

What drives star formation in bars?

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Summary

The conditions for star formation (SF) in bars are still not well understood. While some strong bars show recent massive SF along them, some others, apparently similar, show a complete lack of it. In order to shed light on the conditions that enable or prevent SF we have observed the CO(1-0) and CO(2-1) emission with the IRAM 30m telescope in a sample of 12 nearby galaxies with moderate to strong bars and different degrees of SF. We compare the molecular gas mass, M_{H_2} , to the SF rate (SFR), traced by H α and 24 μm emission, for each position. First results based on an analysis of three galaxies show that molecular gas mass and the SFR exhibit very similar distributions along the bar, if the SFR is calculated from a combination of H α and 24 μm . In this case, the star formation efficiency (SFE), defined as $\text{SFR}/M_{\text{H}_2}$, has values typical for disks of spiral galaxies. This suggests that the SF in the bar is driven to a large extent by the molecular gas content.

The sample and the data

The sample consists of 12 nearby galaxies ($v_{\text{rec}} < 3000 \text{ km s}^{-1}$) of morphological type from Sab to Scd, with moderate inclination ($< 60^\circ$), optical diameter $d_{25} > 2.5''$ and $\text{dec} > -15^\circ$, to guarantee observability and a good spatial resolution.

We selected galaxies with moderate to strong bars (bar strength between 0.2 and 0.6) and different degrees of SF. The sample consists of: NGC 3504, NGC 4123, NGC 4394, NGC 4535, NGC 4548, NGC 4593, NGC 5383, NGC 5850, NGC 5921, NGC 6217, NGC 6951 and NGC 7723.

We have the following data for our sample:

- ❑ **Sloan images** that allow to determine the bar parameters.
- ❑ **H α images** to trace the unattenuated star formation.
- ❑ For about half the sample there are **Spitzer images at 8 μm (PACS) and/or 24 μm (MIPS)** to trace the dust-enshrouded star formation.
- ❑ We observed the **CO(1-0) and CO(2-1)** emission along the bar with the IRAM 30m telescope.

Here, we present the results from a first analysis of three galaxies with weak to moderate SF in the bar. For NGC 4128, with one of the strongest bars in the sample, no Spitzer data is available.

SF and molecular gas along the bars

In order to compare the SFR and the molecular gas mass at each observed position, we multiplied the background-subtracted H α and 24 μm images with the CO(1-0) beam pattern (assumed to be Gaussian) at the positions of the CO pointings and measured the flux from the resulting images. We then calculated the SFR in three different ways:

- ❑ From the H α luminosity, $L(\text{H}\alpha)$: **$\text{SFR}(\text{H}\alpha) (M_\odot \text{ yr}^{-1}) = 5.45 \cdot 10^{-42} L(\text{H}\alpha) (\text{erg s}^{-1})$** (Calzetti et al. 2010)
- ❑ From the 24 μm luminosity, $L(24\mu\text{m})$: **$\text{SFR}(24\mu\text{m}) (M_\odot \text{ yr}^{-1}) = 5.66 \cdot 10^{-36} L(24\mu\text{m})^{0.826} \text{ erg s}^{-1}$** (Calzetti et al. 2010)
- ❑ From both: **$\text{SFR}(\text{H}\alpha+24\mu\text{m}) (M_\odot \text{ yr}^{-1}) = 5.45 \cdot 10^{-42} (L(\text{H}\alpha) + 0.020 L(24\mu\text{m}))$** (Kennicutt et al. 2009)

Fig. 2 shows that the molecular gas and the SFR have a very similar trend with high values in the centers of the galaxies and considerably lower values in the bars. The SFE is slightly lower in the bar but still within the ranges found by Bigiel et al. (2011) within disks of nearby galaxies. An exception is NGC 4123 with an apparently low SFE in the bar, which might, however, be due to the missing internal extinction correction.

Preliminary conclusions and future work

The preliminary results of this study indicate that in bars, as in galaxy disks in general, the SFR is driven by the presence of molecular gas. In NGC 4123, the galaxy with one of the strongest bars in the sample, the SFE based on the H α emission is low, however, this is most likely due to the (uncertain) extinction of H α . Thus, so far, we do not find any clear indications for a deviation of the SFE within the bars from mean value found for spiral galaxies in general. In order to complete this study, we will analyse the remaining galaxies in the sample and apply an appropriate estimate for the extinction correction to those galaxies for which no Spitzer data is available.

