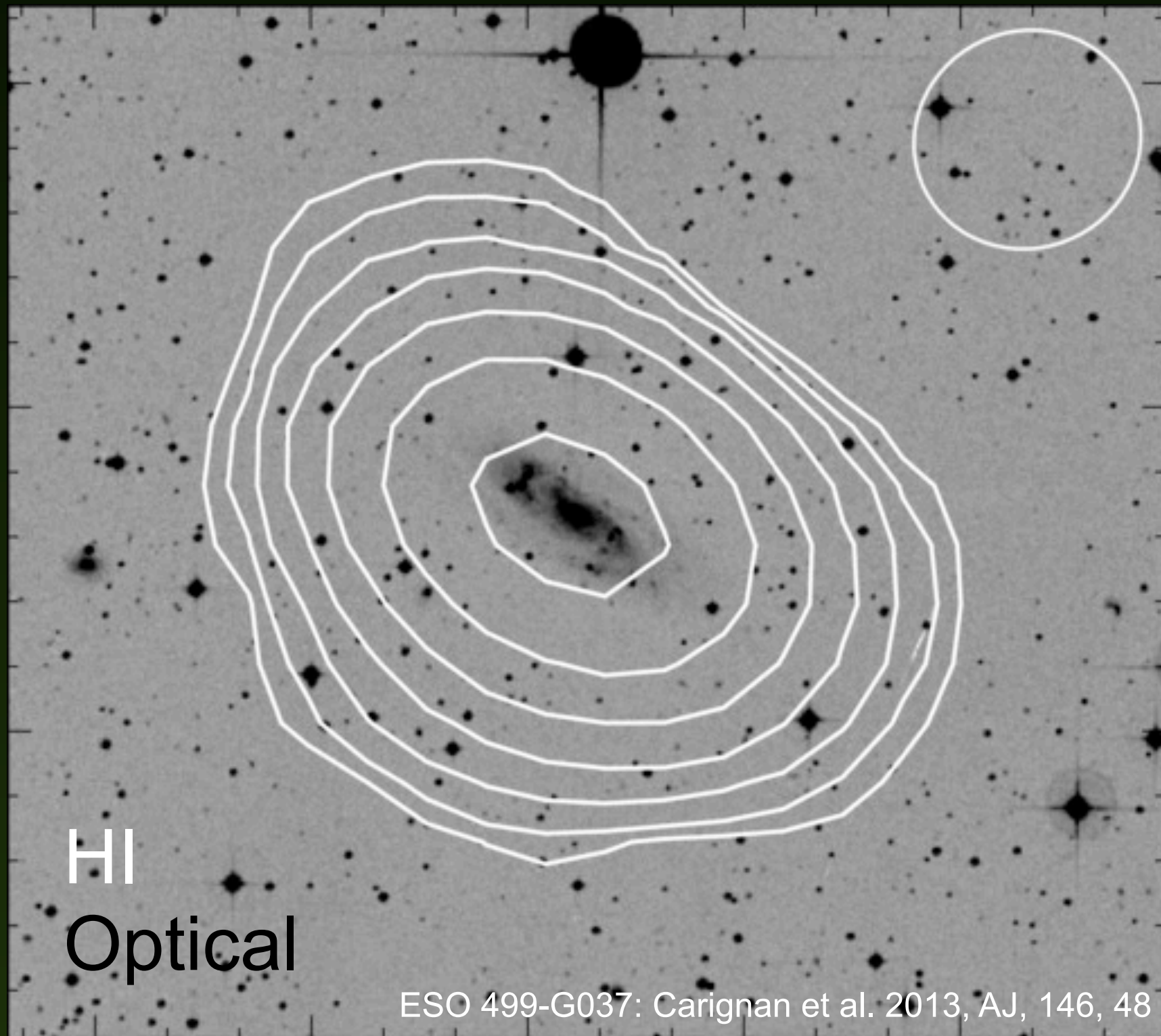


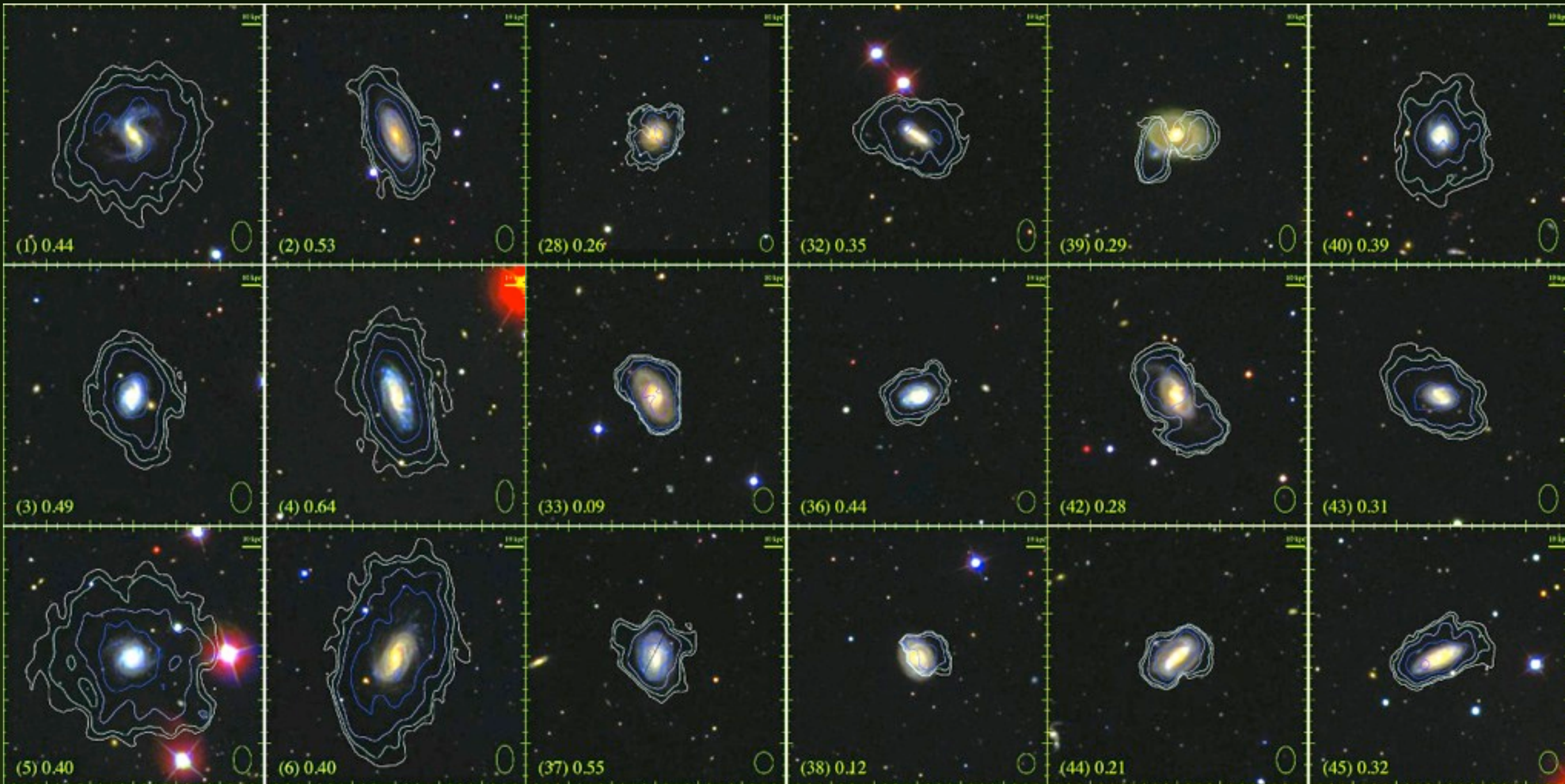
# The HI -- Stellar Mass Relation





# How are HI mass and stellar mass related?

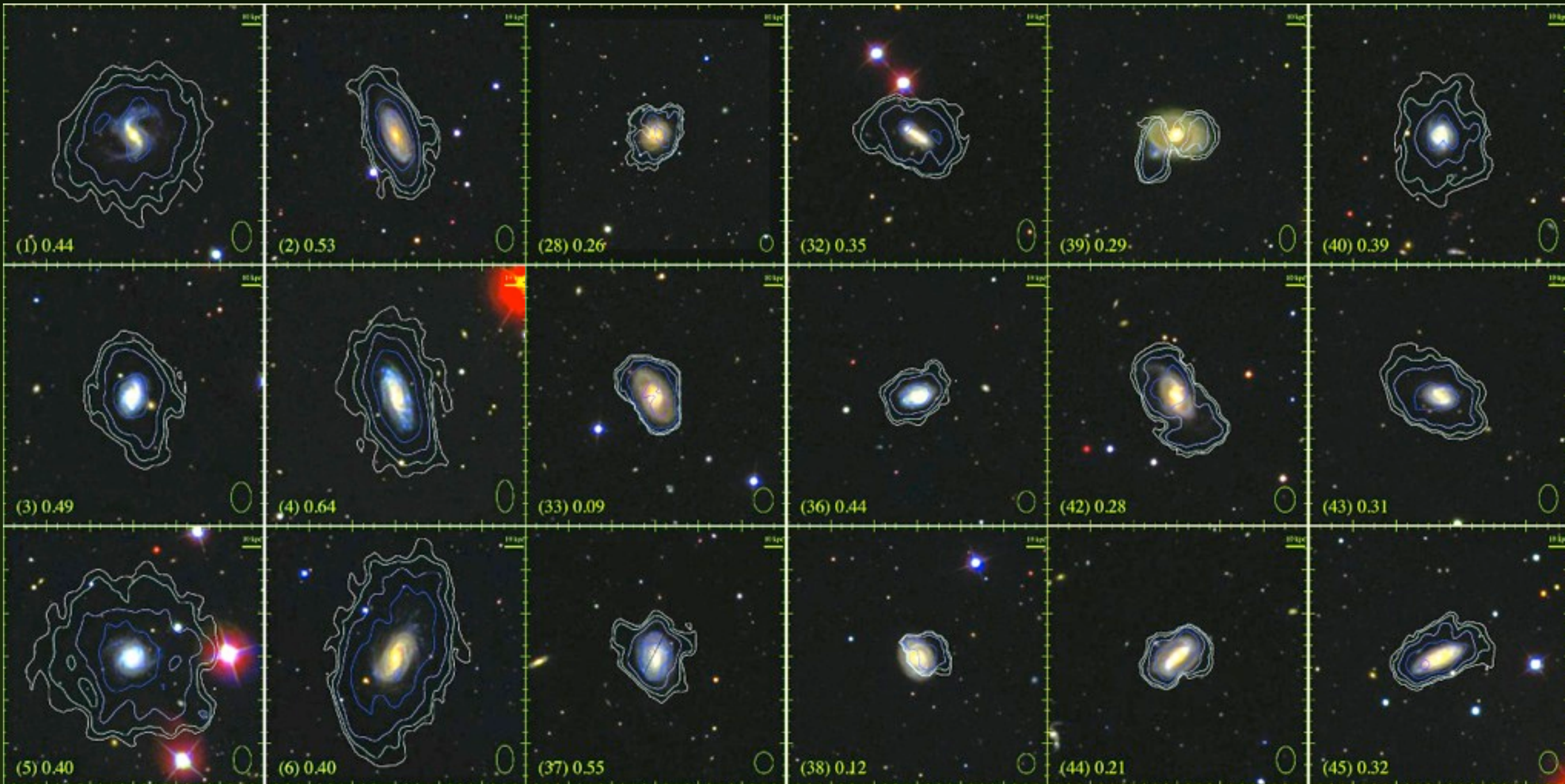
- For a galaxy of a given stellar mass, a wide range of HI masses are possible, from nearly zero, to  $>10M_{\star}$
- Even among gas-rich galaxies, there is a lot of variety





# How are HI mass and stellar mass related?

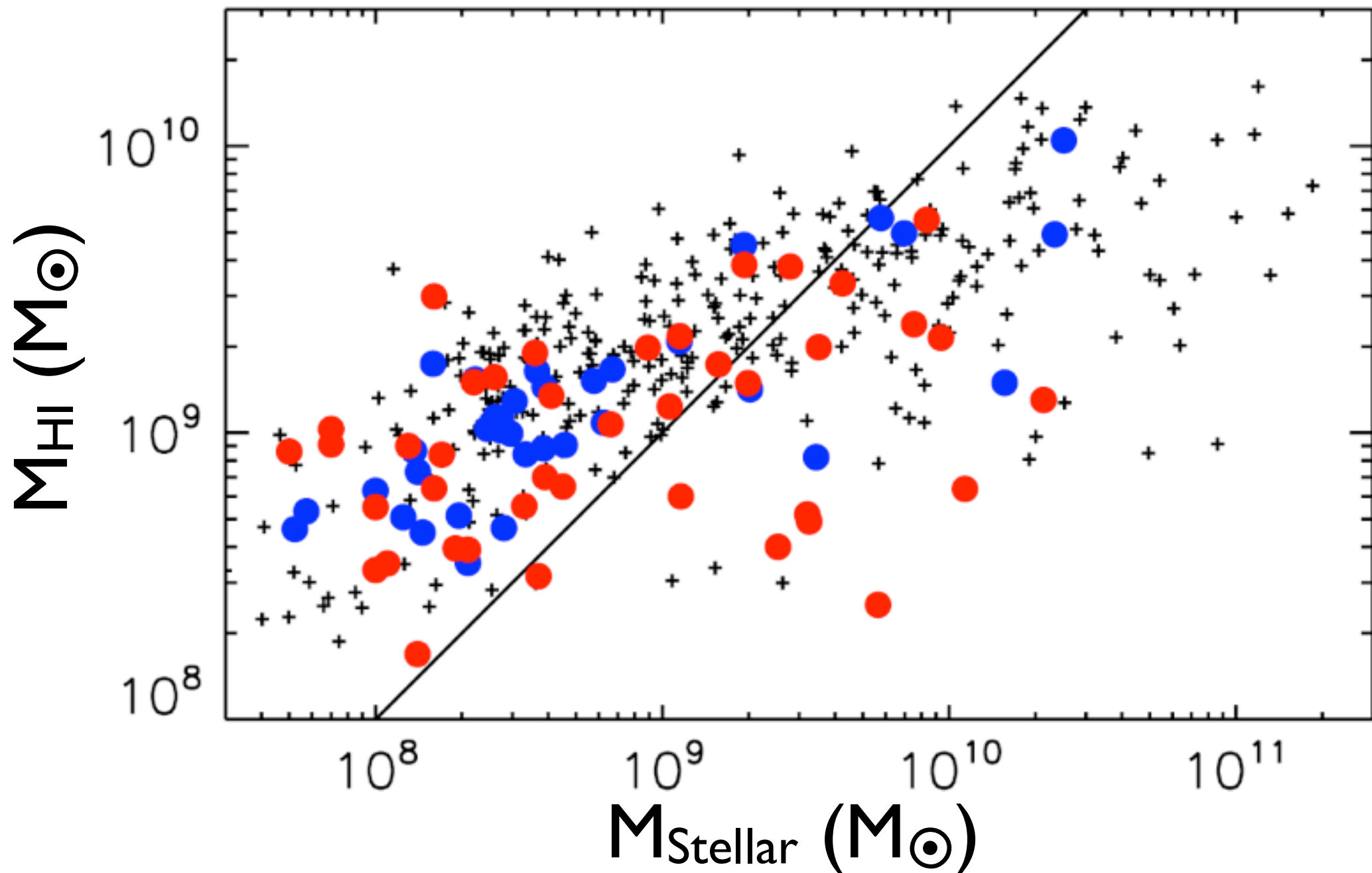
- Restrict to HI-rich galaxies. Is there a relation? Should there be?
- Complicated by gas inflows, outflows, star formation, feedback, mergers, environment, ...





# How are HI mass and stellar mass related?

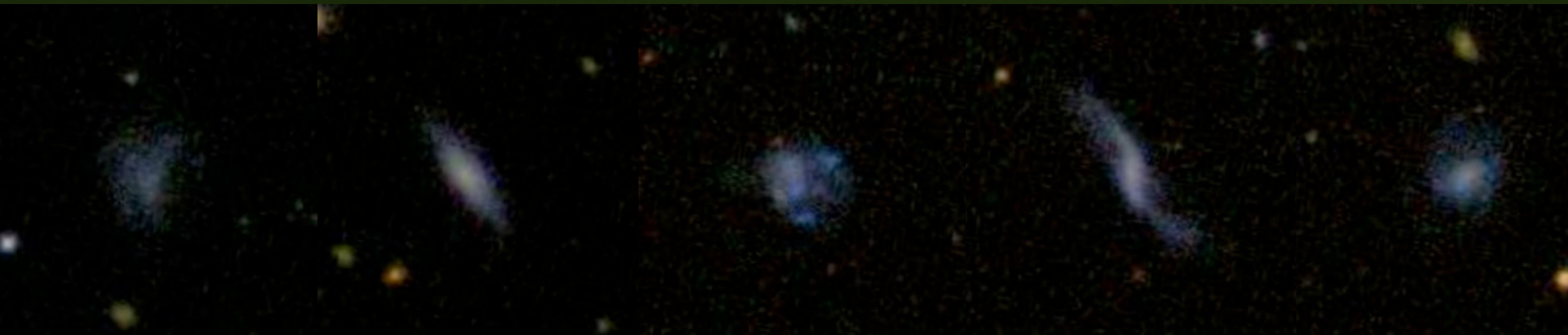
- There is a relation at the high mass end for HI-selected galaxies
- Pretty much all galaxies here have  $10^8 < M_{\text{HI}} < 10^{10} M_{\odot}$
- What about at lower HI and stellar masses?





