Tracing HI in radio AGN: associated absorption from low to high redshifts

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What can we learn from the HI …

occurrence/content/distribution/kinematics of HI to explore:

➡ Kinematics (disks, tails): origin of the gas, formation and evolution of the galaxy

➡ Dependence on type of galaxy and evolution with redshift: conditions of the gas - connection with starformation

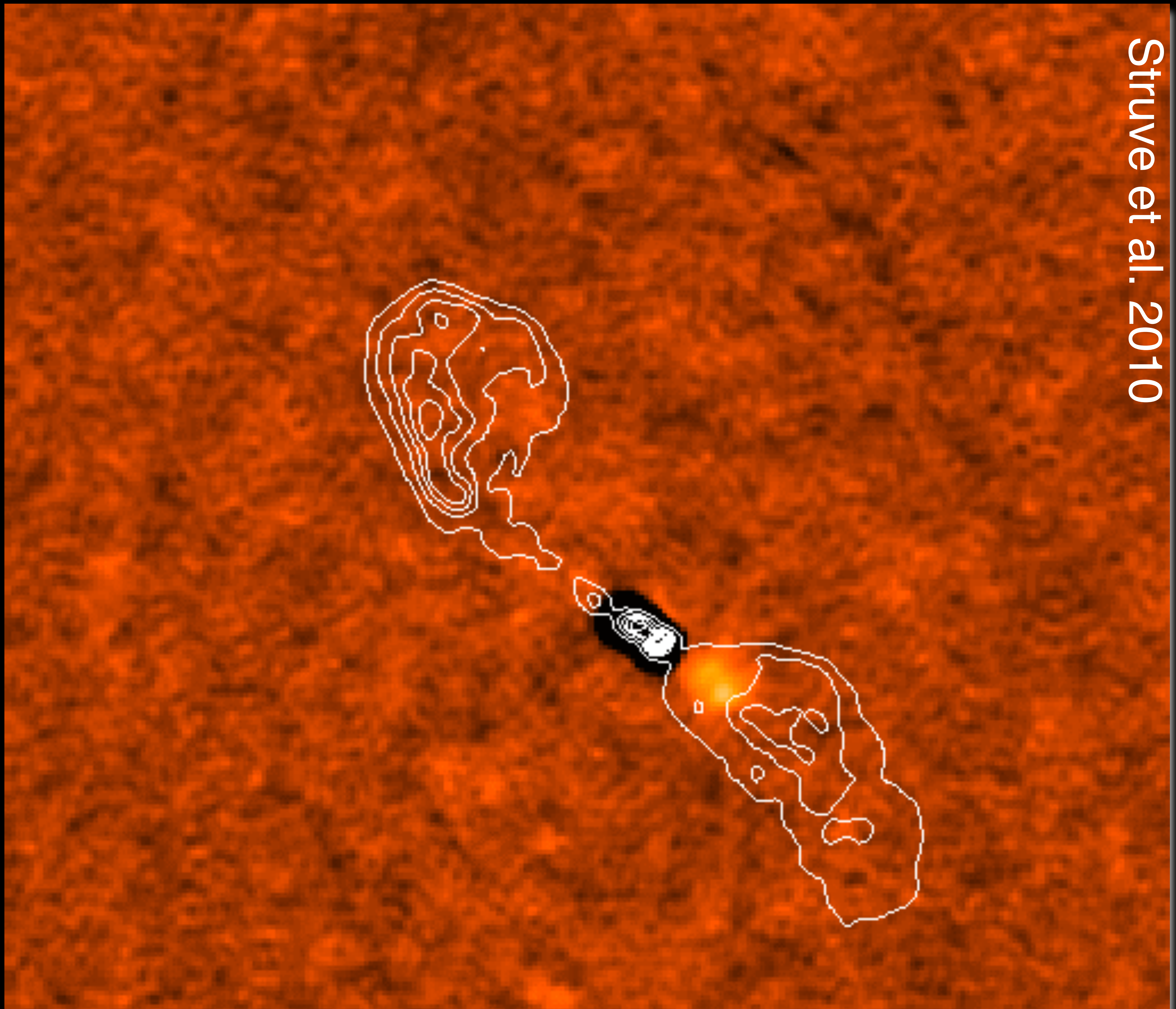
➡ Connection to central activity: feeding/feedback - infall/outflow of the gas

This is what ideally we would like to have for each galaxy

Associated HI absorption:

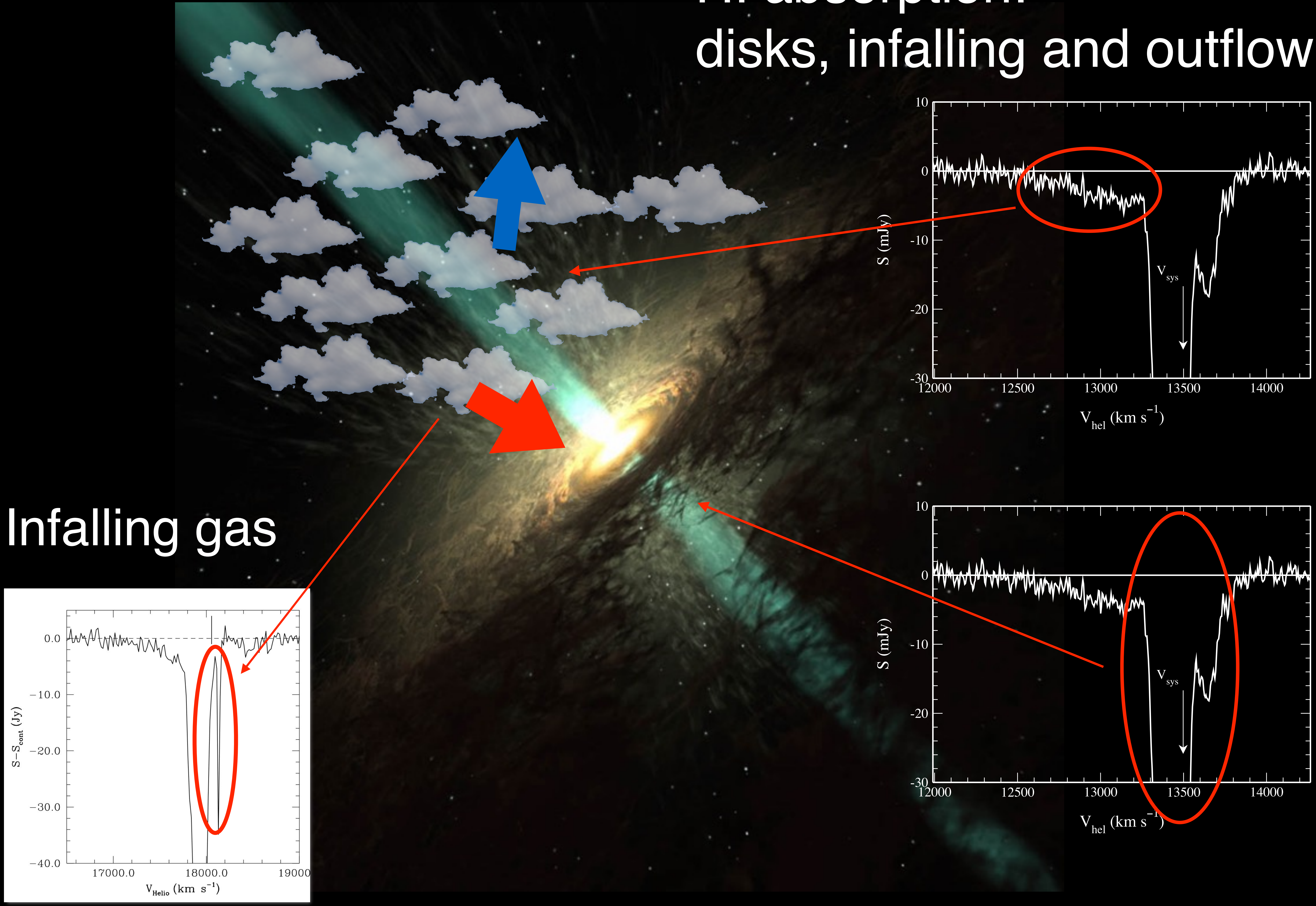
Disadvantages: limited view of the distribution of HI
Advantages: **allows to detect HI at higher redshifts (than emission) high spatial resolution**

Unique info that can provide for understanding AGN



The case of Centaurus A
ATCA observations (Struve et al. 2010)
Peak continuum 4.41 Jy - optical depth HI absorption τ=0.8!

Structures that can be traced with HI absorption:
disks, infalling and outflowing gas



Outflows

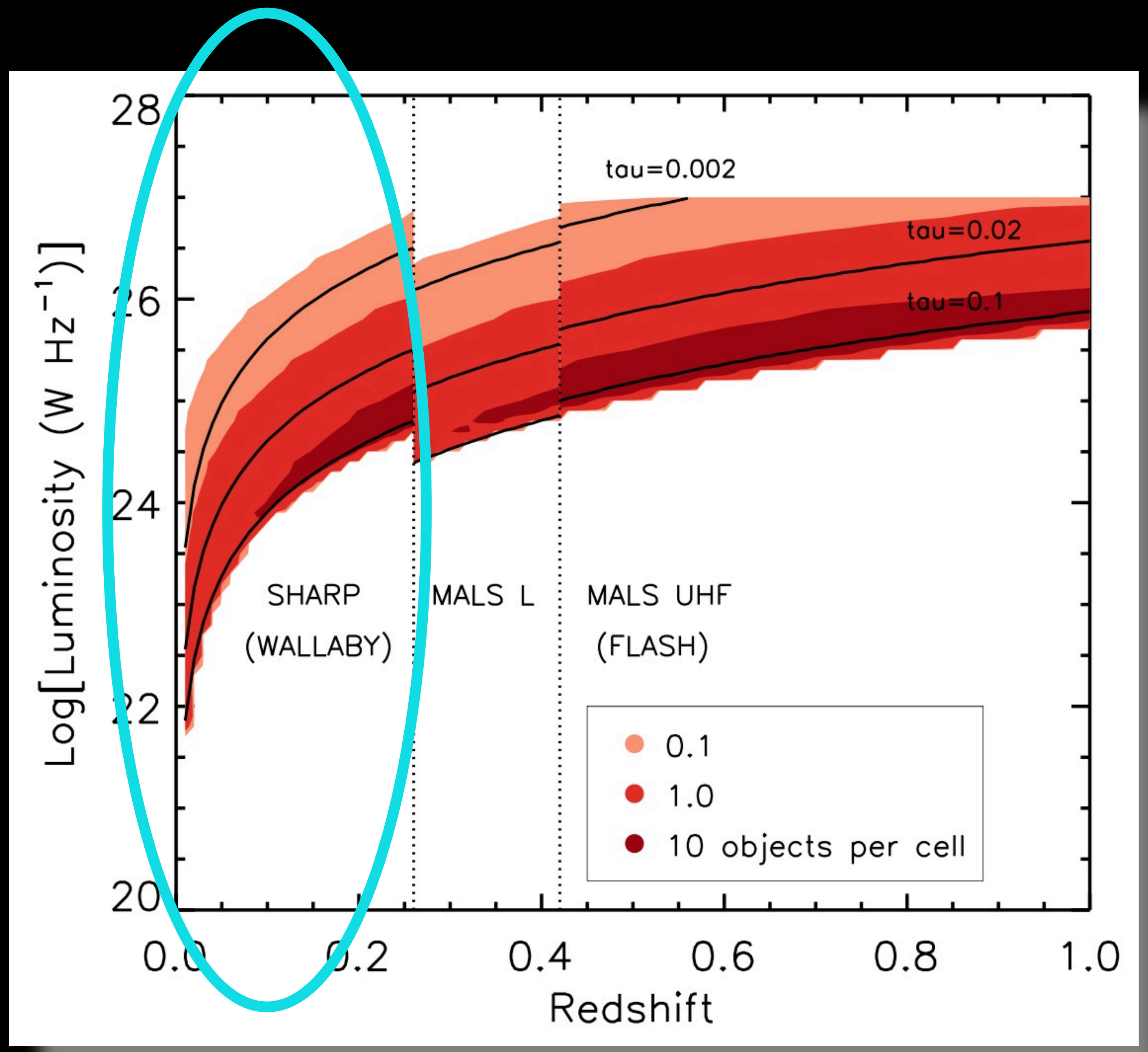
Disks

Infalling gas

Morganti & Oosterloo A&A Rew 2018

HI absorption at low redshift (z<0.2)

[providing a framework for interpreting high-z observations]



