

# Galaxy Kinematics

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MaNGA-CSST-IFS workshop

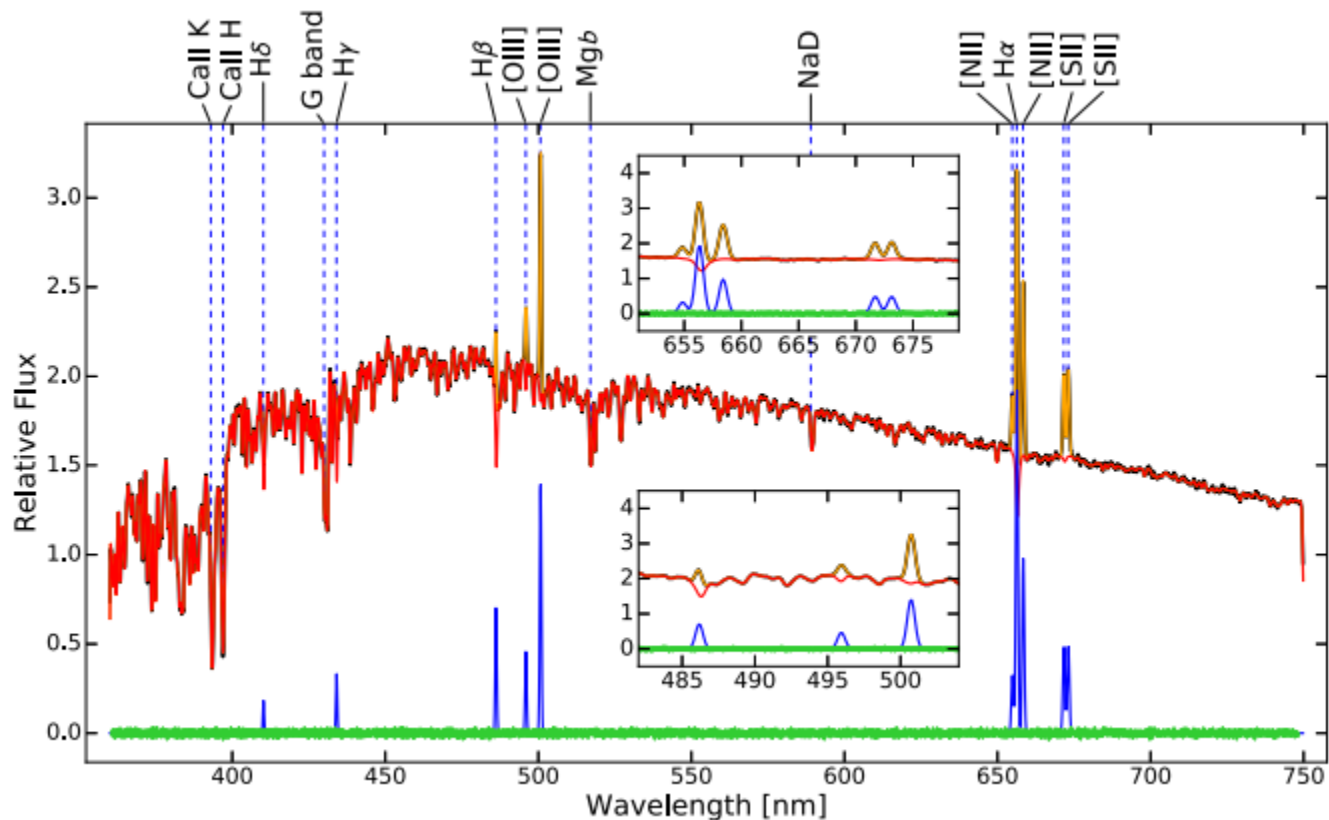
2019-05-24

# Contents

- Line of sight velocity distribution
- Kinematic data of MaNGA
- Several Science Topics

# Spectral Fitting

- Emission line  $\rightarrow$  ionized gas
- Absorption line  $\rightarrow$  stellar
- Observed spectra  $\sim$  template  $\ast$  LOSVD

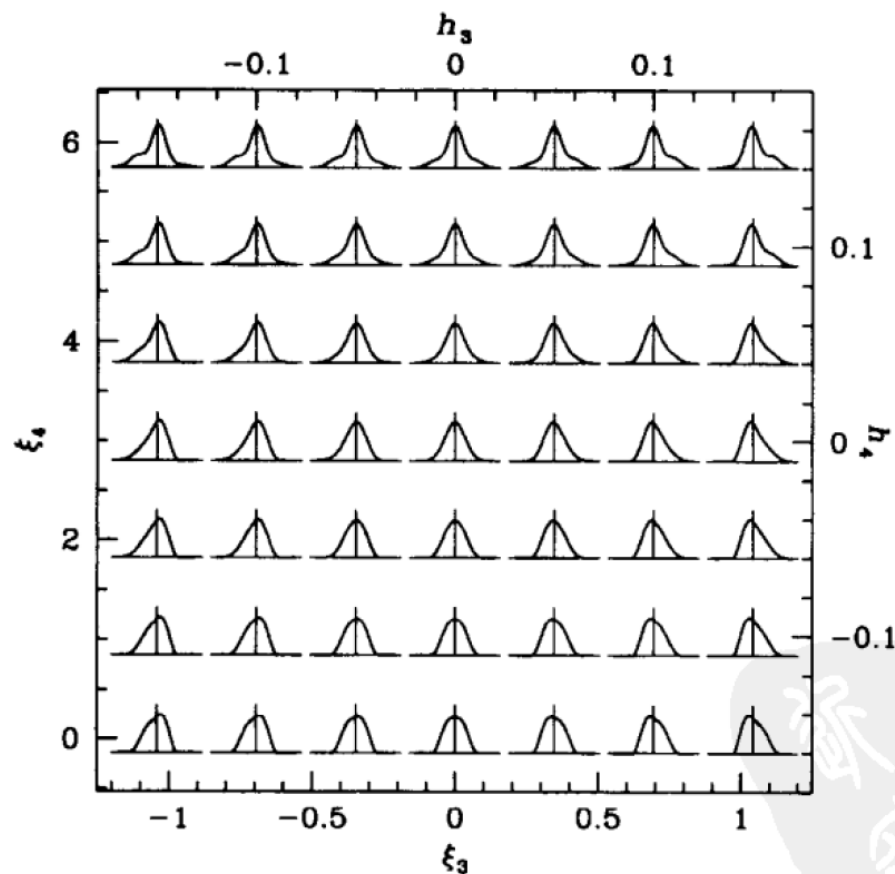
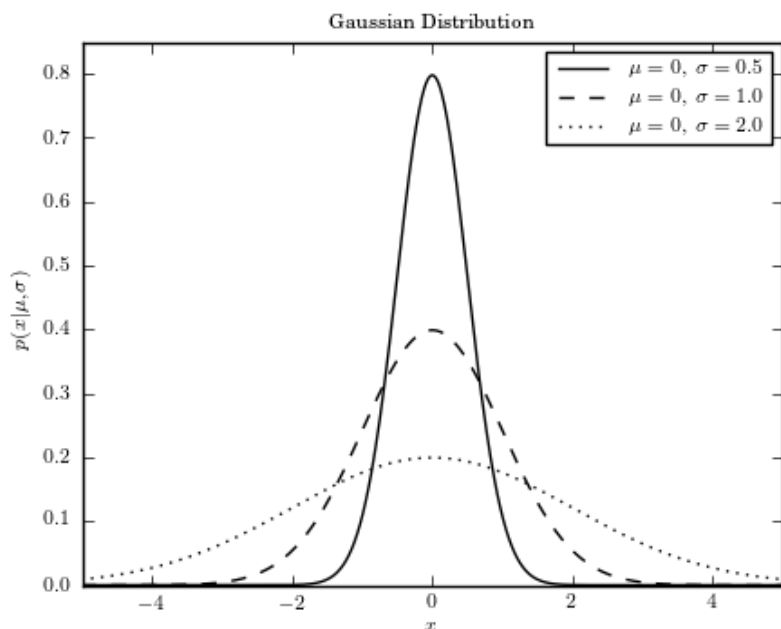


# Line Of Sight Velocity Distribution (LOSVD)

$$\mathcal{L}(y) = \frac{\exp(-y^2/2)}{\sigma\sqrt{2\pi}} \left[ 1 + \sum_{m=3}^M h_m H_m(y) \right]$$

Gerhard (1993)

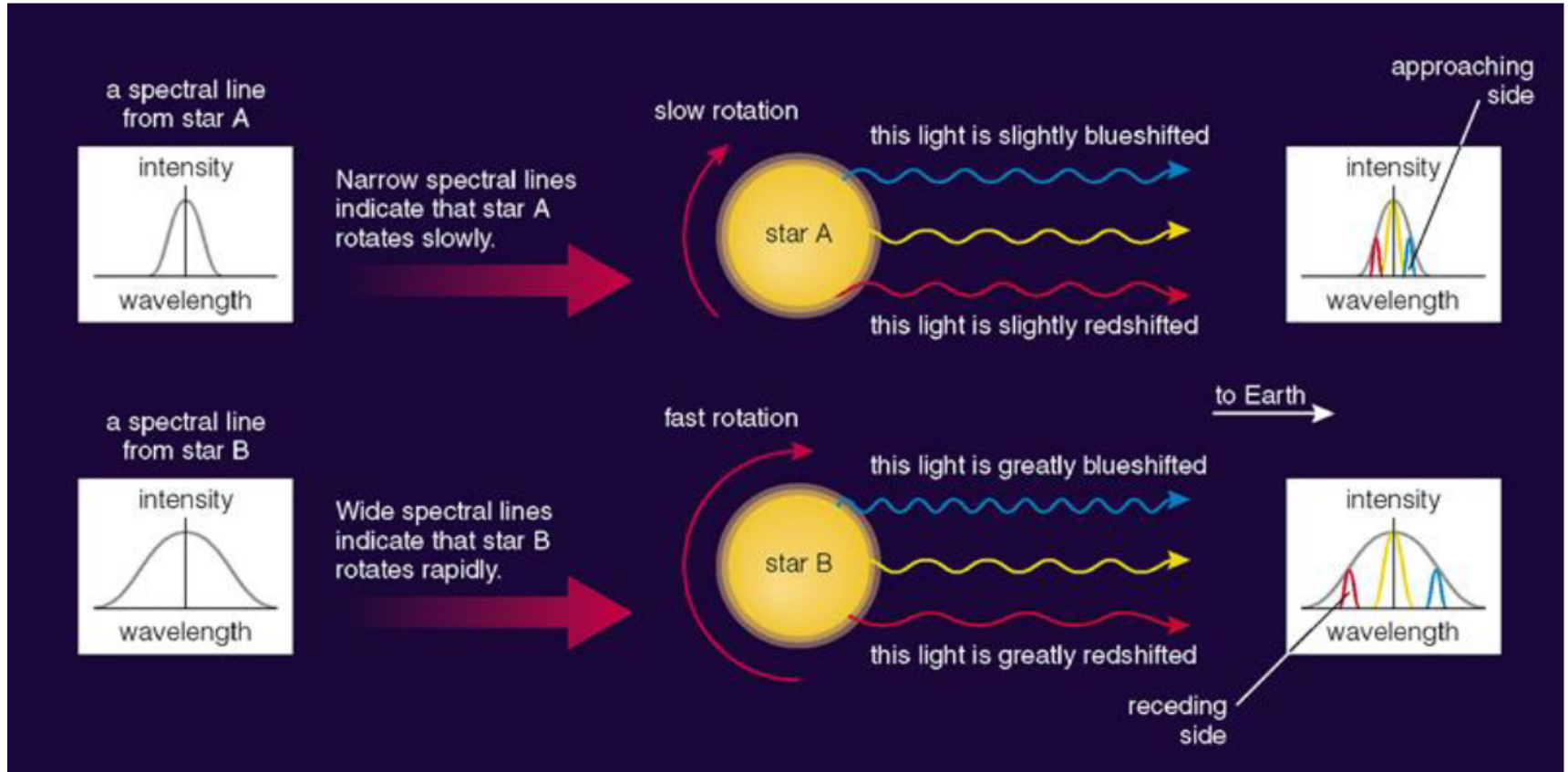
- $y$ , mean velocity
- $\sigma$ , velocity dispersion
- $h_3$ , skewness
- $h_4$ , kurtosis