# How are HI mass and stellar mass related?

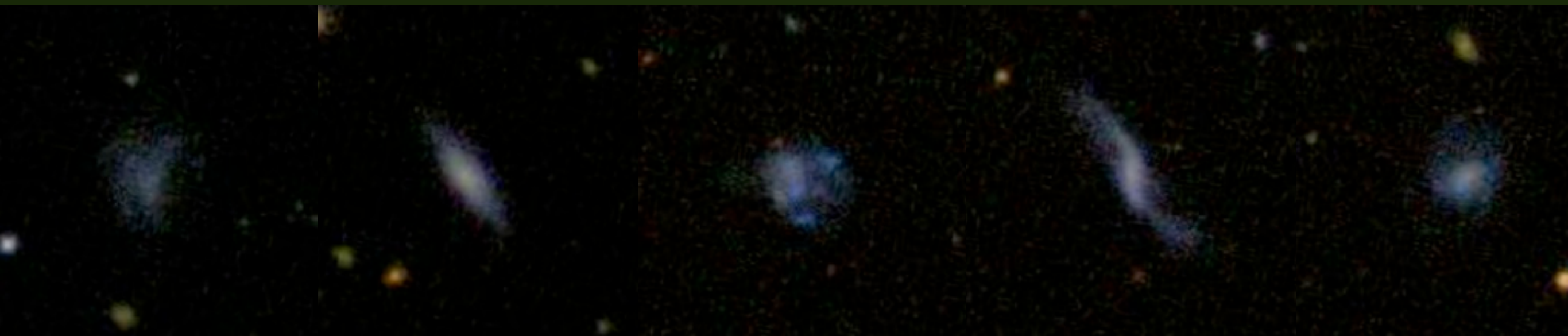
- ALFALFA is a large area, blind HI survey with Arecibo
- Detects galaxies at  $0 < z < 0.06$  with  $10^6 < M_{\text{HI}} < 10^{11} M_{\odot}$ 
  - ➔ Provides information on **gas component** of galaxies





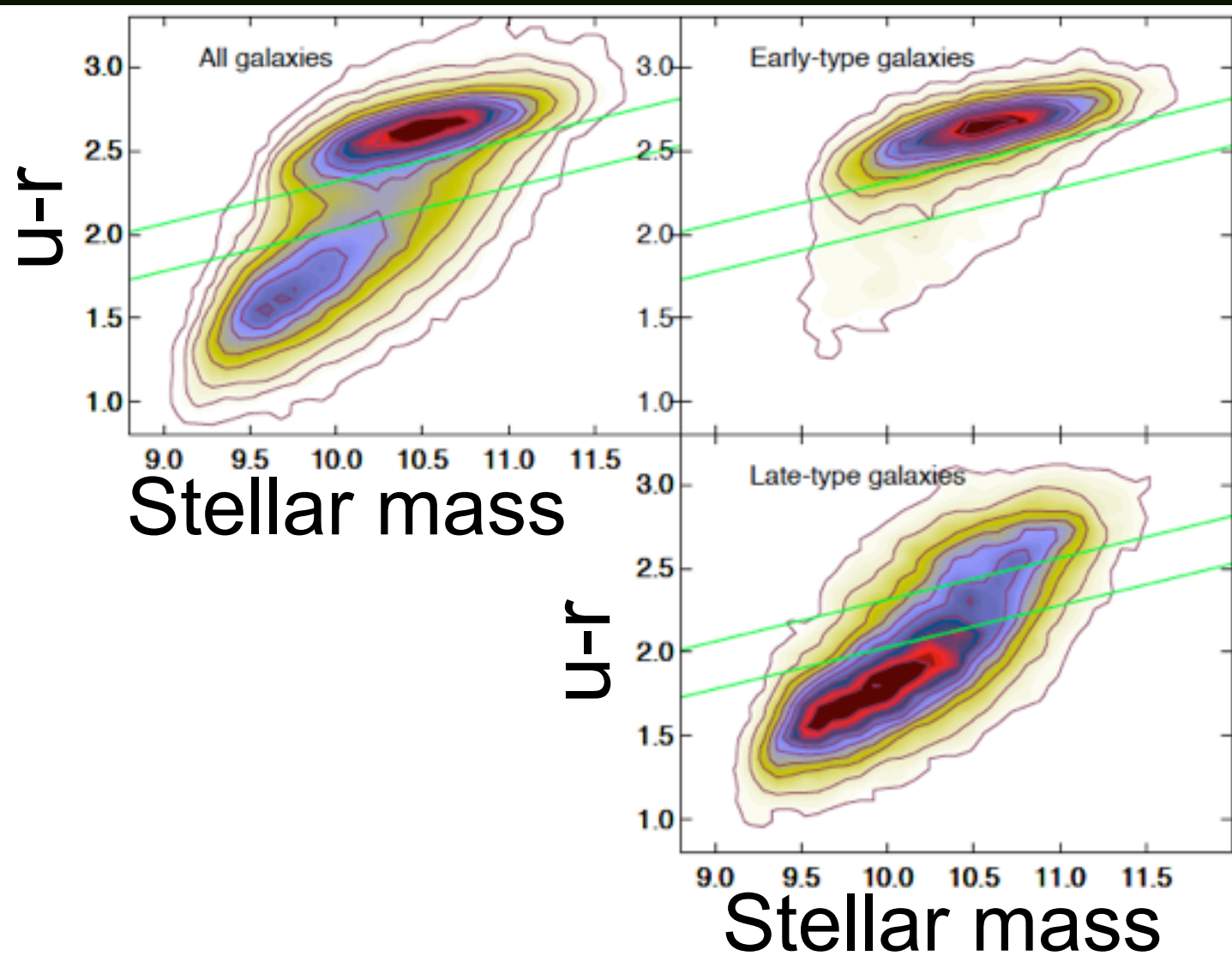
# How are HI mass and stellar mass related?

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  - ➔ Provides information on **gas component** of galaxies
- SDSS optical imaging and spectroscopic survey in the same area
  - ➔ Provides information on **stellar component** of galaxies
- Catalogue of  $>12000$  galaxies with HI and optical information