N. Maddox, see Maccagni et al. 2017

Detection rate: trend with type of radio sources

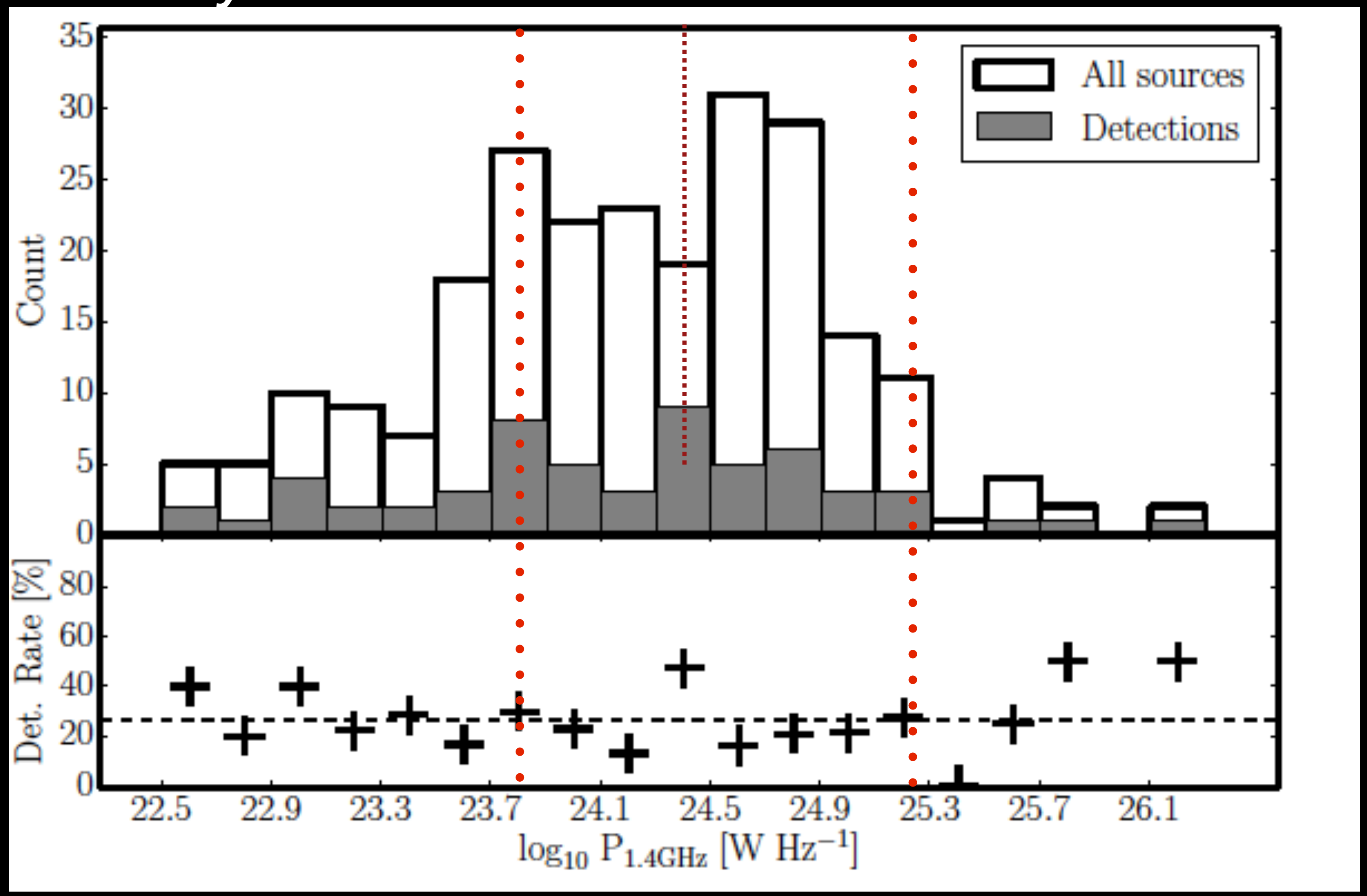
— Seyferts: ~70% (Gallimore et al. 1999)

— Mergers: ~80% (Gereb et al. 2015; Dutta et al. 2018)

— Young radio galaxies: ~30% (Gupta et al. 2006, Chandola et al. 2011, Gereb et al. 2015)

— Extended radio galaxies: 15-20 % (Maccagni et al. 2017)

range radio-quiet Seyferts *range FRI* *range FRII*

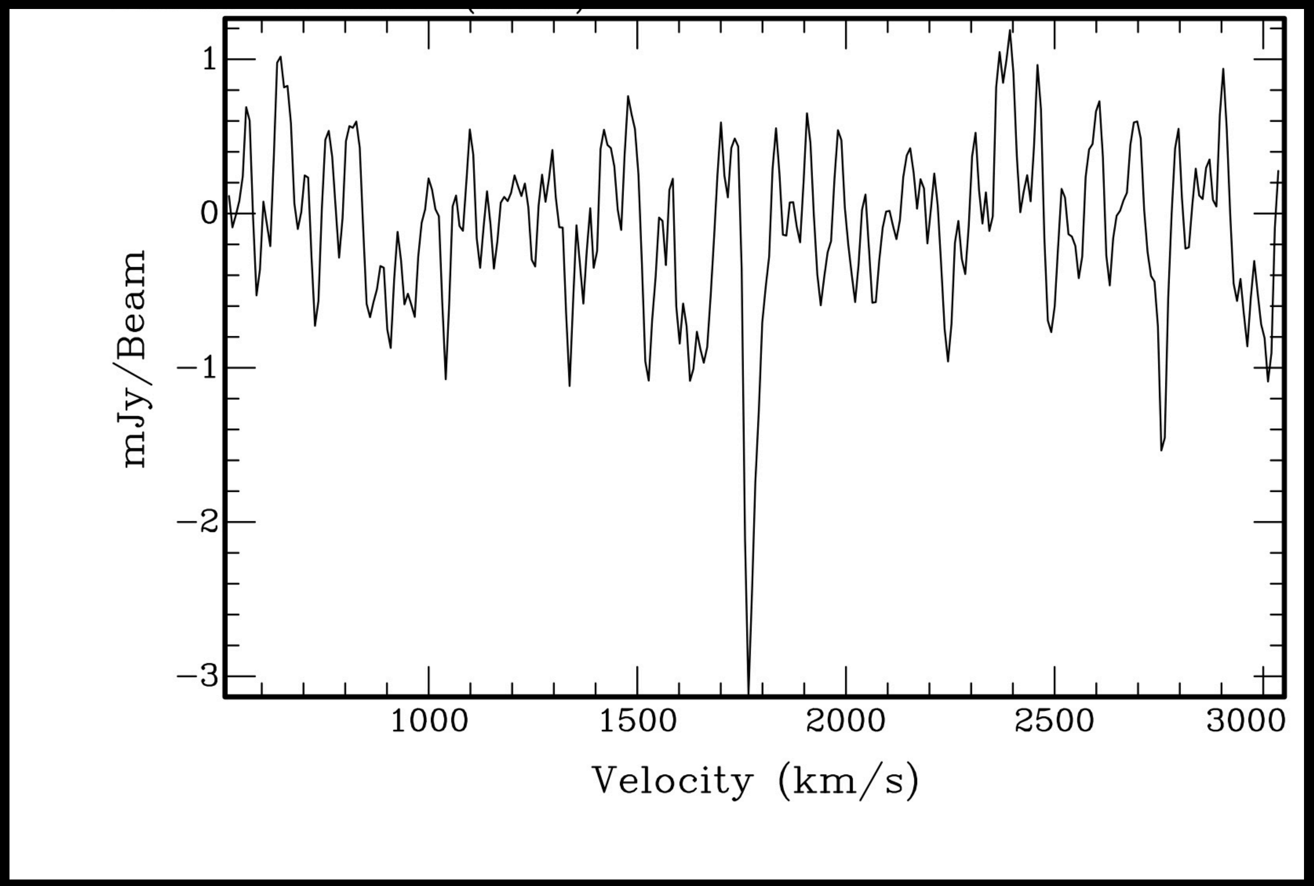


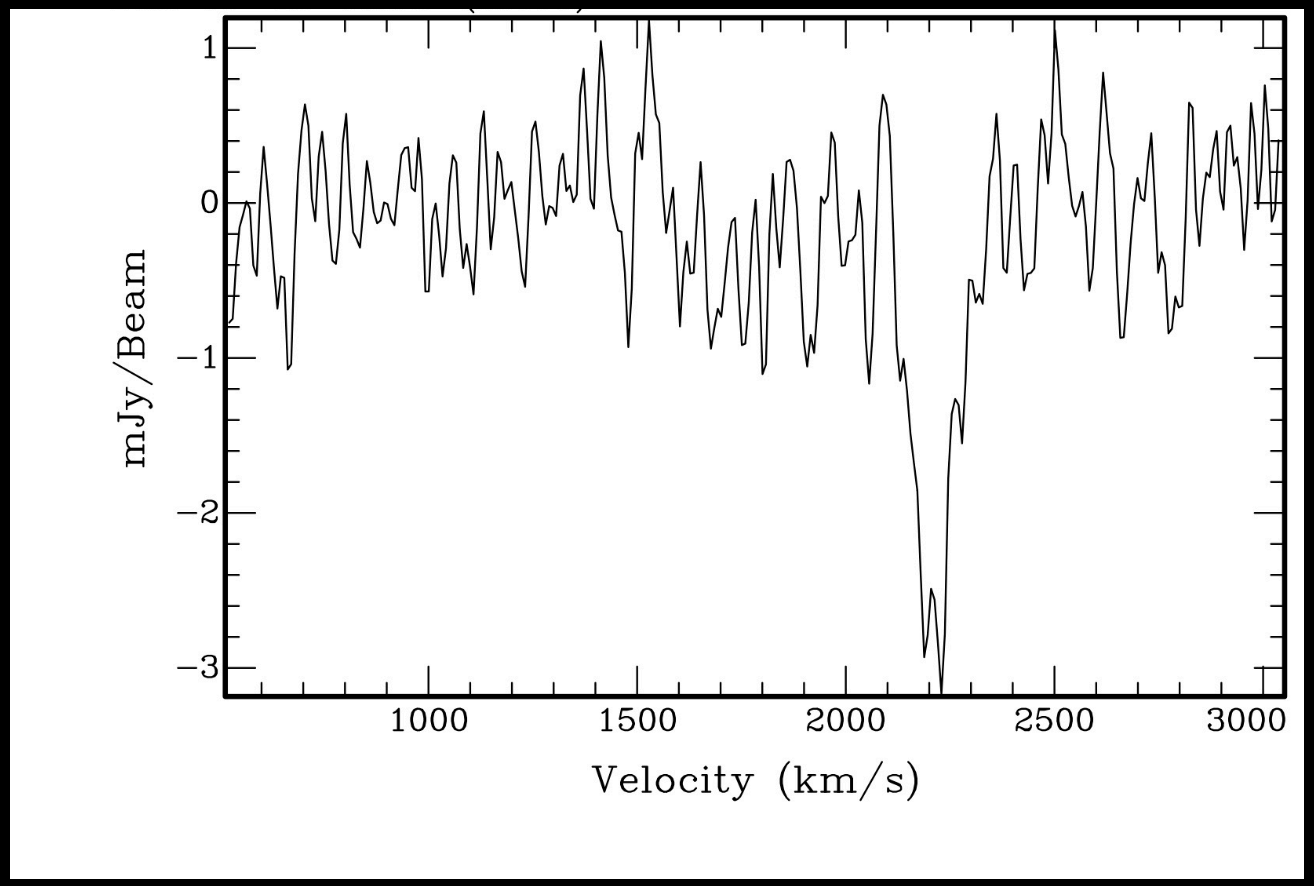
Gereb et al. 2015, Maccagni et al. 2017

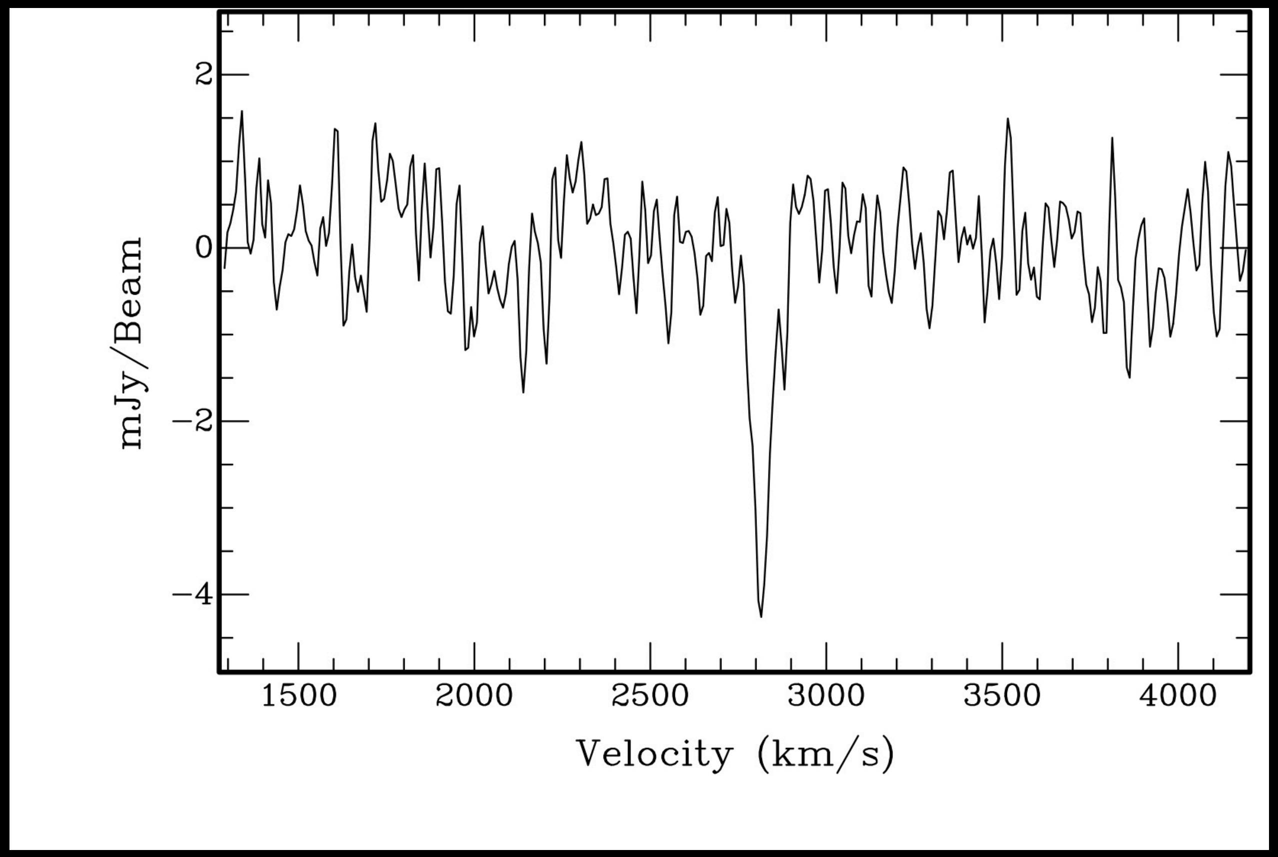
Tracing discs structures with HI absorption