Binney & Merrifield (1998)

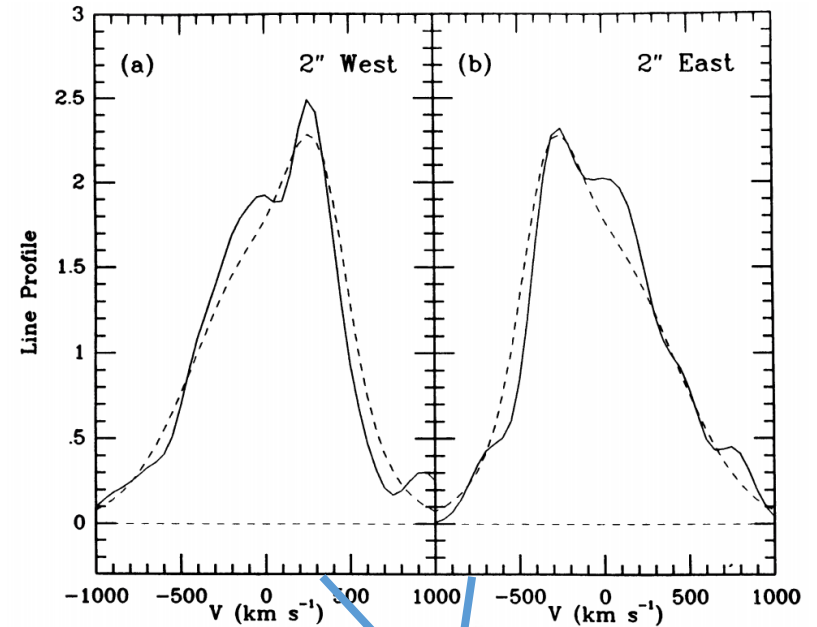
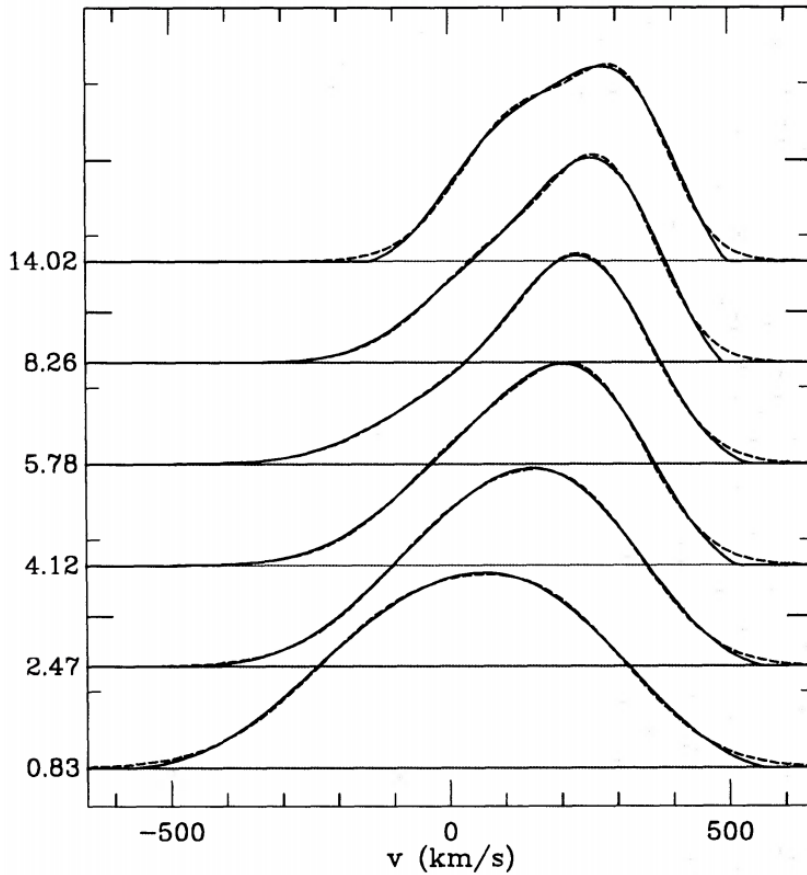


# Line Of Sight Velocity Distribution(LOSVD)



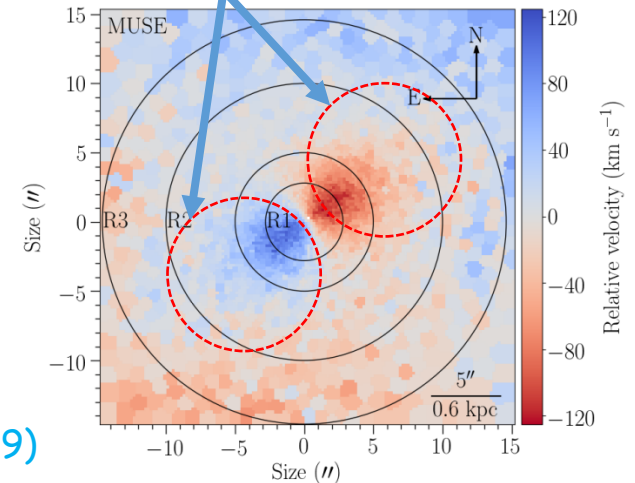
# Line Of Sight Velocity Distribution (LOSVD)

Cinzano et al. (1994)



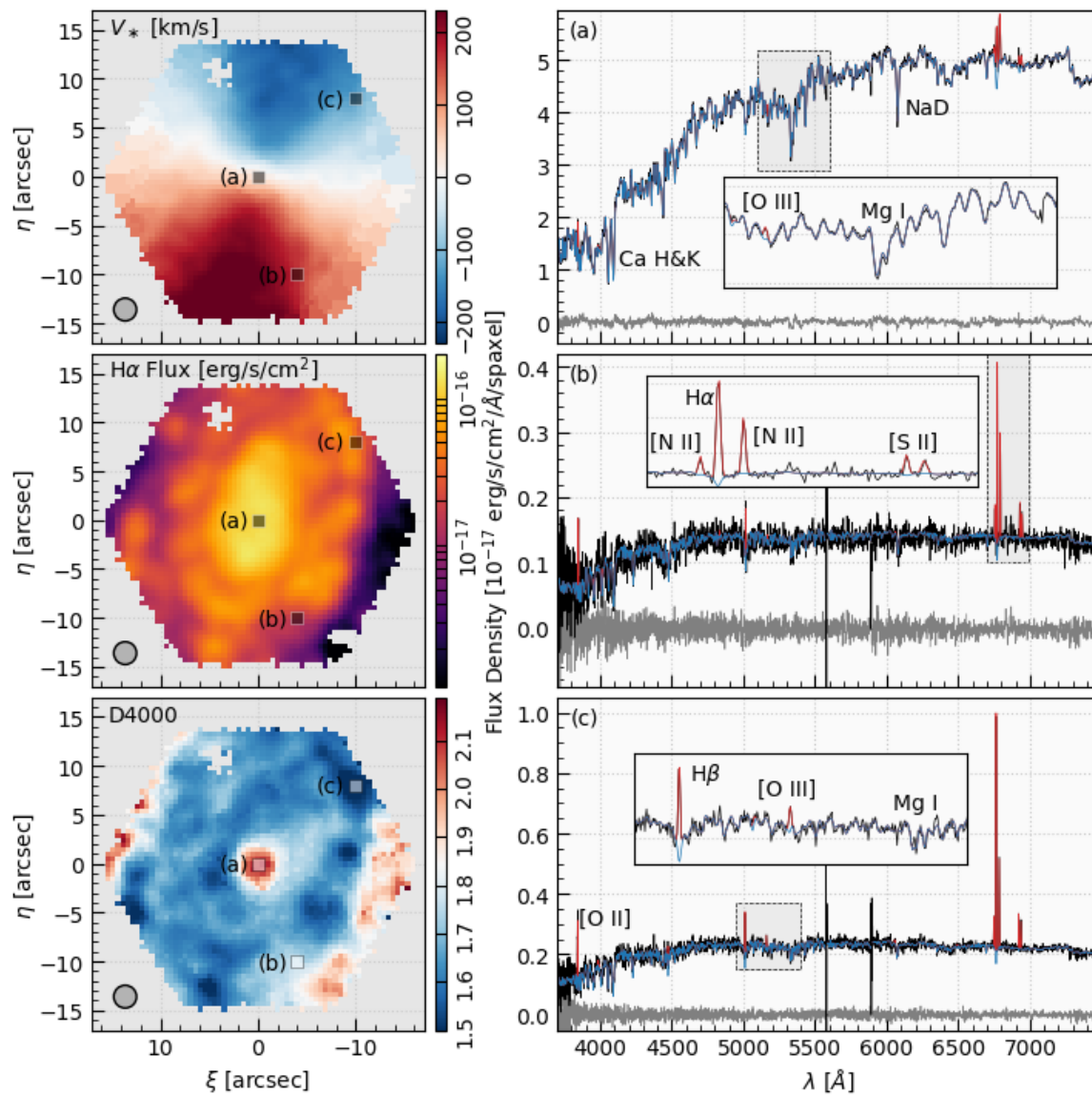
**IC 1459**

Franx et al. (1988)



Laura et al. (2019)

# MaNGA



# LOSVD of MaNGA DAP

15	STELLAR_VEL	1	km/s
16	STELLAR_VEL_IVAR	1	
17	STELLAR_VEL_MASK	1	
18	STELLAR_SIGMA	1	km/s
19	STELLAR_SIGMA_IVAR	1	
20	STELLAR_SIGMA_MASK	1	
21	STELLAR_SIGMACORR	1	km/s

35	EMLINE_GVEL	25	km/s
36	EMLINE_GVEL_IVAR	25	
37	EMLINE_GVEL_MASK	25	
38	EMLINE_GSIGMA	25	km/s
39	EMLINE_GSIGMA_IVAR	25	
40	EMLINE_GSIGMA_MASK	25	
41	EMLINE_INSTSIGMA	25	km/s
42	EMLINE_TPLSIGMA	25	km/s

Line-of-sight emission-line velocity, relative to the input guess redshift (given as `cz` in `SCINPVEL PRIMARY` header keyword and most often identical to the NSA redshift). A velocity is provided for each line, **but the velocities are identical for all lines** because the parameters are tied during the fitting process.

