The baryon cycle: accretion, outflow and the circum-galactic medium

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PLAN

1. Baryons traced by Neutral Gas
2. Gas Flows in Absorption
3. Conclusion

Stephan Frank

RAMSES AMR simulations (Teyssier+)
Lyα, z=0.75, 6.6x6.6x300 (phys) Mpc

Frank..CP+12

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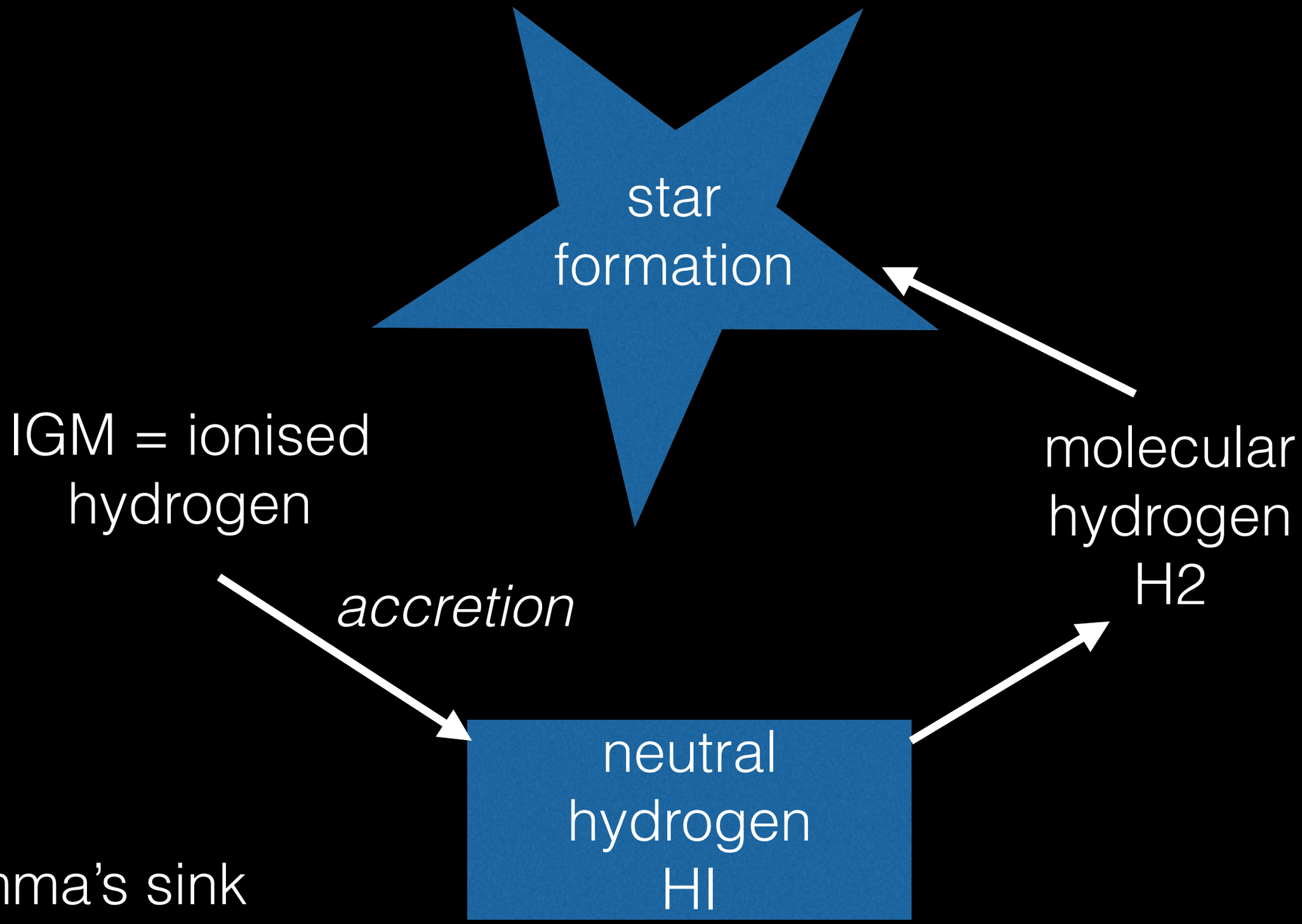
Why Neutral Gas HI?



Attila Popping

The Data

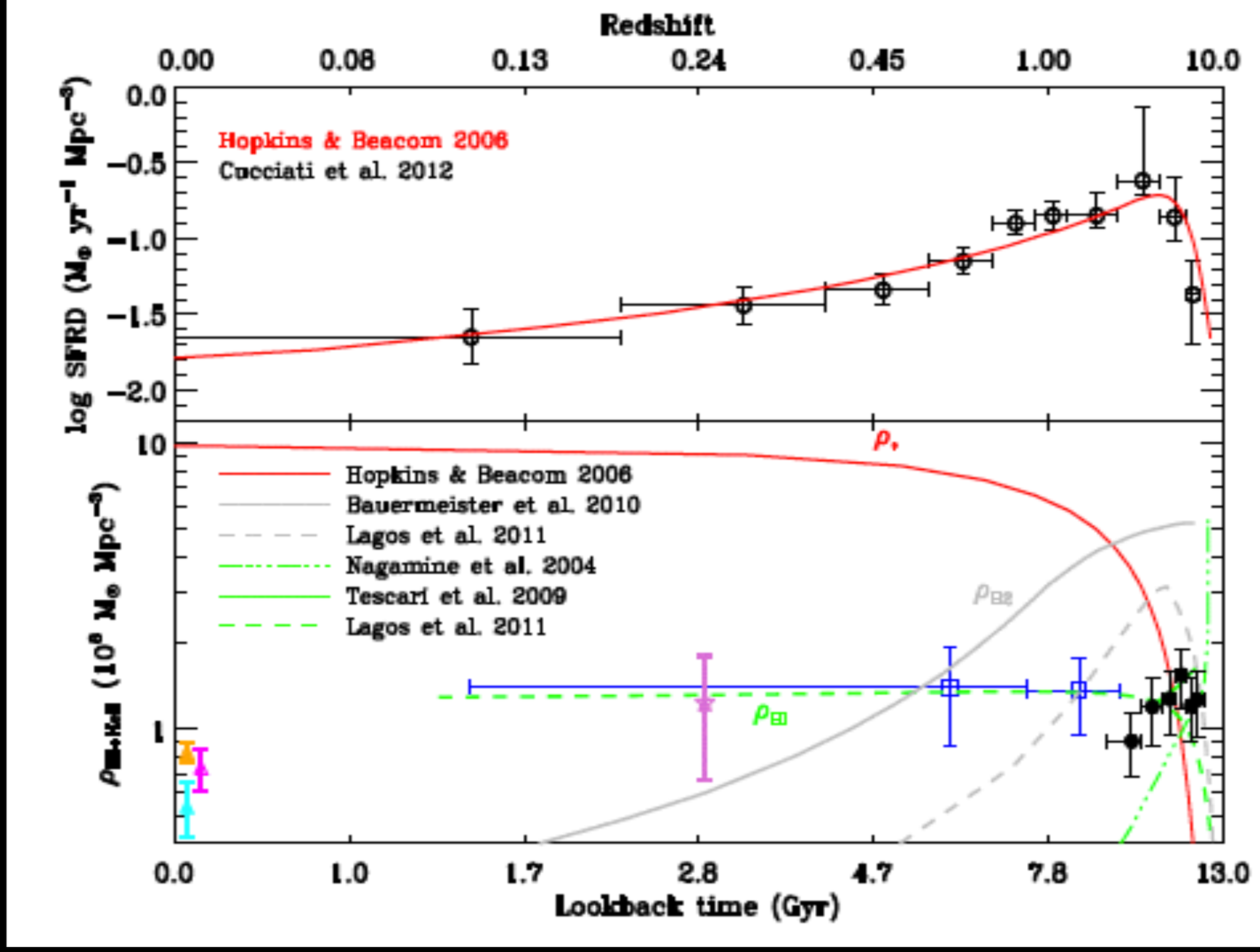
- ESO UVES Advanced Data Products
- 250 quasar spectra, 1500 hrs of VLT time
- 150 DLAs/sub-DLAs

