Magnetic Fields and Mass Inflow in Circumnuclear Starbursts

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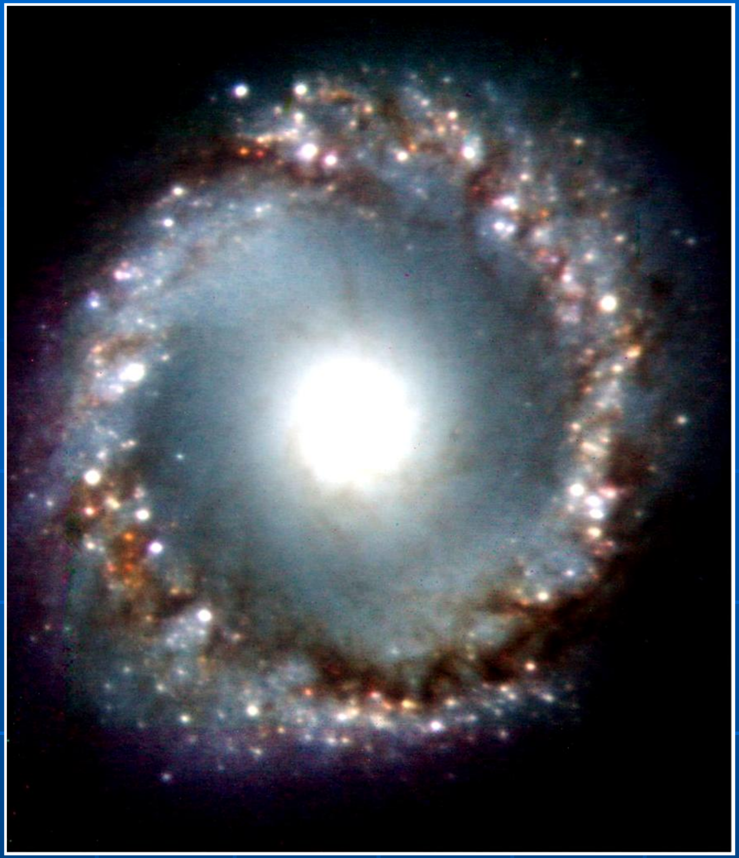
NGC 1097
Circumnuclear ring
VLT
(Prieto et al. 2005)



How to feed an AGN ?

Accretion by magnetic stress
(Beck et al. 1999, 2005)

Basic MHD theory of rotating disks (Balbus & Hawley 1998) :

Mass inflow: $dM/dt = 2\,\pi\,\sigma\,T_{r\Phi} / \Omega$

Stress tensor: $T_{r\Phi} = -< v_{A,r}\, v_{A,\Phi} >$

(V_A : Alfvén velocity)

$$dM/dt = -h/\Omega\,(< B_{tot,r}\, B_{tot,\Phi} > + < B_{reg,r}\, B_{reg,\Phi} >)$$

Radio synchrotron emission is a tracer of interstellar magnetic fields

- Total synchrotron intensity:
  Strength of total magnetic field $B_\perp$
- Polarized synchrotron intensity:
  Strength of ordered $B_\perp$
- Polarization B vectors:
  Orientation of ordered $B_\perp$

Radio continuum survey of barred galaxies

(Beck et al. 2002, 2005a,b)

VLA + Effelsberg:

NGC 1097, 1300, 1365, 2336, 3359, 3953, 3992, 4535, 5068, 7479

Wavelengths: 3.5, 6.2, 18.0, 22.0cm (VLA)
2.8cm (Effelsberg)

ATCA:

