Constraining dark matter content of galaxies: combining stellar kinematics and integrated HI spectrum

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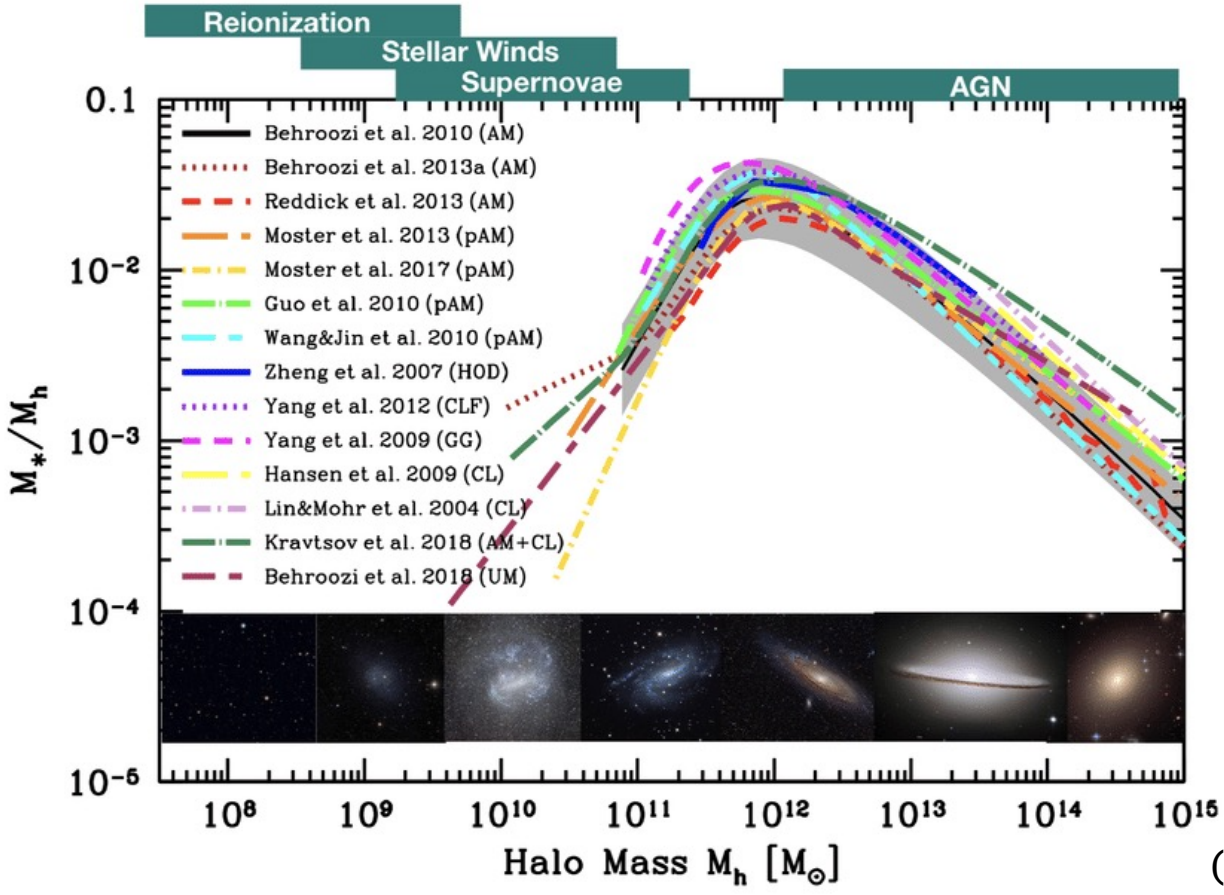
Introduction

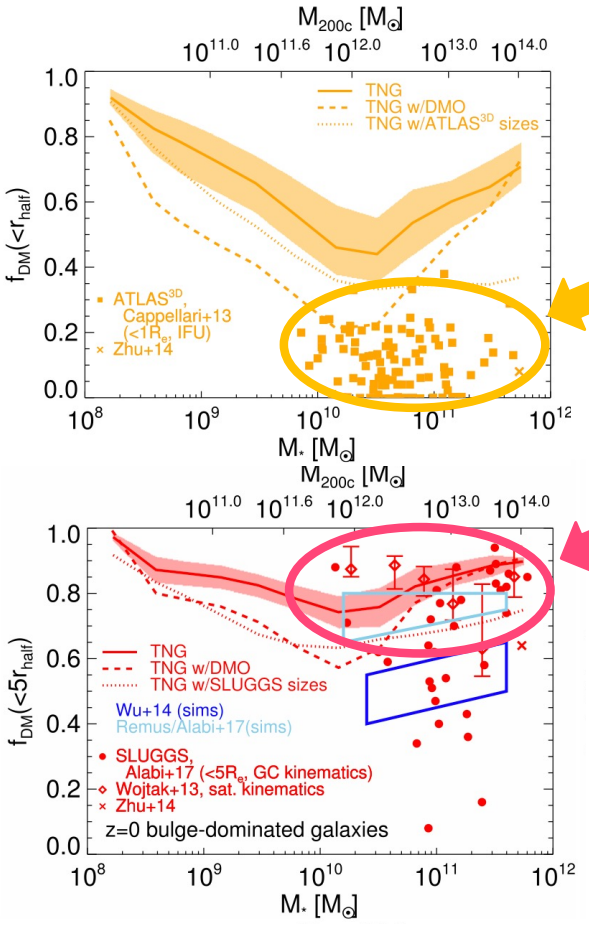
Stellar-to-halo mass relation



(Wechsler & Tinker 2018)

The total mass of the halo (M_h) can't directly get from observation!