Zafar, Popping, CP+13a

Neutral Hydrogen Gas Mass

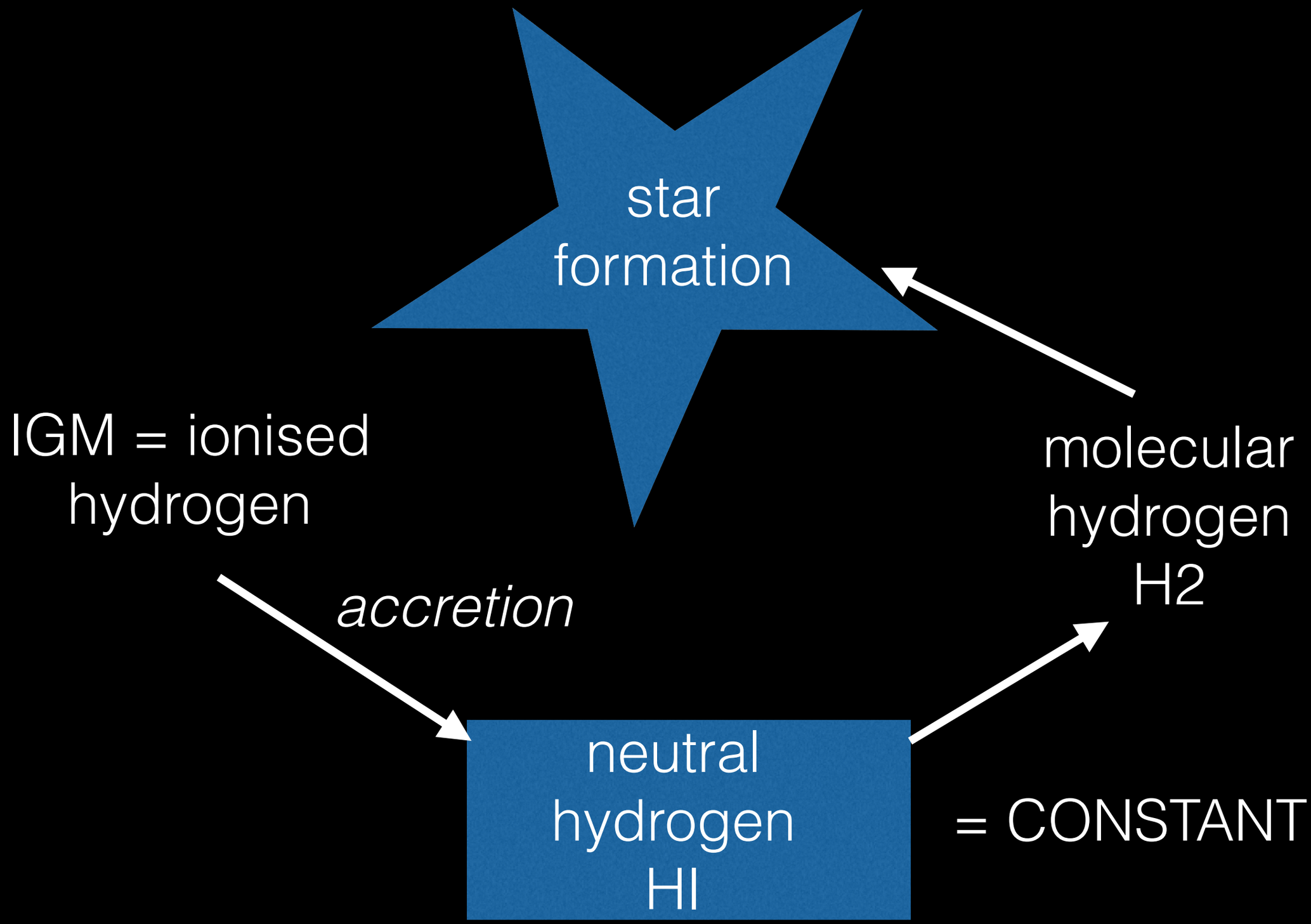
Tayyaba Zafar

- 10% of gas forming stars
- cosmic coincidence

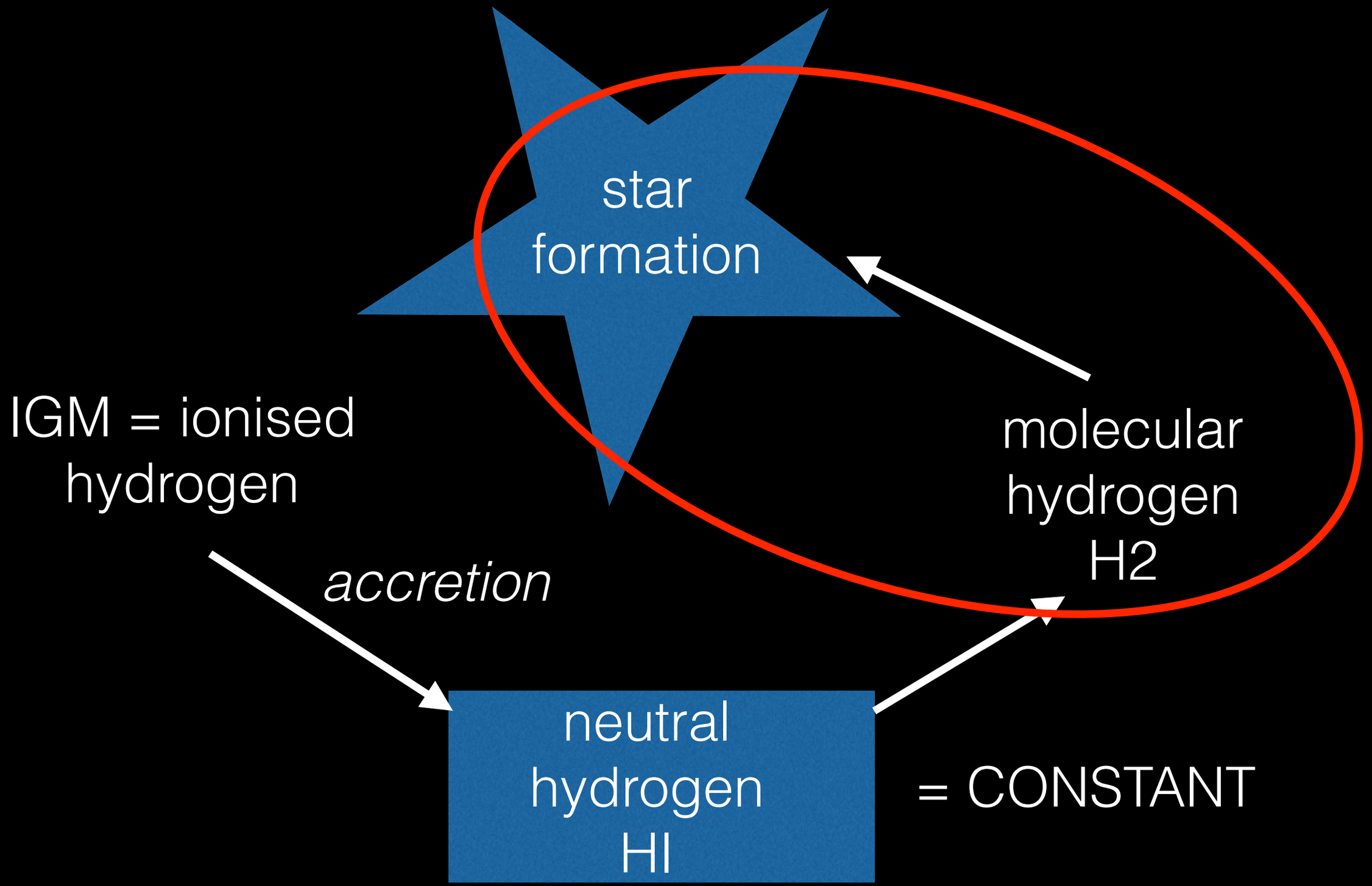


Zafar, CP+13b; Crighton+ 15

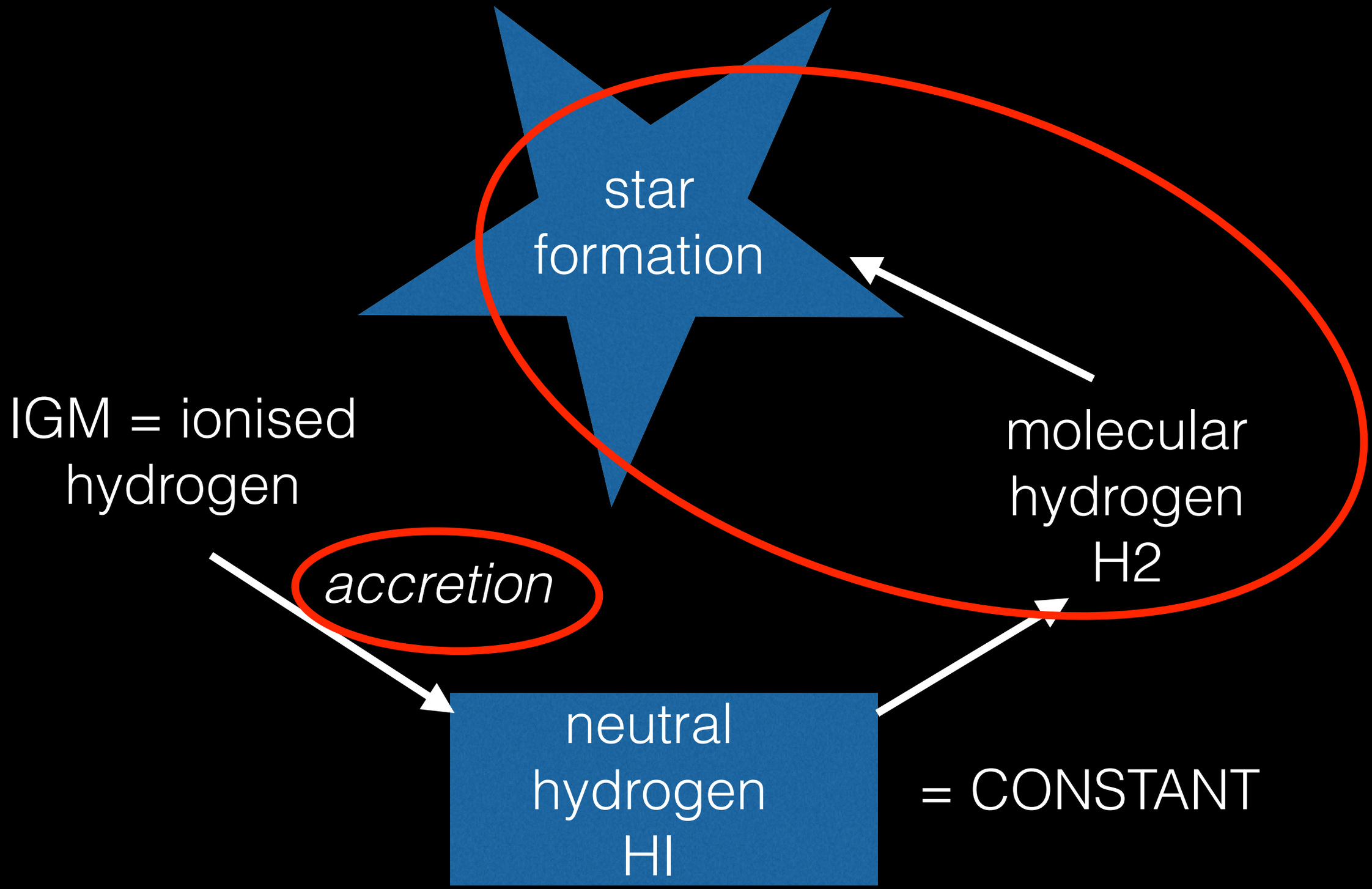
Neutral Gas HI



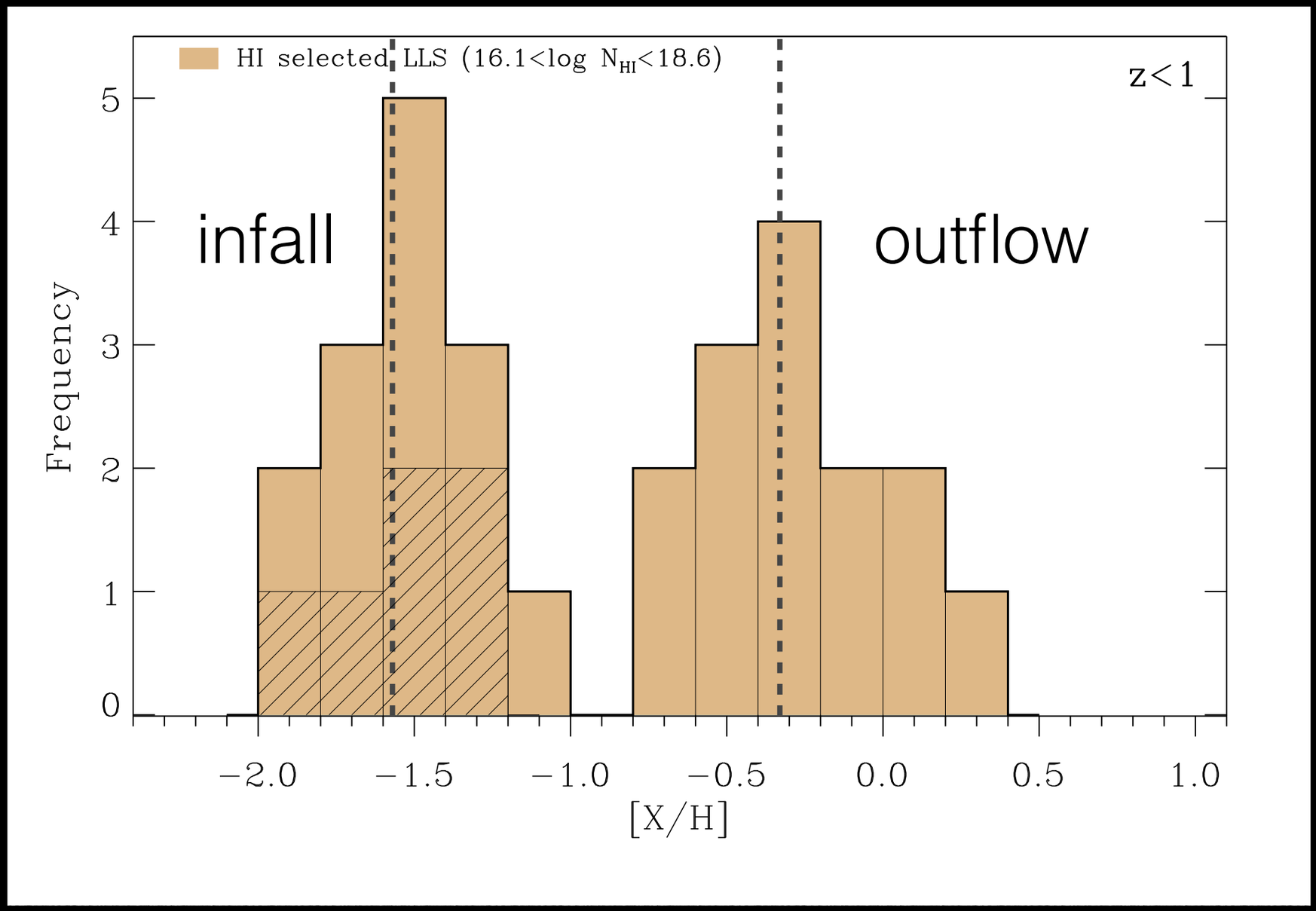
Neutral Gas HI



Neutral Gas HI