NGC 986, 1313, 1433, 1493, 1559, 1672, 2442, 3059, 5643, 7552

Wavelengths: 5.4+6.2, 13.1, 21.7cm

NGC 1097

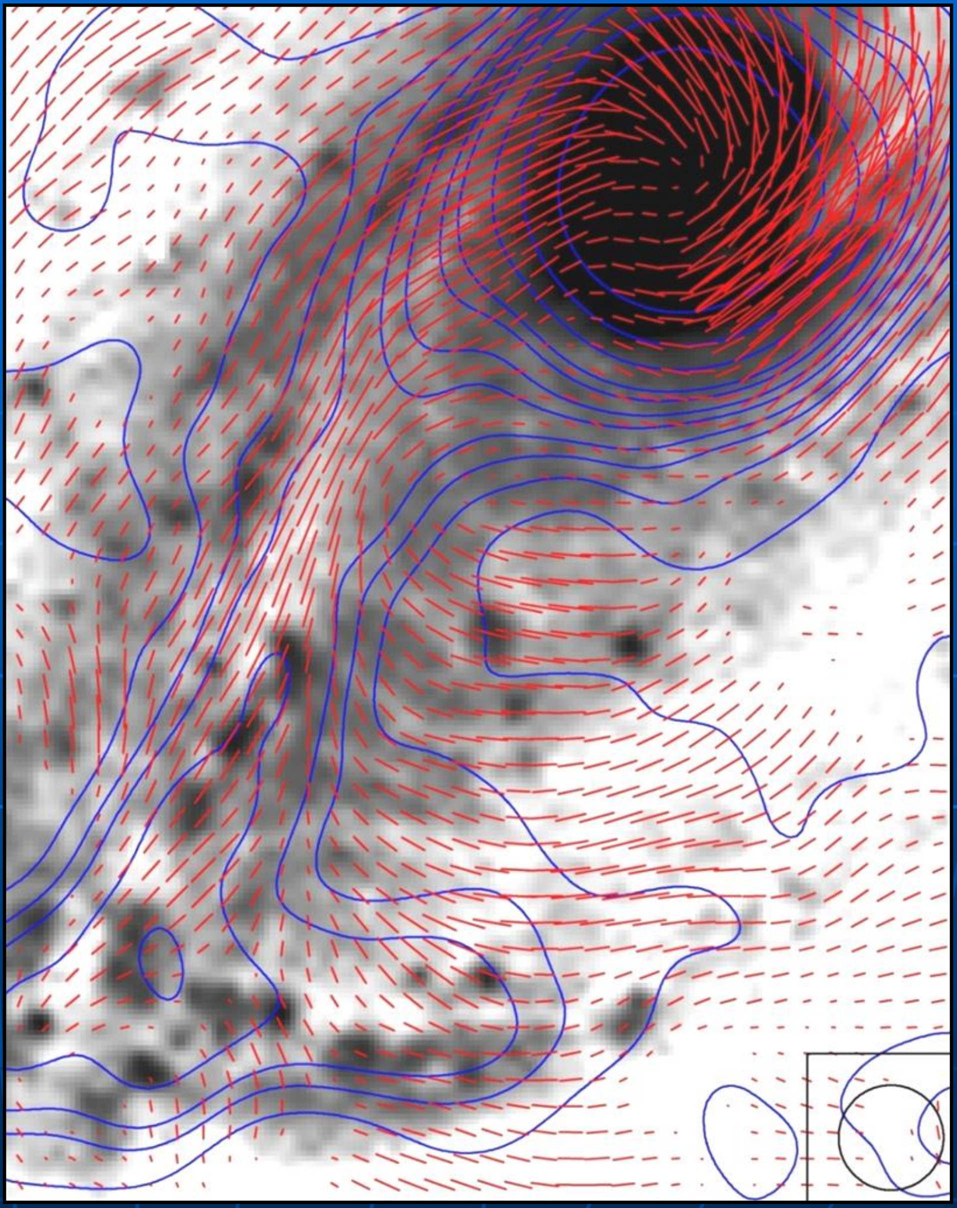
Spitzer

(Henning et al. 2009)

NGC 1097

6cm VLA
Total intensity
+ B-vectors
(Beck et al. 2005a)