Narrow HI absorption (<100km/s) signature of large scales (kpc) disks

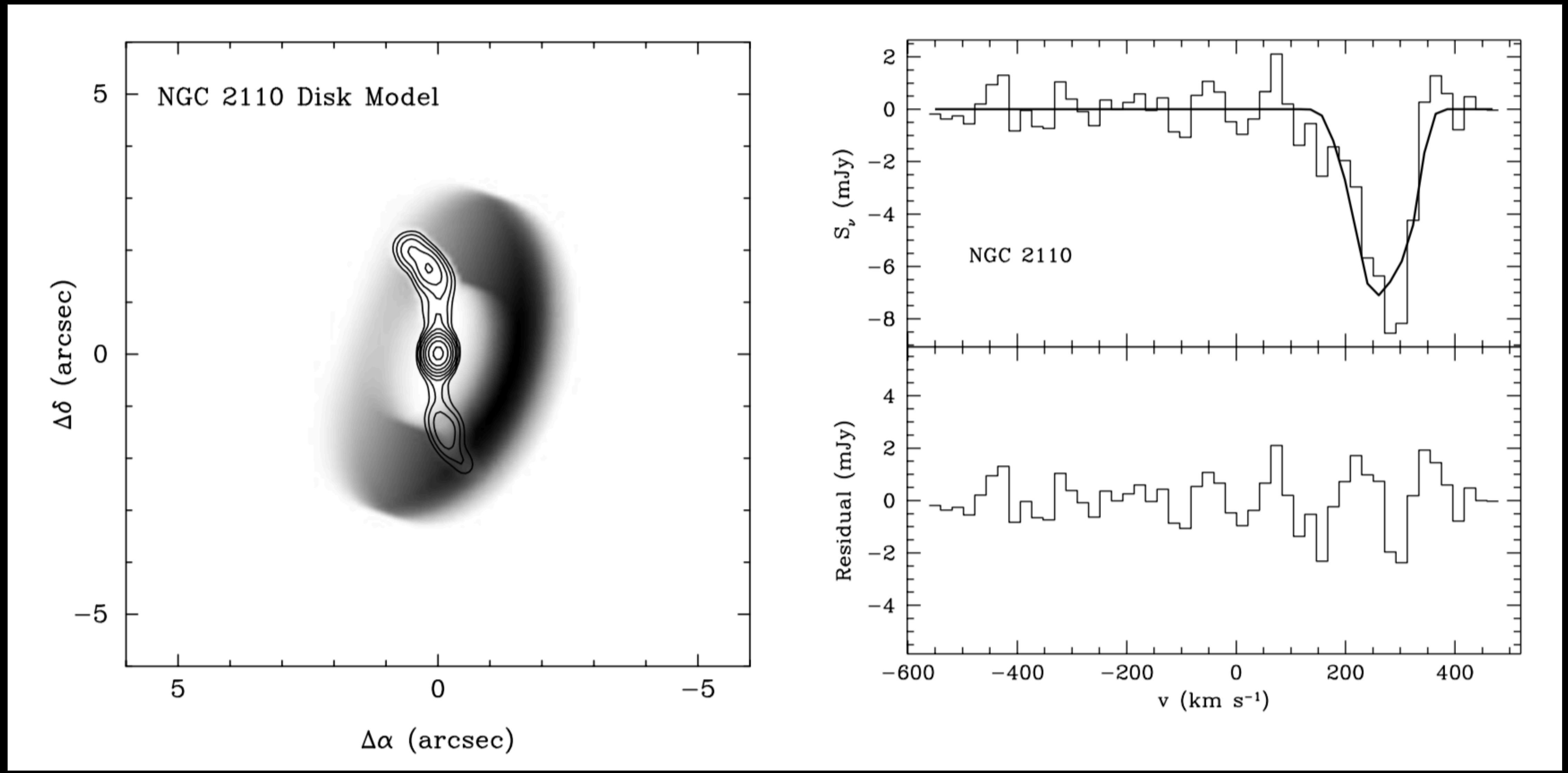
(as seen in emission, e.g. ATLAS3D Serra et al. 2012)







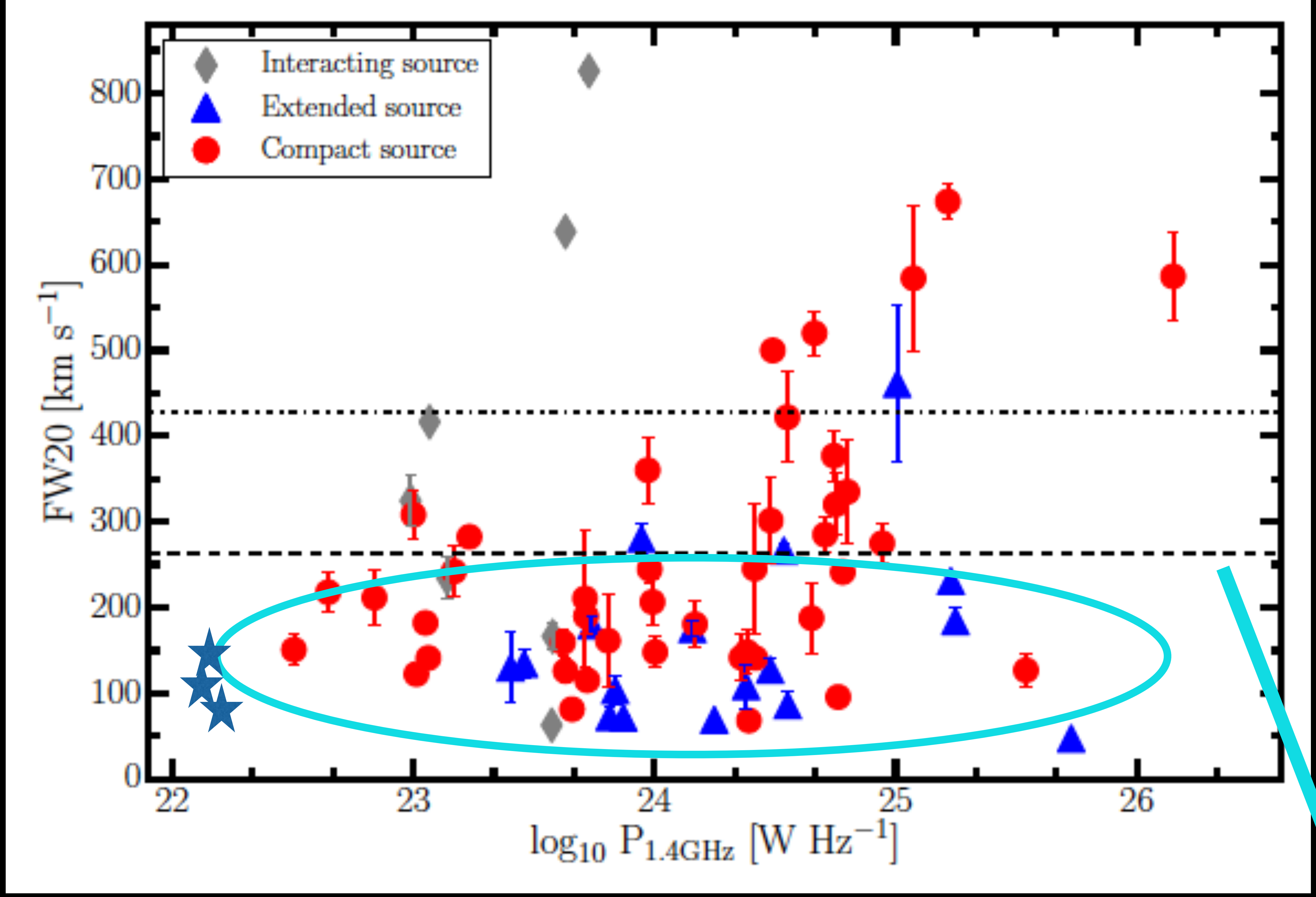
Circumnuclear discs as found in Seyfert galaxies: larger width of the HI profile



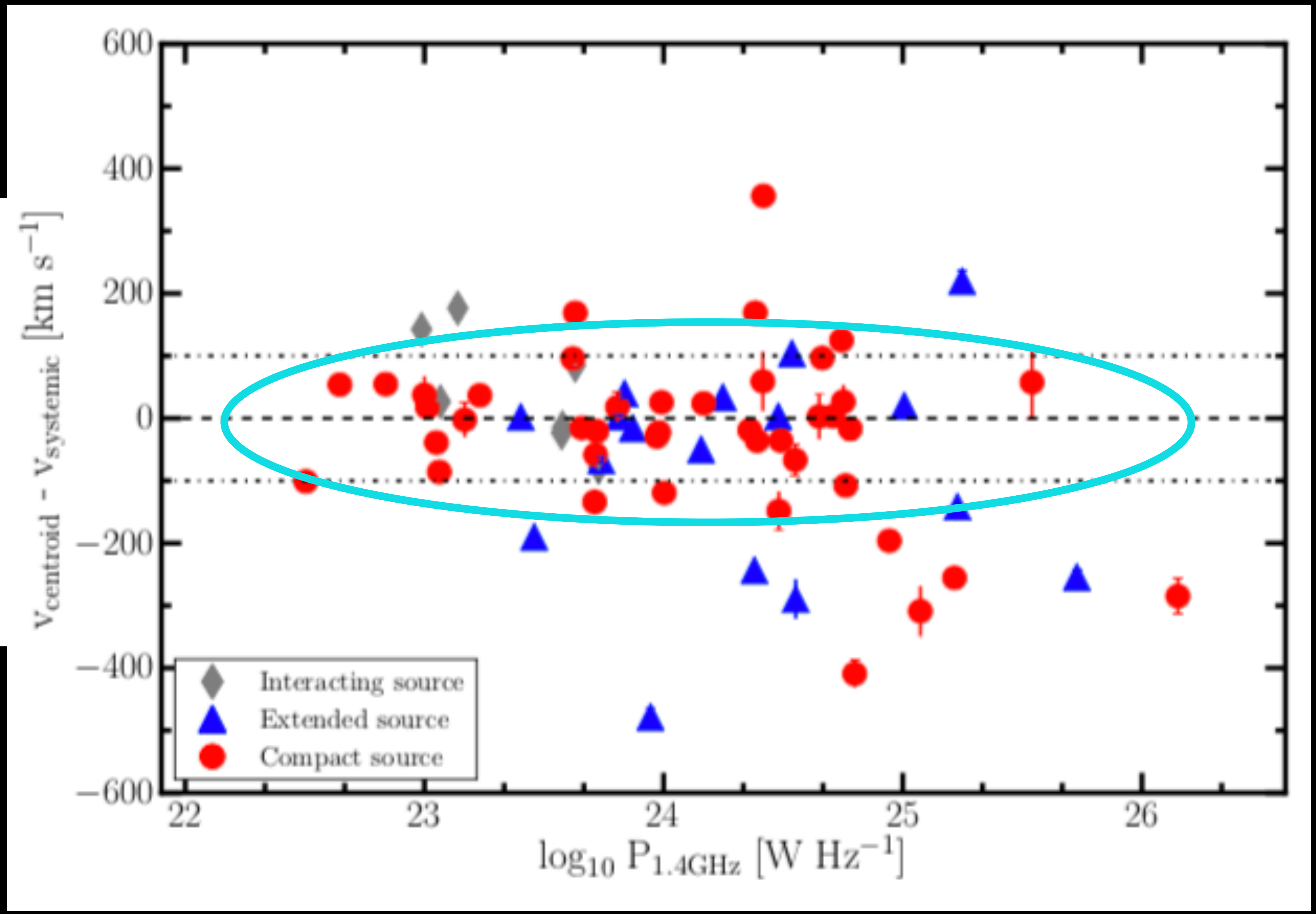
Gallimore et al. 1999

More cases of blueshifted gas highly deviating from the systemic velocities than redshift.