# LOSVD of MaNGA DAP

Gaussian profile velocity dispersion as would be measured from a direct Gaussian fit (**must be corrected** using EMLINE\_INSTSIGMA to obtain the astrophysical dispersion). **The velocity dispersions of the [OII], [OIII], [OI], [NII], [NI] and (H-zeta + HeI 3889) lines are tied and cannot be treated as independent measurements.**

The corrected gas velocity dispersion is:

$$\text{sigma\_gas\_corr} = \text{sqrt}(\text{EMLINE\_GSIGMA}^2 - \text{EMLINE\_INSTSIGMA}^2)$$

The corrected stellar velocity dispersion is:

$$\text{sigma\_star\_corr} = \text{sqrt}(\text{STELLAR\_SIGMA}^2 - \text{STELLAR\_SIGMACORR}^2)$$

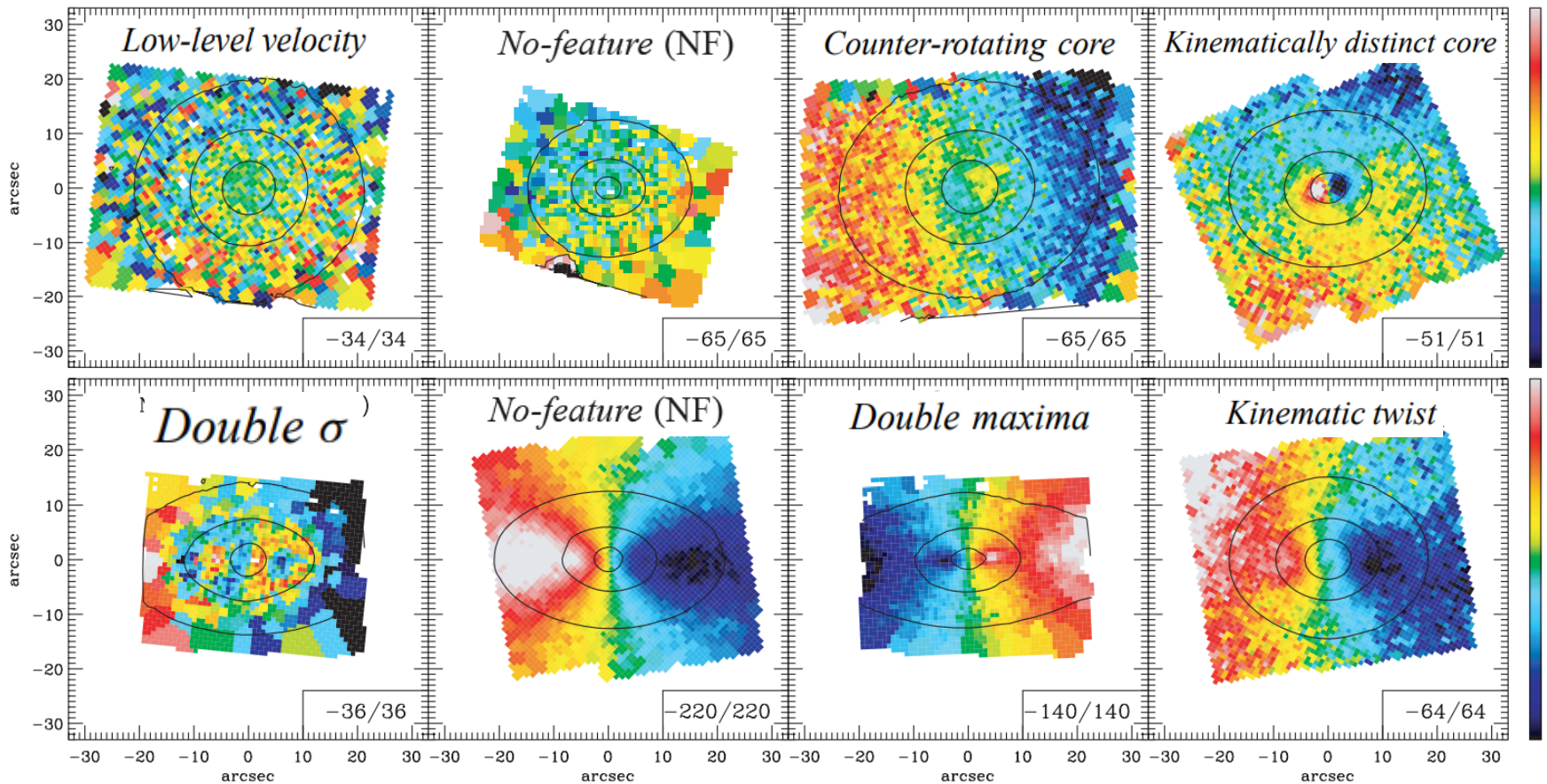
- Kinematics should smoothly vary between adjacent spaxels
- All velocities are statistically well behaved, except possibly at  $S/N < 5$  for  $\sigma \sim \sigma_{\text{inst}}/2$
- Be aware of the *distribution* of  $\sigma$  at a given radius or surface brightness when assessing the data.
- Don't trust single  $\sigma$  measurements at  $S/N < 5$ , only use them to understand the error distribution
- Systematic errors in individual  $\sigma$  become appreciable at:
  - $S/N < 20$  for  $\sigma \sim \sigma_{\text{inst}}/2$  ( $\sim 35$  km/s)
  - $S/N < 10$  for  $\sigma \sim \sigma_{\text{inst}}$  ( $\sim 70$  km/s)

# Science Topic

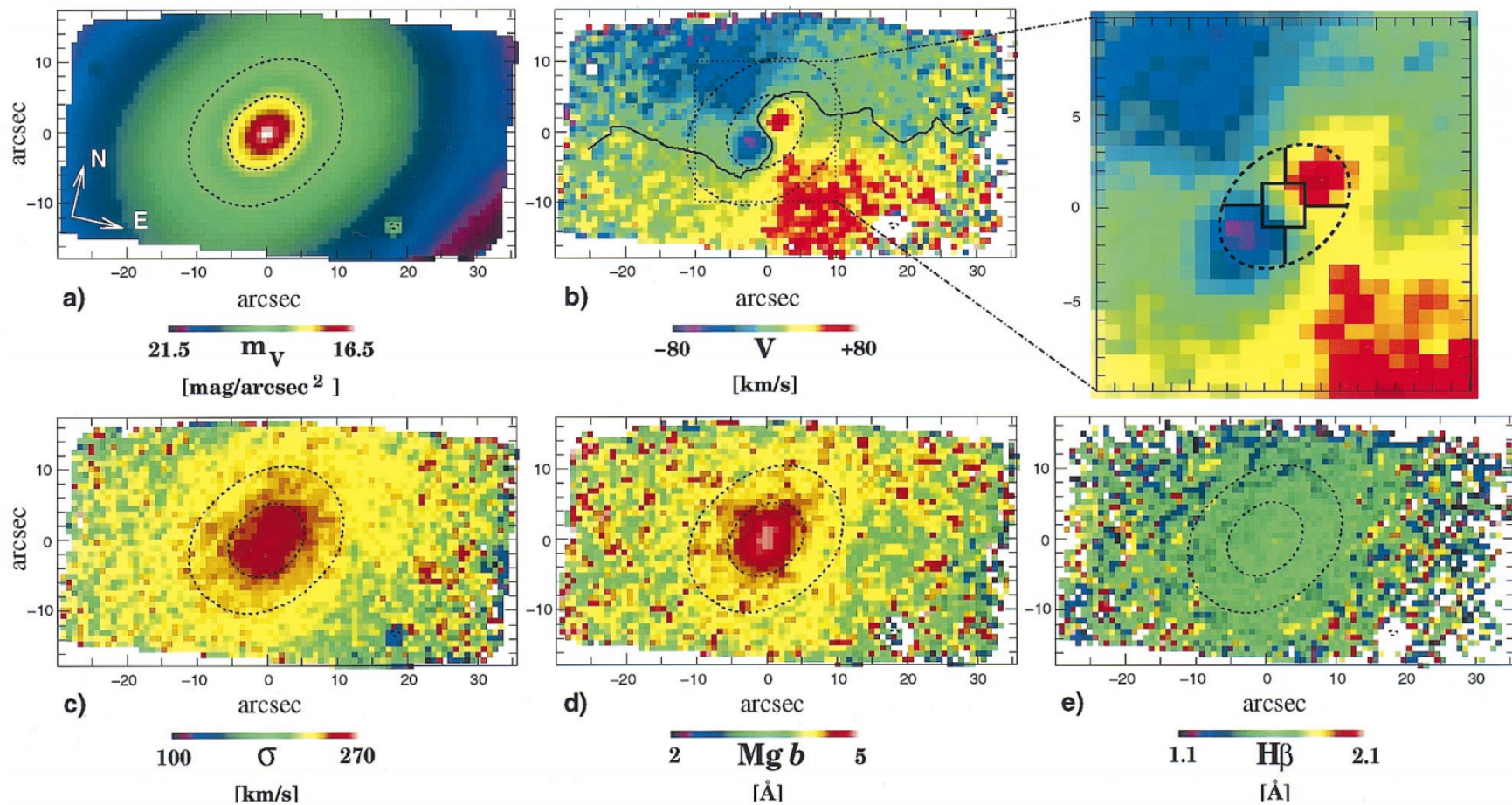
- Special cases of kinematic field
- Rotation curve & Spin & Angular Momentum
- Inflow & Outflow & Galactic Wind
- Galaxy-Galaxy Interaction