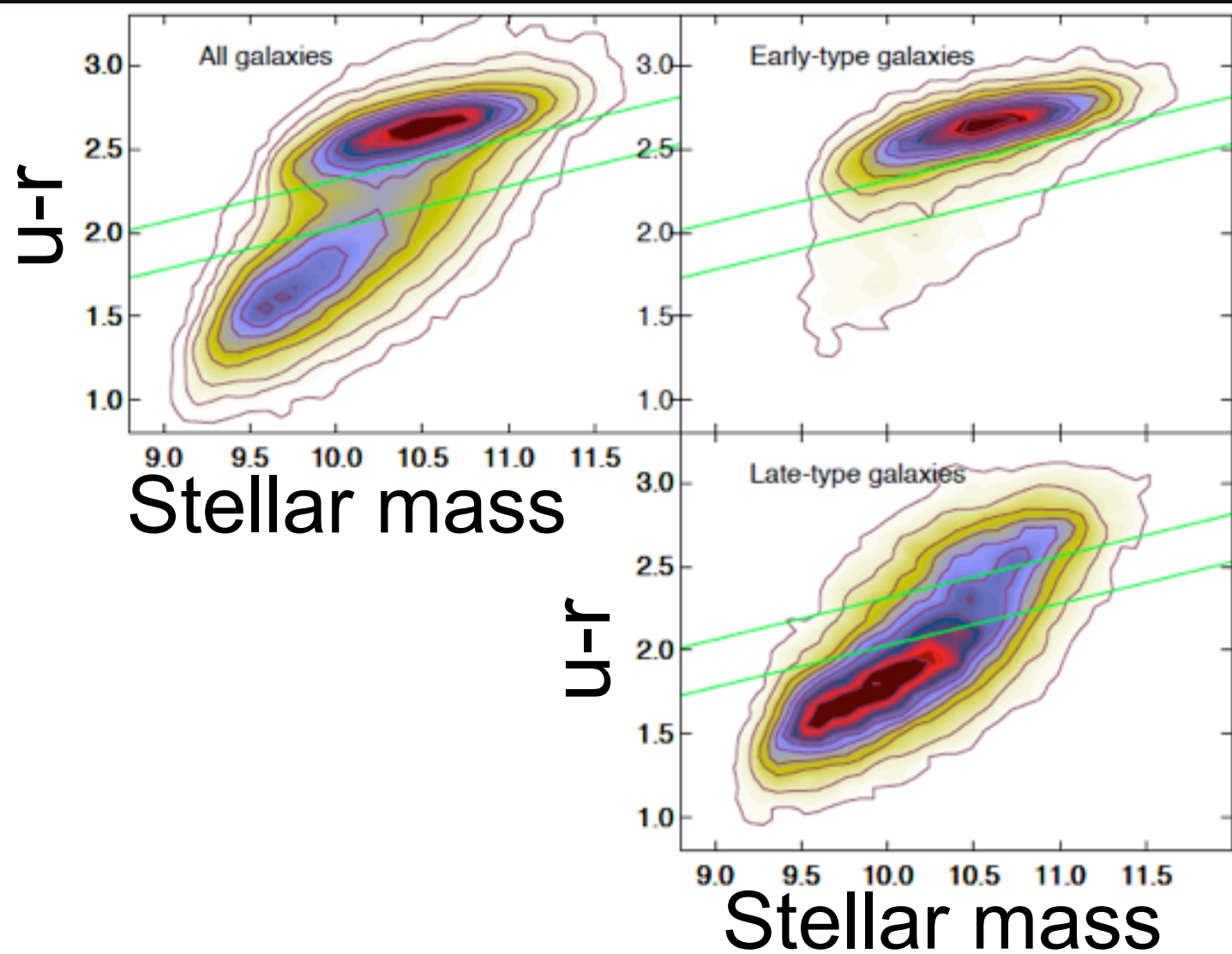


# Which galaxies are H I-rich?

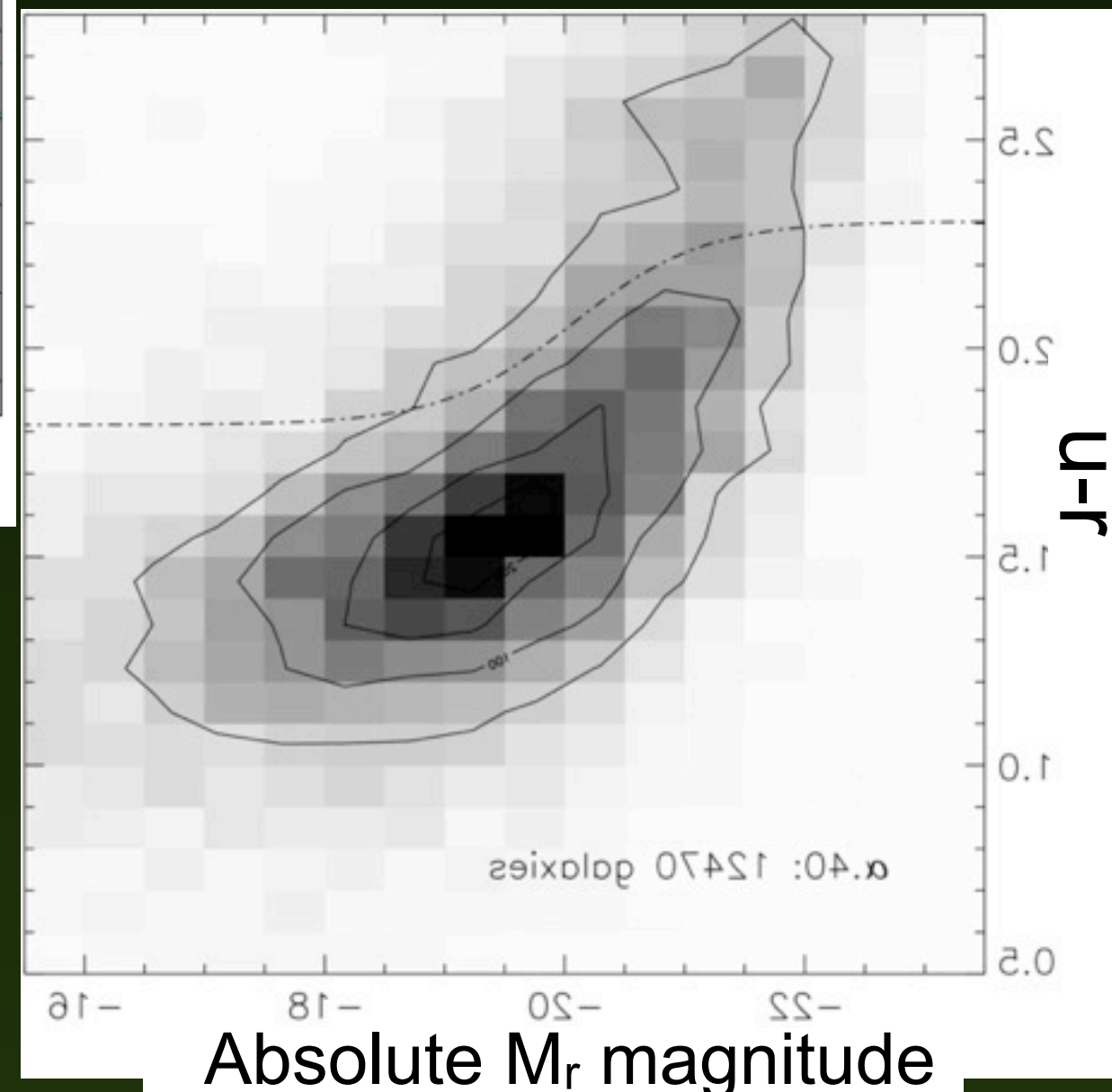


Optically selected SDSS galaxies:  
Schawinski et al. 2014, arXiv 1402.4814

# Which galaxies are HI-rich?



Optically selected SDSS galaxies:  
Schawinski et al. 2014, arXiv 1402.4814



ALFALFA galaxies:  
Haynes et al. 2011, AJ, 142, 170

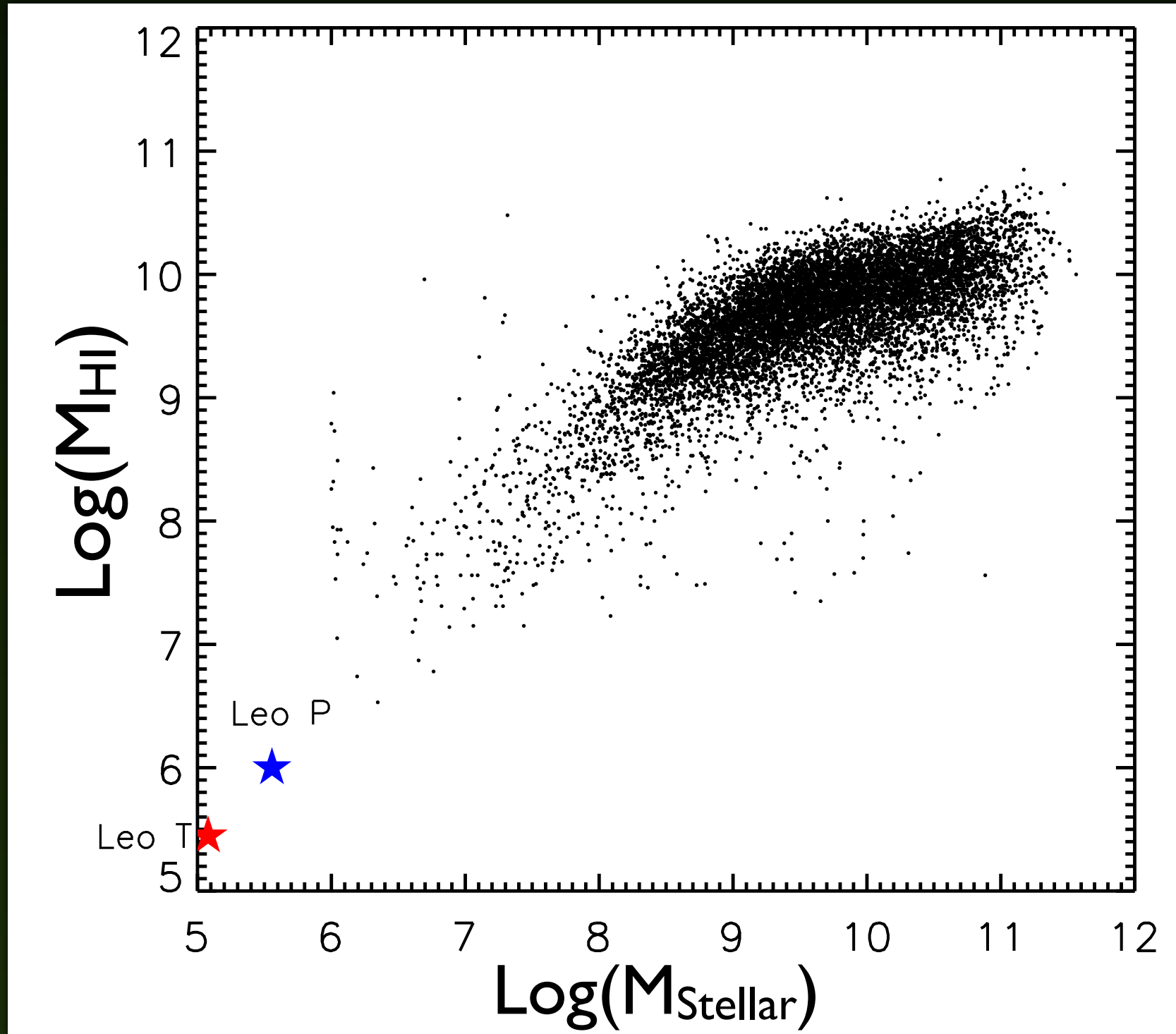


# How are HI mass and stellar mass related?

- >9000 ALFALFA + SDSS galaxies

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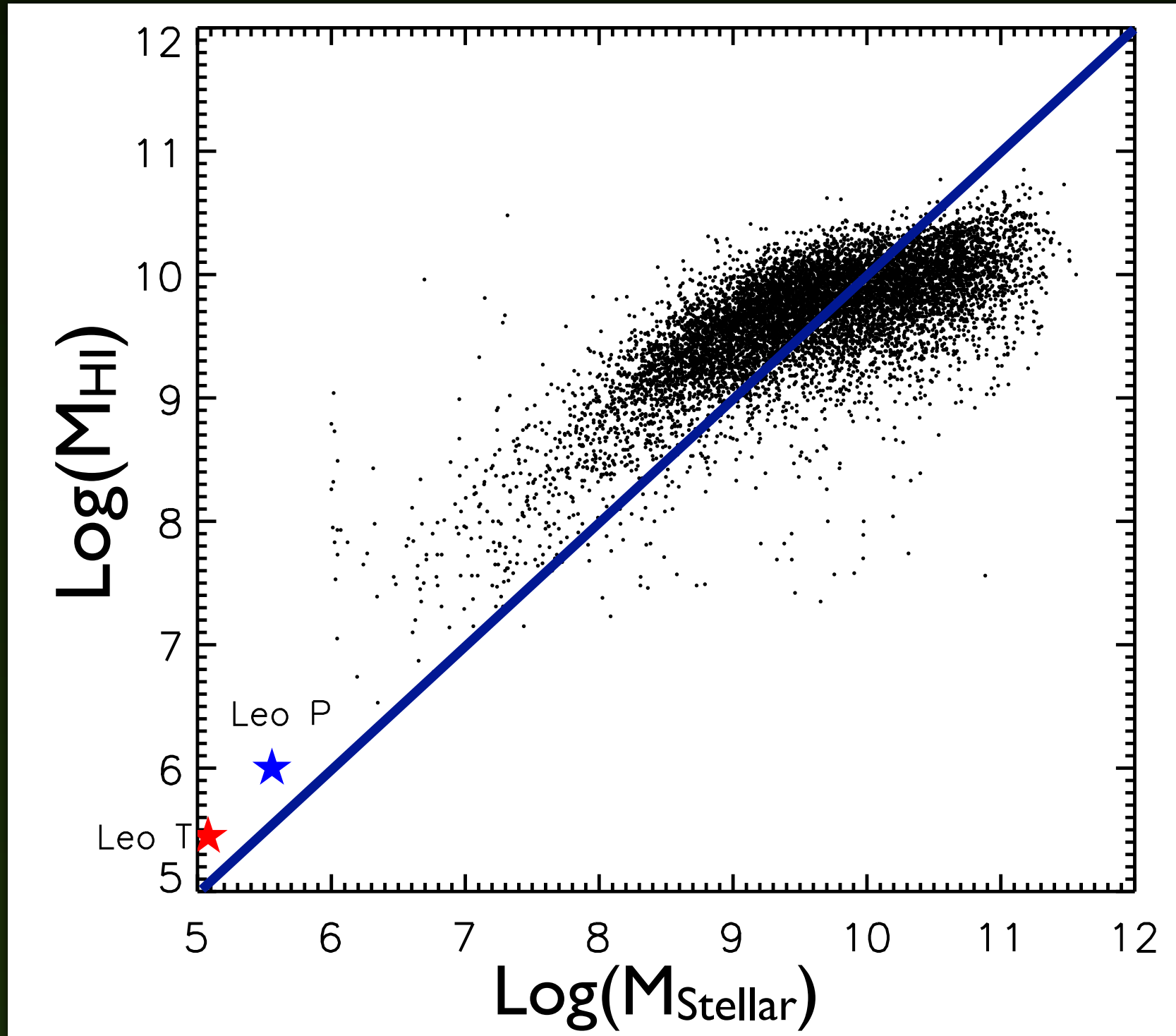
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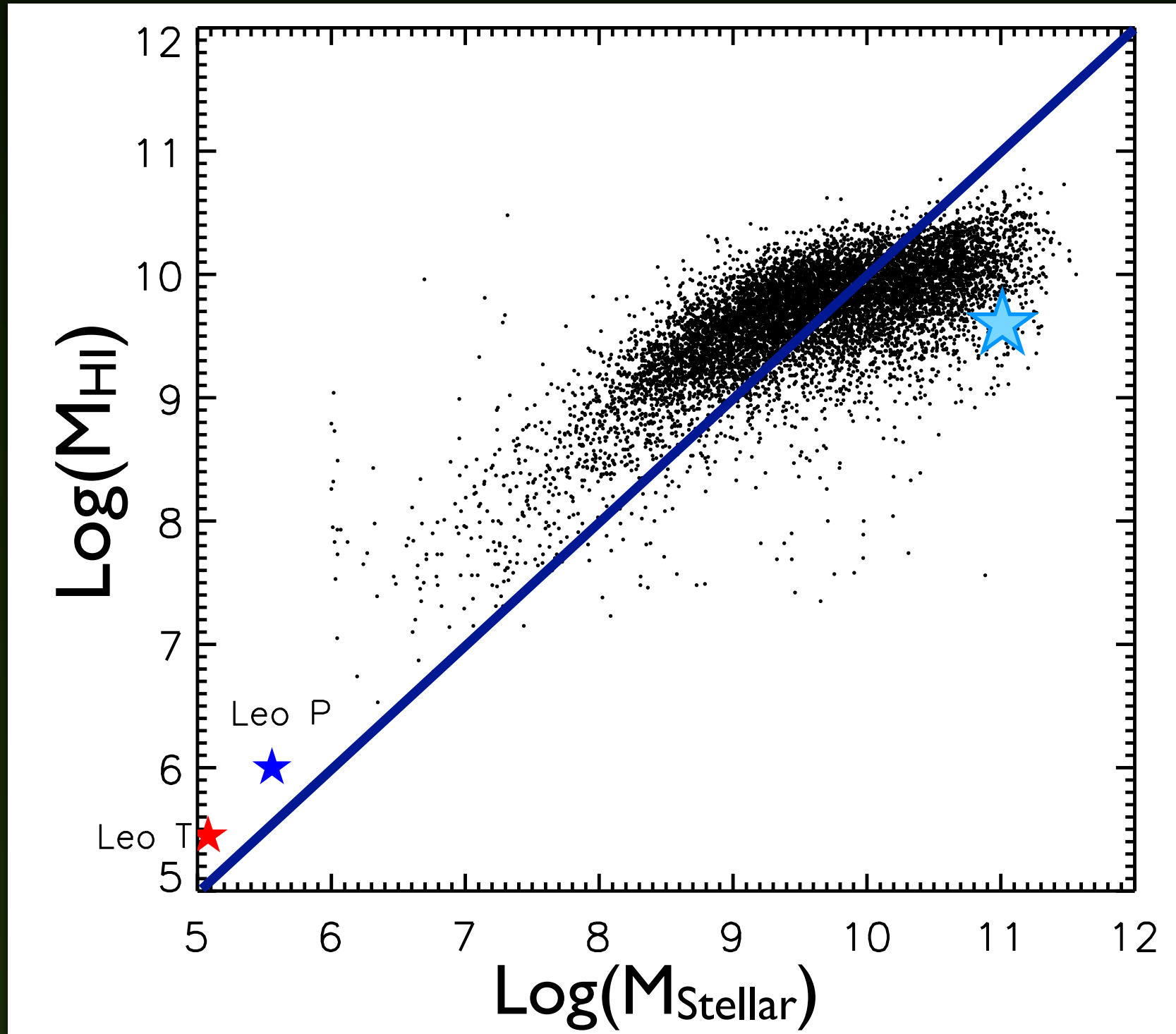
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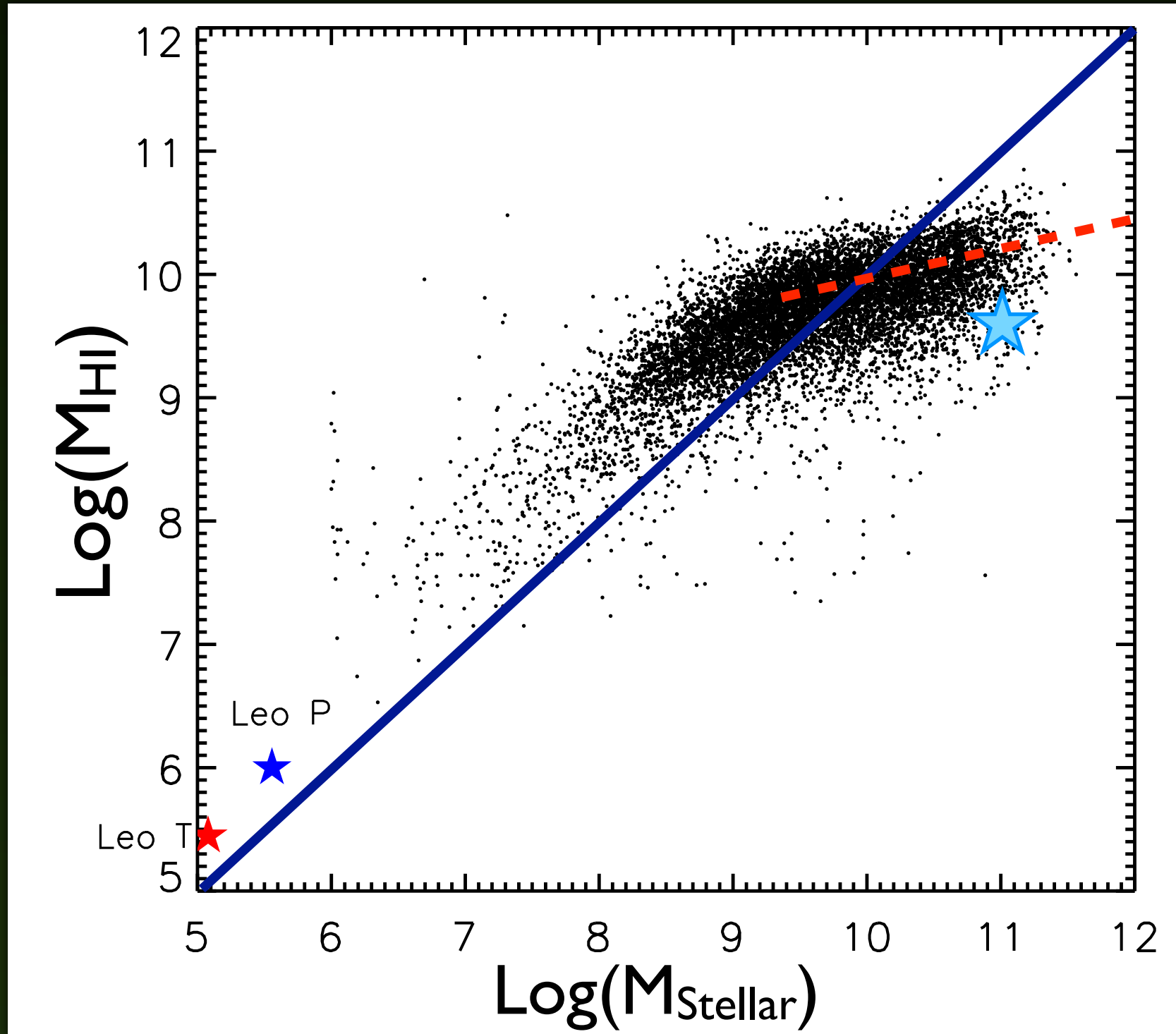
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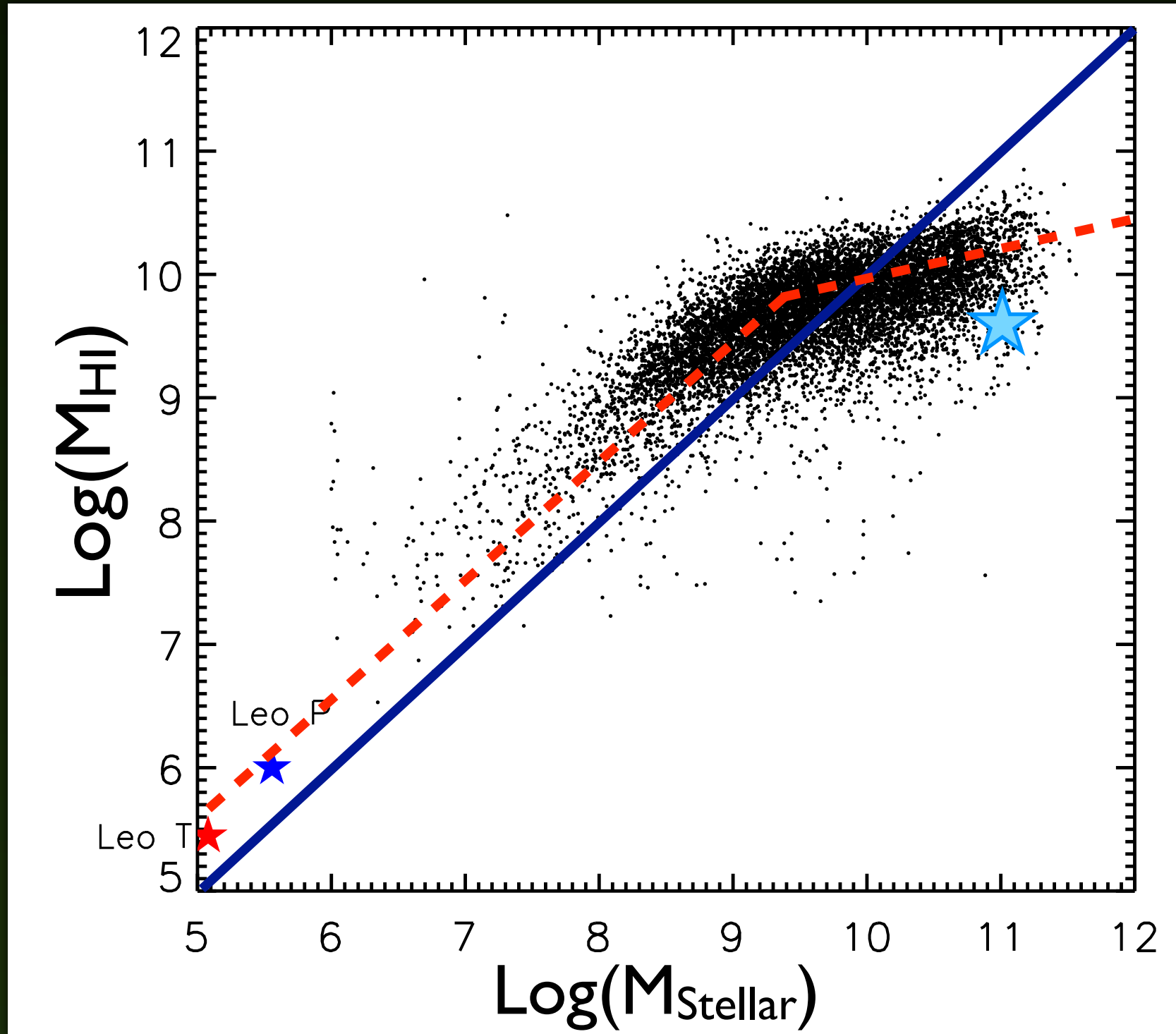
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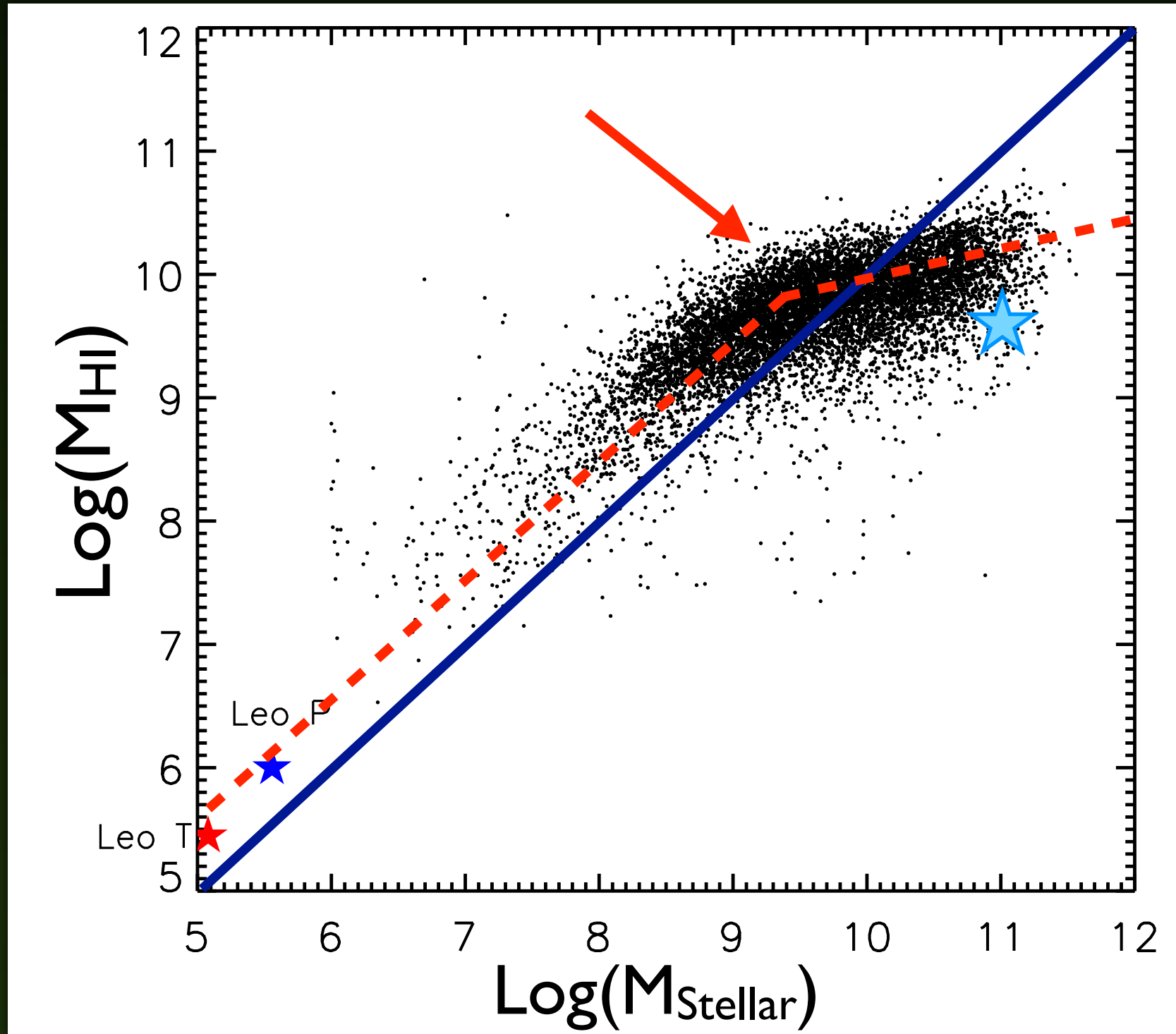
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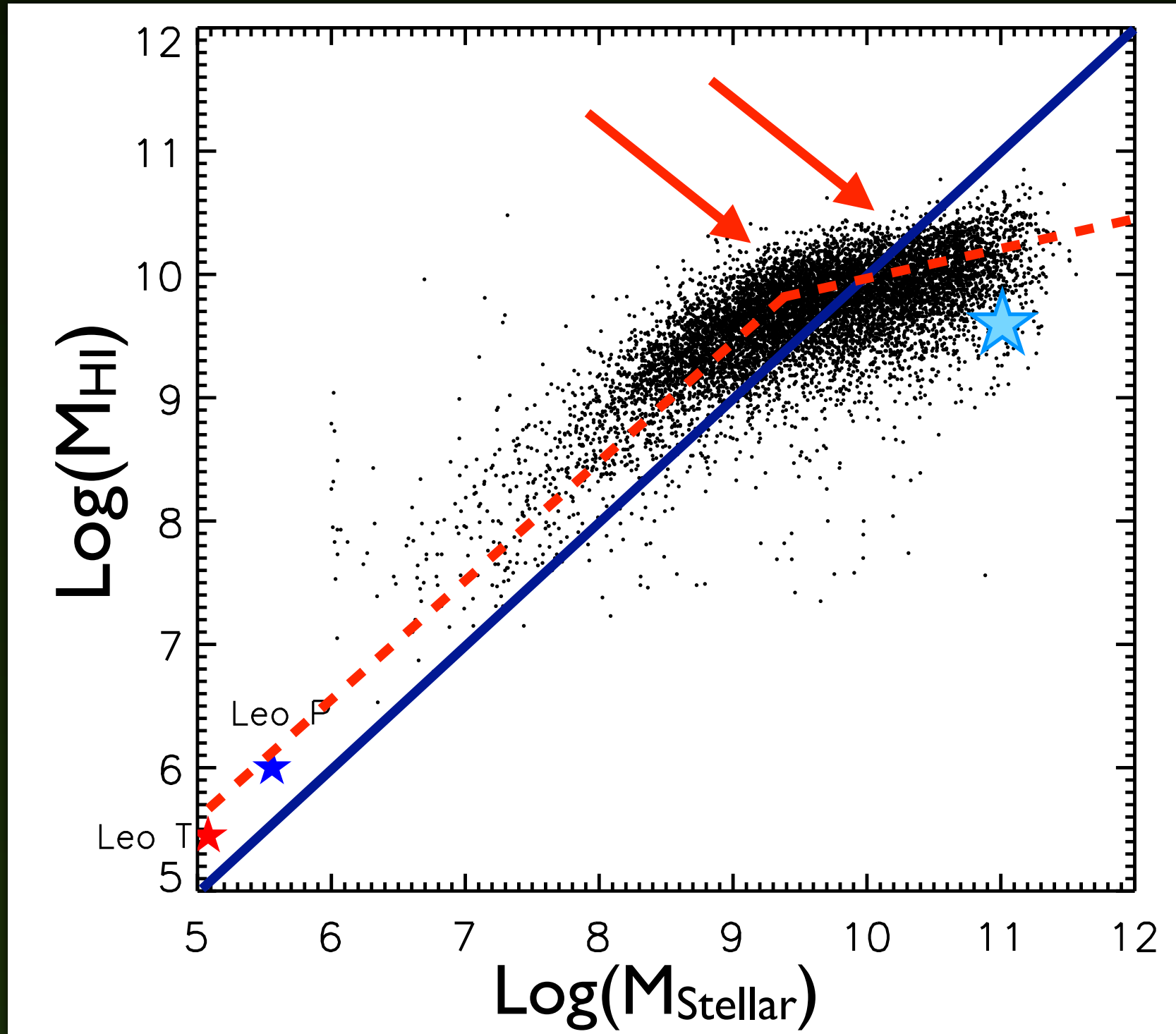
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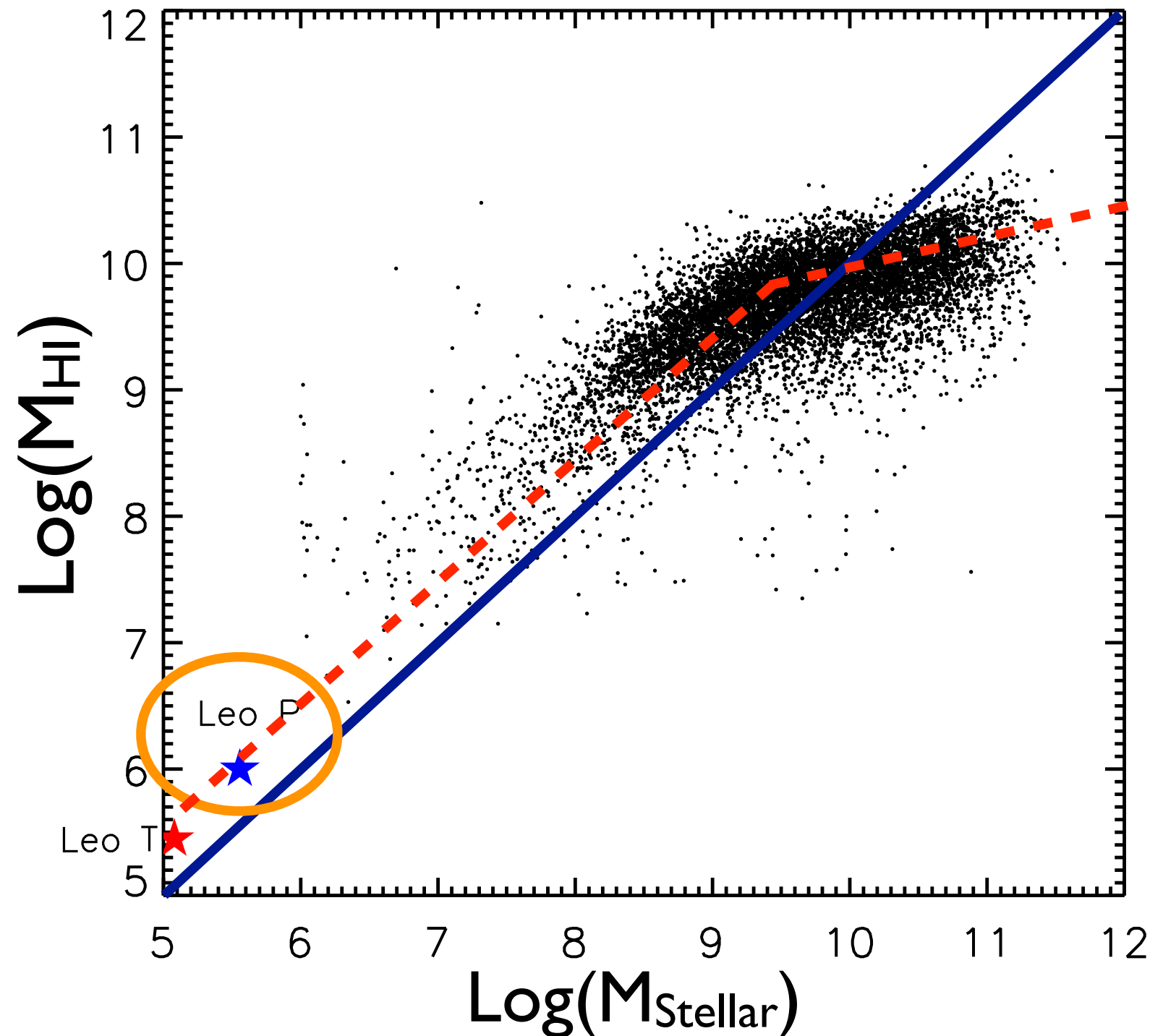
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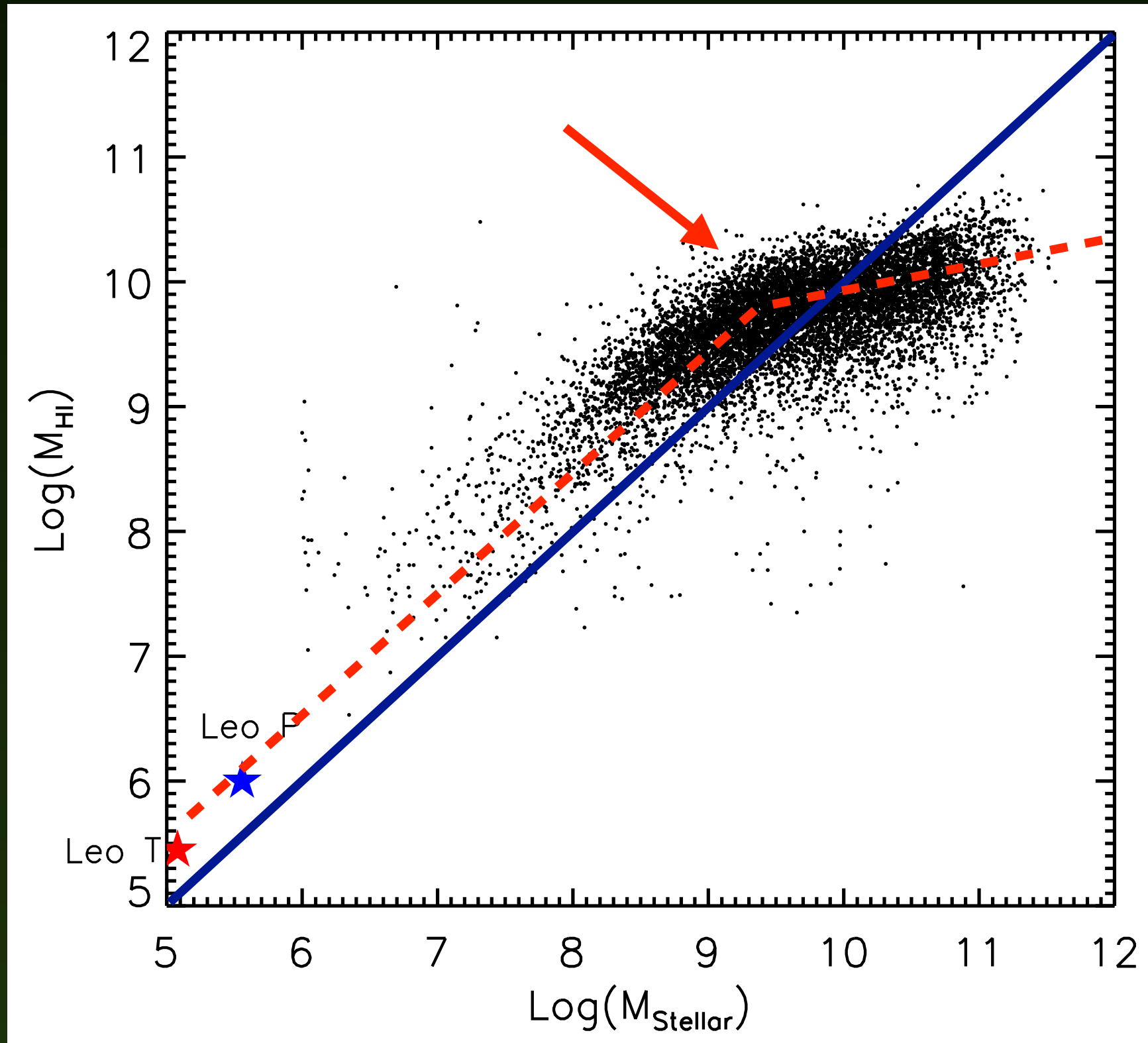