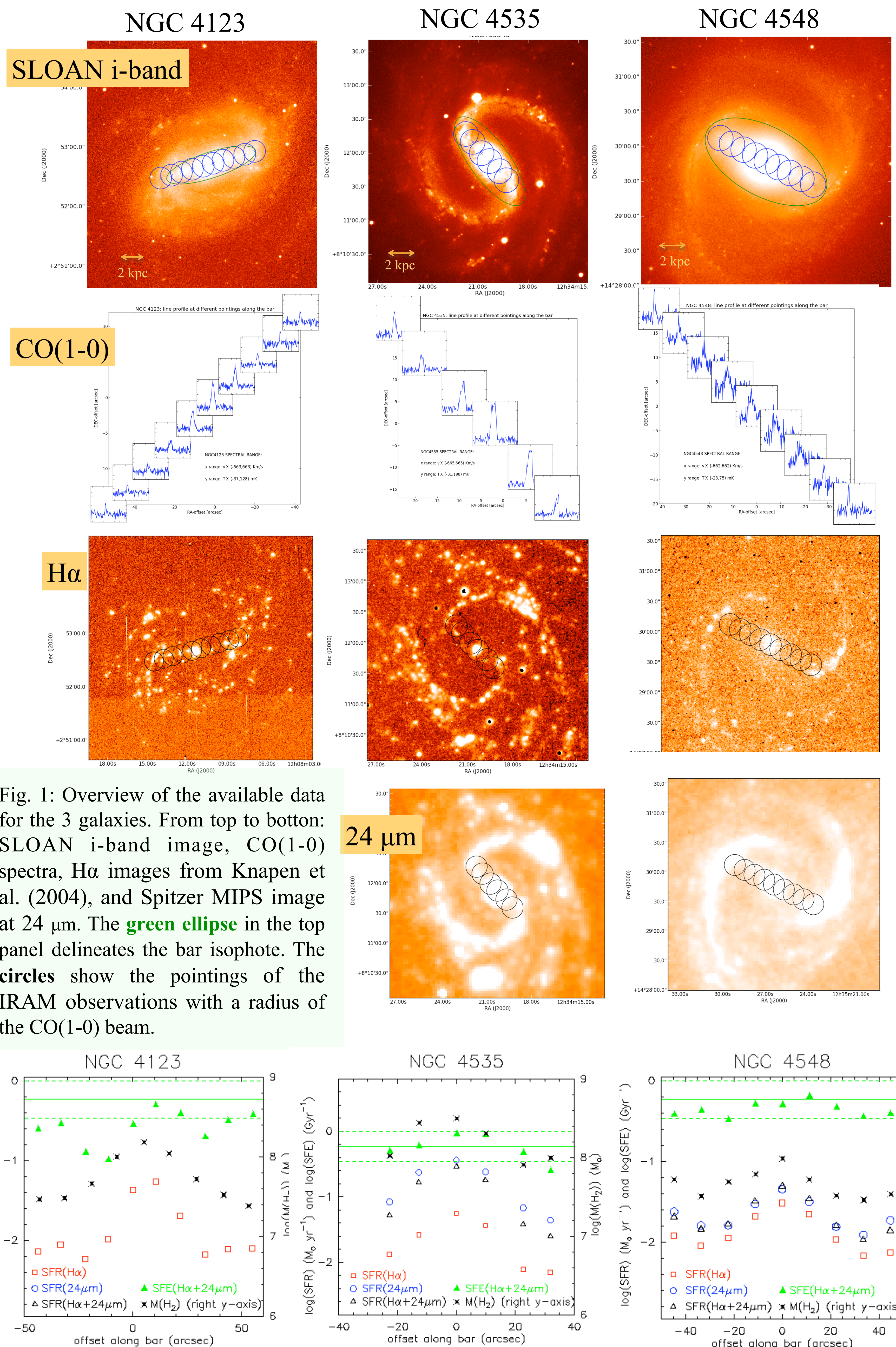


Fig. 1: Overview of the available data for the 3 galaxies. From top to bottom: SLOAN i-band image, CO(1-0) spectra, H α images from Knapen et al. (2004), and Spitzer MIPS image at 24 μm . The **green ellipse** in the top panel delineates the bar isophote. The **circles** show the pointings of the IRAM observations with a radius of the CO(1-0) beam.

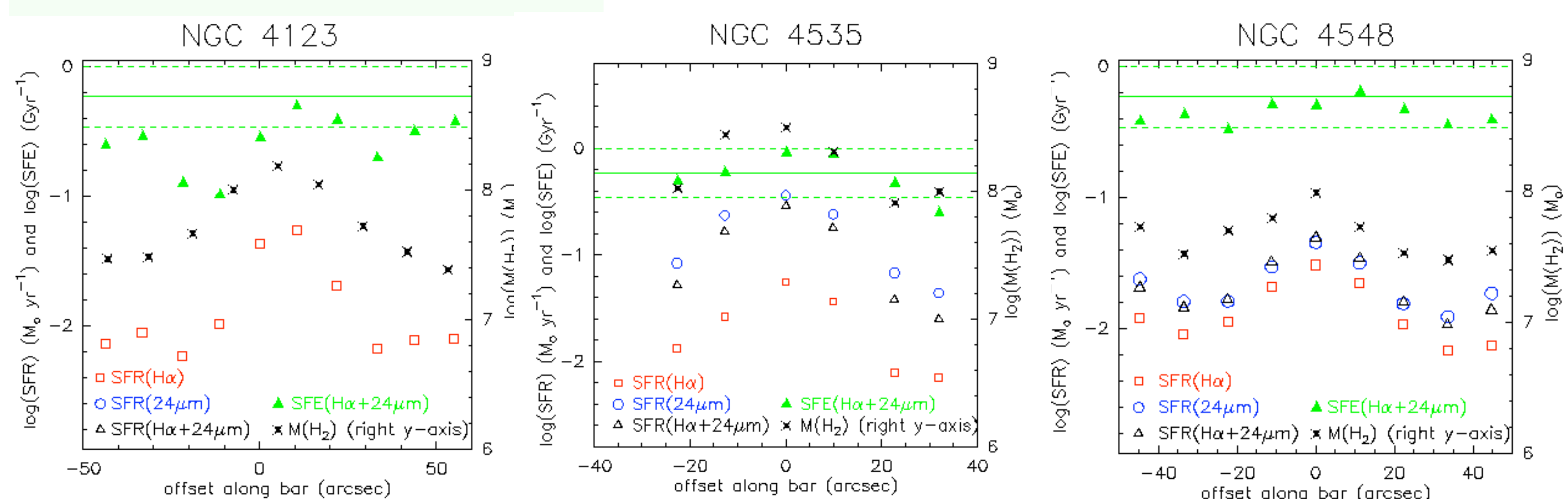


Fig. 2: The distribution of the SFR (as given by the different tracers) within the CO(1-0) beam, of the SFE (left y-axis), and of the molecular gas mass (left y-axis). The green full line shows the mean value of the SFE for spiral galaxies (Bigiel et al. 2012) and its dispersion (green dashed line).