Bimodal Metallicity



LLS at z~1

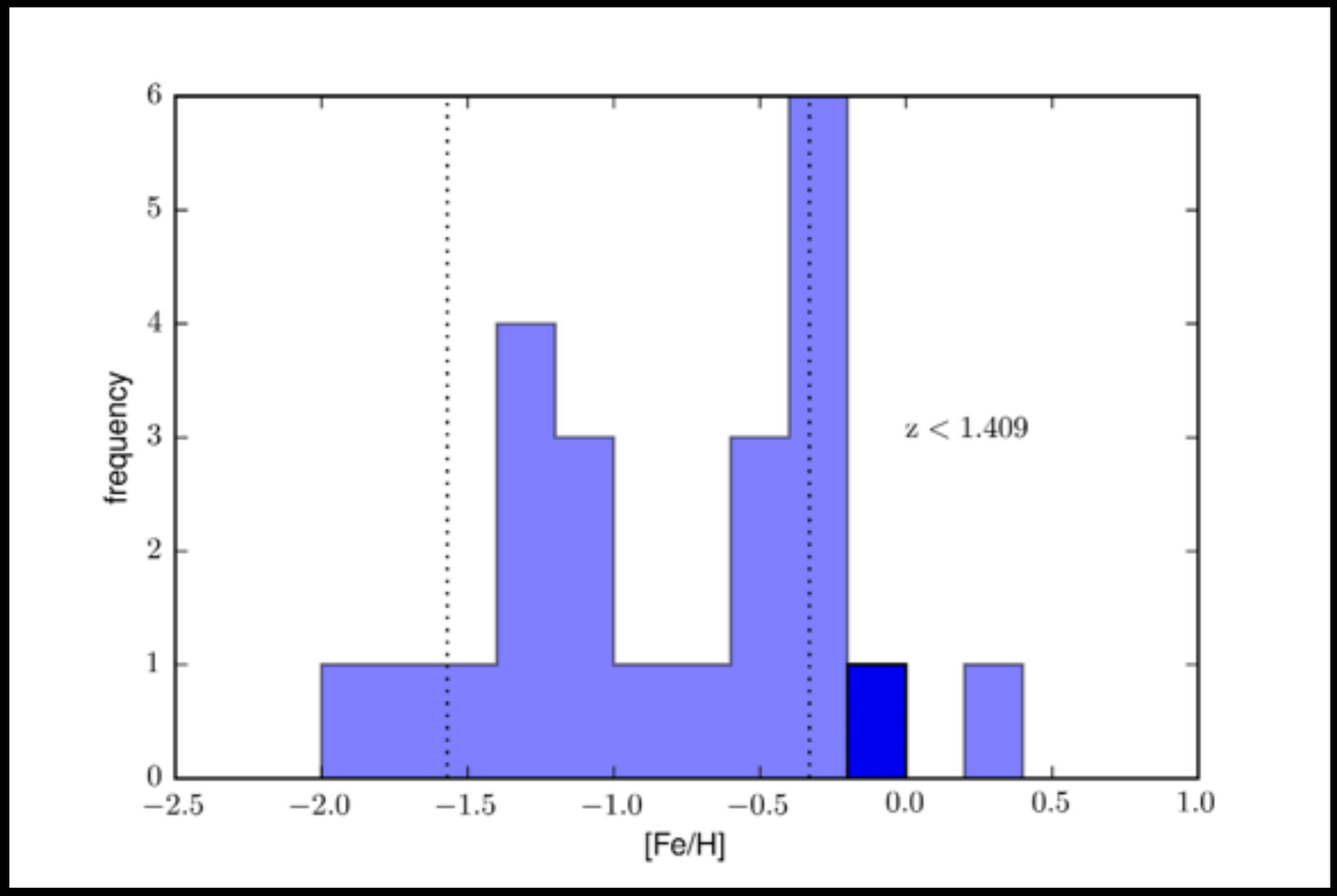
Lehner+13, Wotta+15

Samuel Quiret

Metallicity Distribution

- hint of bimodality?

See Samuel's Poster



sub-DLAs at z<1.4

Quiret, CP+15

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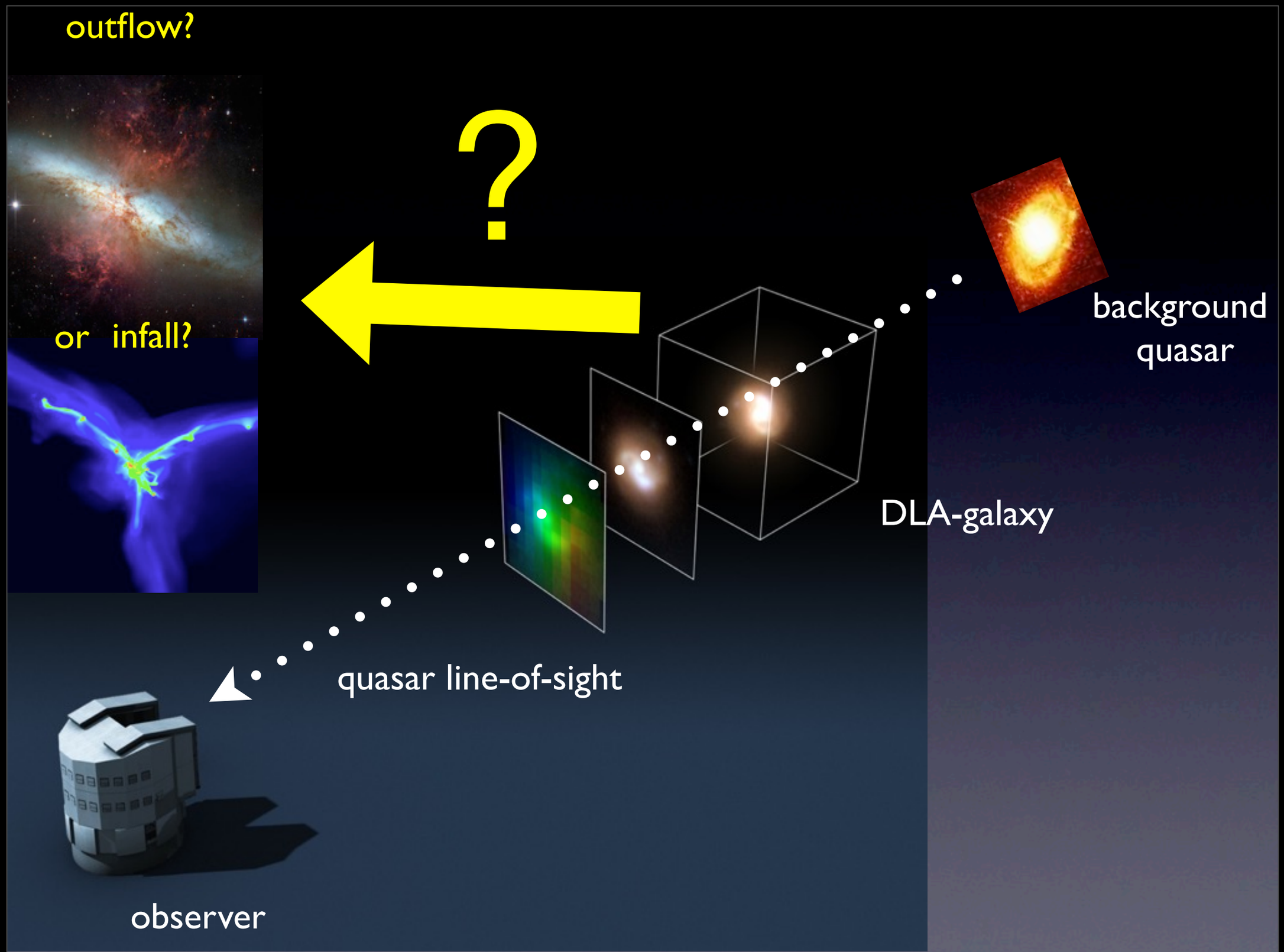
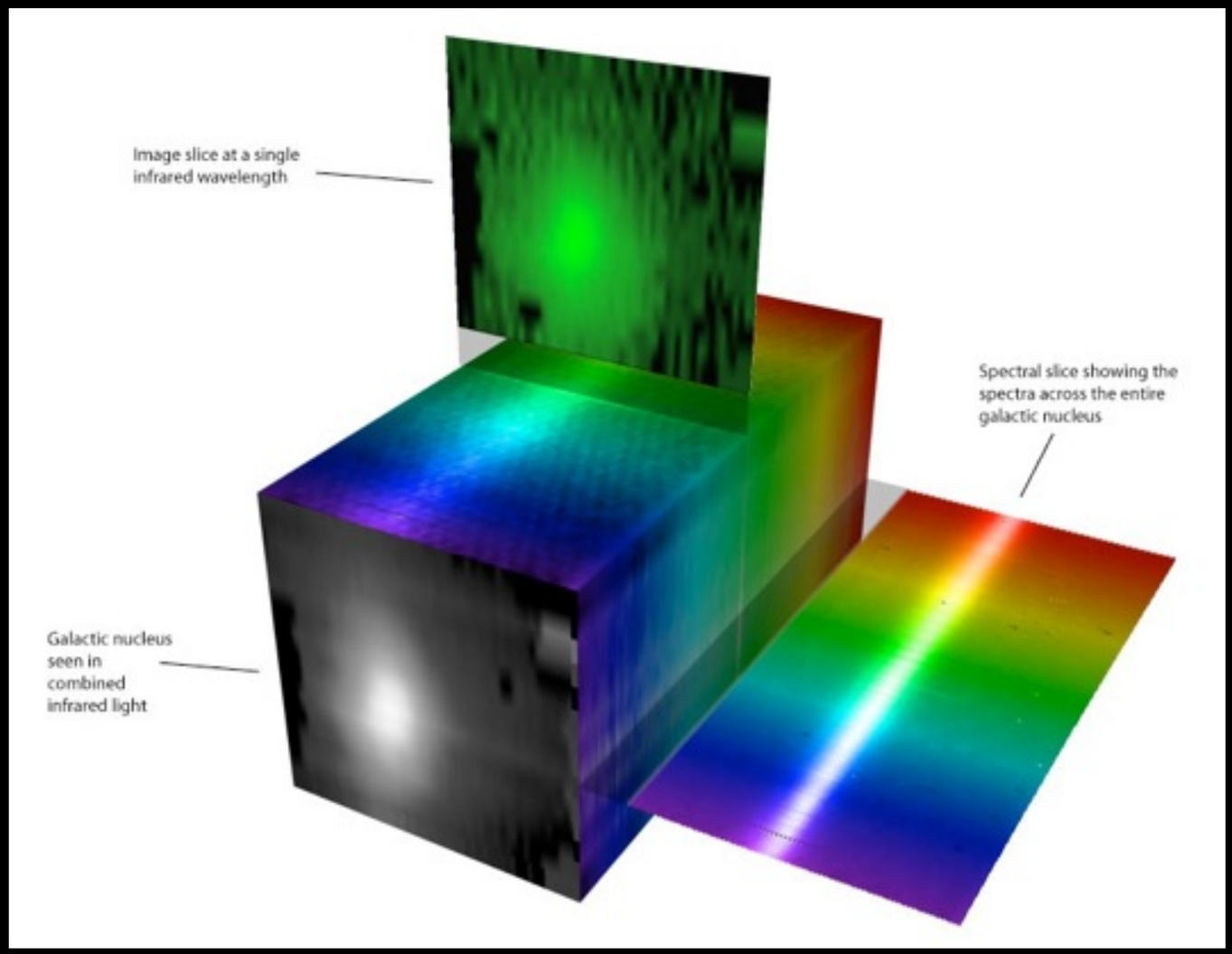
Probing Gas Flows