Dark matter fraction

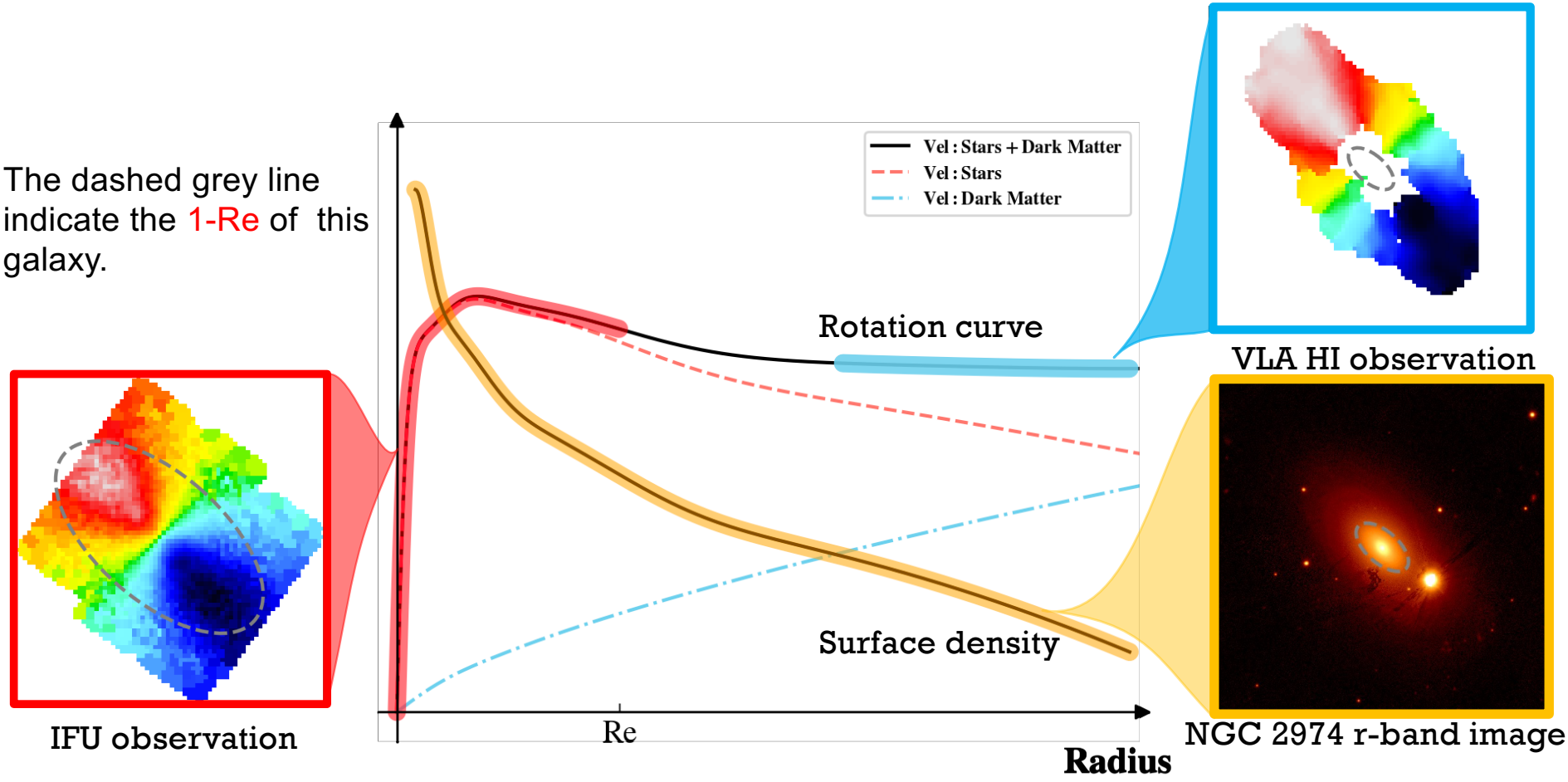


(Lovell et al. 2018)

- Dynamical modeling can tell us the dark matter fraction in different aperture by different kinematics tracers.
  - Stellar kinematic(IFU survey): Atlas3D, MaNGA, CALIFA; only cover inner region of galaxy.
  - GCS, PNe: Only massive haloes have enough samples to make dynamical modeling.
- There is still lack accurate measurement of dark matter mass in a large sample of galaxies that can represent the universal characteristics of the nearby universe.
  - **HI kinematics.**

Different dynamical tracer

The dashed grey line indicate the 1-Re of this galaxy.

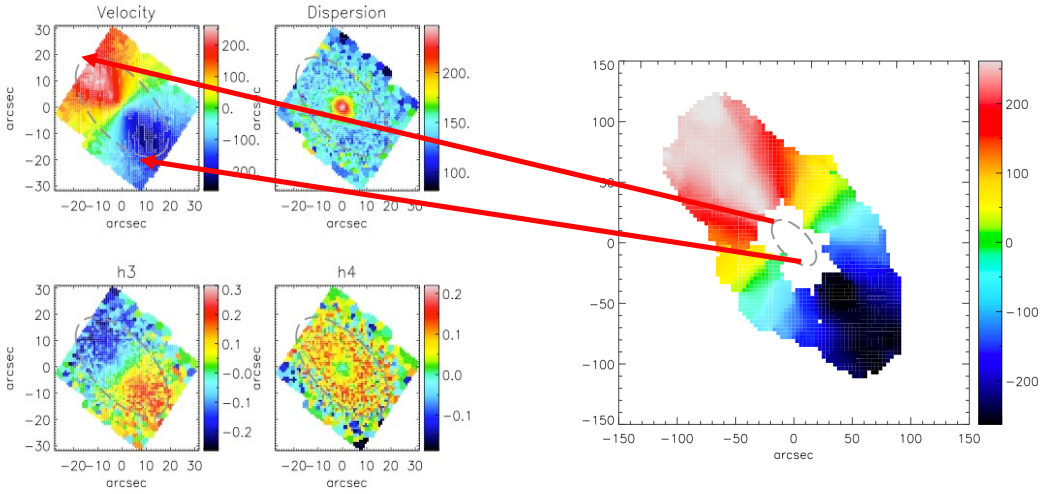


(modify Taranu et al. 2017 Fig 1)

