

The Role of Magnetic Fields in Low Mass Galaxies



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Kelsey Johnson (Virginia), Stefanie Mühle (Bonn),
Tim Robishaw (DRAO), Eric Wilcots (UW-Madison),
Ellen Zweibel (UW-Madison)



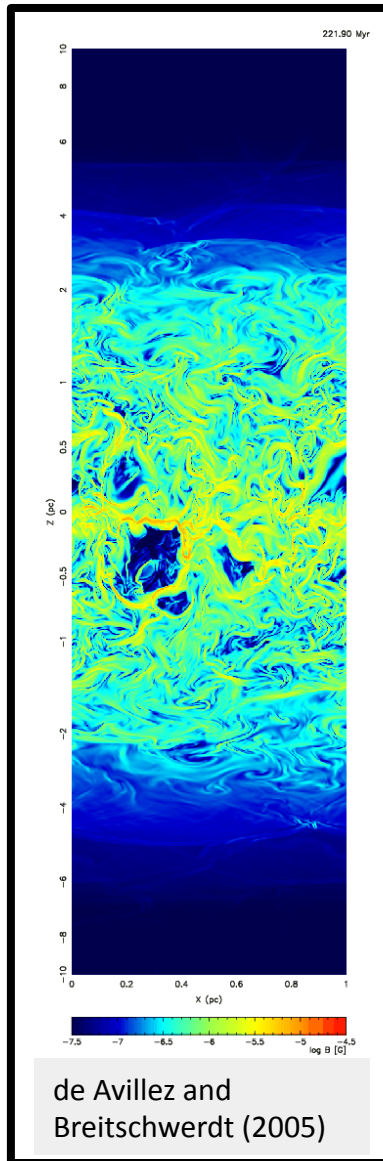
**[T]he larger one's ignorance,
the stronger the magnetic field.**

L. Woltjer

“Remarks on the galactic magnetic field”
in the Proceedings of IAU Symposium 31



Why are magnetic fields important?



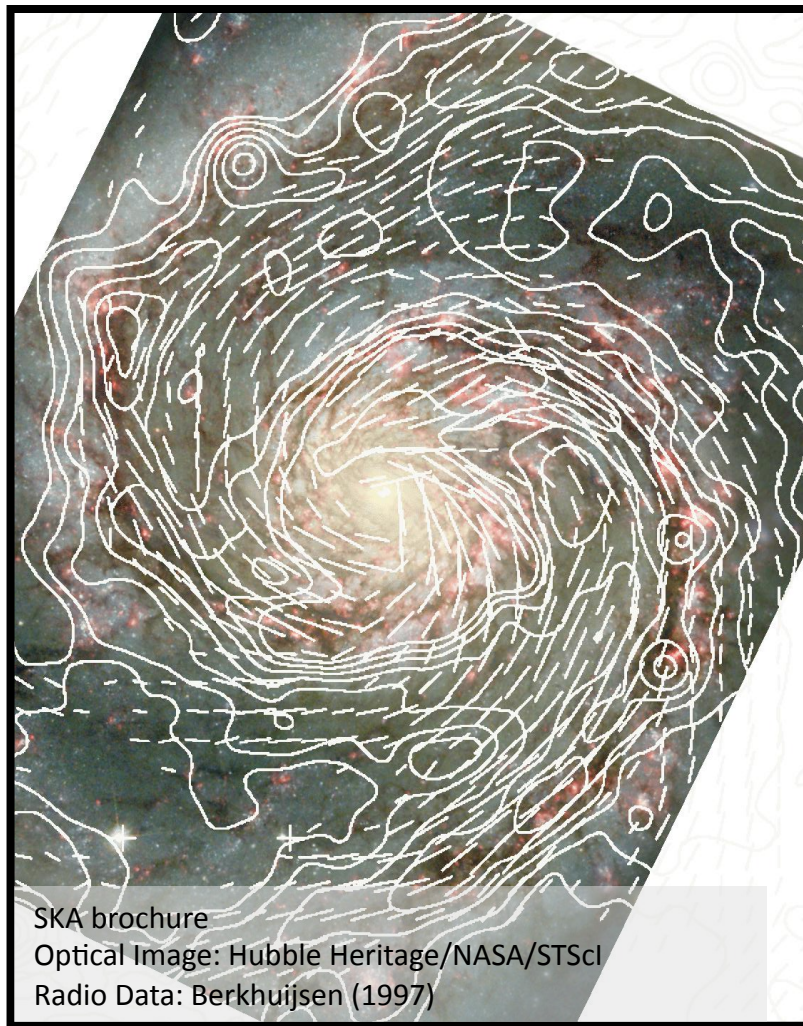
- Influence gas dynamics
- Provide source of pressure
- Accelerate and distribute cosmic rays

Magnetic fields in spiral galaxies are $\sim 10\mu\text{G}$ and well-ordered.

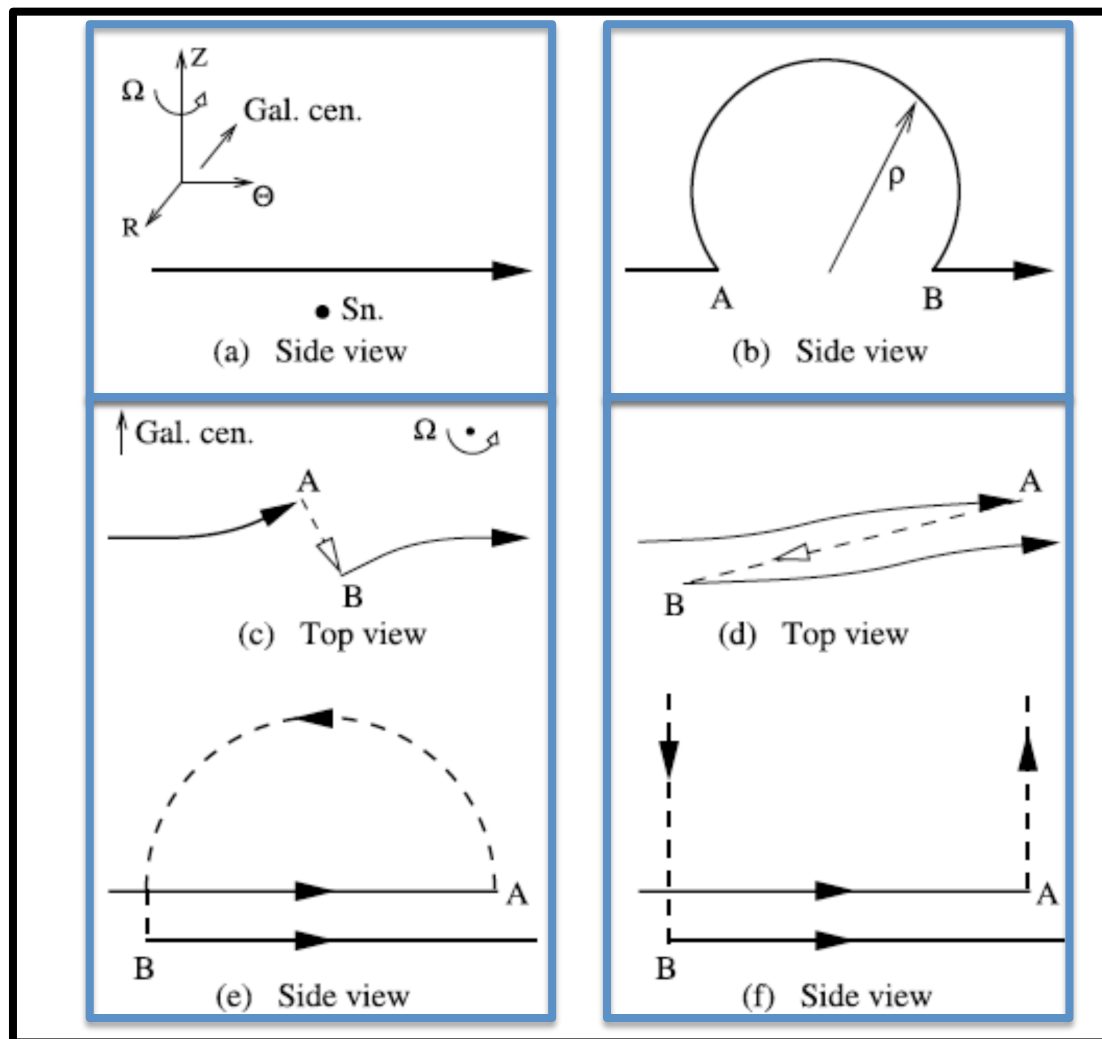
See Rainer Beck's talk for
more information

$$B_t = 15\text{-}21 \mu\text{G}$$

$$B_u = 6 \mu\text{G}$$



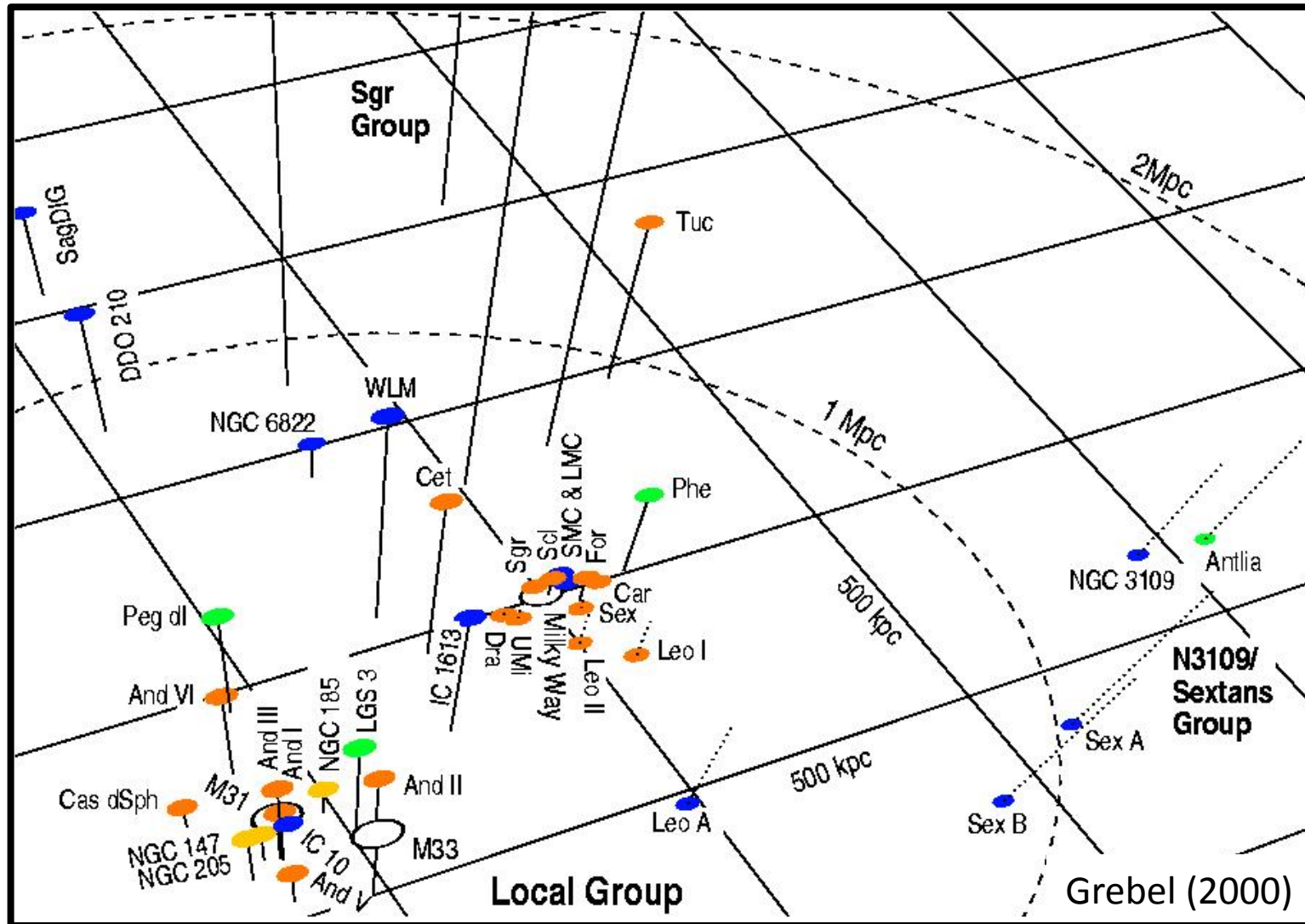
α - ω dynamos amplify magnetic fields in spiral galaxies.