# Classification of Stellar Kinematic



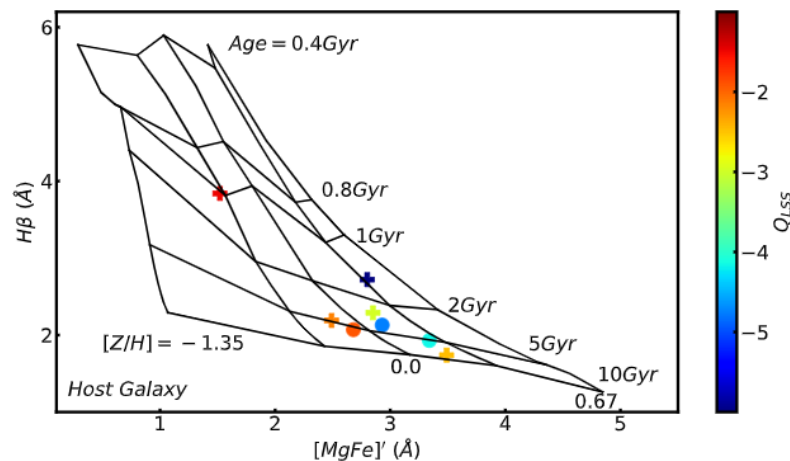
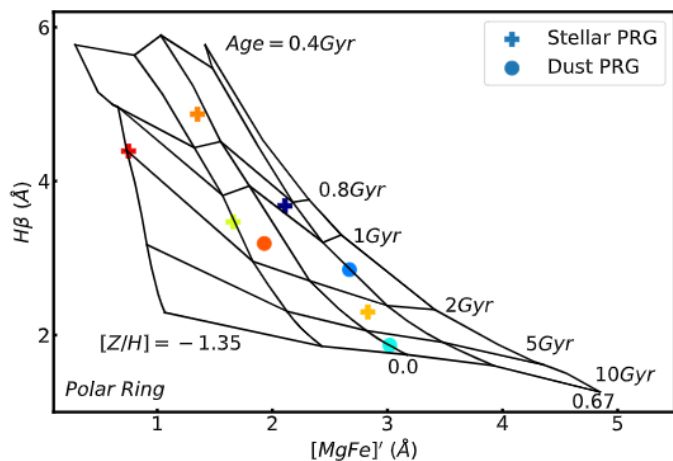
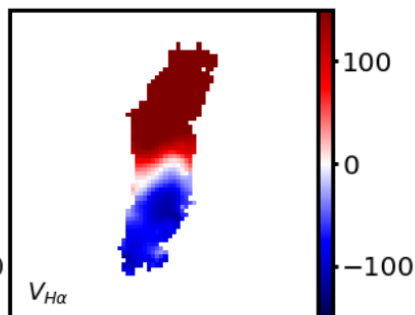
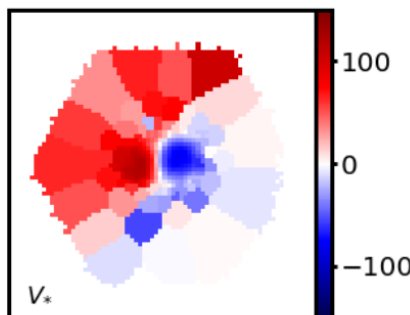
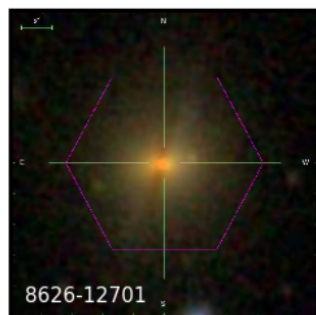
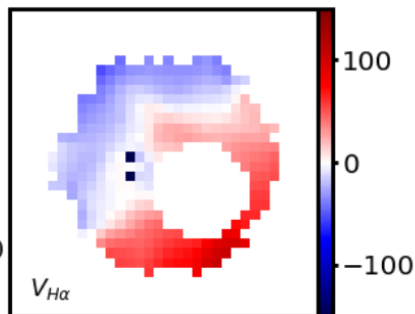
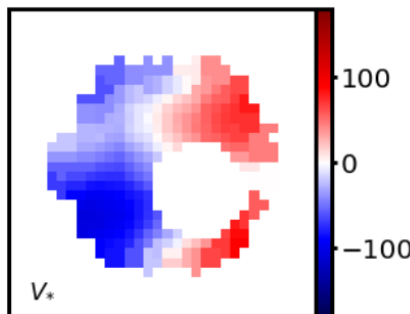
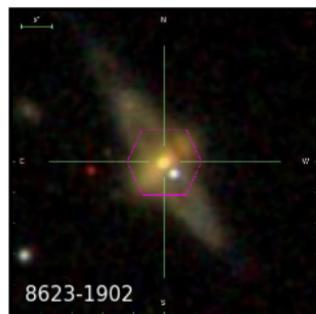
# Kinematic Decouple Core



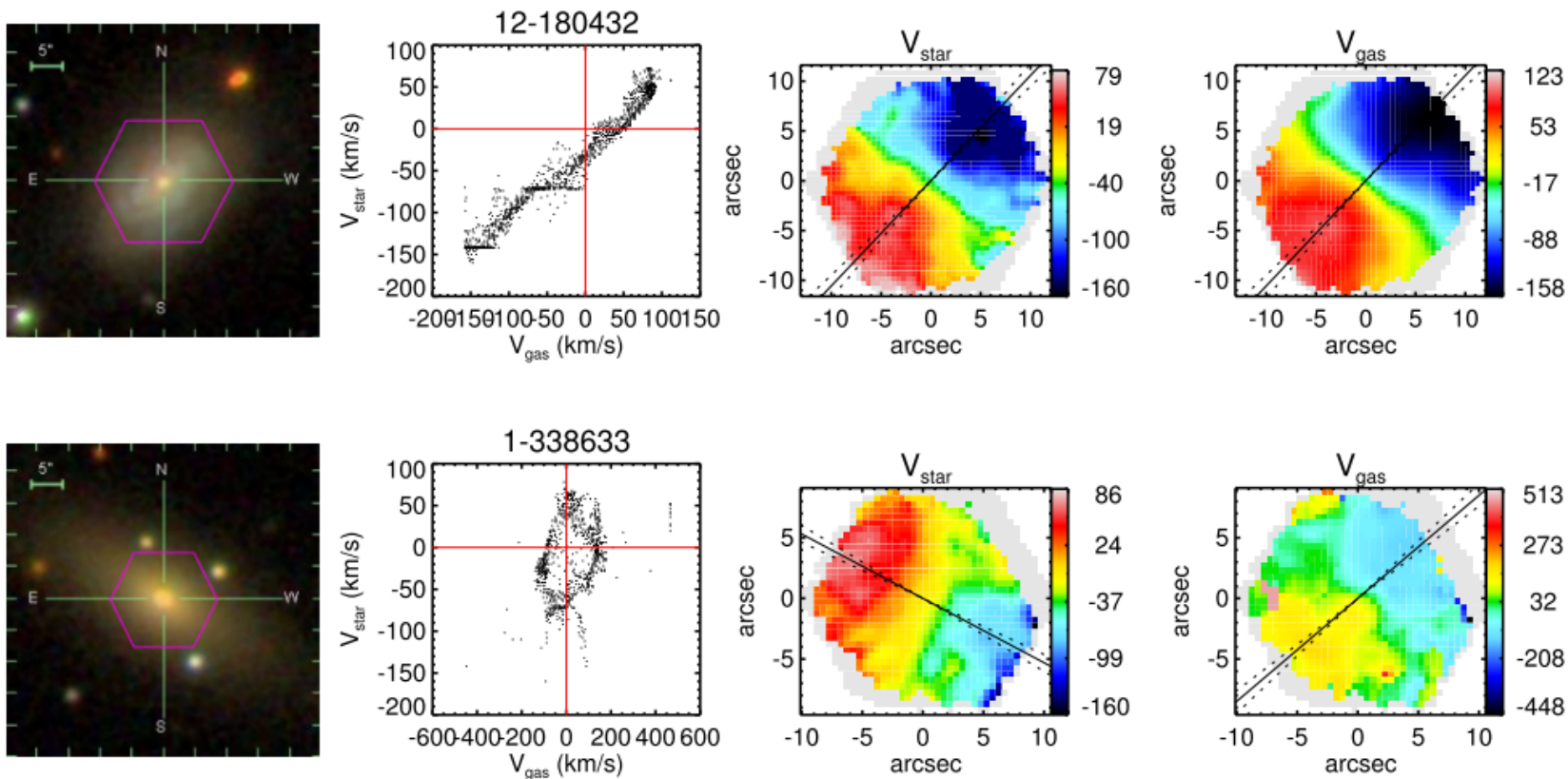


# Polar Ring Galaxy

Feng et al. in prep

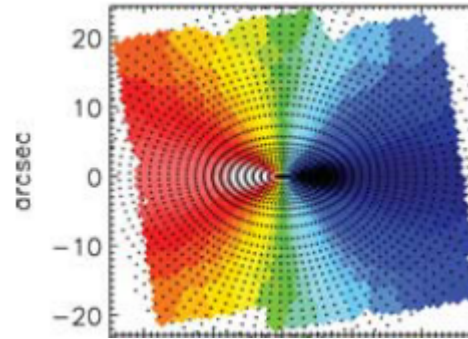


# Gas-Stellar Misalignment



# Kinematics

Krajnovic et al. (2006)