Break dm-baryon degeneracy:
IFU + Extended kinematics tracers in galaxies

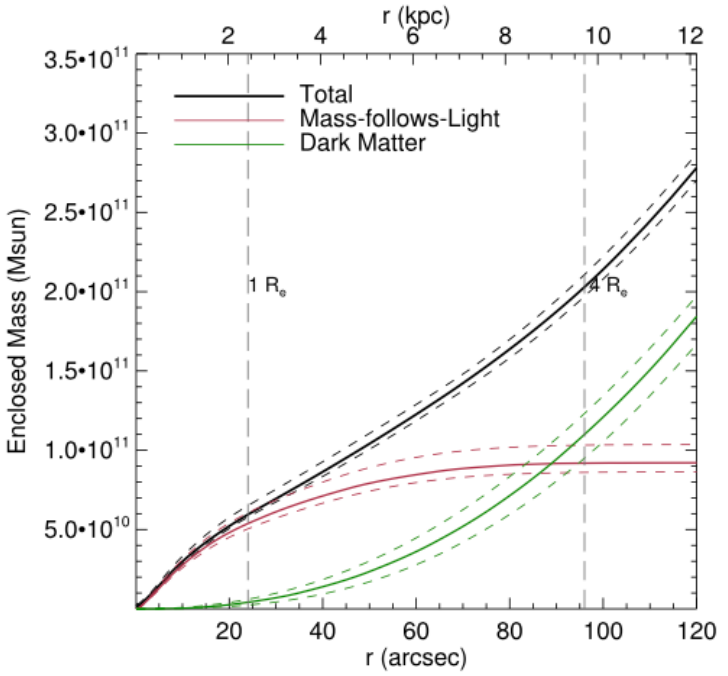
Dynamical modeling

- Stellar kinematics: Schwarzschild's orbit-superposition model.
- HI kinematics: cold thin disk model.



stellar kinematics

resolved HI



(Yang & Zhu et al.2020)

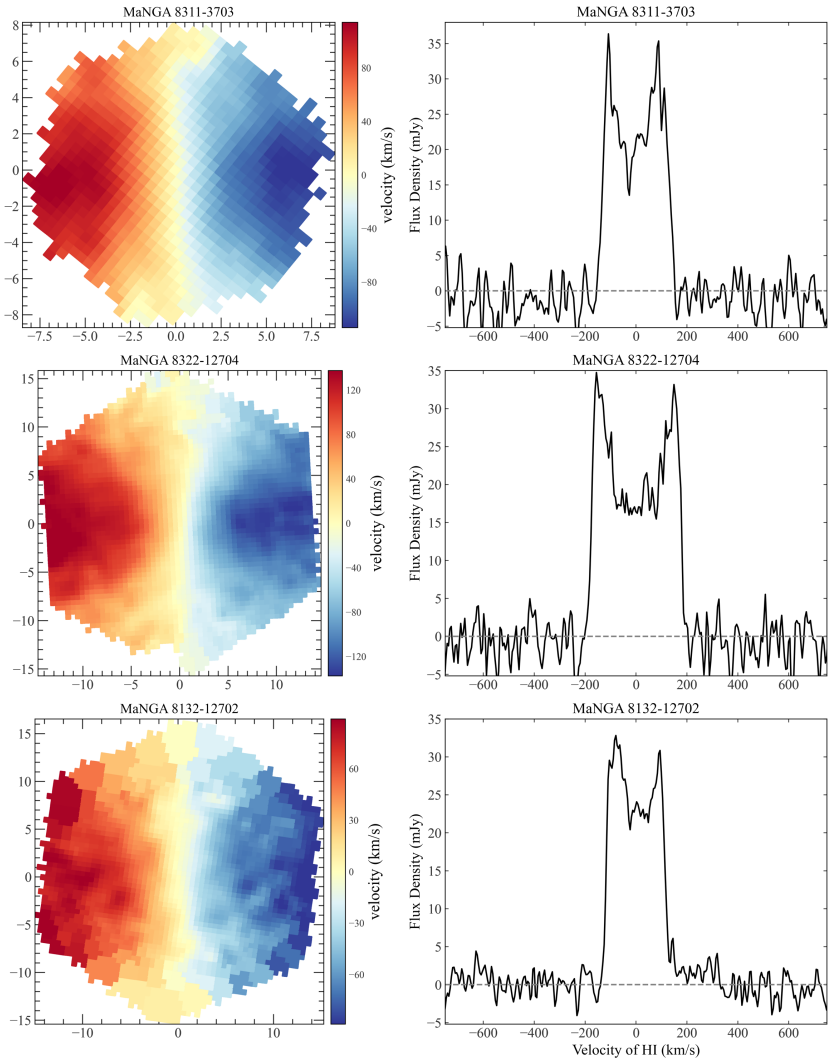
For large sample:
Single Dish Data vs Array Data

- Resolved HI :
  - spatially resolved.
  - expensive, few sample.

