Magnetic fields and cosmic rays effects on star formation processes

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EUROPEAN ARC
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Outline

- ✔ Cosmic rays (CRs) and large-scale magnetic fields interactions with the interstellar medium
- ✔ Ongoing project: comparison between spatially resolved low-frequencies images and star-formation tracers in nearby galaxies
- ✔ ALMA detailed view on GMC in nearby galaxies

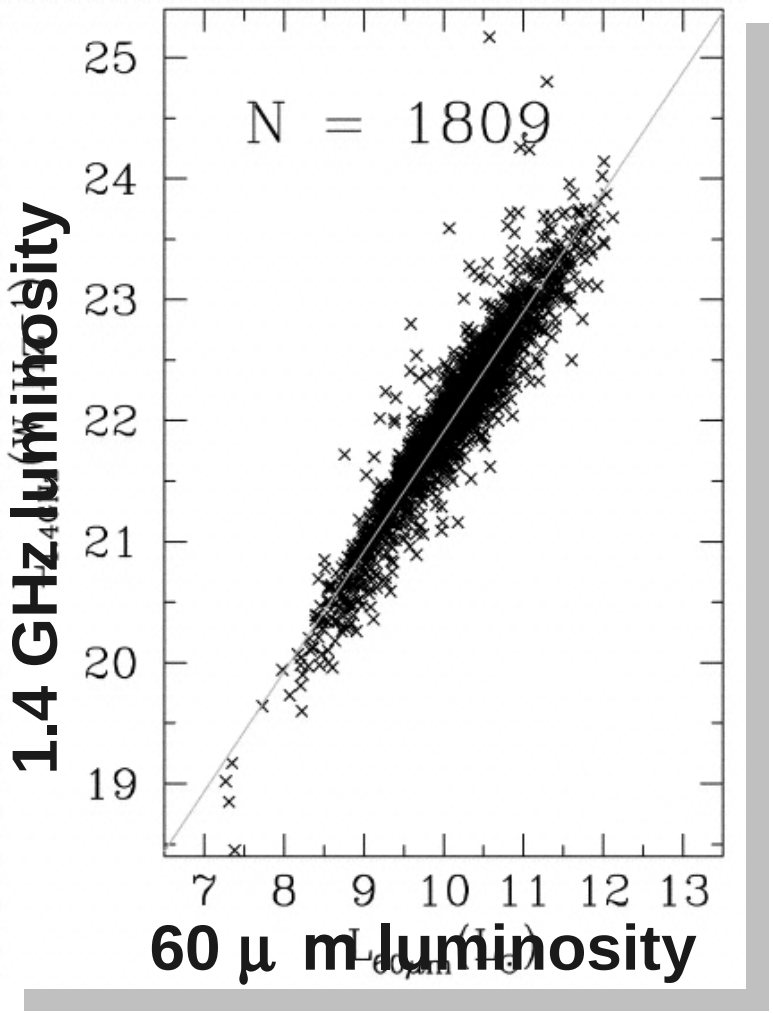
- ✔ CRs are dynamically important components of the ISM in galaxies

  - ✔ CRs and magnetic fields play a significant role regulating star-formation processes
    (Socrates, 2008 – Papadopoulos 2010)

  - ✔ Diffuse emission from the radio to high energy γ-rays can be used to determine the present distribution of CRs.

  - ✔ Their origin and propagation history remain unclear

FIR-radio continuum correlation



Yun et al., 2001

Known since early 70's

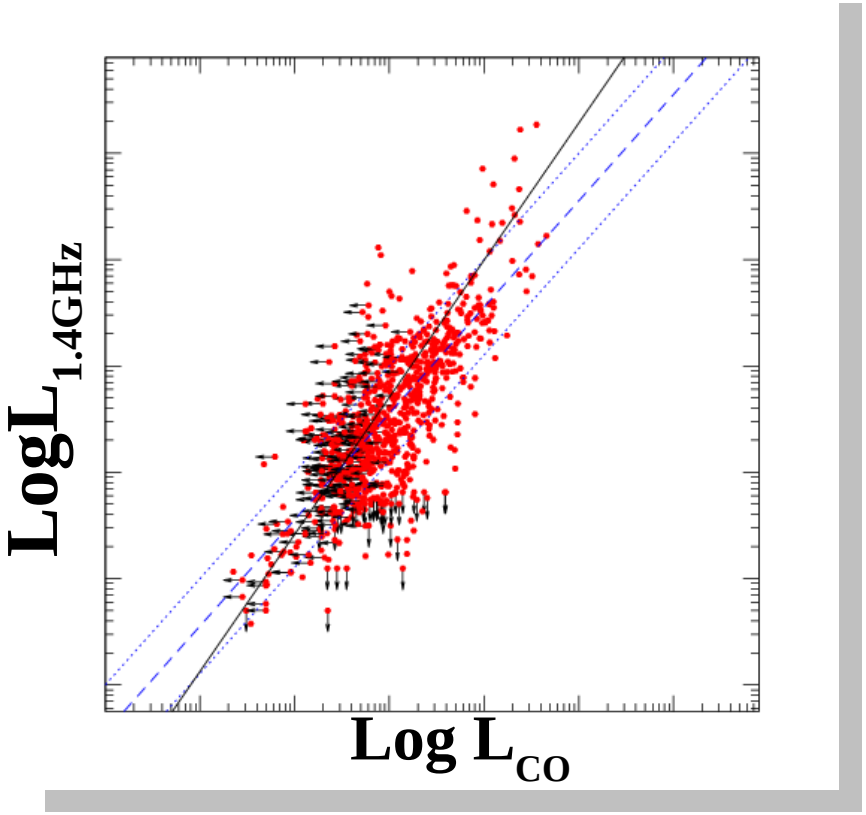
"*Almost miraculous*"

