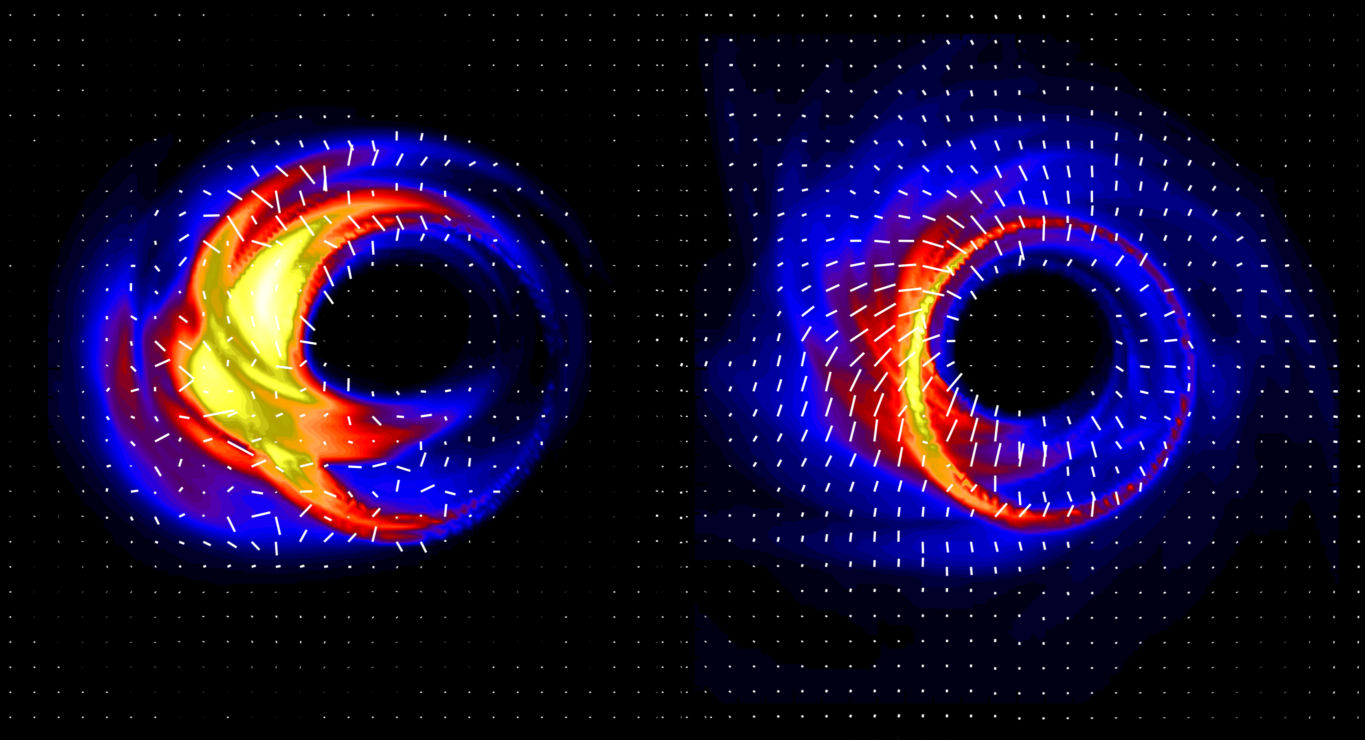
The Millimeter Polarization of Sgr A*

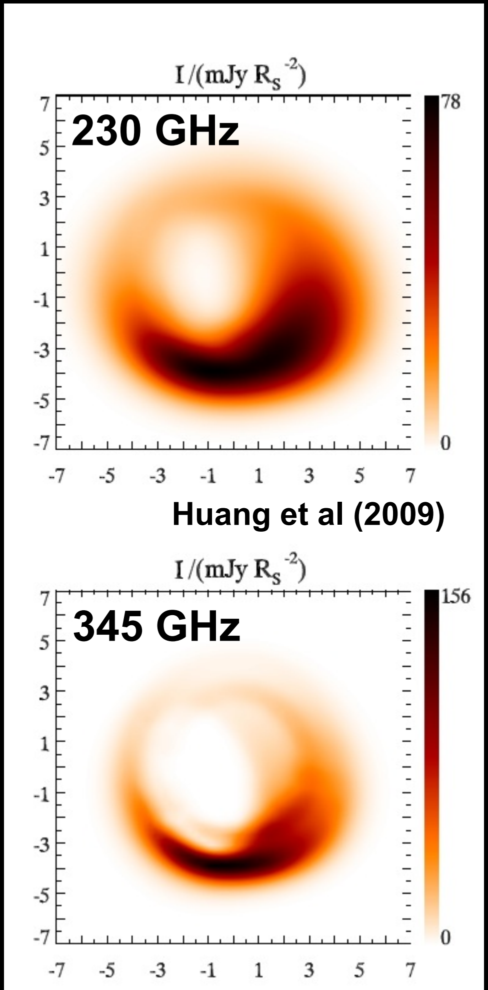


Dexter & McKinney (2013, in prep)

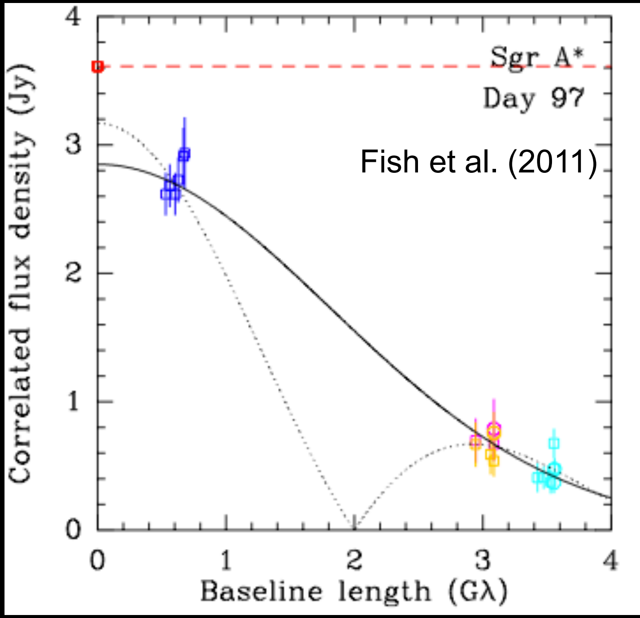
Dan Marrone
University of Arizona
Steward Observatory