- integrated HI spectrum:
  - efficiently obtained with short, single-dish observations.
  - archives sample: ALFALFA, HIPASS(~ 10^4 low-redshift galaxies).
  - IFU follow-up survey: HI-MaNGA, FAST.
  - spatially unresolved. More assumptions are needed.

velocity

HI spectrum



Different dynamical tracer

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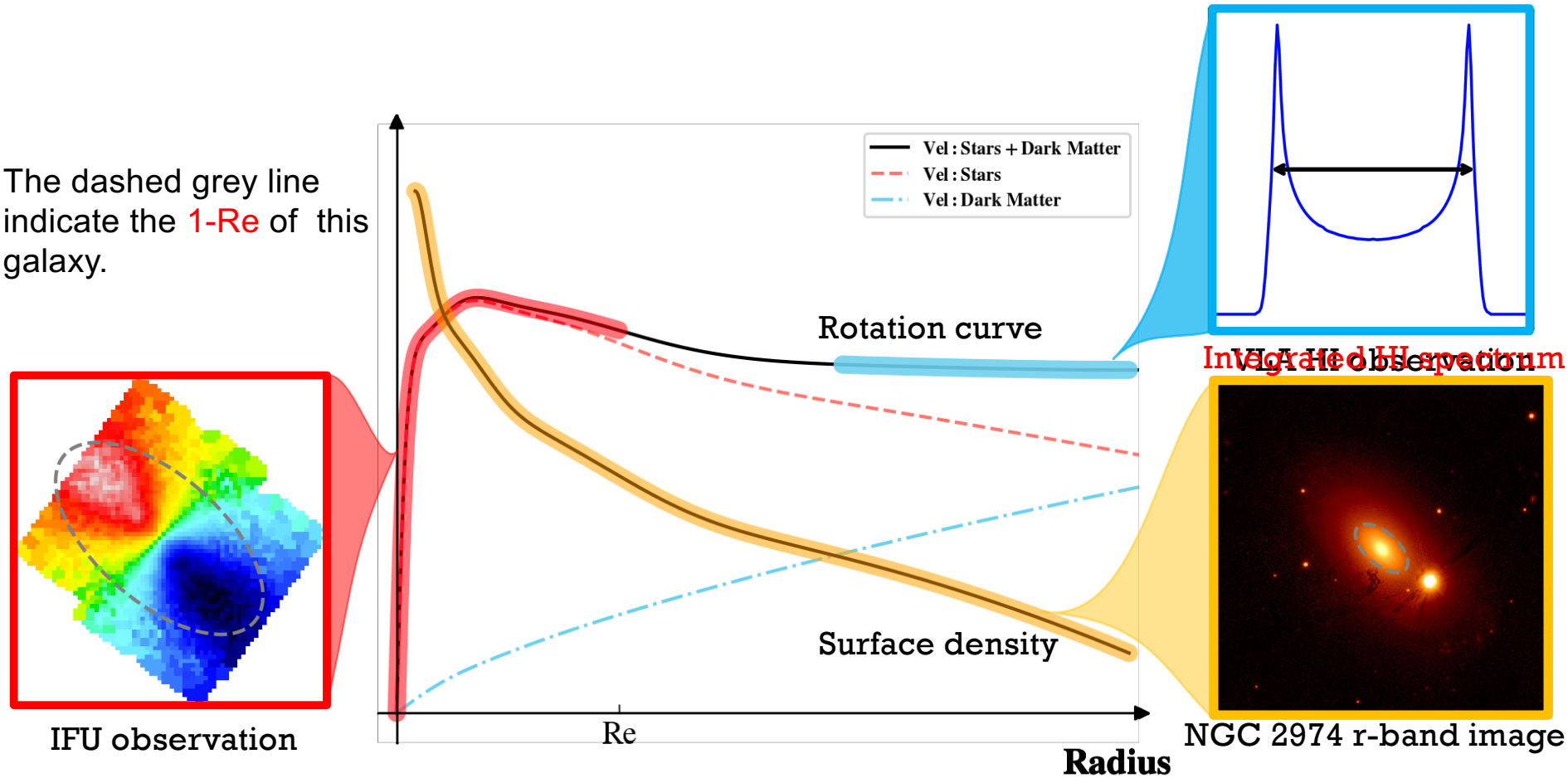
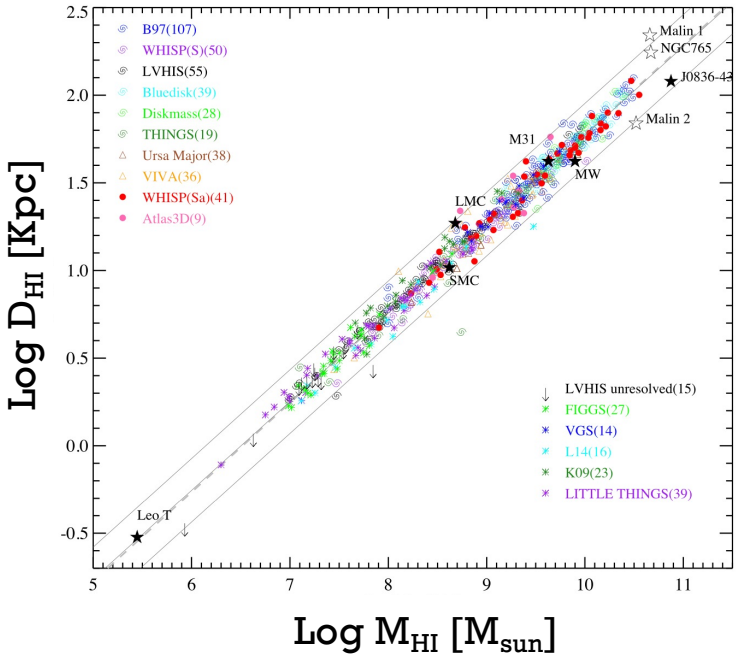
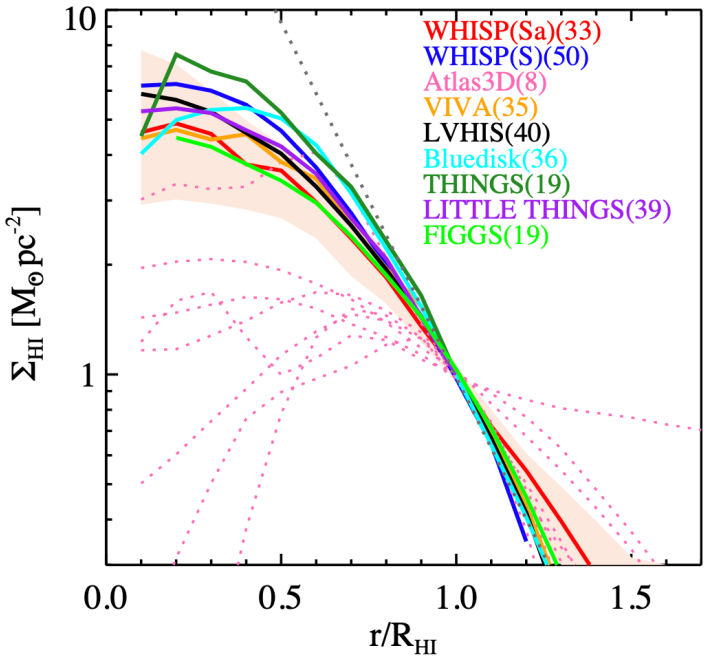


