Hands-on Project 13
Molecular Gas and Star Formation in Spiral Arms

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International school on ISM of galaxies - July 2021

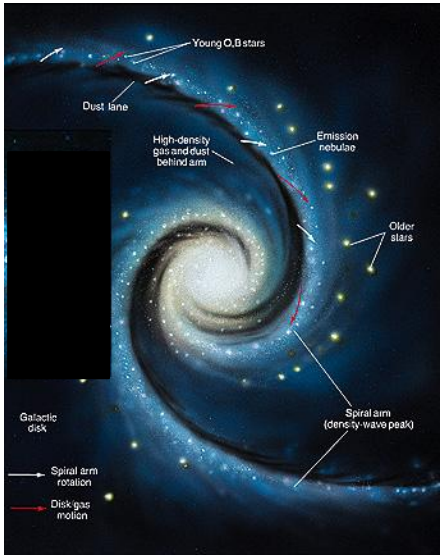
Motivation

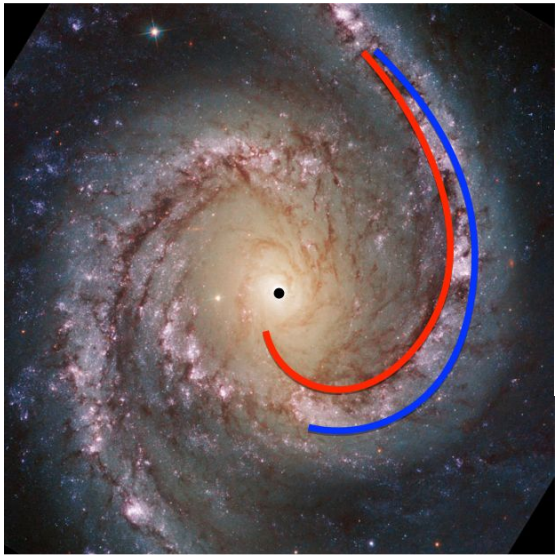
Spiral galaxies are twisted collections of stars and gas that have *beautiful* shapes.

Most galaxies have spiral structure, which affects the gas distribution, the star formation as well as the future evolution of the galaxy.

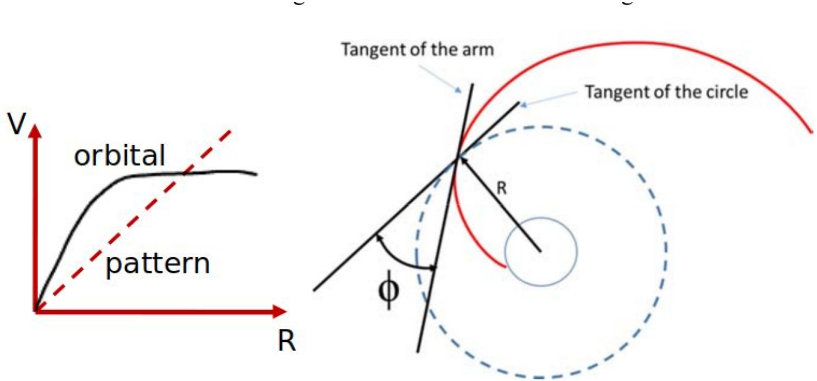
This project takes advantage of open source observational data to characterize morphological properties of spiral arms in order to quantify their impact on star formation. In addition, compare the results with predictions from density wave theory.