Condon, 1992

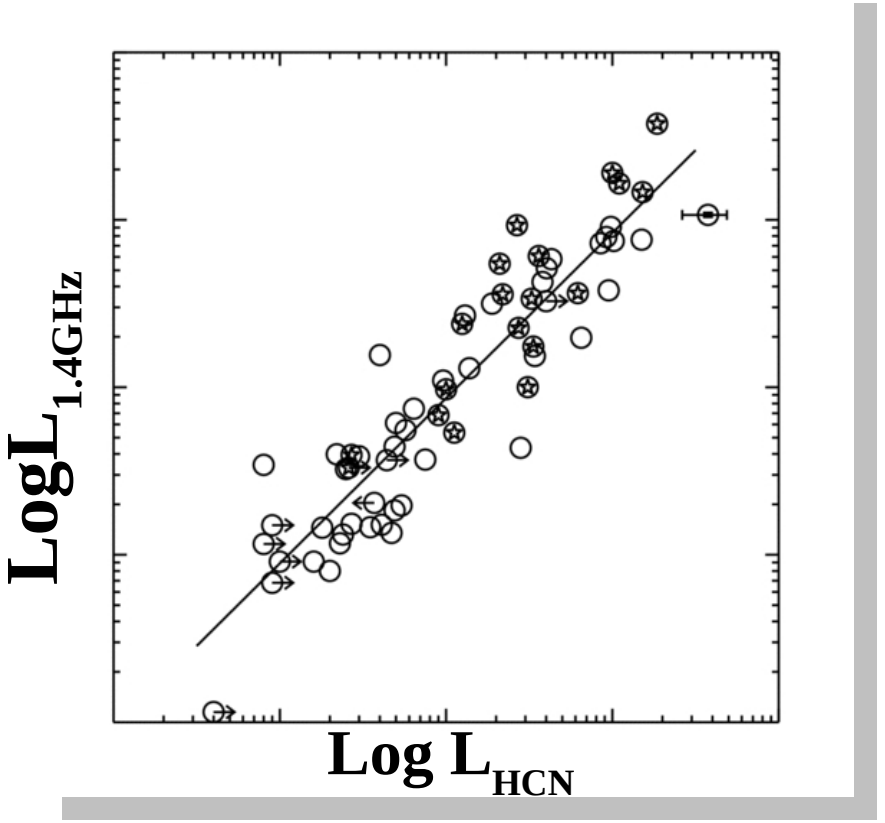
"*Conspiracy*"