The magnetic field traces the flow of the warm diffuse gas



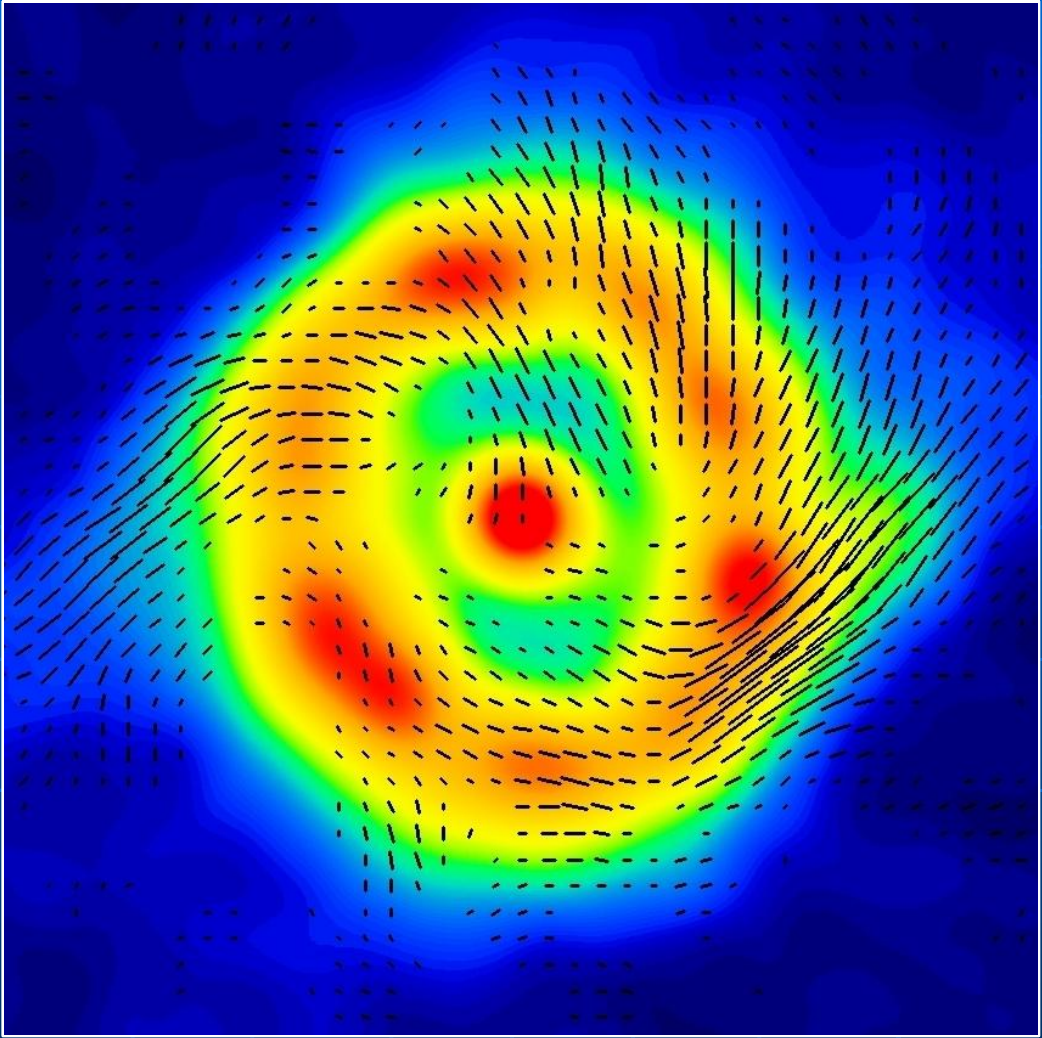
NGC 1097

Circumnuclear ring

3.6cm VLA

Total intensity + B-vectors

(Beck et al. 2005a)