Density Wave Theory and Pitch Angle





HST image of NGC 1566

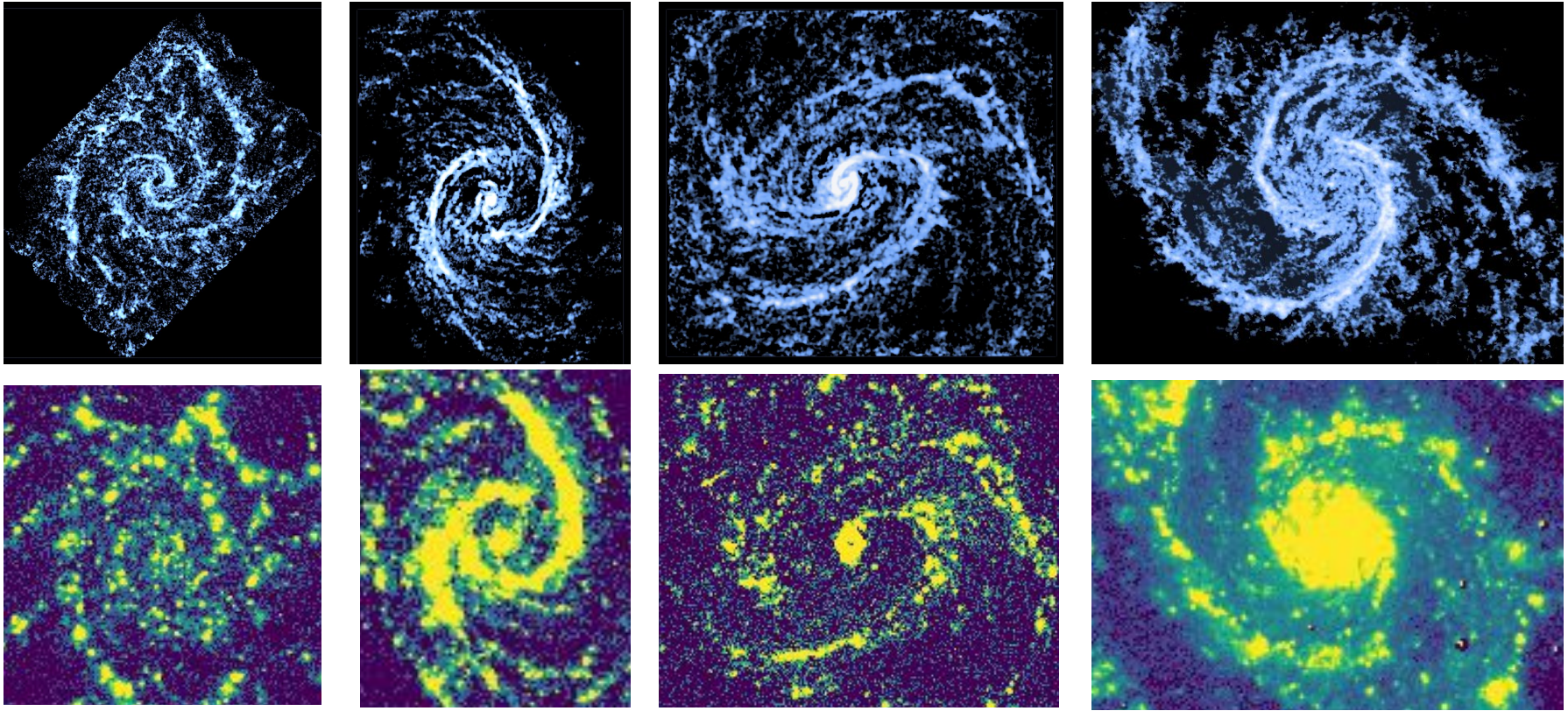


Hongjun Pan et al. 2020

- Proposed by C.C. Lin and Frank Shu.
- Spiral Arms could be viewed as density wave moving with a particular frequency in differentially rotating disk.
- Spiral Arms are amplified by resonances.