Bell, 2003

molecular-radio continuum correlation



Murgia et al., 2002



Liu et al., 2010

Standard interpretation: massive star formation

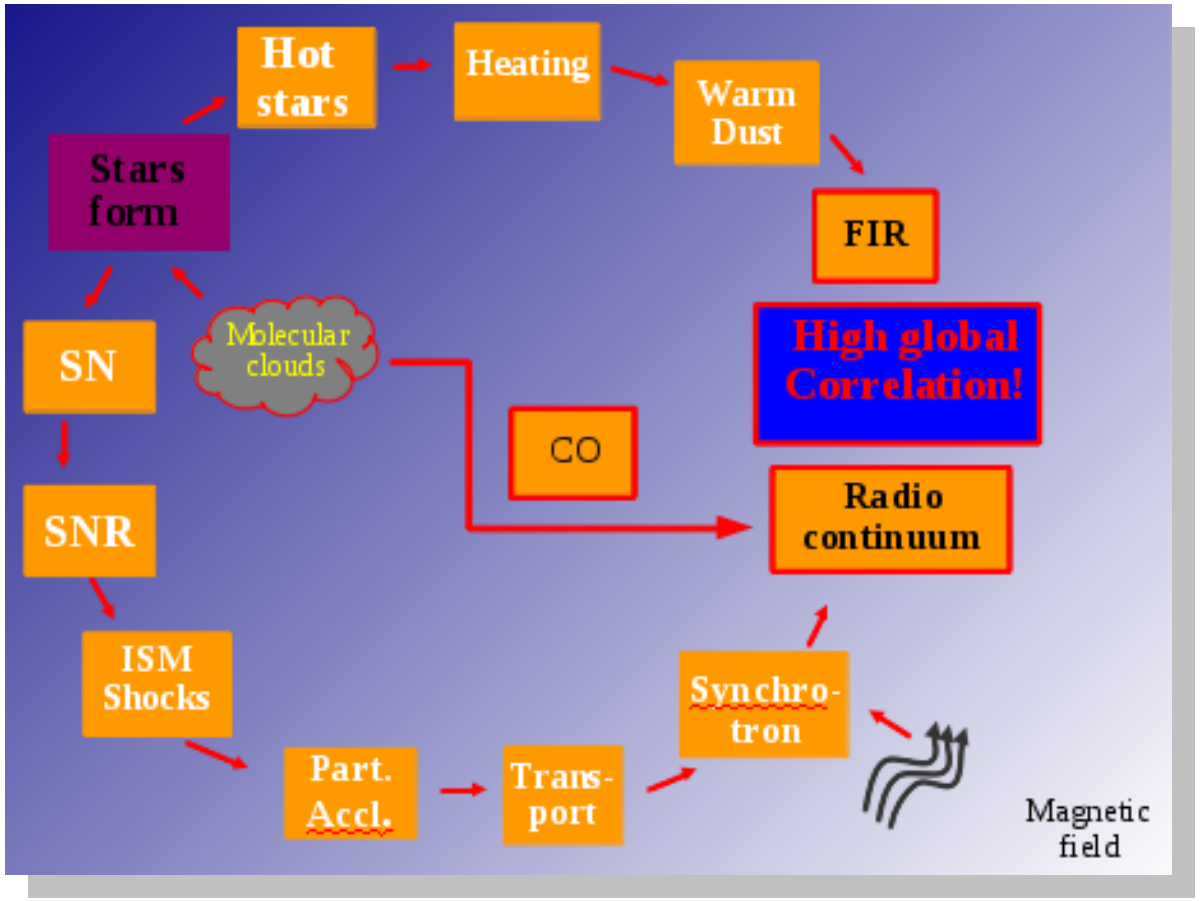
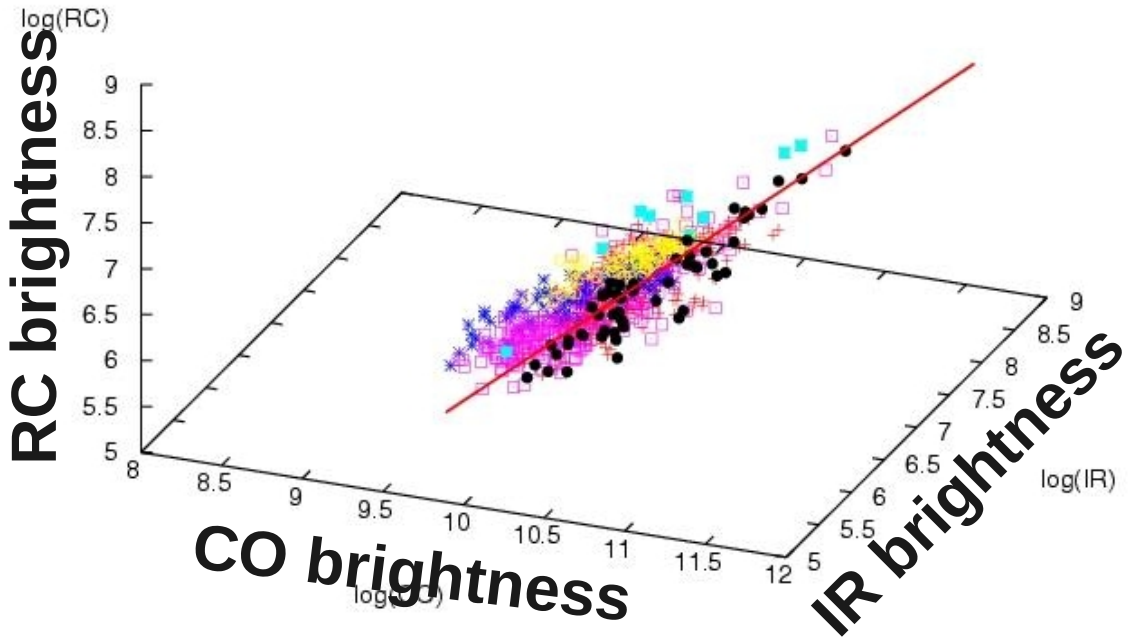


illustration of Ekers, 1991

Correlations at local scales

reported in many papers:
Beck & Golla, 1988
Murgia et al., 2005
Paladino et al., 2006, 2008
Murphy et al., 2006
Tabatabaei et al., 2007
Dumas et al., 2011