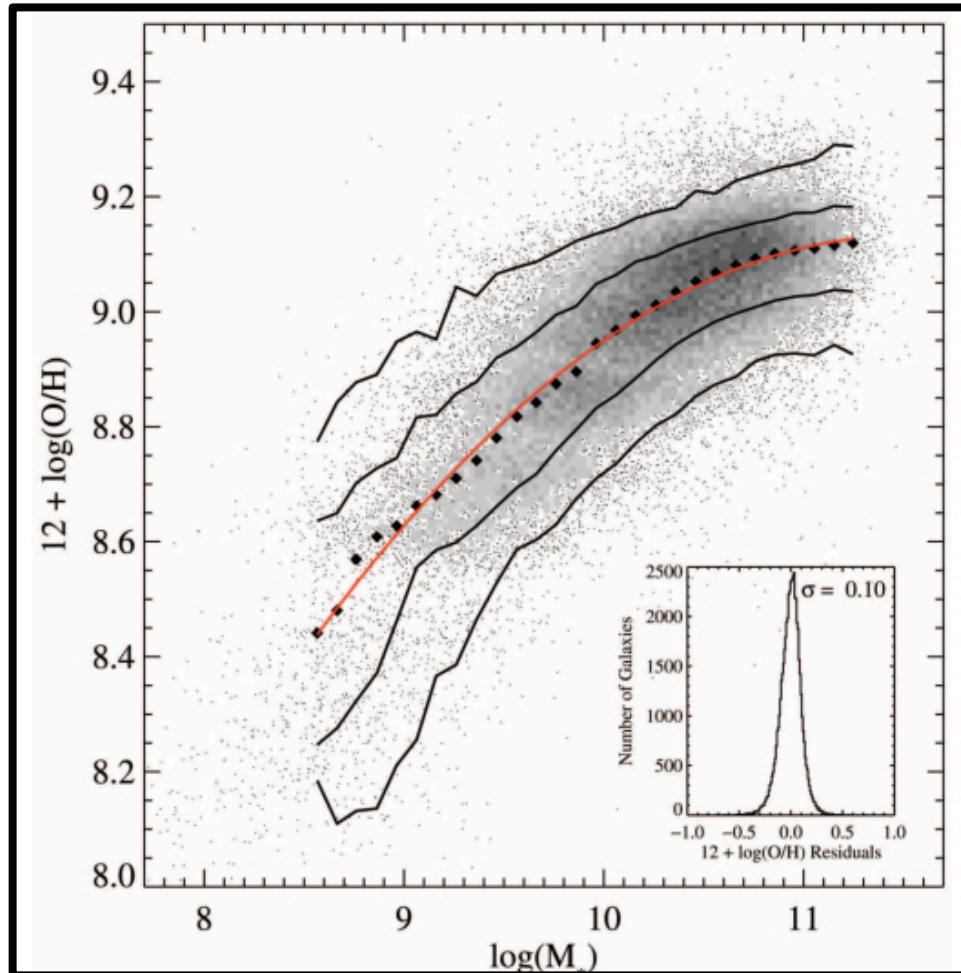
Important parameters:

- Shear
- Turbulence
- Diffusivity

Most galaxies are low mass, not large spirals.



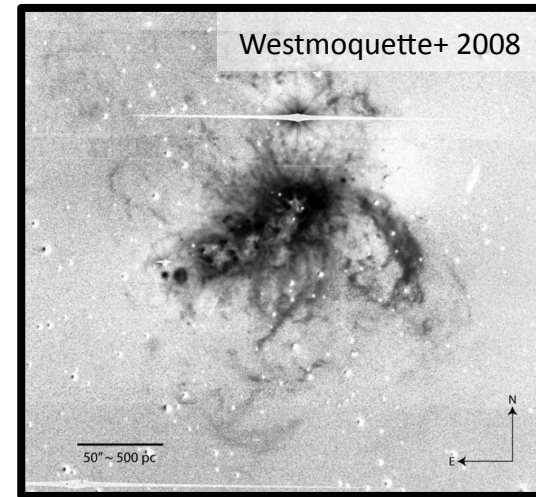
Low mass galaxies are low metallicity.



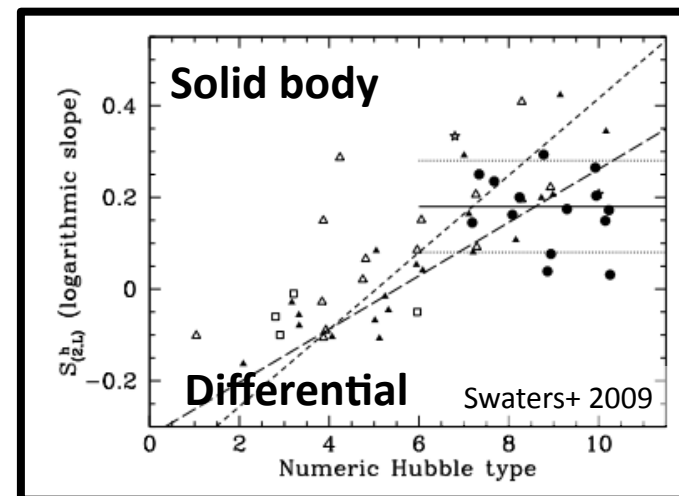
Tremonti+ 04

Low mass galaxies may have their fields amplified by different mechanisms.

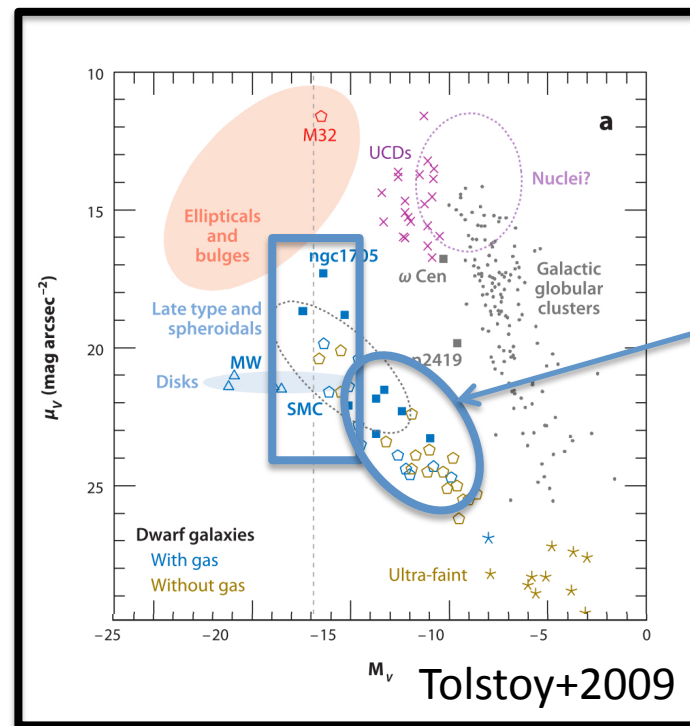
Their shallow potential wells are more easily disrupted.



They rotate more as solid bodies leading to less shear.

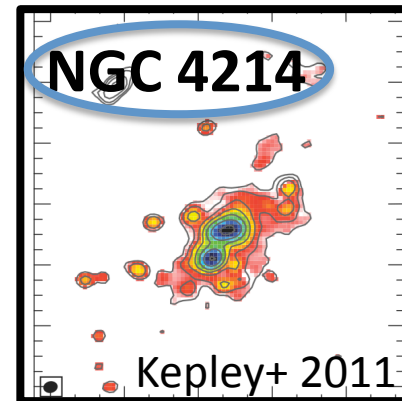
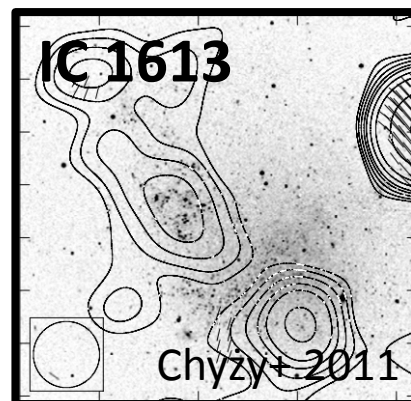
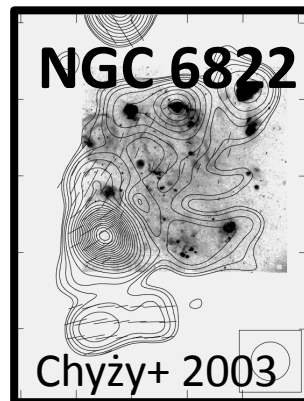
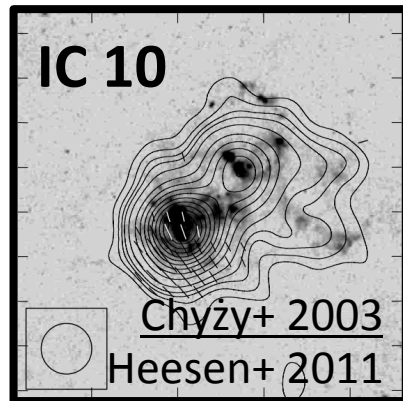
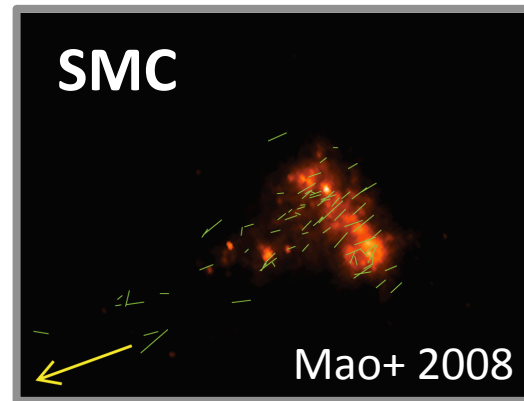
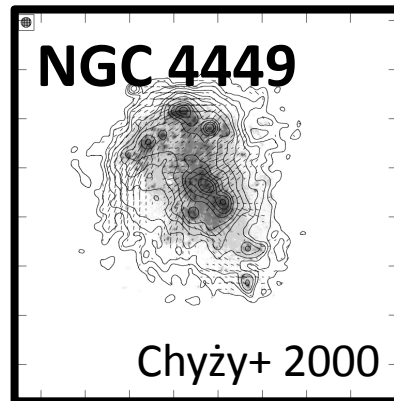
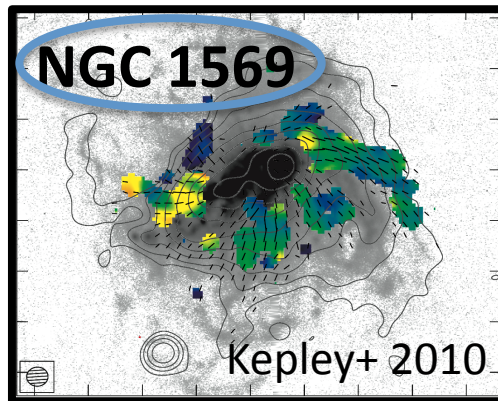


The galaxies in this talk are not “classical” dwarfs, but are still low mass.