- Dwarf galaxies have more mass in HI than in stars
- The relation seems to extend to very low masses



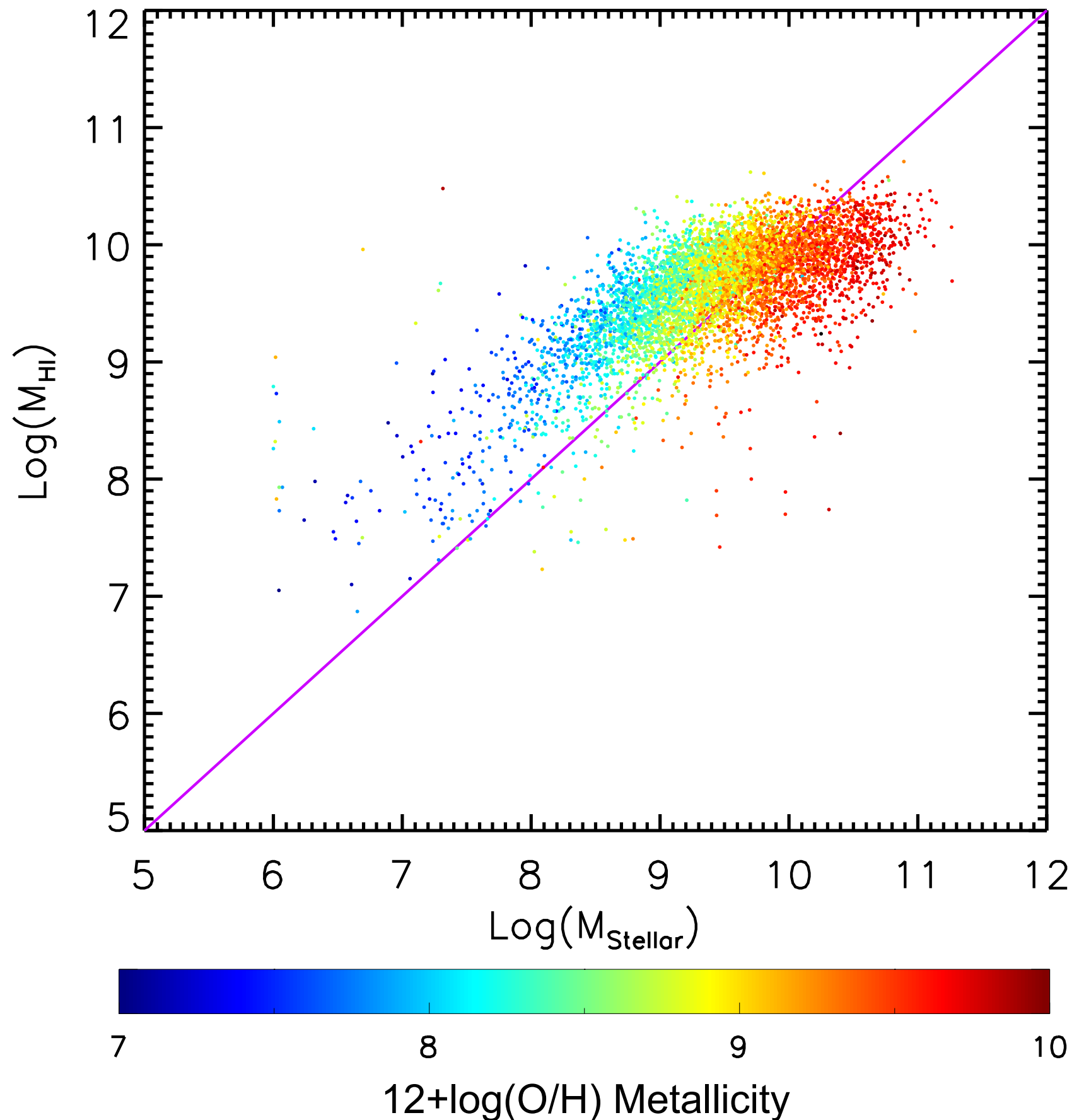
# What drives this relation?

- (I don't know the answer, so suggestions are welcome)



# Metallicity

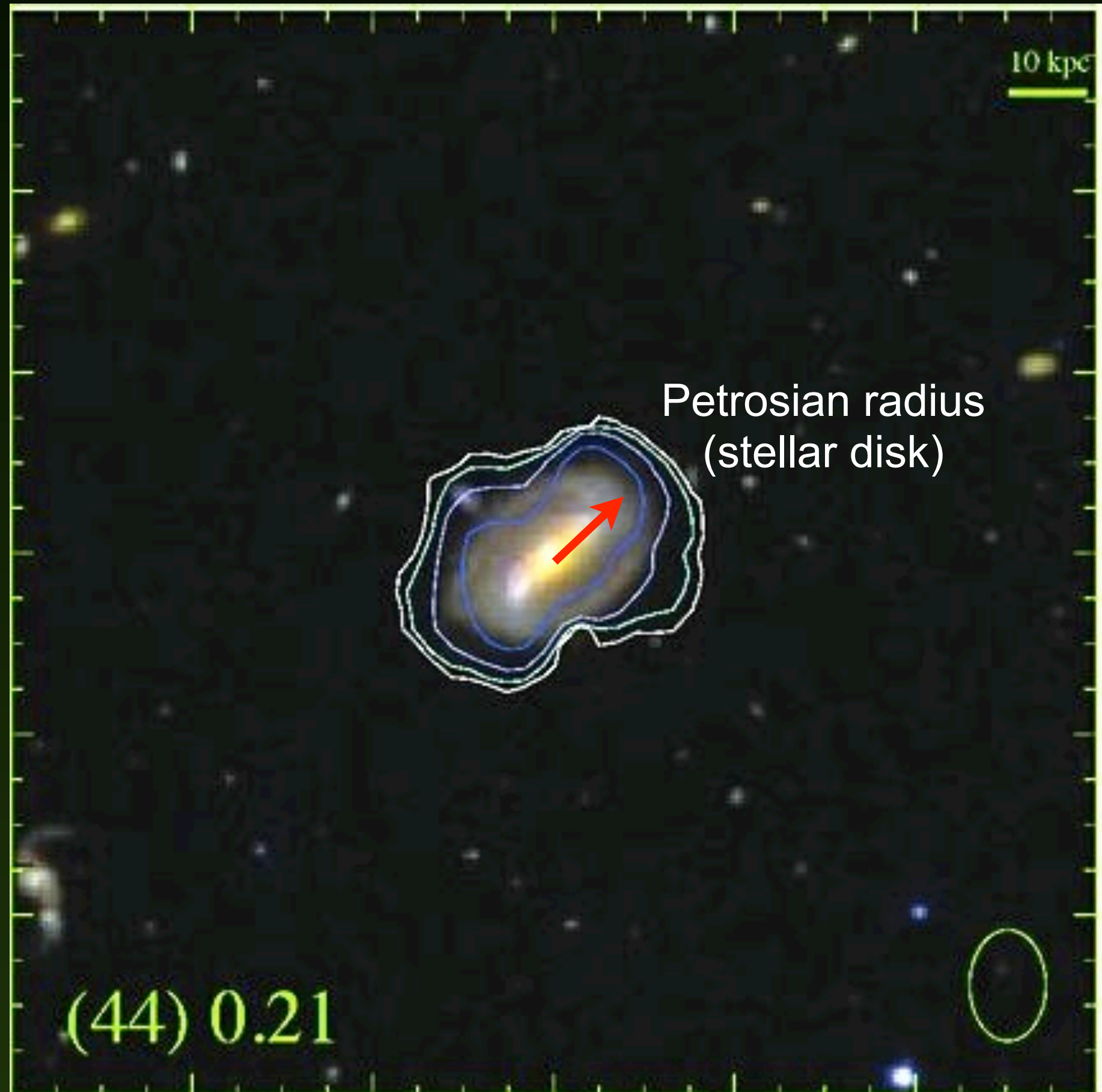
- Metallicity affects star formation efficiency
- Lower  $M_{\text{Stellar}}$  galaxies have lower metallicity
- Galaxies of nearly all  $M_{\text{HI}}$  can have the same metallicity





# Density

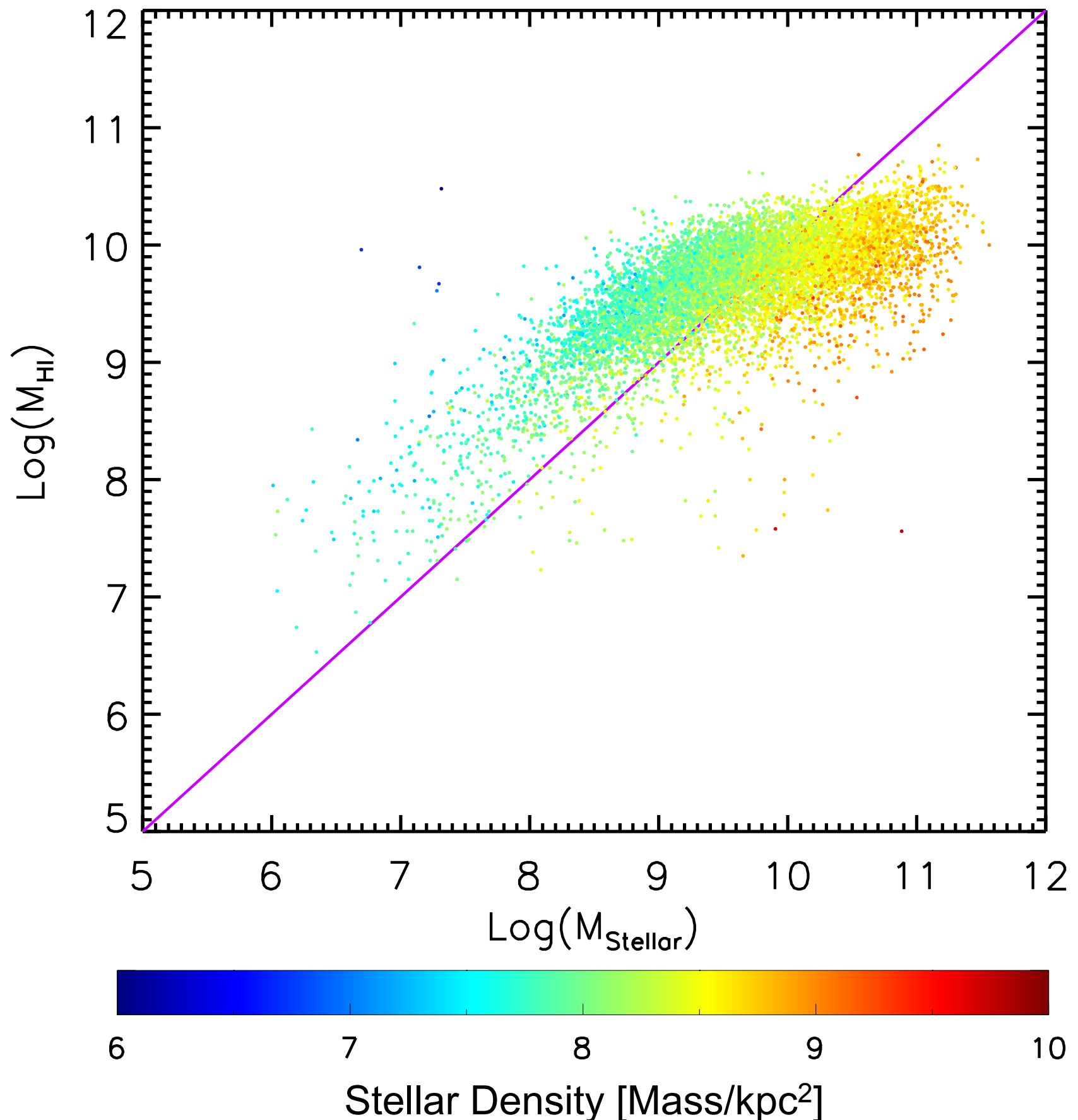
- SDSS provides a measure of the size of the stellar disks for each galaxy
- Can compute a measure of the area of the stellar disk



Surface brightness at  $r$ /average surface brightness within  $r = 0.2 \rightarrow$  Petrosian radius for SDSS

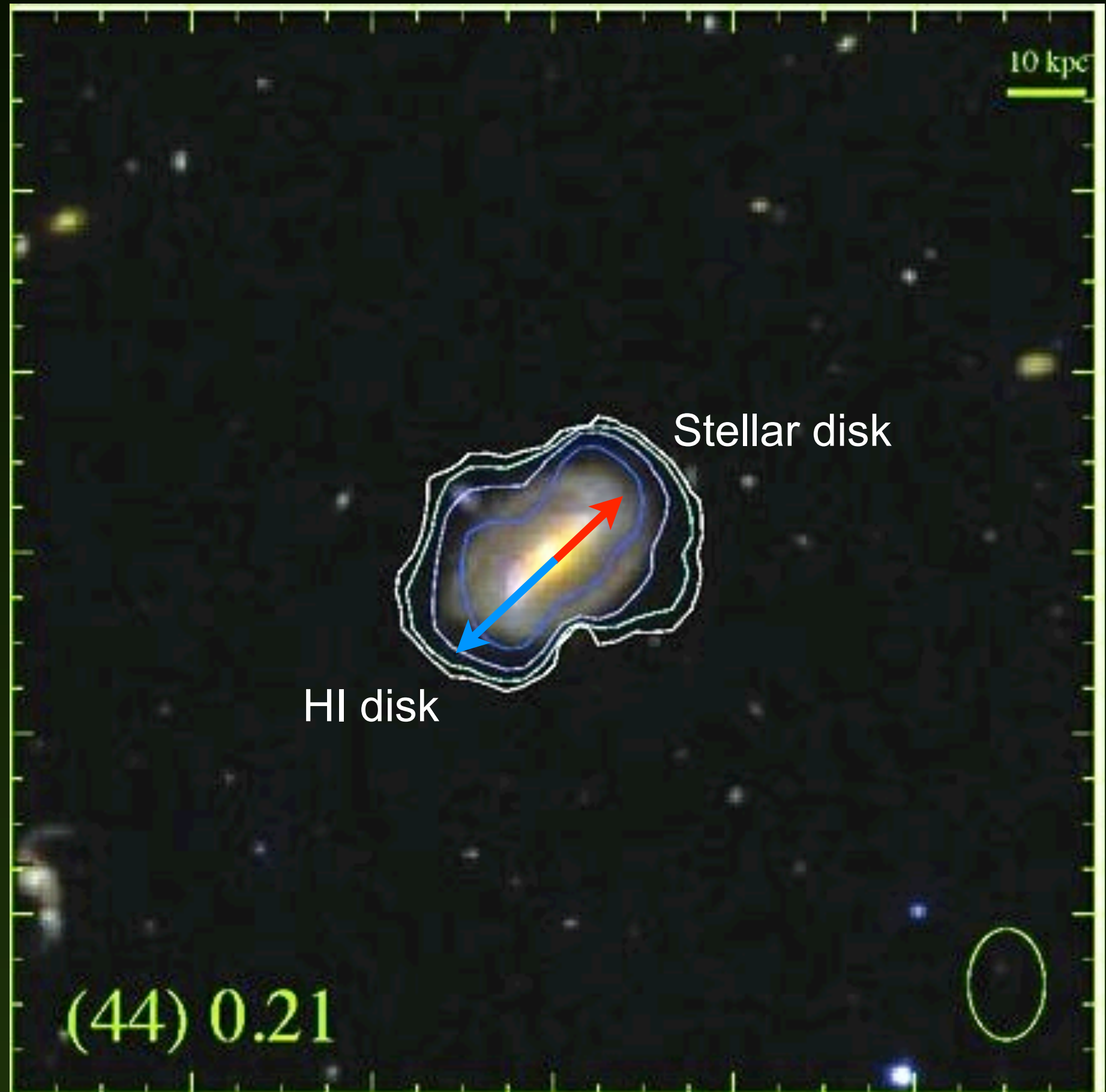
# Stellar density

- $M_{\text{Stellar}}/\text{area of disk}$
- Larger galaxies tend to be more dense
- Do the same thing for  $M_{\text{HI}}/\text{area of disk}$ ...