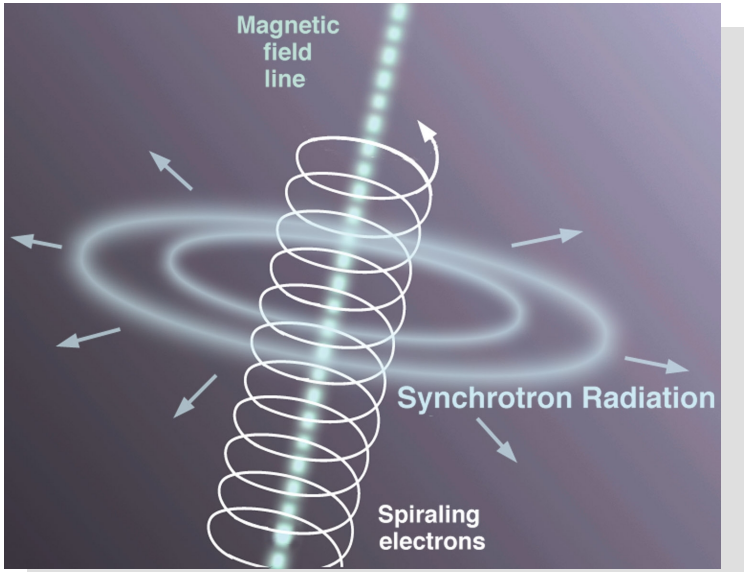
Paladino et al., 2008

Models addressing the local properties are needed

Sources of uncertainty:

The synchrotron radiation traces the product of cosmic rays and
magnetic field energy densities.

$$I_{RC} \propto N_0 B^{\alpha+1} \nu^{-\alpha}$$



CRe's propagation mechanisms poorly known.

$$l_{conv} \propto B^{-3/2} \nu^{-1/2}$$

$$l_{diff} \propto B^{-7/8} \nu^{-1/8}$$

Ongoing project:
spatially resolved radio spectral index images to study star formation processes

collaborators:

Matteo Murgia, Cagliari
Emanuela Orrù, Nijmegen
Aritra Basu, Pune
Rainer Beck, Bonn
Fatemeh Tabatabaei, Bonn
Andrew Fletcher, Newcastle
Dipanjan Marti, Pune

