UNVEILING THE PHYSICS OF STAR FORMATION AND FEEDBACK IN NEARBY GALAXIES

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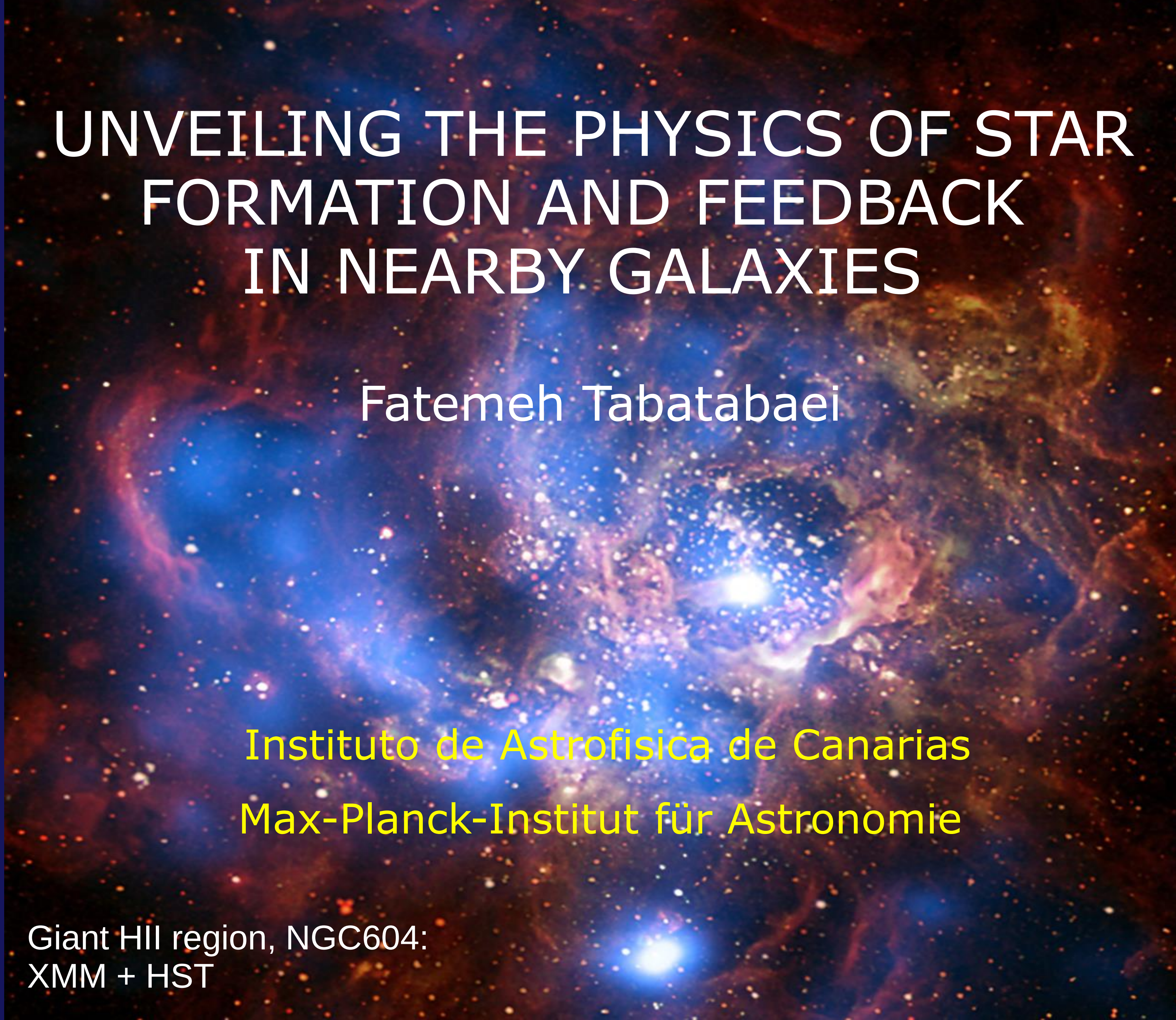


Giant HII region, NGC604:
XMM + HST

Star Formation Feedback→ SF-ISM interplay

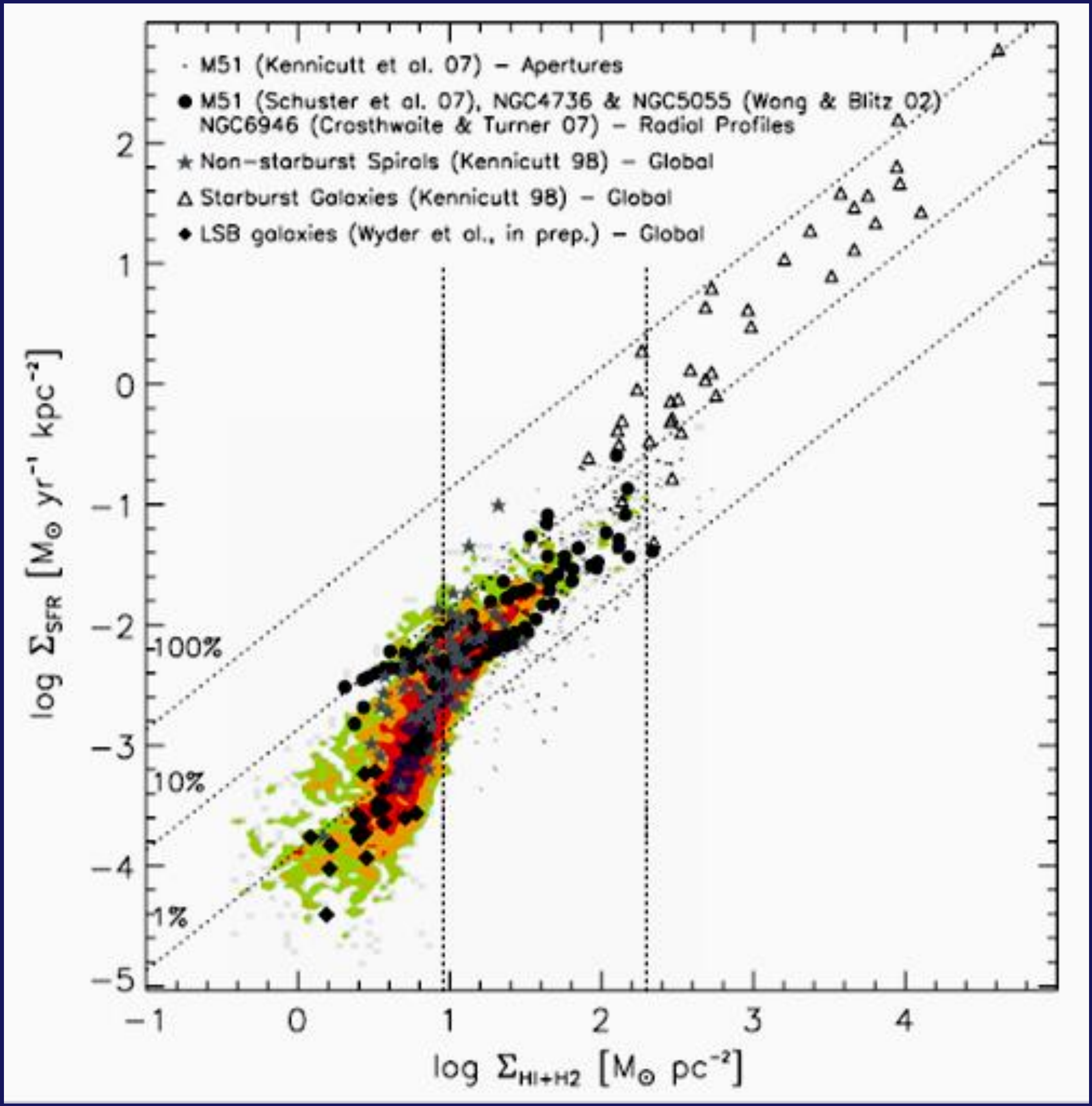
important because it redistributes the gas and derive outflows in galaxies, changes the energetics of the ISM and the host galaxy:

SF-ISM interplay important for:
structure formation,
evolution of galaxies

Connection between SF and gas

The Kennicutt-Schmidt relation

$$\Sigma_{SFR} \sim (\Sigma_{gas})^N$$



Bigiel et al. 2008

At sub-kpc resolution:

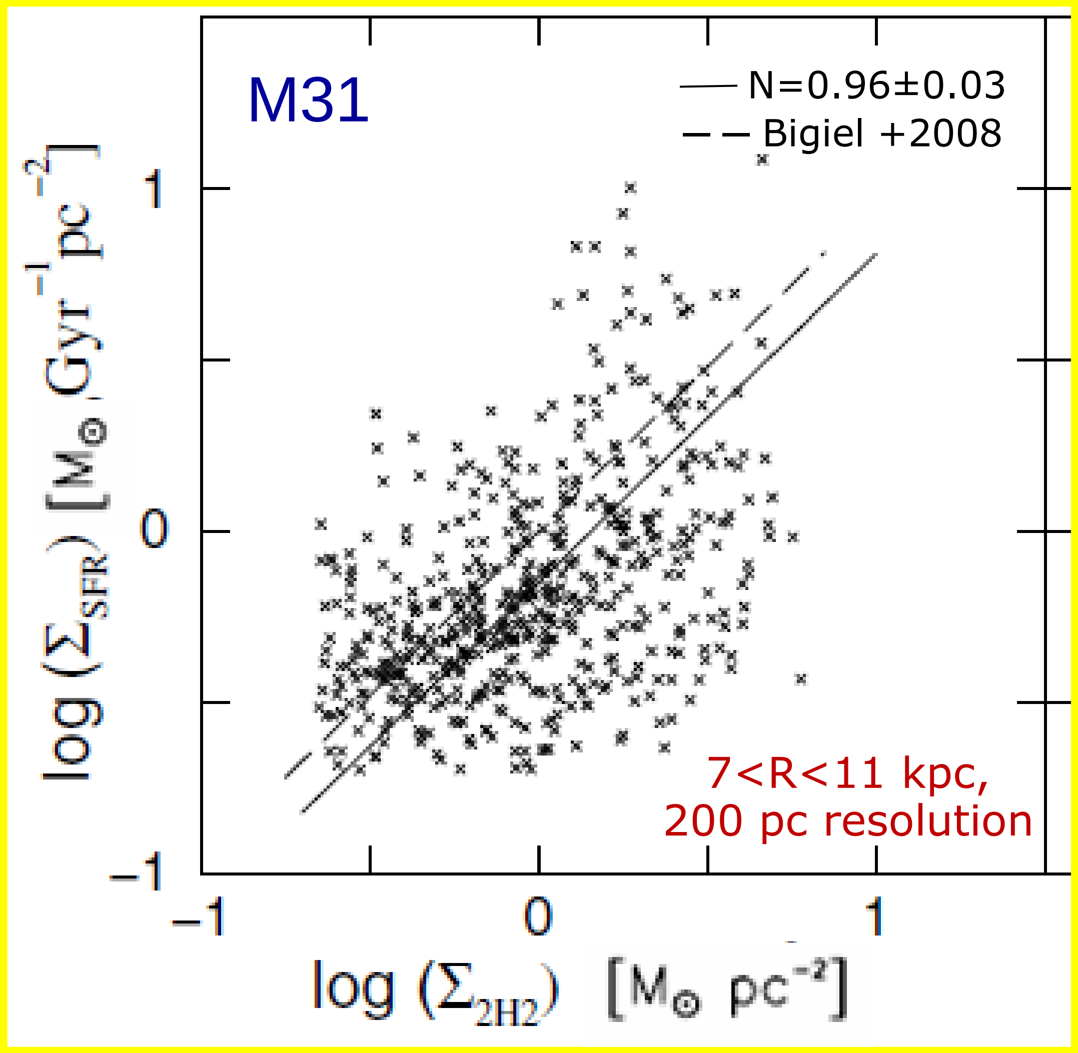
-A linear relation between molecular gas surface density and SF surface density

-A super linear relation between the (atomic+molecular) gas and SF surface densities

Connection between SF and Gas

... the scatter increases at higher resolutions

Linearity resists on ~100pc resolution (Braun+2009)

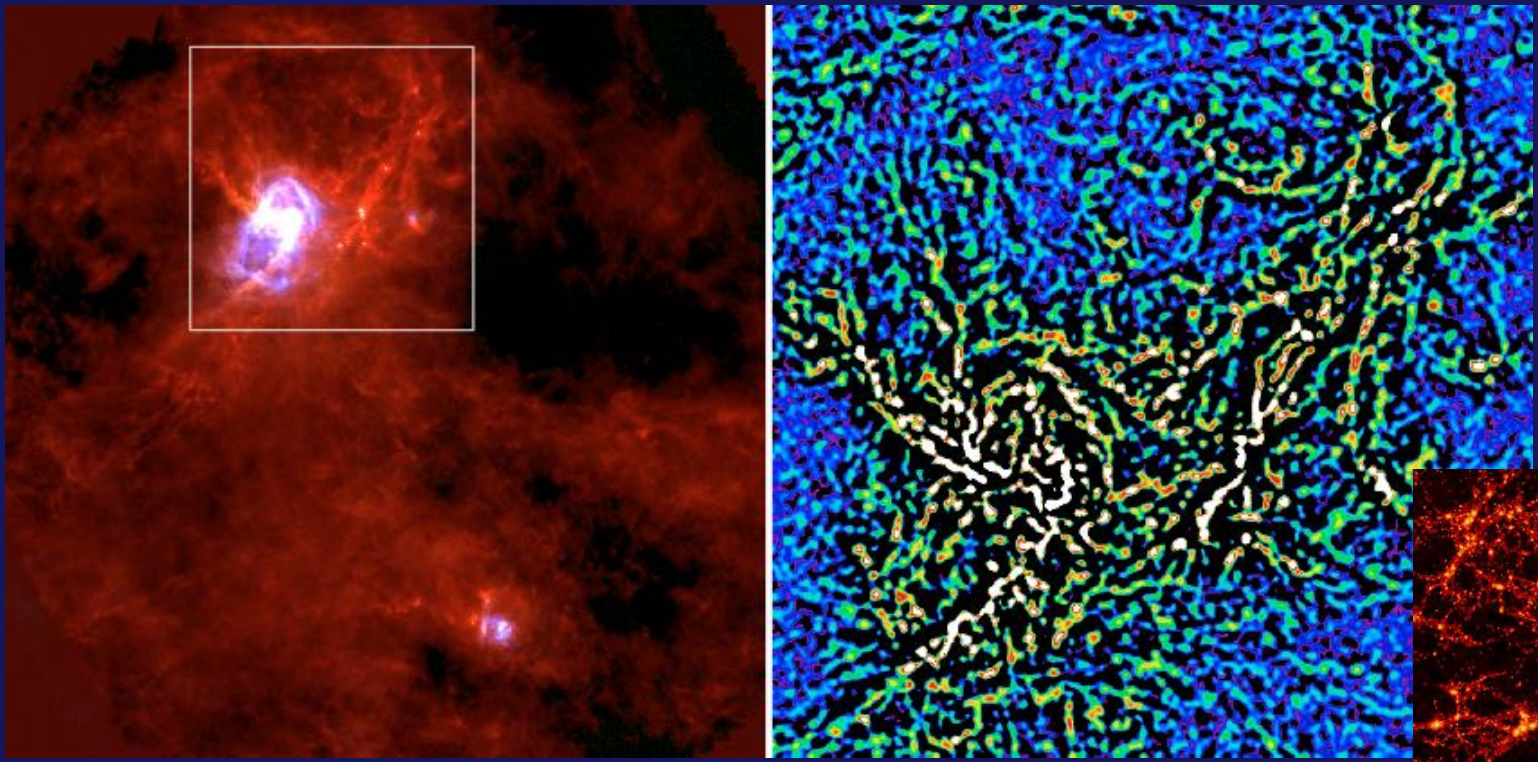


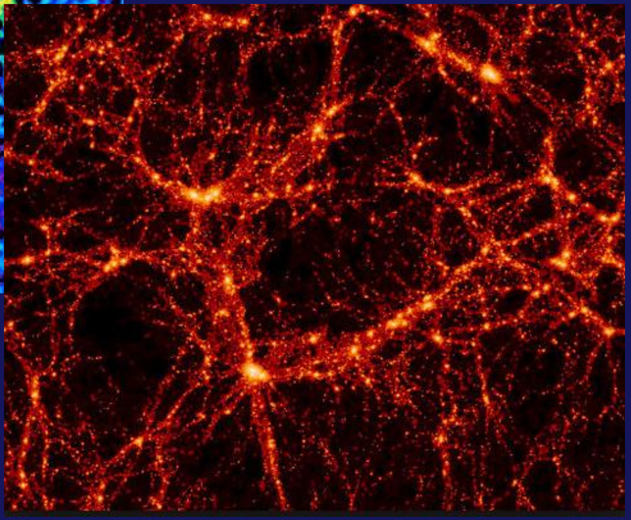
Tabatabaei & Berkhuijsen 2010

→What is the smallest scale of the KS relation and if it is universal?

