Alignments between large-scale structure filaments and galaxy spins

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Supervised by:

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Background

- Regions with denser galaxies: filaments

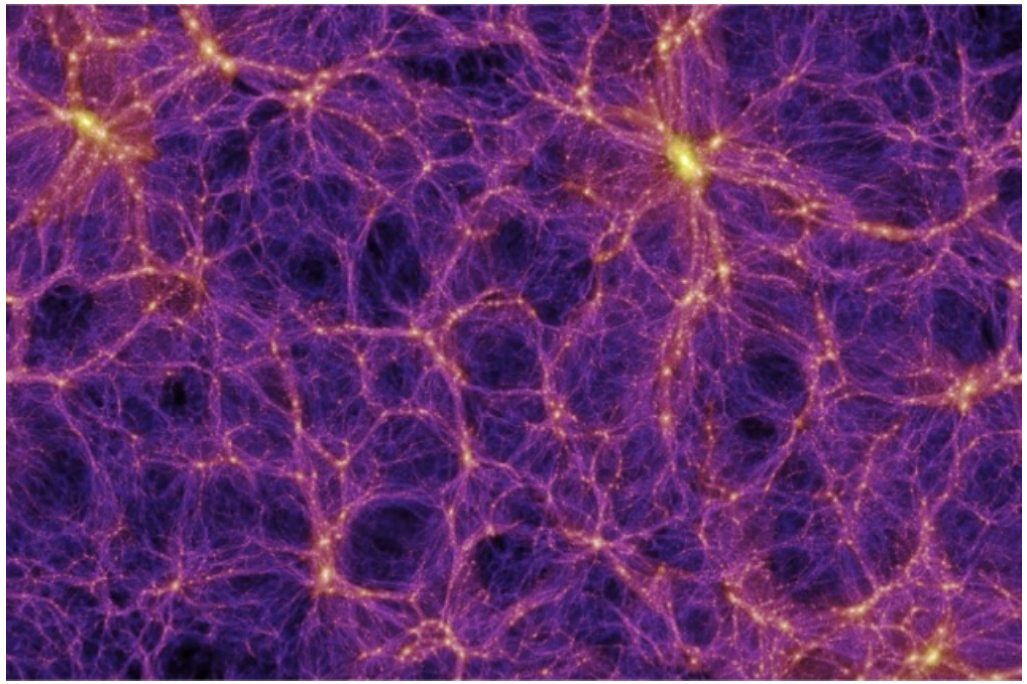


Image from Universe Today by Evan Gough

Background

- Accretion of matter comes from the environment
- Alignment with the filaments
- Studying the alignment between galaxy spins and filaments help understand the origin of the angular momentum of galaxies

Introduction

- Investigate the relationship between galaxy spins and the direction of filaments, mainly mass dependence.
- Using the data of 2779 galaxies from Mapping Nearby Galaxies at APO (MaNGA) integral field survey.
- Write scripts to fit the rotation axis and position angle.