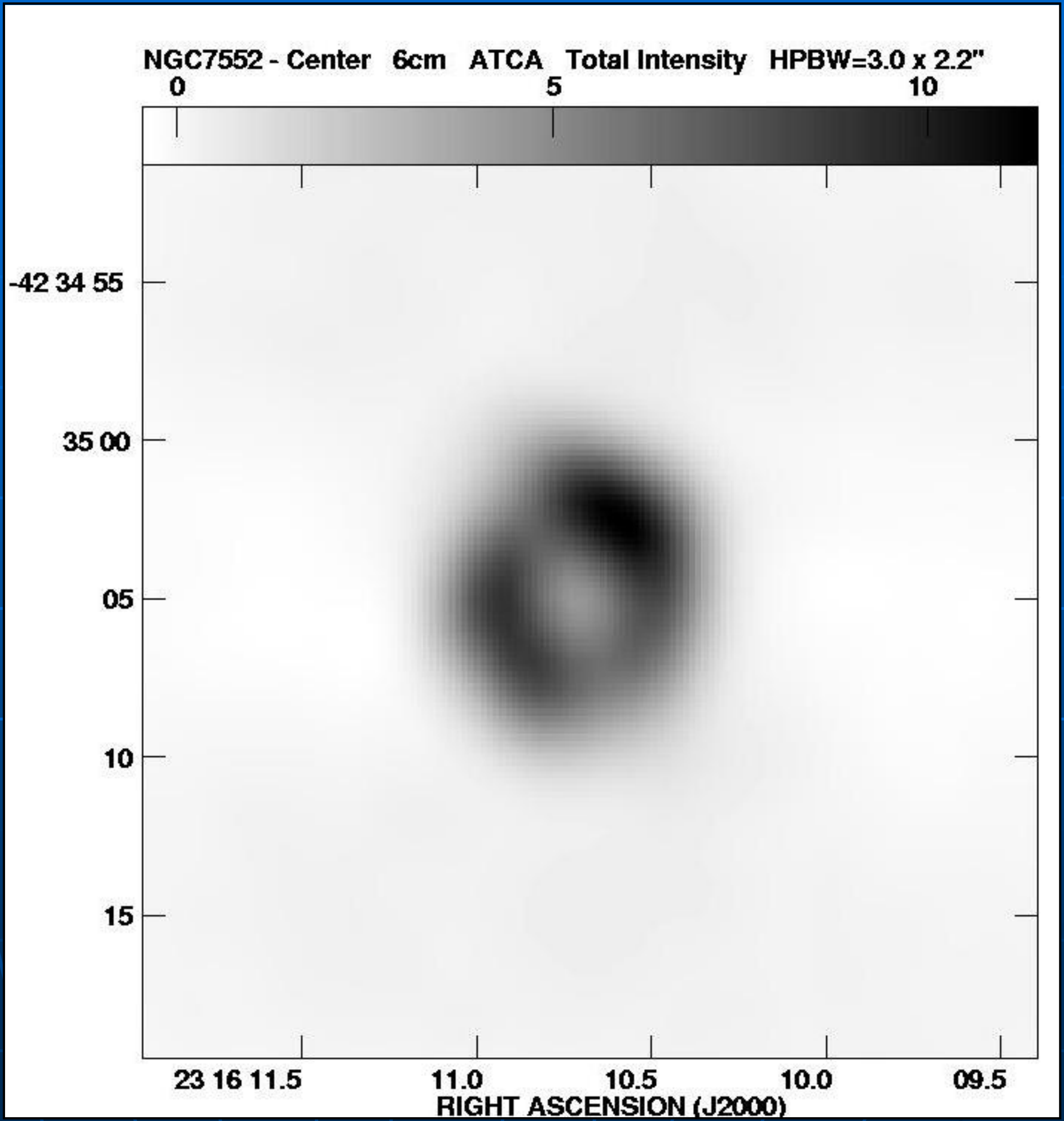


Bright radio ring with an ordered spiral field (dynamo?)

NGC 7552

Circumnuclear ring

6cm ATCA
Total intensity
(Beck et al. 2005b)



