"Tracing star formation with non-thermal radio emission"

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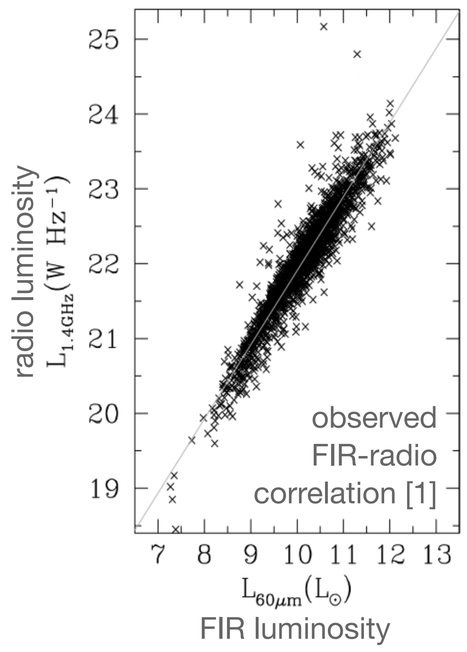
Motivation: Radio-SFR relations



The FIR-radio correlation allows to derive a radio-SFR relation:

FIR-radio correlation [1]

+

FIR-SFR calibration [2]

radio-SFR relation [3]:

$$\frac{\dot{M}_\star}{M_\odot\ \mathrm{yr}^{-1}} \approx 1.74 \times 10^{-4} \frac{L_{1.4\ \mathrm{GHz}}}{L_\odot}$$

Questions addressed in this work:

1) What are the physical processes behind the FIR-radio correlation?
2) Do such relations hold in all types of galaxies?
3) Are radio-SFR relations applicable in galaxies at high redshift?

A physical model for galactic radio spectra

The connection between star formation and galactic radio emission can be explained in the following way:

star formation

The SN rate depends on the stellar initial mass function.

supernovae

Cosmic rays are produced by Fermi acceleration in SN remnants.

cosmic rays

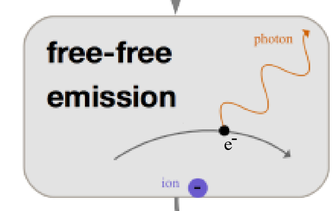
When travelling in the interstellar medium, cosmic rays lose energy via different channels.

turbulence

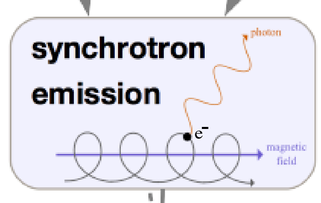
MHD dynamos lead to equipartion between turbulence and magnetic fields.

magnetic field

free-free emission



synchrotron emission

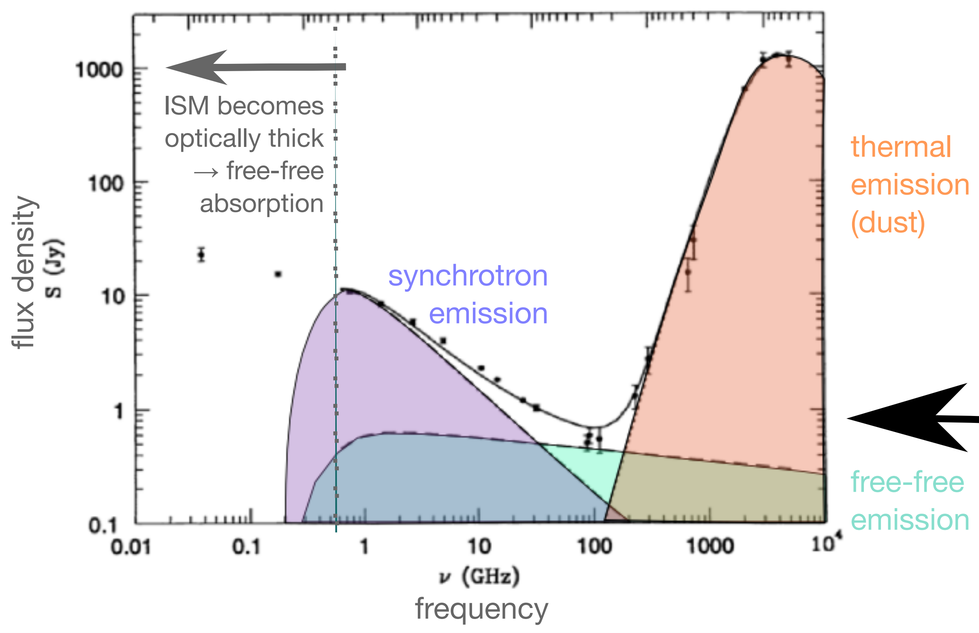


Free-free emission contributes significantly to the flux at high radio frequencies.

free free absorption

Free-free absorption supresses the radio flux at low frequencies, especially at high gas densities.

total radio emission

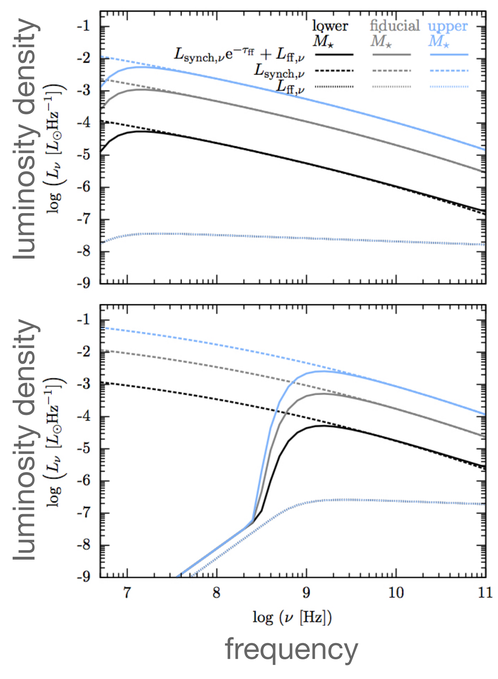


Example:

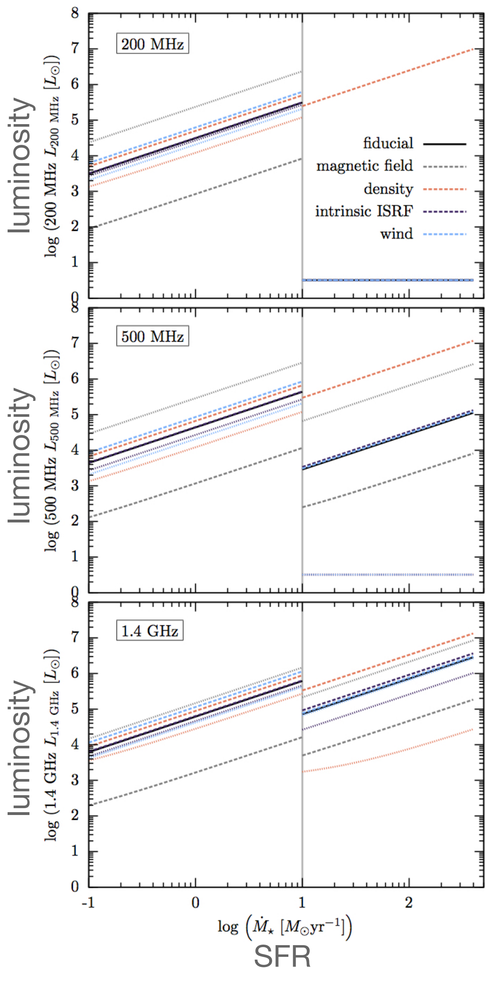
Radio spectrum of M 82
(Figure with data from [4] overlayed with physical interpretation in color.)

Results

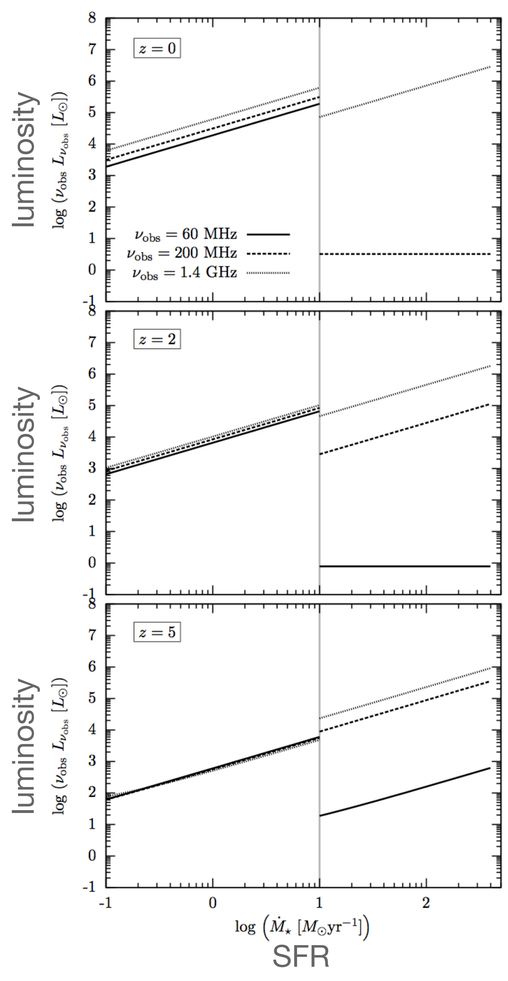
Based on two fiducial models, a Milky Way like galaxy (for SFRs below 10 $M_\odot$/yr) and a M 82 like starburst core (for higher SFRs), radio spectra are calculated. From the model spectra relations between the radio luminosity and the SFR are derived.



Result 1:
Model galaxy spectra
→ The synchrotron flux is proportional to the SFR.
→ Caveat: The critical frequency below which synchrotron flux is absorbed by free-free emission increases with gas density.



Result 2:
Total radio luminosity vs. SFR
(at different frequencies)
→ The correlation breaks down at high frequencies for high star formation rates.



Result 3:
Total radio luminosity vs. SFR
(at different redshifts)
→ Correlations build up again at high redshifts as spectral features move to lower frequencies in the observational frame.

Scaling relations for Milky Way like galaxies:

$$\frac{\dot{M}_\star}{M_\odot\ \mathrm{yr}^{-1}} \approx \begin{cases} 3.20 \times 10^{-5}\ \dfrac{L_{60\ \mathrm{MHz}}}{L_\odot} \\ 2.29 \times 10^{-5}\ \dfrac{L_{200\ \mathrm{MHz}}}{L_\odot} \\ 1.63 \times 10^{-5}\ \dfrac{L_{1.4\ \mathrm{GHz}}}{L_\odot} \end{cases}$$

Scaling relation for M 82 like starburst cores:

$$\frac{\dot{M}_\star}{M_\odot\ \mathrm{yr}^{-1}} \approx 1.39 \times 10^{-4} \frac{L_{1.4\ \mathrm{GHz}}}{L_\odot}$$

Online calculator for individual galaxies galaxies in preparation:

RAiSE
RAdio Star formation Estimator

References

[1] Yun, Reddy, & Condon 2001, ApJ, 554
[2] Leitherer et al. 1999, ApJS, 123
[3] Murphy et al. 2011, ApJ, 737
[4] Condon 1992, ARA&A, 30

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