With: Geoff Bower
Jim Moran
Diego Muñoz
Dick Plambeck
Rebecca Levy (UA Undergrad)

The Polarization Scene



- ~1mm emission from region around event horizon
- Synchrotron emission
- Opacity relatively low



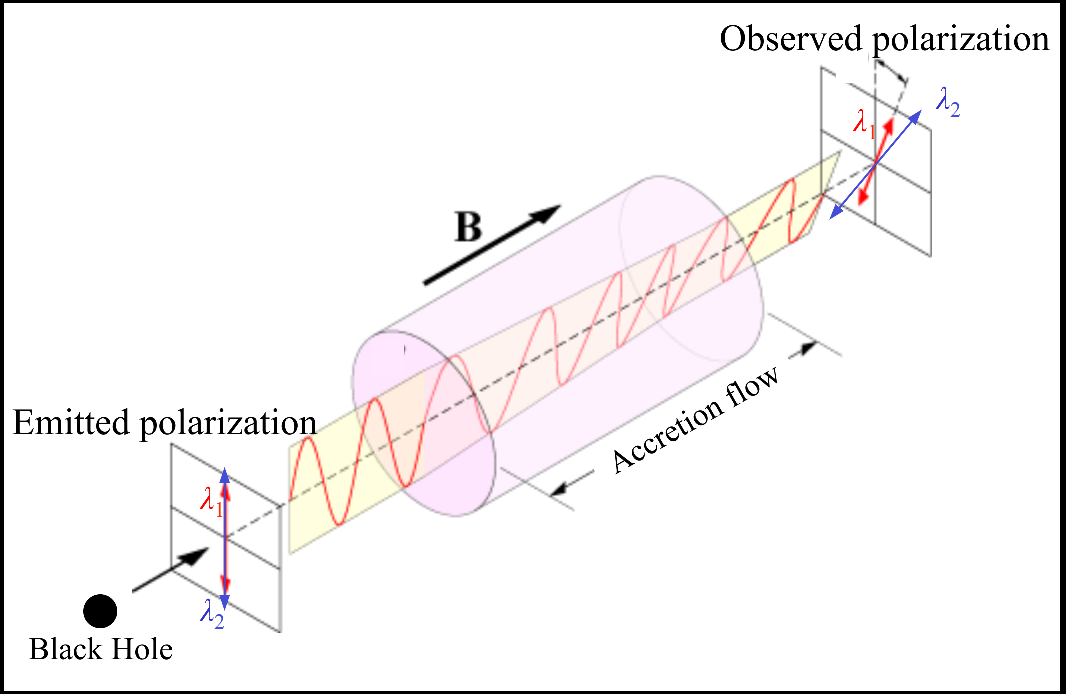
The Polarization Scene

- Synchrotron emission is highly polarized
- Passes through accreting material to reach us
- Faraday rotation!

$$\chi(\lambda) = \chi_0 + \lambda^2 RM$$

$$RM \propto \int n_e(r) B(r) \cdot dr$$

- Measure:
  - Accretion profile
  - Turbulence!