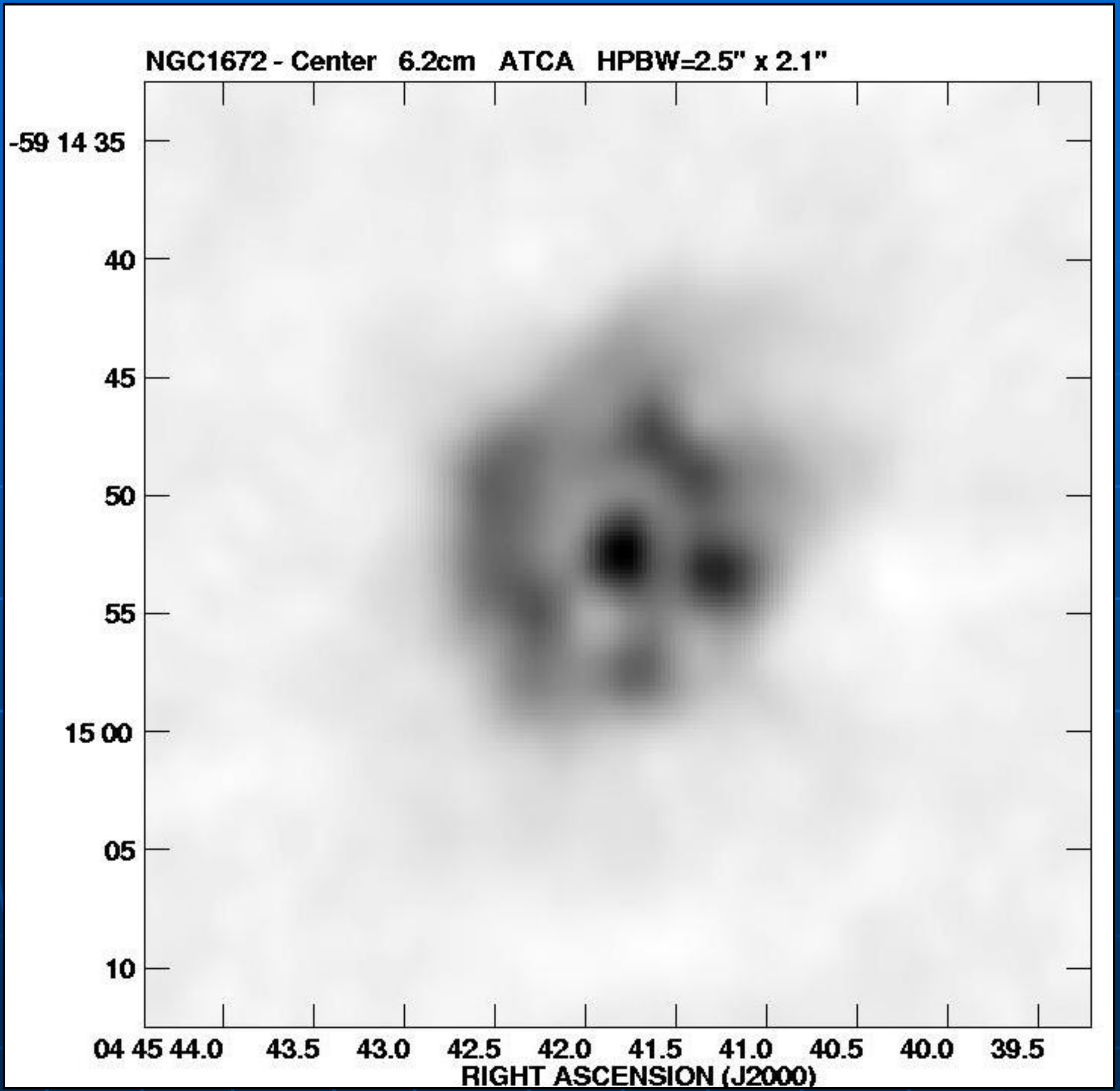
NGC 1672

Circumnuclear ring

6cm ATCA

Total intensity

(Beck et al. 2005b)