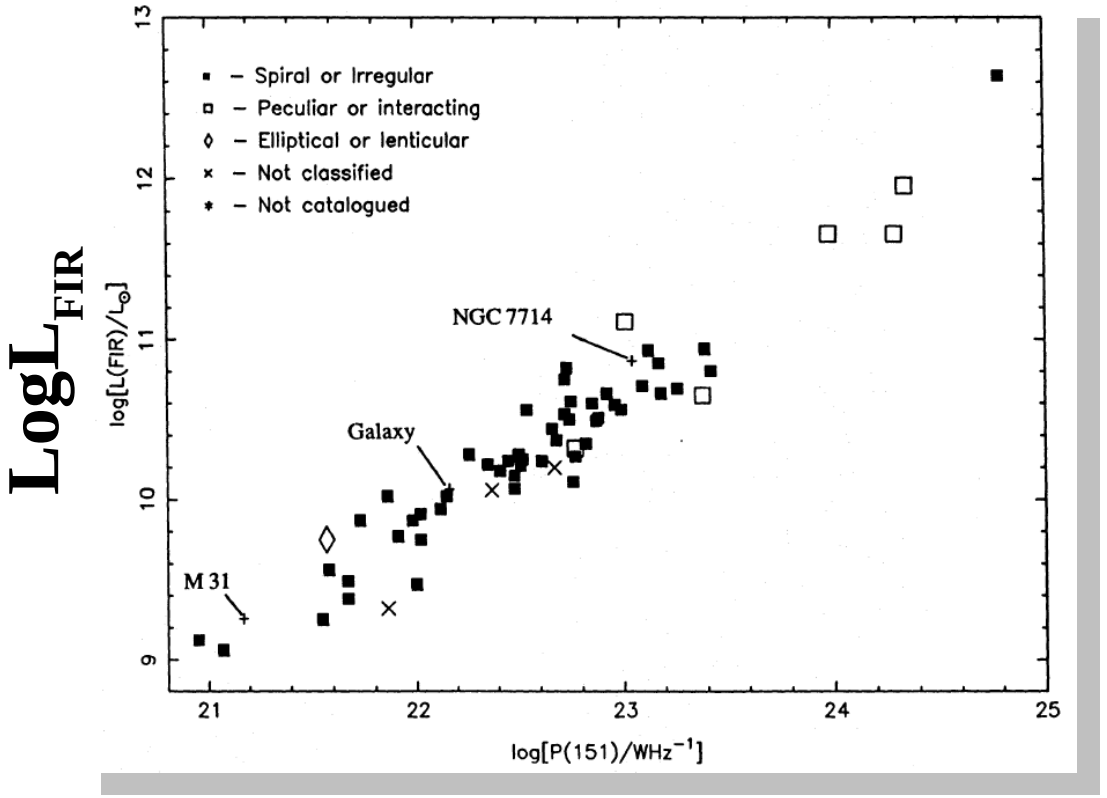
GMRT observations

freq	resol
150 MHz	20”
235 MHz	13”
327 MHz	9”
610 MHz	5”

LOFAR will cover the range 10-250 MHz with resolutions ~2” - 0.1”

Purposes of the project

✔*Study the break down scales of the FIR-RC correlation at low-freq*



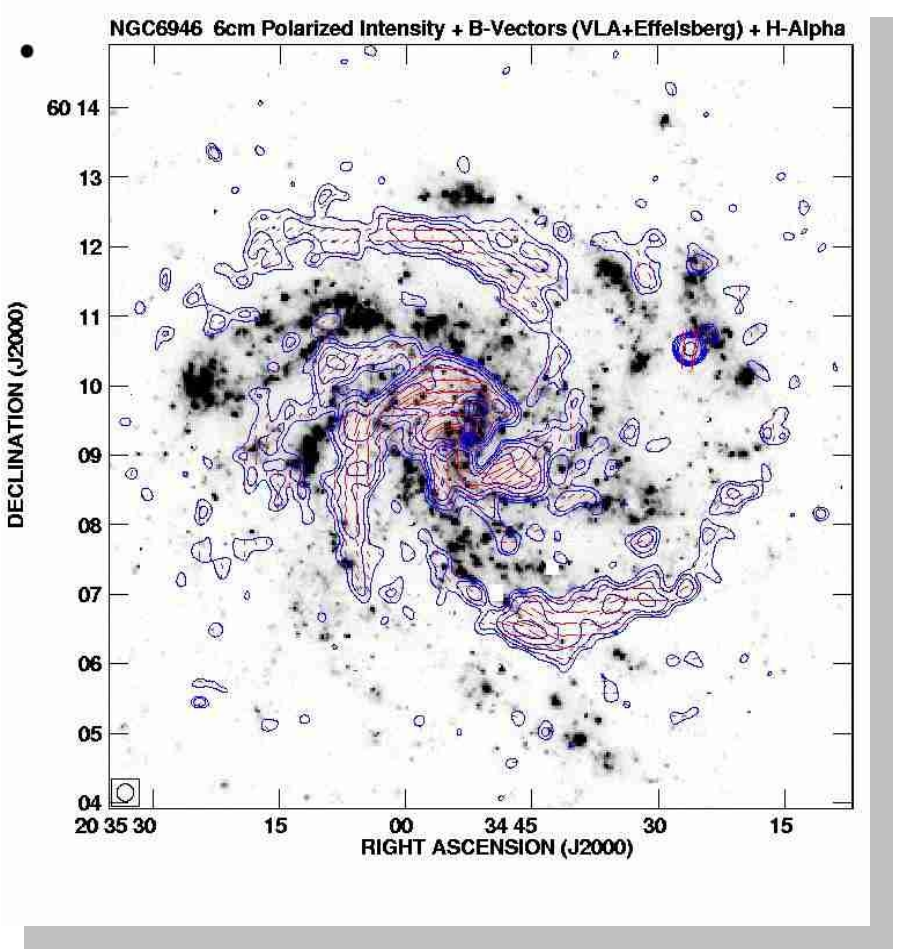
LogL$_{FIR}$

LogL$_{150MHz}$

Cox et al., 1988

Purposes of the project

✔ *Study of the degree of polarization of magnetic field in different regions of the source*