(modify Taranu et al. 2017 Fig 1)

Modeling HI spectrum

HI size-mass relation



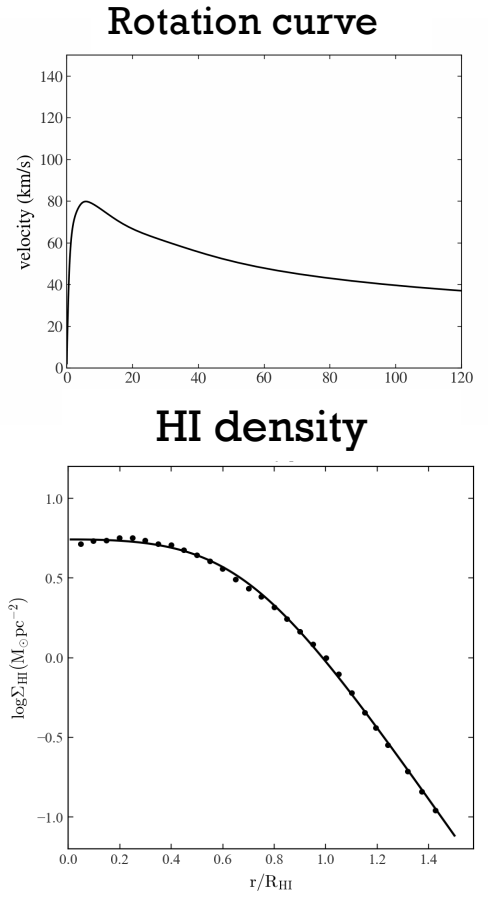


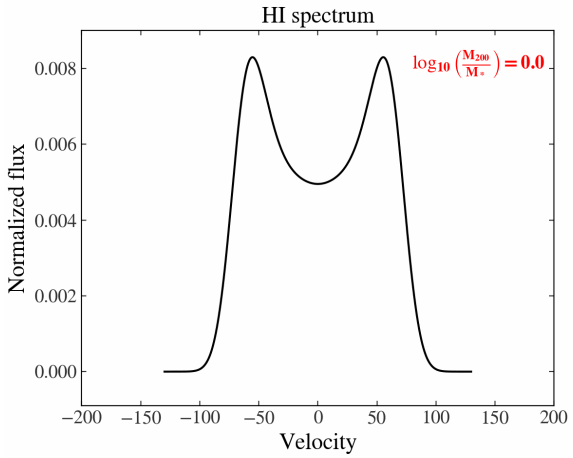
- the HI size–mass ($D_{HI}-M_{HI}$) relation of galaxies is remarkably tight.
- HI density profile show a homogeneous shape in the outer regions, which is well described by an exponential function.

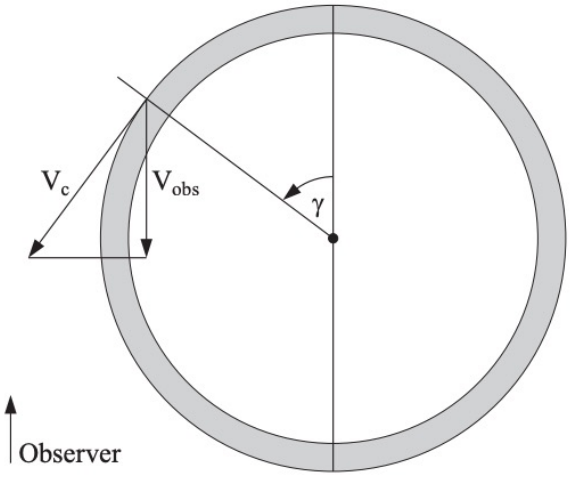
(Wang et al.2016)

Modeling integrated HI spectrum

- HI mass-weighted distribution of line-of-sight velocities.