width of the HI absorption profiles



Offset of the HI absorption profiles



Maccagni et al. 2017

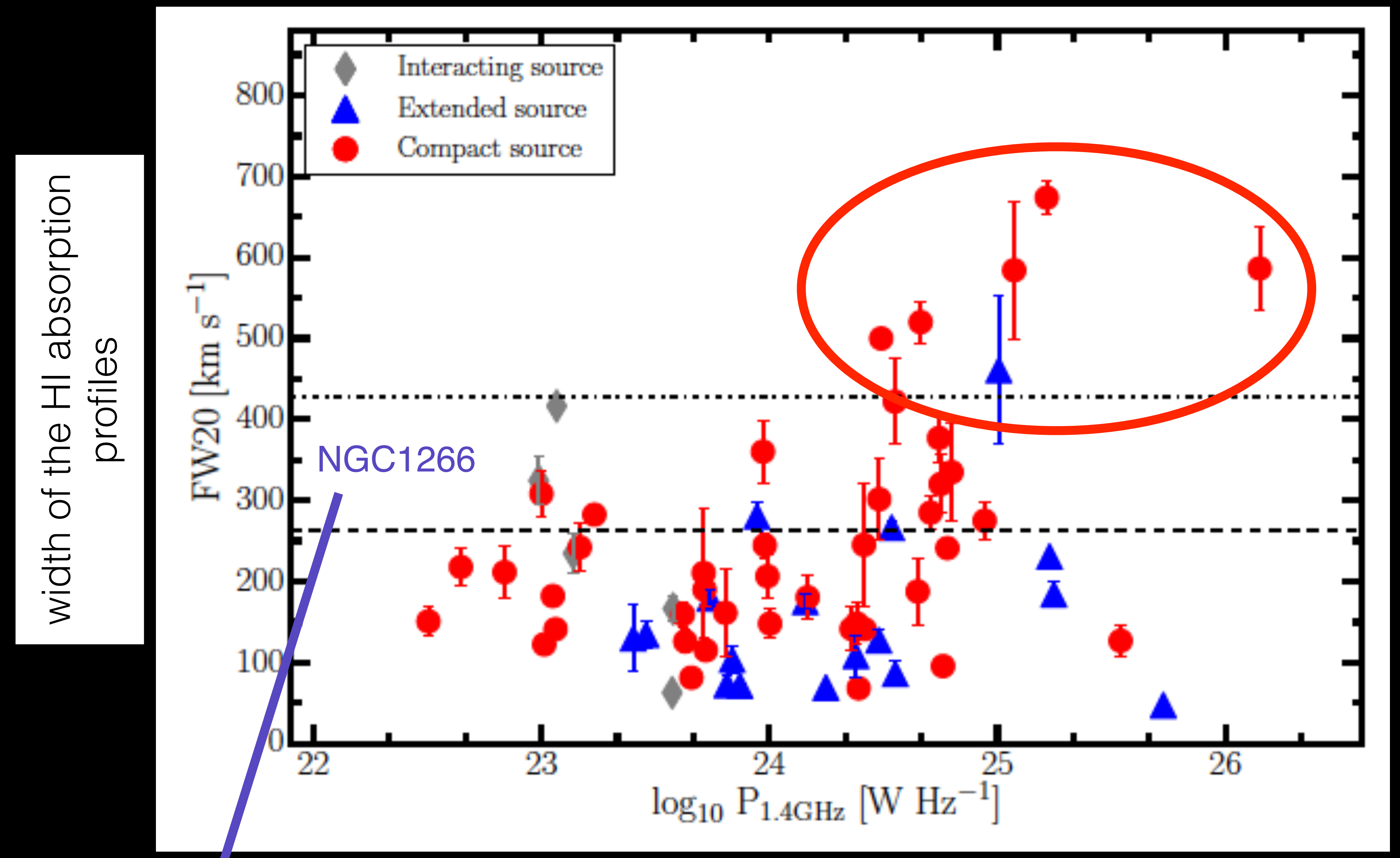
Mergers: Gereb et al. 2015; Dutta et al. 2018

mean of the distribution of rotational velocities of the sample (derived from TF relation, K magnitude…)

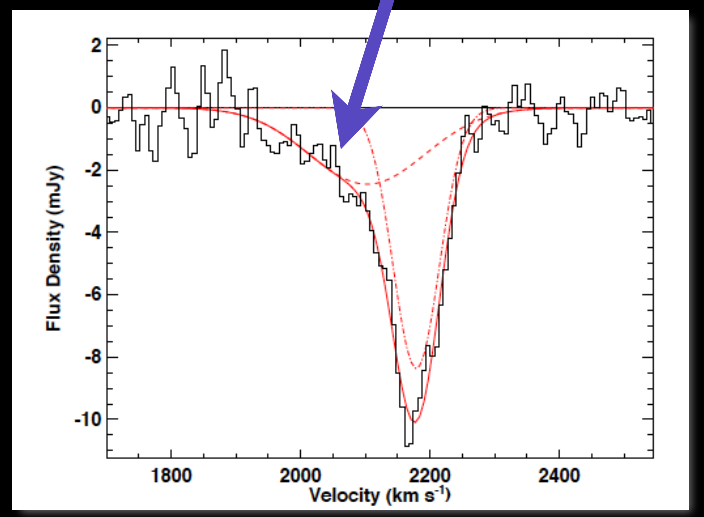
Outflowing/turbulent HI

Outflowing/turbulent HI

HI outflows: occurrence and properties



Alatalo et al. 2011



at least 5% of the all sources (15% of HI detections) show HI outflow (FWZI=500-1000 km/s)

higher detection rate for young (and restarted) radio galaxies and trend with radio power

(consistent with results from the ionised gas, e.g. Holt et al. 2008)

Small sub-kpc size and steep, peaked spectrum

Outflowing HI distributed over few tens to kpc scales

HI mass in the outflows from a few x10^6 to 10^7 $M_\odot$;

Mass outflow rates up to 20-50 $M_\odot$/yr

For HI outflows $\dot{E}_{kin}/L_{edd}$ ~10^{-4} (few x 10^{-3} bolometric luminosity)

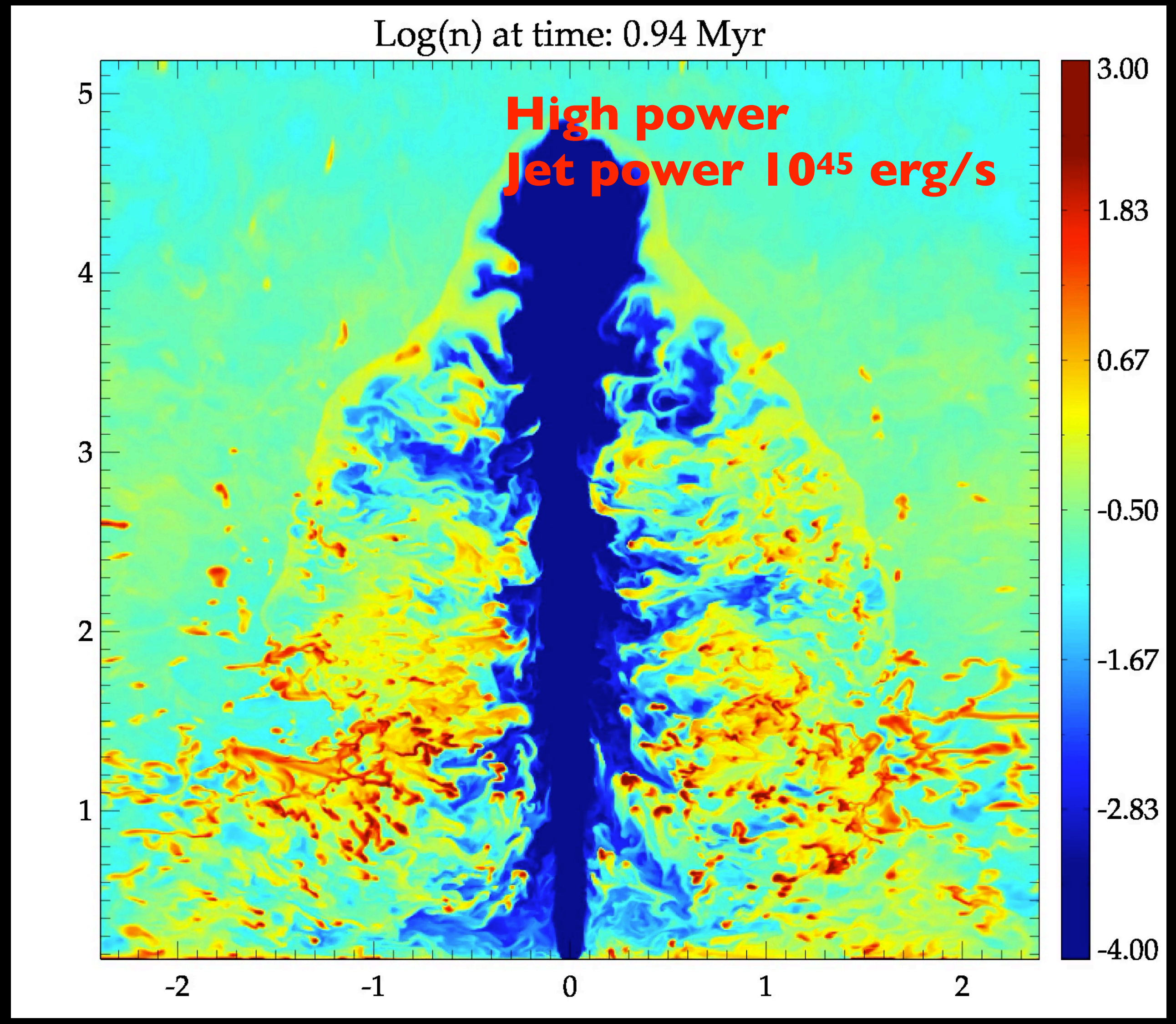
Suggest a role for the radio jet ➜ effect on galaxy evolution
increasing turbulence and redistributing gas
Efficient cooling of the gas after being shocked

Can the jet drive the outflows?

from Wagner & Bicknell 2011, 2012, Mukherjee, Bicknell et al. 2016, 2017, 2018

Numerical simulations of a newly created radio jet

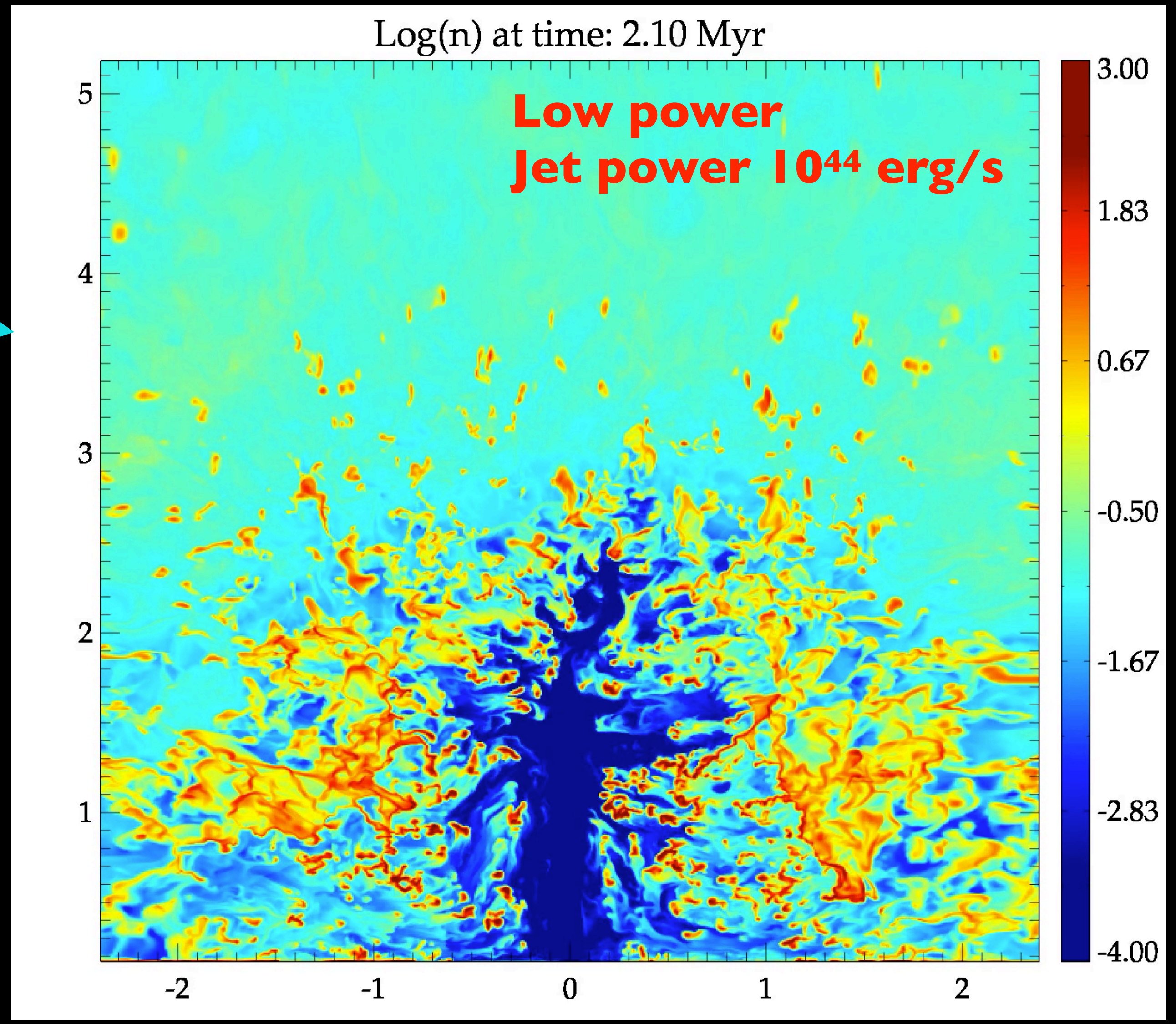
- Jets couple strongly with host's **clumpy ISM**:
  whatever the initial narrowness of the jet, the flow is broadened by the interaction with the first cloud (Wagner et al. 2012)



- A newly created jet (or restarted) jet has the largest impact

clumpy medium (spherical distribution), different jet power

- Effect depends on **jet power: low power jets are important!**
  Couple more with the ISM, will induce more turbulence and they are more numerous!

