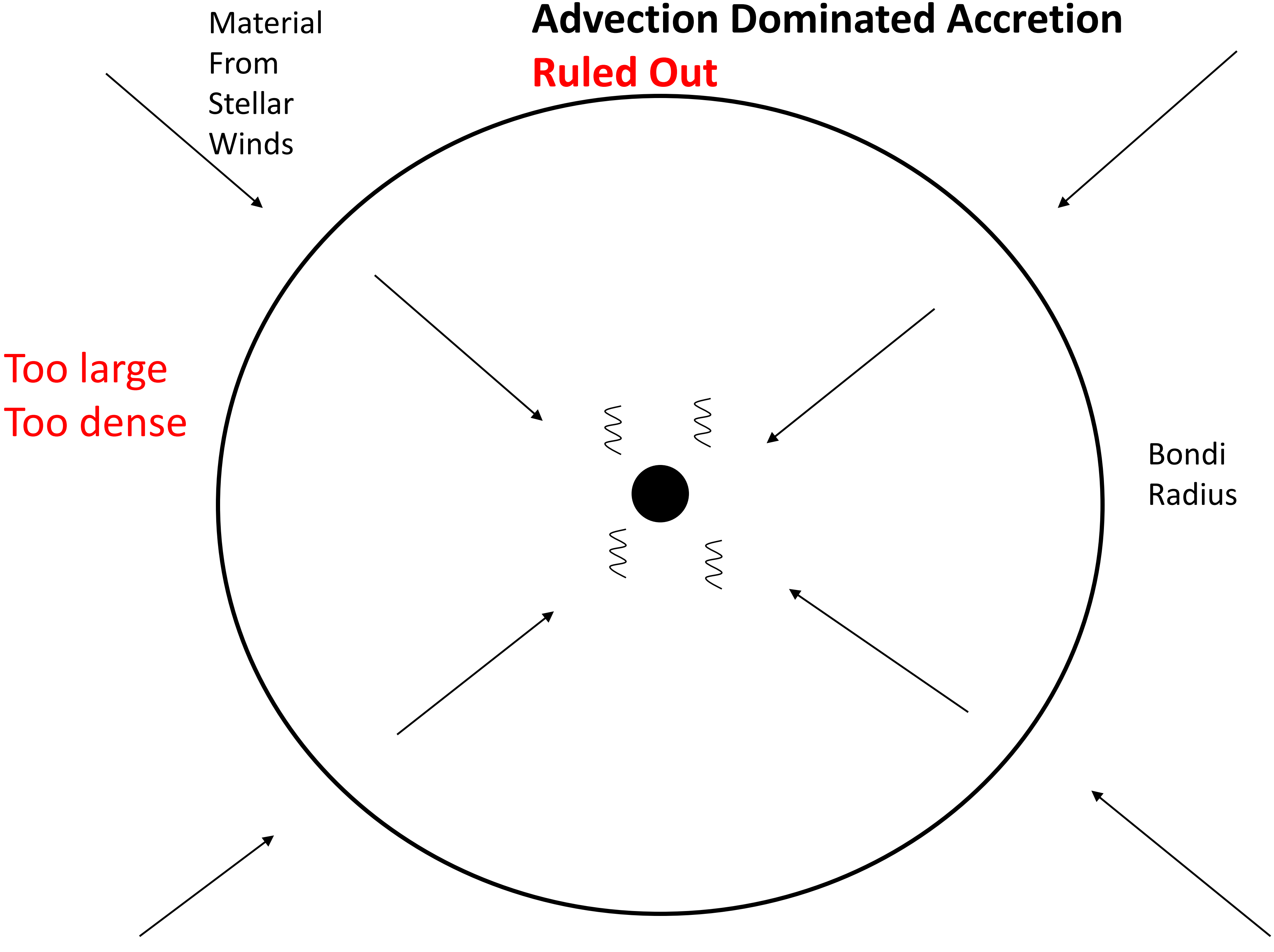
Bondi Accretion

Ruled Out



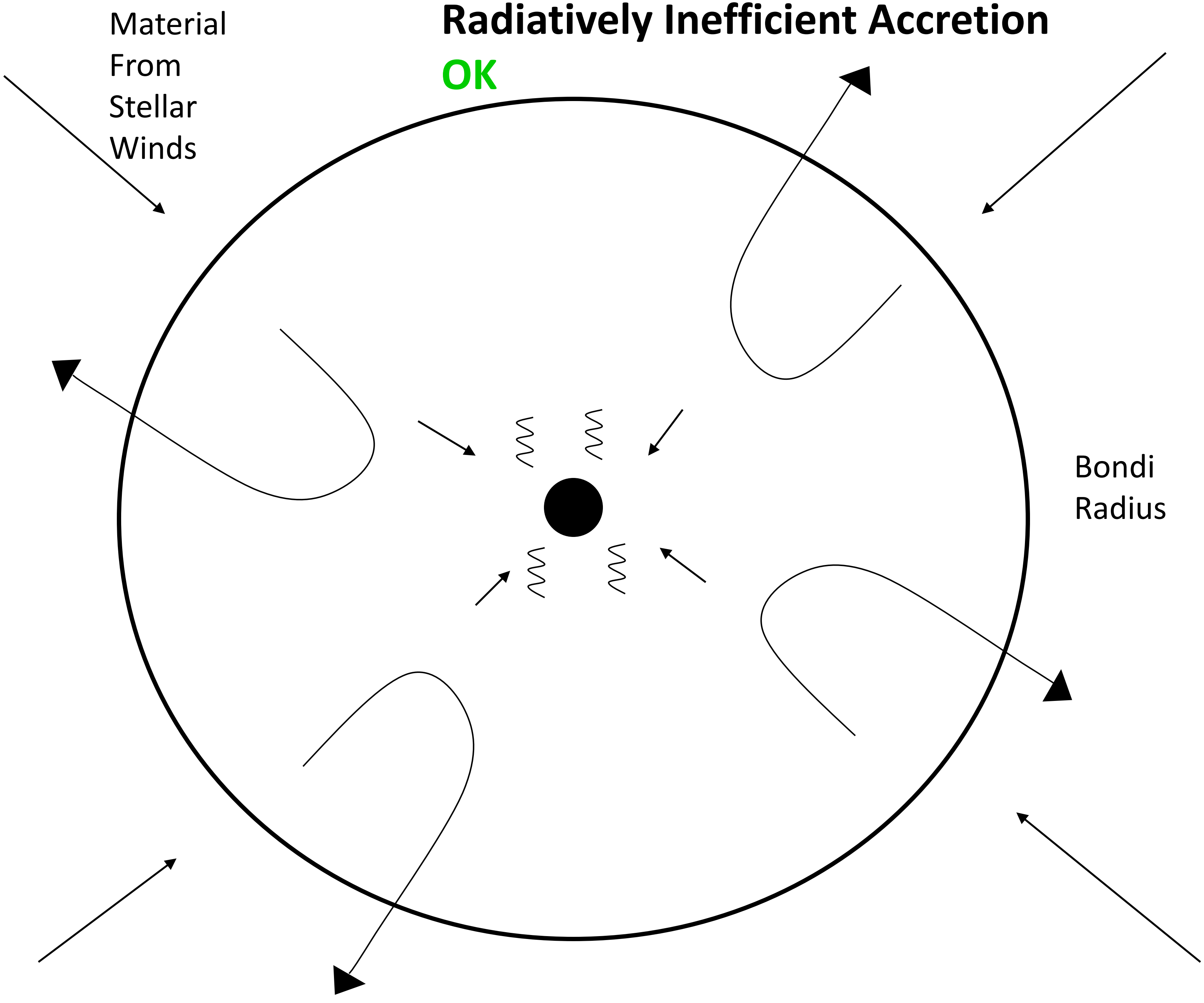
Advection Dominated Accretion

Ruled Out