Stars form in filaments of clouds

Aquila- Herschel observations (Ma’shchinkov+2013)





Filaments → Cores→ Stars

Timescales set by:
turbulence+ magnetic fields + self gravity?

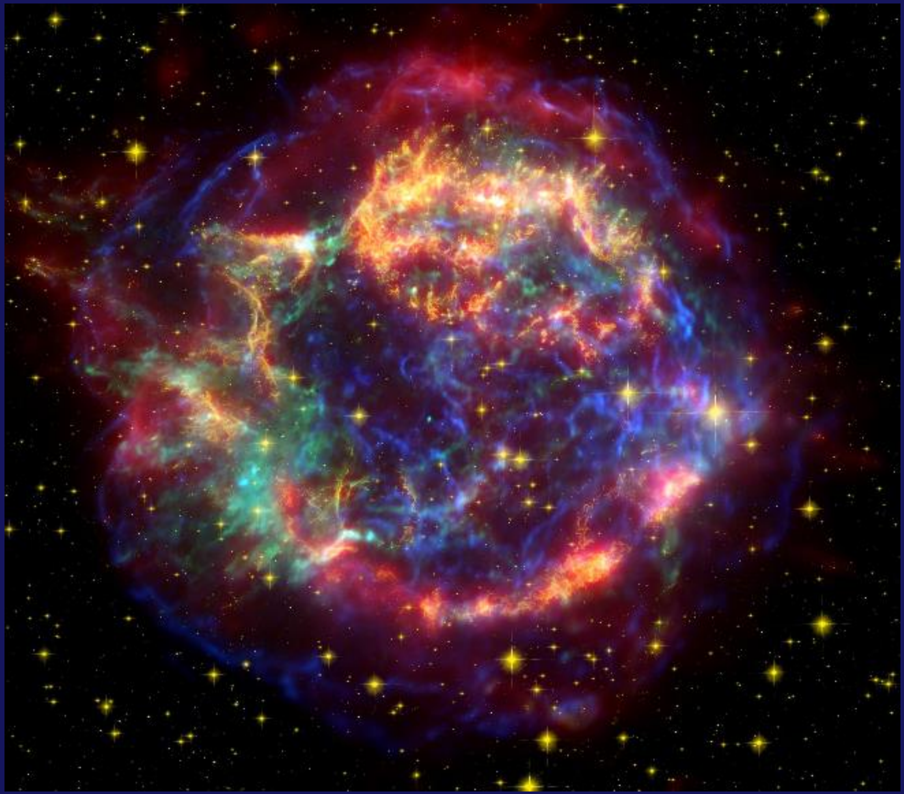
→ Awaits observational confirmation

weak or strong

fast mode or slow mode

Connection between SF and CRs

Supernova and their shoks as sources of cosmic rays (Longair 2002)



- What about other sources like strong winds in extragalactic giant HII? (accelaration regimes, energy index?)

- Observational evidences for various cooling mechanisms CREs?

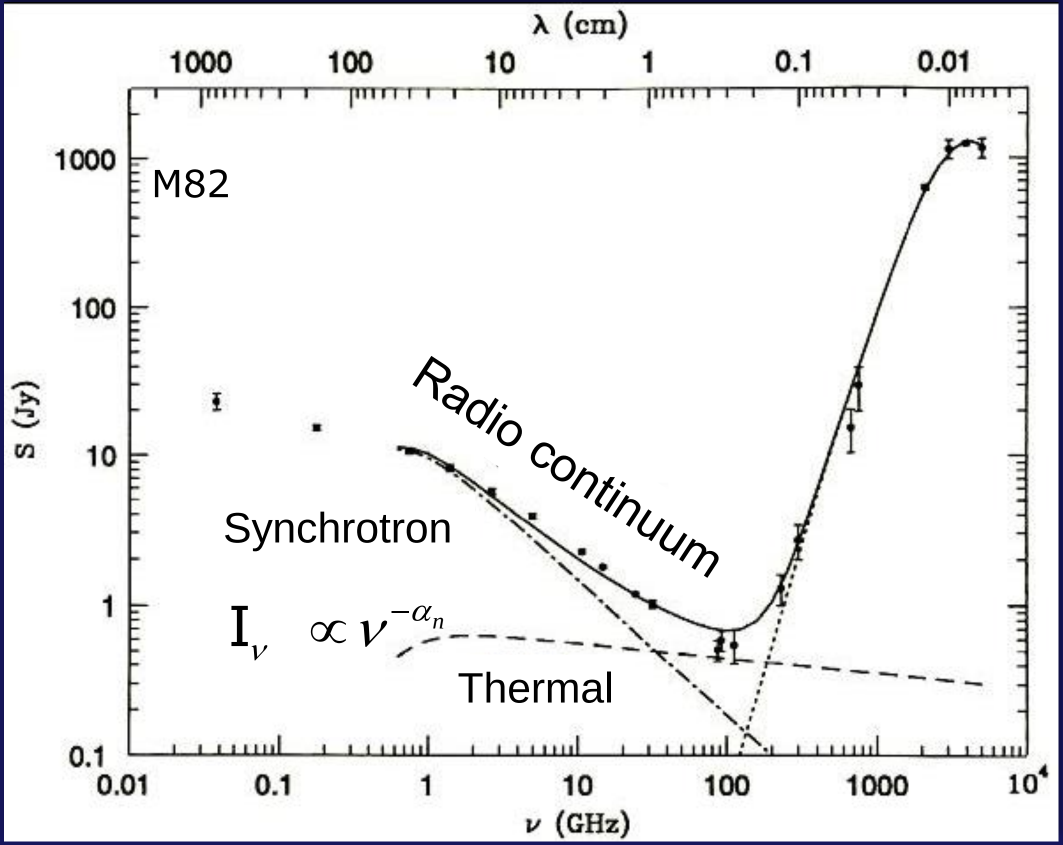
Multi-Resolution Radio Continuum Surveys

MAIN GOALS

- Star formation & feedback
- How do magnetic fields and CRs contribute in feedback?

Synchrotron Emission Probes The Nonthermal ISM

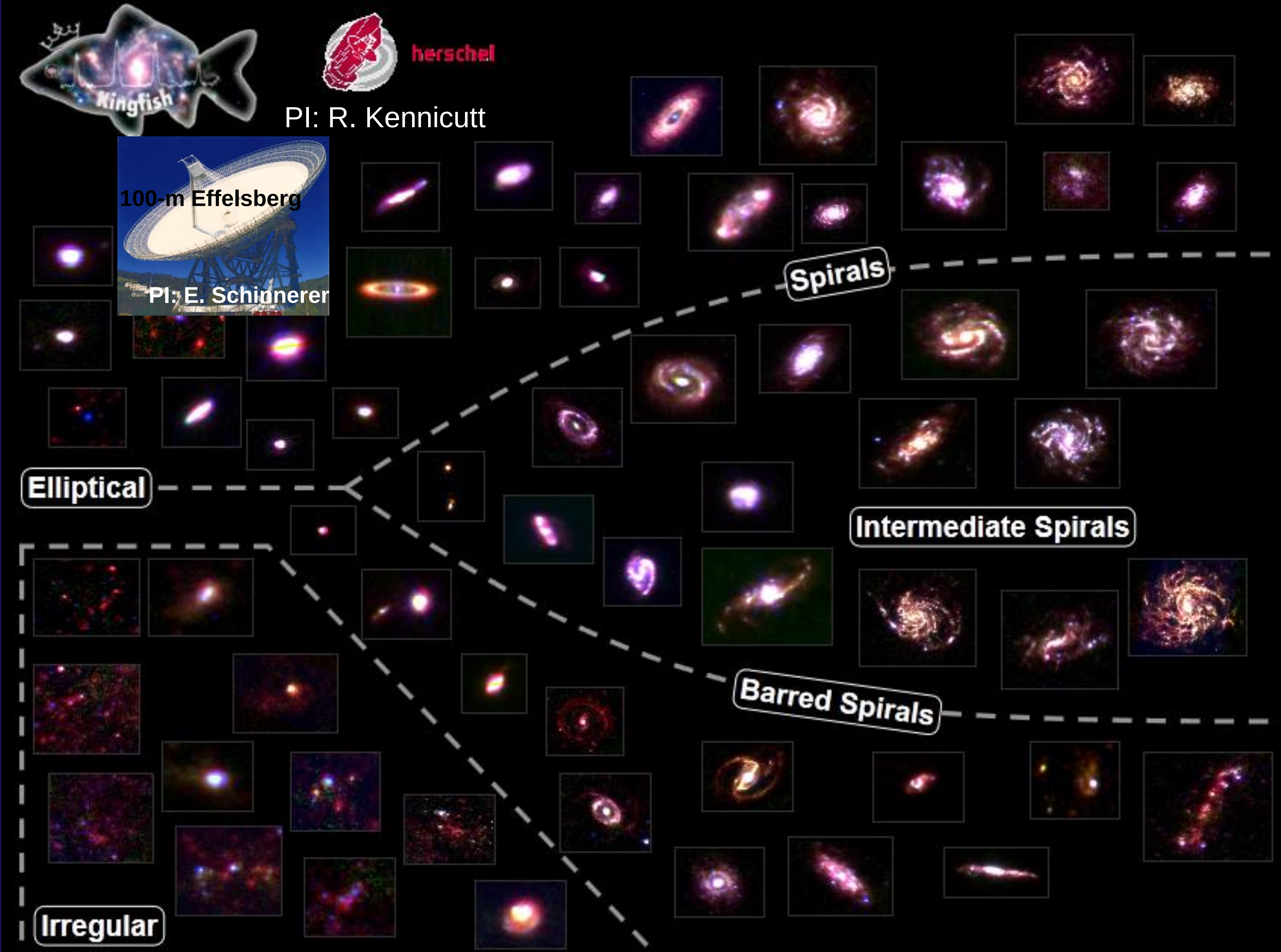
- It is linearly polarized
- Power-law spectrum with unknown index (α_n)
- Study of magnetic fields /CREs