Introduction

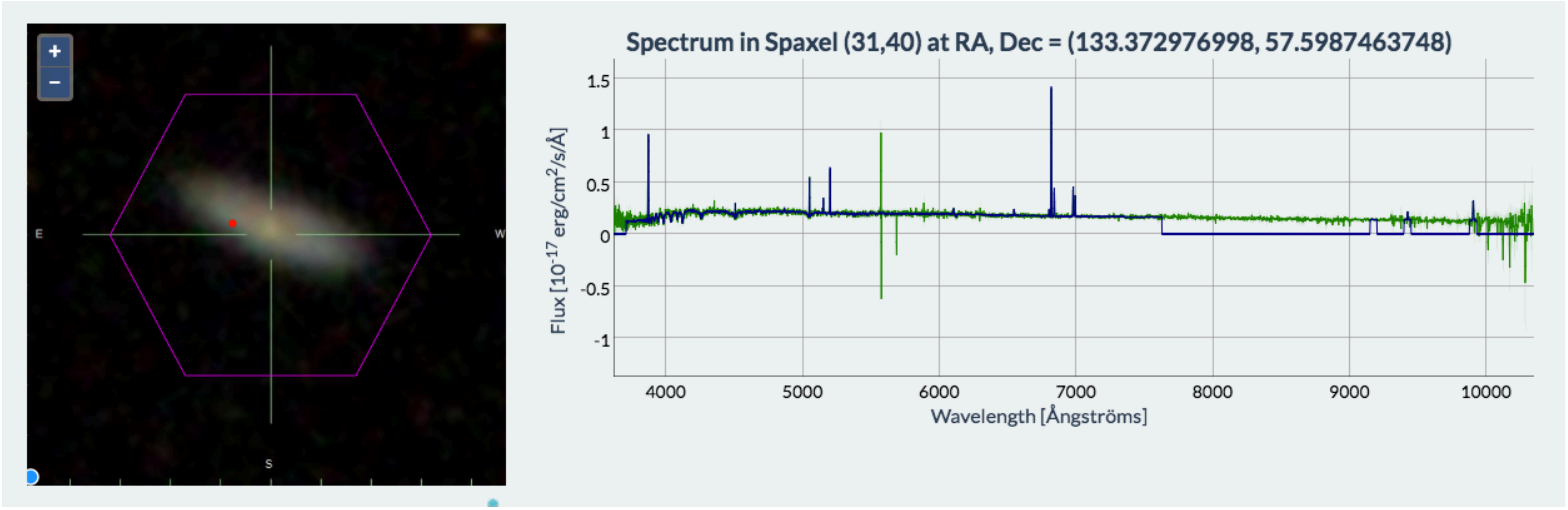
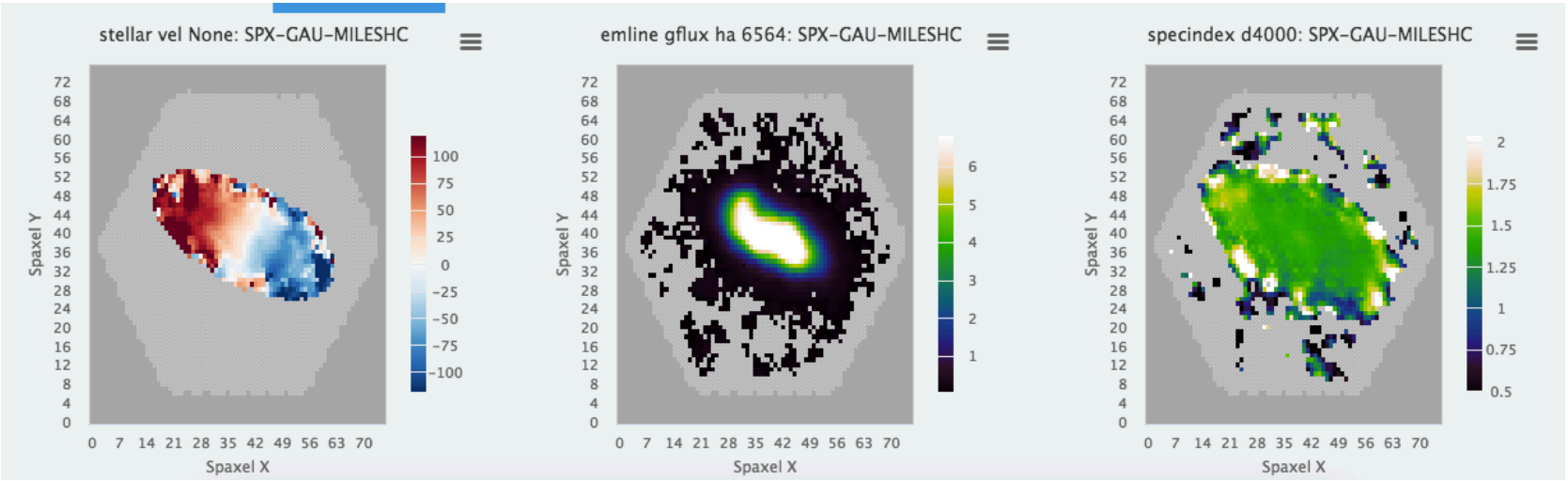