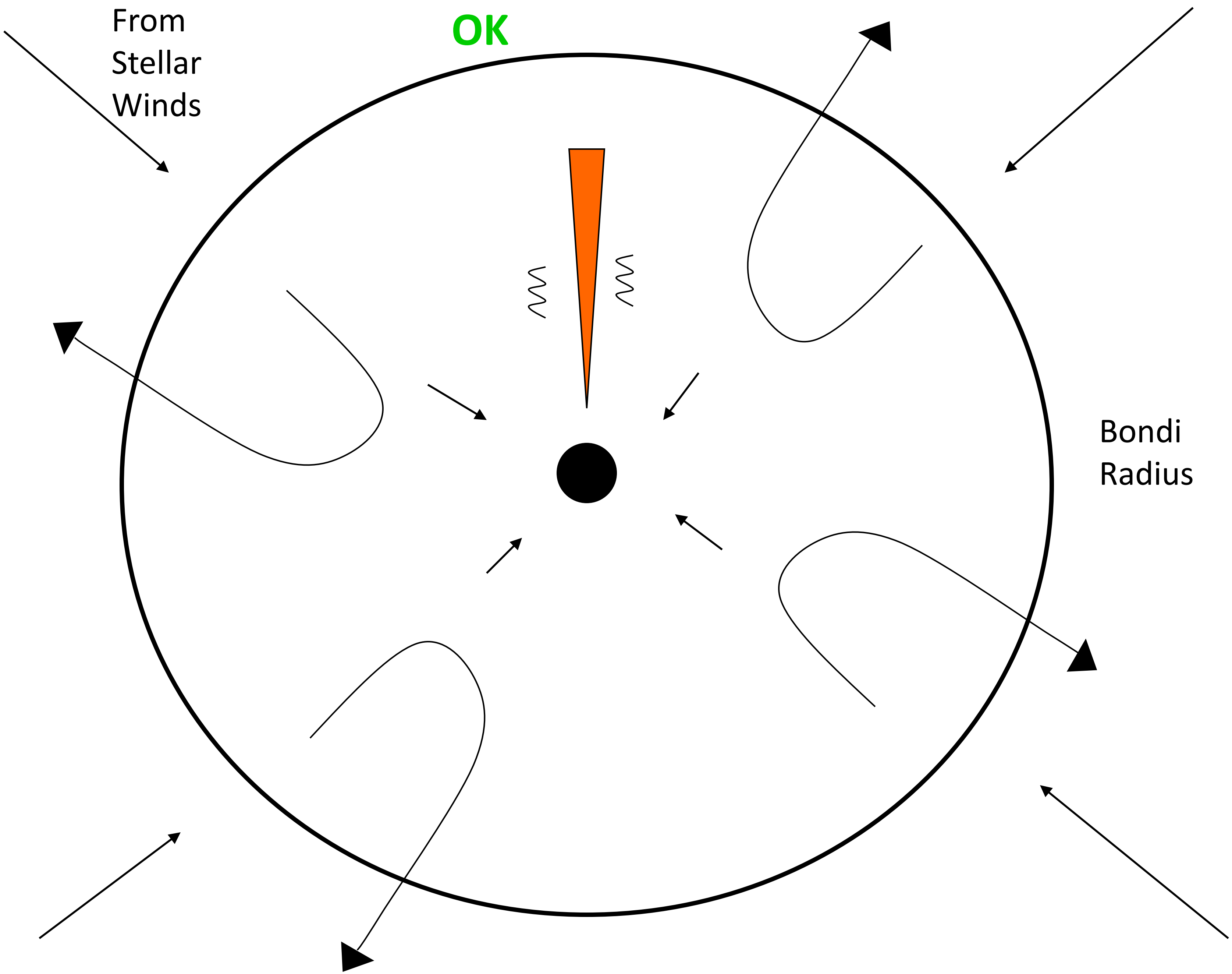
Radiatively Inefficient Accretion

OK

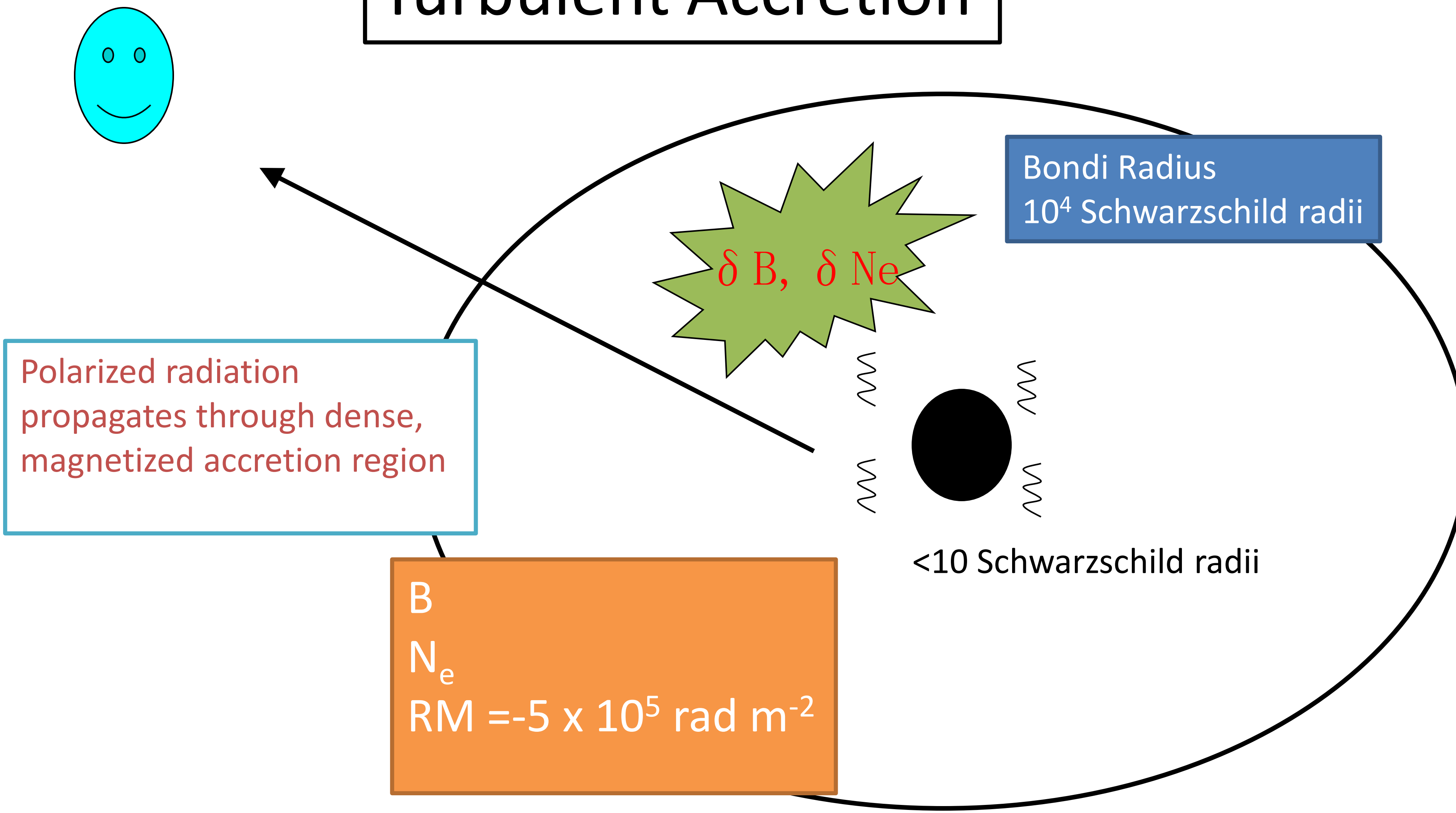


Jet+Radiatively Inefficient Accretion