Condon (1992)

→The true structure of the nonthermal ISM is unknown, unless the observed RC is corrected for thermal emission

Multi-frequency surveys

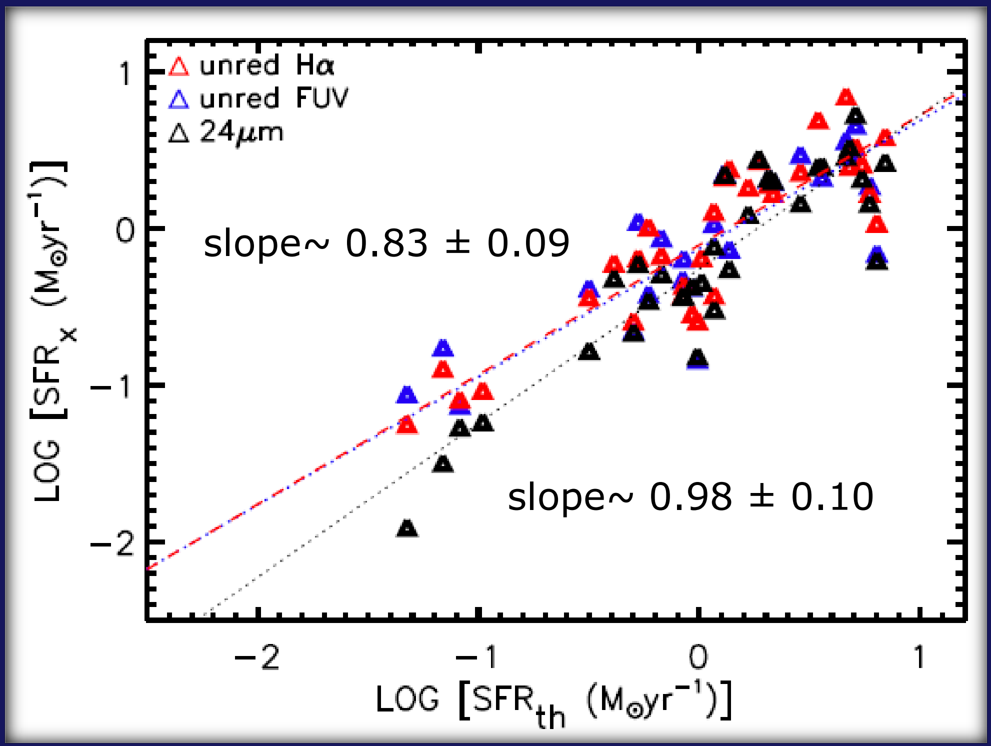


Kingfish
herschel
PI: R. Kennicutt
100-m Effelsberg
PI: E. Schinnerer
Spirals
Elliptical
Intermediate Spirals
Barred Spirals
Irregular

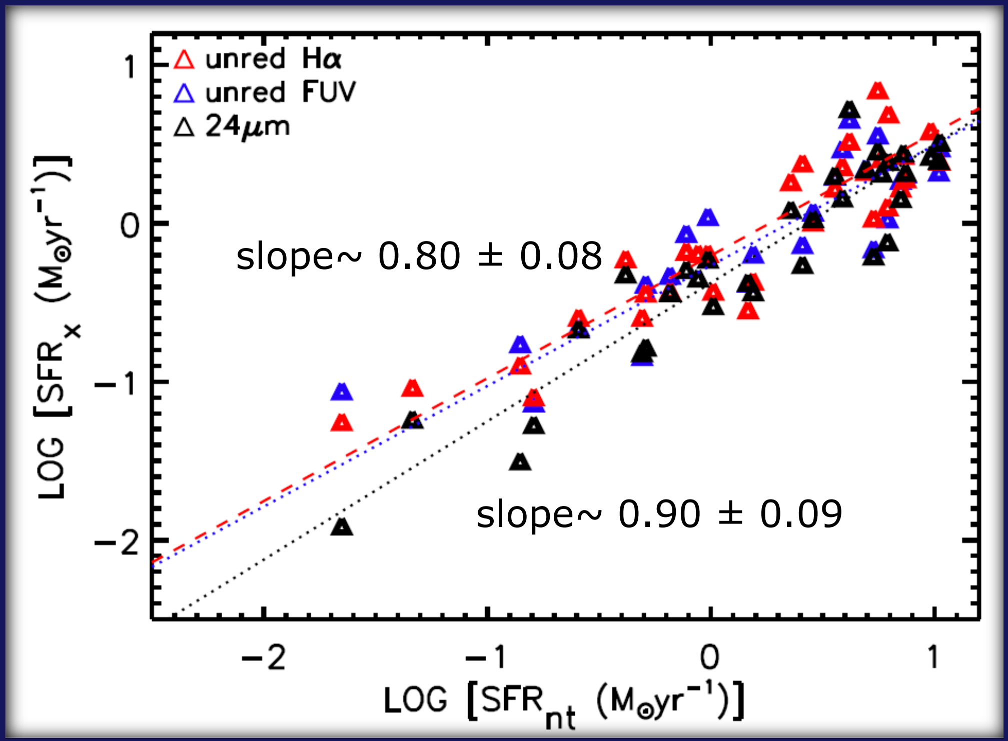
Synchrotron as Global SF Tracer

SFR Calibrations: Condon (1990,92) - Murphy et al. (2011)