Image of a galaxy from the MaNGA survey

Some of the data available from the survey

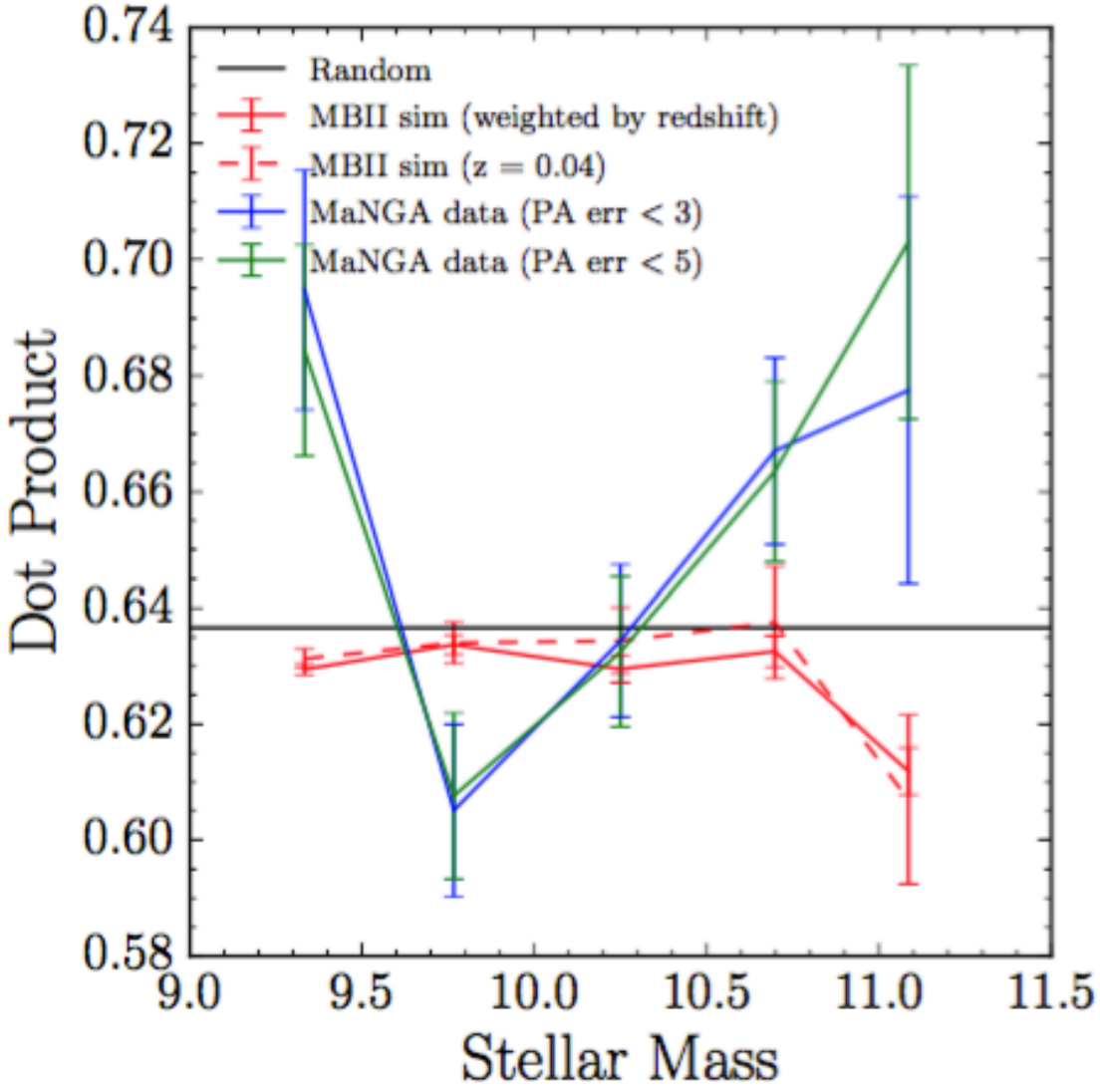


Motivation

- Previous studies determined galaxy spins by the shape and arrived at conflicting conclusions.
- Determine galaxy spins by kinematic fields should give accurate results.

Motivation

- Hydrodynamic simulations predicted the mass dependence of alignment.
- Conclusion drawn from stellar velocity does not agree with simulations.
- My task is to redo the analysis with gas velocity (H-alpha) of the galaxies.



Methods

- Velocity maps from the MaNGA Data Analysis Pipeline. These give us a velocity at each pixel in every galaxy.
- Pixels with data flagged as problematic or signal to noise ratio <5 are masked.
- Choose the position angle to minimize the chi-square between the data and the symmetric model.