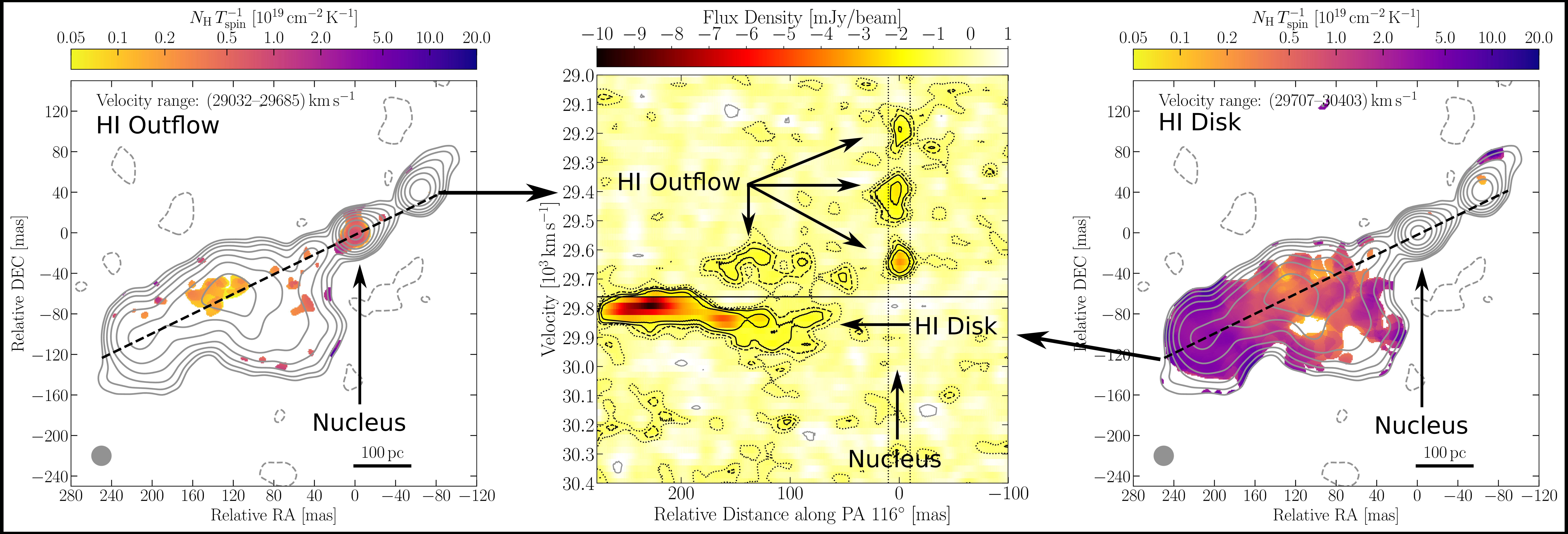


Tracing the clumpy medium at pc resolution

HI VLBI observations (resolution ~10 pc)

HI clouds outflowing at ~ 600 km/s observed already in the inner few x 10 pc from the nucleus (< 40pc).

Average density of the HI clouds n_e ~150-300 cm^{-3} (0.28–1.5 x 10^4 $M_\odot$)



Case of the radio galaxy 3C236

Schulz, RM et al. 2018 (arXiv:1806.06653) neutral gas density of the universe has been decreasing over the past 10 Gyrs (Nelemans et al. 2016)

Expansion to the high-z

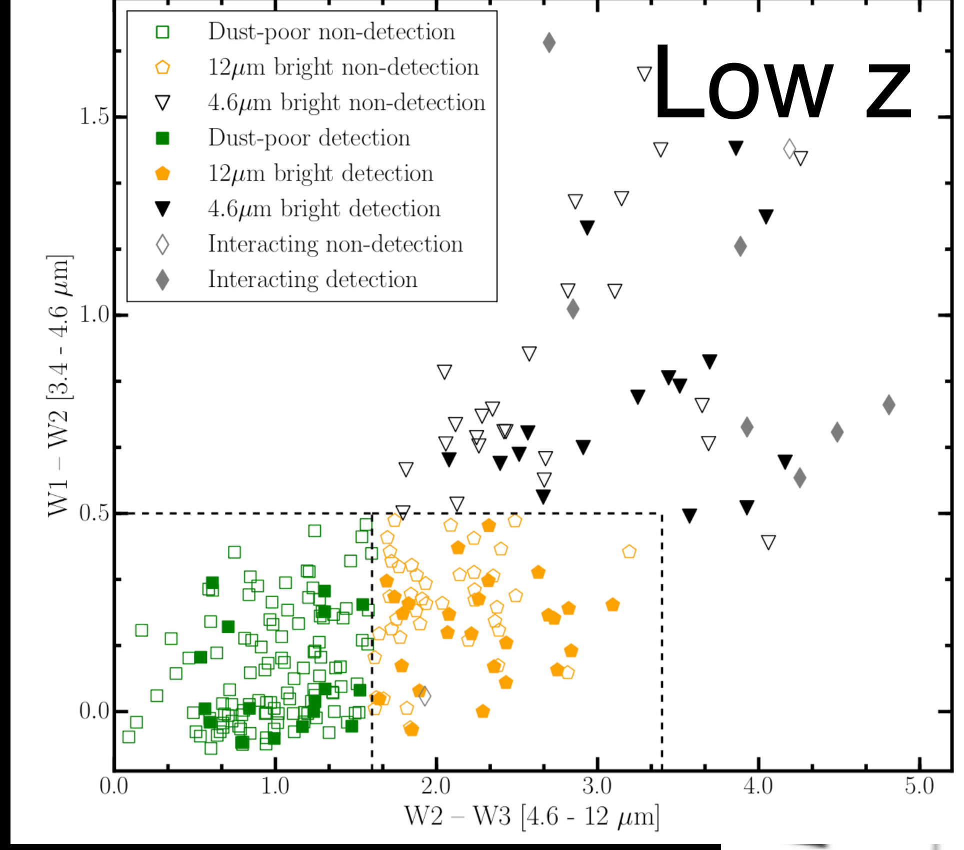
➜ galaxy evolution requires the knowledge of the gas content (for starformation and feedback) and properties at high-z

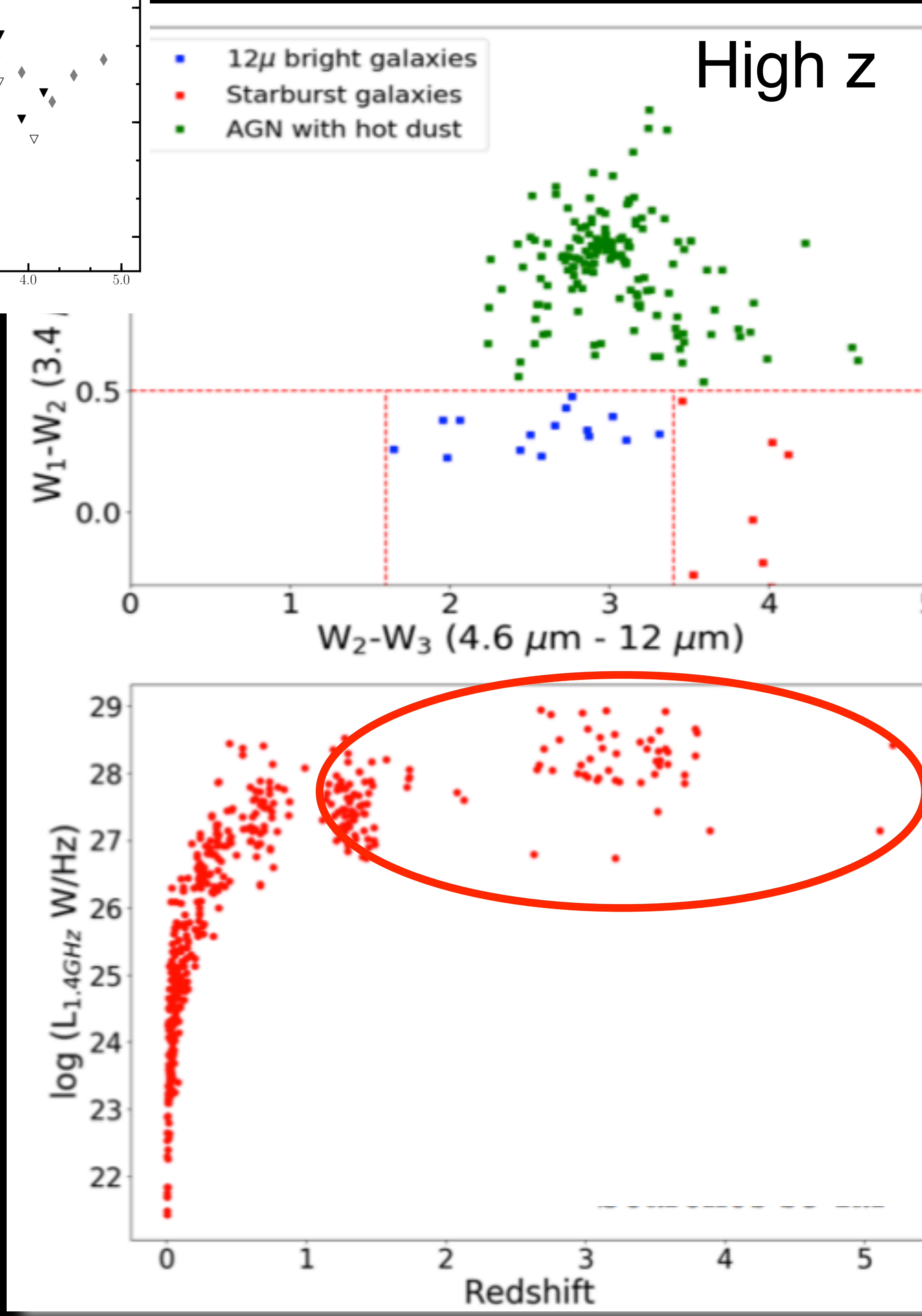
➜ predicted higher density of neutral gas at high-z

Key role of the GMRT: see talks of Suma Murthy and Aditya

Challenging task!

Expansion to the high-z: difficulties





- ➜ hostile RFI environment
- ➜ poorer linear resolution: more difficult to separate core and extended structures (covering factor more uncertain)
- ➜ search at high-z limited to extreme AGN: affecting the physical conditions of the gas?