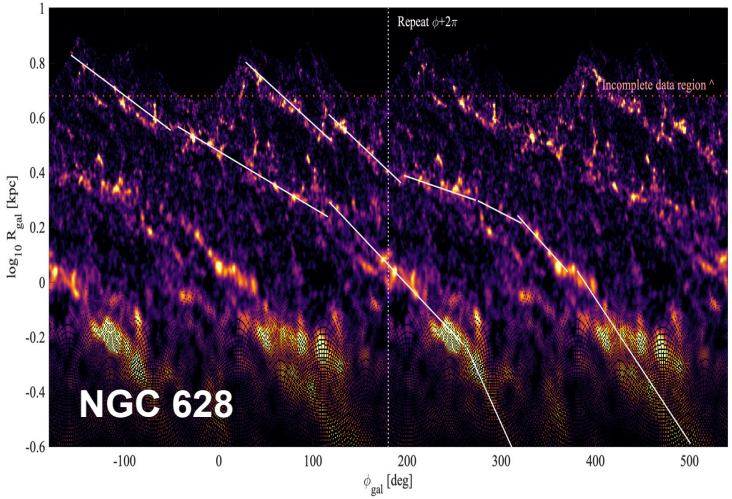
Targets and Datasets: [CO (ALMA) and Hα(SINGS)]

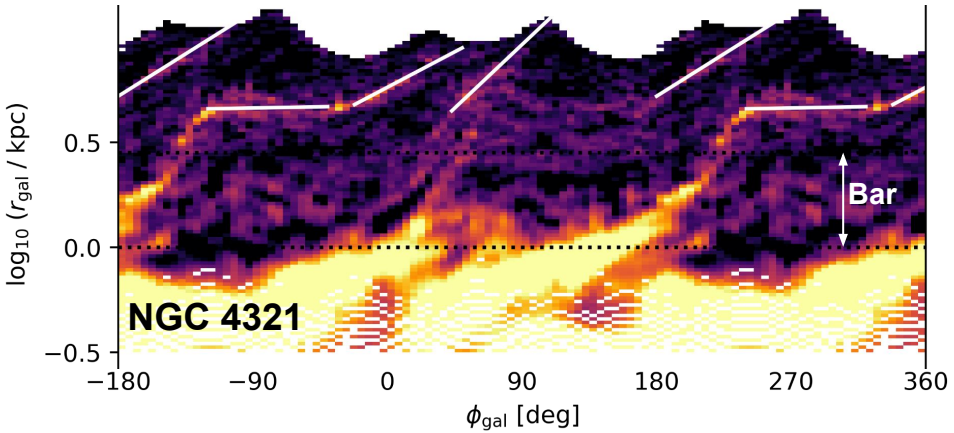
NGC 628 (M74) | NGC 1566 | NGC 4321 (M100) | NGC 5194 (M51)