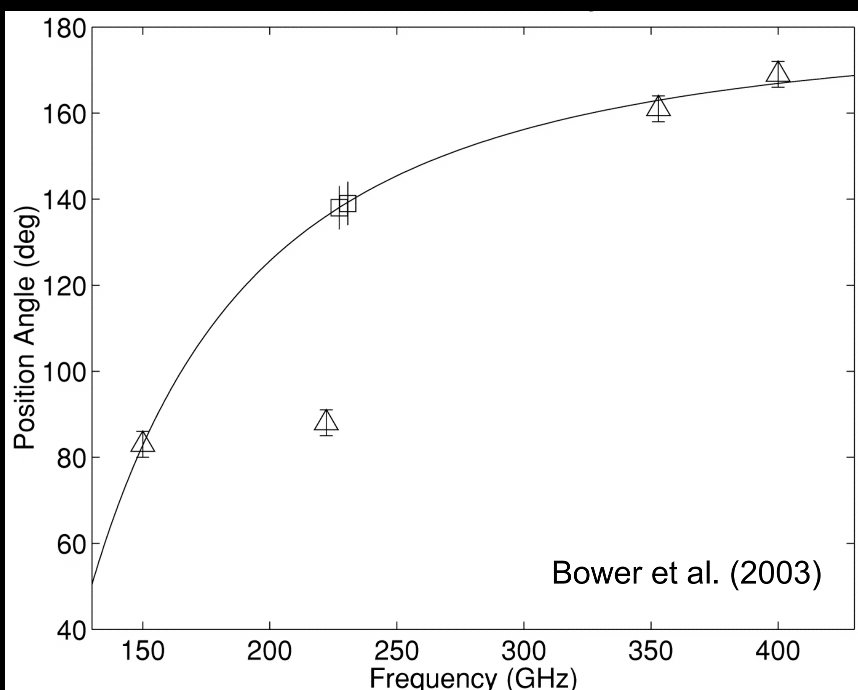


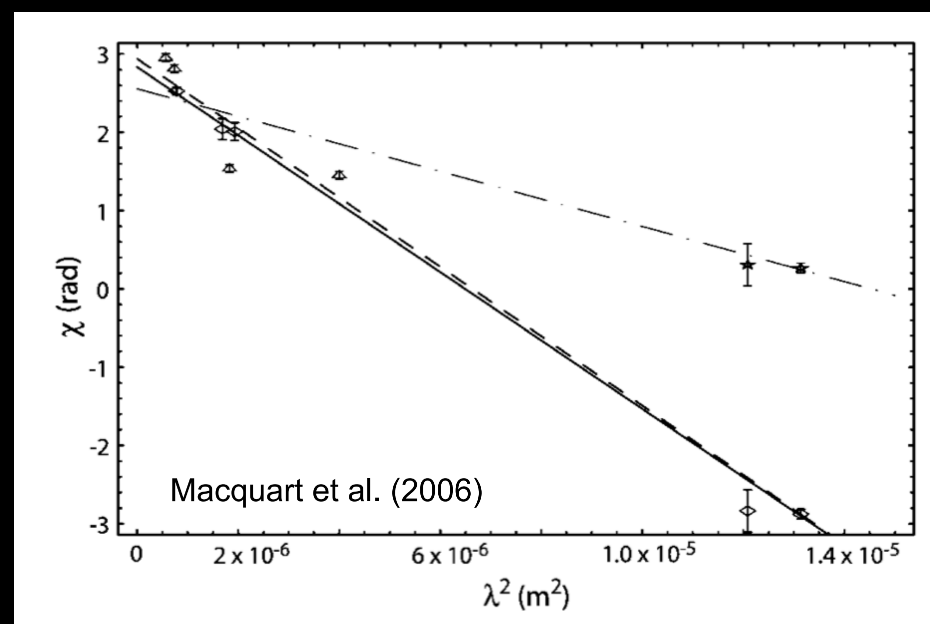
The Polarization Scene

Linear Polarization Picture

- Starts very simply (Aitken et al. 2000)
  - Mere detection of polarization implies very low accretion rate
  - Quataert & Gruzinov (2000), Agol (2000)

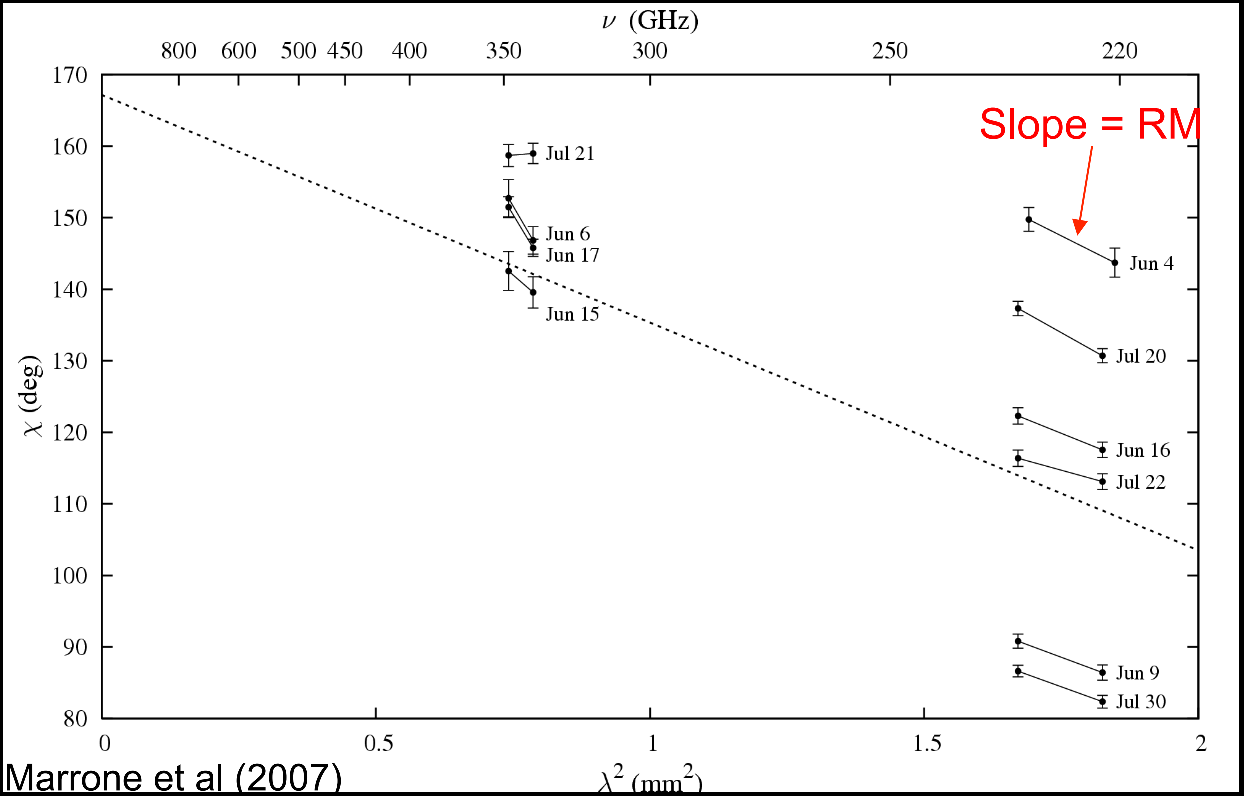
- Average polarization angles approximate λ^2 curve





Linear Polarization Picture

- Slight complication – variability of polarization
- Simultaneous measurements at 220/230 GHz fix this

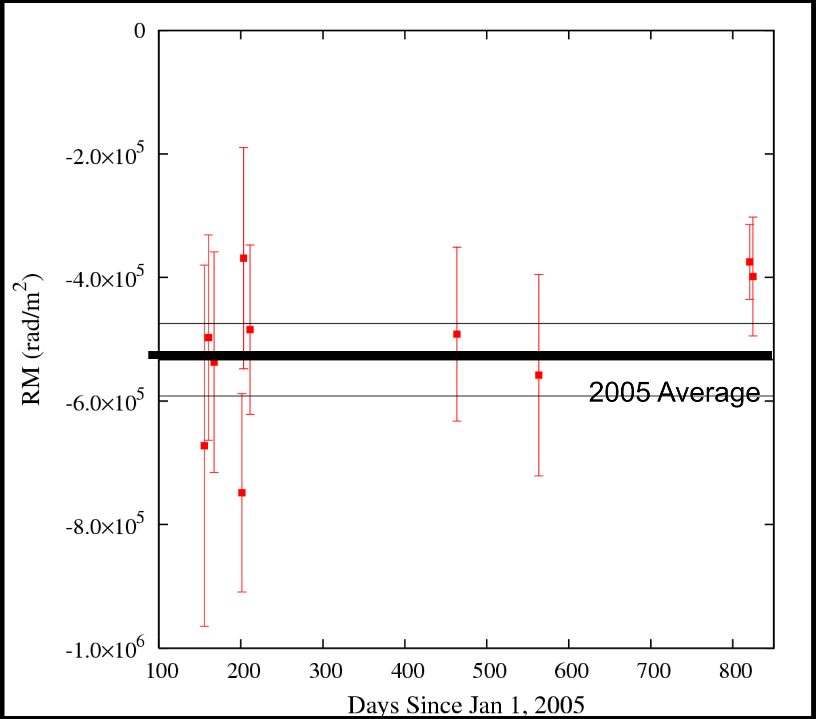


Marrone et al (2007)