Difficult to disentangle these effects

Searches so far…

Expansion to the high-z: status

➜ low detection rate so far (5%)

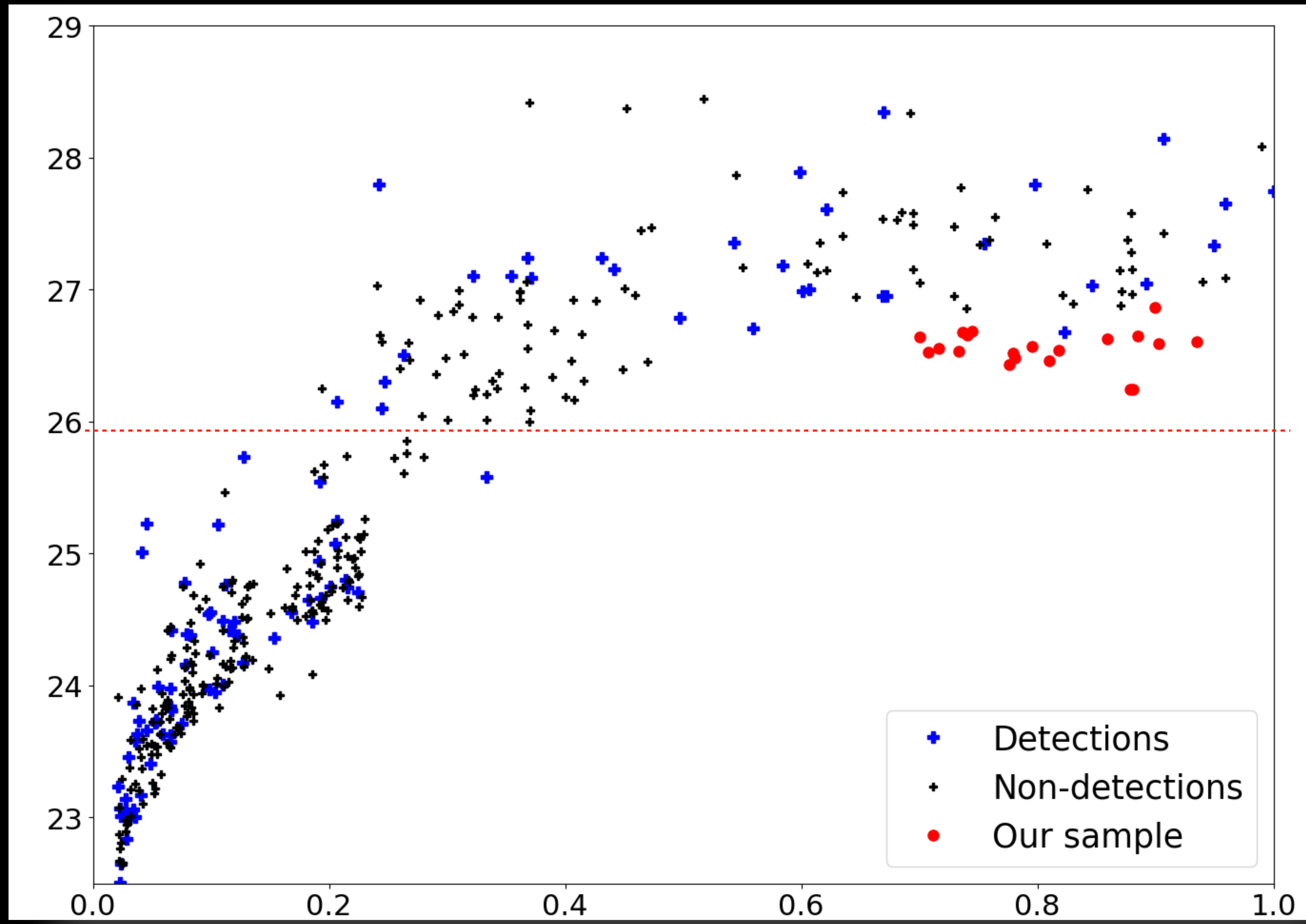
➜ but exploring a different type of AGN compared to low-z

★ Powerful radio AGN

★ High UV luminosity? (Curran et al. 2008+)

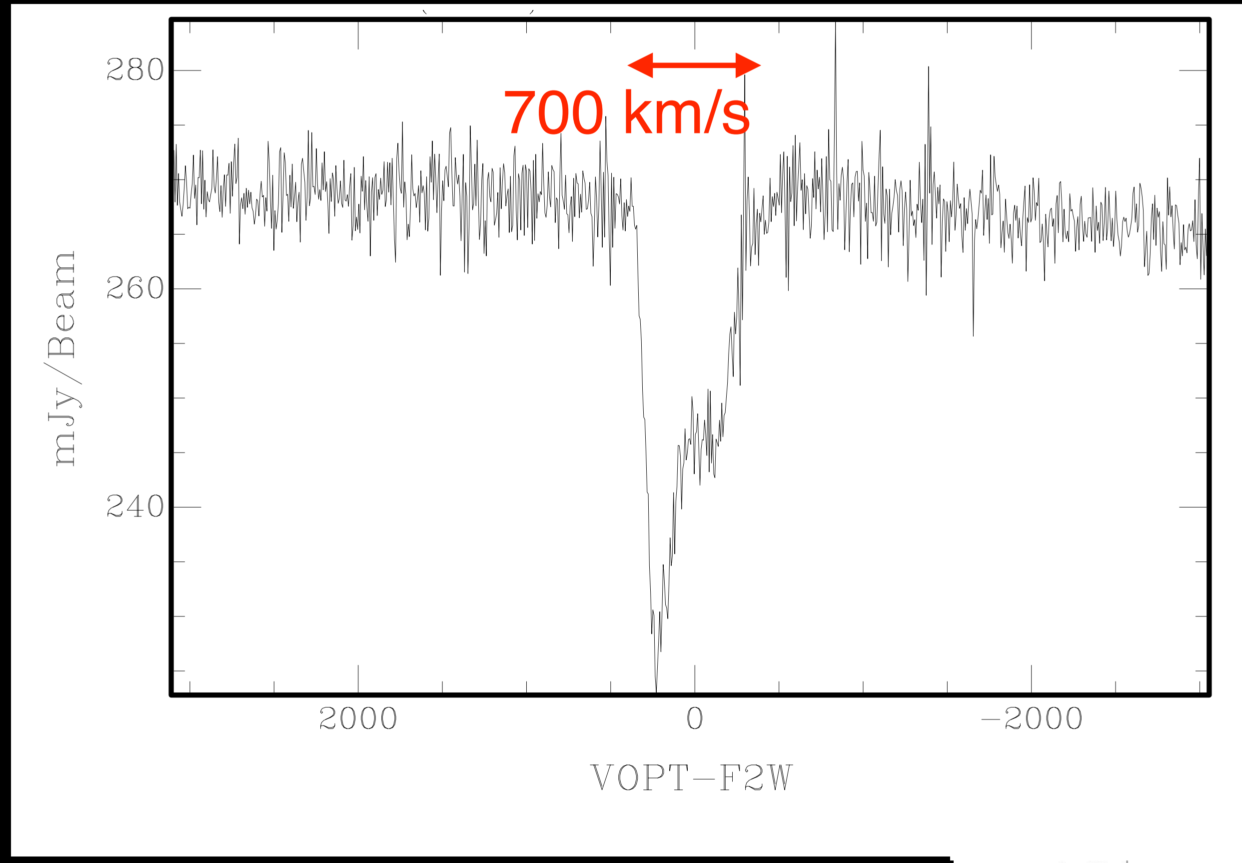
★ Higher T_{spin}? (Kanekar et al. 2014)

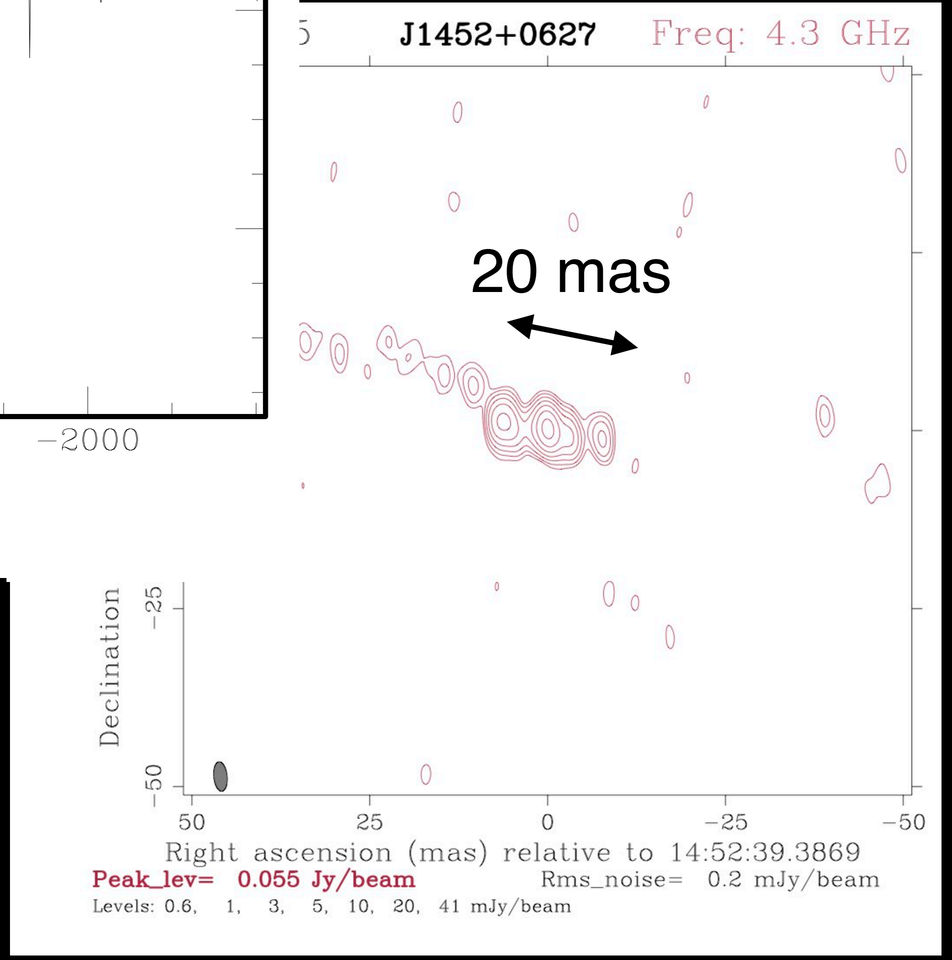
★ Core fraction not always well know



★ Young GPS radio sources have similar detection rate at low/ high z (Aditya&Kanekar 2016)