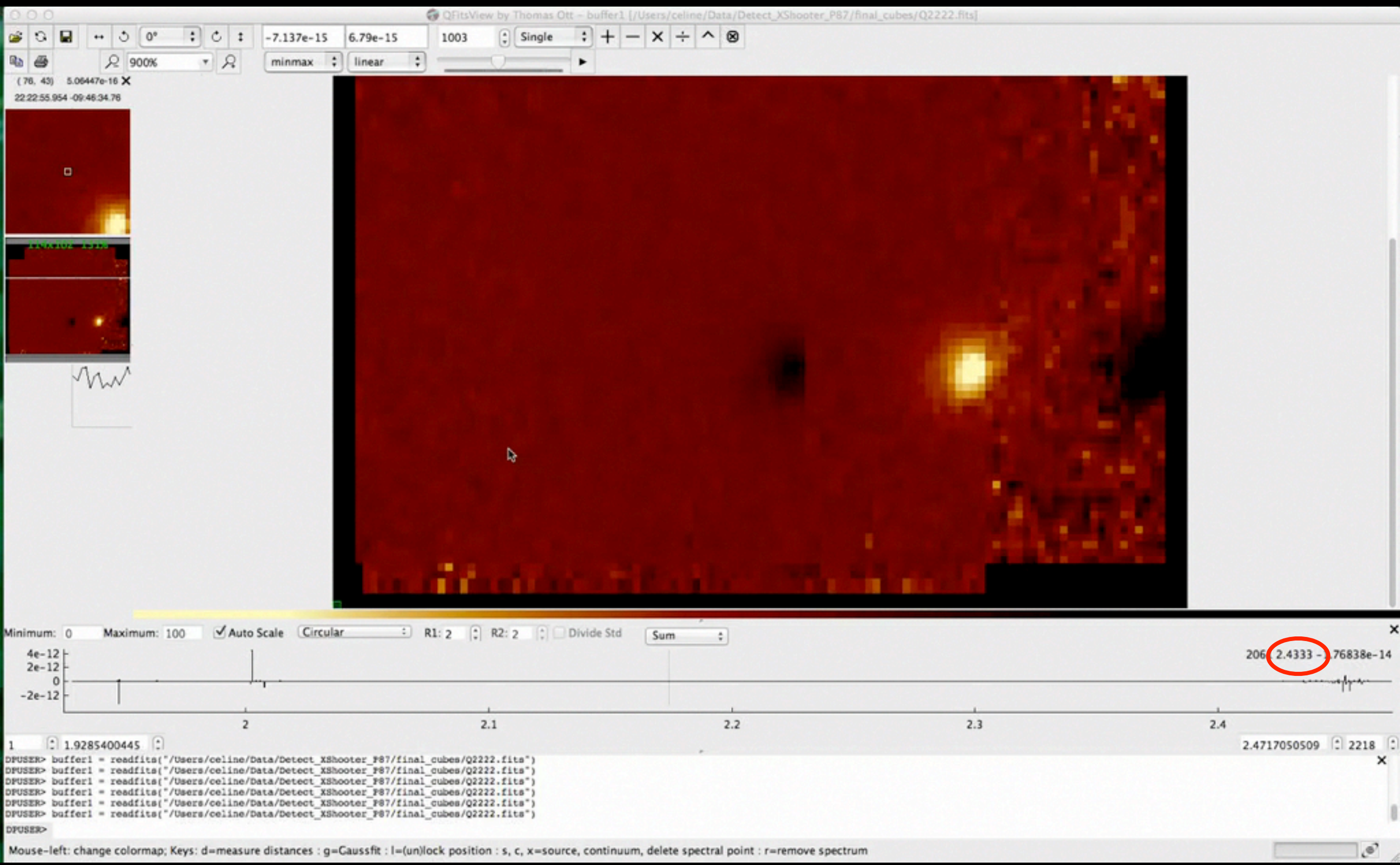


Observational Strategy: Kinematics

- search for stellar content of absorbers with **known N(HI)**
- IFU allows to remove signature of background quasar



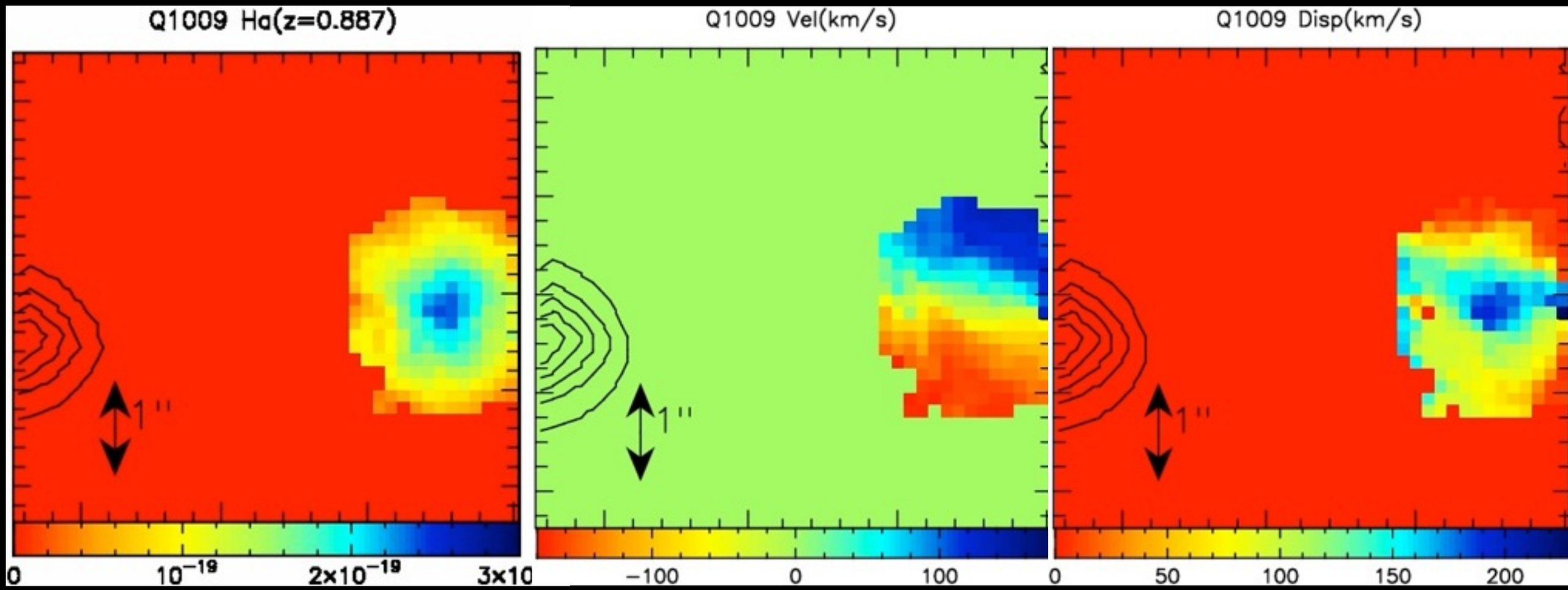
VLT/SINFONI



- spectral PSF subtraction (SPSF)

CP+12

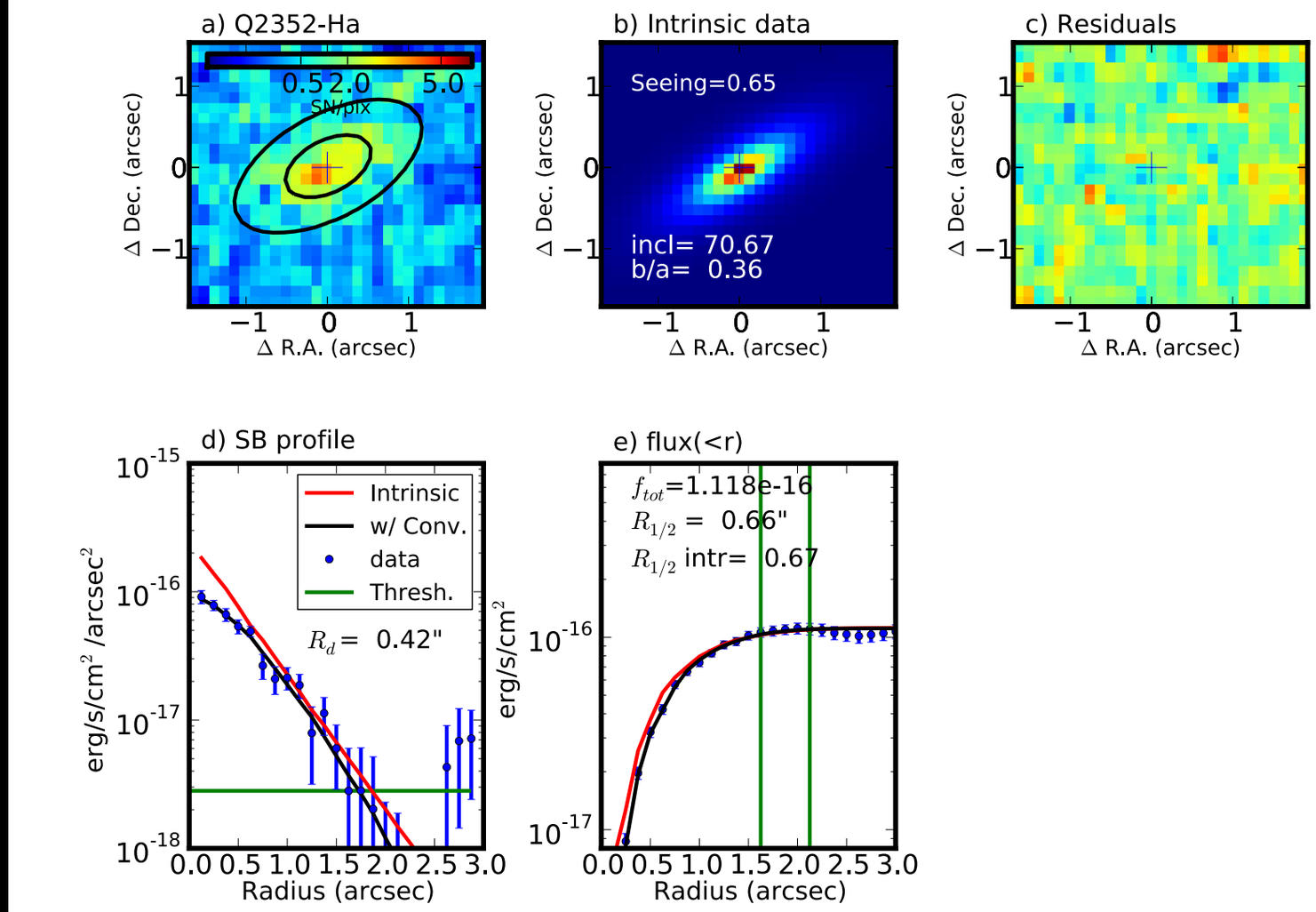
Kinematics



- orientation, inclination
- velocity, dispersion

CP+11b

Mass Estimates



GalPak3D

CP+13, Bouche+15

Previous Results

Quasar	Galaxy Orientation	b [kpc]	Direction to quasar line-of-sight aligned with	V_{max} [km/s]	Δv [km/s]	Absorption Profile	Conclusion
Q0302−223	edge-on	25	minor axis	11	120	doubled-peaked	⇒co-rotating/outflow?
Q0452−1640	face-on?	16	major axis	100	230	either-side of z_{gal}	⇒merger/outflow?
Q1009−0026	edge-on	39	minor axis?	250	334	asymmetrical	⇒outflow
Q2222−0946	edge-on	6	n/a†	20	200	centred and complex	⇒outflow
Q2352−0028	edge-on	12	major axis	140	220	centred and complex	⇒co-rotating/outflow?

†: in the case of Q2222−0946, the major axis is undefined because of the compact nature of the galaxy.