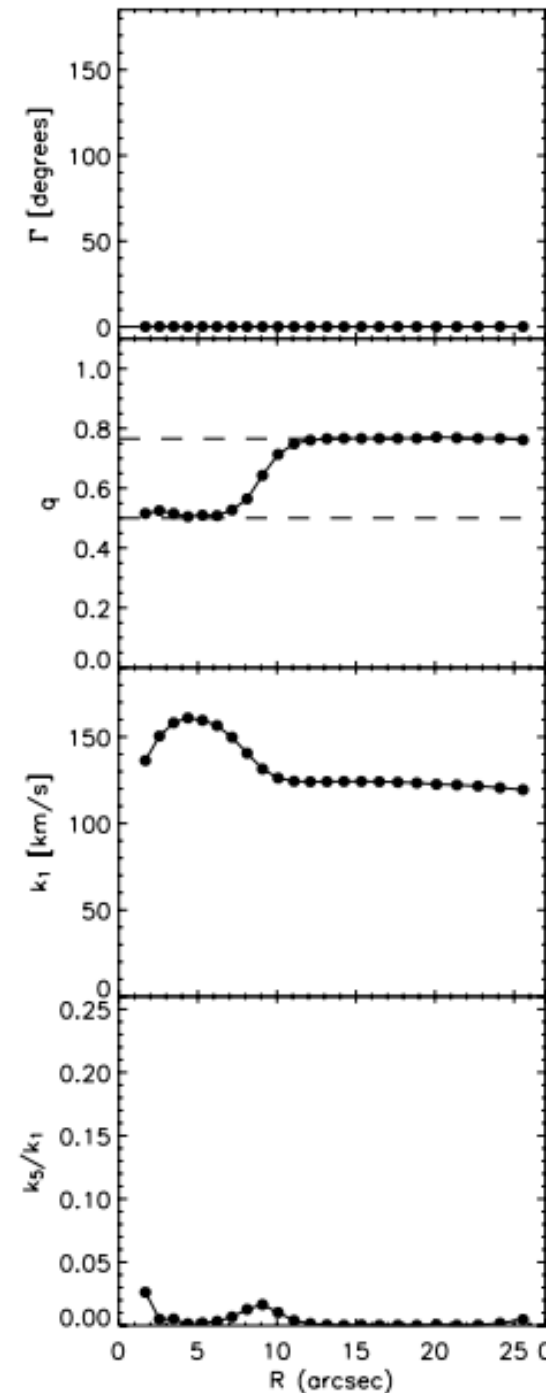


- Modeling kinematic maps as a sequence of concentric ellipses

$$V(R, \psi) = V_0 + V_c(R) \sin i \cos \psi,$$

- For each ellipse, the kinematic moment is extracted and decomposed into the Fourier series

$$K(a, \psi) = A_0(a) + \sum_{n=1}^N A_n(a) \sin(n\psi) + B_n(a) \cos(n\psi),$$



# Quantify Kinematic Asymmetry

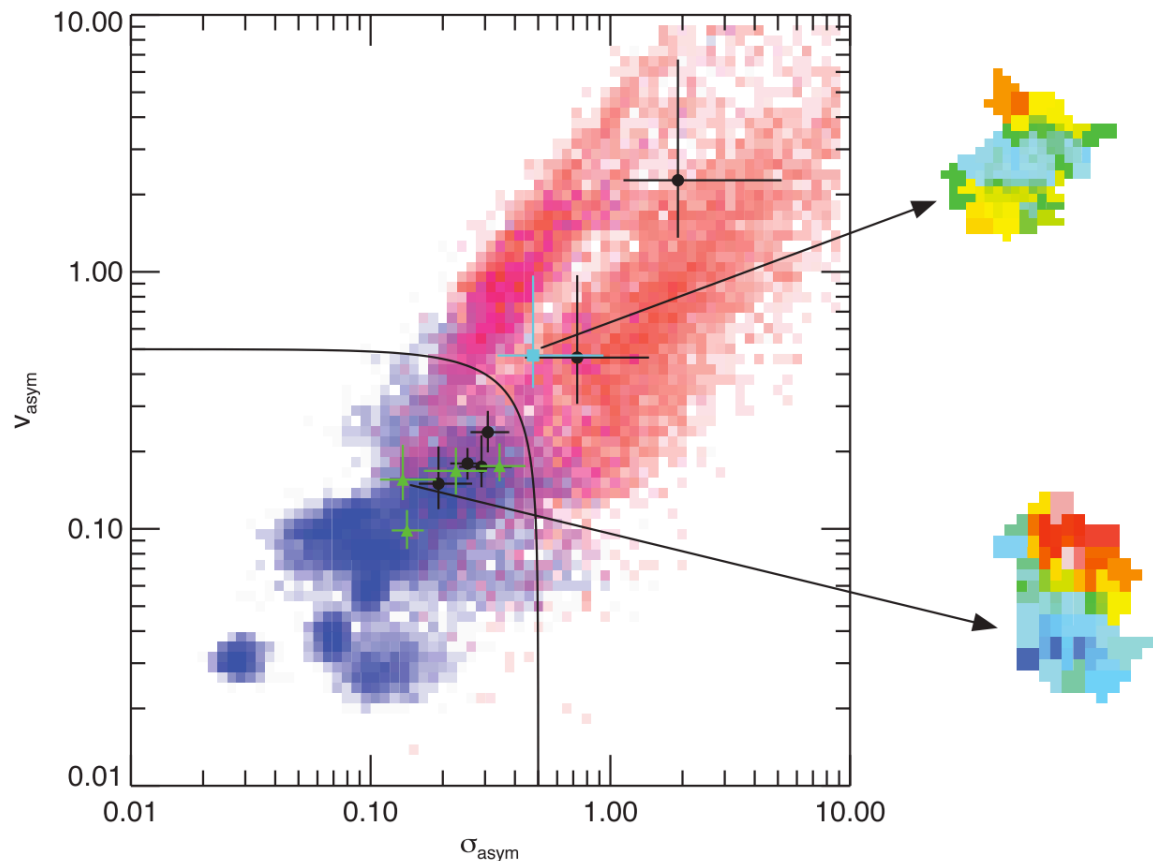
- Radial kinematic asymmetry value of velocity and velocity dispersion field

$$v_{\text{asym}} = \frac{k_{3,v} + k_{5,v}}{2k_{1,v}}$$

$$\sigma_{\text{asym}} = \frac{k_{2,\sigma} + k_{4,\sigma}}{2k_{1,v}}$$

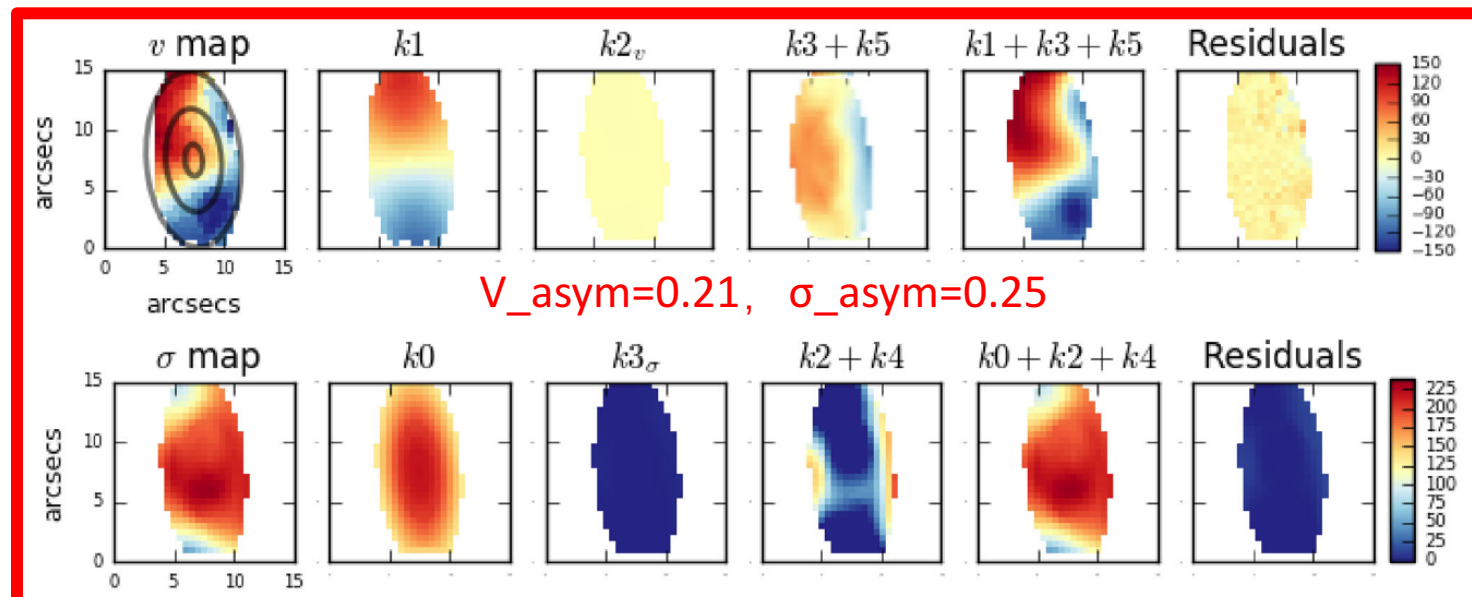
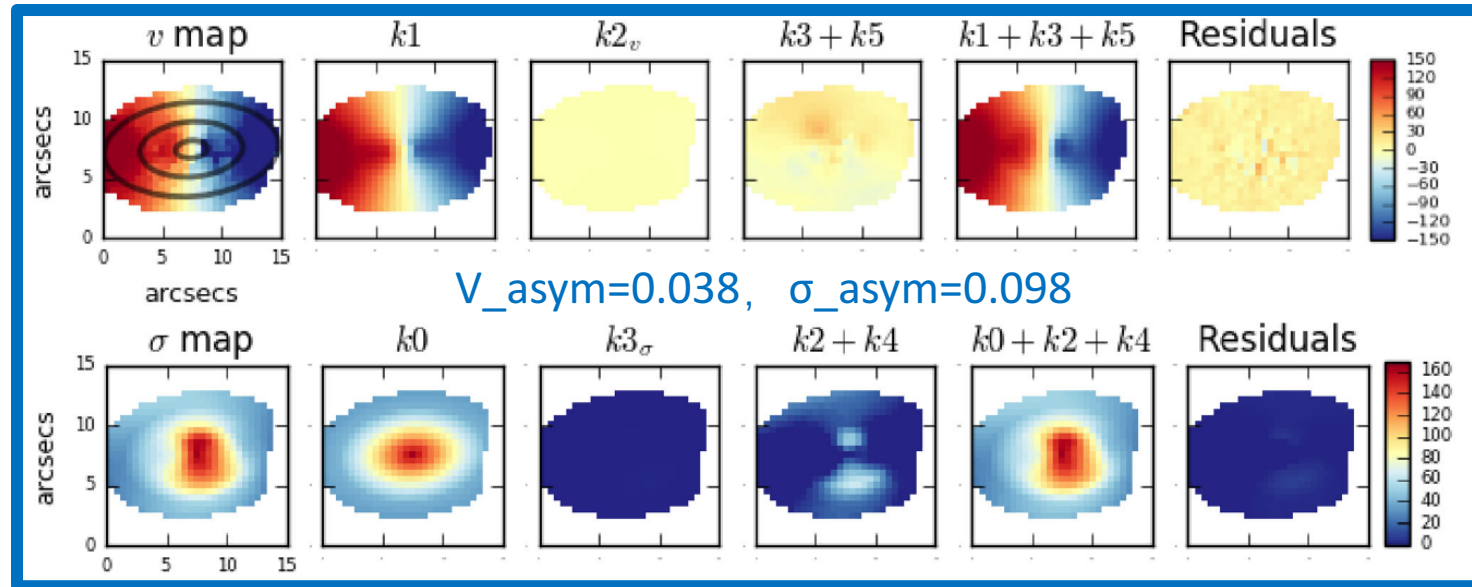
$$k_n = \sqrt{A_n^2 + B_n^2}$$