# “Density”

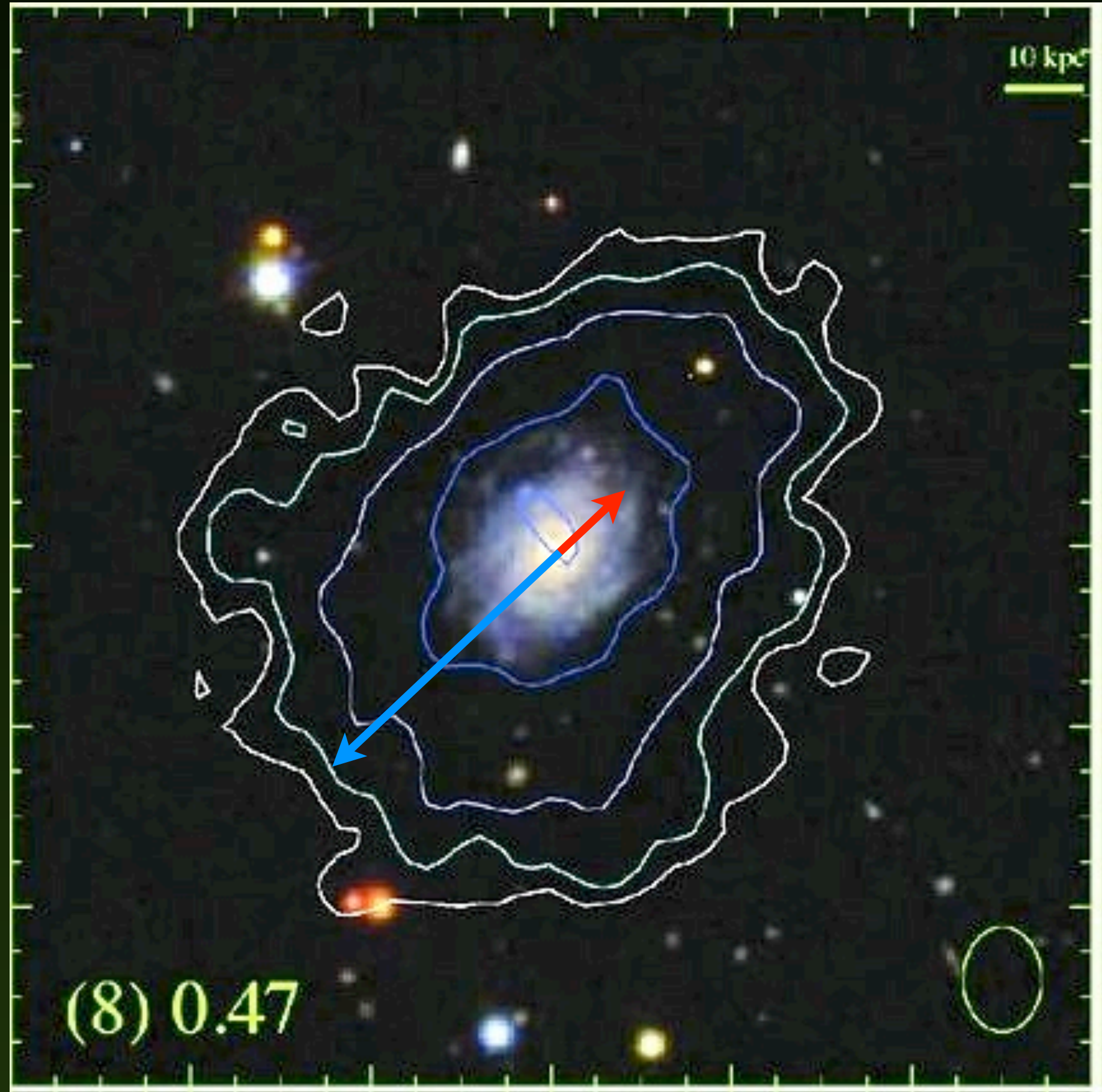
- For some galaxies, the size of the stellar disk is a good proxy for the size of the HI disk
- For some galaxies, this is ***not*** a good proxy for the size of the HI disk





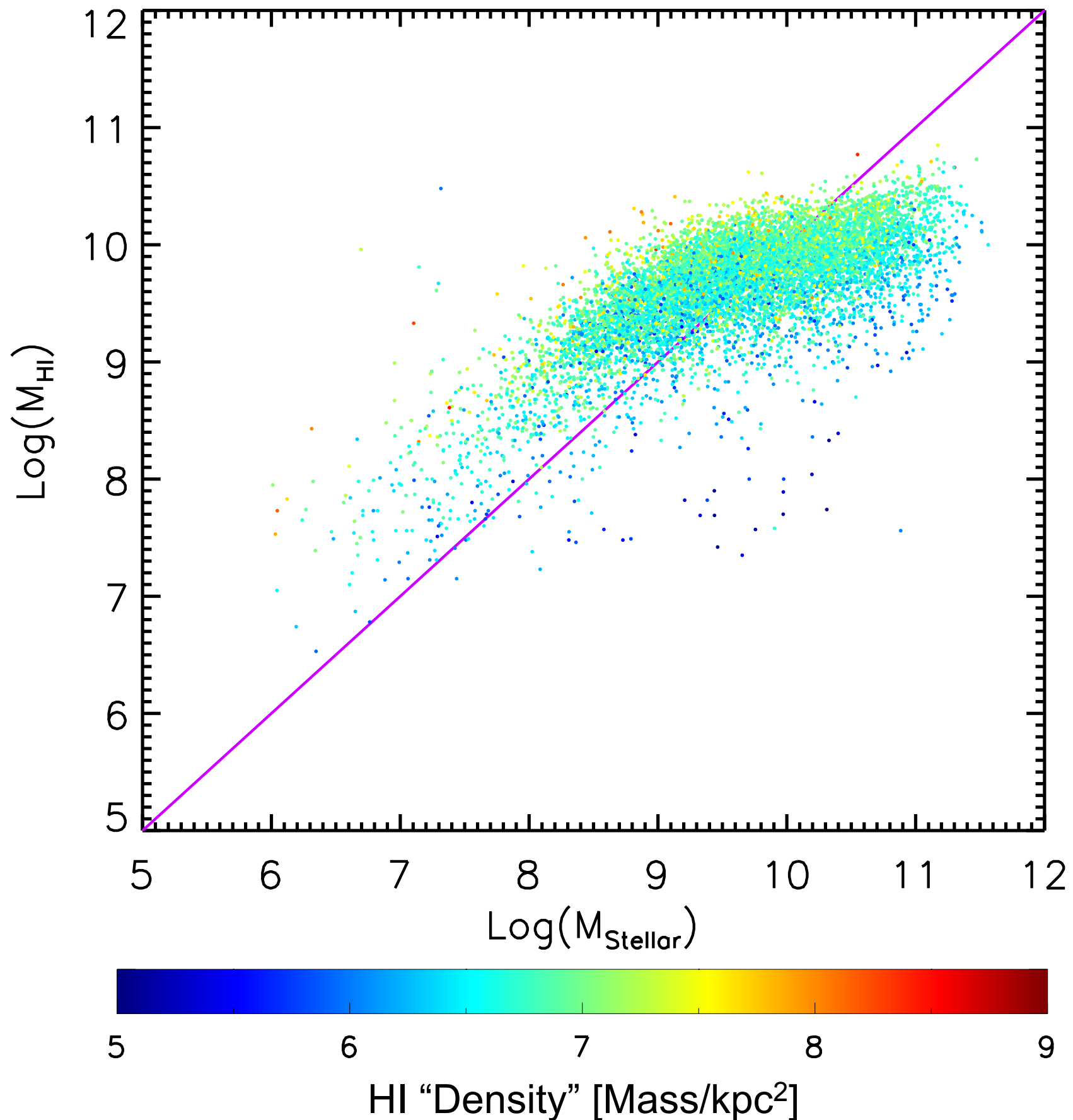
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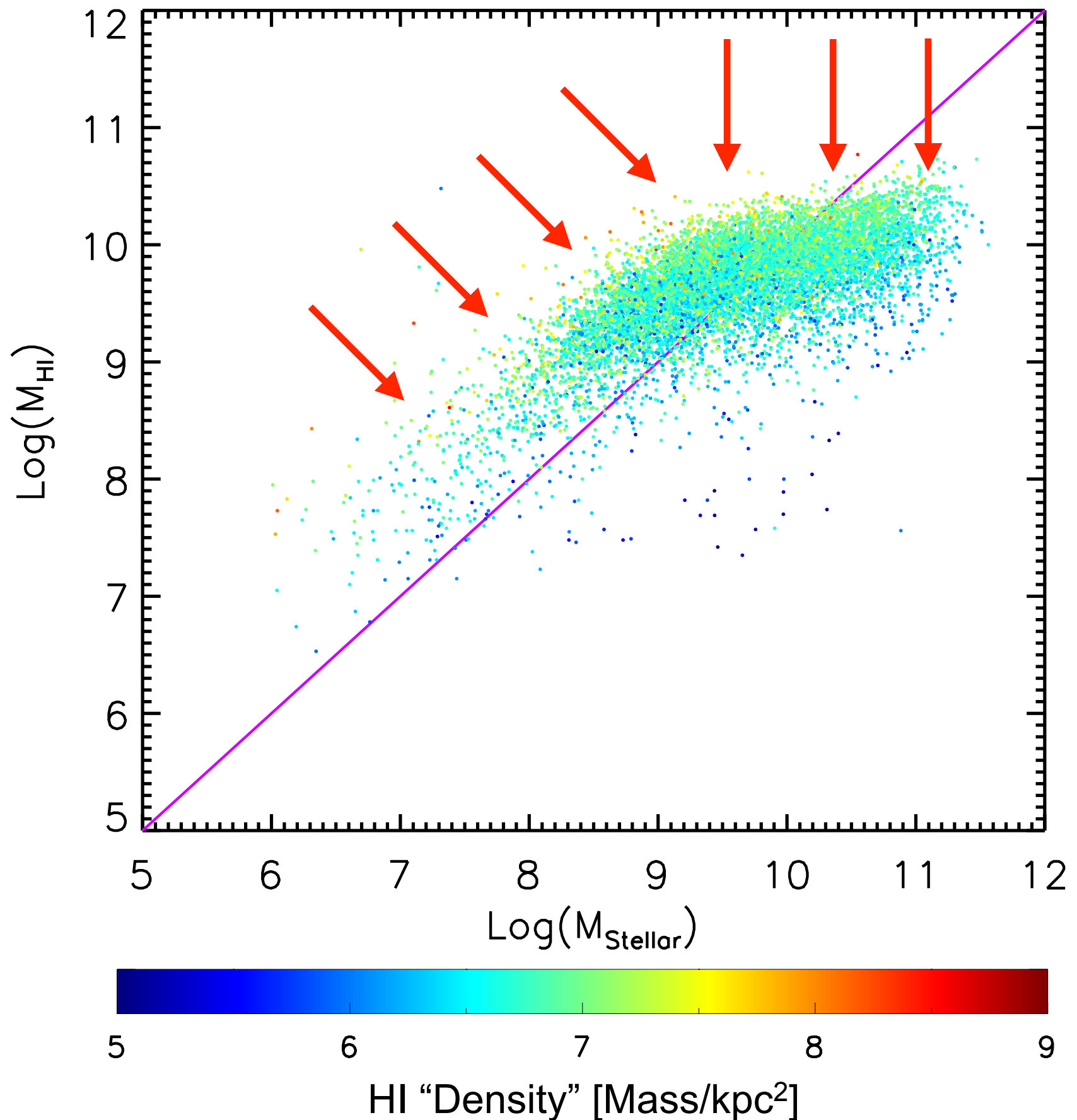
# HI “density”

- $M_{\text{HI}}$ /area of *stellar* disk
- There is an upper envelope of dense HI



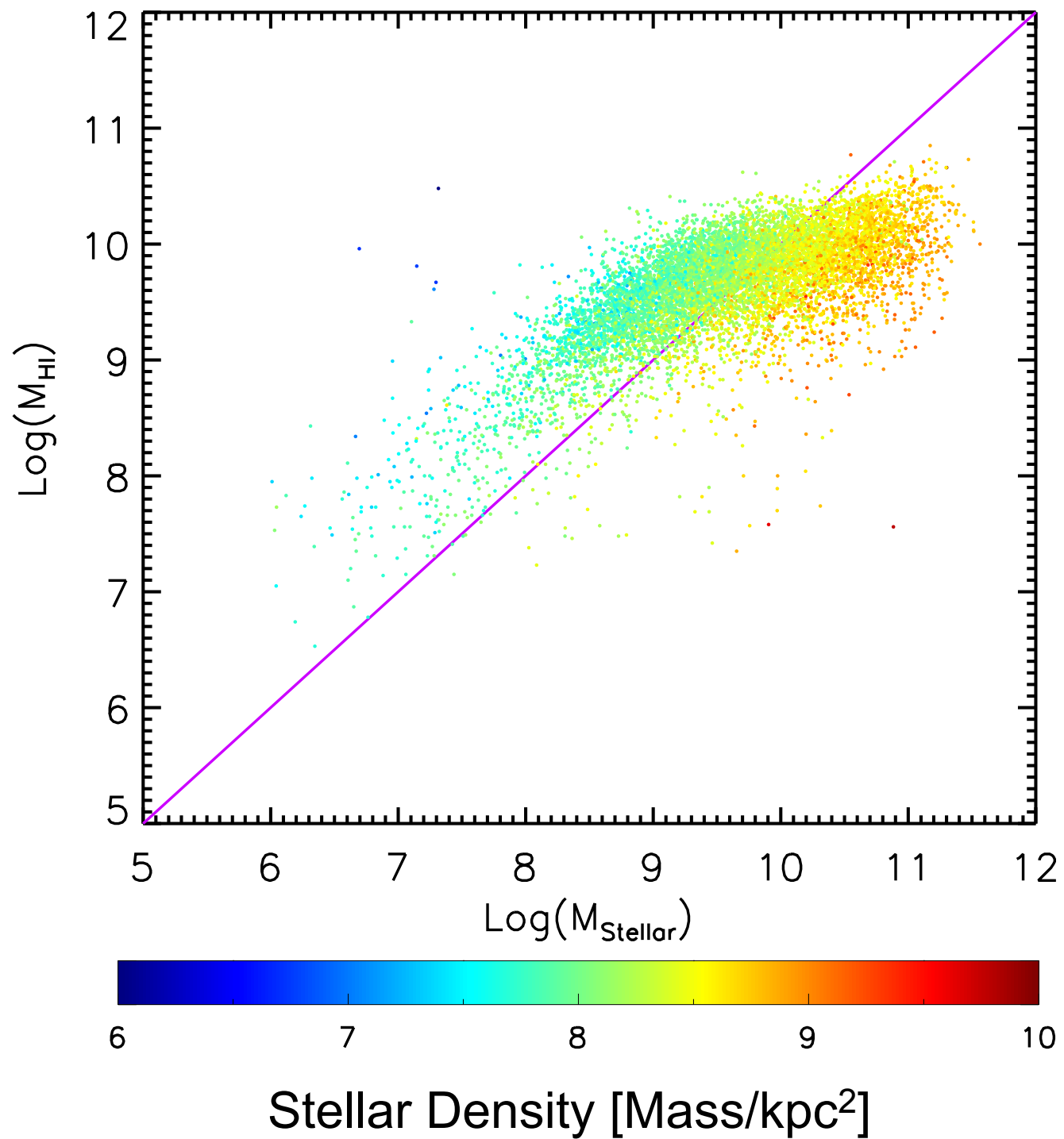
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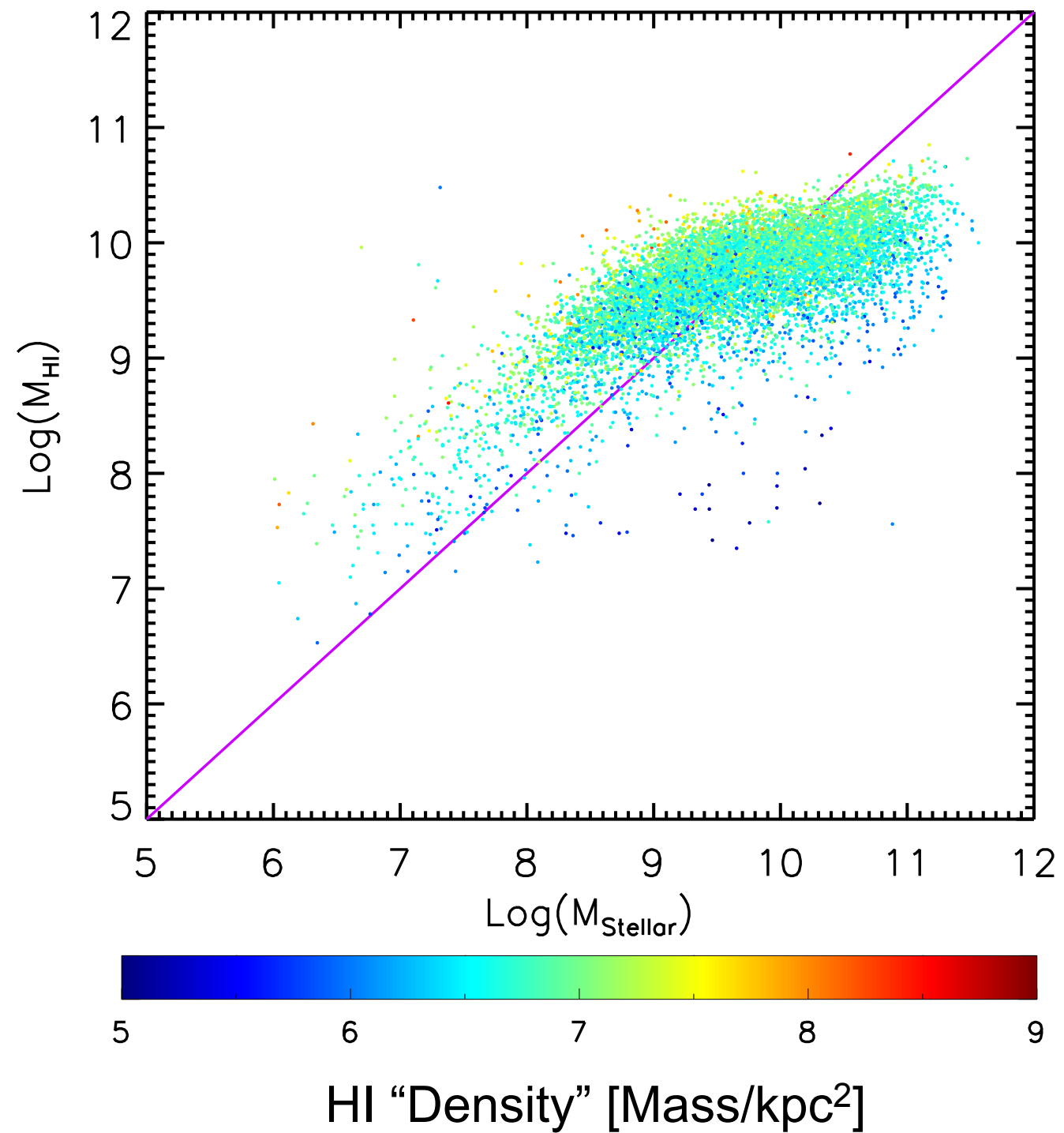