Non-radio SFR vs. Thermal SFR



Non-radio SFR vs. Nonthermal SFR



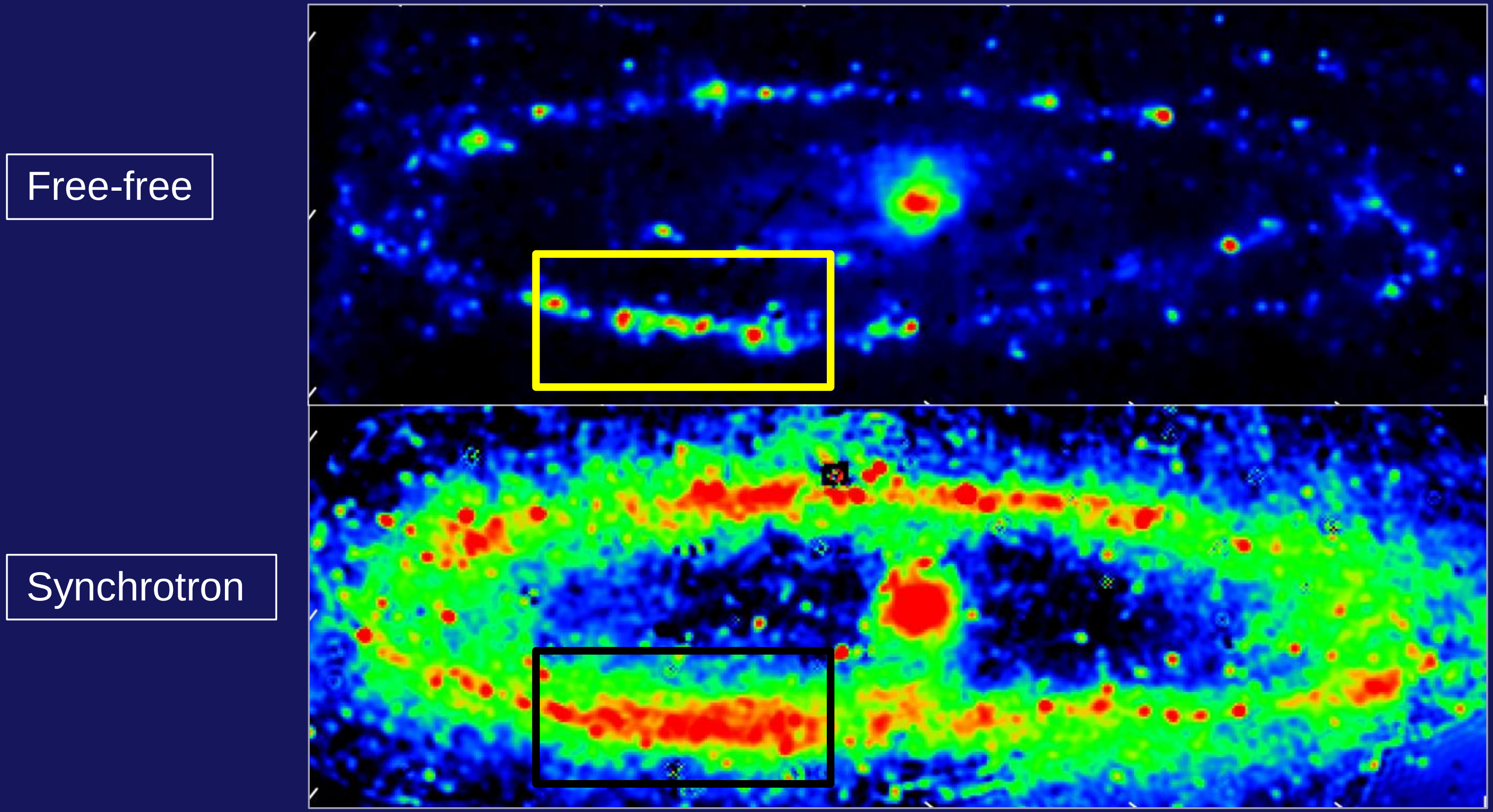
Tabatabaei, Schinnerer + in prep.

Thermal & nonthermal → similar global relations w other SFR tracers

Resolved Thermal & Nonthermal Separation (M31)

TRT Separation Technique:

Synchrotron spectral index varies in the disk
as CREs experience various energy losses
(Tabatabaei et al. 2007& 2013a)



Synchrotron emission is extended, yet strong near SF regions

→ enhanced turbulent B/fresh CREs?

→ Synchrotron a SF tracer

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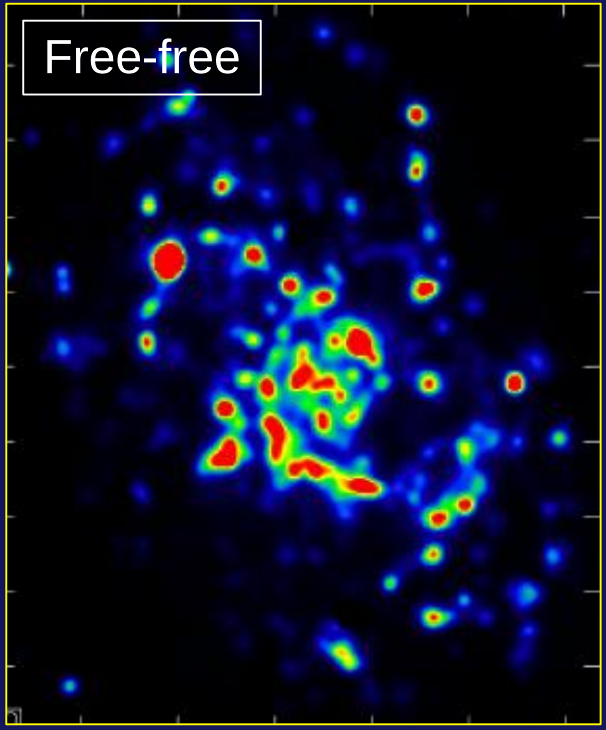
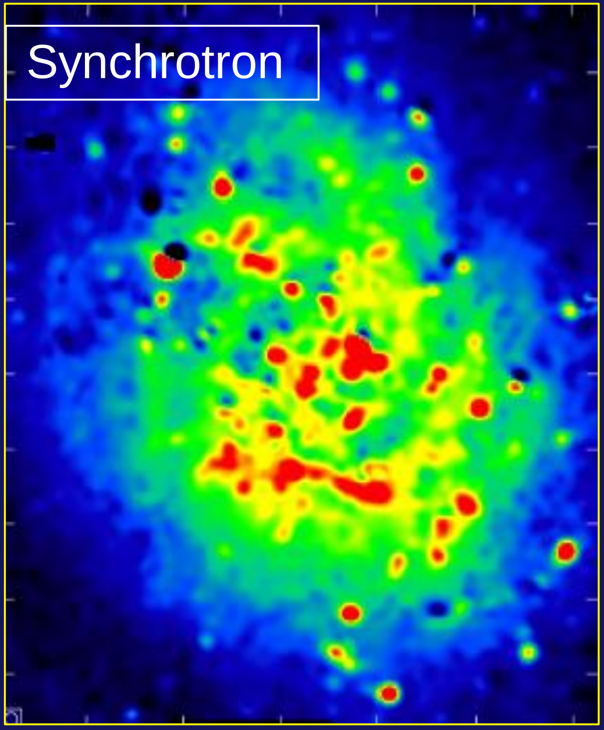




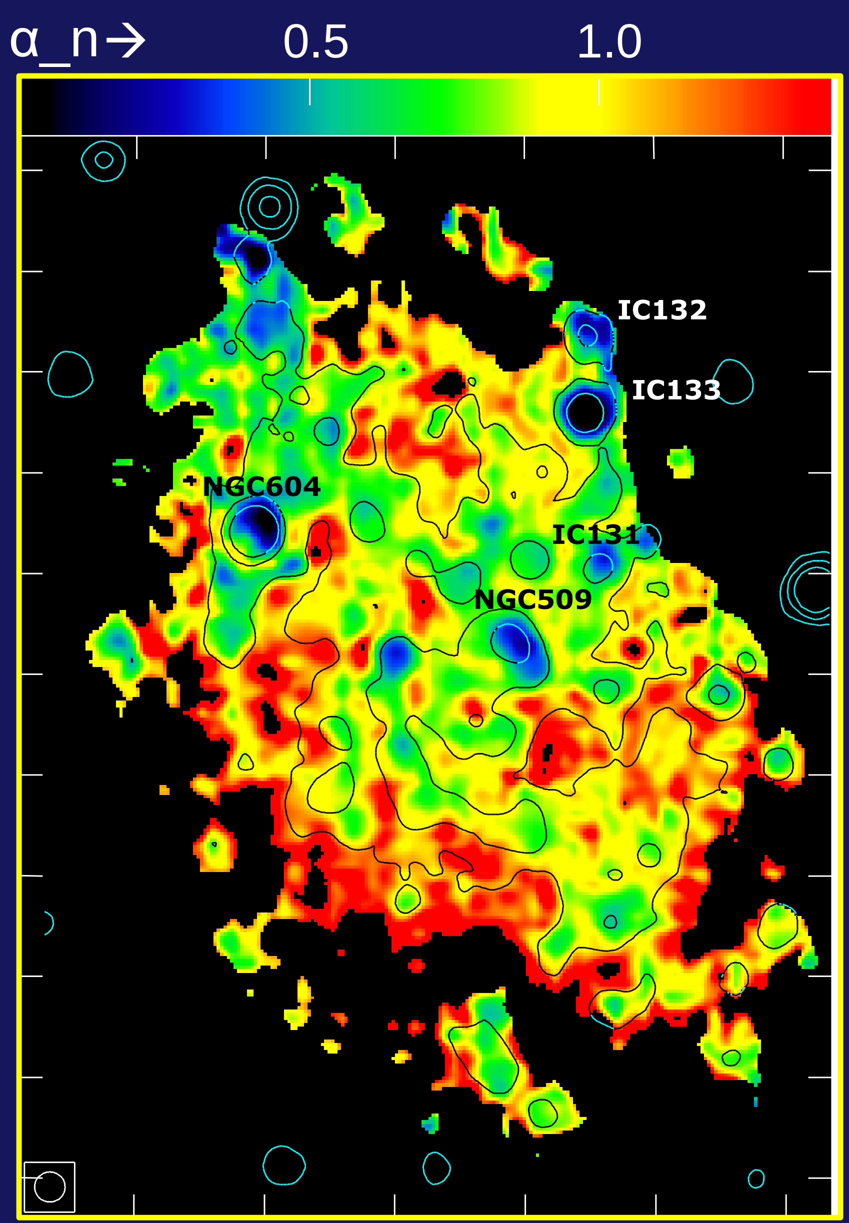
Synchrotron emission is extended, yet strong near SF regions

→ enhanced turbulent B/fresh CREs?