Shapiro et al. (2008)



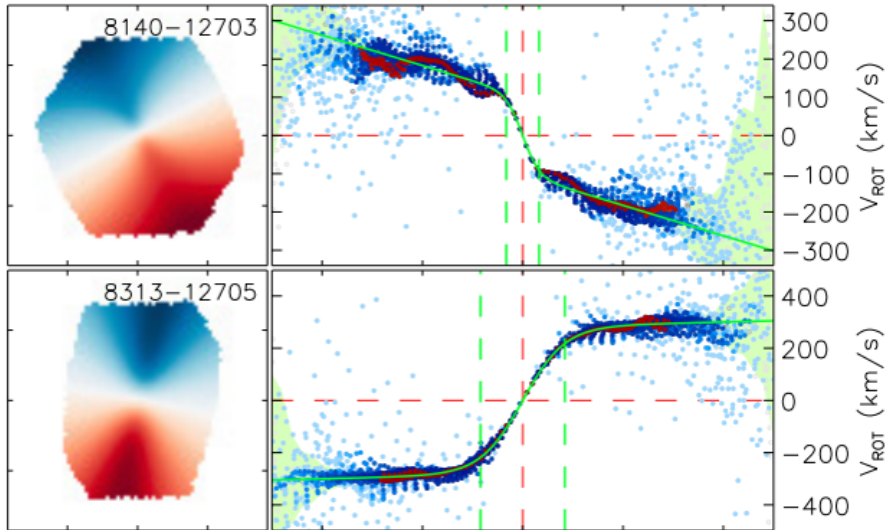
# Kinematic Asymmetry

Bloom et al. (2017)

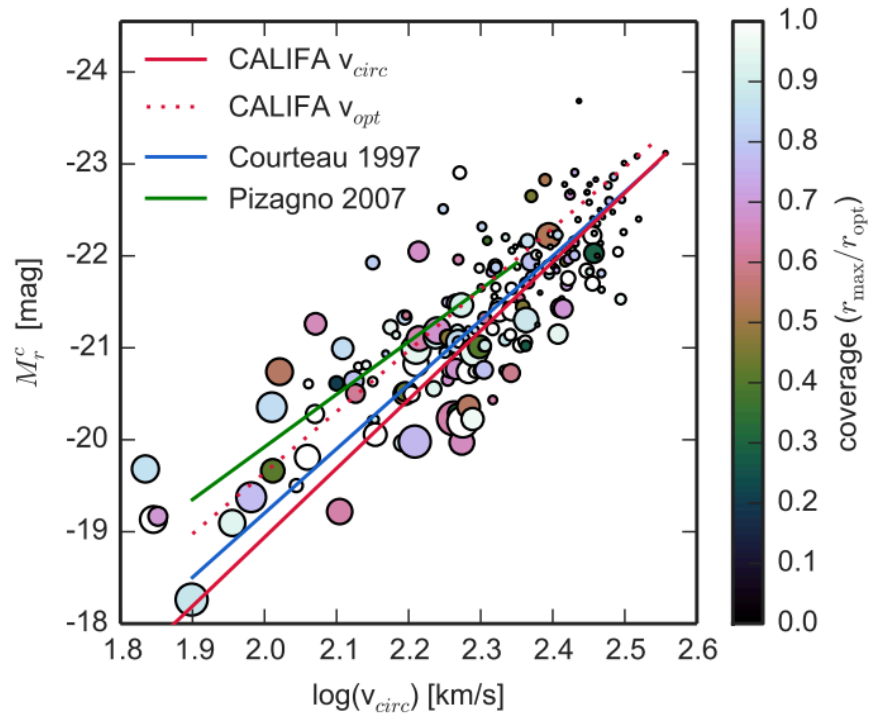


# Rotation Curve

Chung et al. (2018)

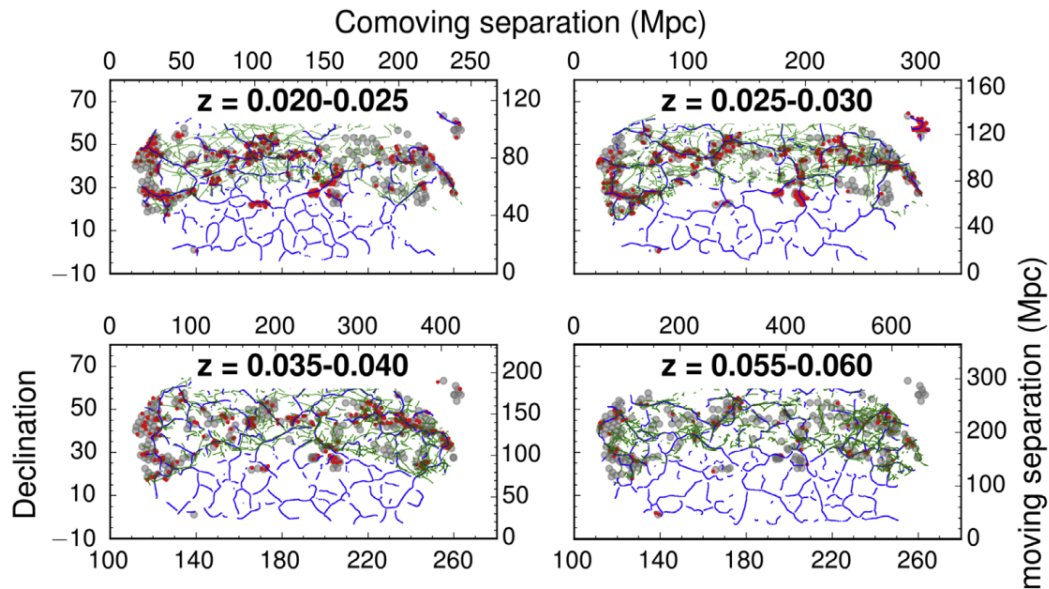
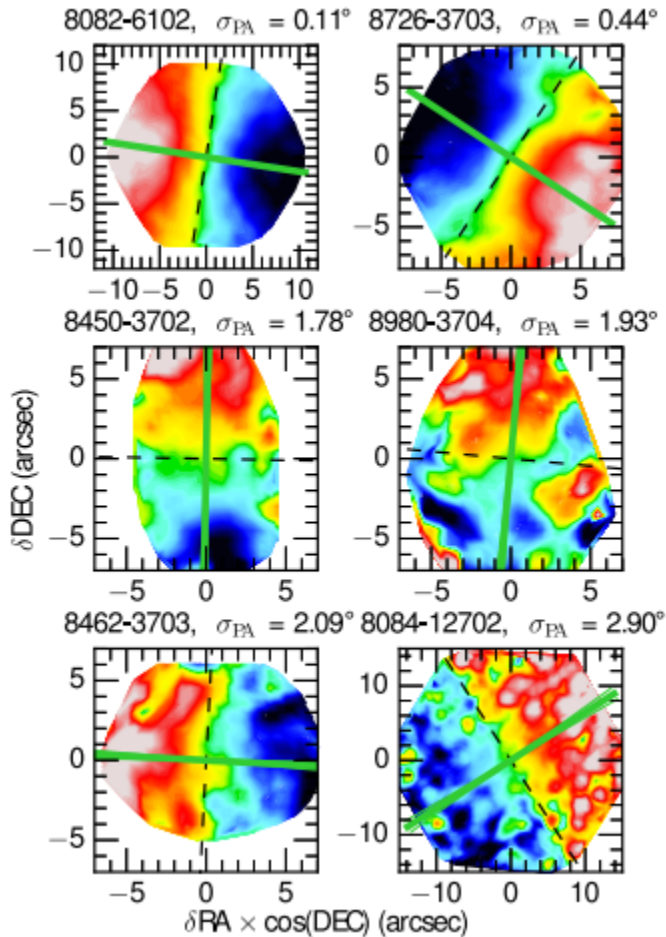


Bekeraite et al. (2016)