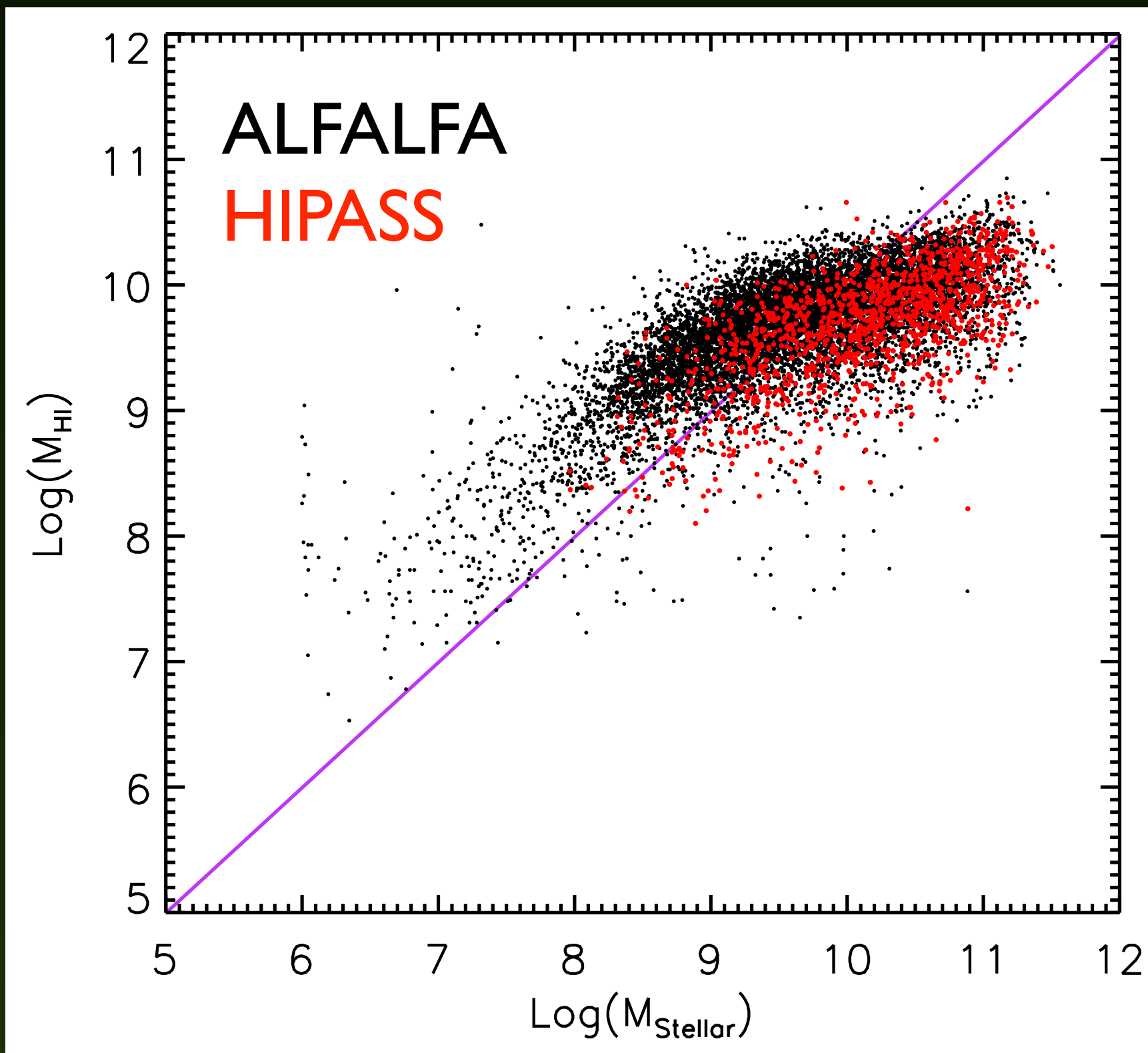
# Stellar density



# HI “density”



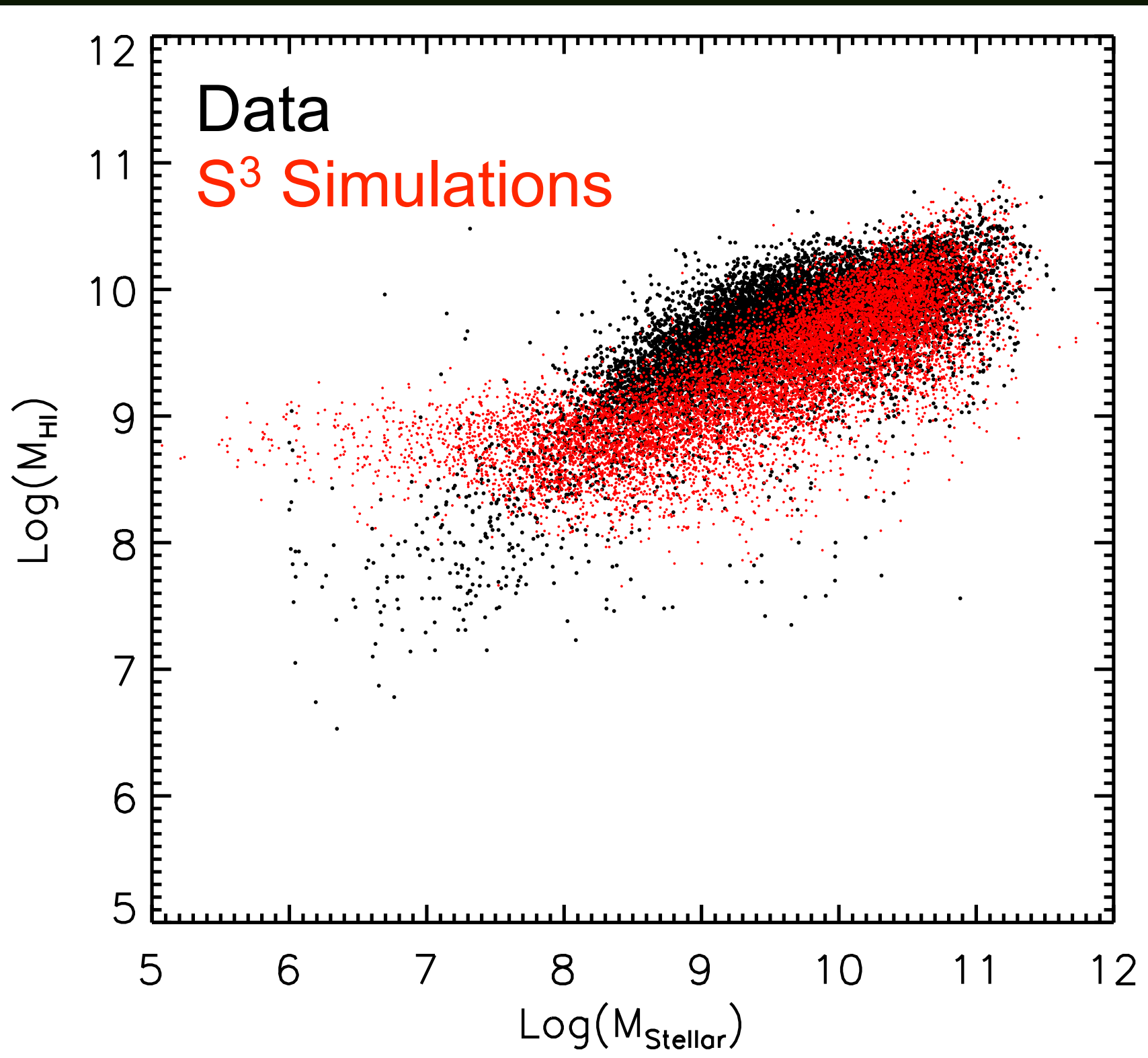
# ALFALFA vs HIPASS



Thanks for the  
data, Danail!

# How do simulations compare with the data?

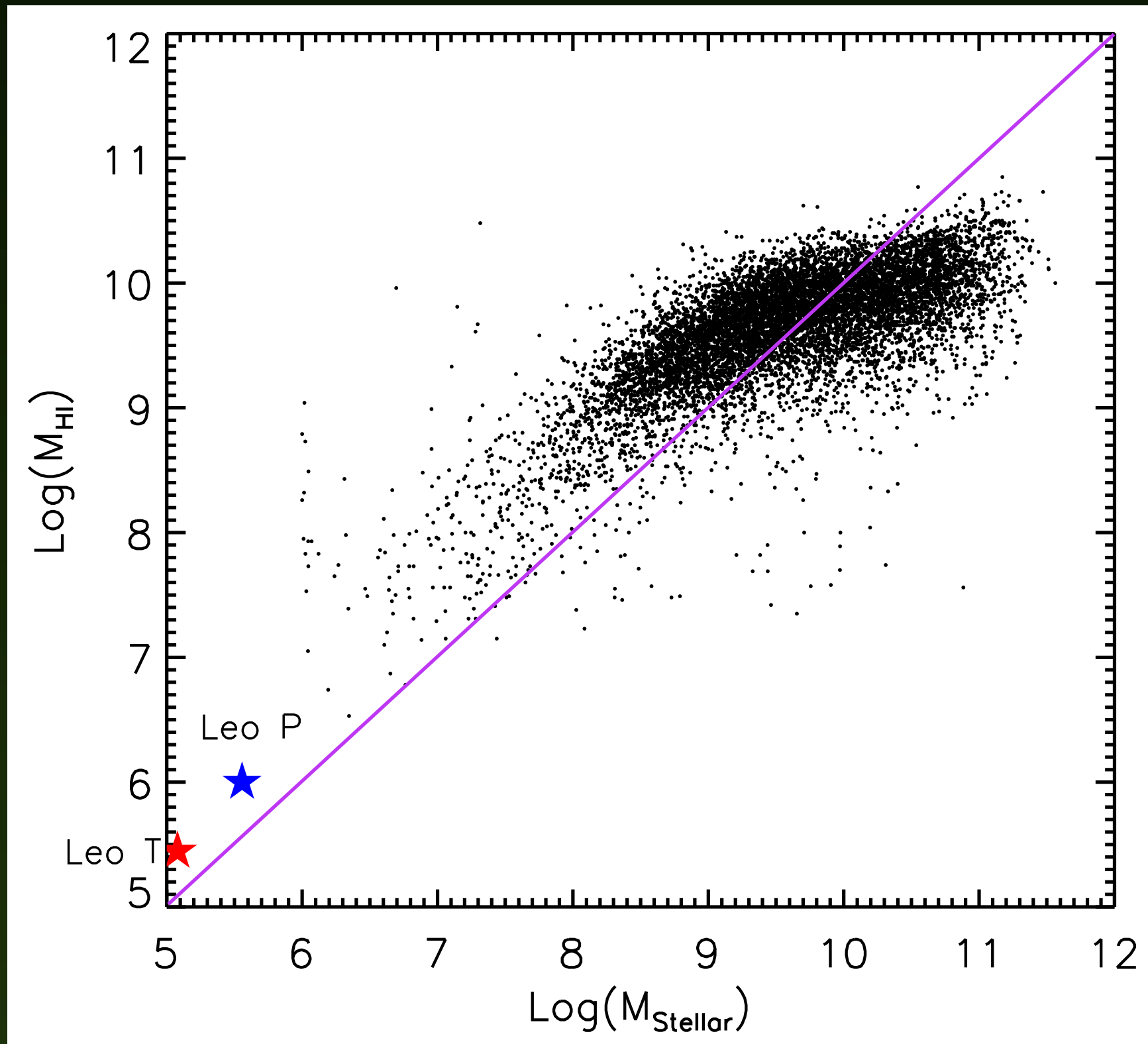
- SKA Simulated Skies ( $S^3$ ) → Talk to Danail for details
- Millenium simulation + semi-analytic galaxy formalism + HI and H<sub>2</sub>
- Extract a volume from the simulations approximating ALFALFA
- Overall normalization is correct, but the slope is wrong and the break is missing
- H<sub>2</sub> is also available, so should look at that as well



Thanks for the  
simulations, Danail!

# How do galaxies move within this plot?

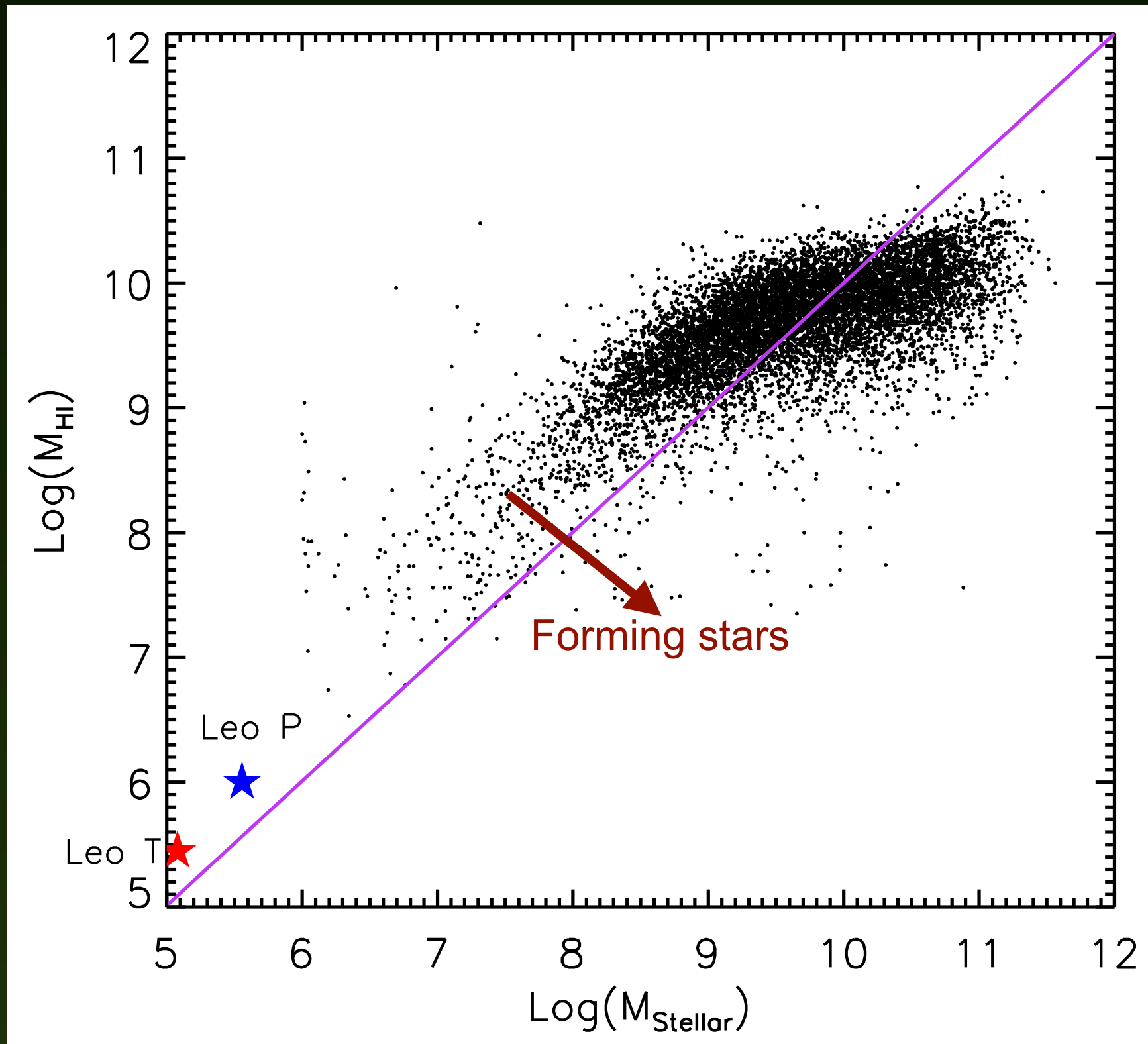
- Would be interesting to follow the path of galaxies in simulations