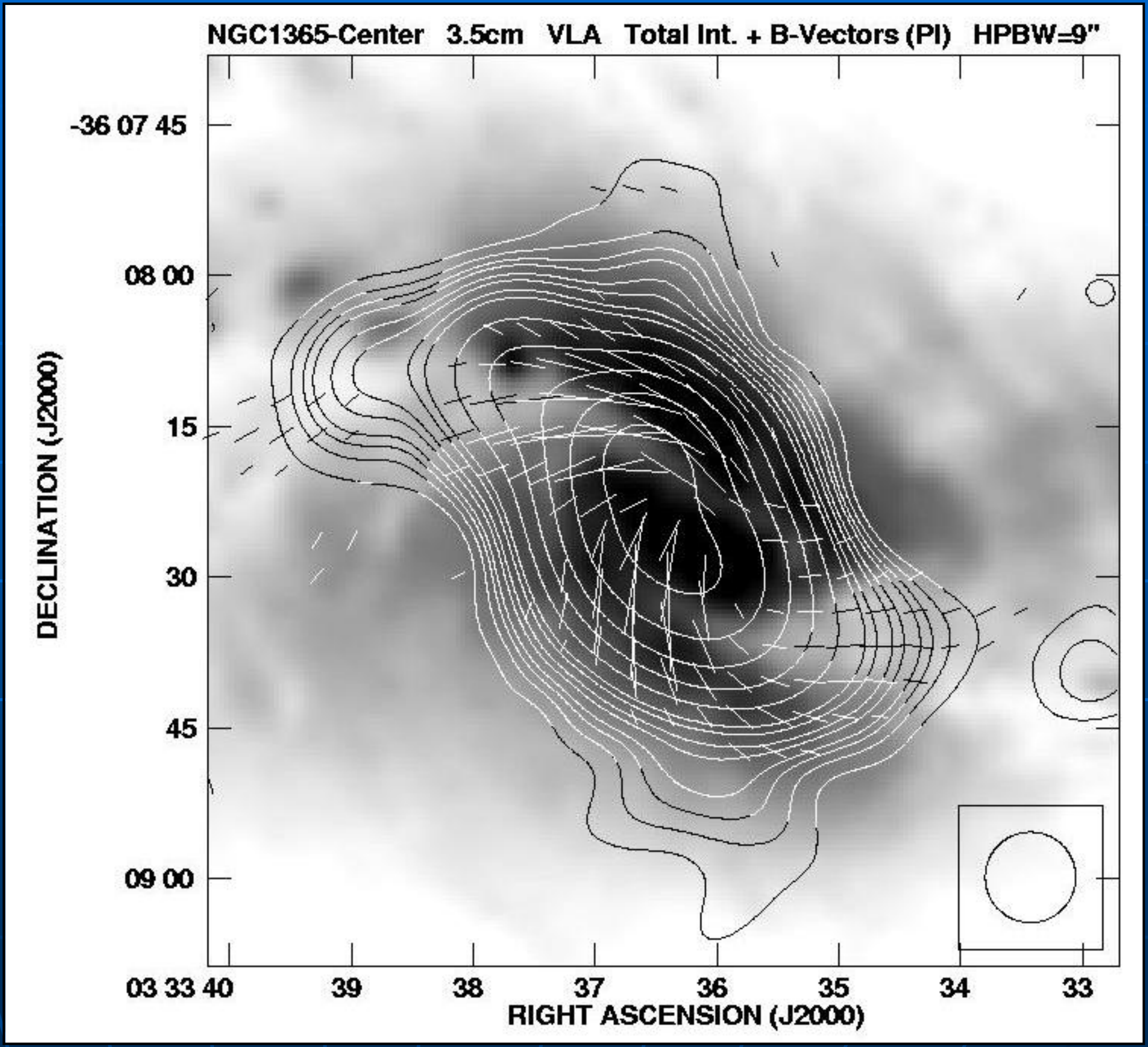


NGC 1365

Circumnuclear region

3.6cm VLA Total intensity + B

(Beck et al. 2005a)



Total magnetic field strengths in central starburst regions

(assuming equipartition with cosmic rays – *lower limit* in case of energy losses)

- NGC 1097 (ring knots): 60μG
- NGC 1365 (dust lanes): 63μG
- NGC 1672 (ring knots): 68μG
- NGC 7552 (ring knots): 105μG

Dynamically important !

Accretion by magnetic stress

(Beck et al. 1999, 2005)

$dM/dt = -h/\Omega\ (< B_{tot,r}\ B_{tot,\Phi} > + < B_{reg,r}\ B_{reg,\Phi} >)$

NGC 1097:

h=100 pc, v=450 km/s,

$B_{tot,r} \approx B_{tot,\Phi} \approx 50\mu G$, $B_{reg,r} \approx B_{reg,\Phi} \approx 10\mu G$:

$dM/dt \approx 1\ M_o/yr$

Magnetic fields are able to drive accretion

Accretion rate and star formation

Linear radio – FIR correlation:

$$dM/dt \approx -(h/\Omega)\, B_{tot}^{2} \sim -(h/\Omega)\, I_{RC}^{0.5} \sim -(h/\Omega)\, I_{FIR}^{0.5}$$