Methods

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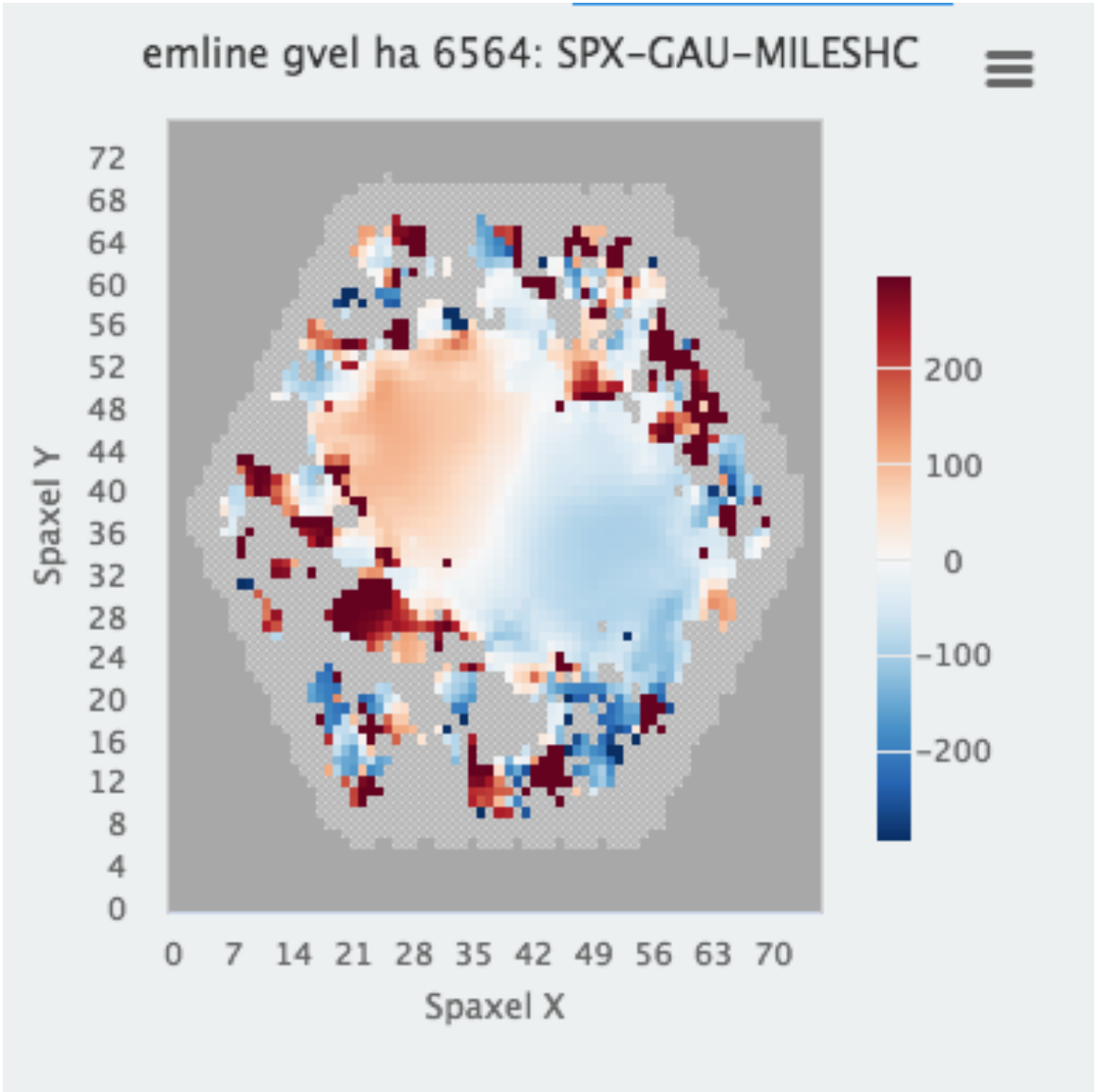
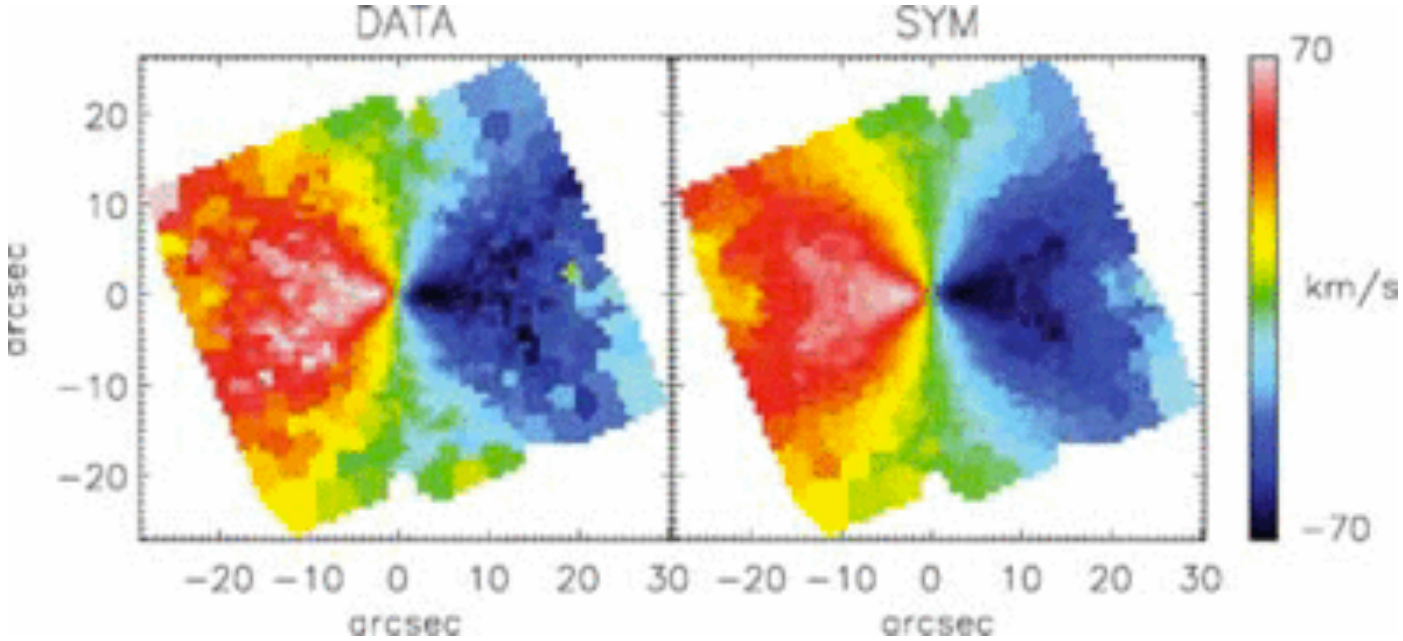
- Pixels with data flagged as problematic or signal to noise ratio < **5** are masked.
- Choose the position angle to minimize the chi-square between the data and the symmetric model by FIT_KINEMATIC_PA routine (Krajnovic et al. 2006).