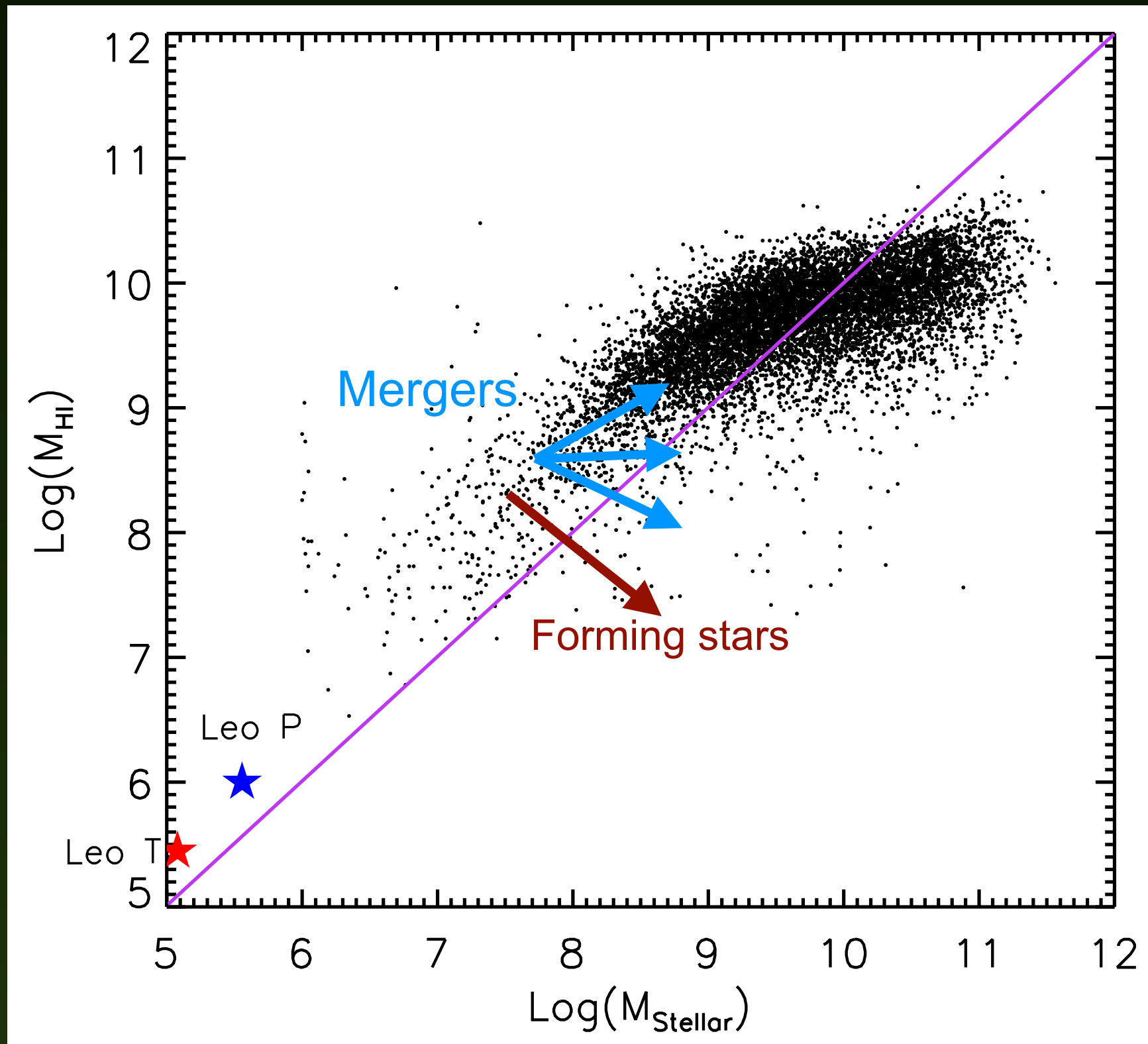
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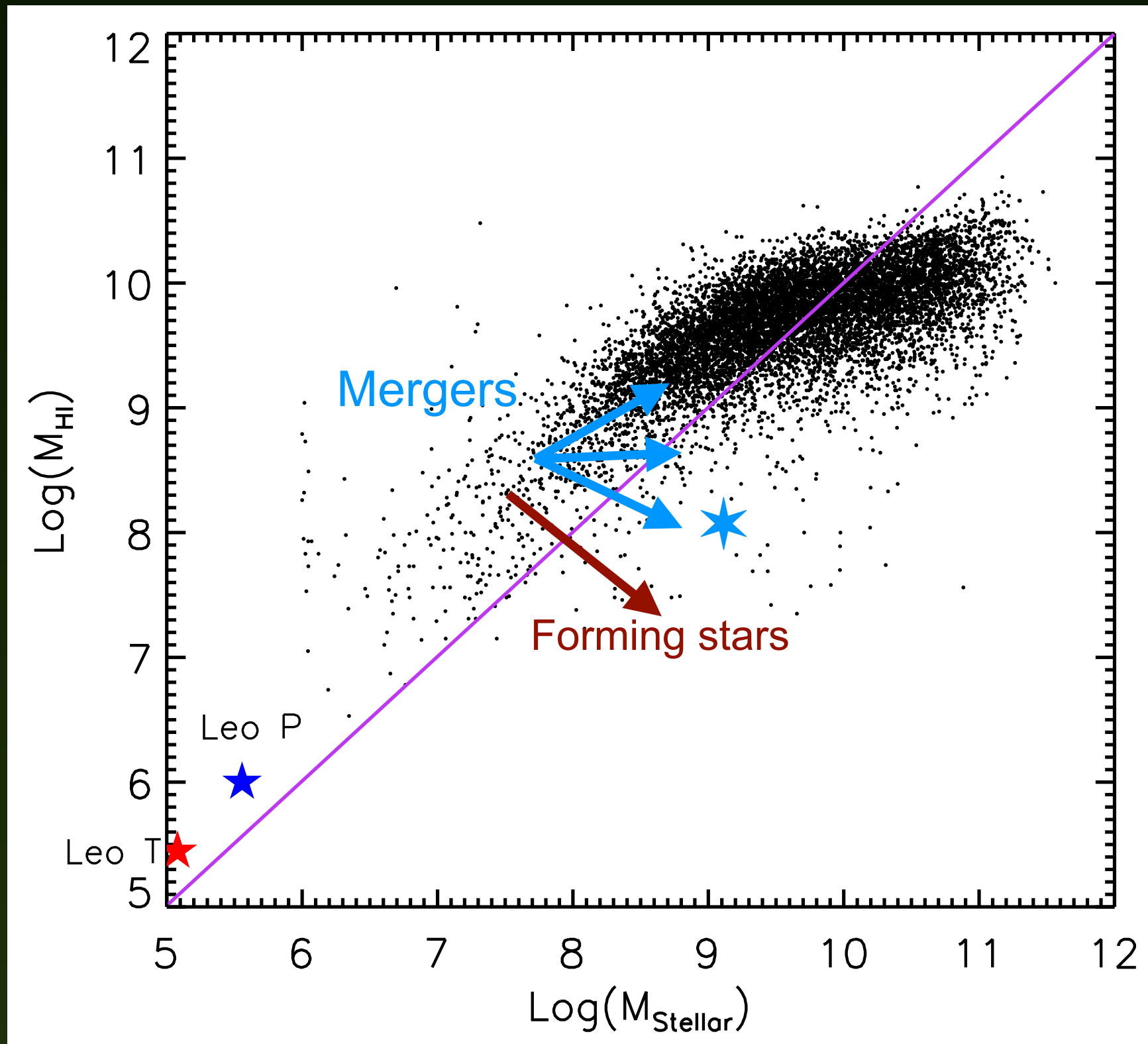
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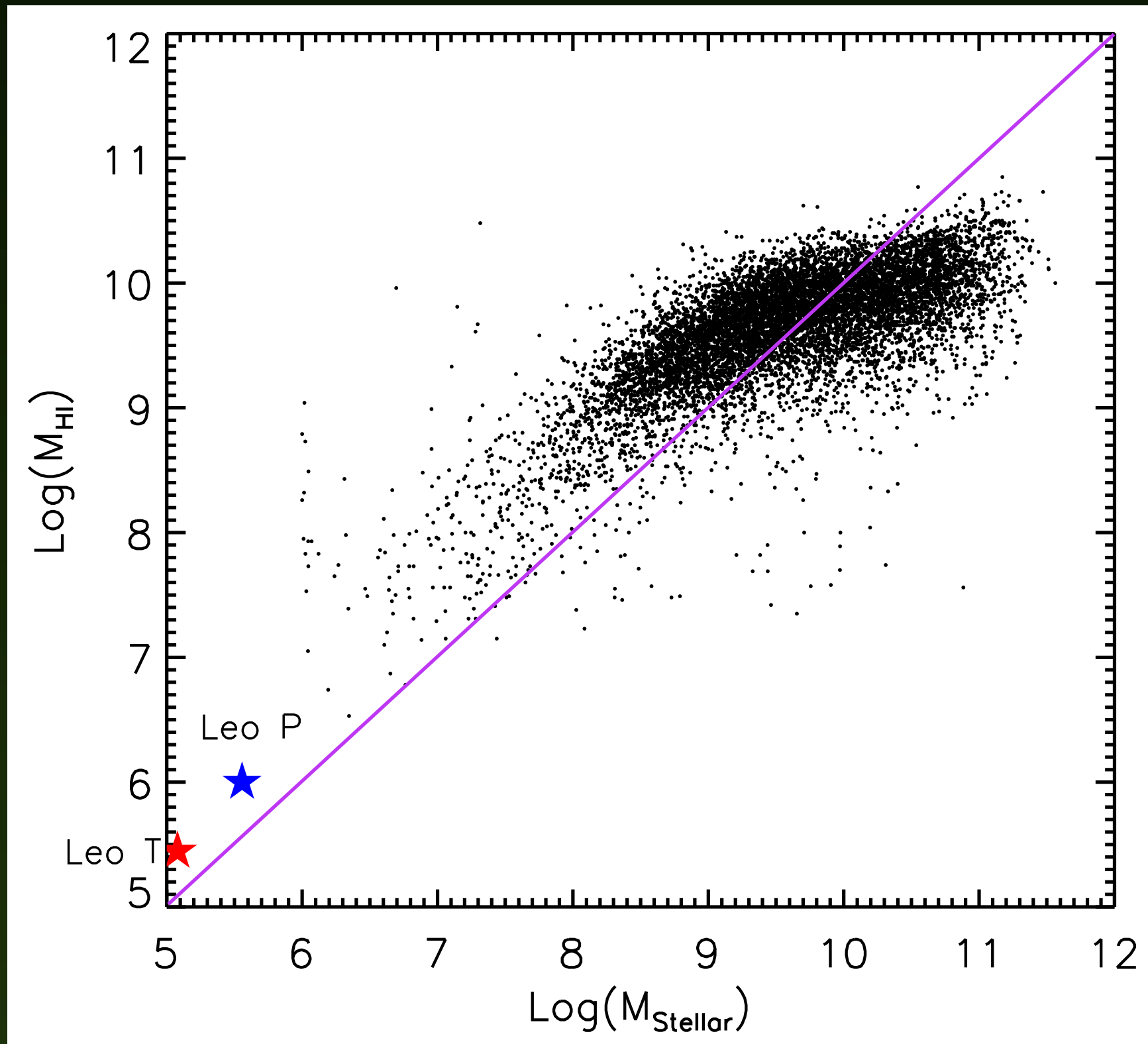
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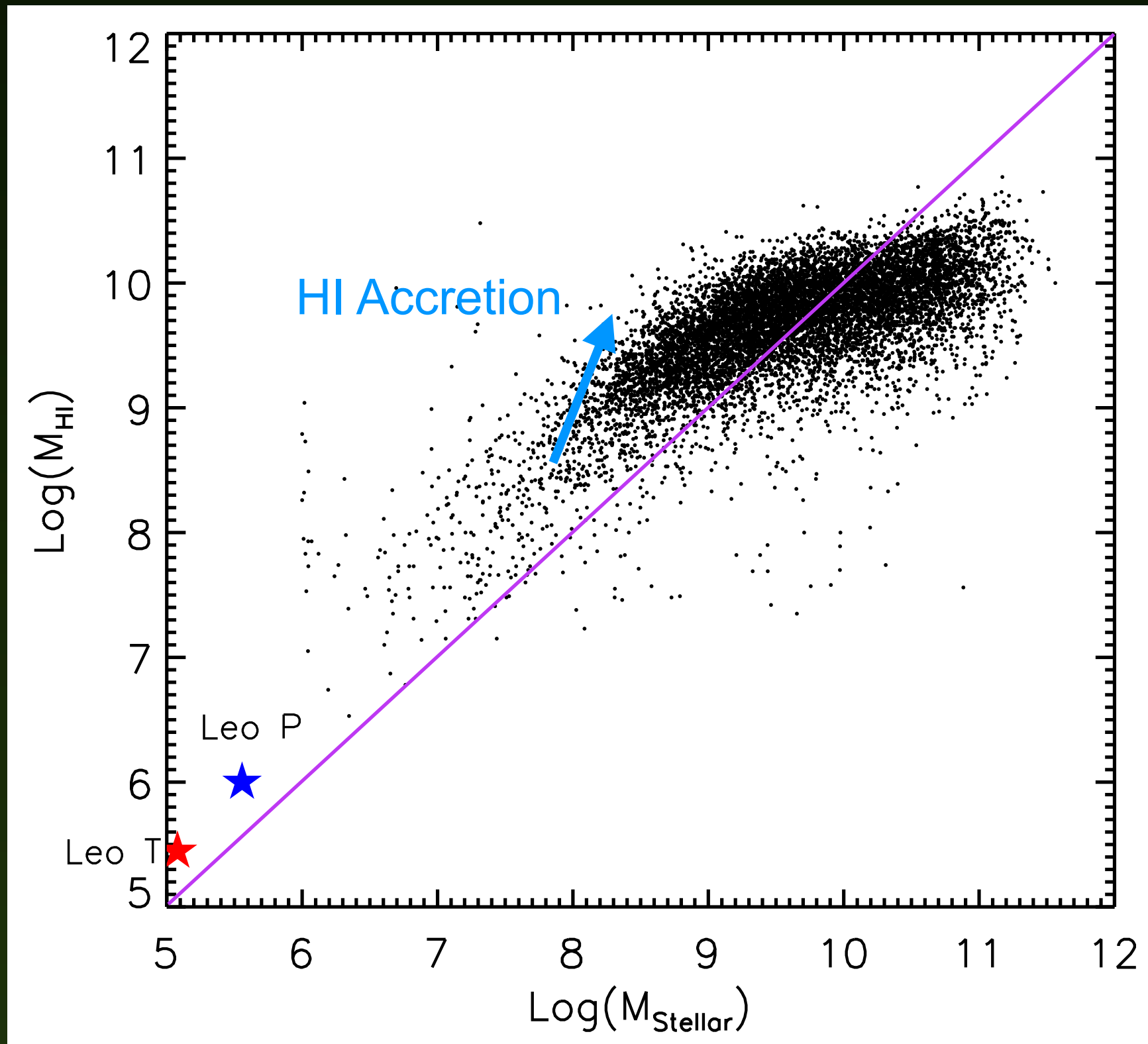
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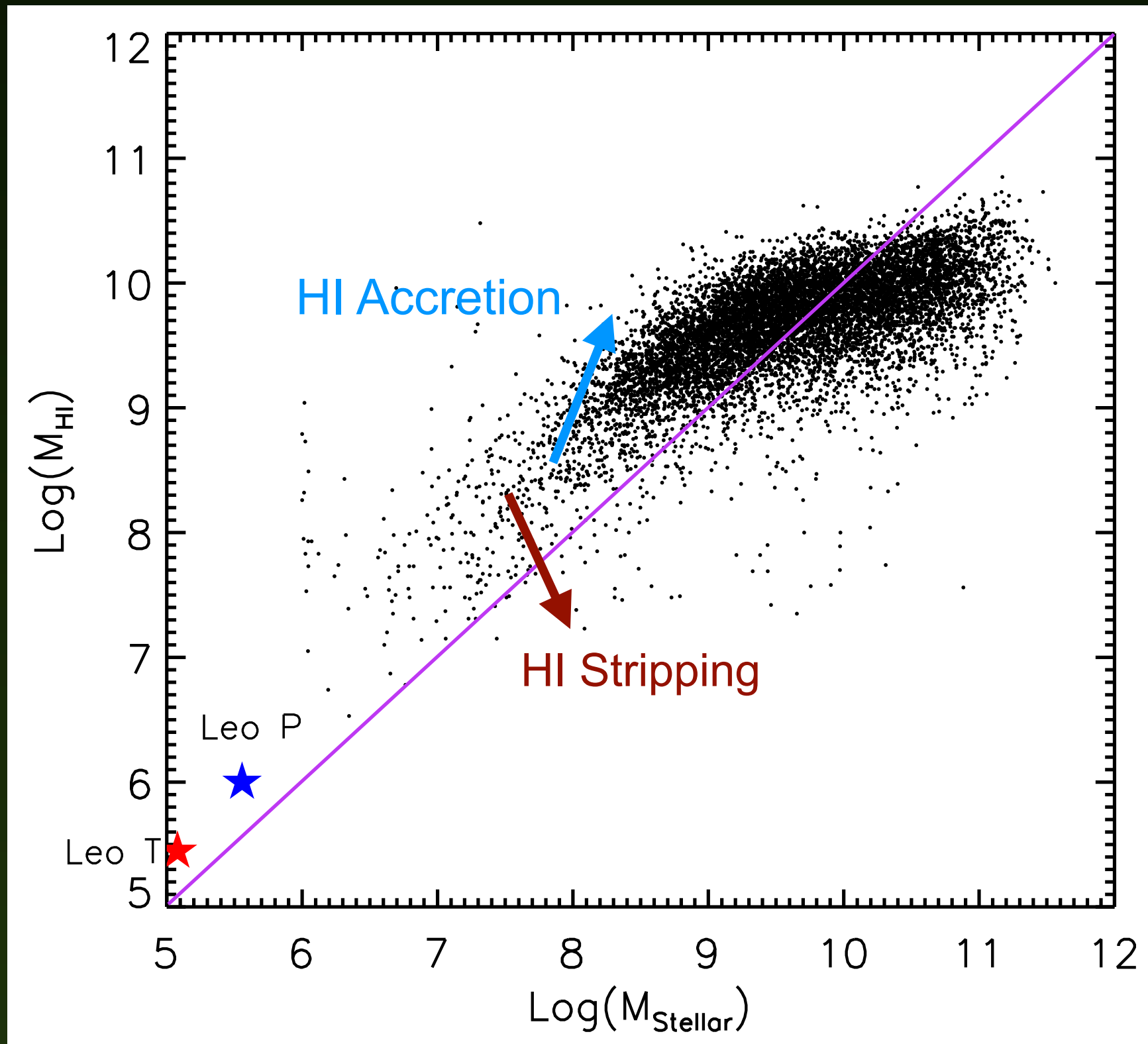
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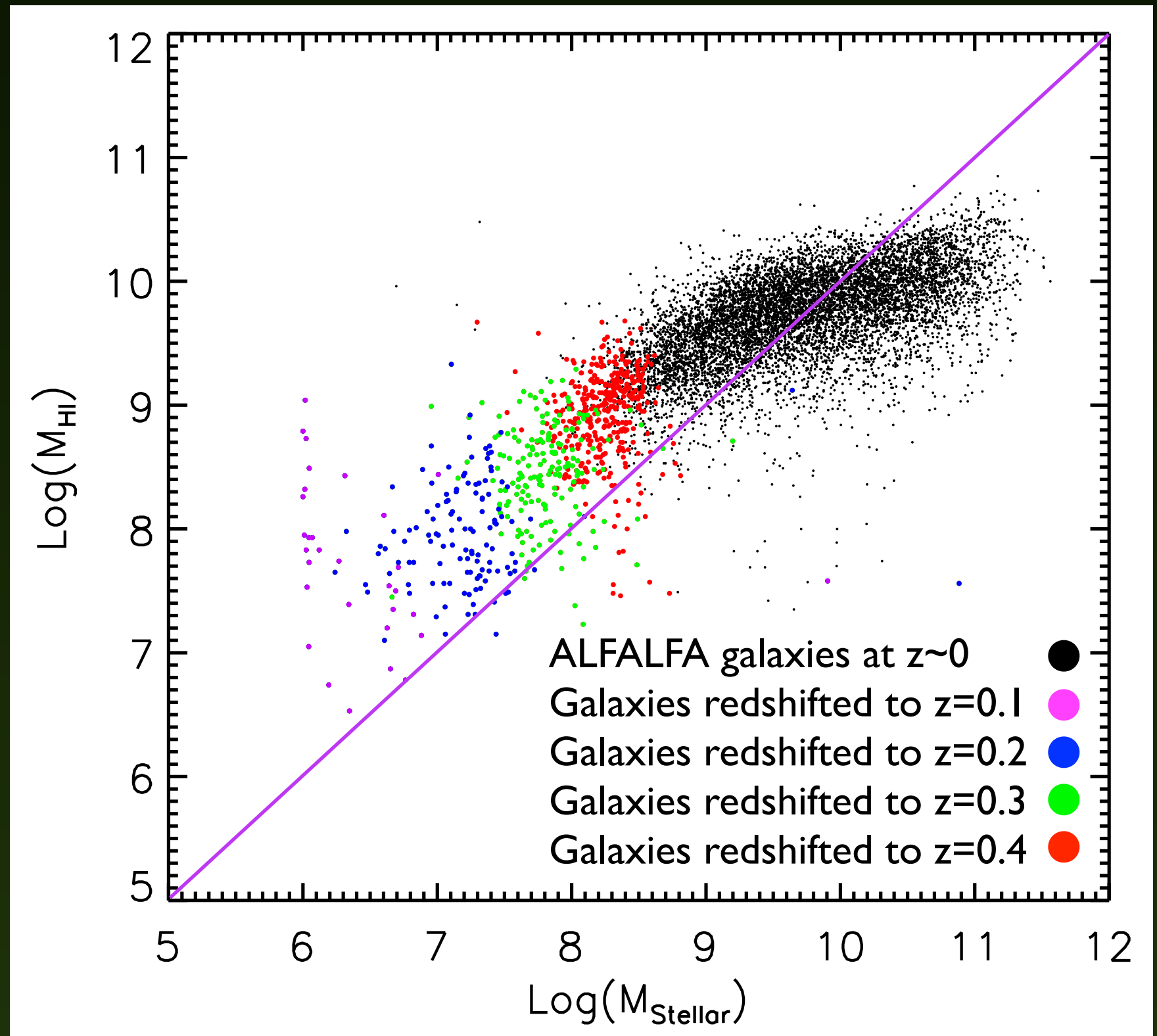
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# What will the SKA and precursors contribute?