(1) The accretion rate is related to radio synchrotron or far-infrared intensity of the nuclear region

$B_{tot} = \rho^{\gamma}$ (flux freezing) , SFR $\sim \rho^{3/2}$ (Schmidt-Kennicutt law):

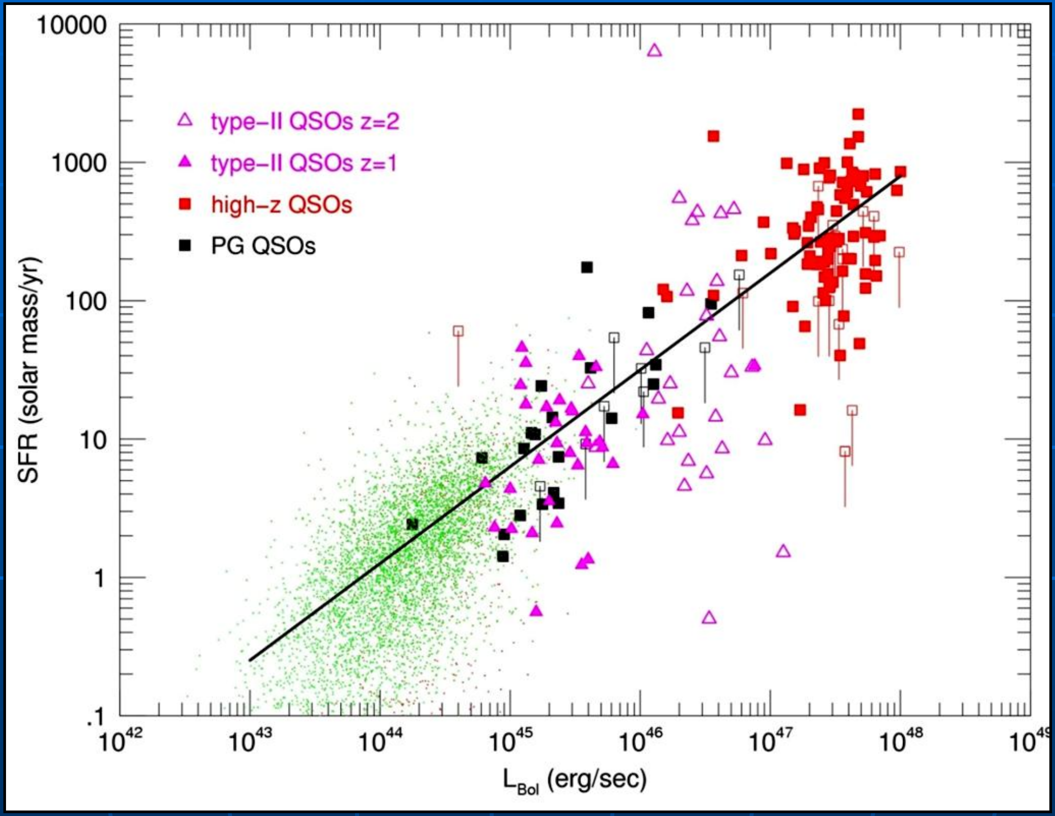
$$dM/dt \sim -(h/\Omega)\, \rho^{2\gamma} \sim -(h/\Omega)\, SFR^{(4\gamma/3)}$$

$$\sim -(h/\Omega)\, SFR^{0.4 \ldots 0.7}$$

(2) The accretion rate is related to the star-formation rate in the nuclear region

Star formation rates and AGN luminosity

(Trakhtenbrot & Netzer 2010)