$$\tilde{\psi}(V_\lambda, V_c) = \begin{cases} \frac{1}{\pi\sqrt{V_c^2 - V_\lambda^2}} & \text{if } |V_\lambda| < V_c \\ 0, \text{otherwise} \end{cases}$$

$$\psi(V_\lambda, V_c) = \frac{\sigma_{HI}^{-1}}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} dV \exp\left[\frac{(V_\lambda - V)^2}{-2\sigma_{HI}^2}\right] \tilde{\psi}(V, V_c).$$

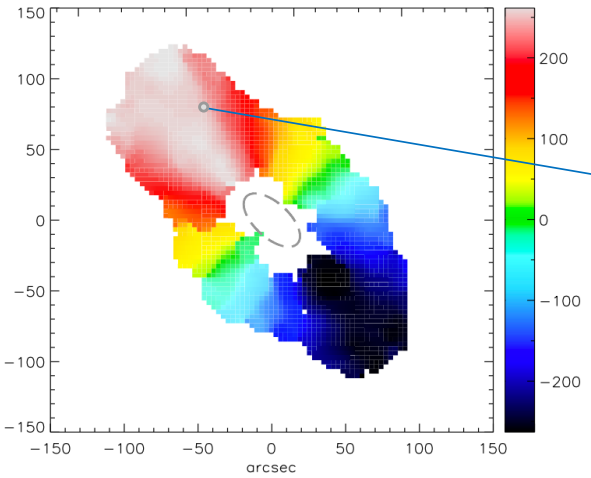
$$\Psi_{HI}(V_\lambda) = \frac{2\pi}{M_{HI}} \int_0^\infty dr r \Sigma_{HI}(r) \psi(V_\lambda, V_c(r))$$

(Obreschkow et al. 2009)

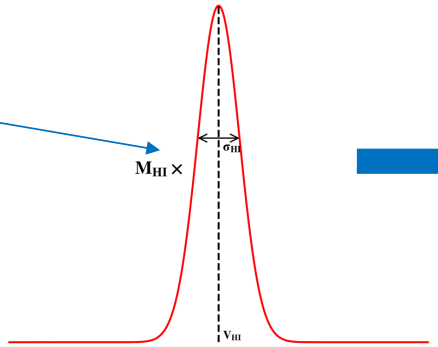
Method test

Test with mock data

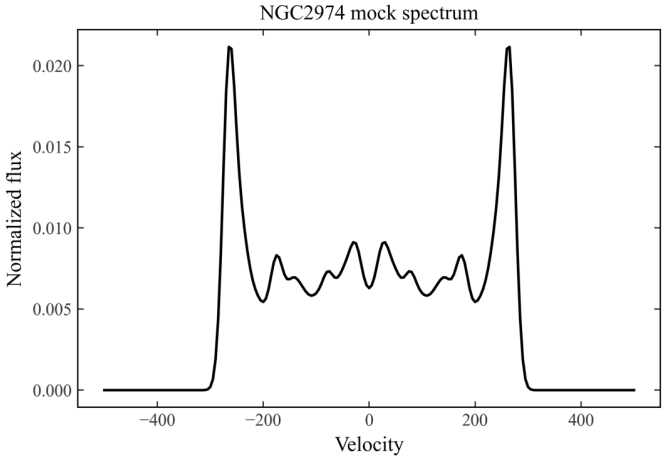
- Stellar kinematics modeling : Schwarzschild's orbit-superposition model.
- HI kinematics modeling: generate mock integrated spectrum with resolved HI of NGC 2974.