OK

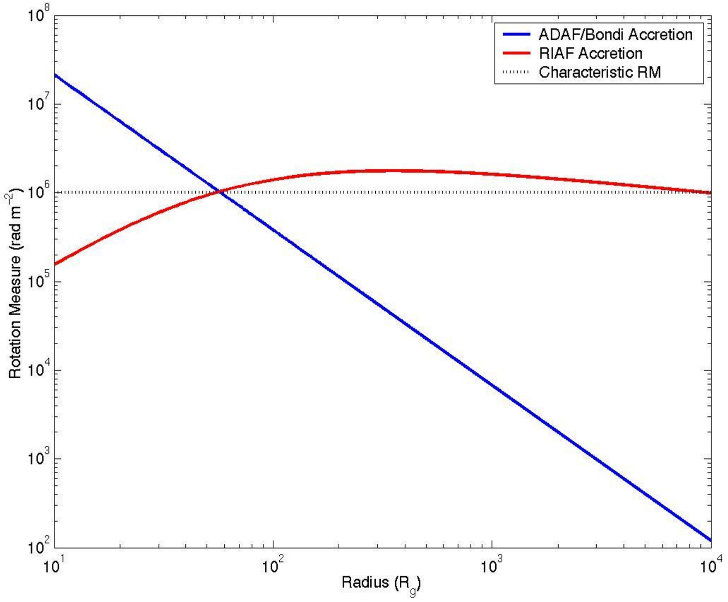


Turbulent Accretion



Turbulent Accretion

- Changing density/B-field in accretion region