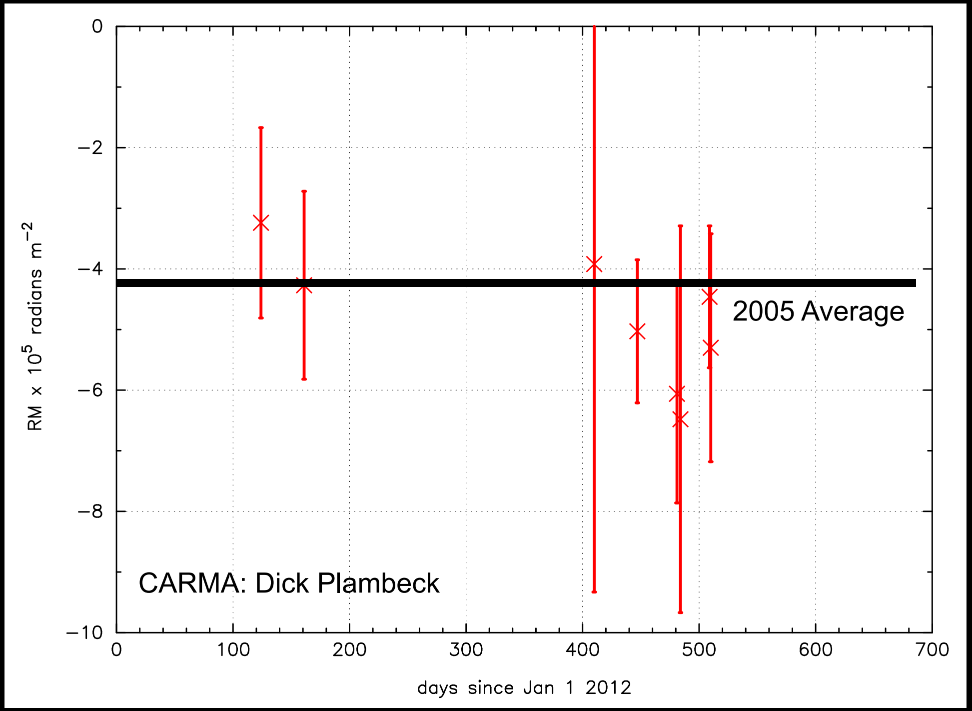
- Parameterization of accretion flow models (Marrone et al. 2006, 2007) → 10^{-9} to 10^{-7} M_{Sun}/yr
- 2-4 orders of magnitude below Bondi capture rate at larger radius

Linear Polarization Picture

- Expect RM variations from turbulence
- More complicated: Still haven't seen them
- Don't see G2 either (as of Summer 2013)