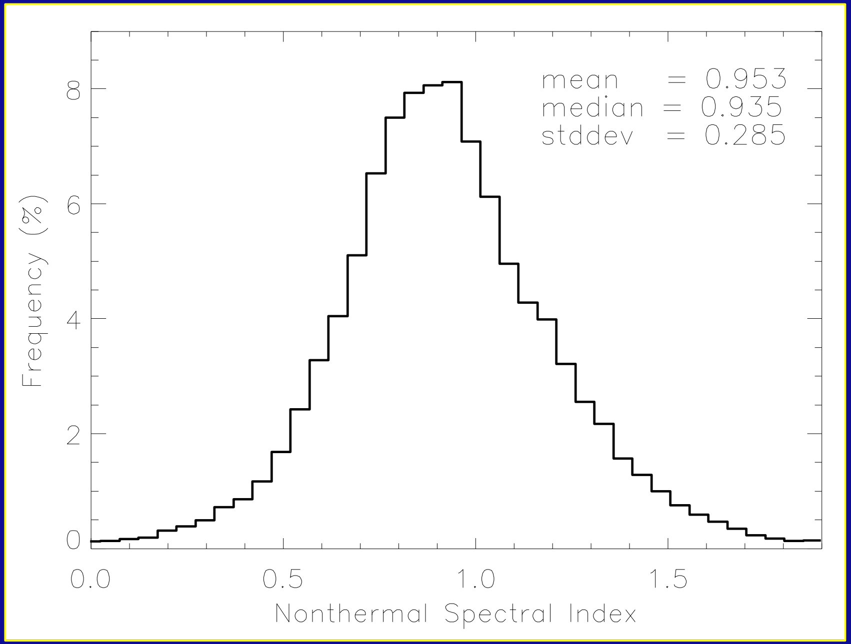
→ Synchrotron a SF tracer

✓ global radio-IR correlation models (Helou 1985)

CREs Energy Index: Injection and Cooling (M33)



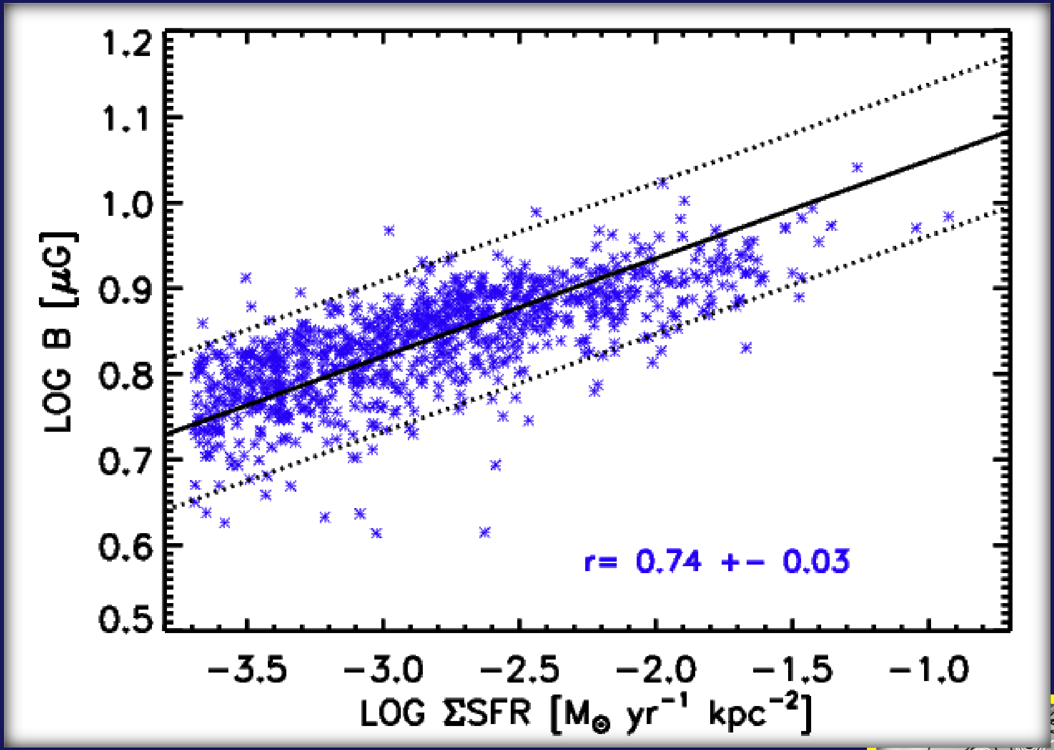
Tabatabaei + 2007



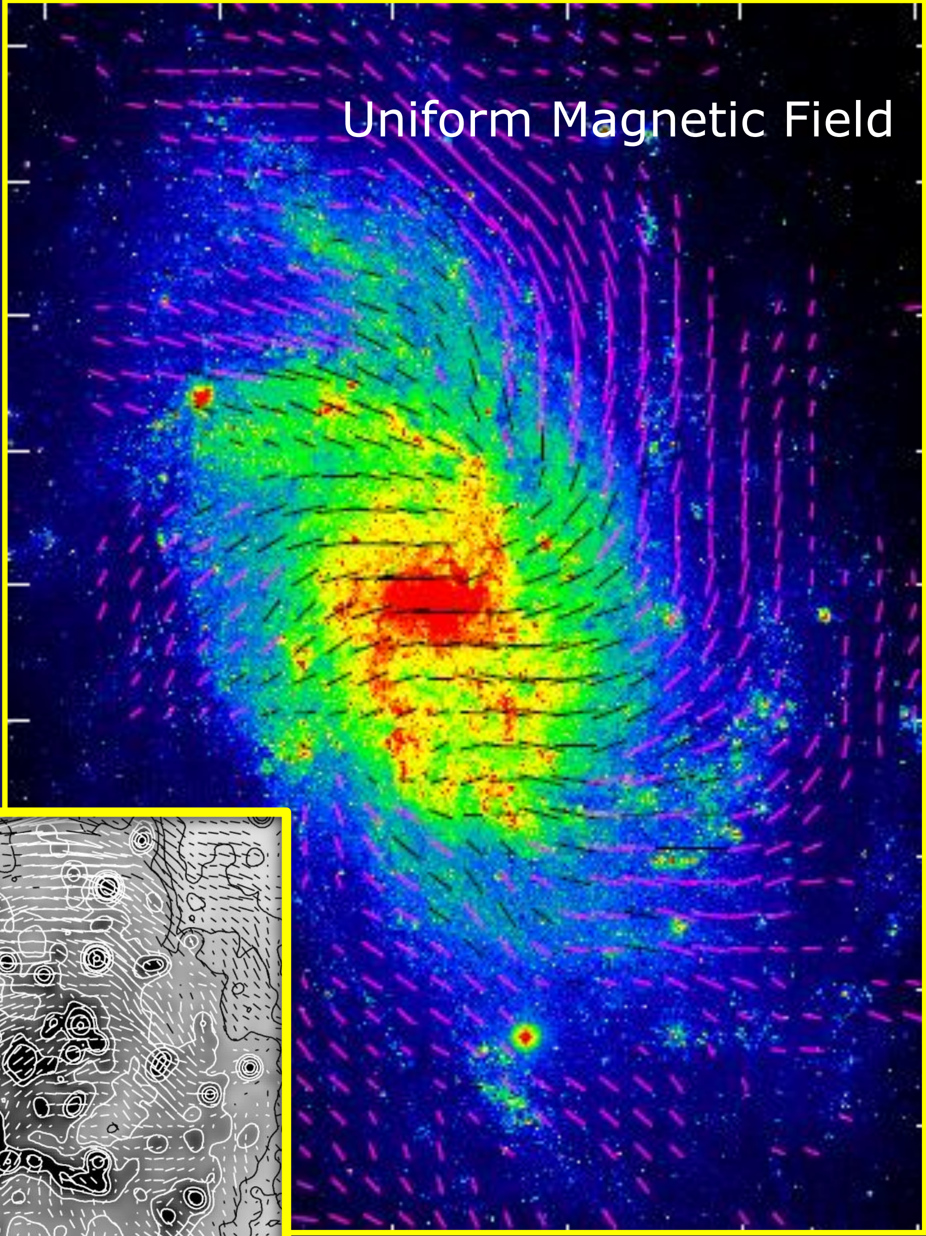
- α≈0.5 in star forming regions: injection of CREs
- α=1.0 ±0.1 in between the arms and the outer parts: Inverse Compton (+synchrotron) energy loss