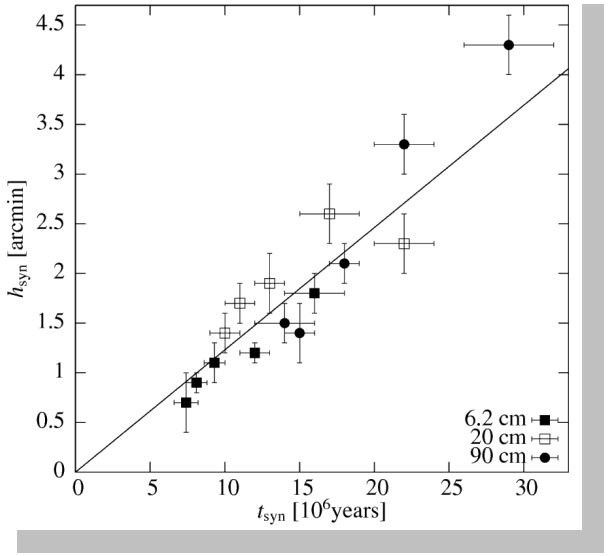


Beck et al., 2004

Purposes of the project

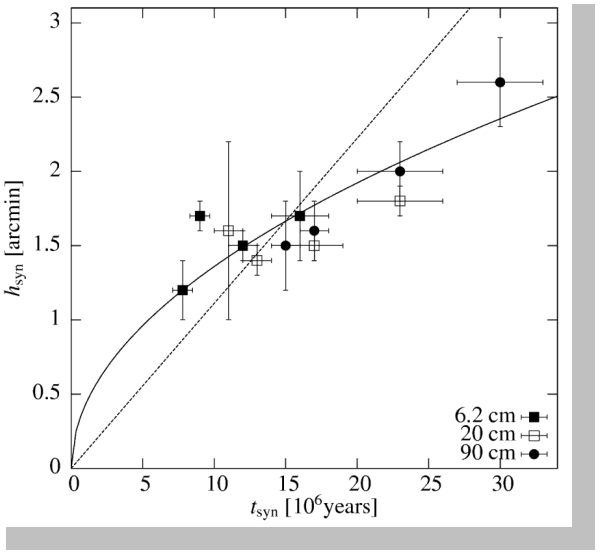
✔ *Estimate the propagation lenght with wavelet analysis, frequency dependence allow to distinguish between the two mechanisms*

NGC253



$$L_{conv} \propto \tau_{syn}$$

$V \sim 300$ km s^{-1}



$$L_{diff} \propto \sqrt{\tau_{syn}}$$

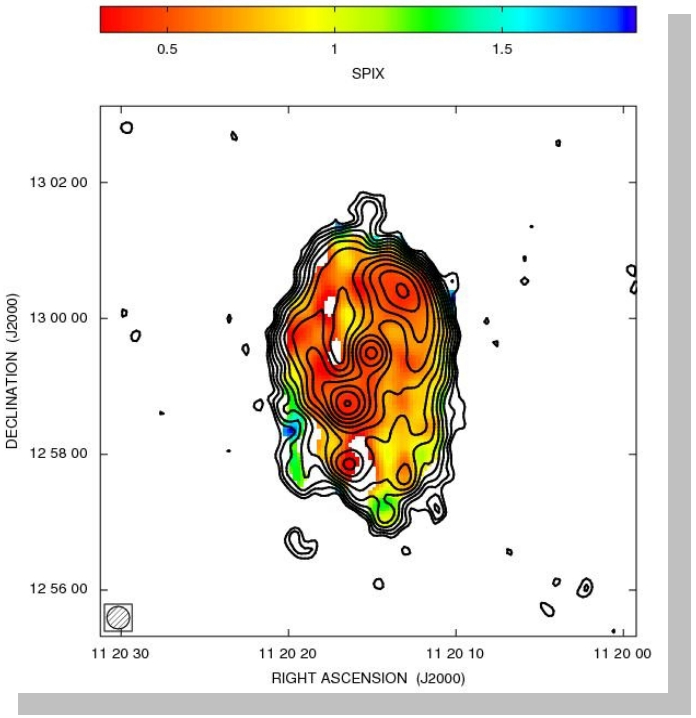
$D \sim 10^{29}$ cm^2 s^{-1}

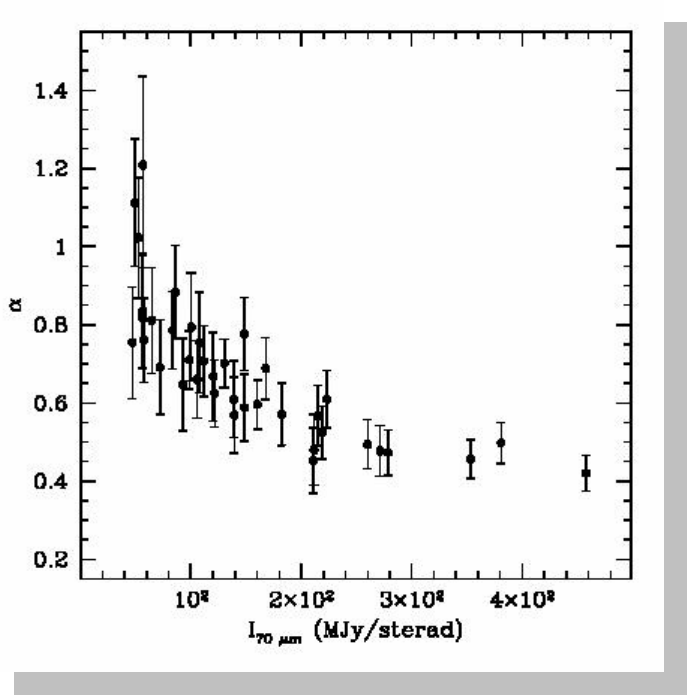
Heesen et al., 2009

Purposes of the project

✔ ***Comparison between spatially resolved non-thermal spectral index α and star- formation tracers***

$$S(\nu) \propto \nu^{-\alpha}$$





Paladino et al., 2009

GMRT sample

Newly observed

NGC 2403
NGC 4826
NGC 3621
M 81

Basu et al., 2012

NGC1097
NGC3034
NGC4736
NGC5055
NGC5236
NGC6946

New perspectives & synergies

mm observations:

IRAM-PdBI, @ mm λ **ALMA**

ATCA and CARMA

~ arcsec **< 0.1 arcsec**

ALMA cycle 1 already 0.6 arcsec @ 115 GHz

low frequency studies:

@ MHz **LOFAR**

VLA and GMRT

@ GHz **SKA**

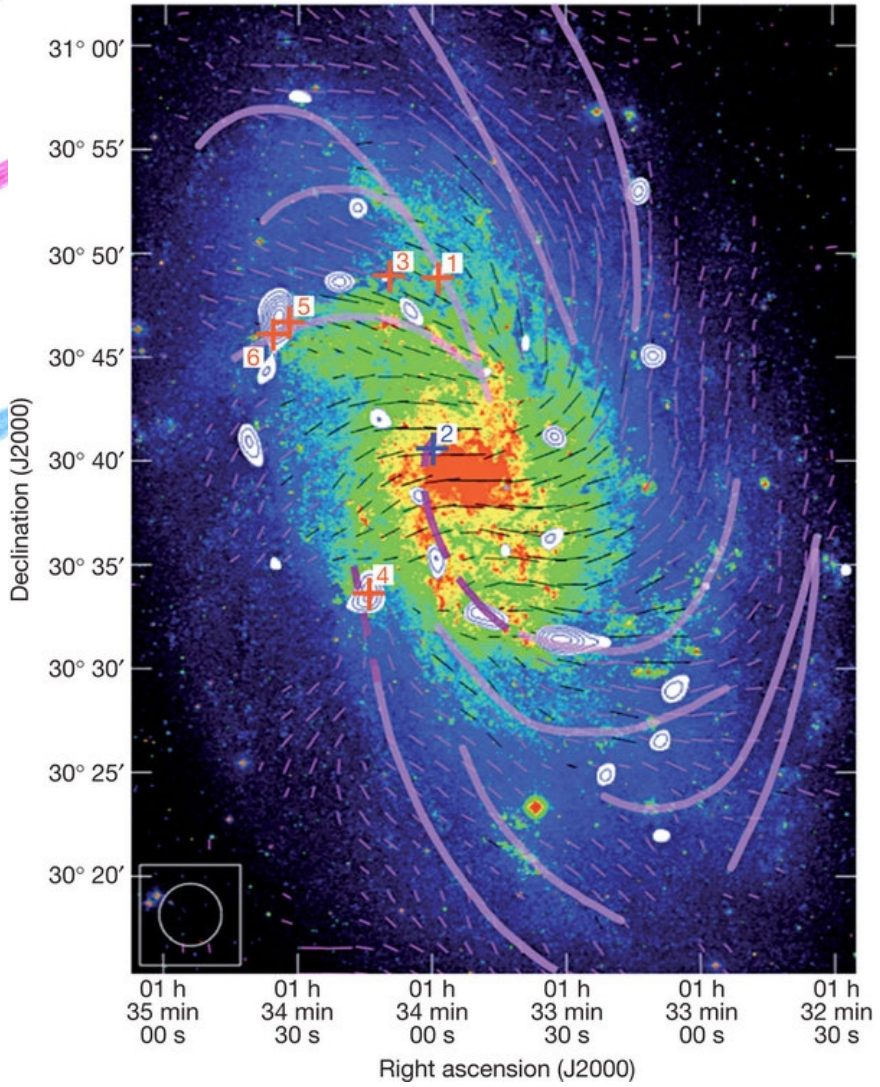
~ arcsec **~ 0.1 arcsec**

New possibilities with ALMA

Exploiting ALMA's polarization capabilities it will be possible to observe the magnetic field in giant molecular clouds complexes in nearby galaxies.

Comparison between large-scale galactic magnetic field and clouds field.
Our location in the Milky Way makes it difficult to have a clear view of the situation.