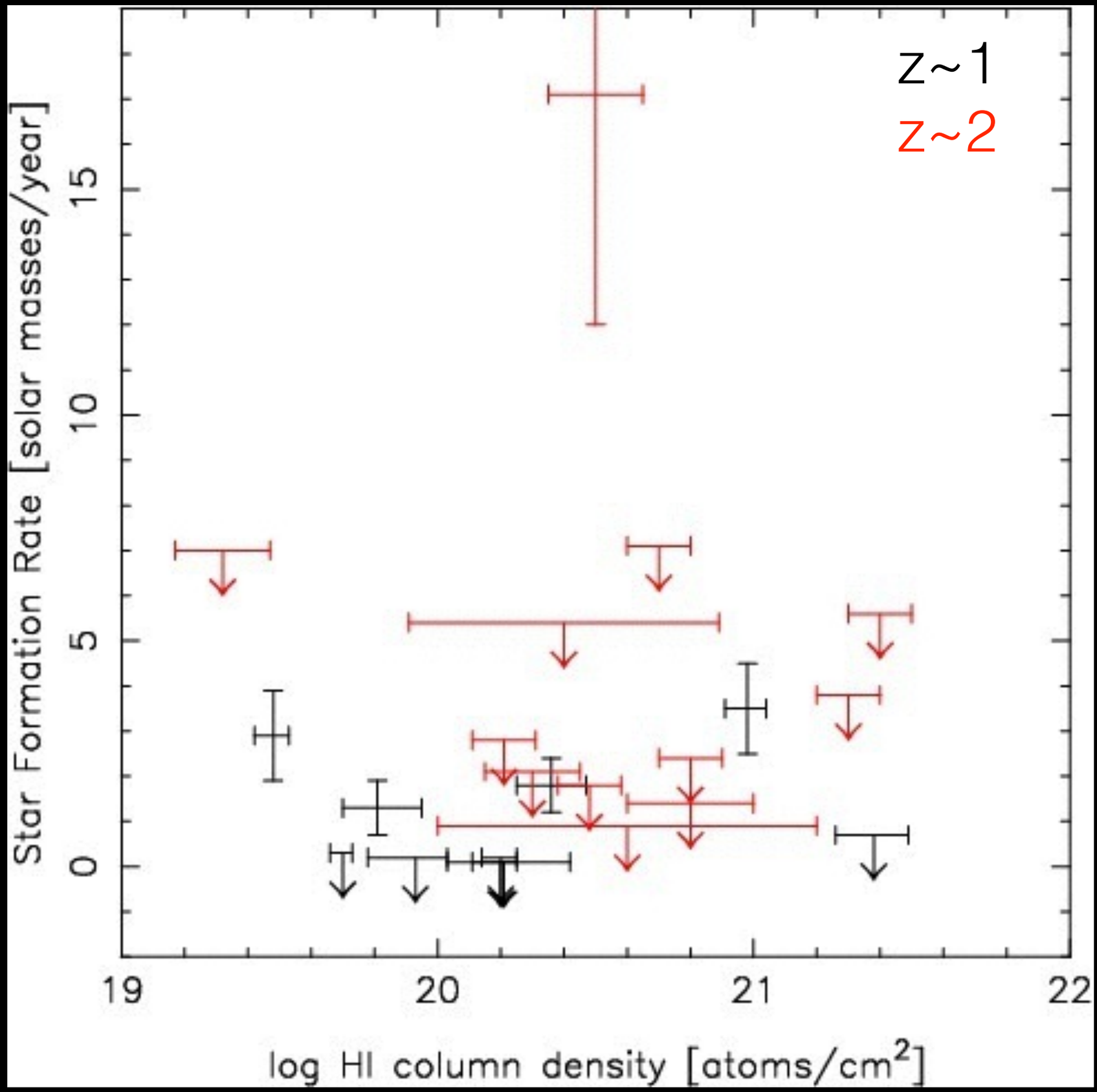
=> in 2 cases, we have strong indications of outflows

CP+13

Star Formation Rates

- SFR~ few $M_\odot$/yr
- b~10-40 kpc

CP+12



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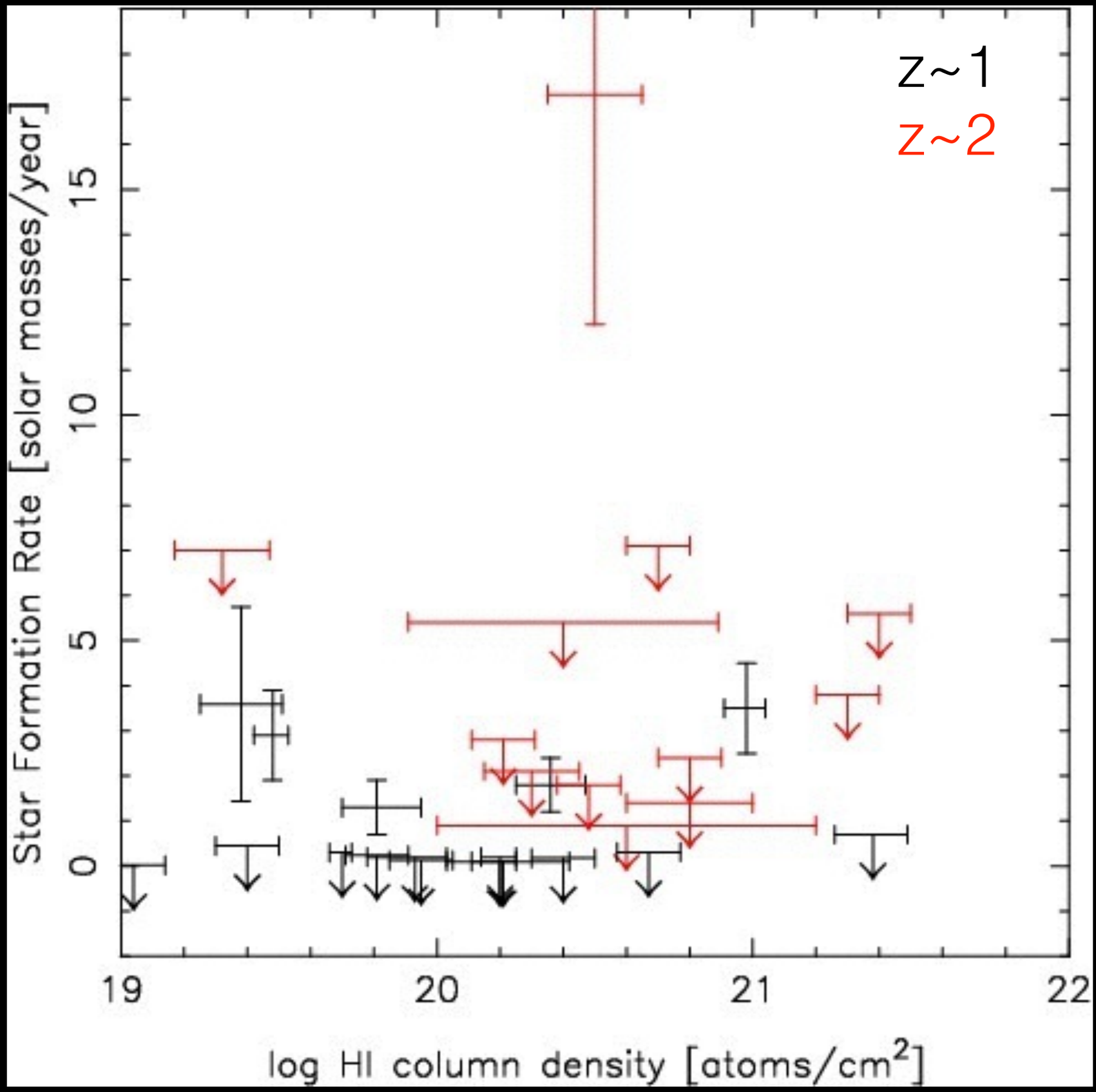
CP+ in prep



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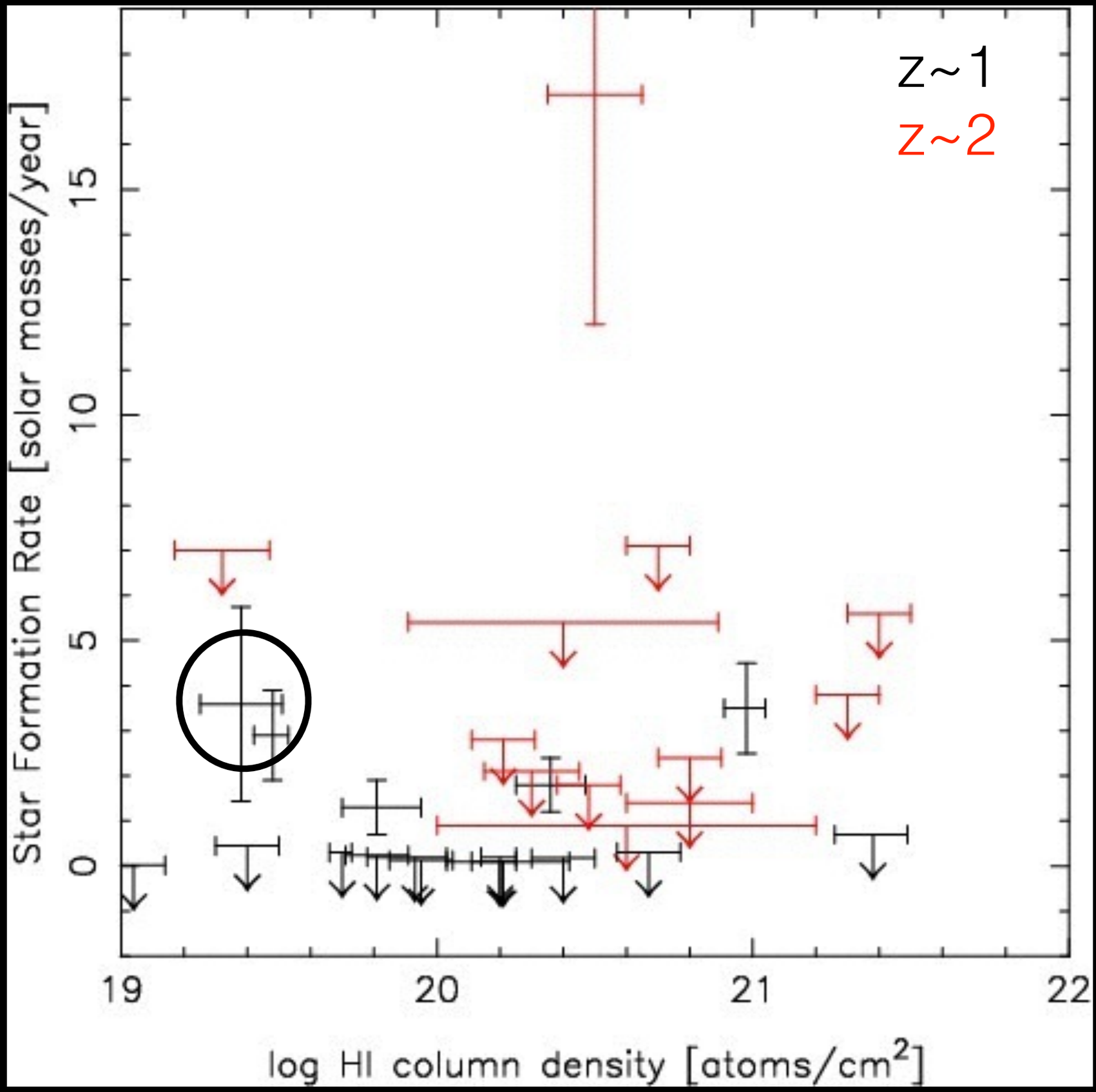
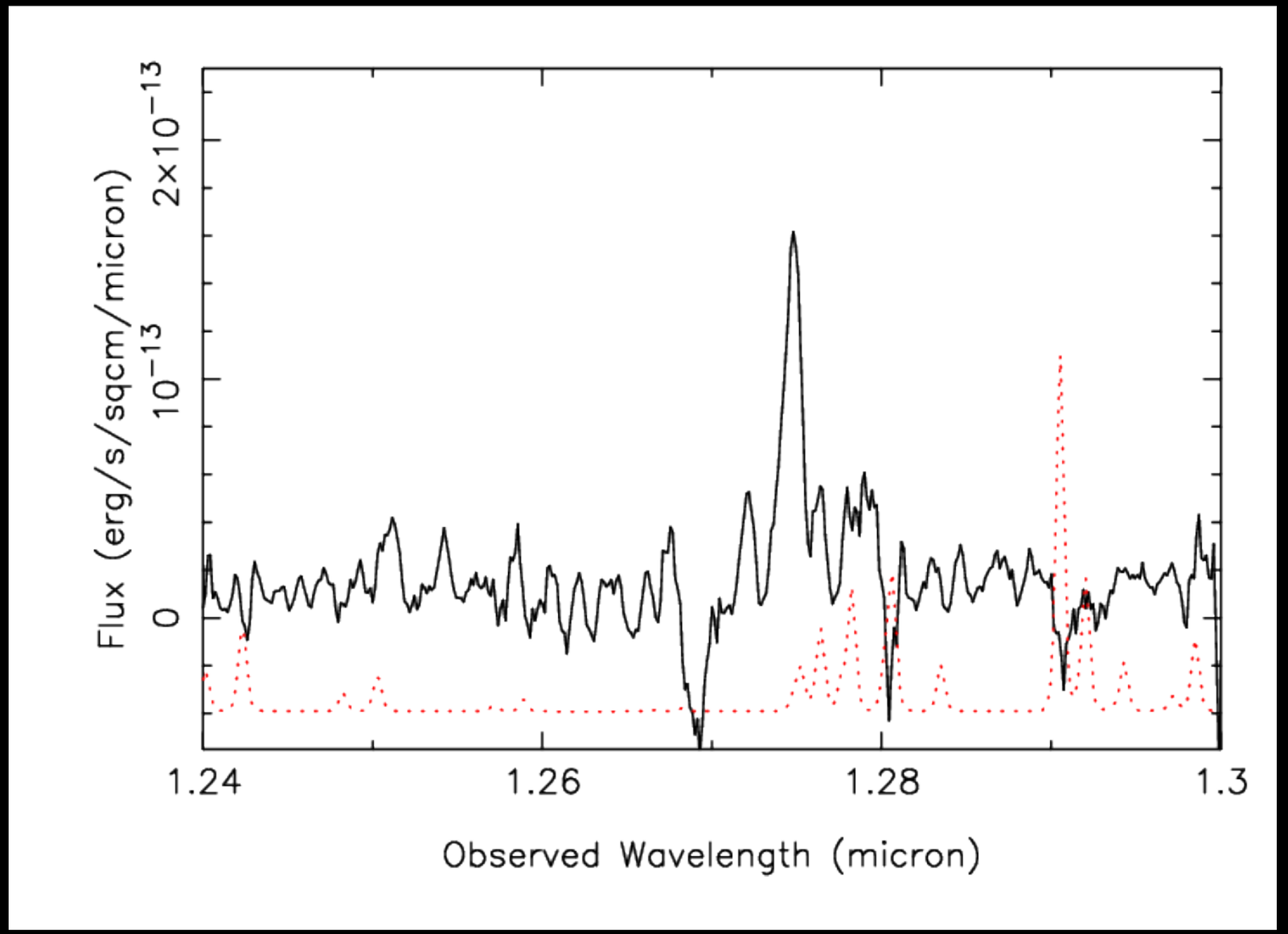