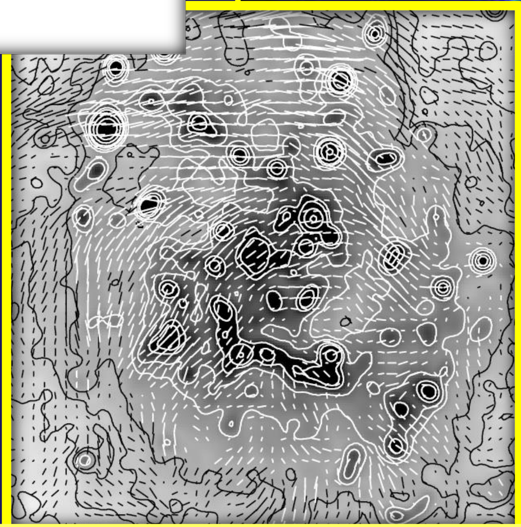
Magnetic Fields in M33

The total B strength and SFR correlated



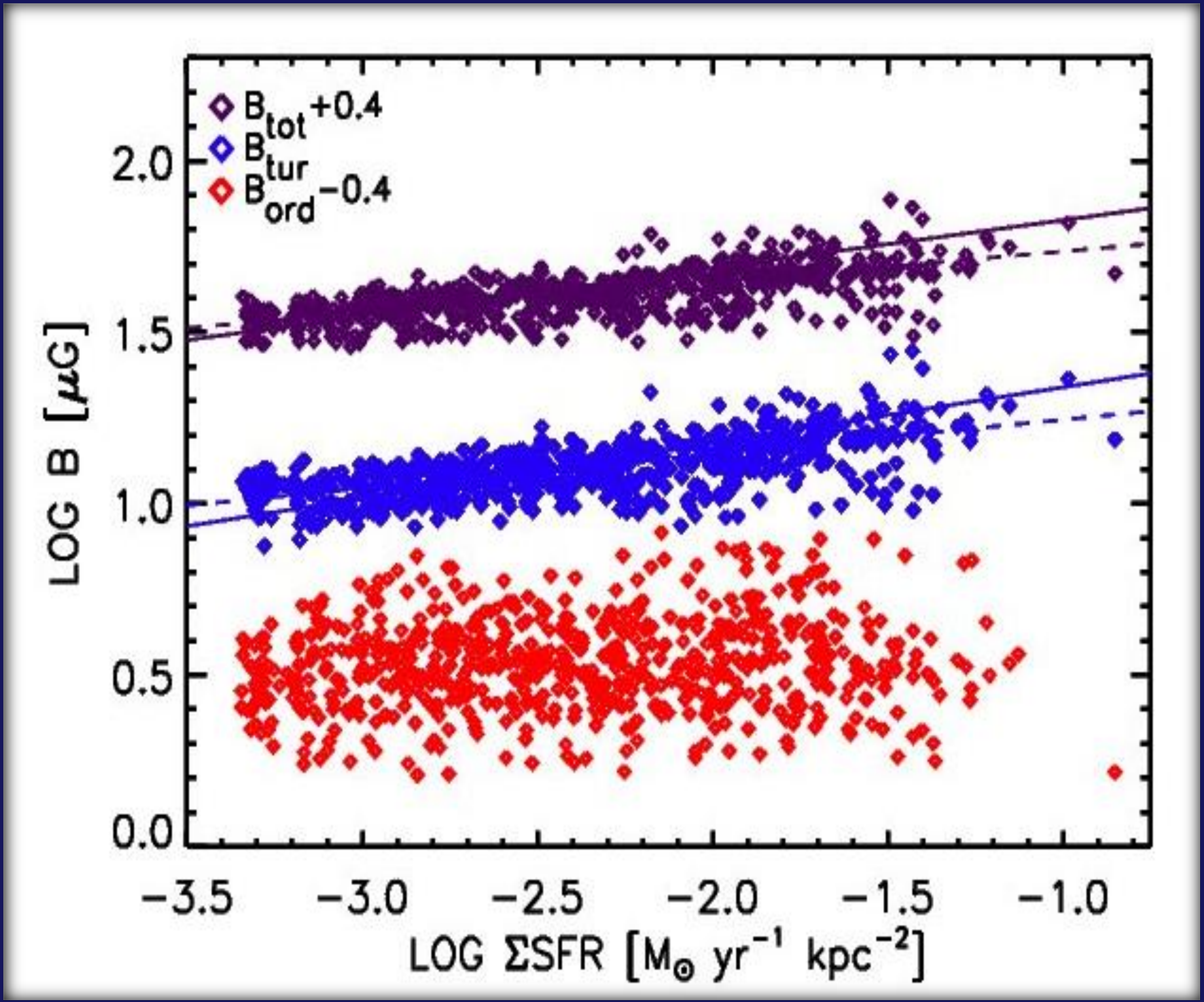
$$\log B_{\mathrm{tot}} \propto (0.12 \pm 0.01) \log \Sigma_{\mathrm{SFR}}$$





Tabatabaei +2008

Magnetic Fields vs. SFR: NGC6946



Tabatabaei + 2013b

* Total B and SFR correlated:

$$\boxed{\log B_{\text{tot}} \propto (0.14 \pm 0.01) \log \Sigma_{\text{SFR}}}$$

* Turbulent B and SFR as well

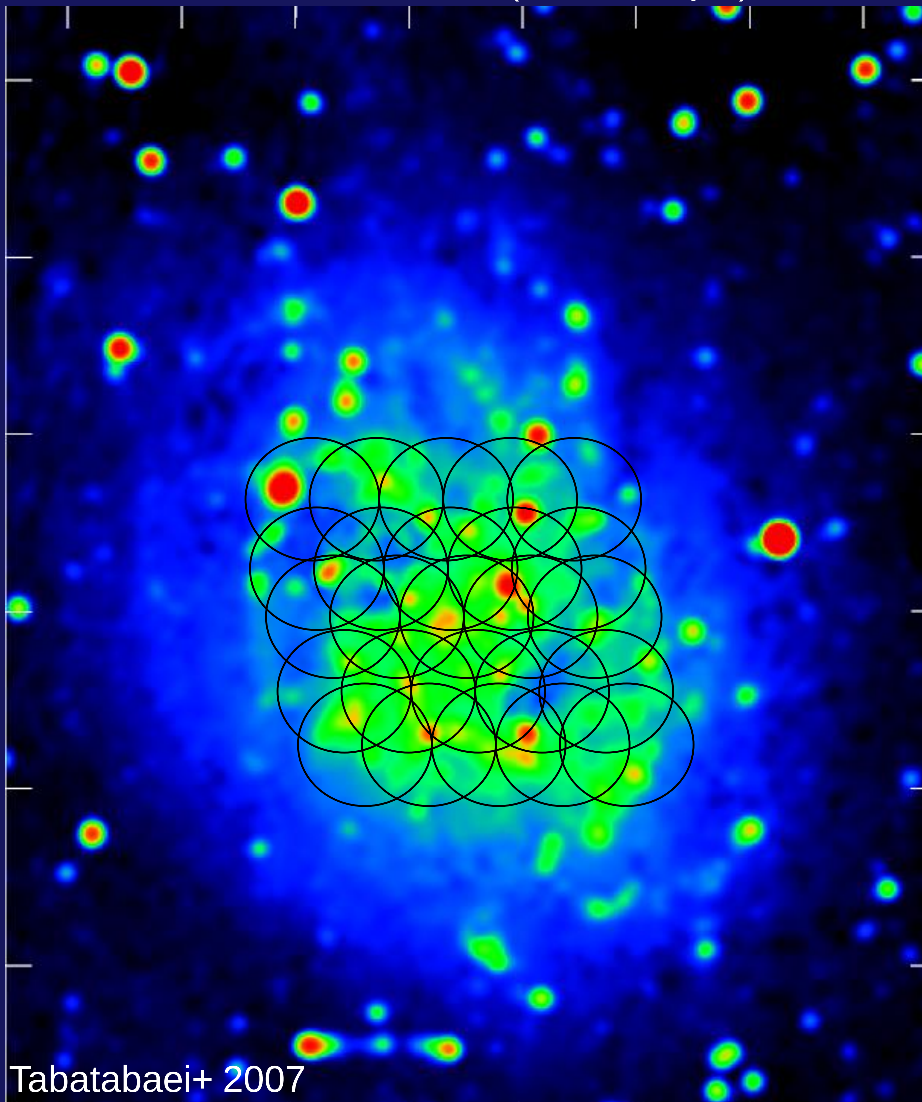
$$\boxed{\log B_{\text{tur}} \propto (0.16 \pm 0.01) \log \Sigma_{\text{SFR}}}$$

* No ordered B-SFR correlation

→Amplification of turbulent B by SF?