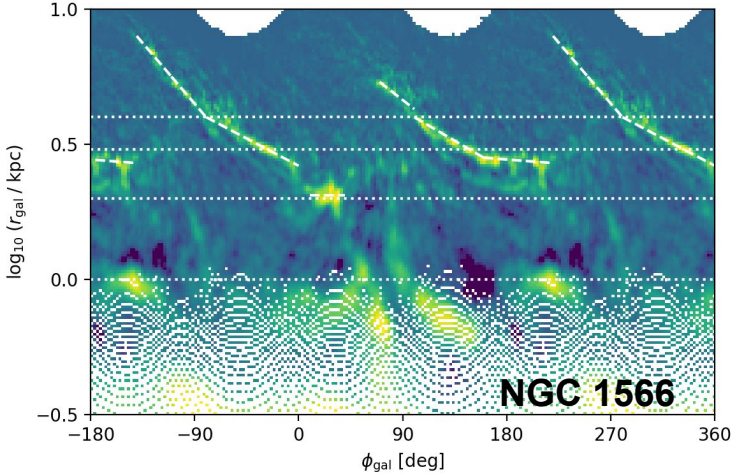


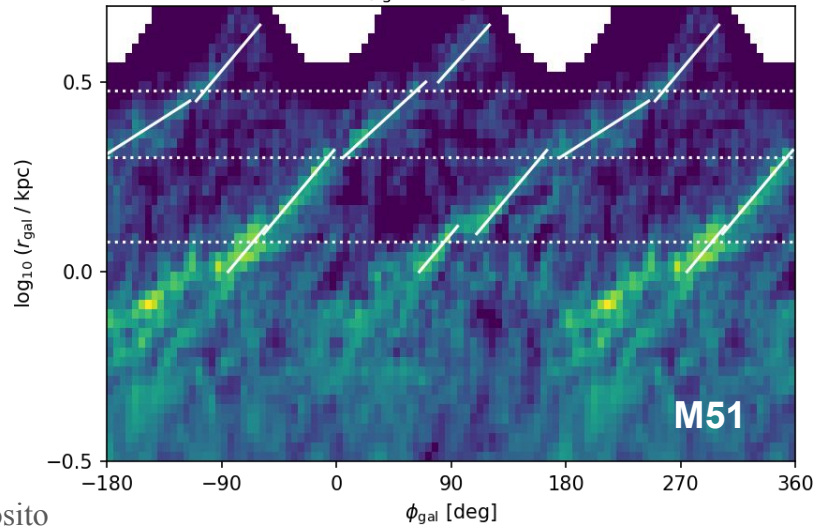
Result A - Arm Segment Identification

CO (2-1) in polar coordinates





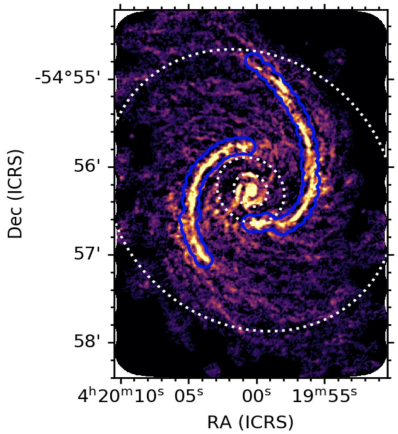


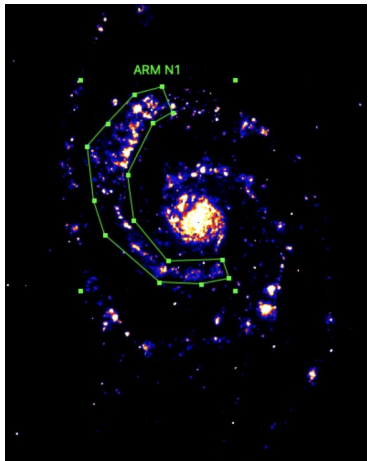


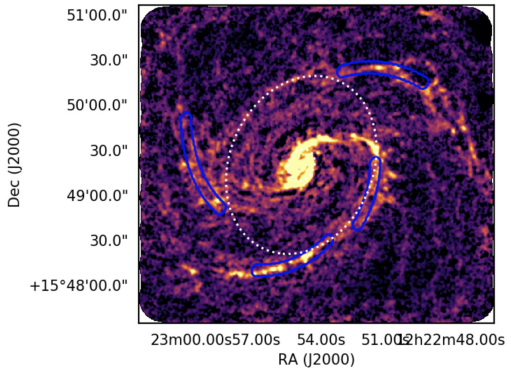
Result B - Fraction of CO and Hα in the Arms

This is a measure of the relative arm strength made by defining a region surrounding the arm segments we defined.

Galaxy	NGC 628 (M74)	NGC 1566	NGC 4321 (M100)	NGC 5194 (M51)
Arm CO fraction	37%	58%	41.3%	30-55%
Arm Hα fraction	-	-	29-31%	14-35%