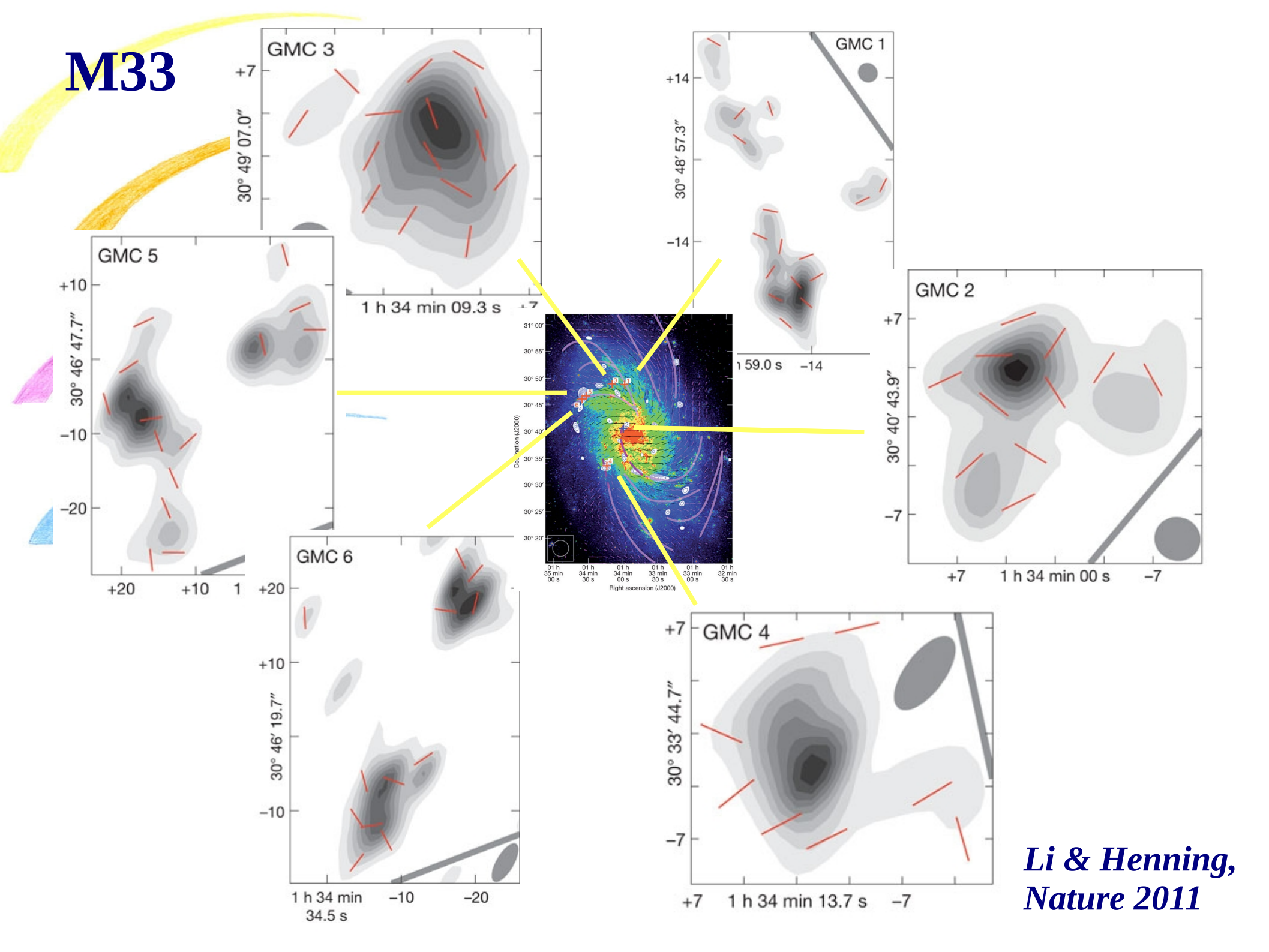
Recent results on M33



- ✔ SMA observations at 230 GHz
- ✔ at M33 distance (900 Kpc) spatial resolution ~15 pc
- ✔ the six most massive GMC's have been observed
- ✔ magnetic field orientation for these six GMC's has been determined from the polarization of CO lines

Li & Henning, Nature 2011

M33



Li & Henning, Nature 2011

Recent results on M33

✔ The magnetic fields of the GMCs are aligned with the spiral arms, suggesting that the large-scale field in M33 anchors the clouds.

✔ The Milky Way field have rich structures at the scale of the GMCs instead of being aligned with the disk.

✔ The simplest explanation is that the B-field of spiral arms can have much more structure perpendicular to the disk than within the disk plane.

✔ A different point of view on clouds can offer important new insights into GMC/galaxy dinamics.

ALMA

Spatial resolution @ 230 GHz

Name	Cycle1	fullALMA
	pc	pc
NGC1097	21	1.4
NGC3034	6.3	0.42
NGC4736	6.7	0.45
NGC5055	13.4	0.89
NGC5236	6.6	0.44
NGC6946	9.9	0.66

Grazie!

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