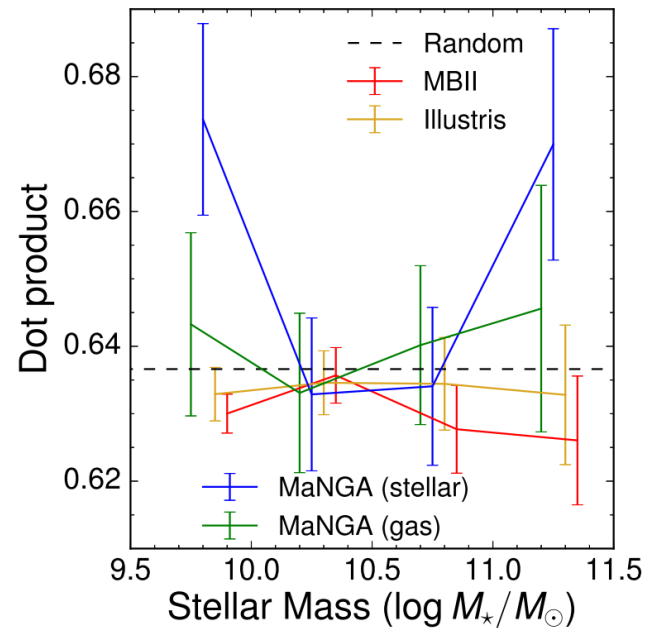




# Spin Axis



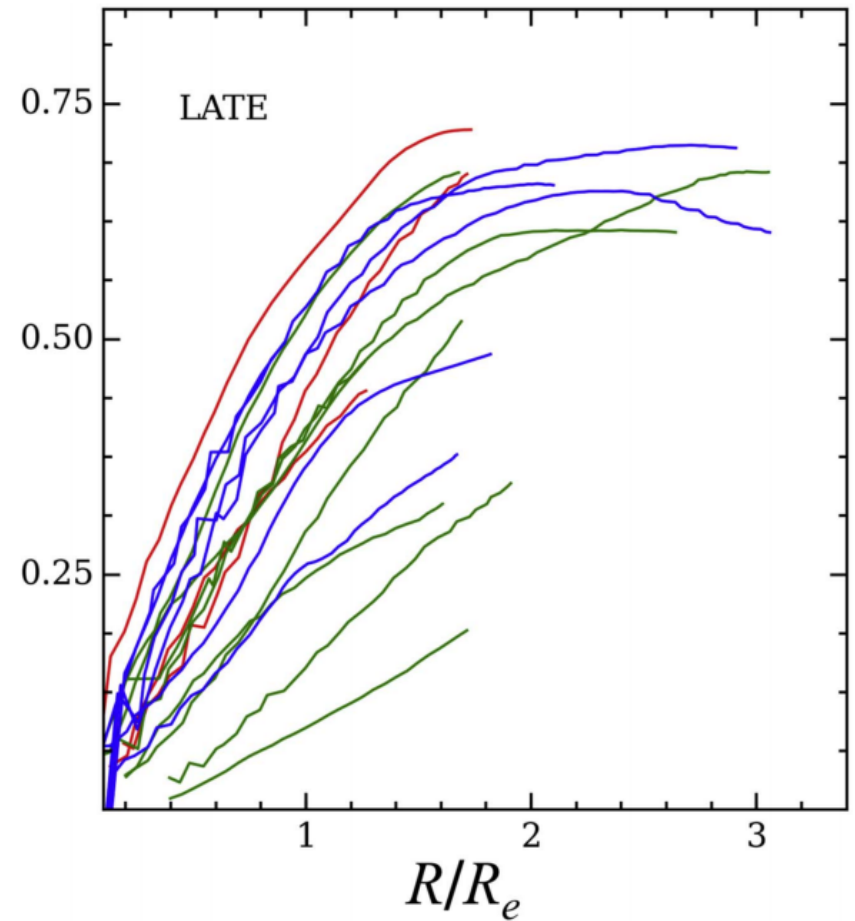
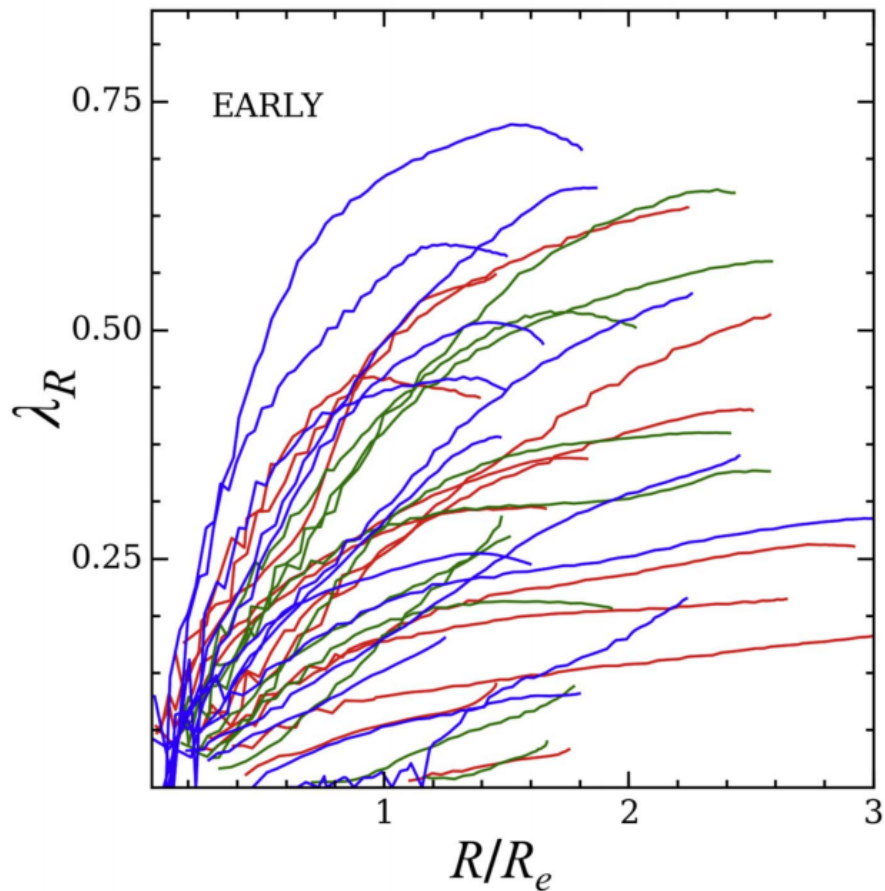
Krolewski et al. (2018)



# Angular Momentum

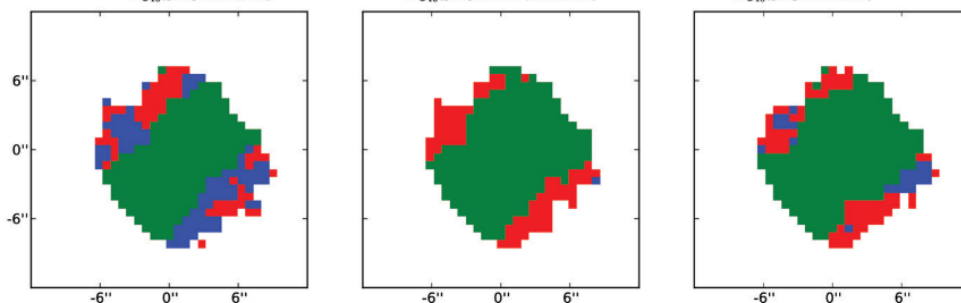
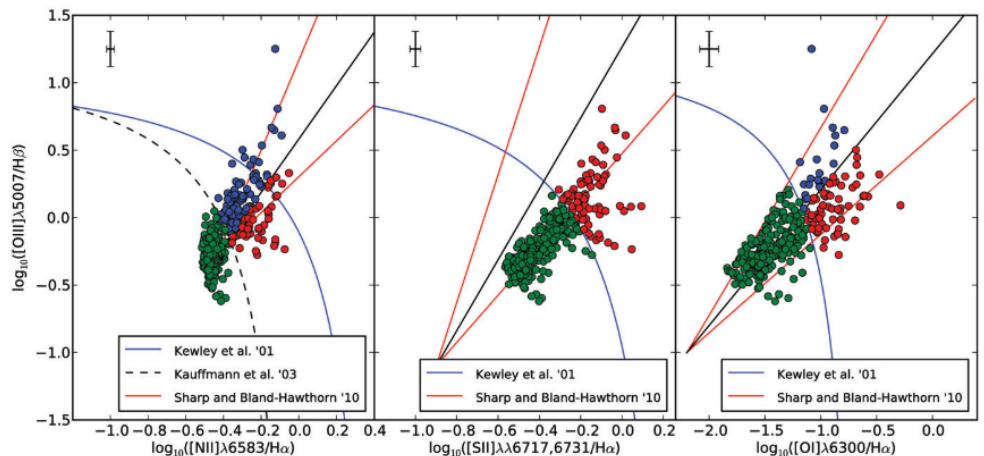
$$\lambda_R = \langle R|V| \rangle / \langle R\sqrt{V^2 + \sigma^2} \rangle.$$

Greene et al. (2018)

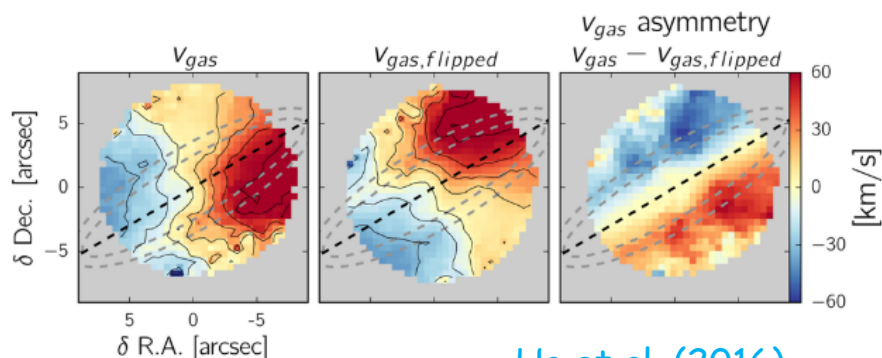
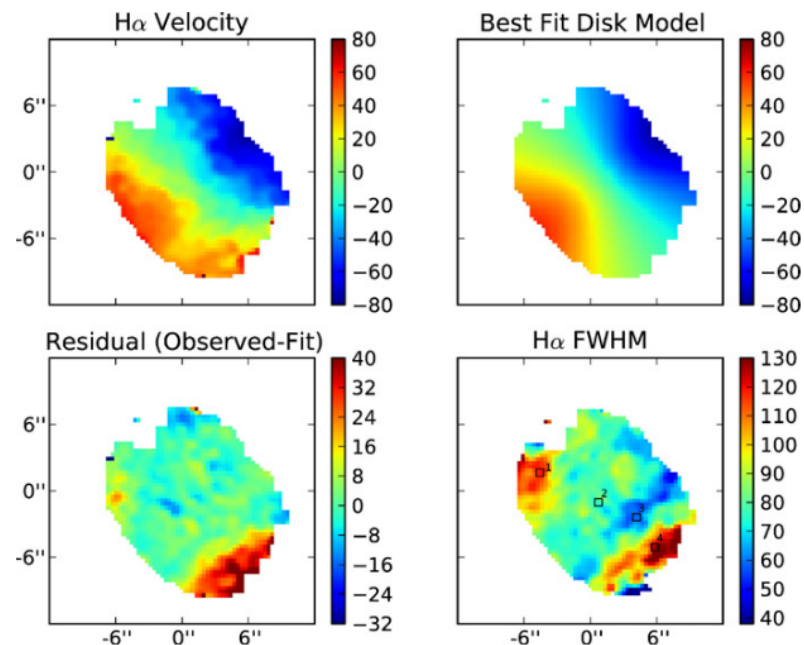
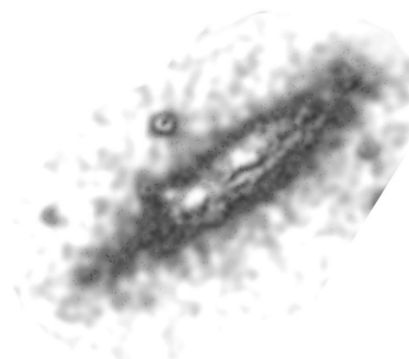




# Galactic Wind

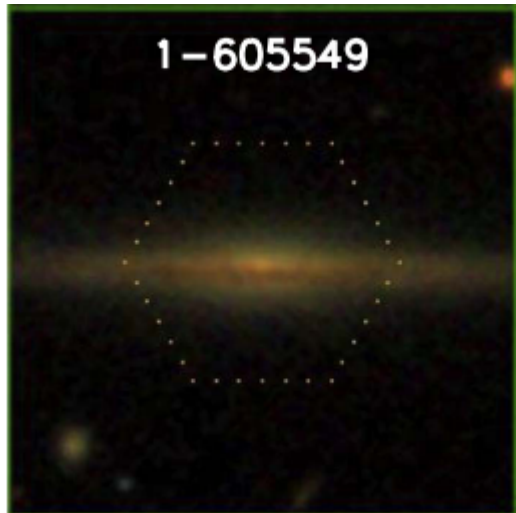


Fogarty et al. (2017)