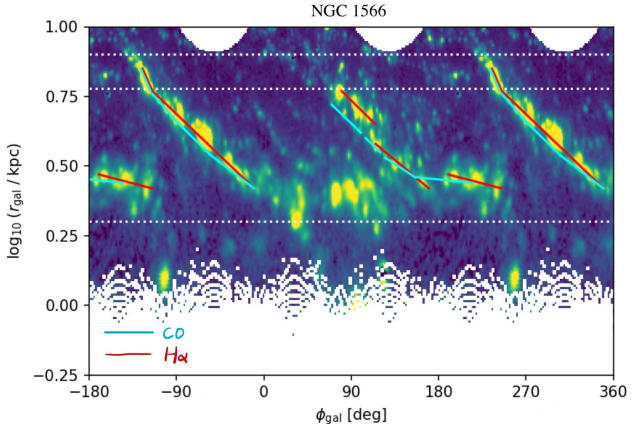


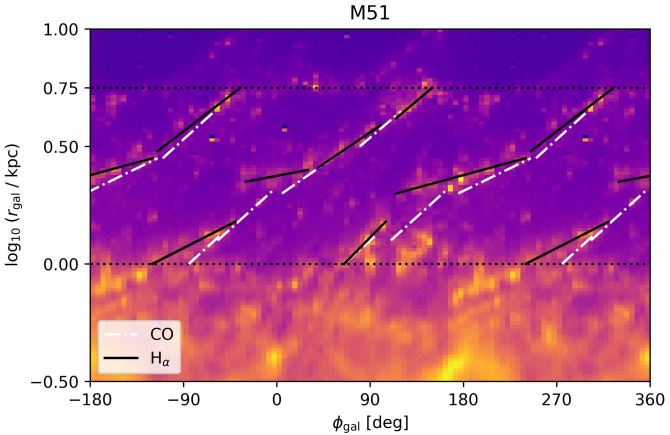


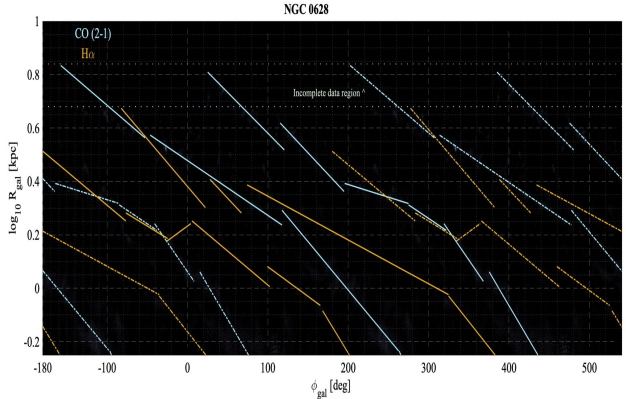


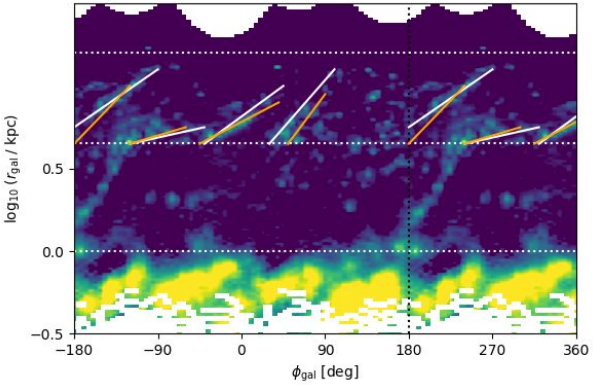
E. Iles

Result C - Comparing CO and Hα





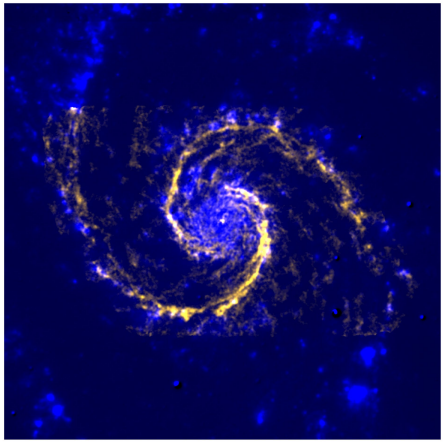




CO and Ha spiral arms are defined by ‘spines’- lines with different colors.