Intrinsic velocity dispersion ~10km/s

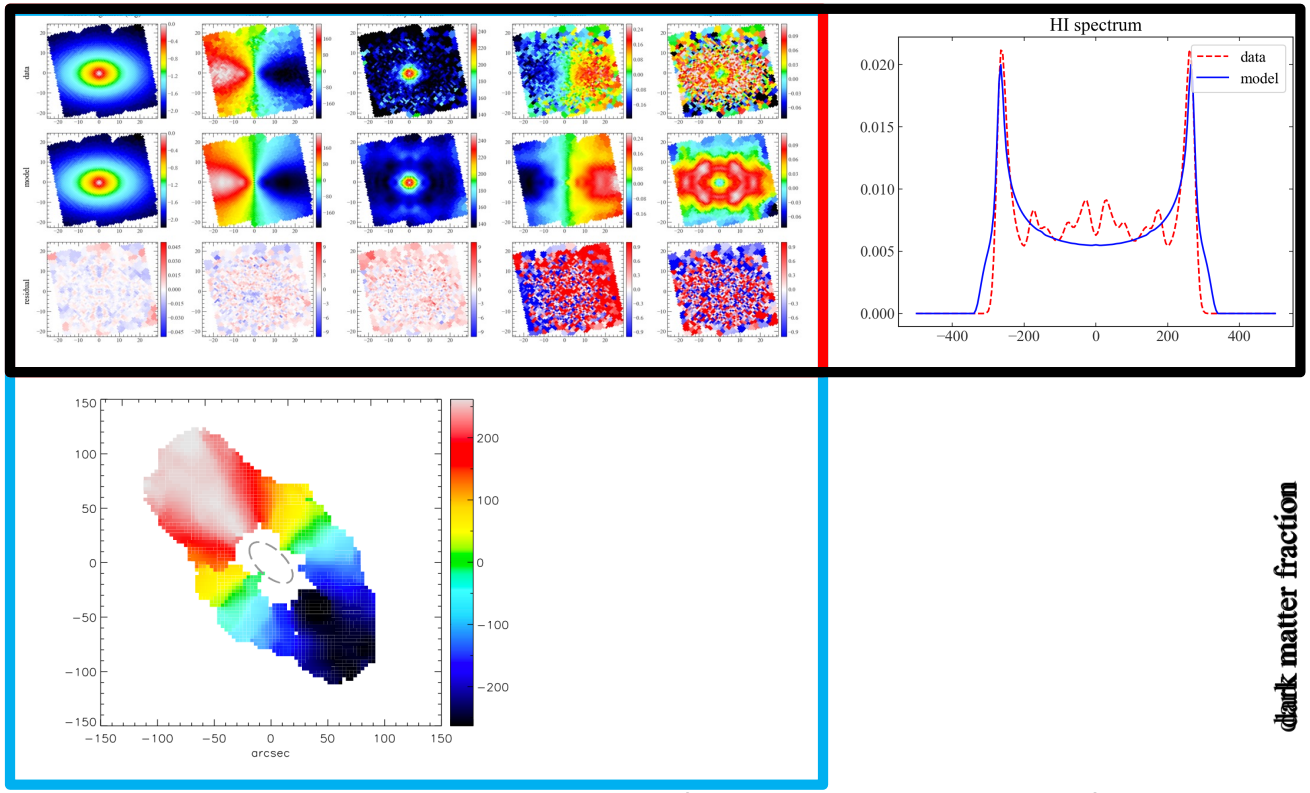


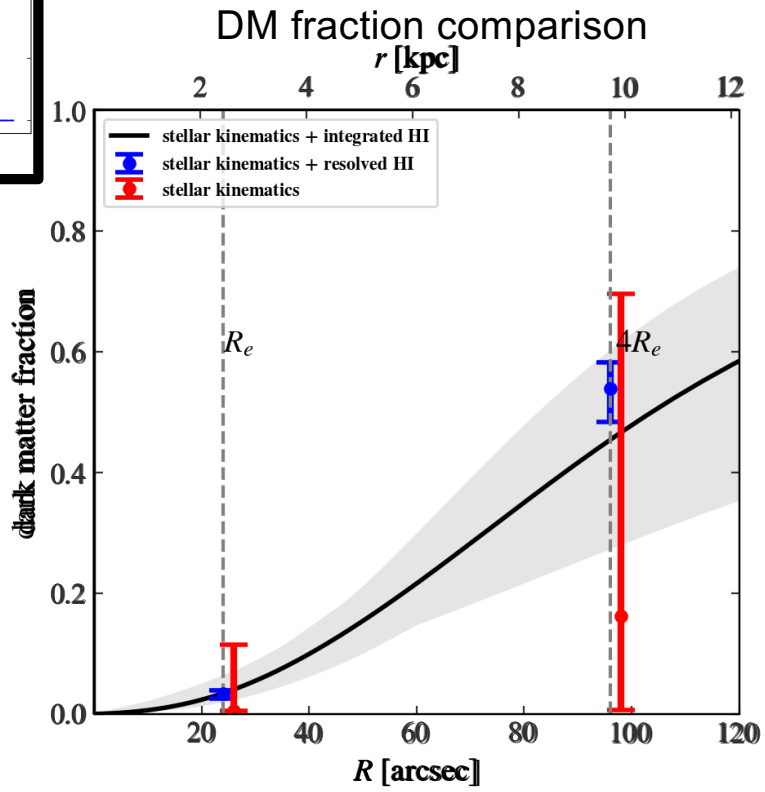
Symmetrize for modeling



Mock HI spectrum

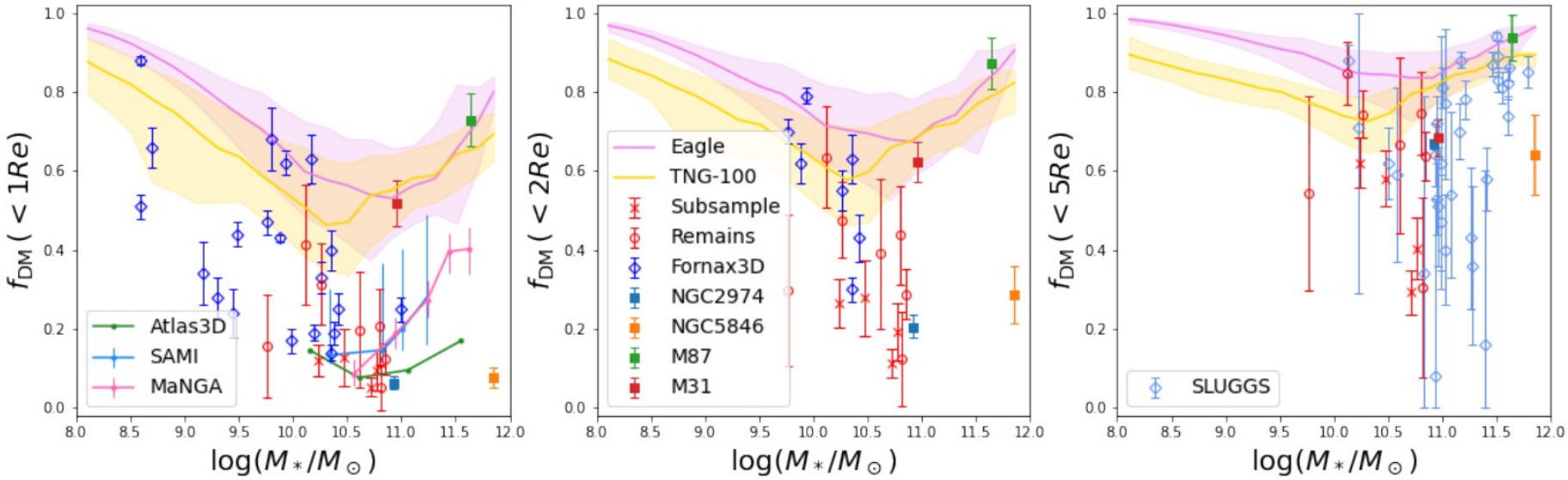
Test with mock data: result





- consistent with IFU + resolved HI(Yang & Zhu et al.2020) within 1-sigma uncertainty.
- combining integrated HI spectrum break dark matter-baryon degeneracy.