See Chyży+ 2011
and Roychowdhury
& Chengalur (2012)

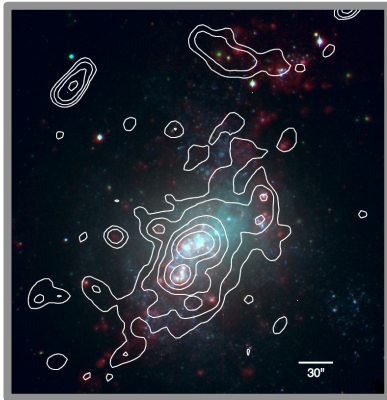
Magnetic fields in low mass galaxies are $\sim 10 \mu\text{G}$, but less well-ordered.



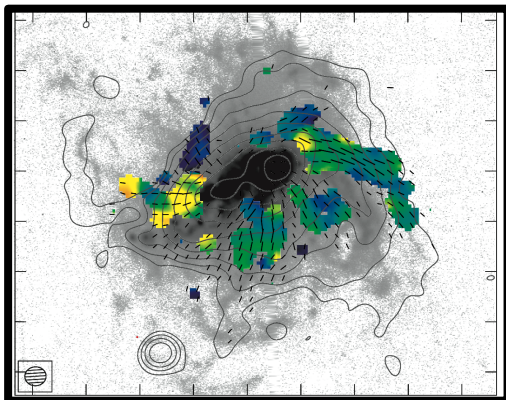
+ I Zw 18 -- See Marek Wezgowiec's talk



How do we measure magnetic fields in low mass galaxies?



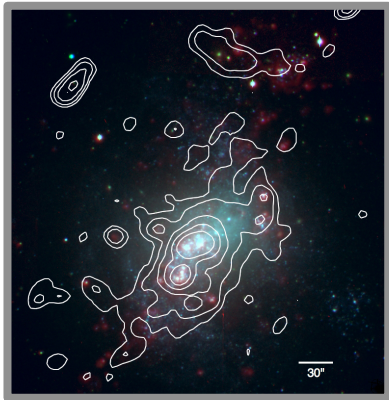
What role do magnetic fields play in the ISM of low mass galaxies?



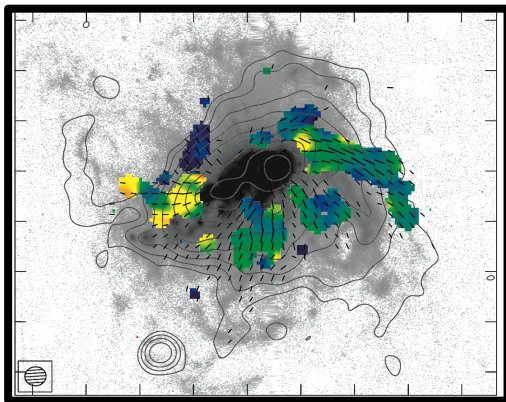
How do low mass galaxies generate ordered magnetic fields?



How do we measure magnetic fields in low mass galaxies?

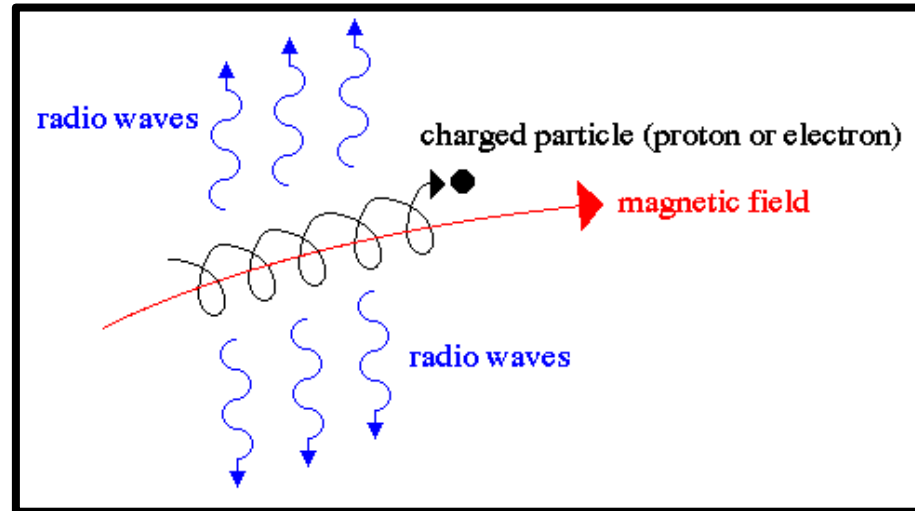


What role do magnetic fields play in the ISM of low mass galaxies?



How do low mass galaxies generate ordered magnetic fields?

Magnetic field properties can be measured using synchrotron emission.



Synchrotron emission gives magnetic field strength and structure.

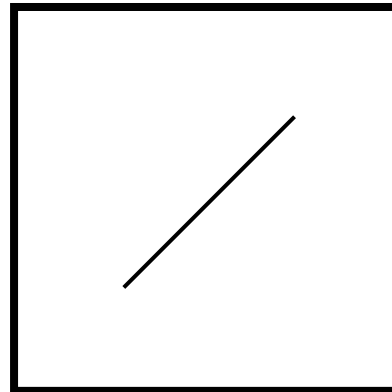
Intensity

$$I_{synch} \propto l N_0 B_{\perp}^{1-\alpha} \nu^{\alpha}$$

- geometry
- cosmic rays
- frequency

Plane of sky
Field strength

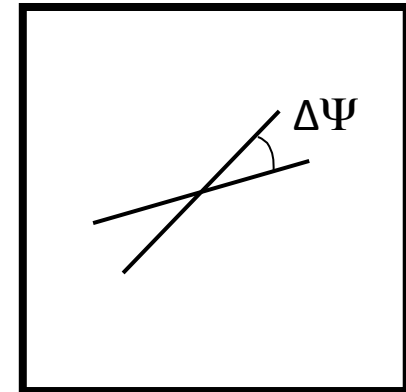
Polarization



angle + $\sim 90^{\circ}$

Plane of sky
Field orientation

Rotation Measure



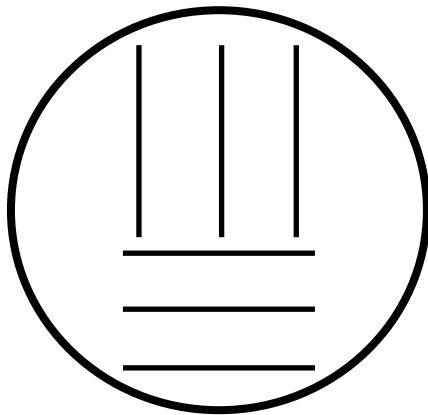
$$\Delta\Psi = \lambda^2 \text{RM}$$

$$\text{RM} = K \int n_e B_{\text{los}} ds$$

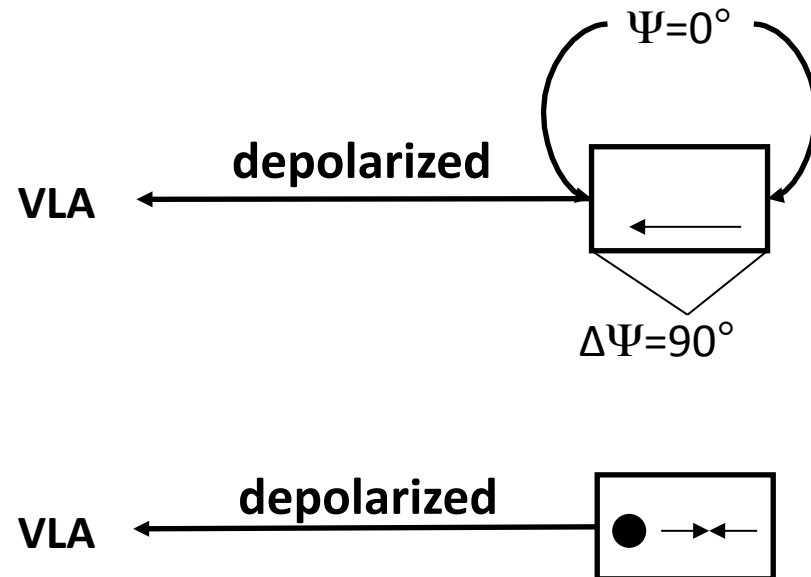
Line of sight
Field direction

Magnetic field structure measurements can be affected by observational biases.

Beam Depolarization

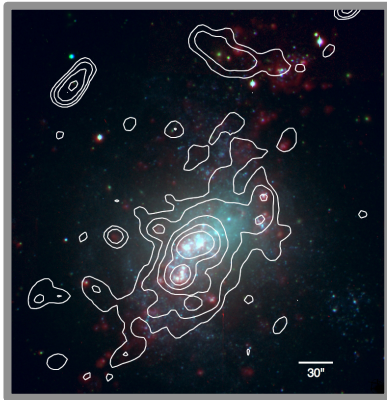


Depth Depolarization

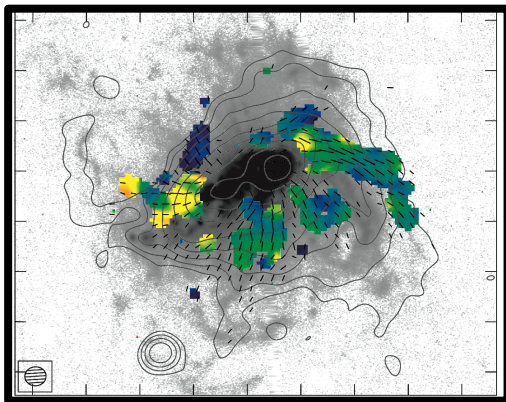




How do we measure magnetic fields in low mass galaxies?