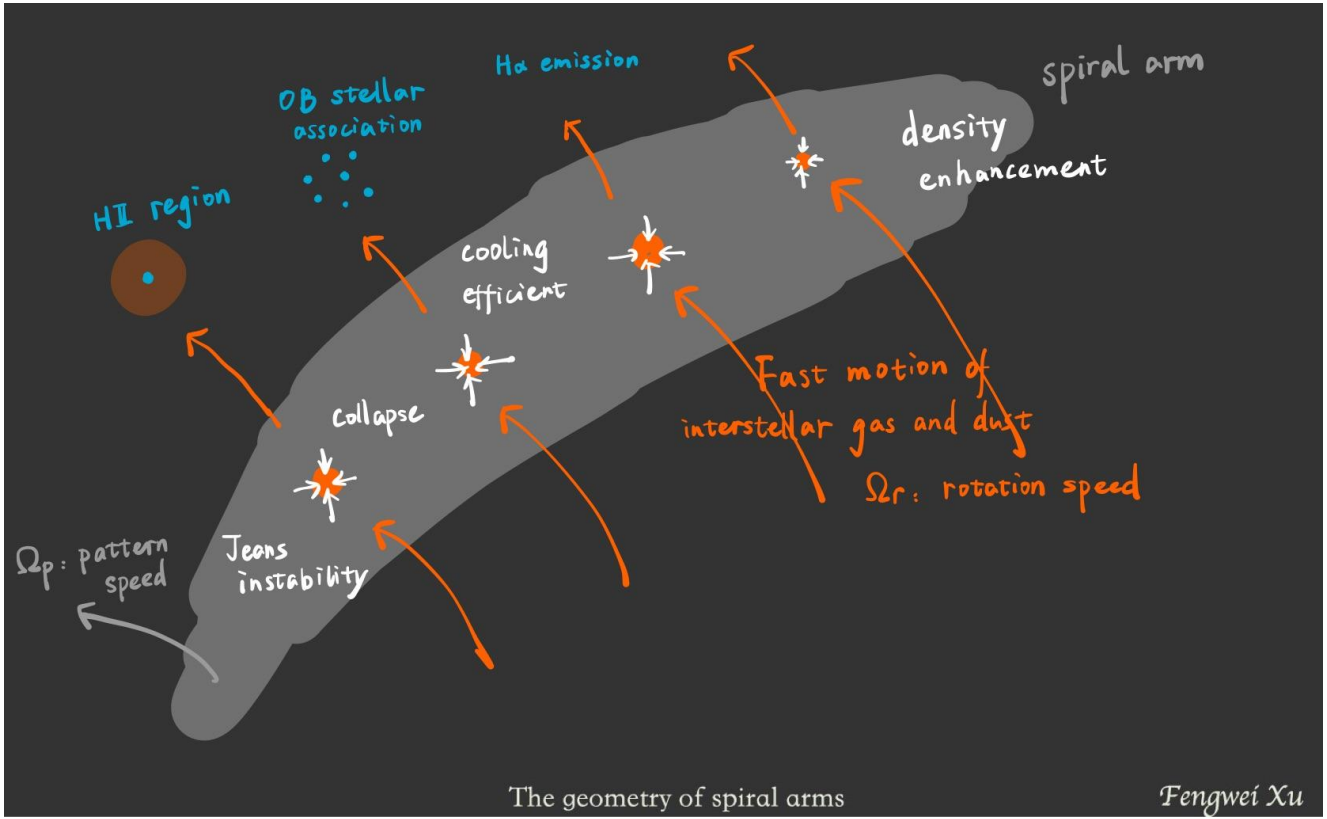
Offsets of ‘spines’ are observed in all four galaxies.

M51 CO ‘golden arms’



F. Xu

Result C - Comparing CO and Hα, supporting the theory



Movie

Conclusion

- Individual spiral arm segments are well described by logarithmic spirals.
- For CO emission, between 30 to 58% of the emission is associated with spiral arms. For Hα, this fraction is between 14 to 35%.
- Given the relatively narrow width we adopted for the spiral arm footprints, these high fractions suggest that spiral arms can at least efficiently collect molecular gas and thus newly formed young massive stars in galaxy disks.
- CO and Hα arms generally have systematic offset, supporting the idea of density wave theory of galaxy spiral arms.

Thank you