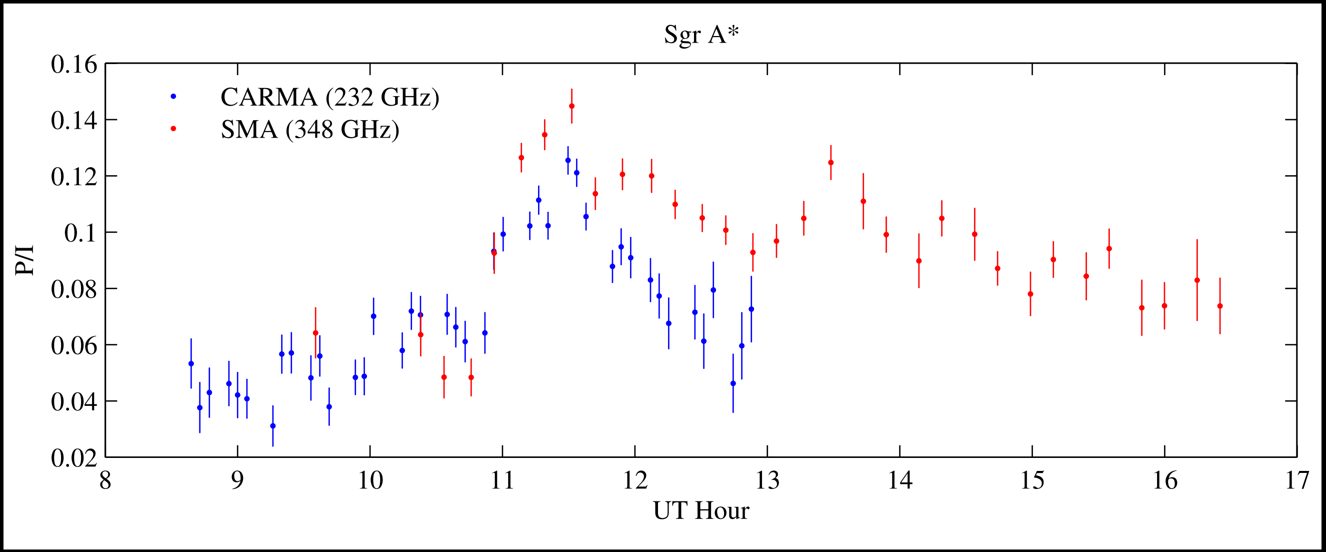
Rotation Measure: 2005-2007



… 2012-2013

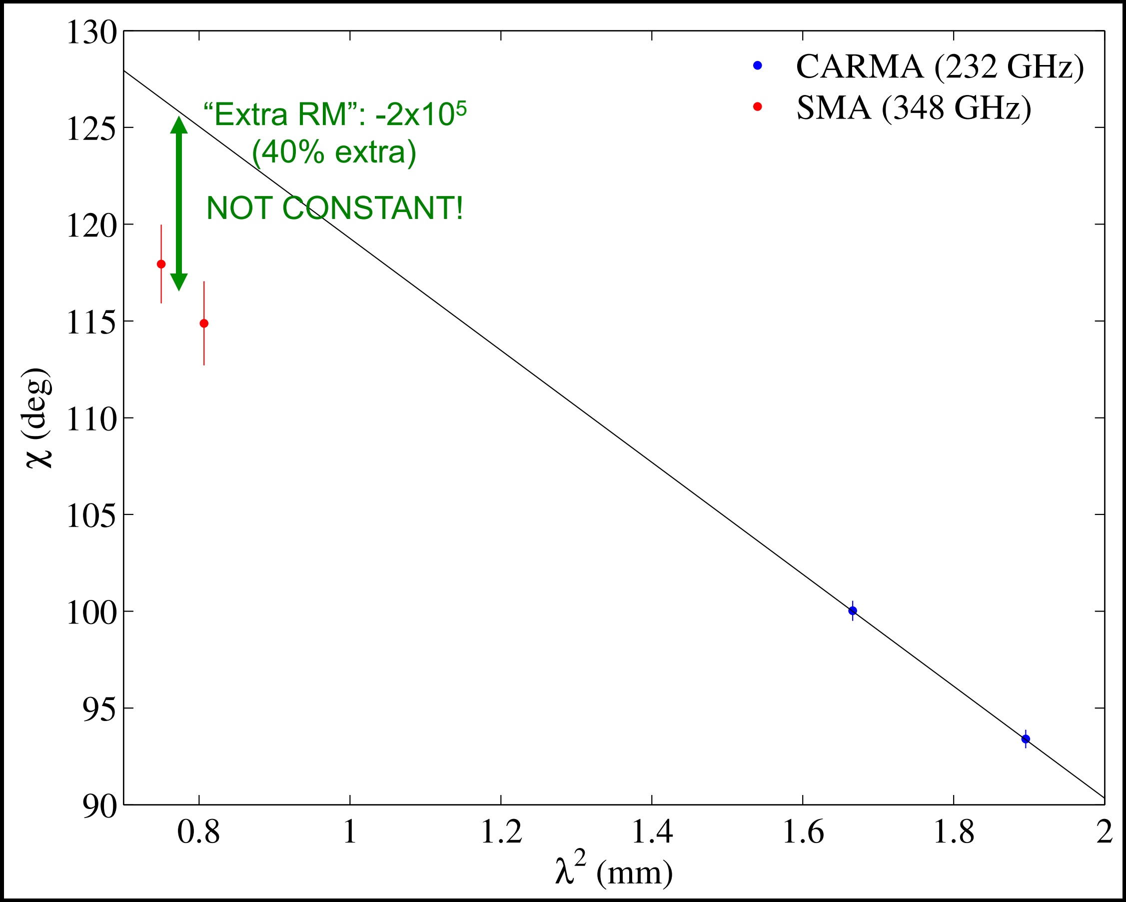
Linear Polarization Picture

- More sensitivity: simultaneous SMA+CARMA at 345/230 GHz
- Polarization varies jointly:



- Does it follow λ^2?

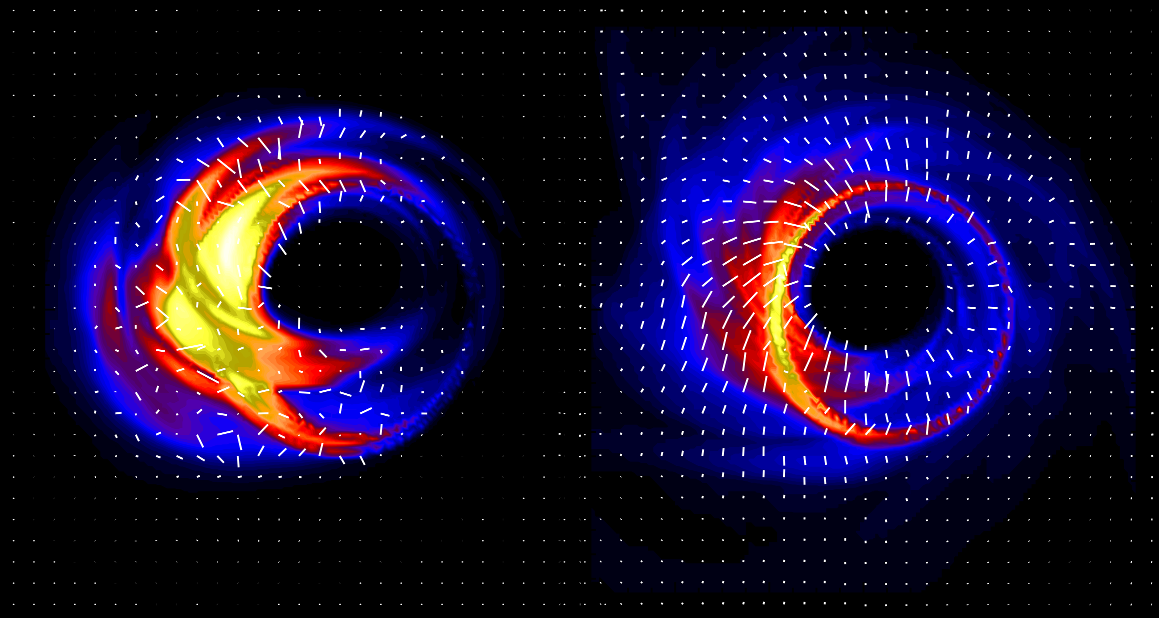
Linear Polarization Picture



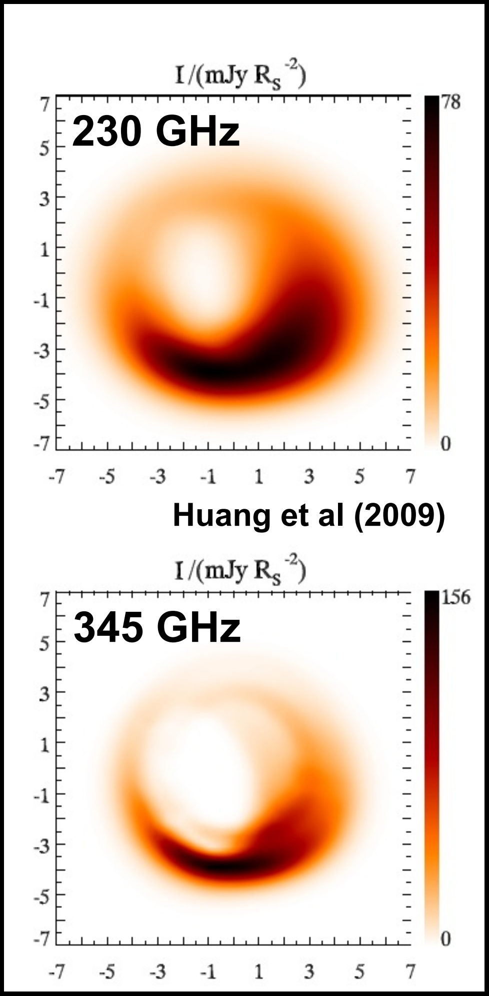
- Does it follow λ^2?
  - No (?)
  - Still some cross-checking/calibration to do

Linear Polarization Picture

- Should it follow λ^2?
  - No (?)