Gas velocity map of a galaxy

Methods

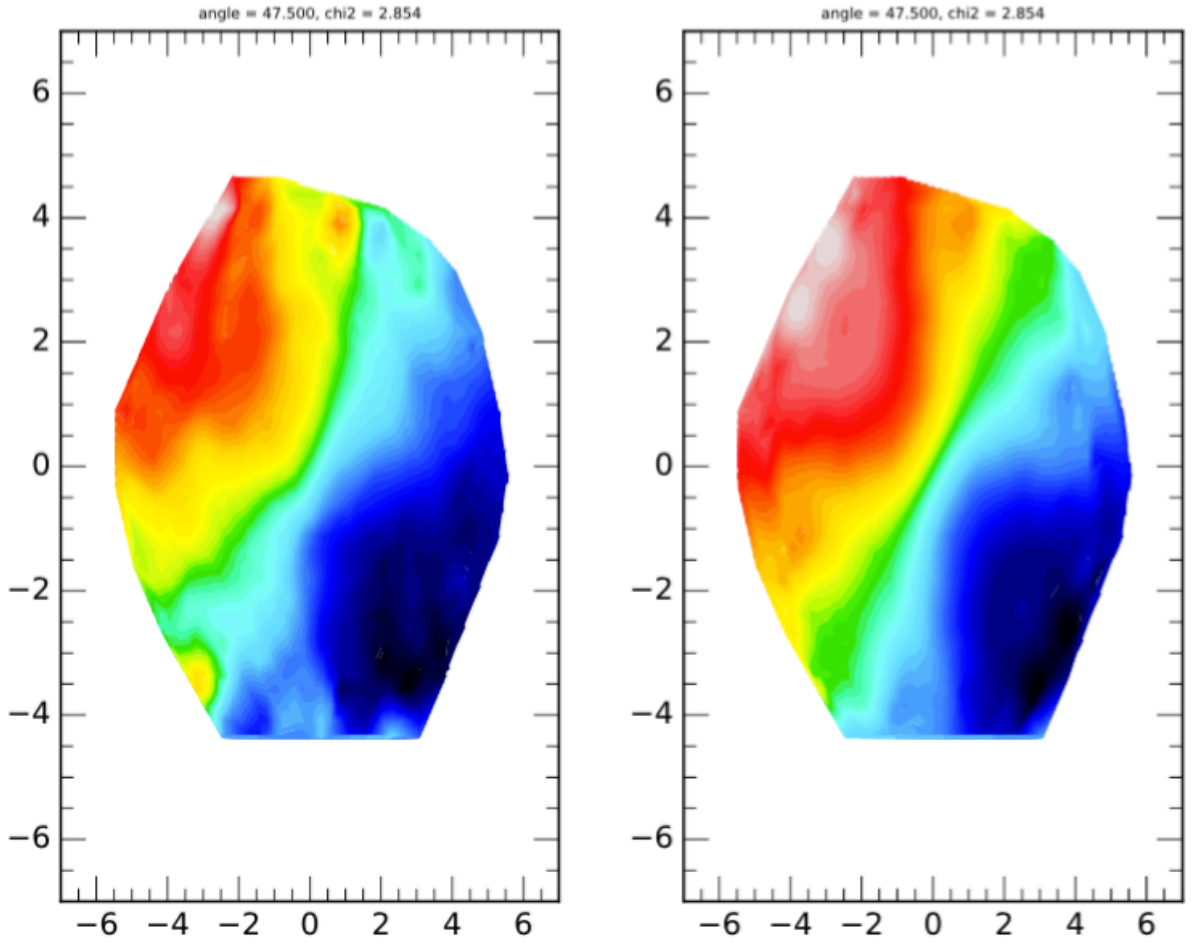
- Here is how we construct the symmetrized velocity map.
- Following the FIT_KINEMATIC_PA routine, we define the symmetrized model from the data: $V'(x,y) = \frac{V(x,y)+V(x,-y)-V(-x,y)-V(-x,-y)}{4}$,where the x and y coordinates are rotated from north-south and east-west by the given position angle.



Comparison of observed velocity map (left) and symmetric map (right) (Krajnovic et al. 2006)