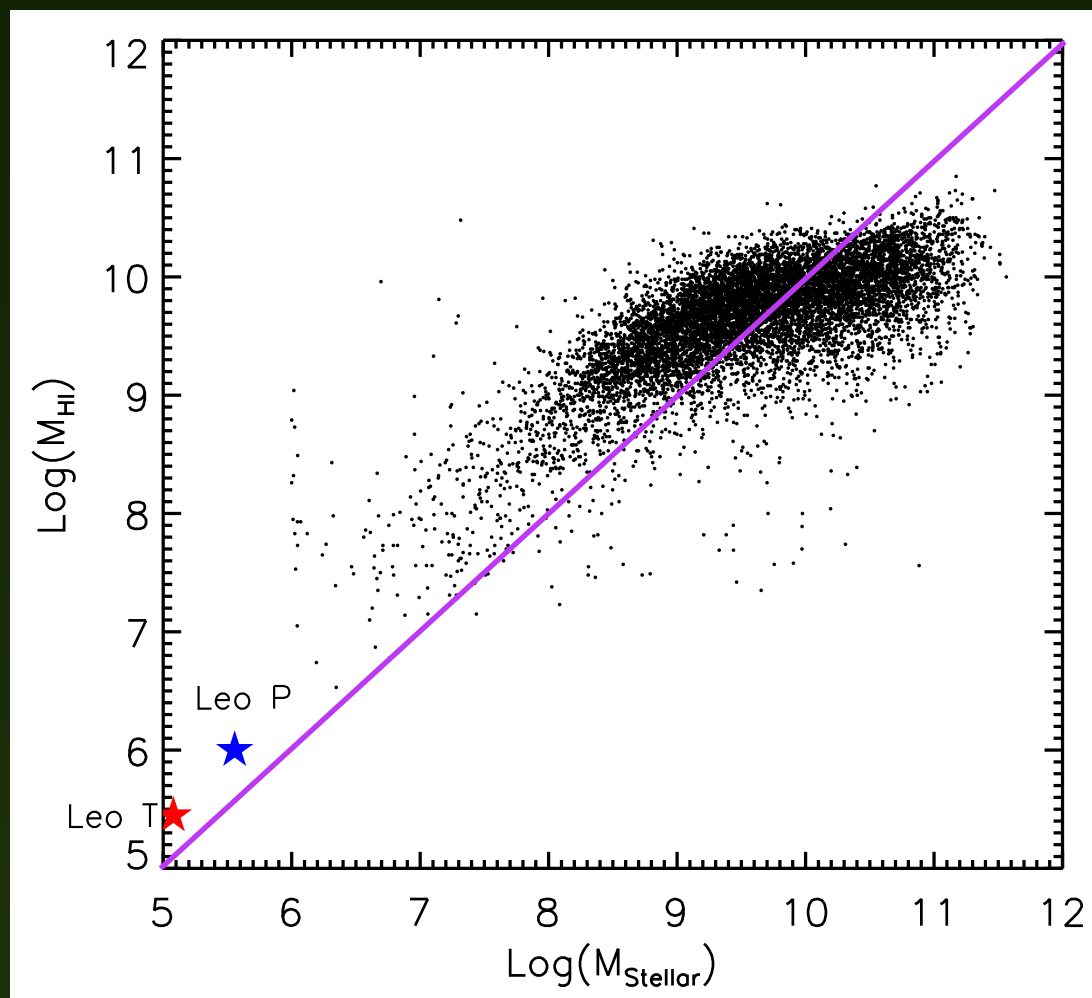
- Large area surveys to cosmological redshifts
- With new telescopes  $M_{\text{HI}}$  (y-axis) is easy,  $M_{\text{Stellar}}$  (x-axis) more difficult

- Optical spectroscopy from GAMA to  $r < 19.8$
- Optical imaging from KiDS to  $r < 25.2$
- Imaging magnitude limit well matched to HI sensitivity of DINGO



# Summary and work to do

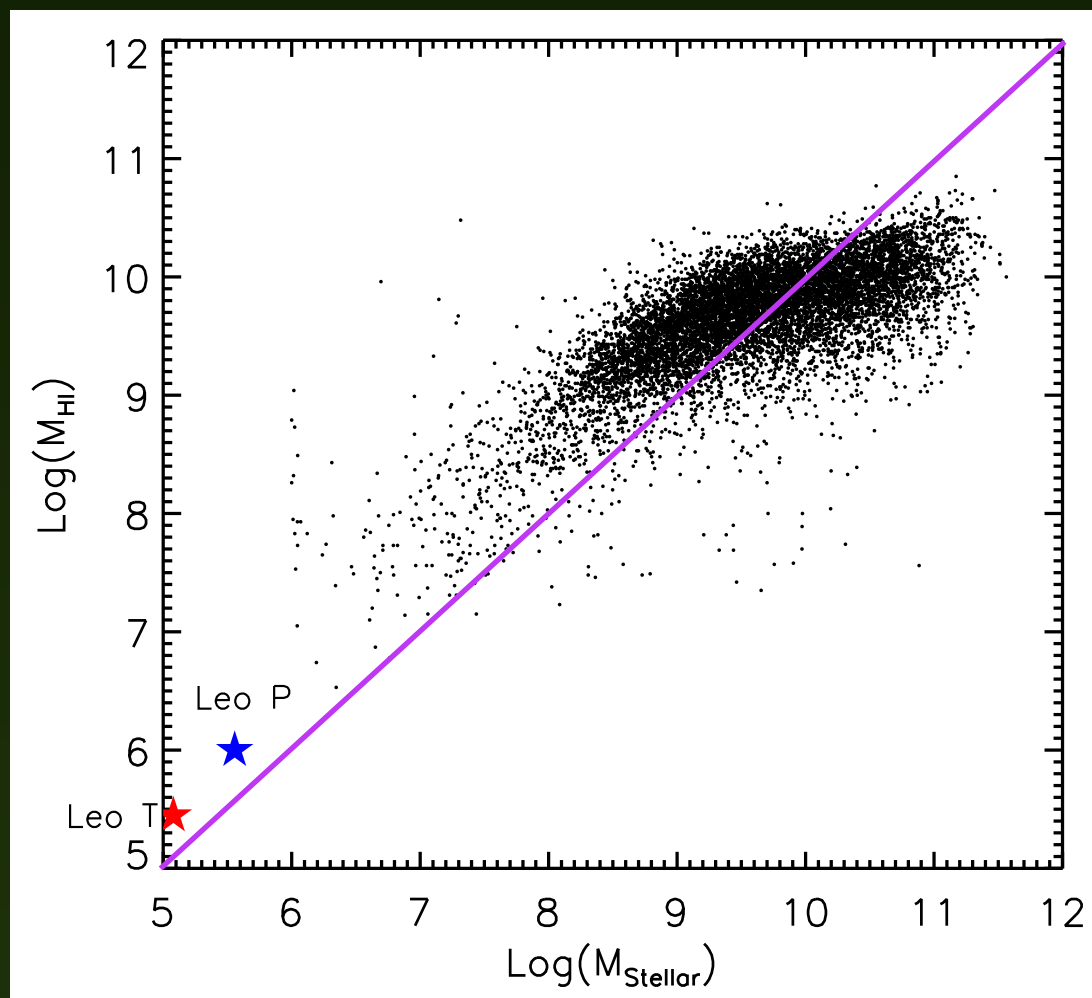
- Current large surveys are exposing previously unseen trends in galaxy populations
- The underlying cause of the  $M_{\text{HI}}\text{--}M_{\text{Stellar}}$  relation remains uncertain, but HI density is a possible candidate
  - ➔ Compare data with available simulations
  - ➔ Investigate movement of galaxies within the  $M_{\text{HI}}\text{--}M_{\text{Stellar}}$  plot
  - ➔ Investigate the galaxies at the break ( $M_{\text{Stellar}} \sim 10^9 M_{\odot}$ )





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With thanks to

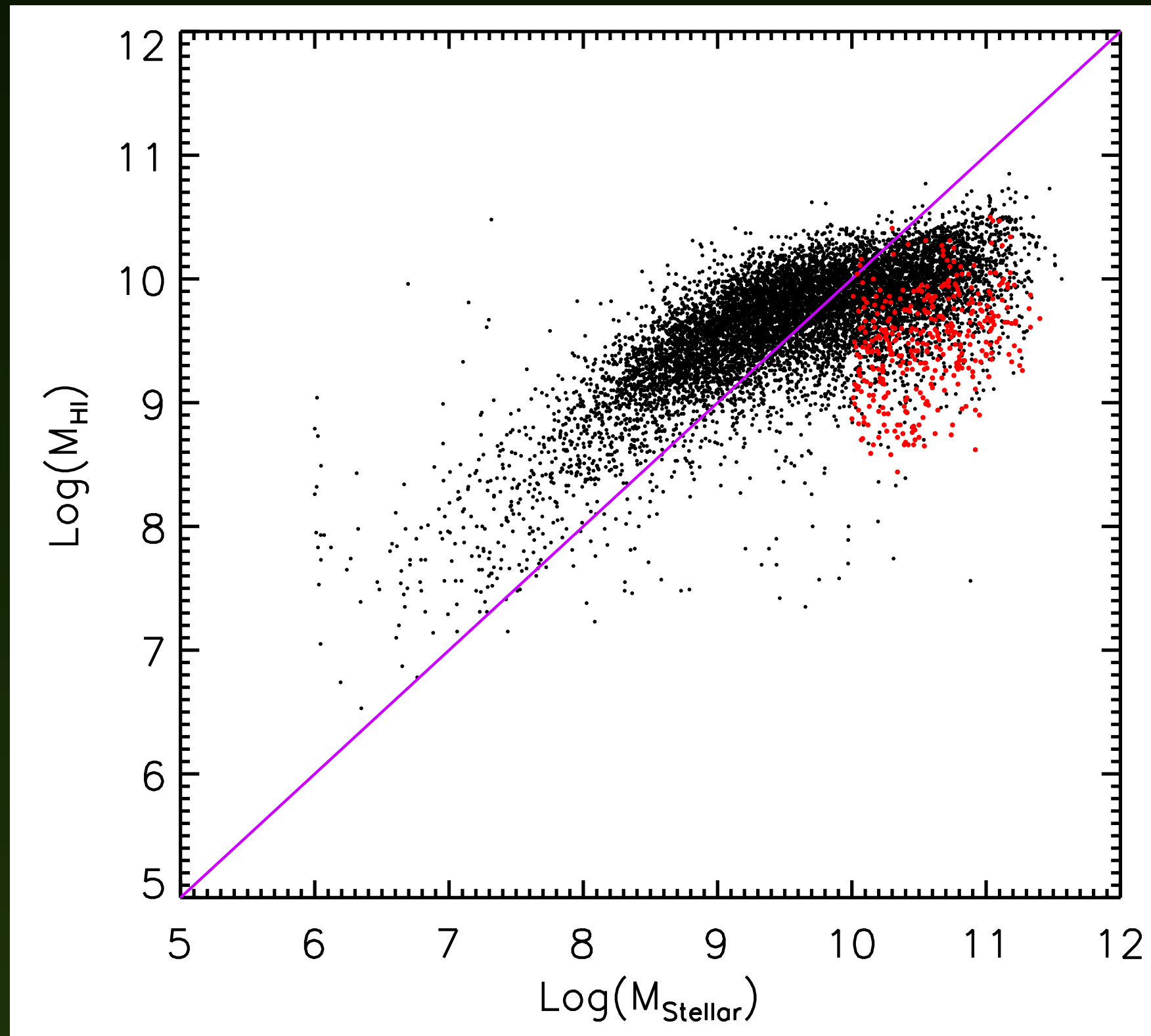






# GASS galaxies

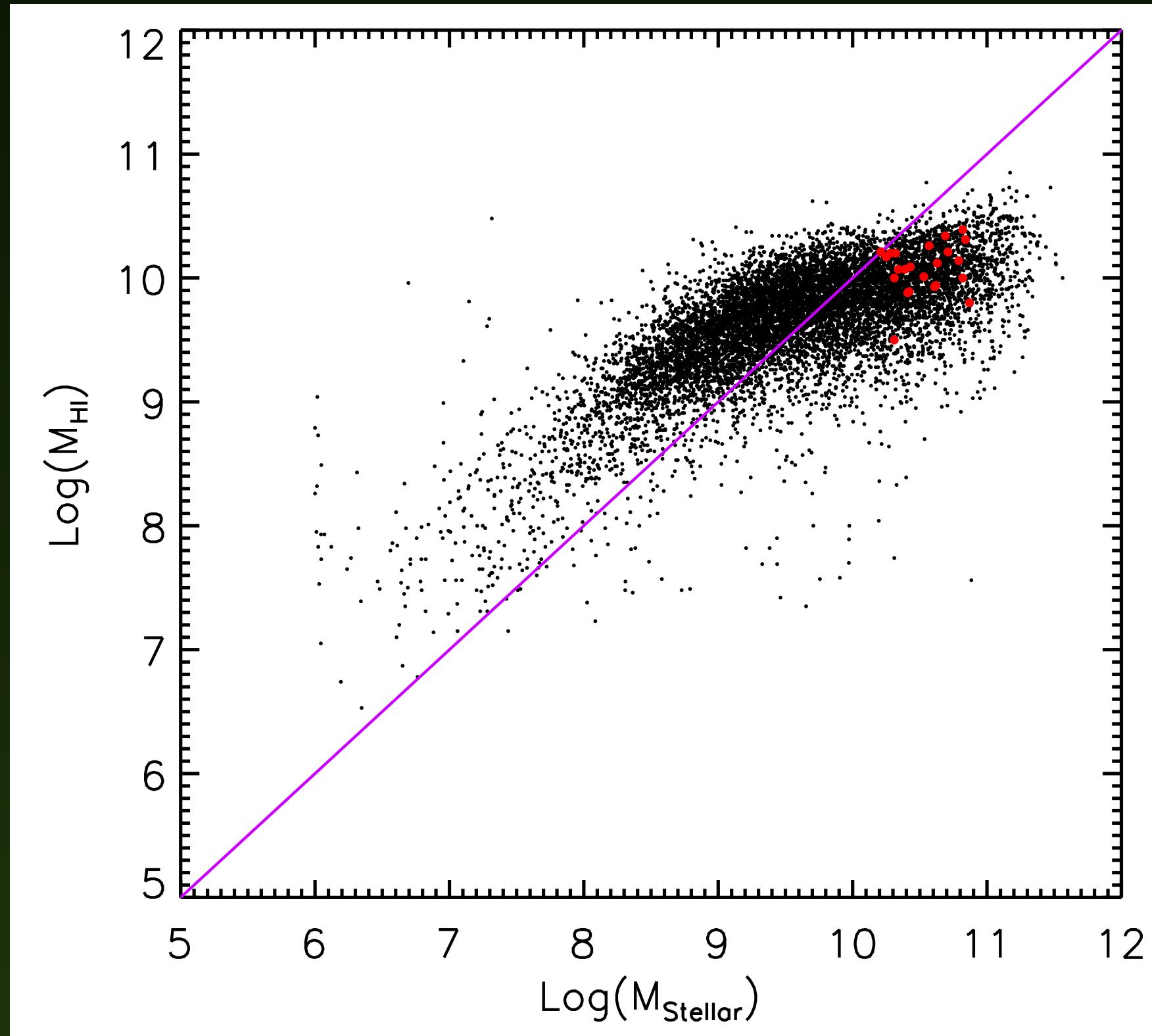
- Stellar mass-selected galaxies



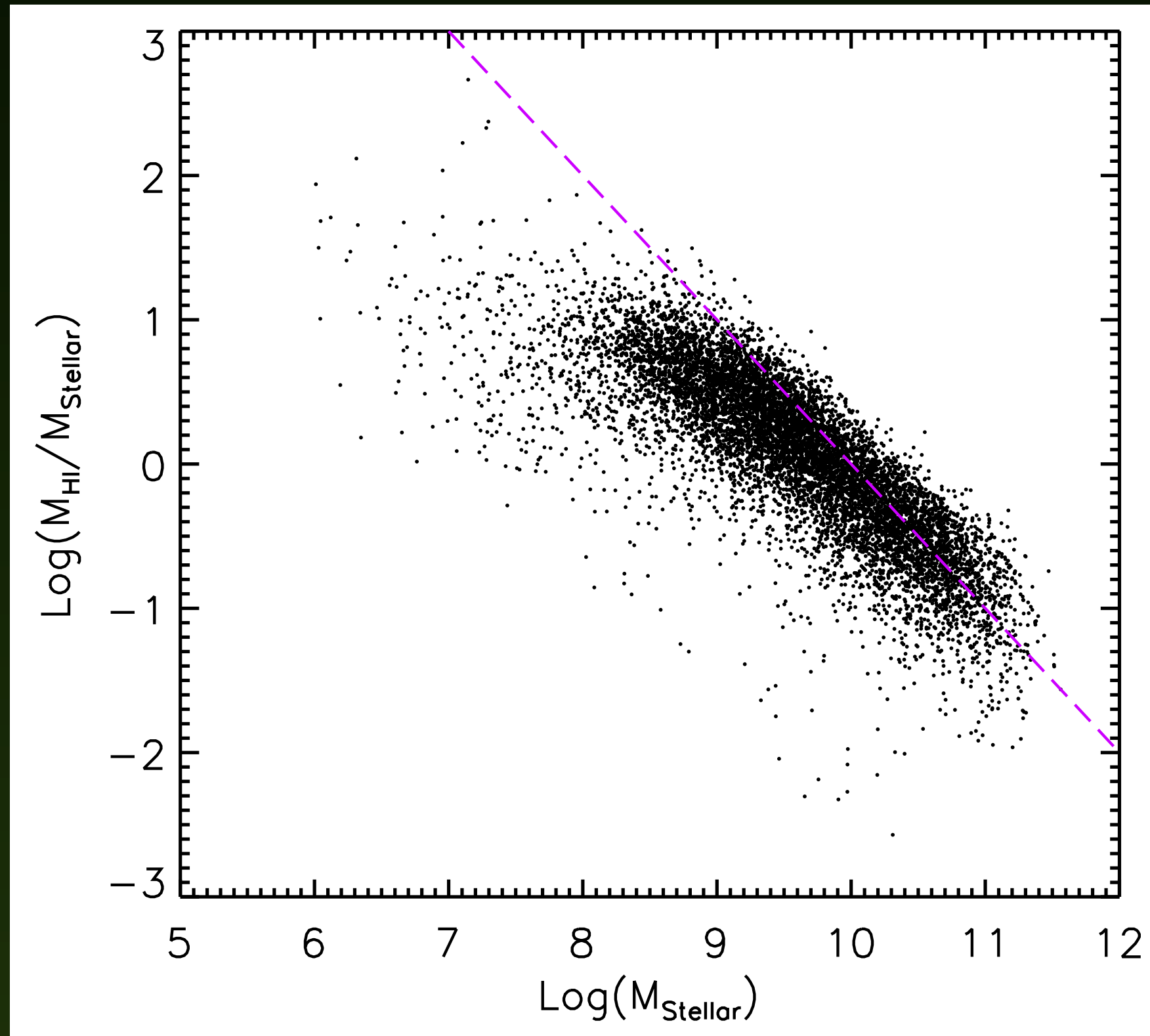


# Bluedisk galaxies

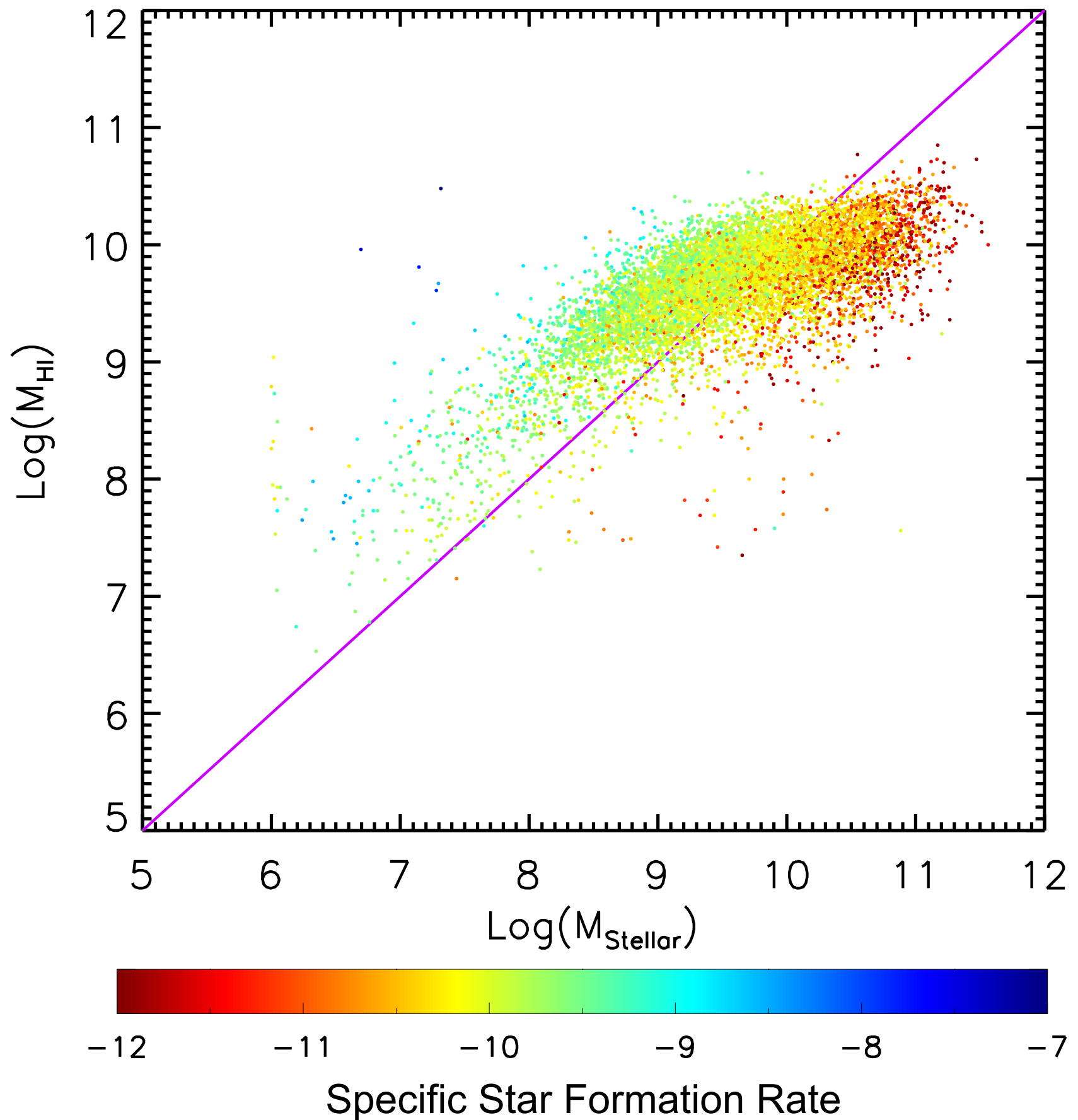
- Stellar mass-selected galaxies



# HI mass fraction



# Specific Star Formation Rate



# Optical g-r colour