- Radius:≥ 10 - 1000 R_g
- Time: hours to years
  - Viscous time scale
- Structure function of $\delta \mathrm{RM}$ will provide accretion structure
  - CARMA, SMA, ALMA



Accretion Simulations

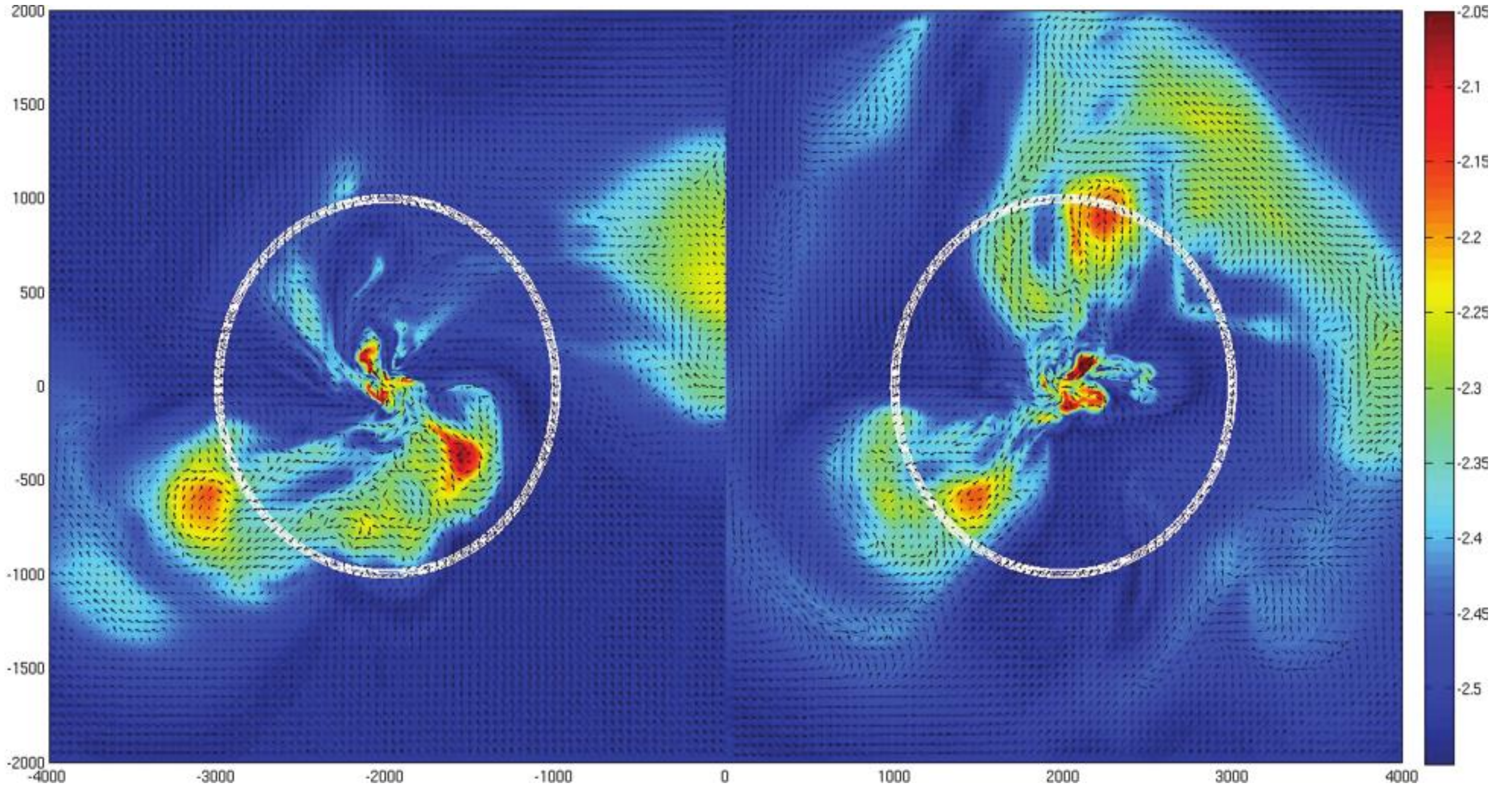
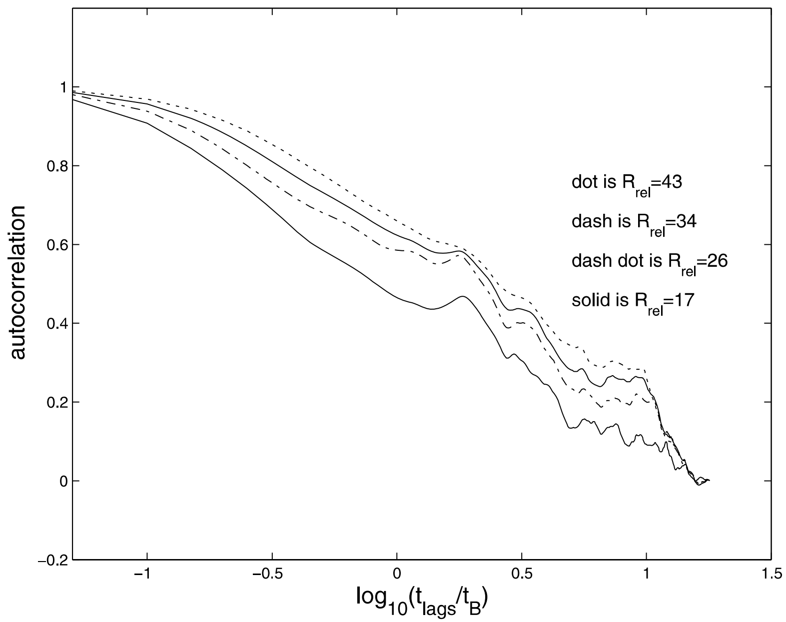
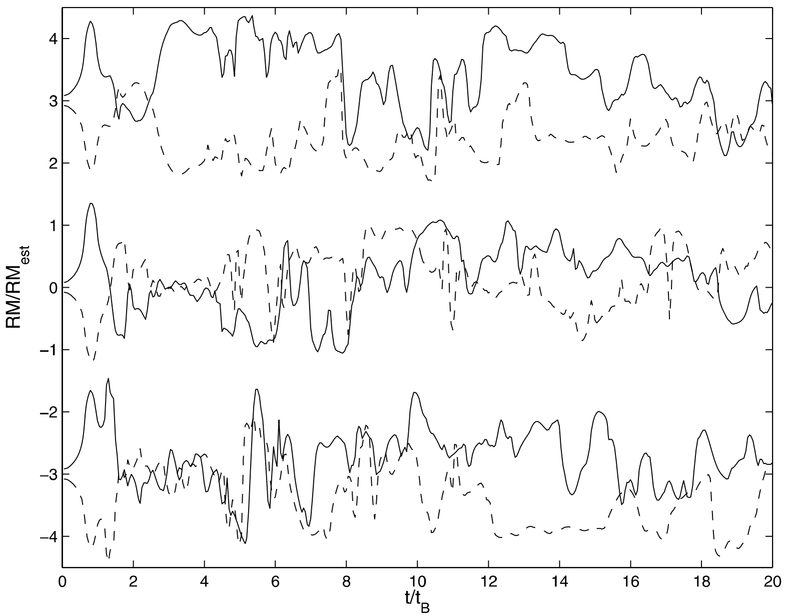