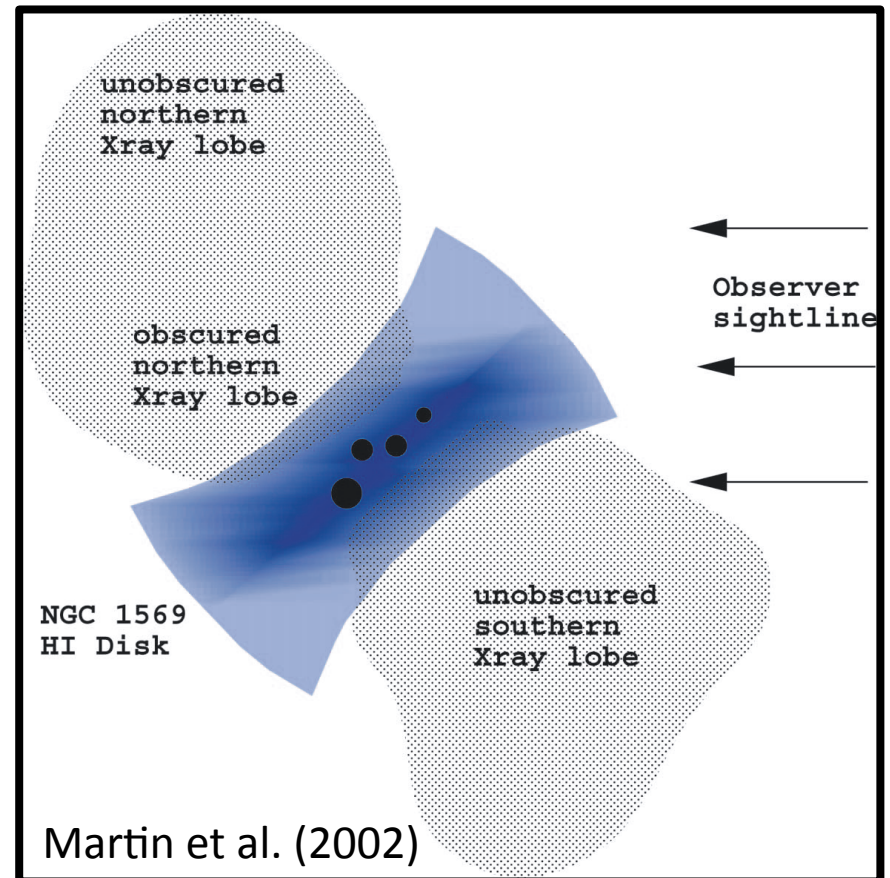
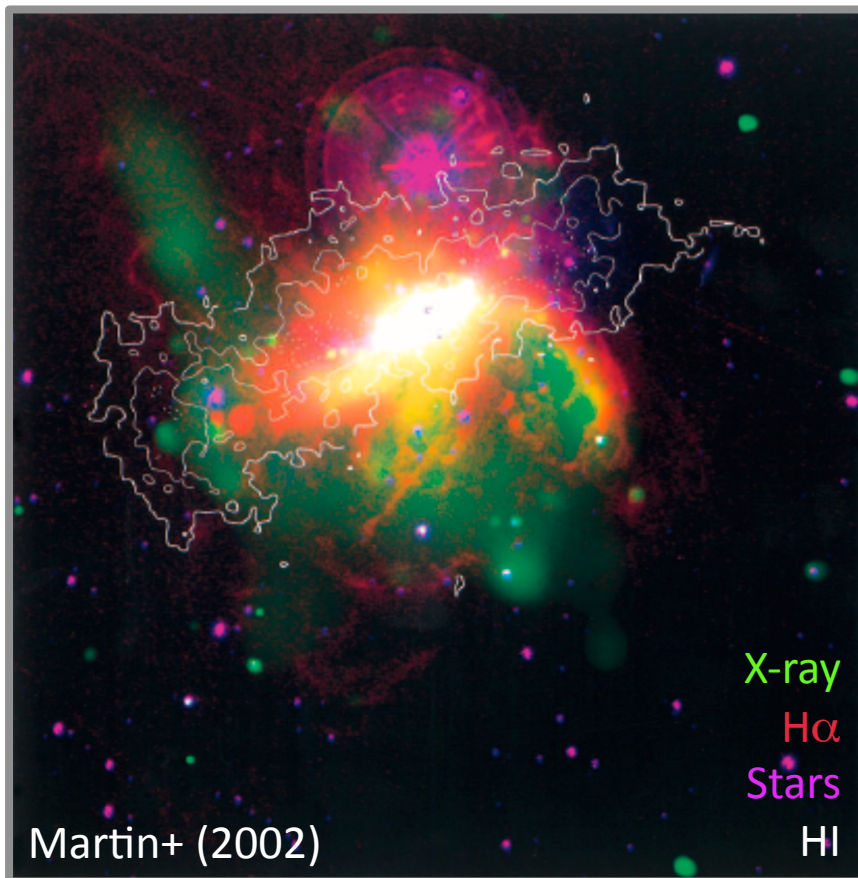


What role do magnetic fields play in the ISM of low mass galaxies?

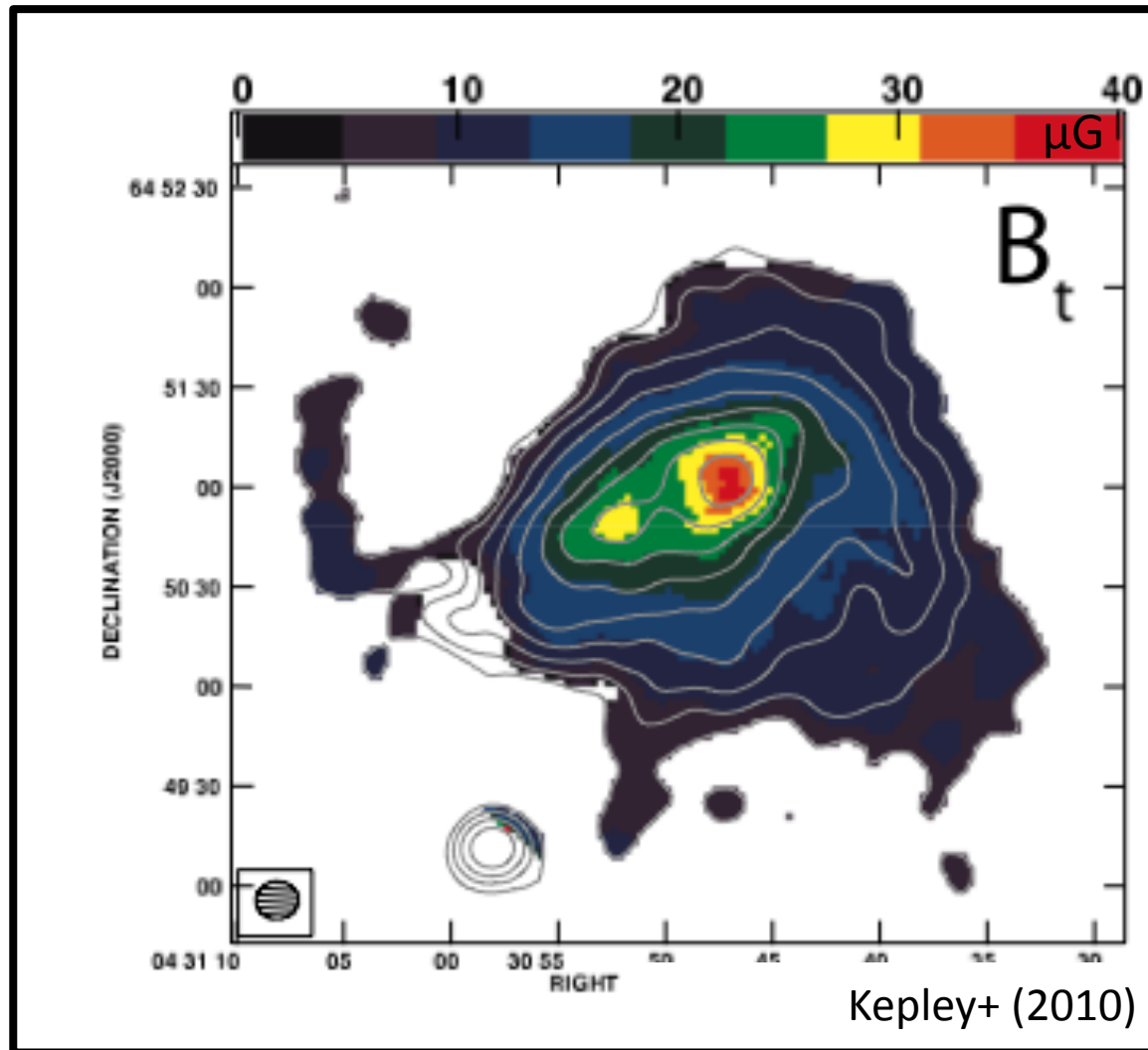


How do low mass galaxies generate ordered magnetic fields?

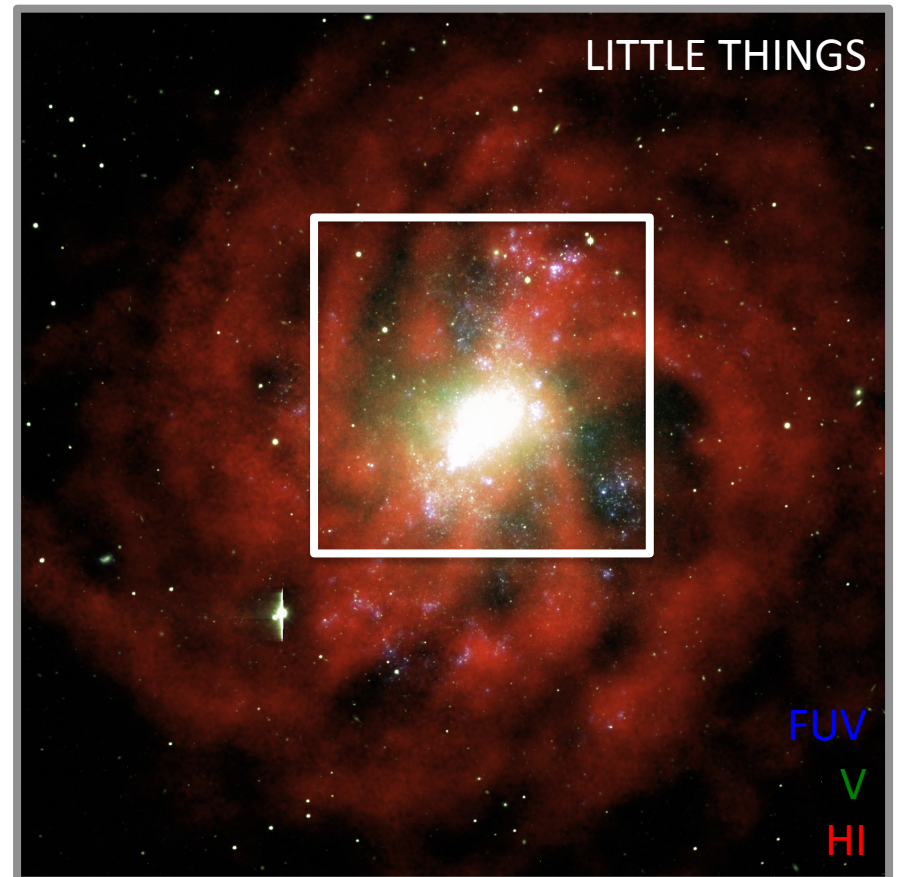
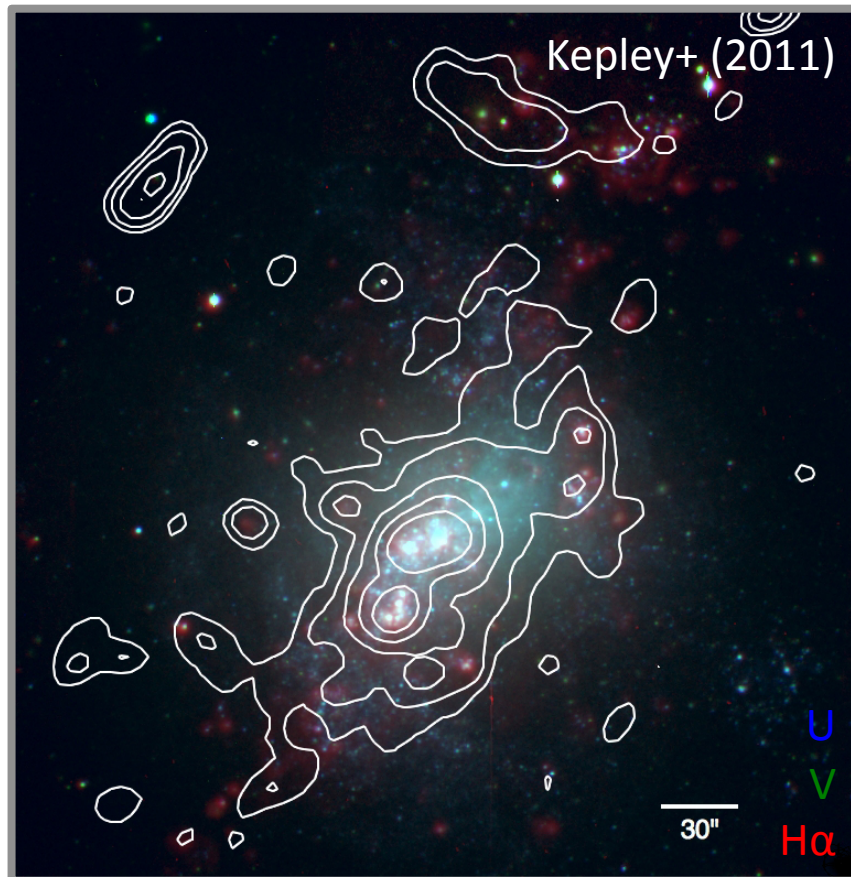
NGC 1569 is an interacting, post-starburst dwarf galaxy.