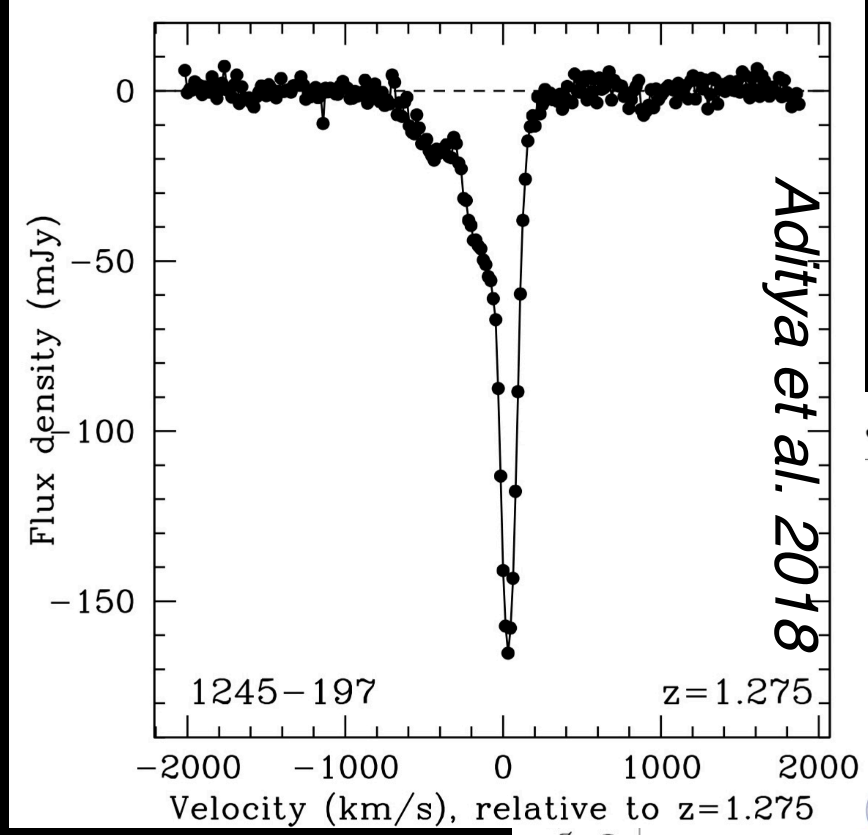
And some interesting cases

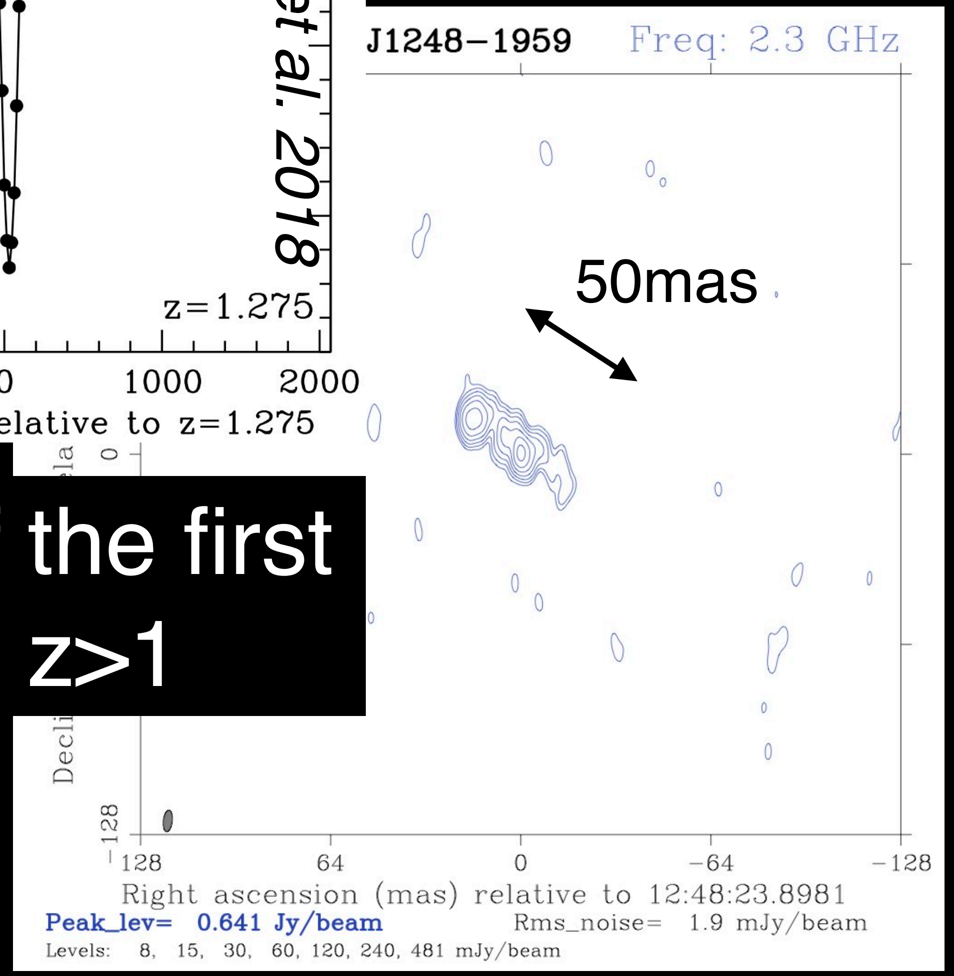




Flat spectrum compact @ z~0.3

(VLA data, paper in prep)





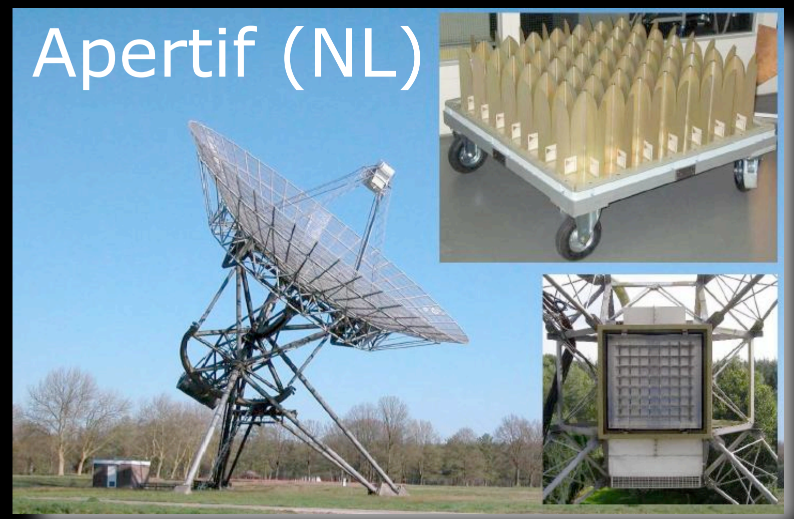
GPS one of the first detection at z>1

Continuum from Astrogeo VLBI FITS image database

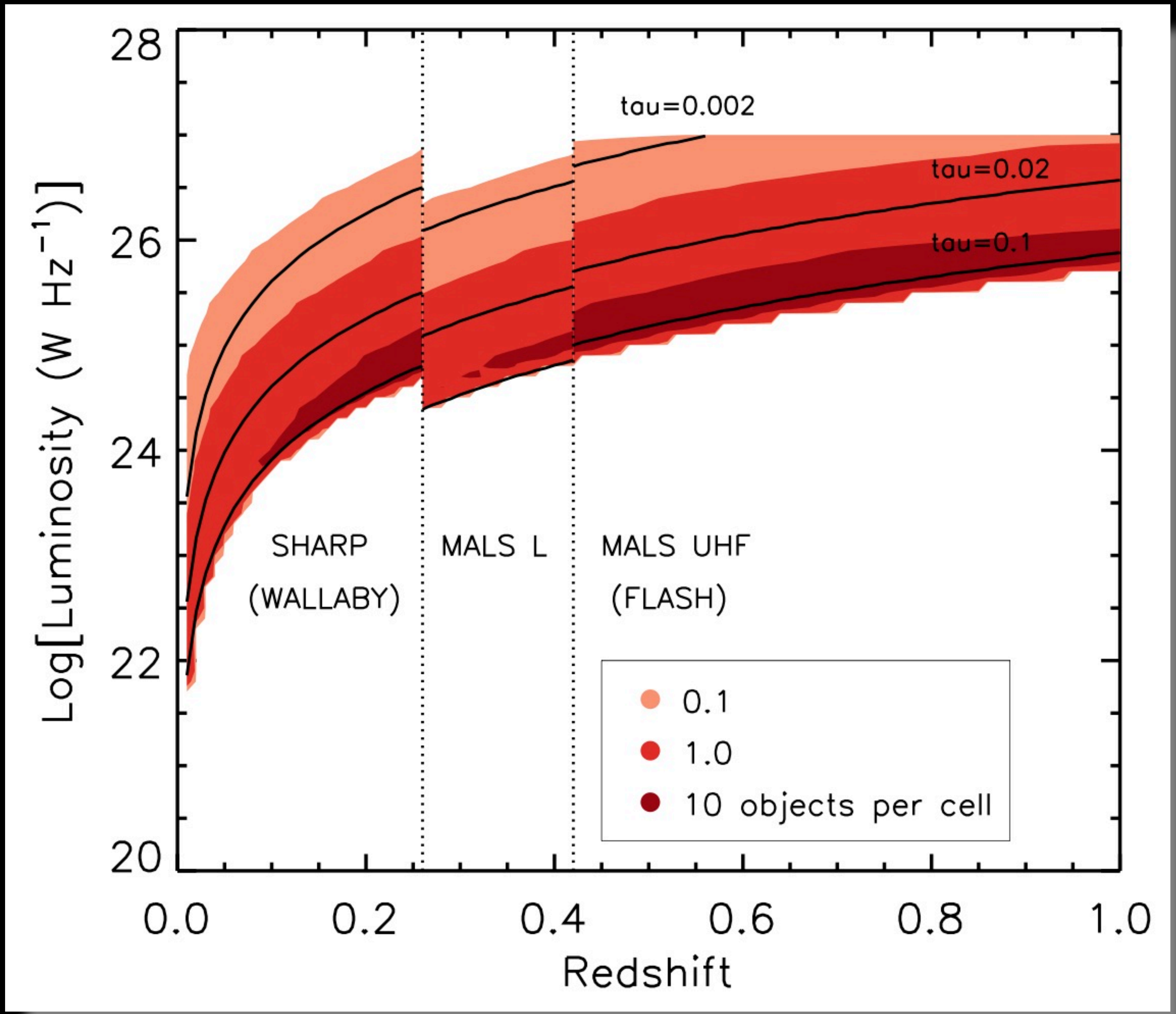
The upcoming HI absorption surveys

Increase the statistics and explore the high-z Universe

Gupta's presentation



Verheijen's presentation



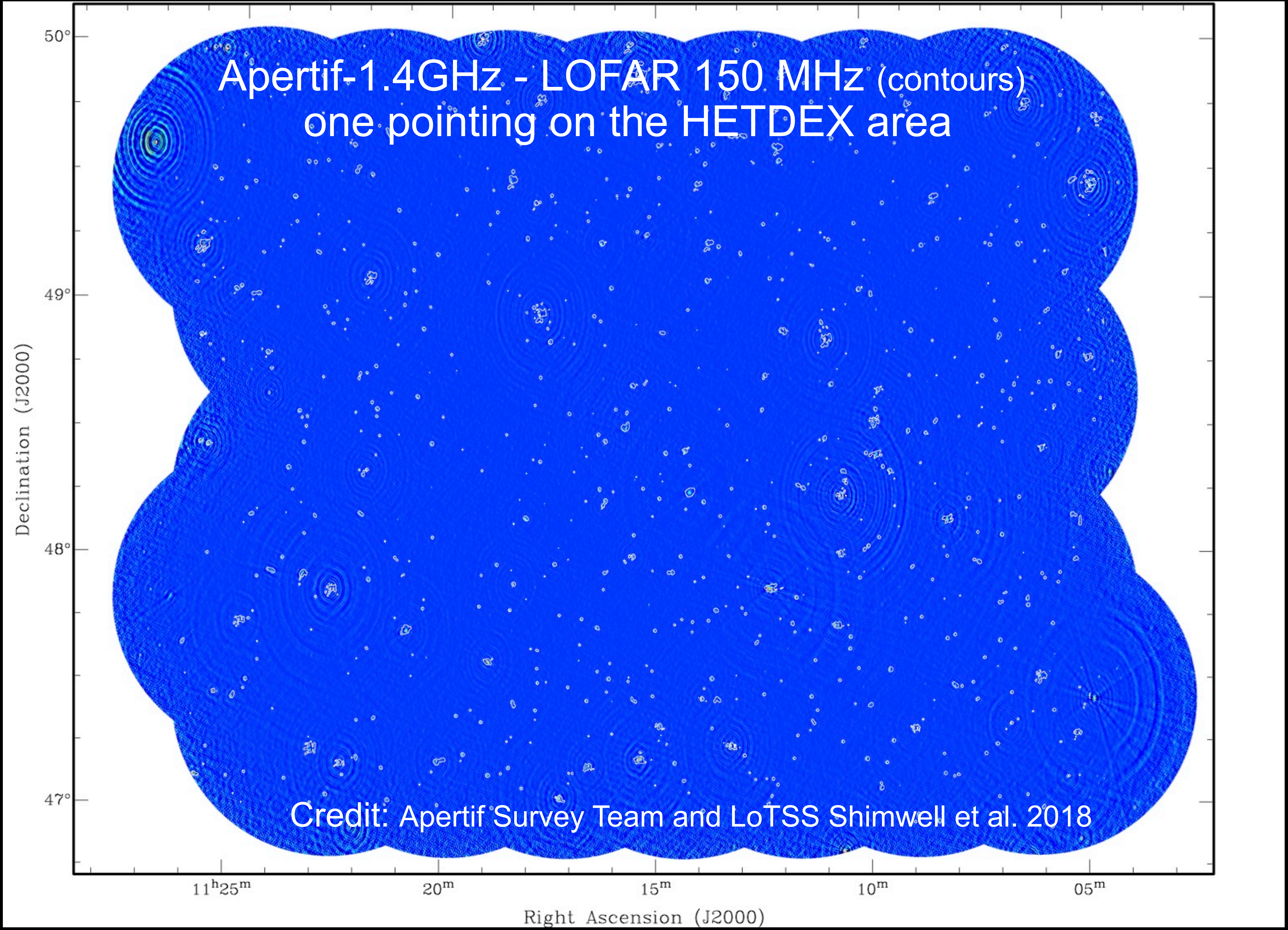
N. Maddox, see Maccagni et al. 2017

ASKAP: The First Large Absorption Survey in HI
FLASH (PI: E. Sadler)

Search for HI absorption with APERTIF
SHARP (PI: R. Morganti)