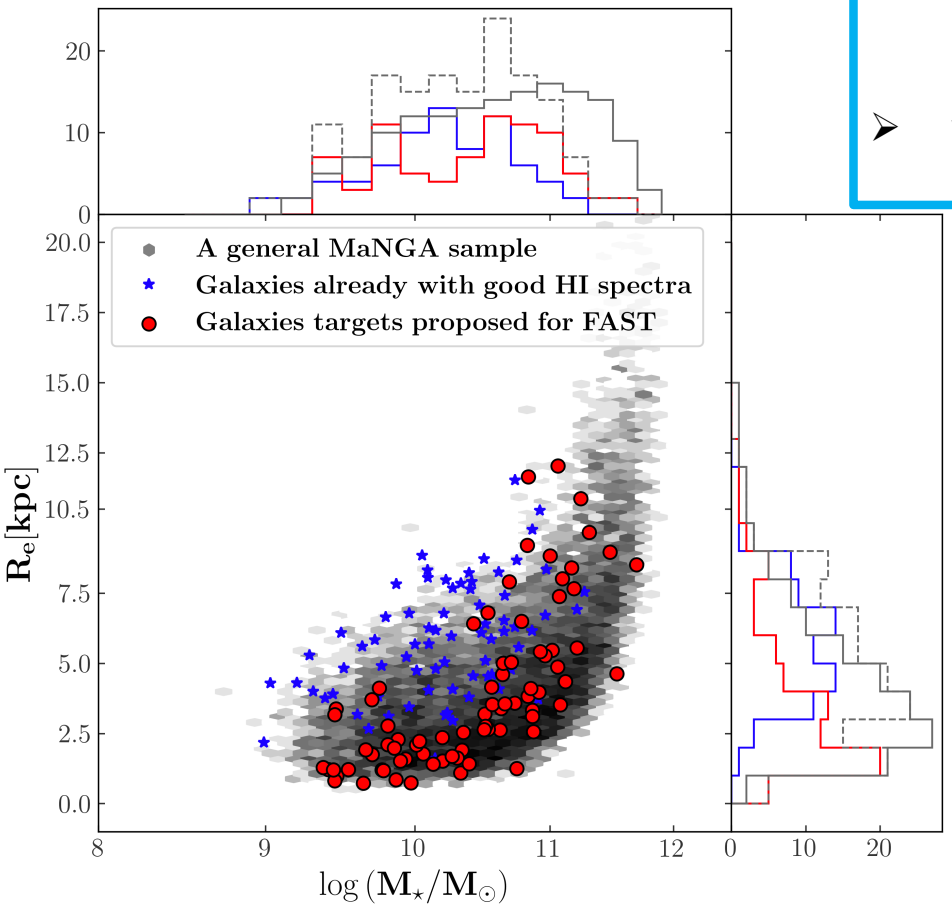
Dark matter fraction

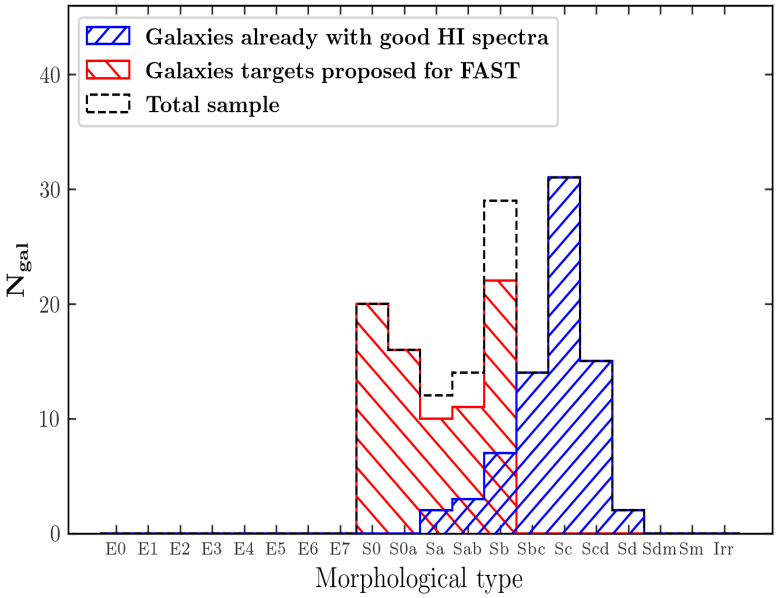


(Yang & Zhu et al. in prep.)

Scientific goal

- To build a representative sample in the mass-size plane and across a wider range of Hubble types, combining HI-MaNGA and FAST observations.
- we current have 45 galaxies in HI-MANGA , and we are granted fast observation time for 79 galaxies.





Summary

- We develop a method: combining stellar kinematics and integrated HI spectrum to constrain dark matter in galaxies.

- We test our method with mock HI spectrum. We find our method can break dark matter-baryon degeneracy.

- We plan to apply this method to about one hundred samples from MaNGA which also observed by ALFALFA, GBT and FAST.

THANKS!