Physical Properties

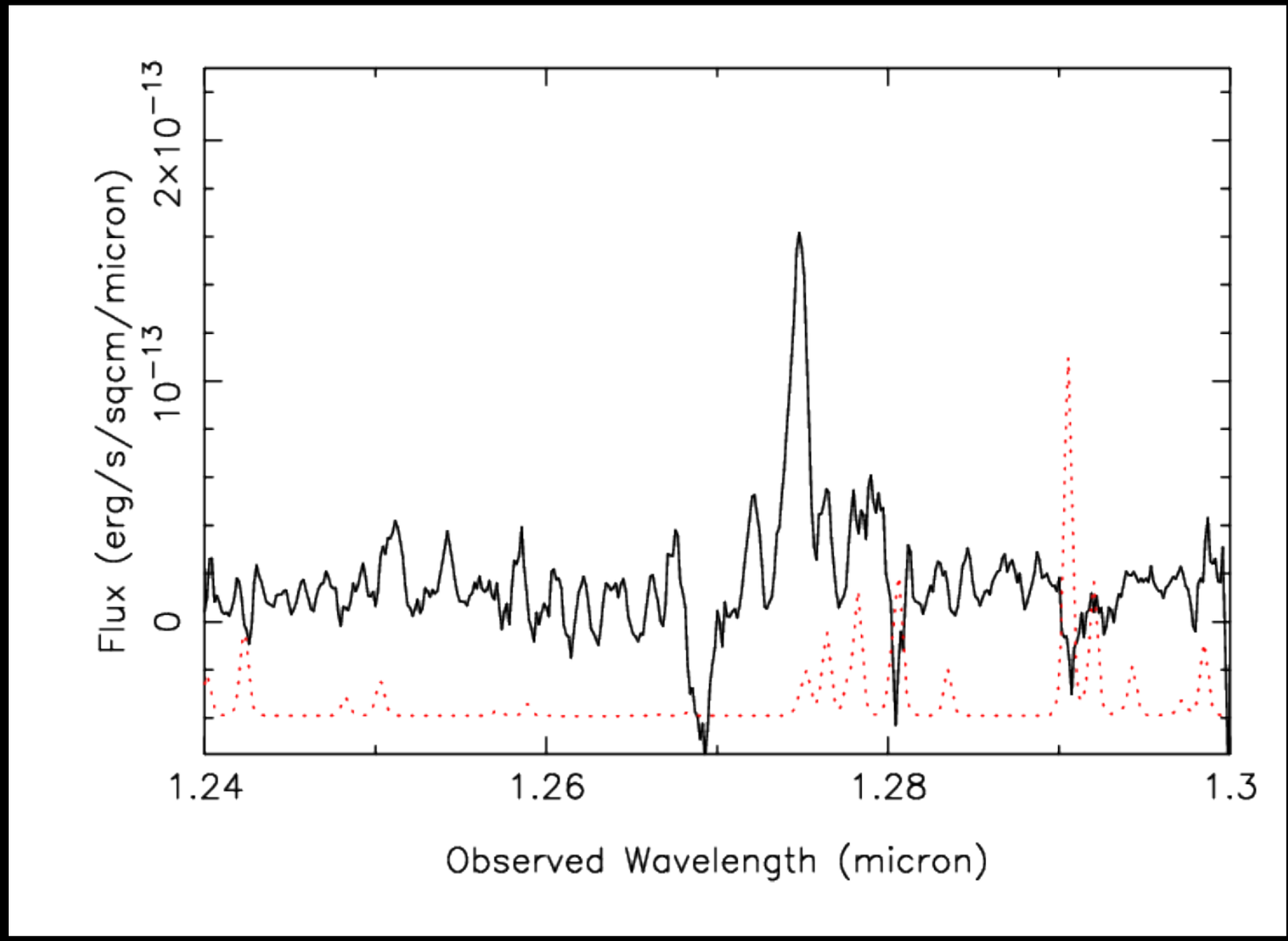
- F(Ha)~2x10^{-16} erg/s/cm^2
- SFR~3.6+/-2.1 M_{sun}/yr
- b=10.8”
  b=85 kpc



CP+ in prep

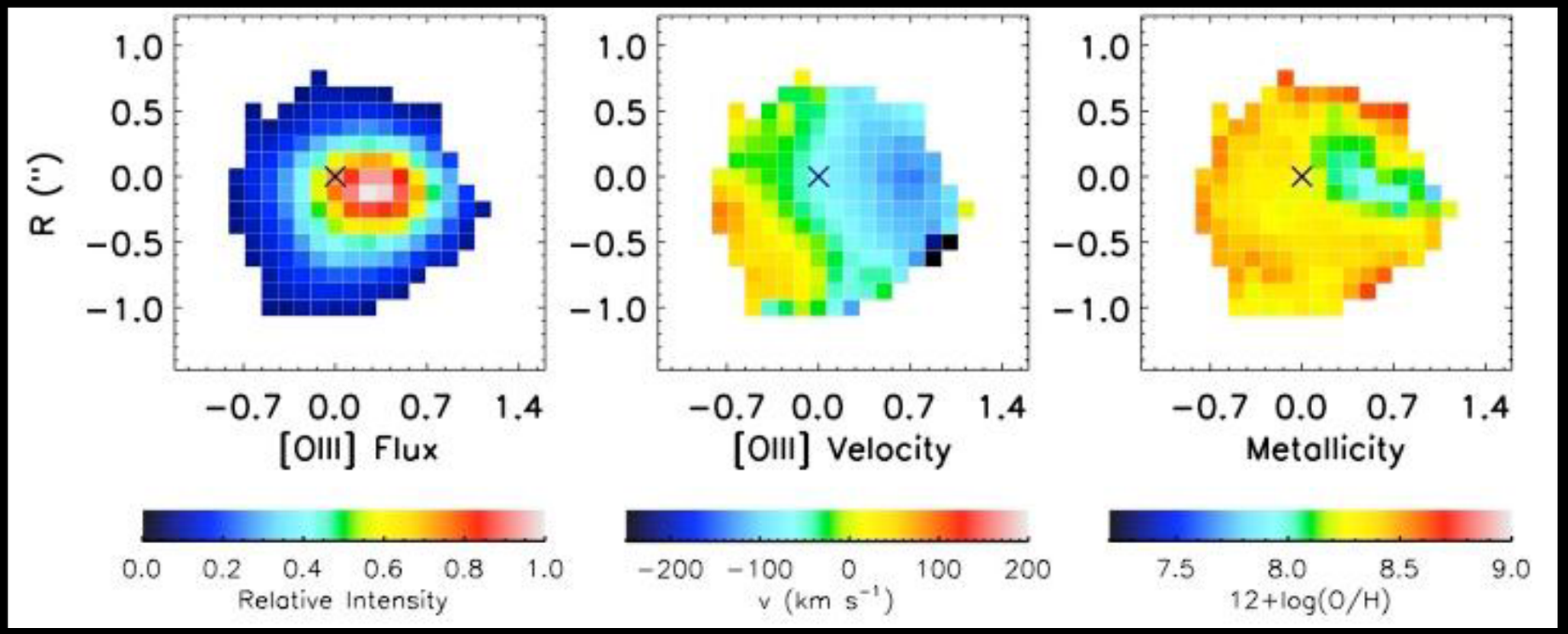
Physical Properties

- N2 undetected
- [O/H] metallicity from N2 is $12+\log(O/H)<9.20$



CP+ in prep

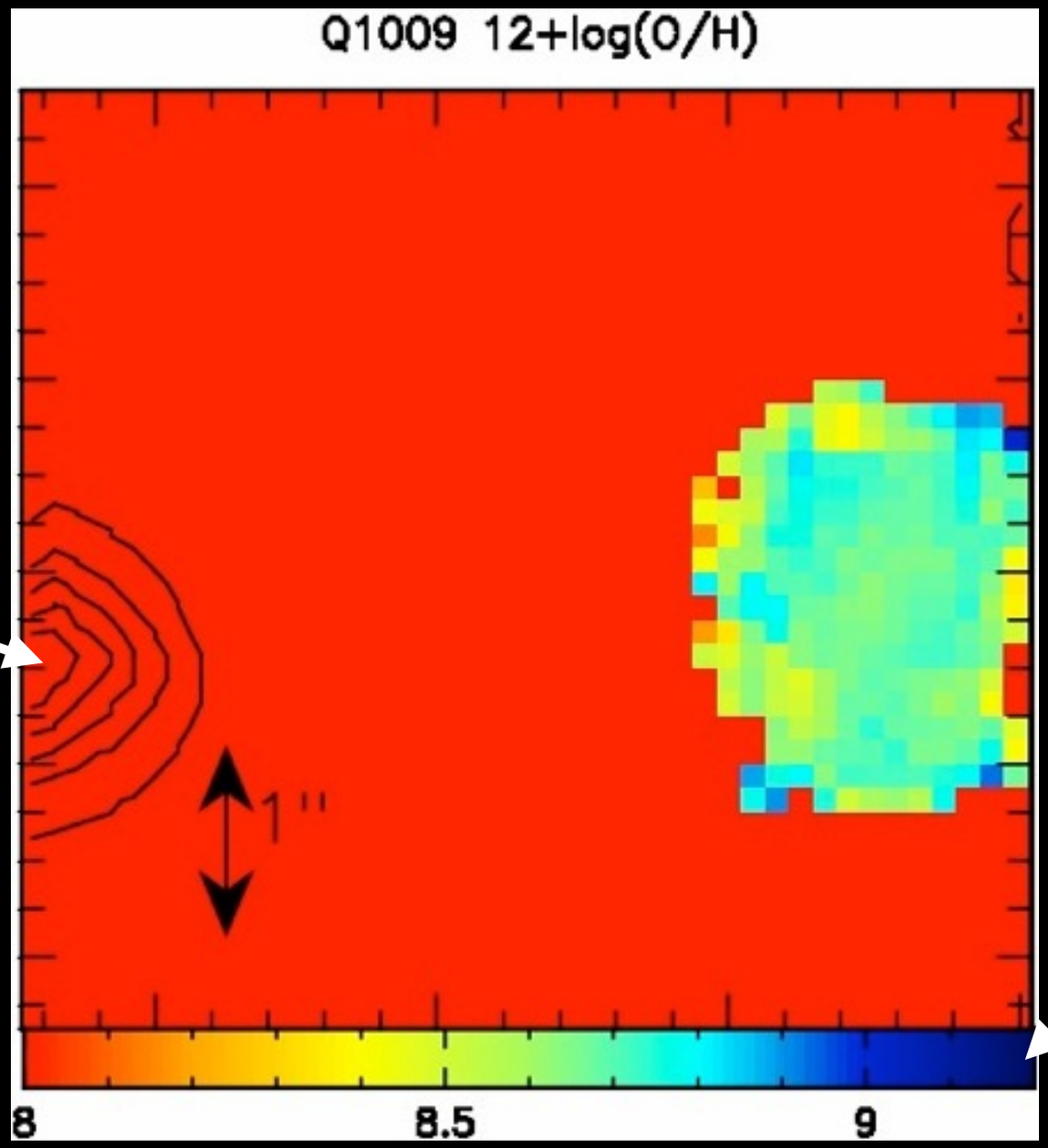
Metallicity Gradients



- "inverted" metallicity gradients: accretion or merger?