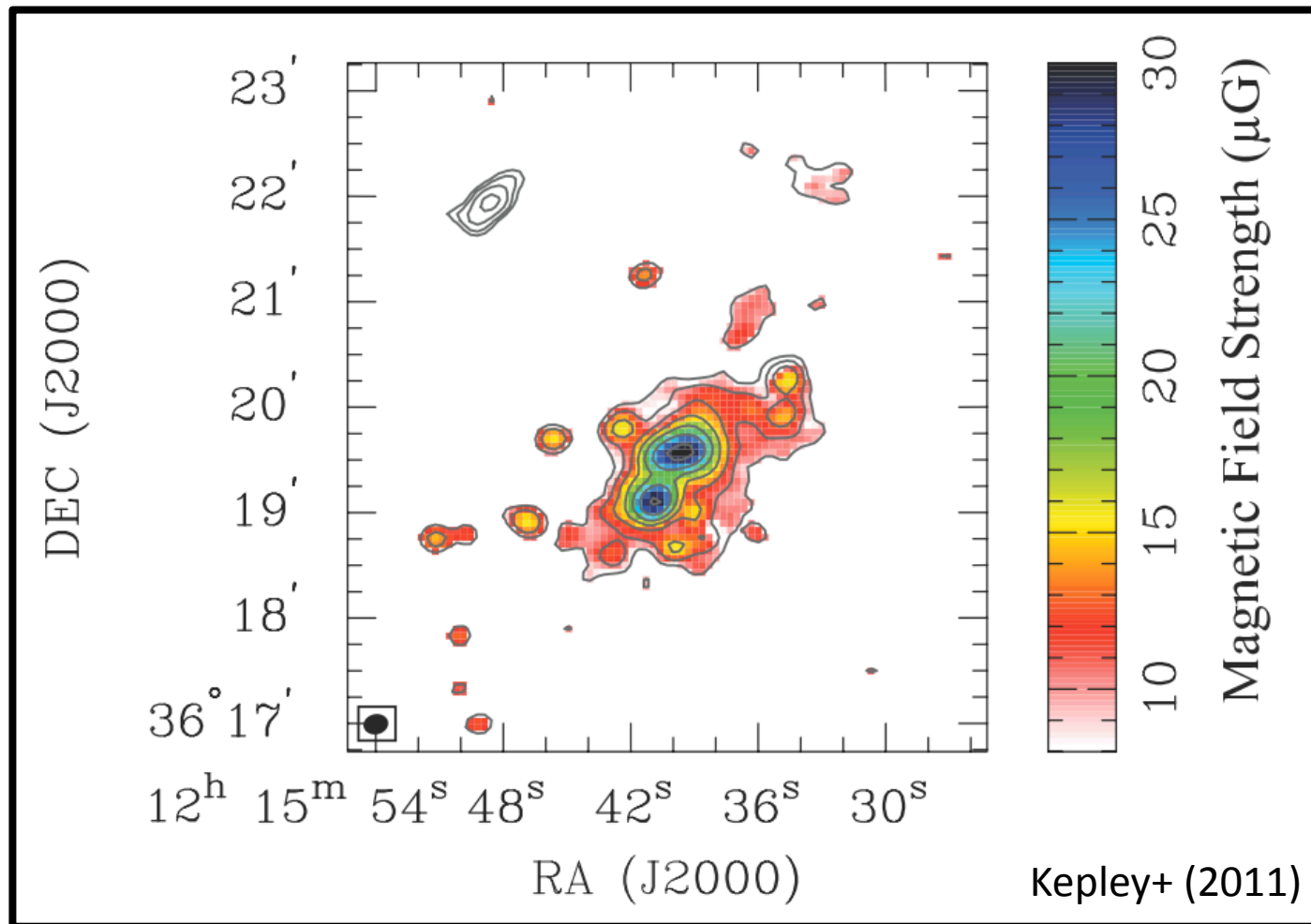
NGC 1569 has a strong magnetic field.



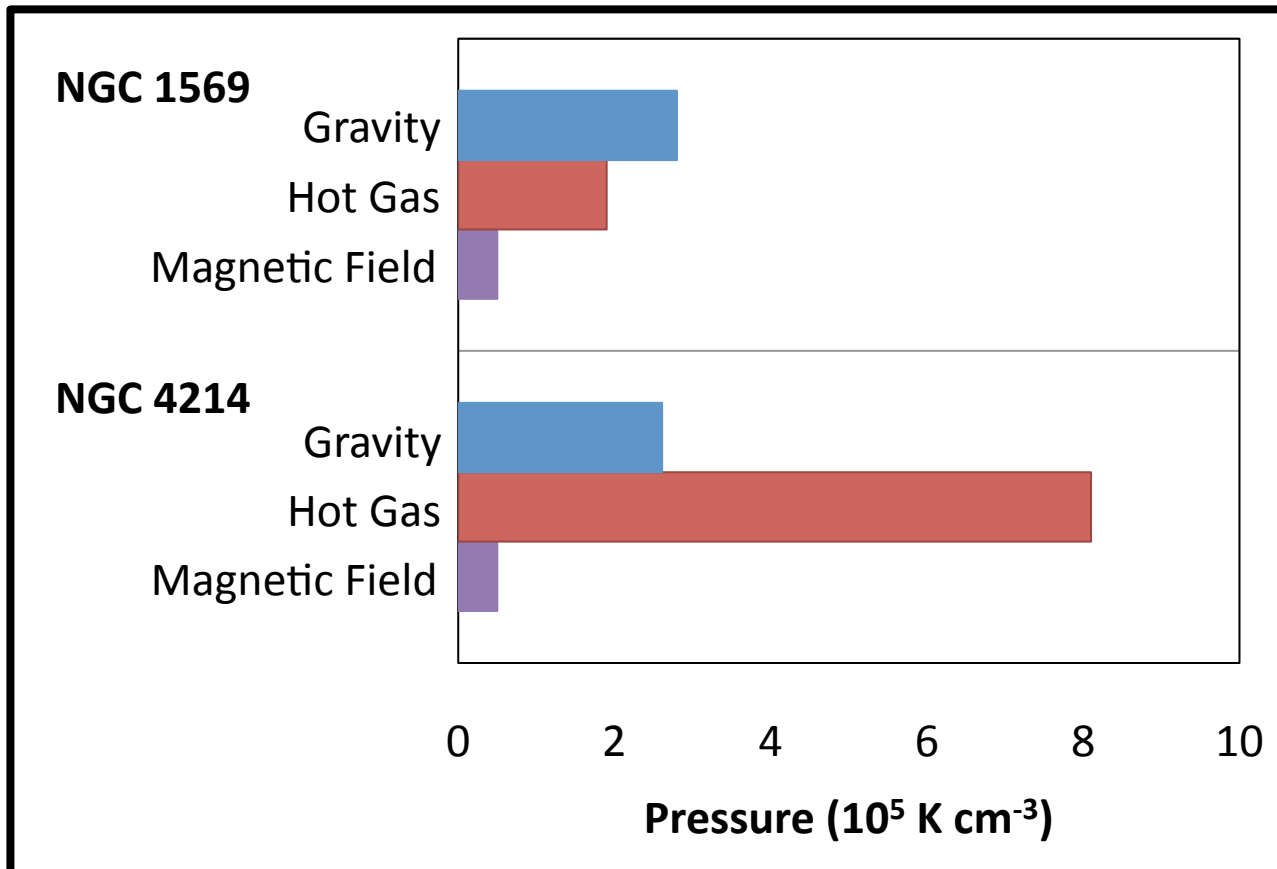
NGC 4214 is a young starburst,
embedded in an neutral hydrogen disk.



NGC 4214 has also a strong magnetic field.



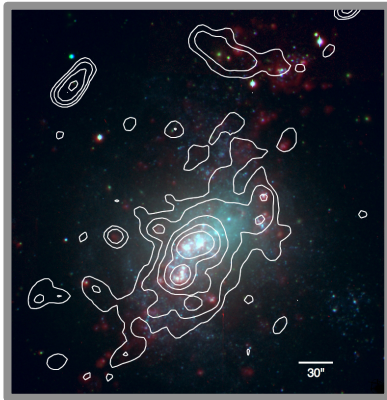
Magnetic field pressures are similar to the pressures of other ISM components.



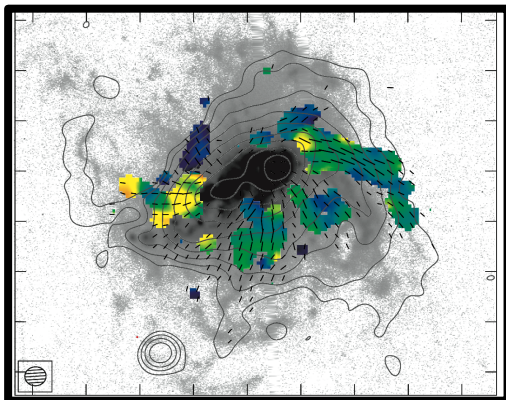
Magnetic field and gravitational pressures from Kepley+ 2010, 2011.
Hot gas pressures from Ott+ 2005.



How do we measure magnetic fields in low mass galaxies?