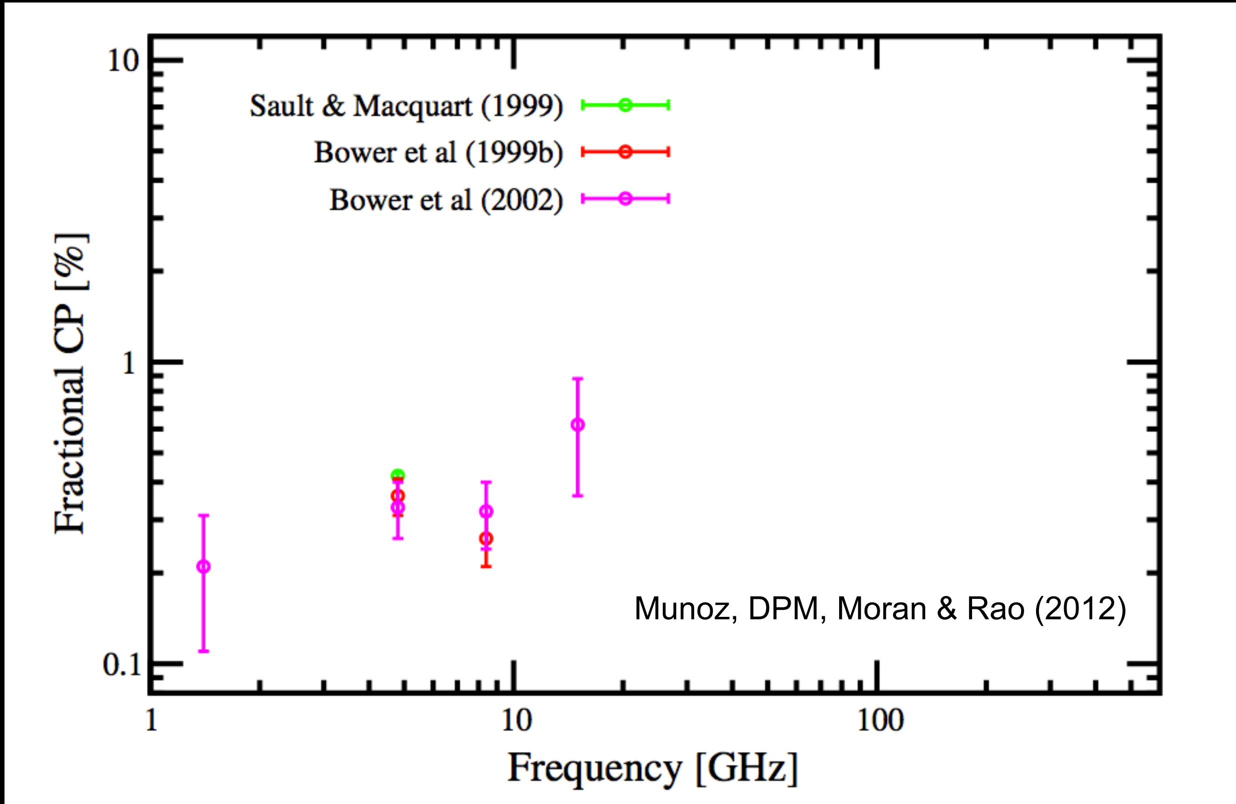
Dexter & McKinney (2013, in prep)