Cresci+10, Nature, Epinat+12

Metallicity Maps



quasar

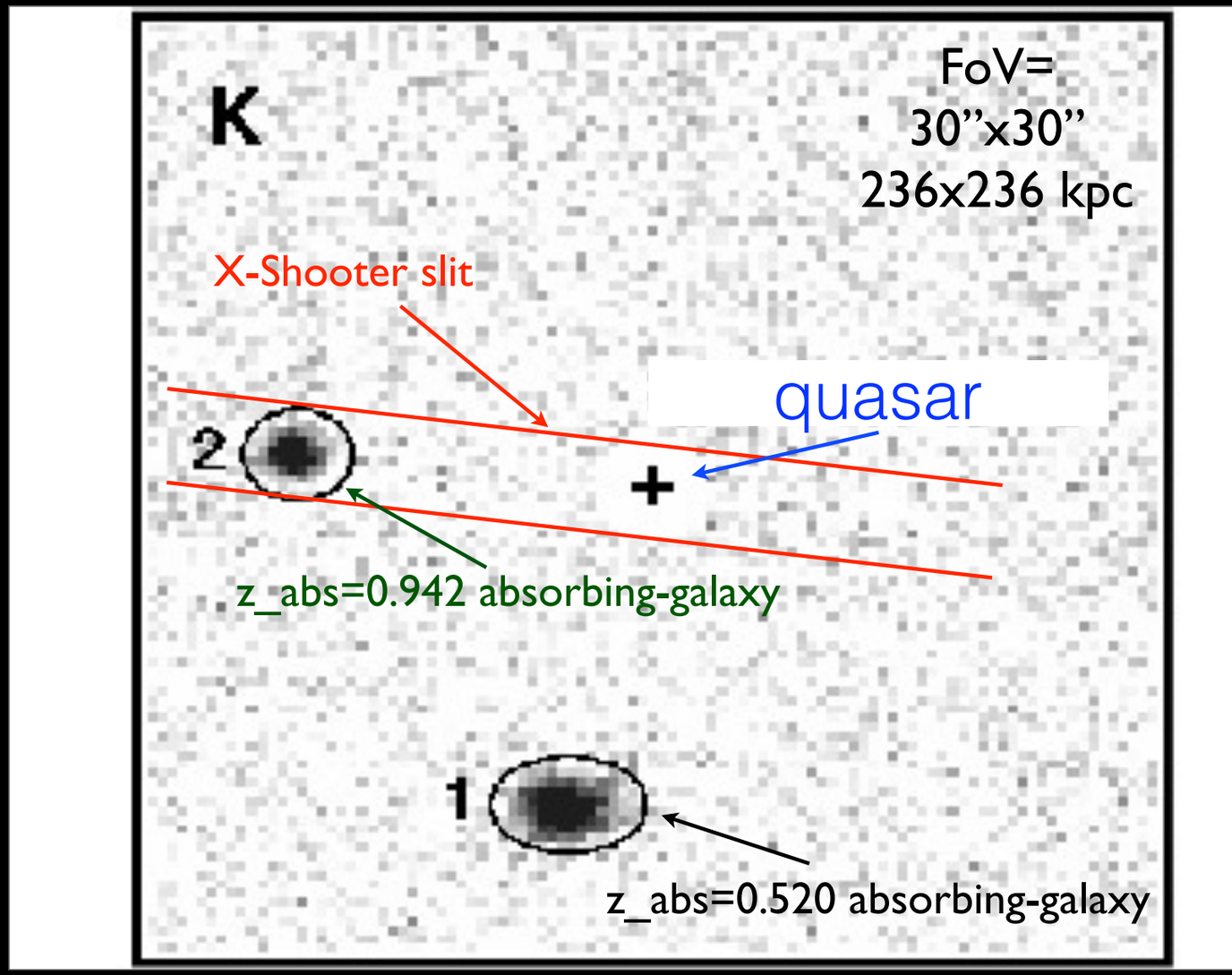
metallicity wrt solar

- gradients uniform

CP+11a

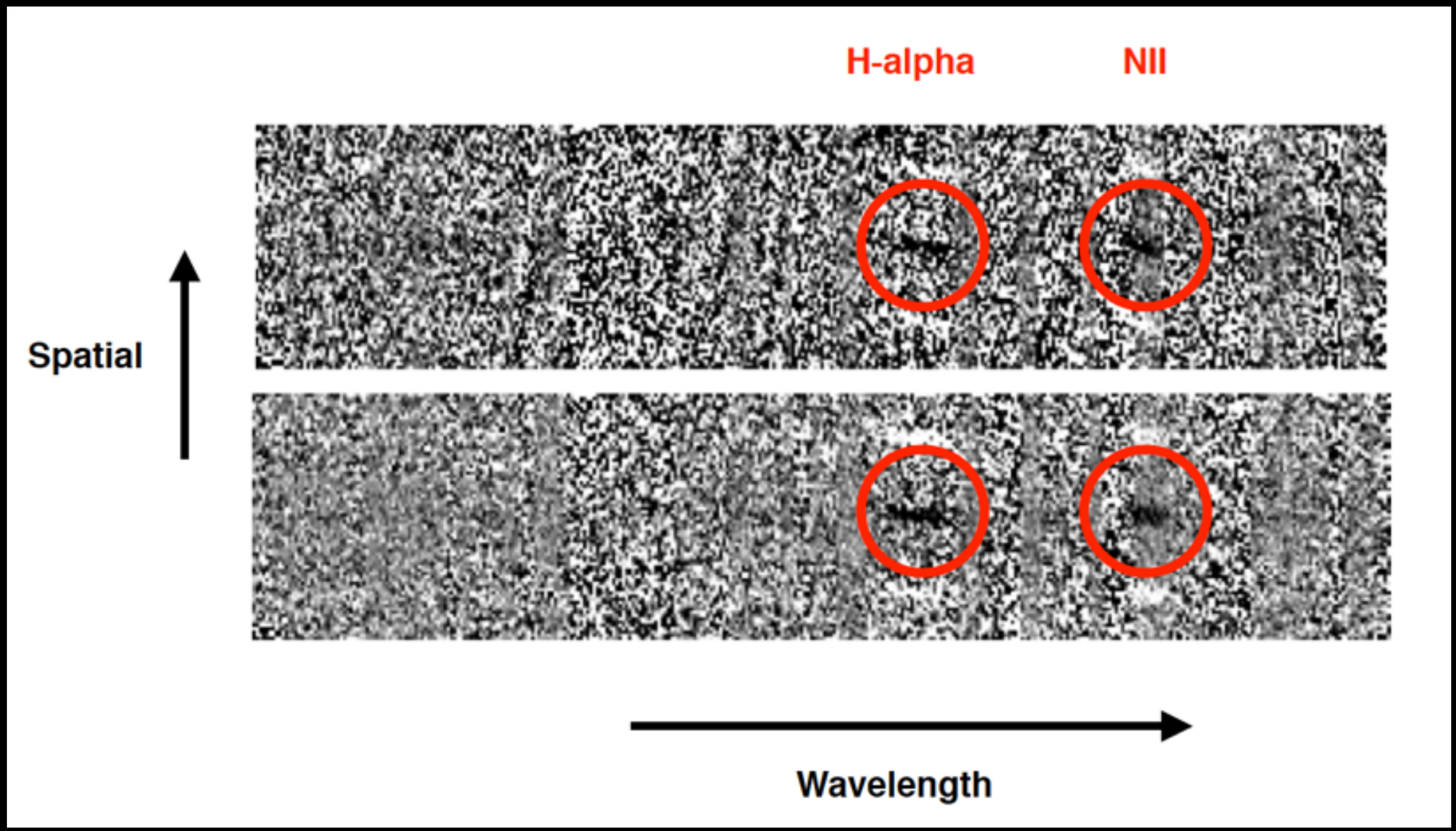
Observational Strategy: Metallicity

- long slit covering both background quasar and foreground galaxy
- direct comparison of HI and HII gas



VLT/X-Shooter

HII Emission Metallicity



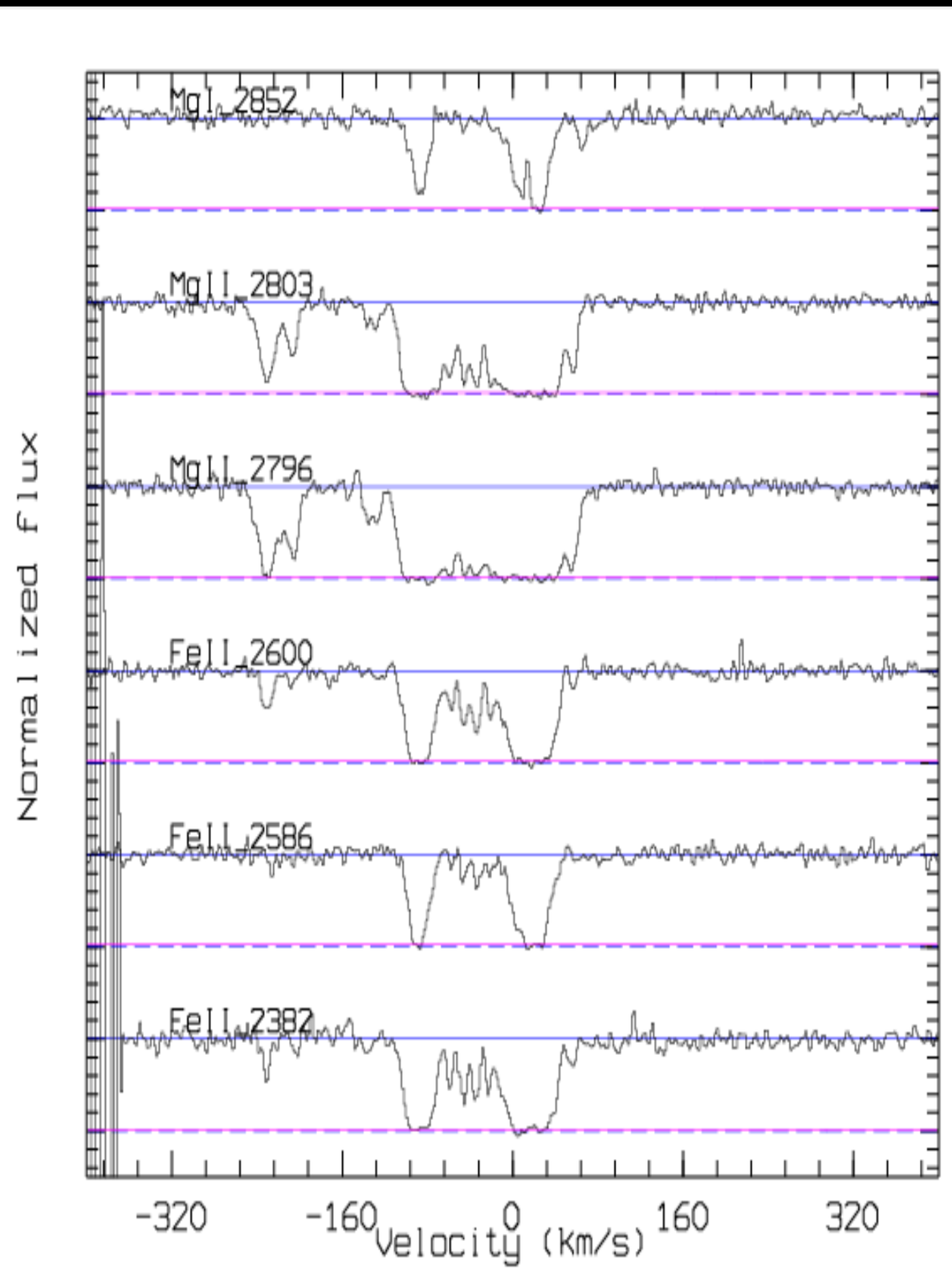
VLT/X-Shooter

HI Neutral Gas Metallicity

- detecte AlIII, SiII, FeII, MgII and MgI
  Zn, Cr, Ti undetected
- [Fe/H]=-0.21+/-0.14
  [Zn/H]<-0.41