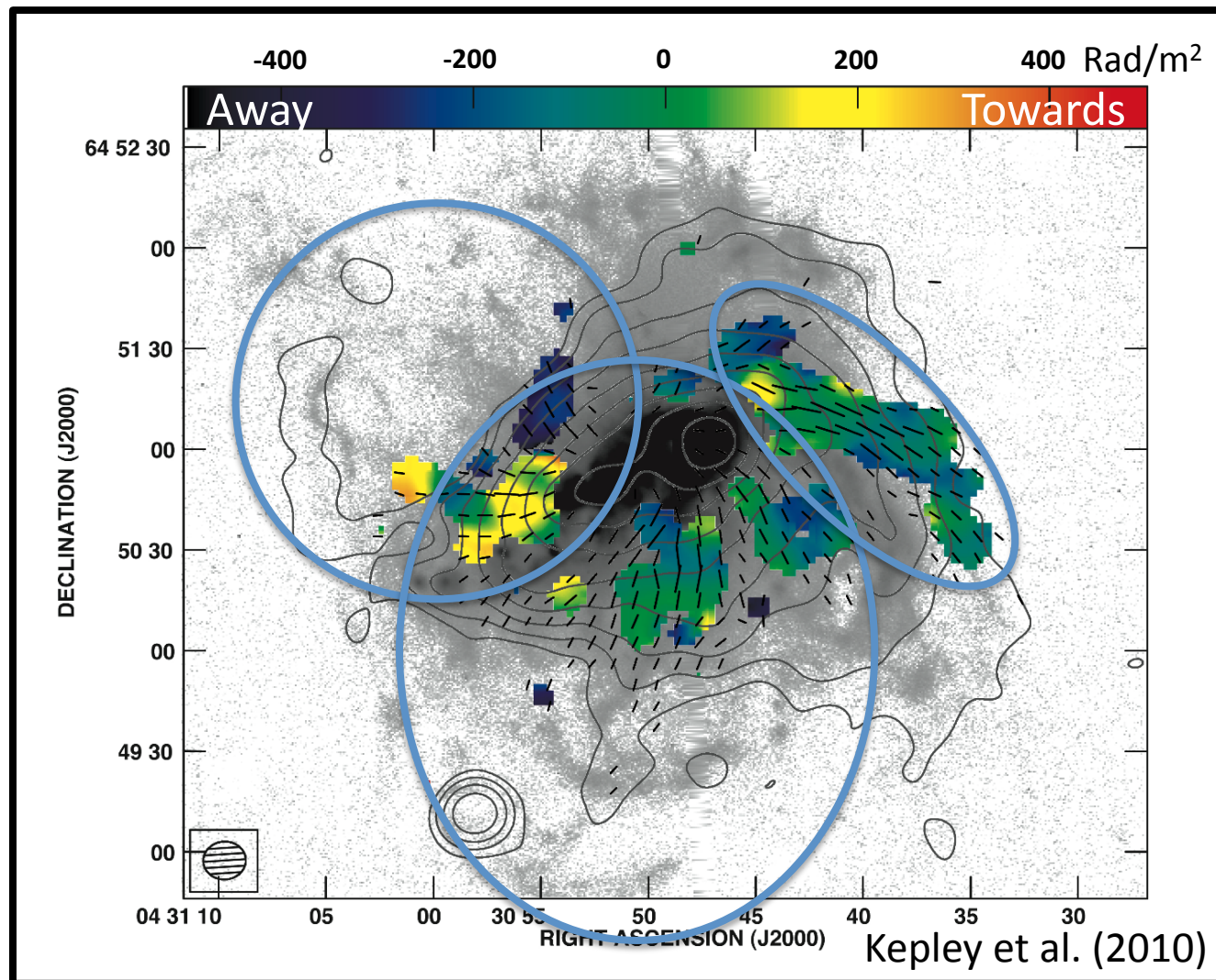


What role do magnetic fields play in the ISM of low mass galaxies?



How do low mass galaxies generate ordered magnetic fields?

NGC 1569's magnetic field structure is shaped by its starburst-driven outflow.



Greyscale: $H\alpha$

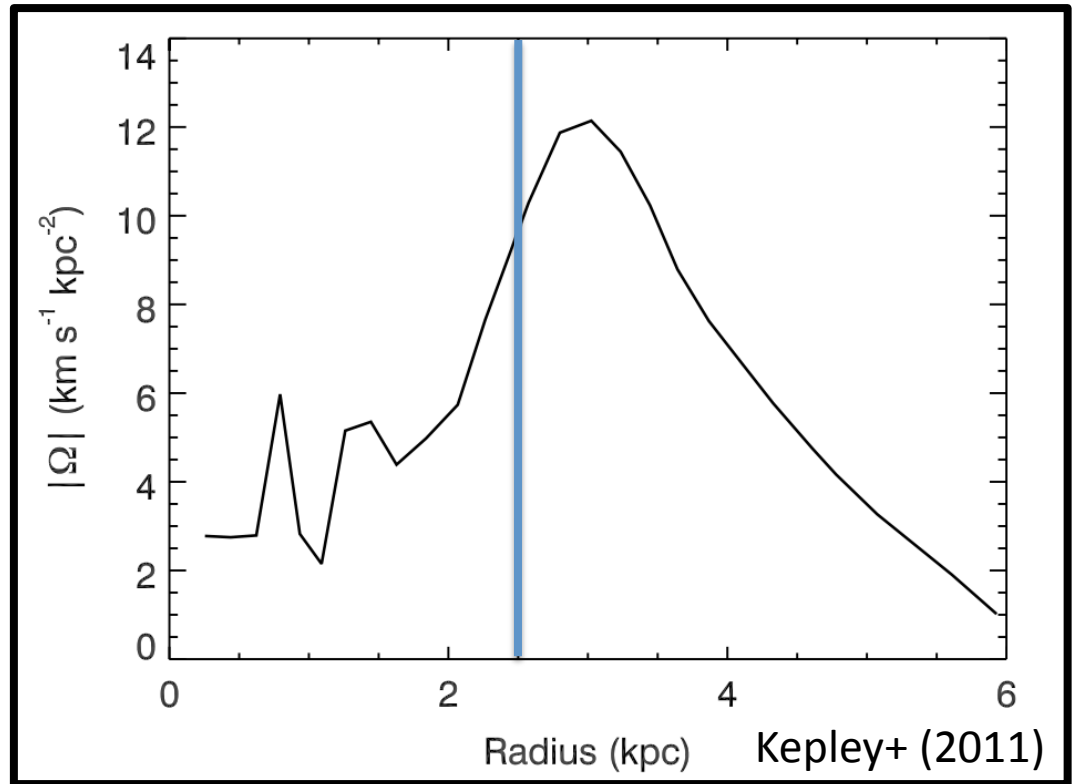
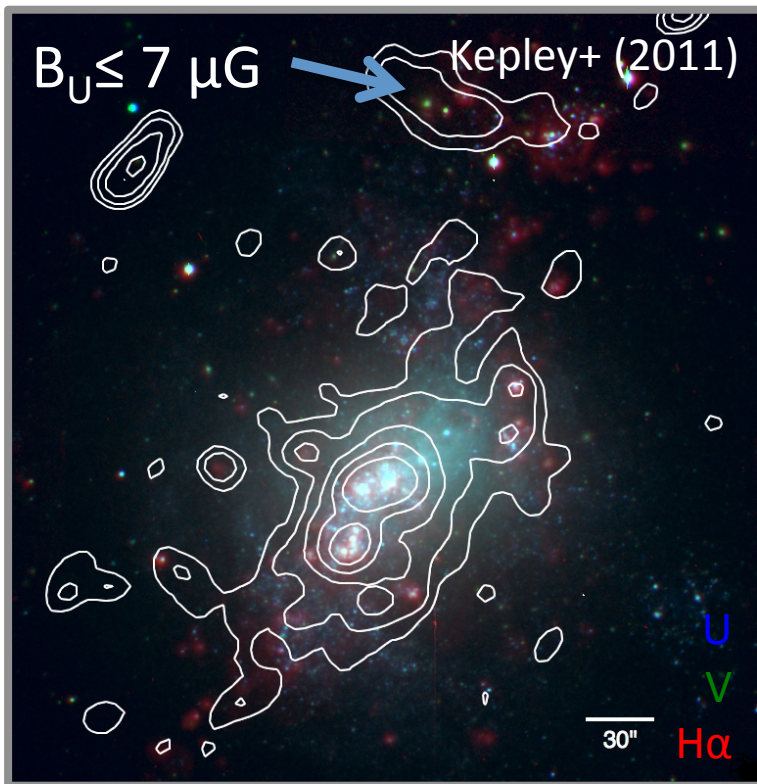
Contours: 3cm
radio continuum

Vectors: uniform
B field

Color: Rotation
Measures

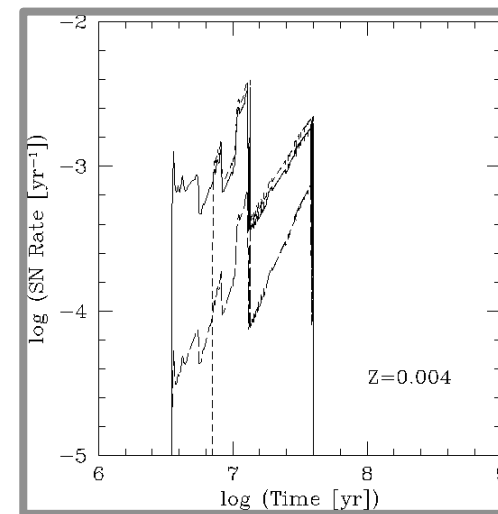
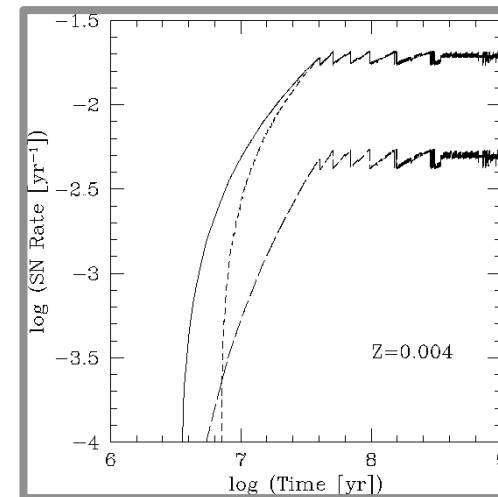
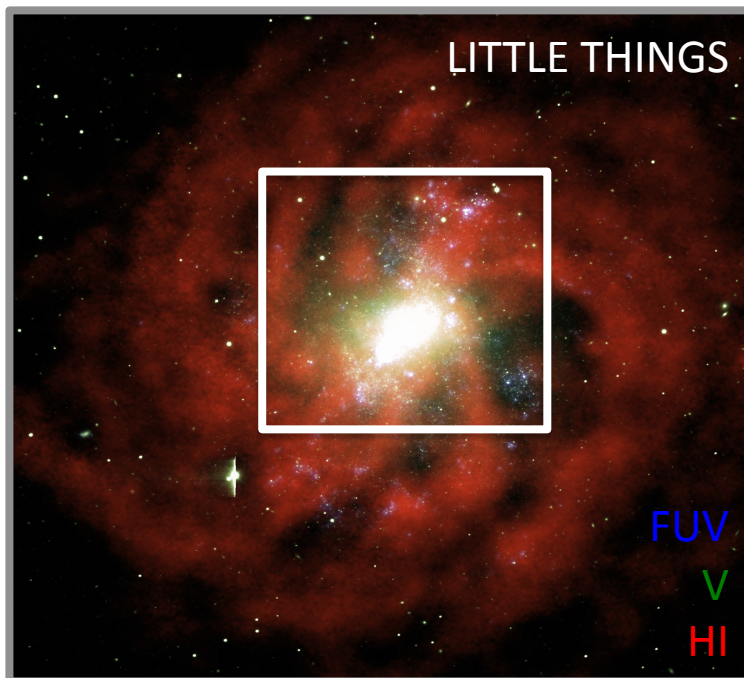
No RM
synthesis
because only
two channels.