Figure 1. 2D slice of the simulation for 600^3 box at 15 Bondi times. Colour represents the entropy, and arrows represent the magnetic field vector. The right-hand panel is the equatorial plane (*yz*), while the left-hand panel a perpendicular slice (*xy*). White circles represent the Bondi radius ($r_B = 1000$). The fluid is slowly moving, in a state of magnetically frustrated convection. A movie of this flow is available as Supporting Information with electronic version of this article (see Appendix C for a description).

Pang, Pen, et al 2011

Simulated RMs





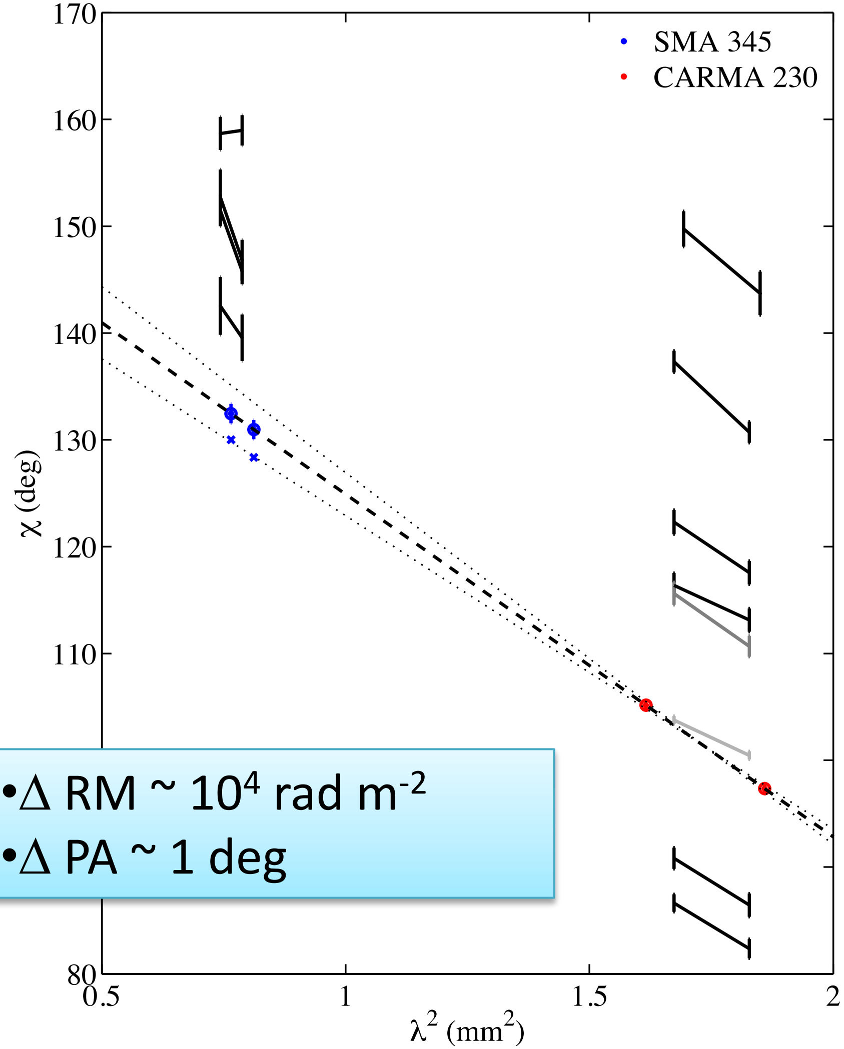
~1 Year

Sensitive to
- Accretion Profile
- Radius of relativistic electrons
- Viewing Angle
- Magnetic Field Stability

Pang, Pen, et al 2011

Planned Simultaneous SMA/CARMA Observations

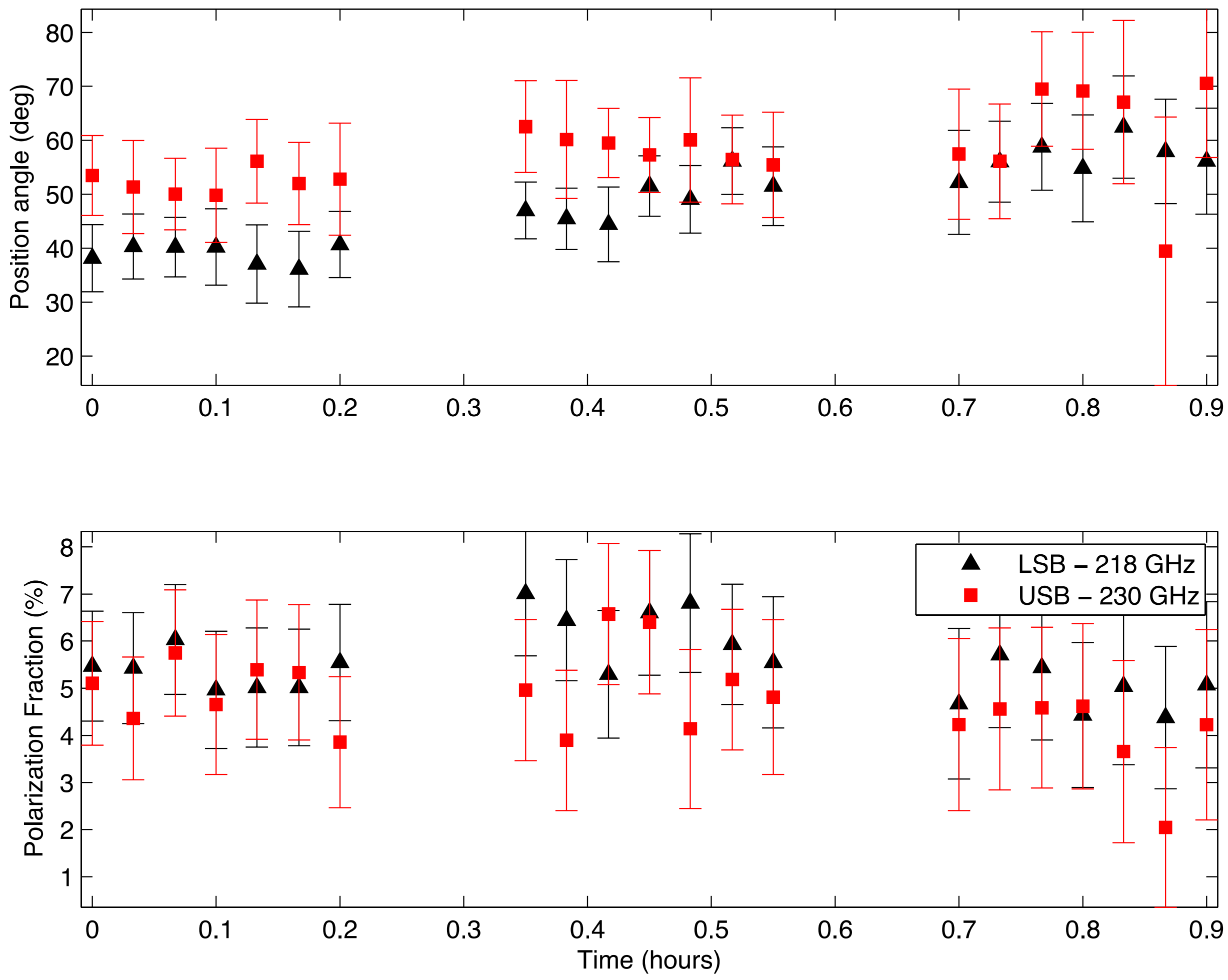
- What causes the stability of the RM?
- How stable and on what timescale is the RM?
- Are there non-λ^2 effects?
- Is there a relationship between LP, CP, and RM variability?