Cloud-Scale Studies of SF-ISM Interplay in M33

VLA 1.4 GHz (50“~200pc)



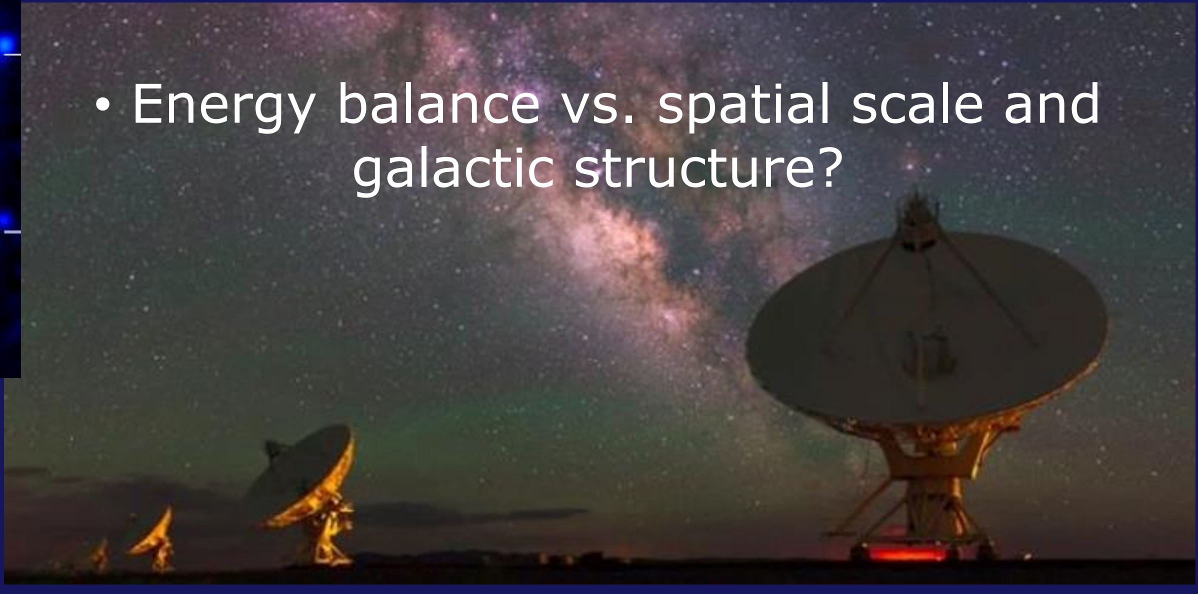
EVLA Full Polarization 40-pc survey →

25 mosaics at 4-7 GHz (D-array)

12 mosaics at 1-2 GHz (C-array)

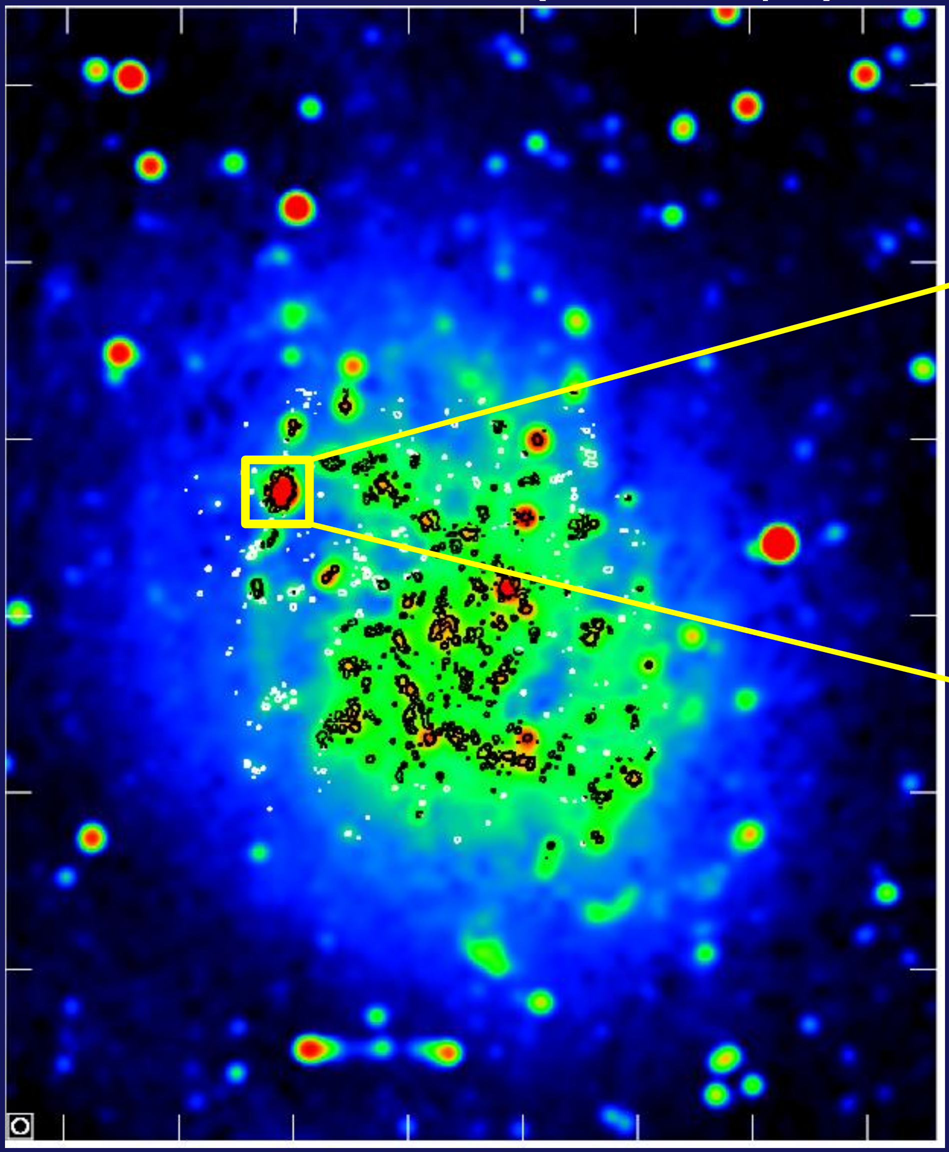
GOALS

- Unbiased SF tracer, from YSO to SNR
- How clouds/stars form out of the magnetized ISM?
- Is feedback thermal or nonthermal ?
- Energy balance vs. spatial scale and galactic structure?

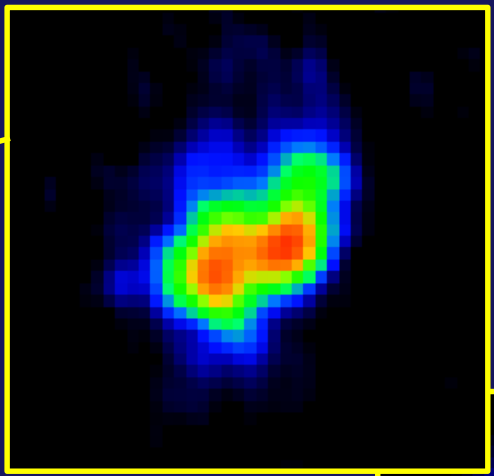


First Results

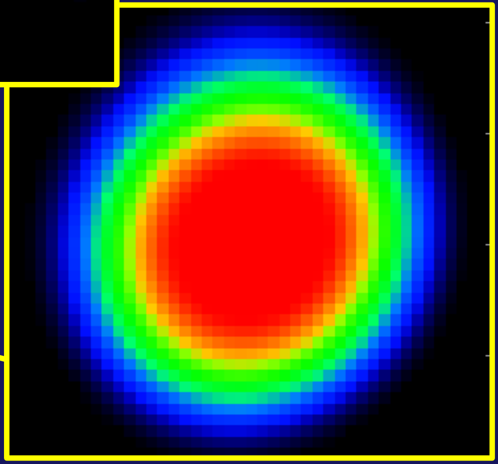
EVLA 1.4 GHz (11″~44pc)



Giant HII- N604



New obs.



Old obs.

Summary

• In **general,** strong synchrotron emission emerges from shell- and filament-like features around SF regions. This is explained by the direct proportionallity between SFR and turbulent magnetic field/ fresh CREs.

• Both the thermal and nonthermal RC are ideal SFR tracers globally. Agreement between resolved SF and global RC-SFR.

• Observations confirm the energy loss theory of CREs and put constraints on the cooling mechanisms vs. ISM conditions (higher-resolution studies are needed, see M33@EVLA).

• A tight correlation between RC and CO could indicate the B-gas coupling, or the role of B in controlling the gas/GMC structures.