NGC 4214's field is mostly random with hints of a uniform field.

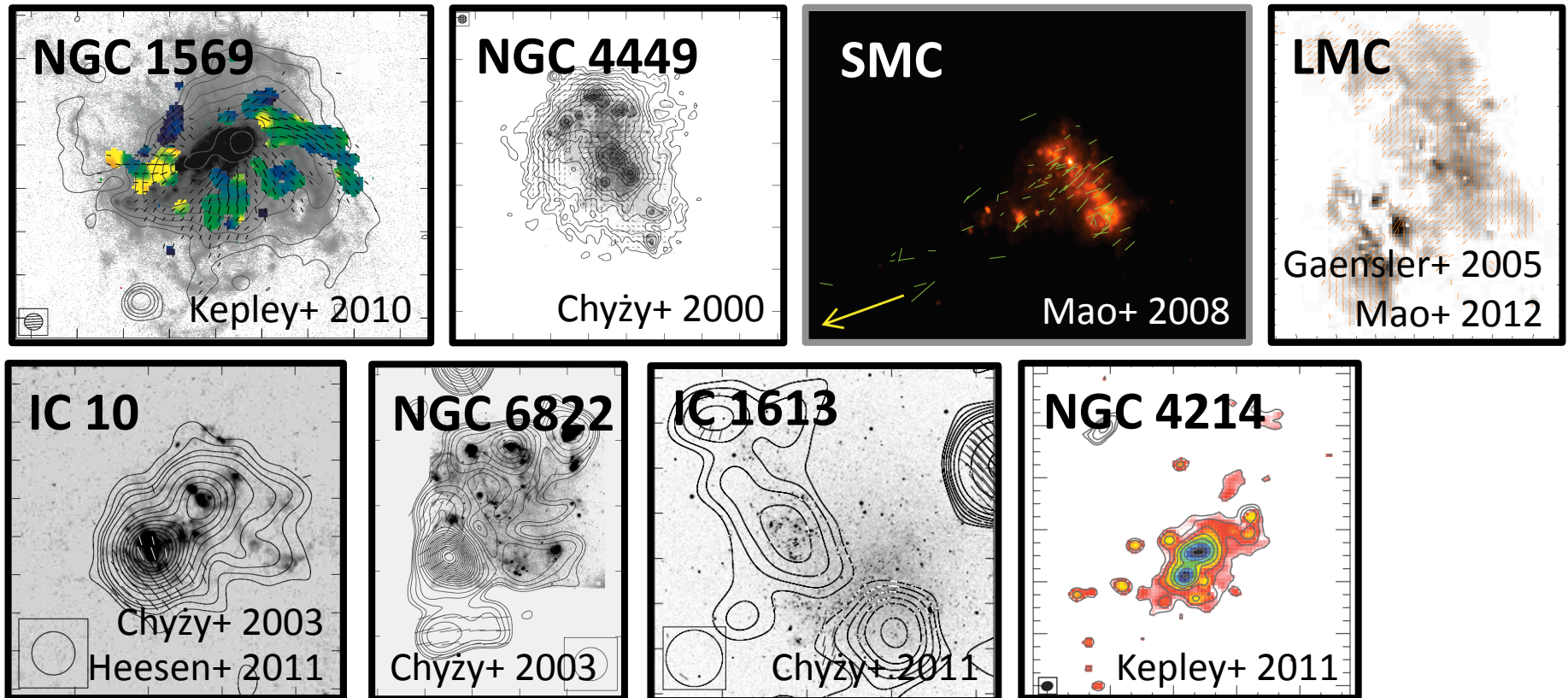


Could there be “dark” magnetic fields?

Starburst99 (Leitherer+99)



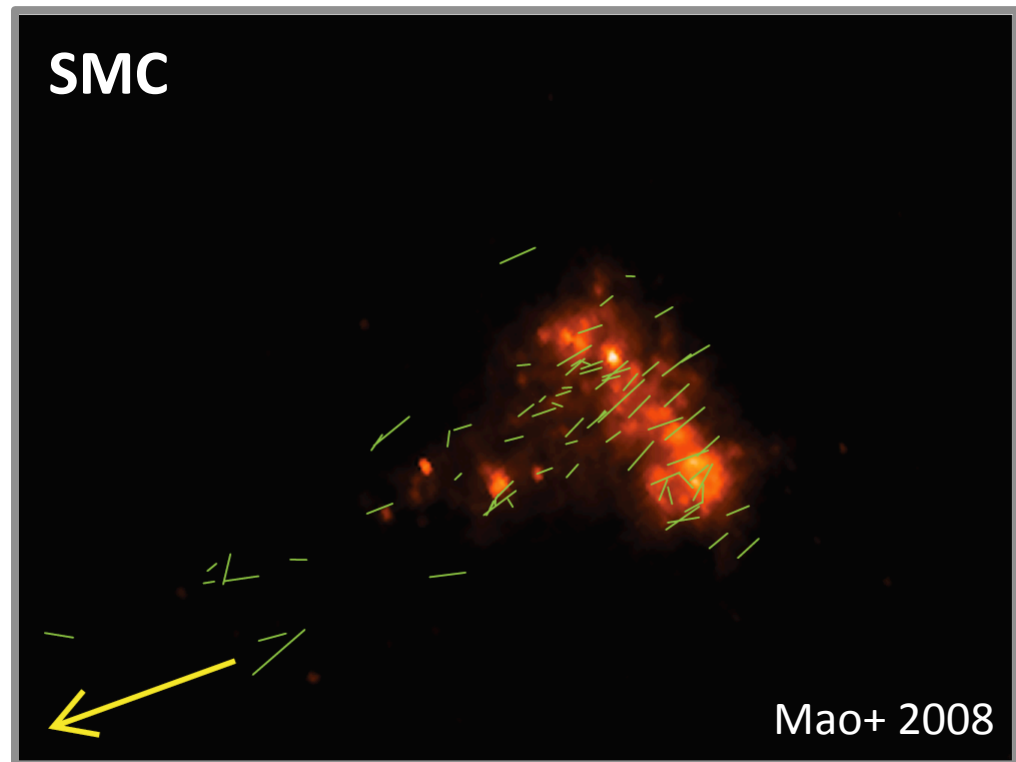
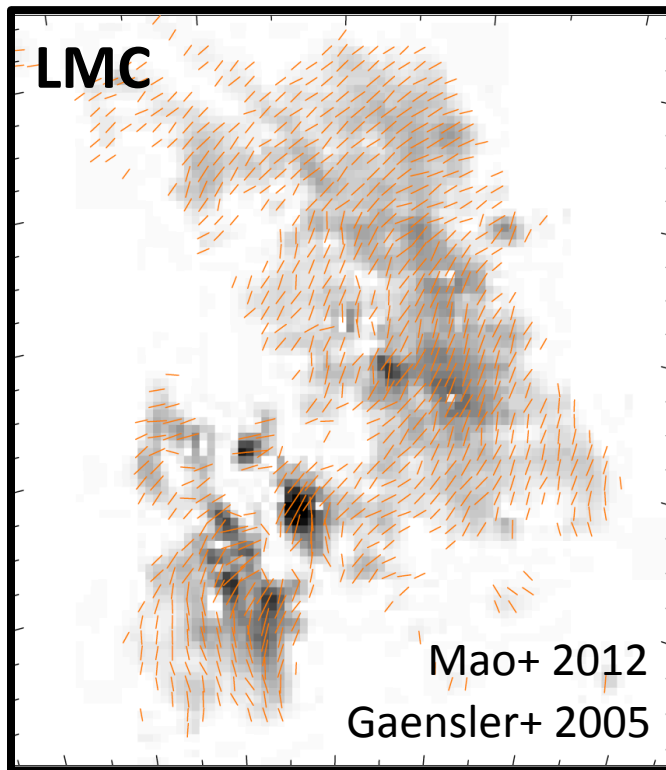
Magnetic field structures in most low mass galaxies are shaped by local processes.



+ I Zw 18 -- See Marek Wezgowiec's talk

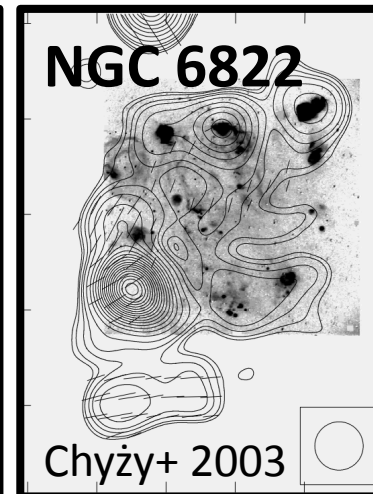
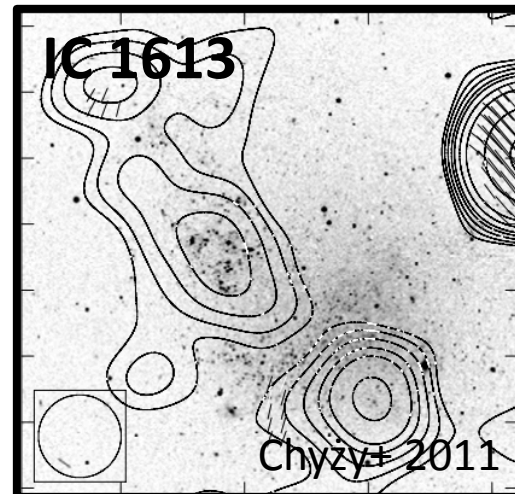
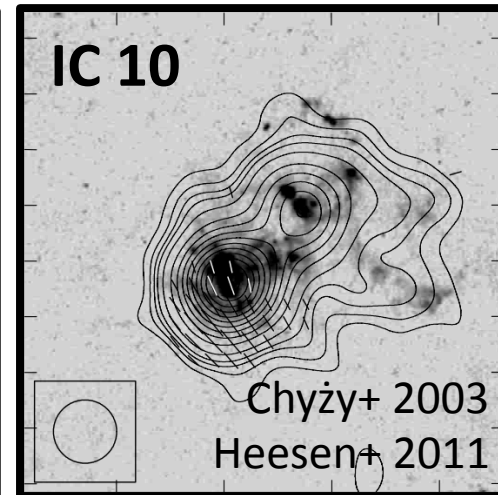
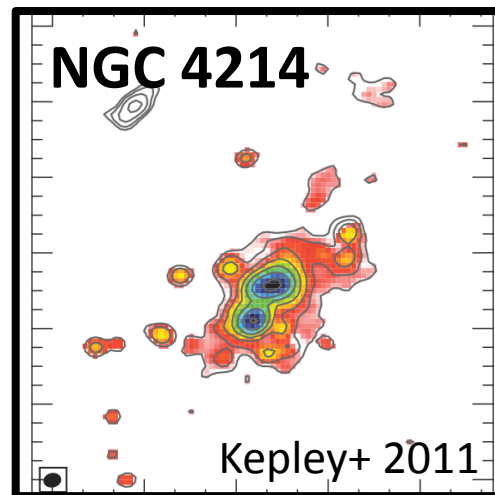
Magnetic field structures in most low mass galaxies are shaped by local processes.