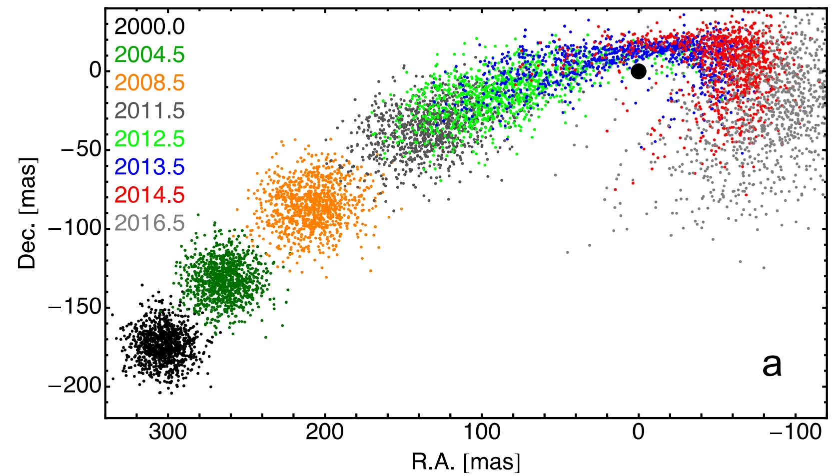
- Δ RM ~ 10^4 rad m^{-2}
- Δ PA ~ 1 deg

CARMA Time Resolved Polarimetry of Sgr A*

- 1.3 mm
- October 2011
- *Preliminary!*



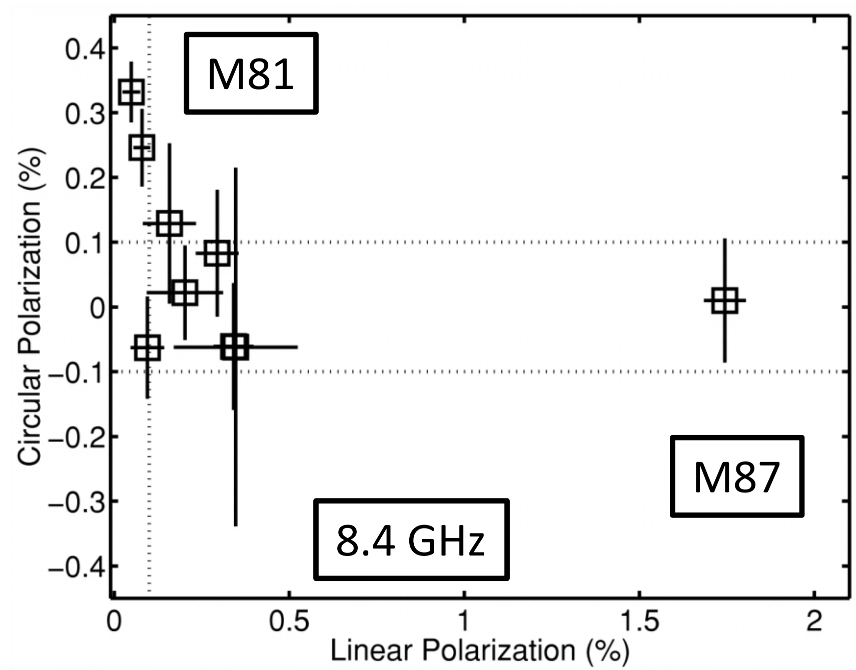
The Wildcard Event



Gillessen et al 2011

LLAGN

- Share many properties with Sgr A*
  - $L \sim 10^{-5} L_{Edd}$
- Nearby LLAGN show no or weak LP at cm wavelengths



M81*

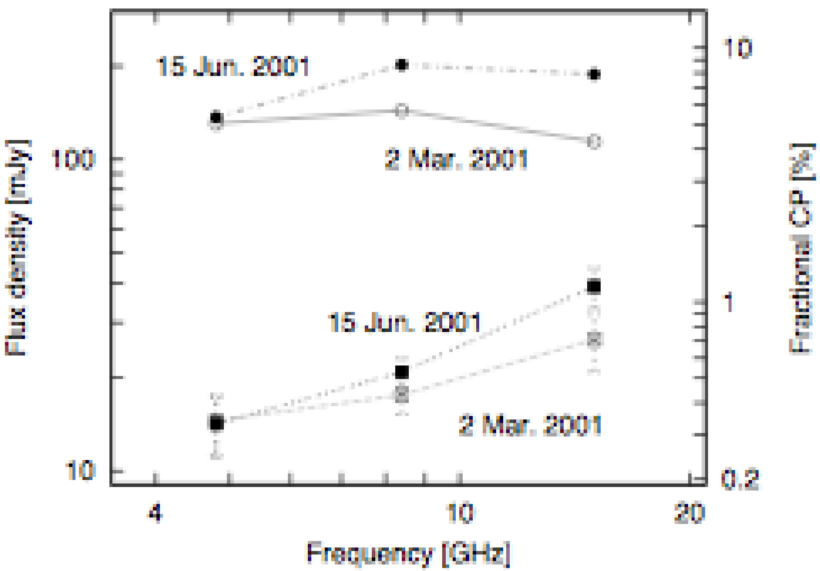
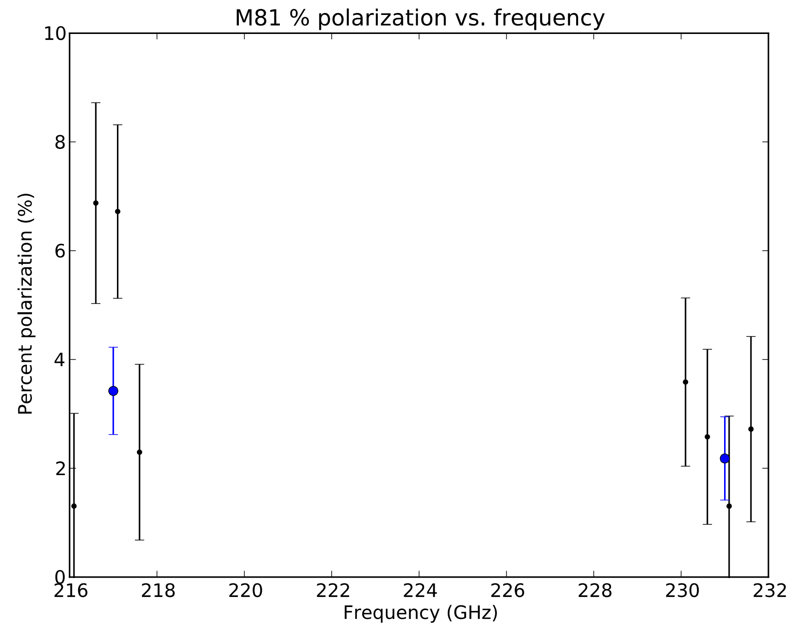