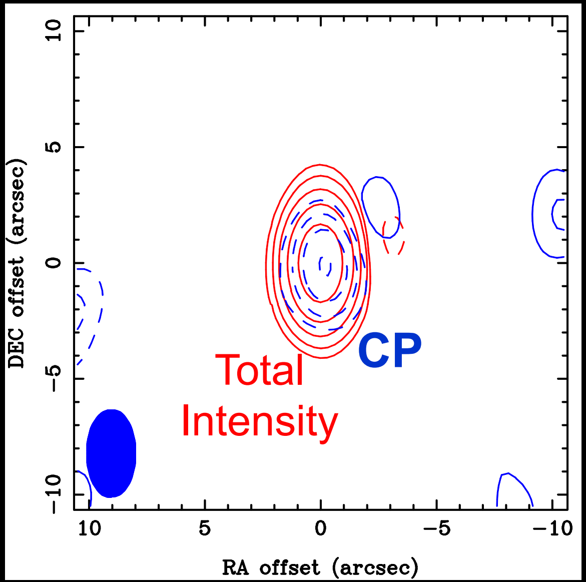
Circular Polarization Picture

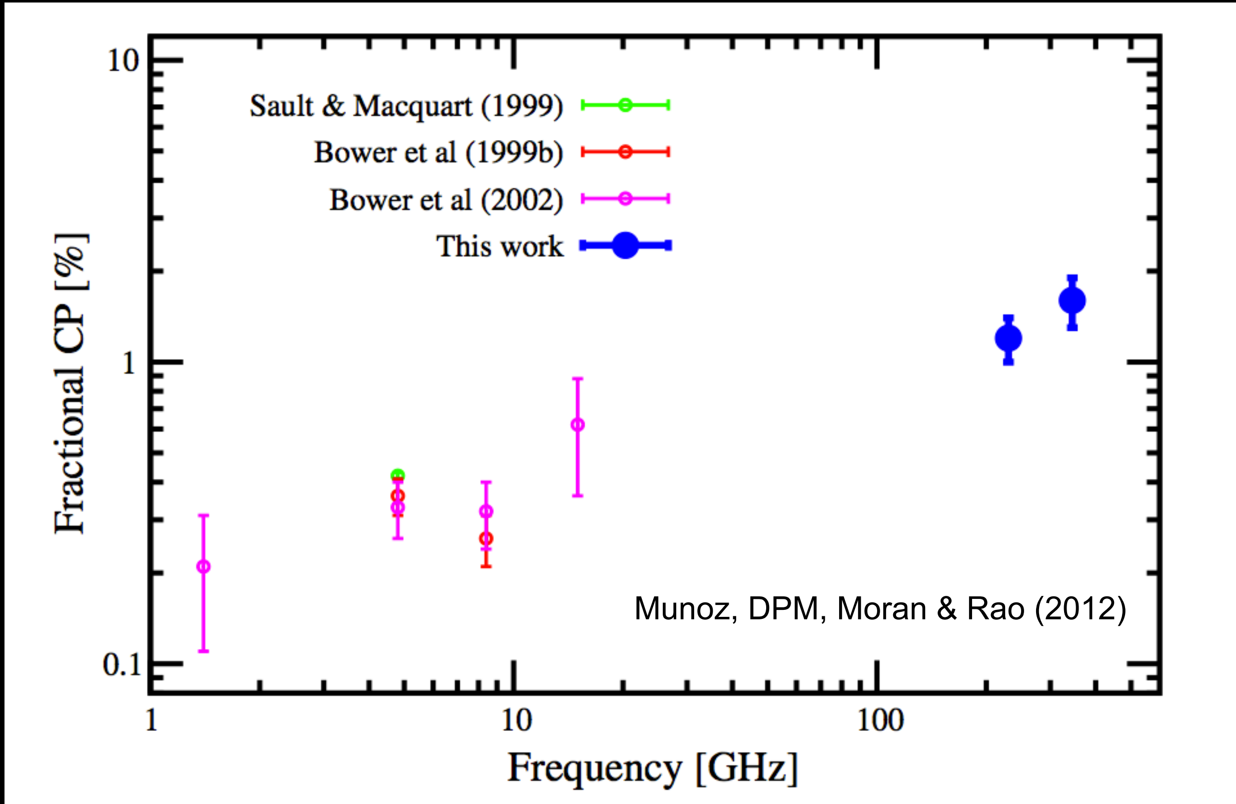
- Known at cm wavelengths since 90s
- Persistent since early 80s
- Persistent sign (negative)