Interactions



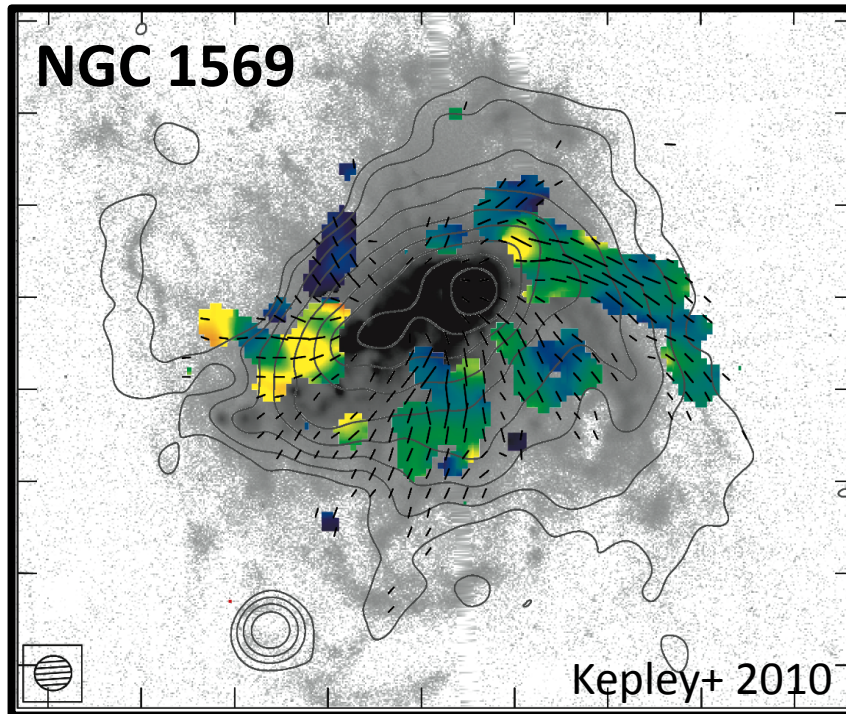
Magnetic field structure in most low mass galaxies is shaped by local processes.

Star Formation

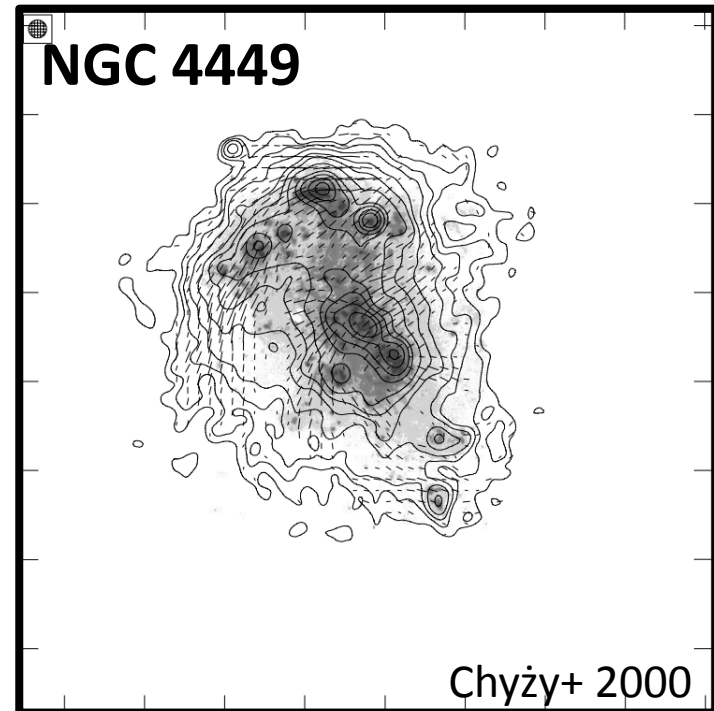


Magnetic field structure in most other low mass galaxies is shaped by local processes.

Star Formation
+ interactions?

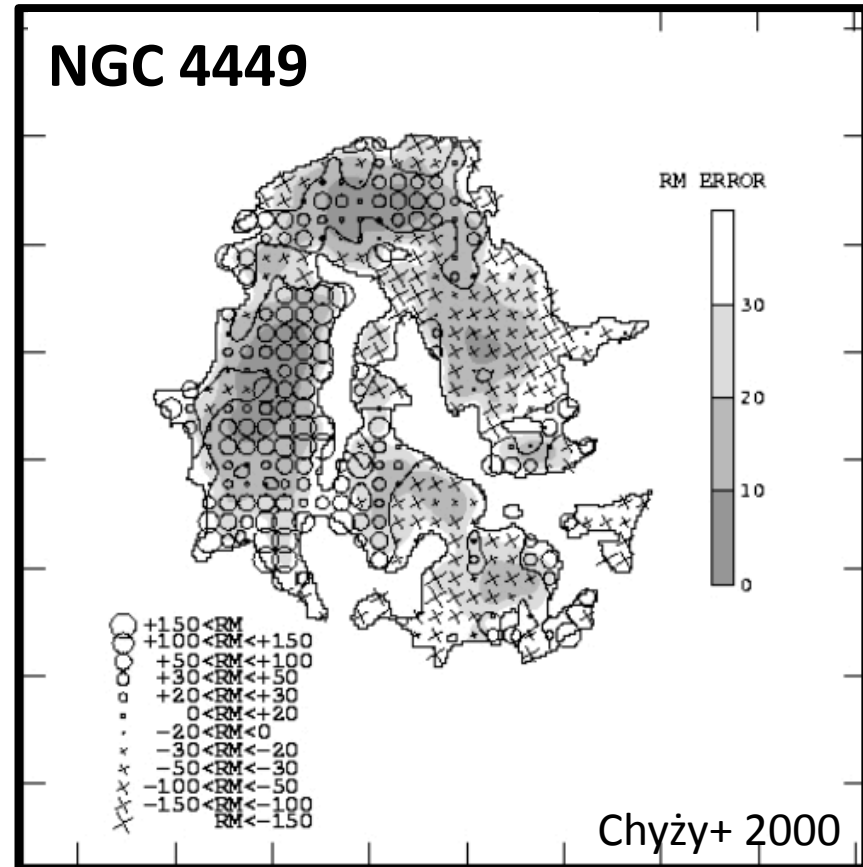
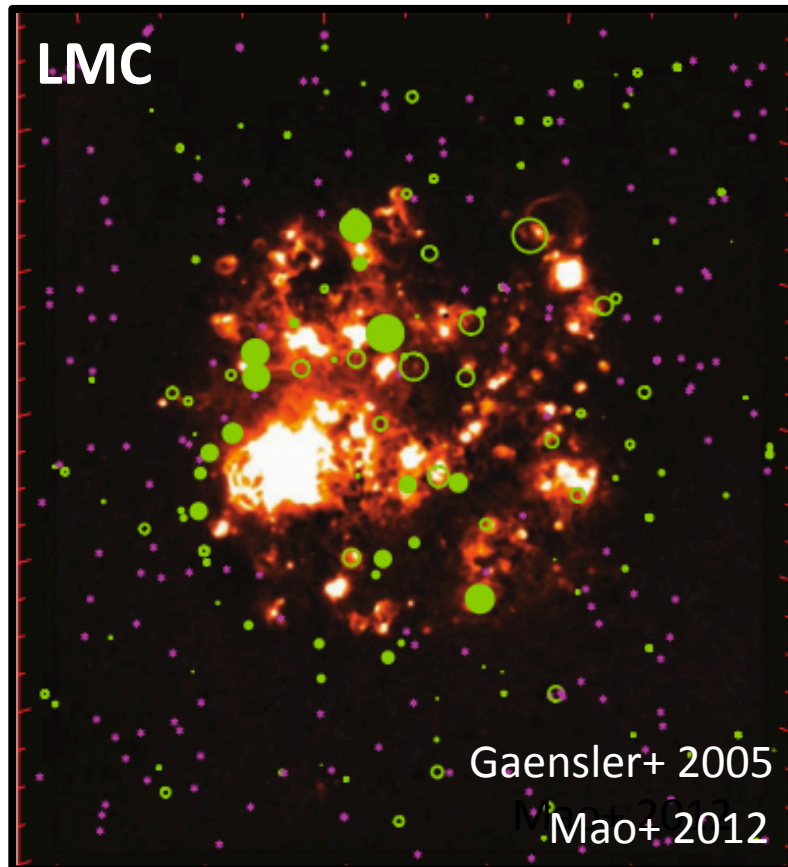


Mühle+ 2005, Johnson+ 2012
found interacting HI cloud.



Rich+ 2012 found faint
interacting companion.

Cosmic ray driven dynamos also may operate in some low-mass galaxies.



The EVLA & GBT are poised to revolutionize observations of magnetic fields.

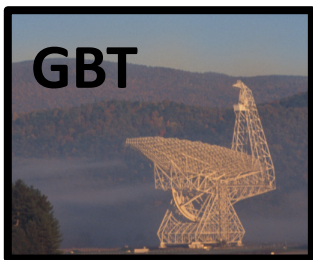


100 MHz VLA

2 GHz EVLA

8 GHz EVLA

+ many more channels!



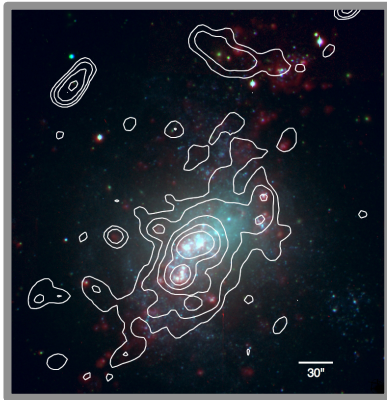
400 MHz Spectrometer

10 GHz VEGAS

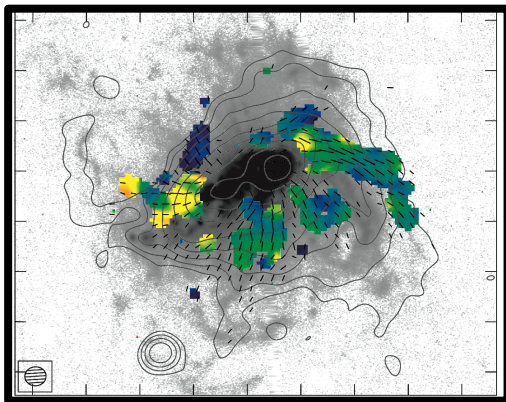
Plus stay tuned for the Square Kilometer Array!



We can measure the magnetic field properties of low mass galaxies using synchrotron emission.



Magnetic fields do not dominate the ISM of low mass galaxies.



Ordered magnetic fields in low mass galaxies may result from mostly local processes.

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