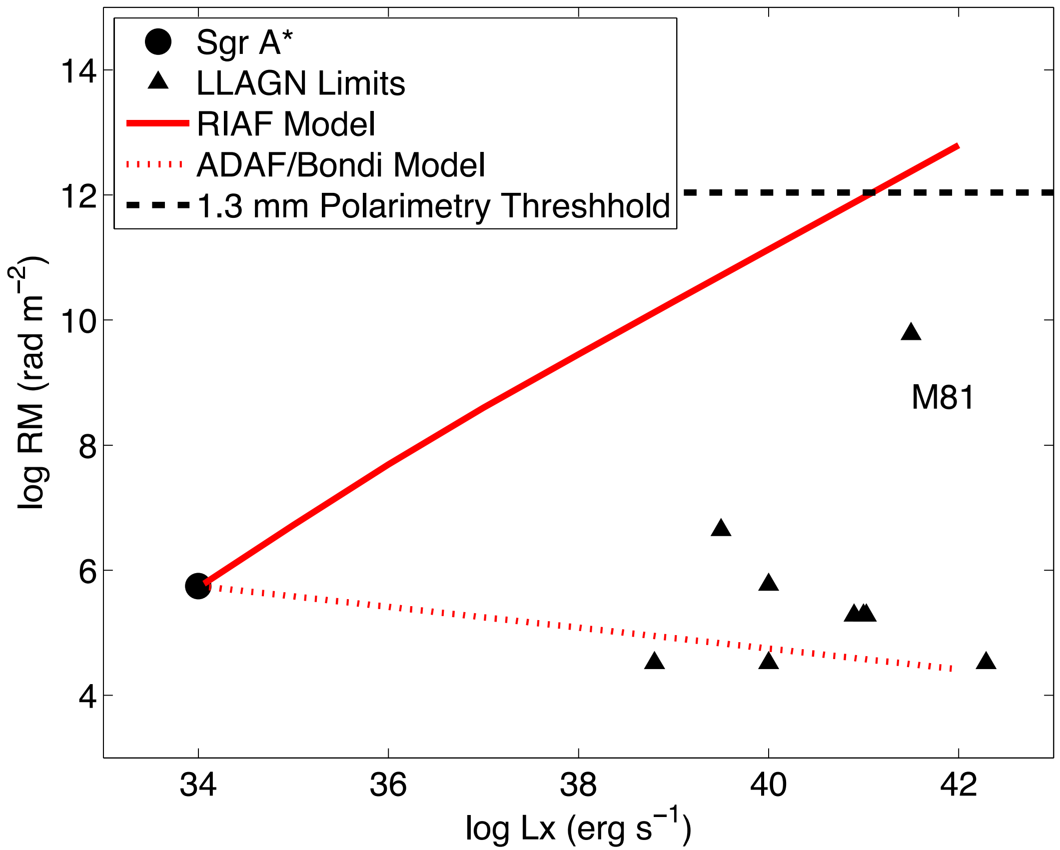
Fig. 4. Spectra of the total intensity (circles) and the fractional circular polarization (squares) from 2 March 2001 (open) and 15 June 2001 (filled).



CARMA Upper Limits at 230 GHz
LP < 1.3%

RM Limits for LLAGN

- High Frequency VLA Survey Finds no LP from LLAGN up to 43 GHz
- Clearly distinct from other AGN population
- Assuming bandwidth depolarization, allows us to set lower limits on RM



ALMA Polarimetry of Sgr A*/LLAGN

- High sensitivity to short timescale variations over wide frequency range
- Sensitivity to RMs >10^{12} rad m^{-2}
- Large sample of nearby LLAGN to explore statistical properties

Summary

- Polarimetry probes the turbulent accretion structures of LLAGN
- EVLA/CARMA/SMA observations can provide significant improvements over the current capabilities
- *We need ALMA polarimetric capabilities!*