Methods

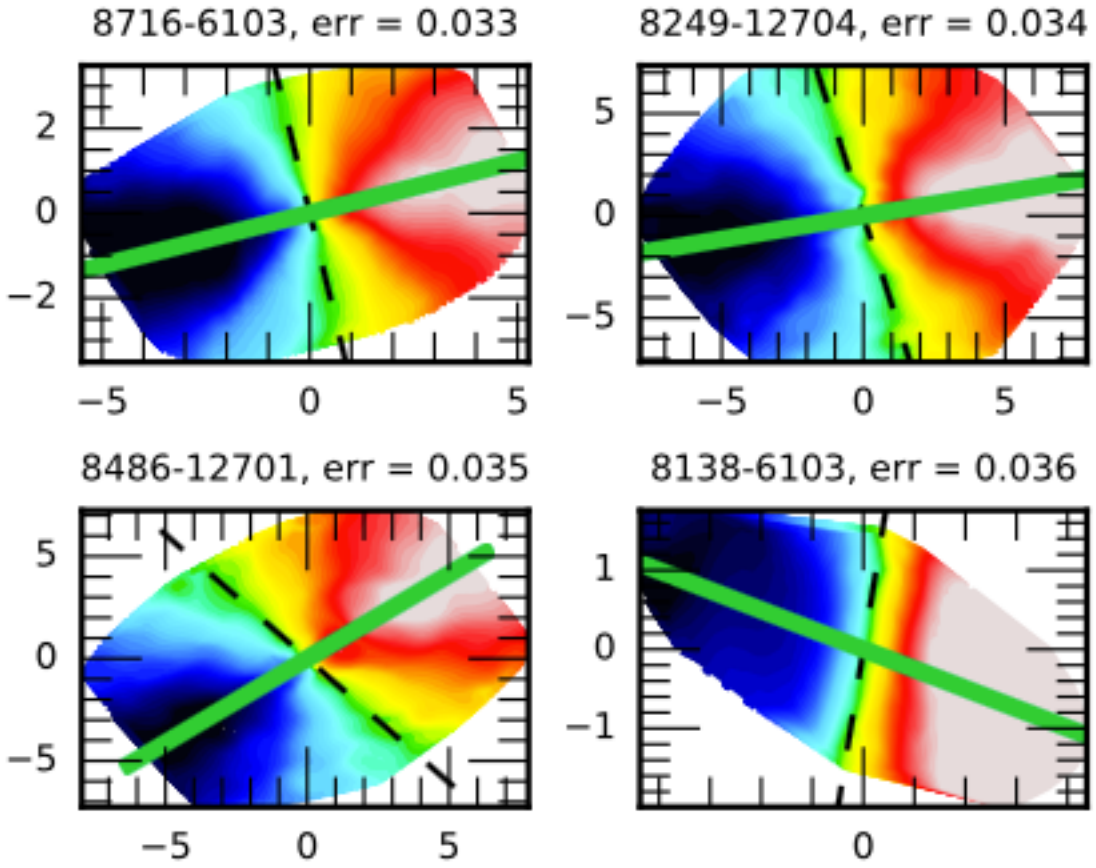
- The position angle is chosen to be the angle which minimizes the chi-square.
  $\sum_{n=1}^{N}(\frac{V'(x,y)-V(x,y)}{\Delta V(x,y)})^2$
- Repeating the above process on 100 random realizations of the data (assuming that the velocities follow a Gaussian distribution with error given by the velocity error).
- The PA is then obtained from the mean of these 100 separate runs, and the error is the standard deviation