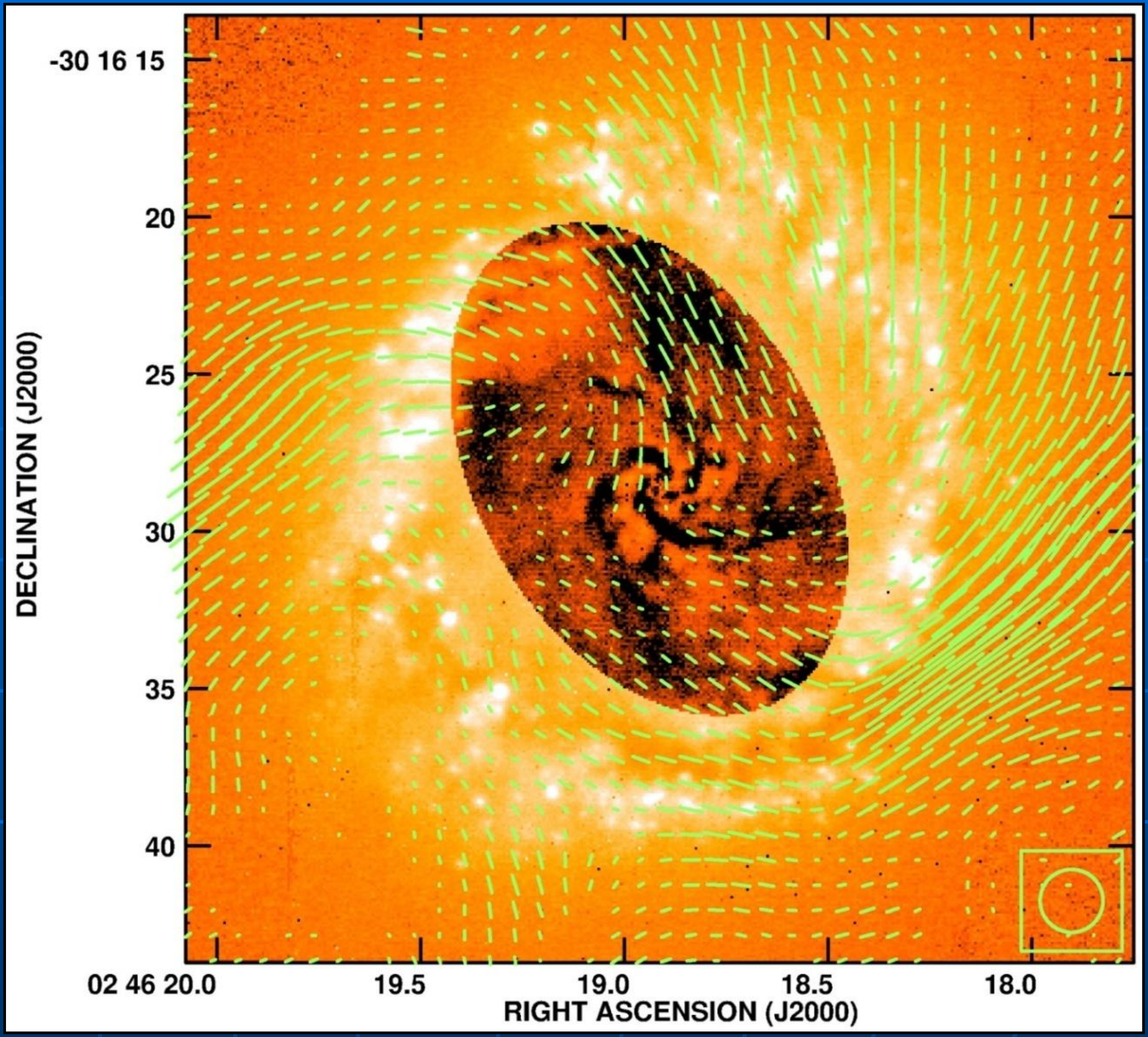
Consistent with the magnetic scenario – but needs detailed investigation

NGC 1097

Circumnuclear ring

VLT

(Prieto et al. 2005)



Spiral field along spiral dust filaments:
tracing the flow or driving it?

Conclusions

- Magnetic fields in central starburst regions are strong and dynamically important
- Magnetic stress can drive gas inflow, sufficient to feed the nuclear activity
- The accretion rate is related to the synchrotron or far-infrared intensity and to the star-formation rate in the nuclear region
- The accretion flow is related to the spiral magnetic field

Needed:

- MHD simulations of accretion flows
- High-resolution radio polarization observations (EVLA, SKA)
- Optical/NIR polarimetry (E-ELT)