- Resembles M81* (jet source, LLAGN) in CP/LP at cm wavelengths

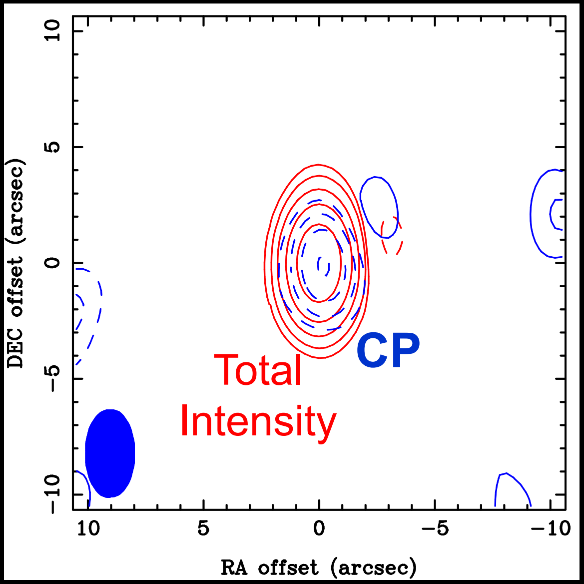


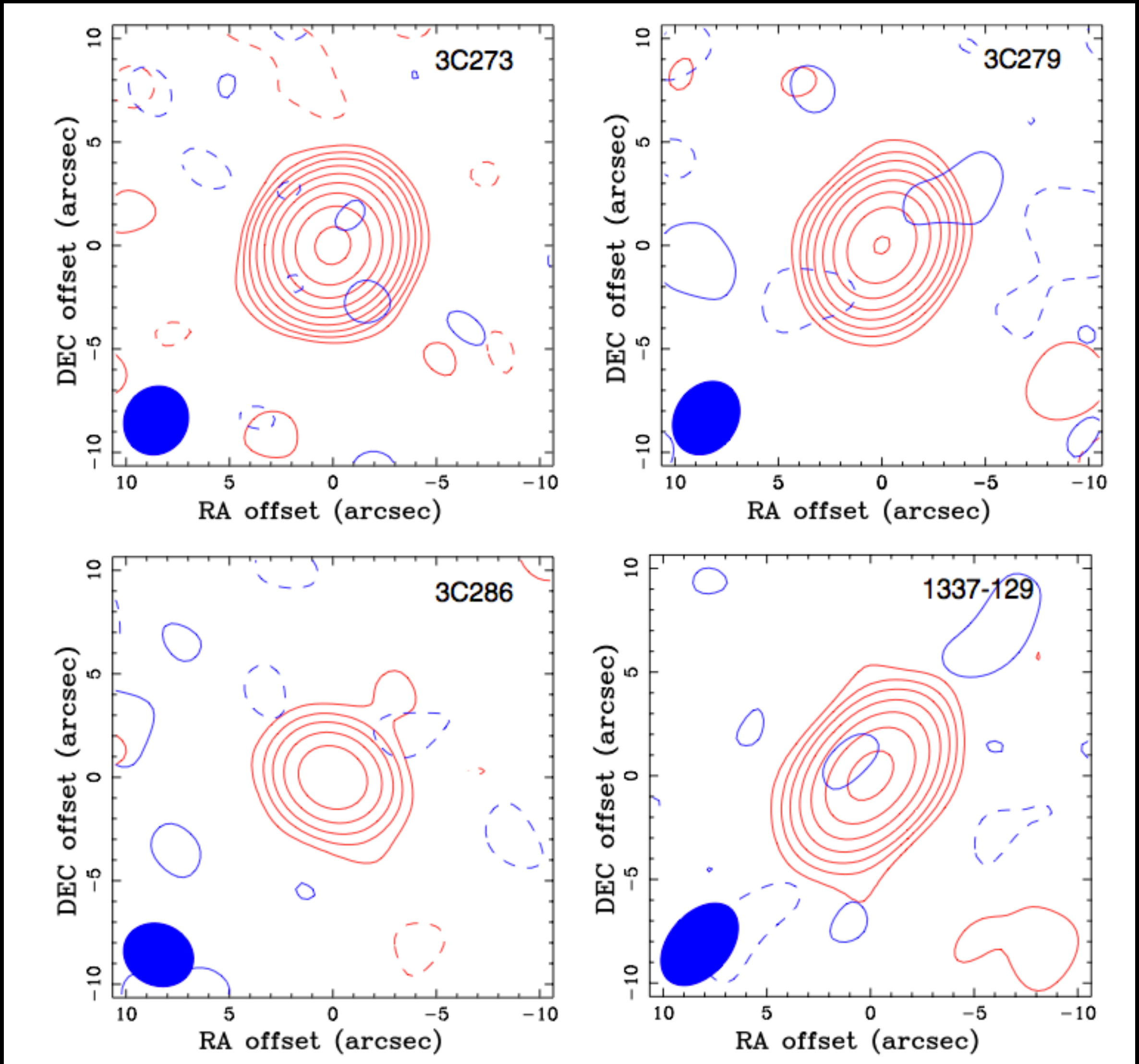
Circular Polarization Picture





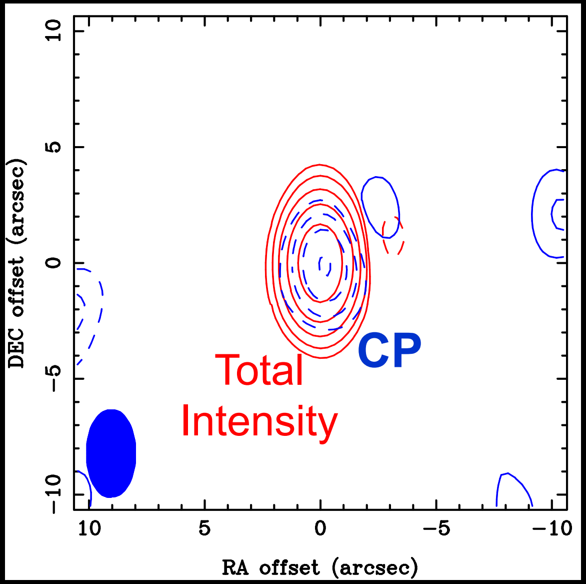
Circular Polarization Picture

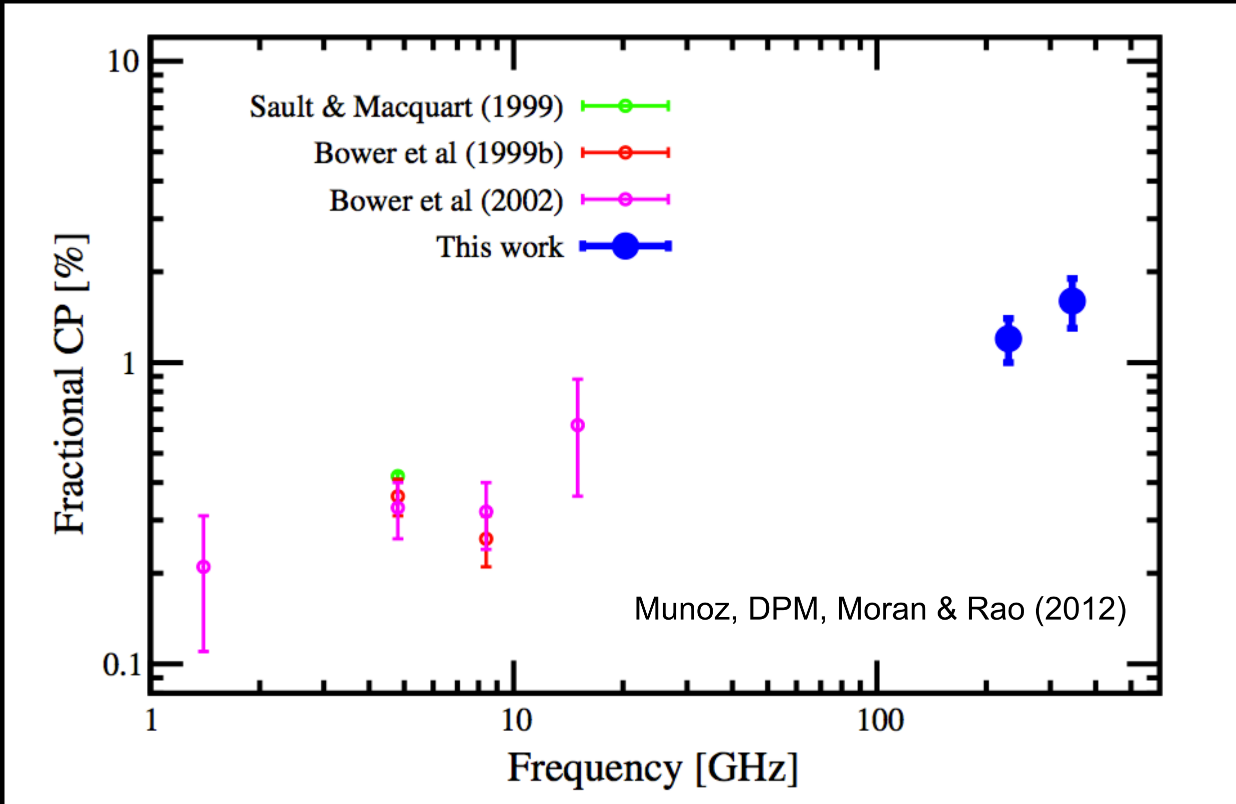




Circular Polarization Picture

- CP present at ~1mm too!
- Same sign as cm wavelengths
- Persistent: 2005-2013 1-1.5%
- CP spectrum monotonically increases, $\sim\nu^{0.35}$





Circular Polarization Picture

- Interpretation? Plausibility argument from Munoz, DPM, Moran & Rao 2012
  - CP can be created from LP via Faraday conversion
  - Other mechanisms seem improbable
  - Stability of RM and CP sign – both are magnetically driven – should be related
- Faraday conversion (in emitting plasma) requires Faraday rotation
  - Synchrotron emits in Q (local B field coordinates), conversion from U→V
  - If RM handedness is stable, so is direction of Q→U, so is sign of V

~~Circular Polarization~~ Overall Picture

Can this be made to hang together?

- Strong field
- New information from magnetar about B near Sgr A*

~~Circular Polarization~~ Overall Picture

Can this be made to hang together?

- Strong field
- New information from magnetar about B near Sgr A*

Simulations can do this in more detail:

Shcherbakov et al. (2012)