Estimated gas velocity field from real data (left), Symmetric velocity field with minimized chi-square (right).

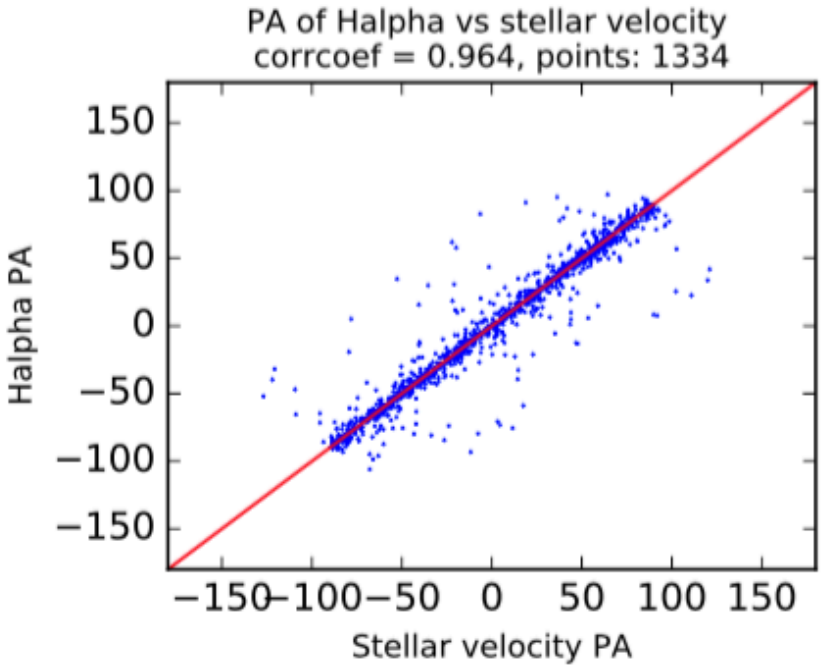
Some example plots

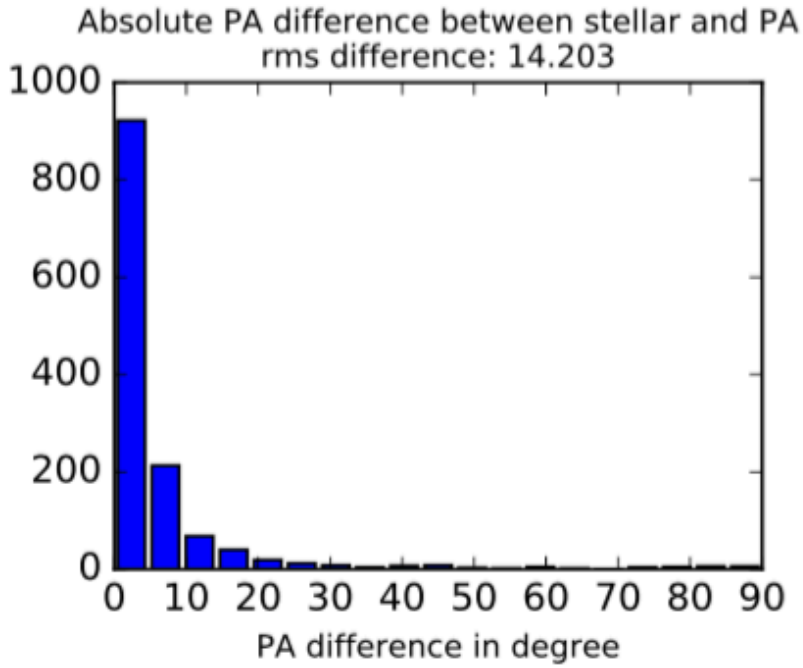
- Position angle (green line) and spin axis (dashed line) of each galaxy gas velocity field can then be drawn.



Gas vs Stellar components

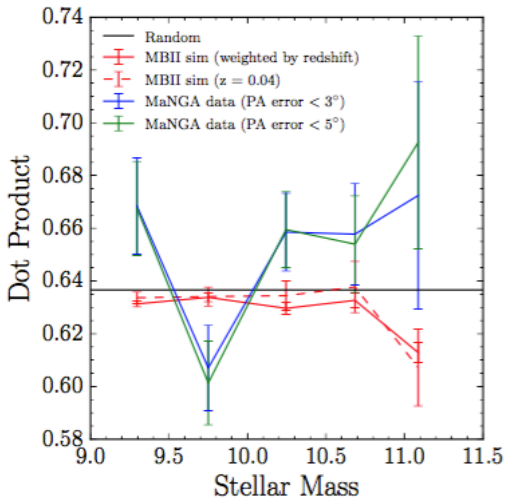
- In most galaxies, the gas PA agrees with the stellar PA.
- However, there are a number of galaxies with significantly misaligned stellar and gas rotation (>20^{o}).



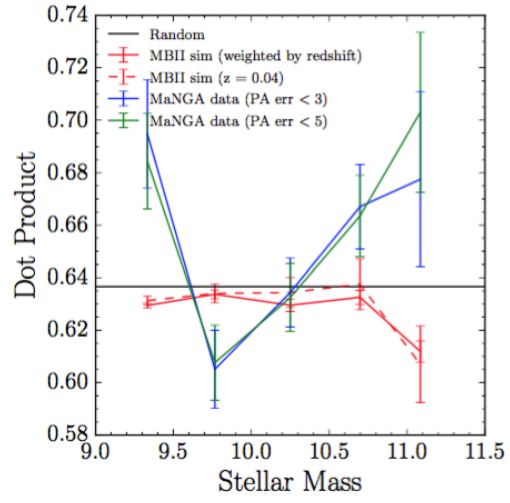


Gas vs Stellar components

	Misaligned	Well-aligned	Significance
Stellar Mass	$(4.09 \pm 0.50) \times 10^{10} M_{\odot}$	$(2.98 \pm 0.15) \times 10^{10} M_{\odot}$	2σ
Sersic Index	(4.07 ± 0.19)	(2.43 ± 0.05)	8σ
U-R color (relative flux)	(2.24 ± 0.05)	(1.98 ± 0.01)	5σ
Redshift	(0.0372 ± 0.0021)	(0.0406 ± 0.0006)	(same population)



Gas component (H-alpha)



Stellar component

Results and future work

- Similar to the result obtained from stellar velocity, the discrepancy between real data and theoretical predictions of alignment between galaxy spins and filaments is still significant.
- No existing theoretical model can explain the mass-dependent trend.

- Possible improvements:
  - Extend the range of PA to 360
  - Look into the error of filaments measurement

References

- Krajnović, D., Cappellari, M., de Zeeuw, P. T., & Copin, Y. 2006, MNRAS, 366, 787
- Freeke van de Voort, Timothy A. Davis, Duˇsan Kereˇs, Eliot Quataert, Claude-Andŕe Faucher-Gigu`ere, and Philip F. Hopkins, 2015, 451, 3269
- Zel’dovich, Y. B. 1970, A&A, 5, 84