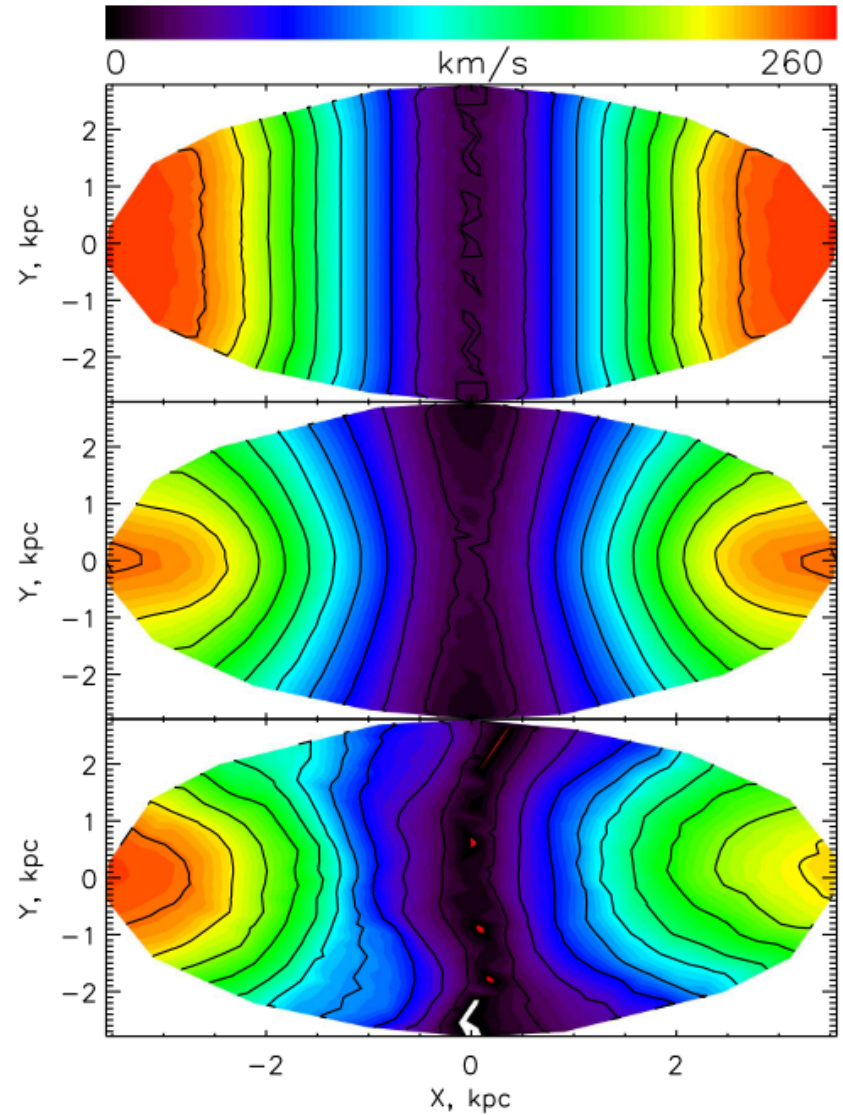


Ho et al. (2016)

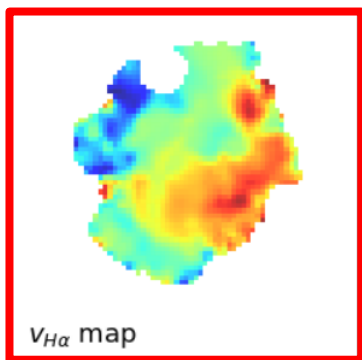
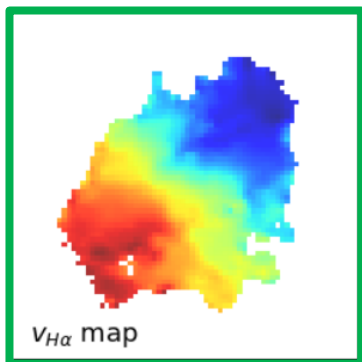
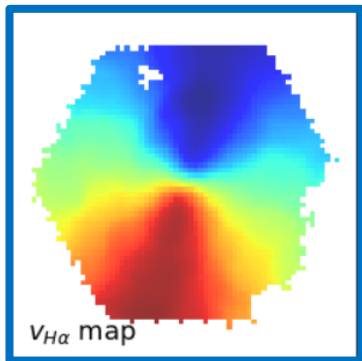
# Accretion of Gas?



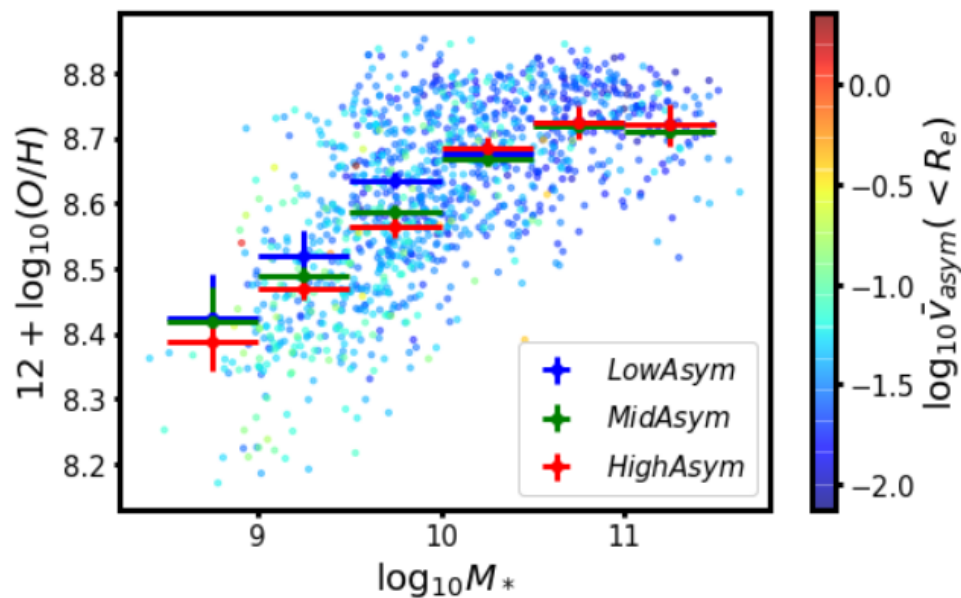
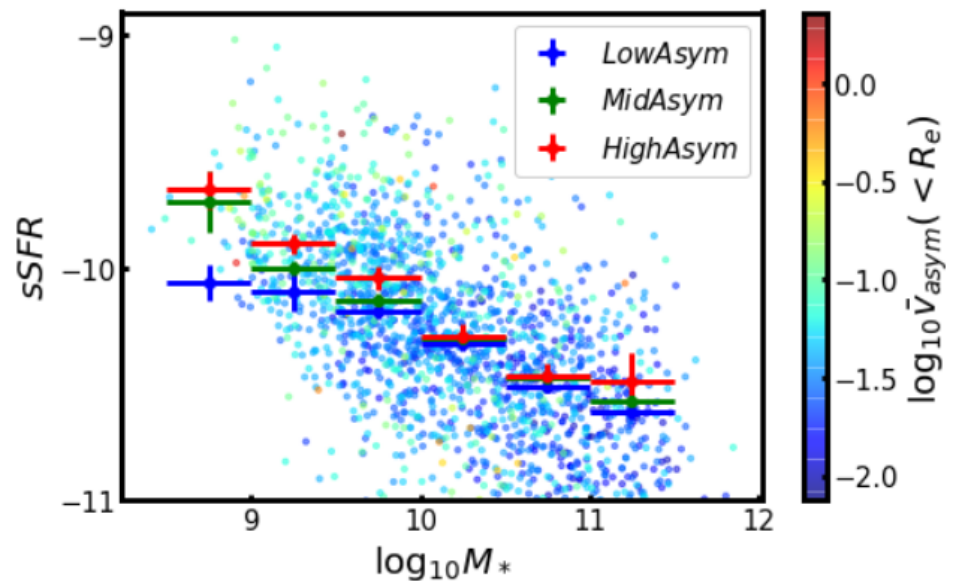
Bizyaev et al. (2017)



# Inflow

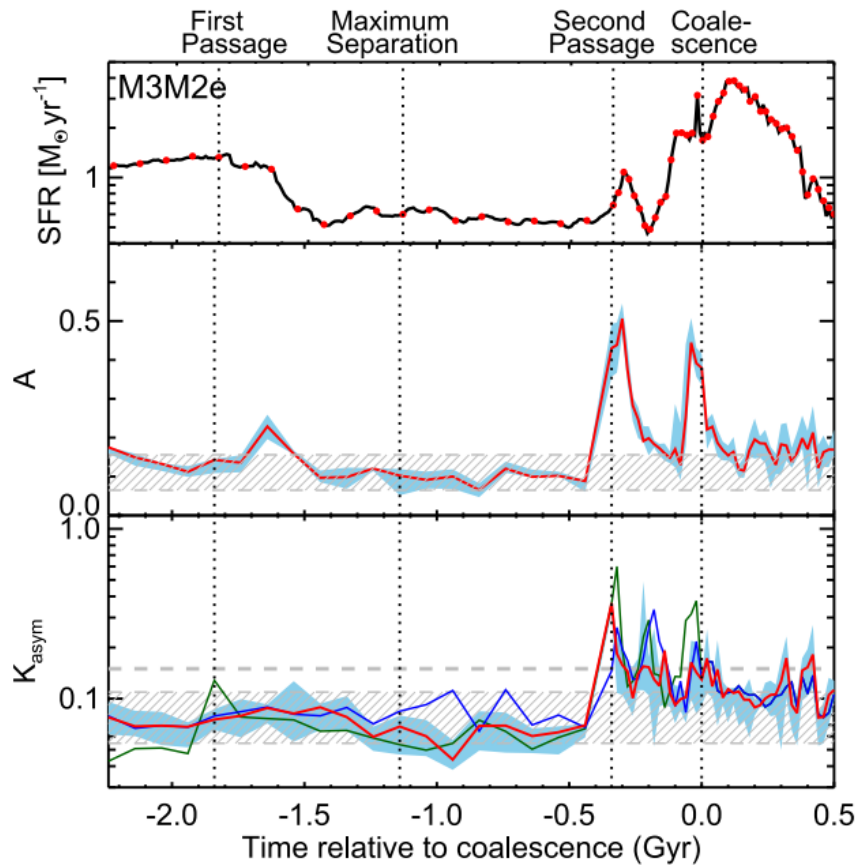


$$v_{\text{asym}} = \frac{k_{3,v} + k_{5,v}}{2k_{1,v}}$$



Feng et al. in prep

# Galaxy-Galaxy Interaction



Hung et al. (2016)