Dessauges-Zavadsky+09

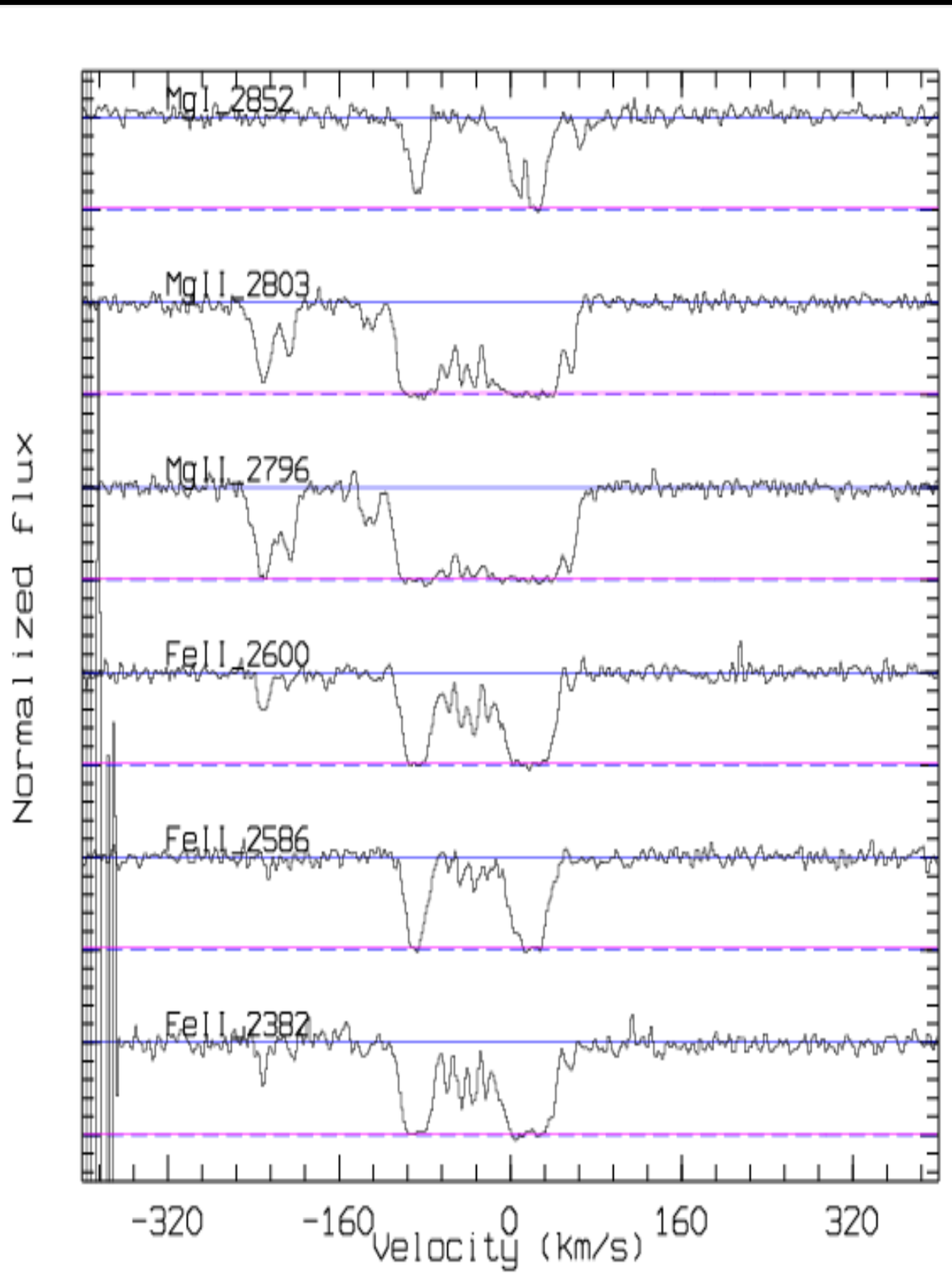
VLT/UVES



HI Neutral Gas Kinematics

- vel=0 is zem
- double-peak profile
- additional blue-shifted component in the strongest absorption lines

VLT/UVES



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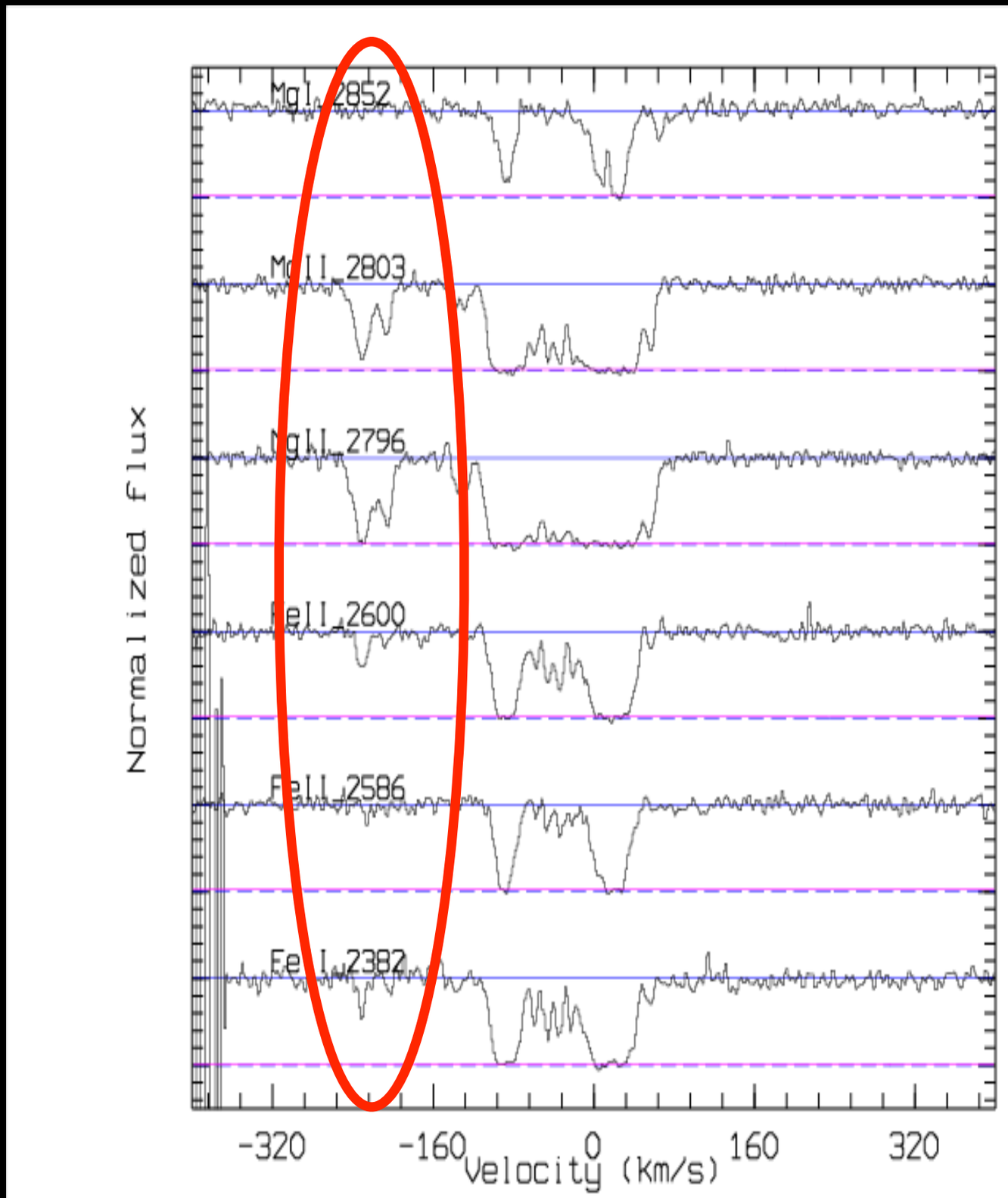
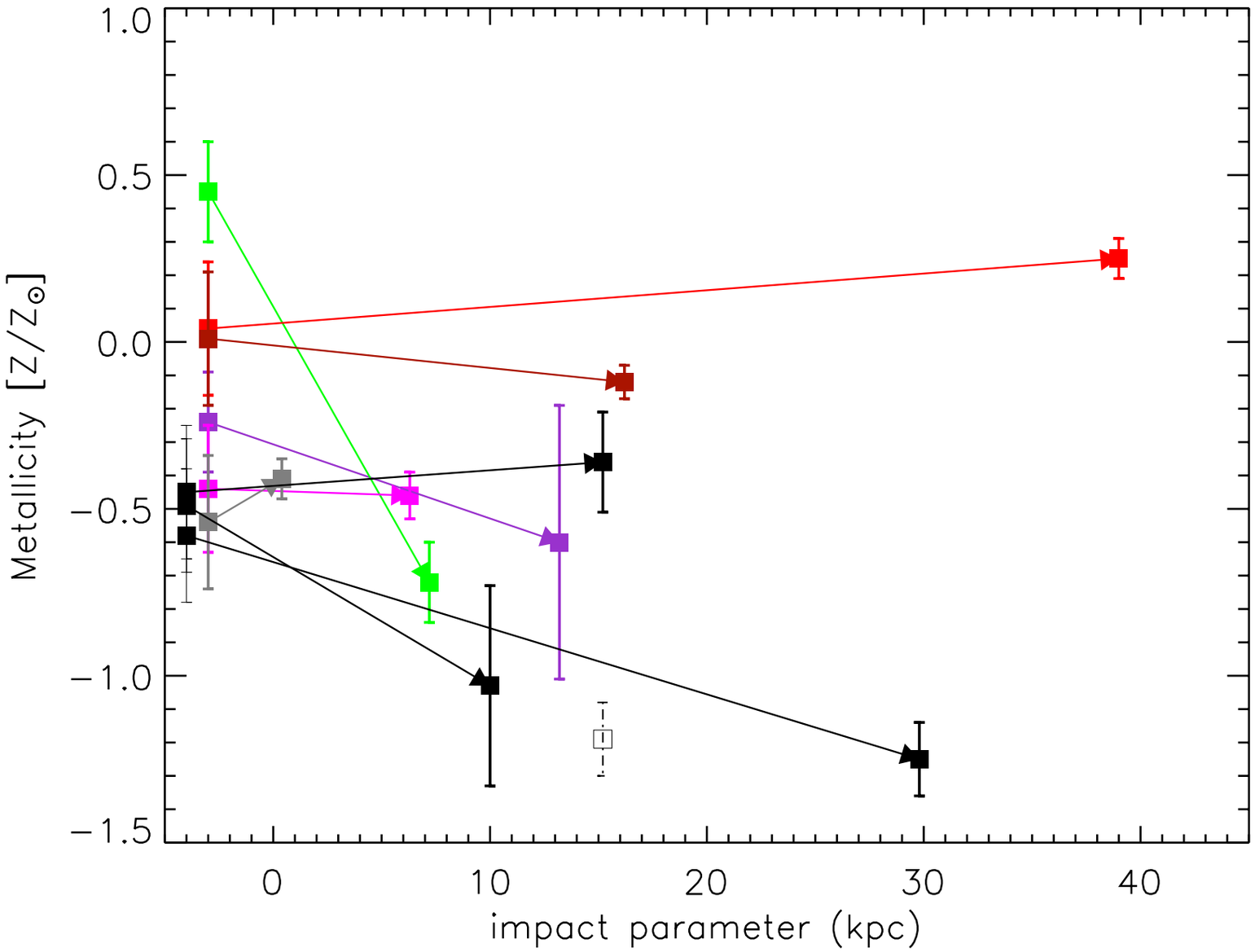


Metallicity Gradients

Hadi Rahmani

HII emission metallicity →

See Hadi's Poster



z~0.6

← HI absorption metallicity

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Conclusion

1. Neutral gas is constant across cosmic time: evidence for accretion on global scales
2. A combination of IFU and absorption techniques allow to characterise gas flows around galaxies