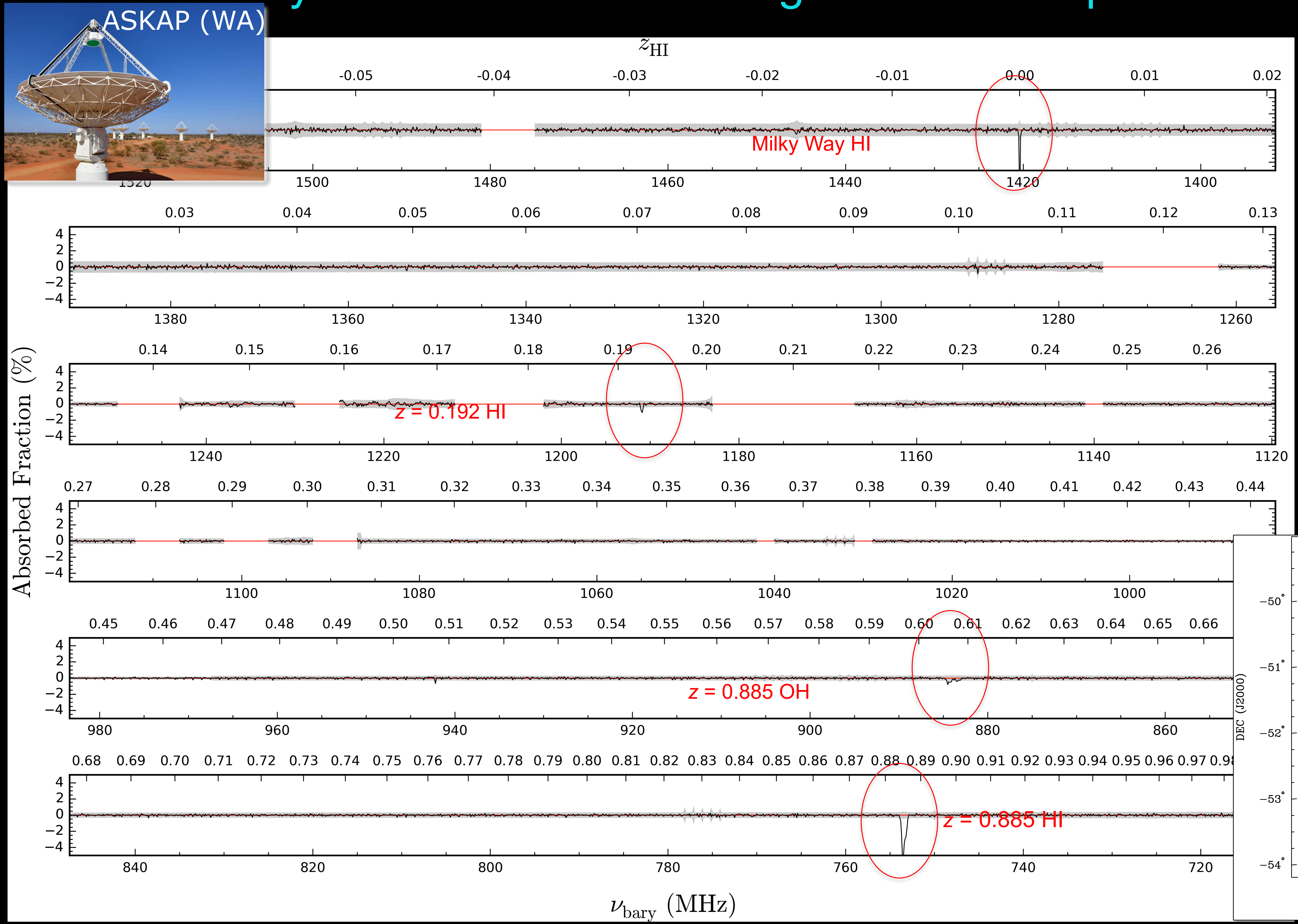
The MeerKAT Absorption Line Survey
MALS (PI: N. Gupta)


Apertif surveys test observations
HETDEX area
~12 arcsec
HI < 0.3
Apertif (NL)
+50°
+49°
2000)
beam09 (#8): J111040.91+474702
S [mJy beam^{-1}]
cz (km s^{-1})
?
beam17 (#6): J111410.83+481907
S [mJy beam^{-1}]
Schulz, Oosterloo,RM
SHARP
Credit: Apertif Survey Team



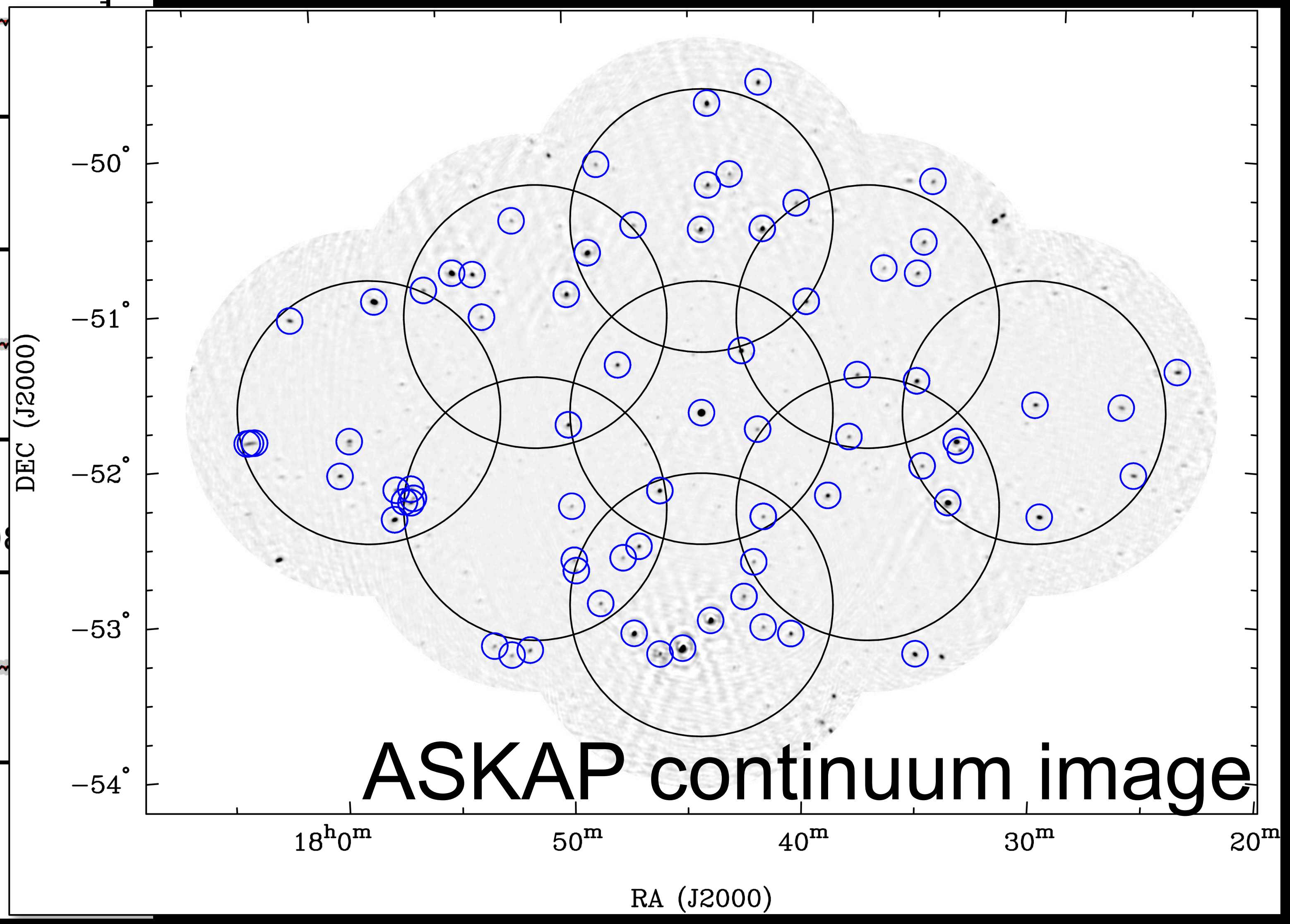
Apertif-1.4GHz - LOFAR 150 MHz (contours)
one pointing on the HETDEX area
Credit: Apertif Survey Team and LoTSS Shimwell et al. 2018
Declination (J2000)
Right Ascension (J2000)
50°
49°
48°
47°
11h25m
20m
15m
10m
05m

ASKAP - Very broad redshift coverage for HI abs up to z=1

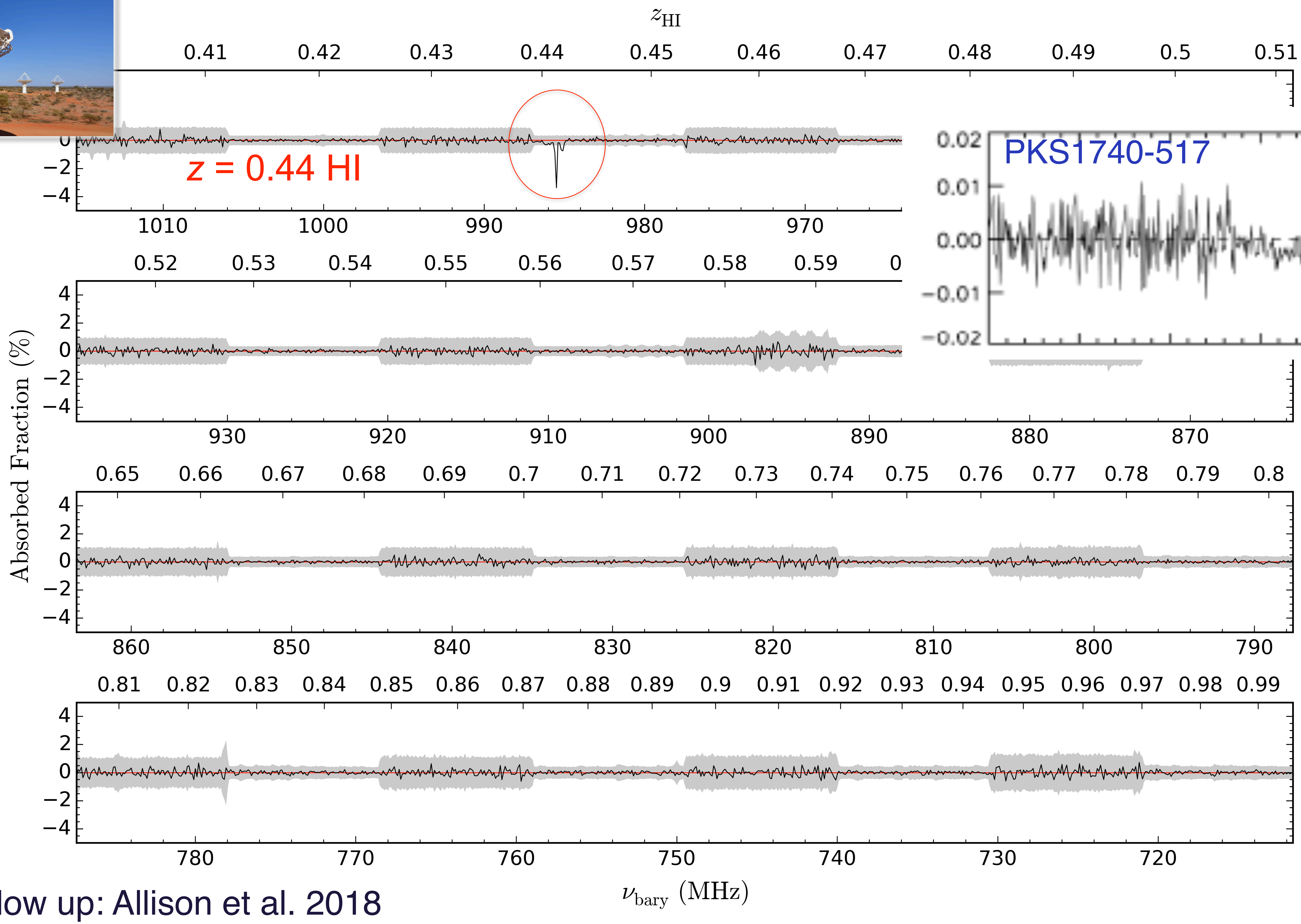


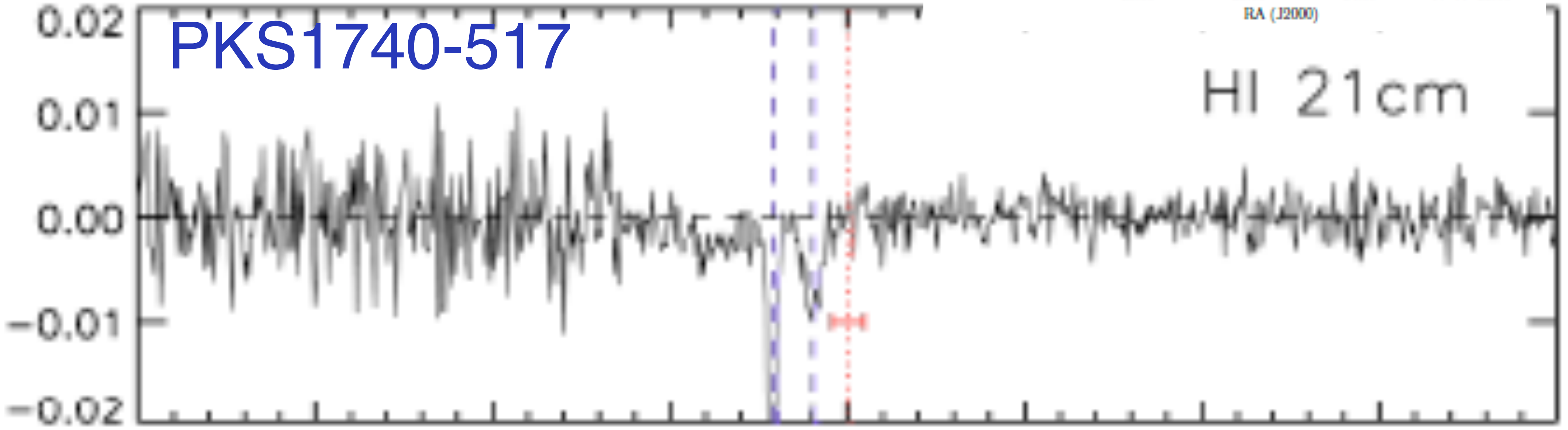
Allison et al. (2016)

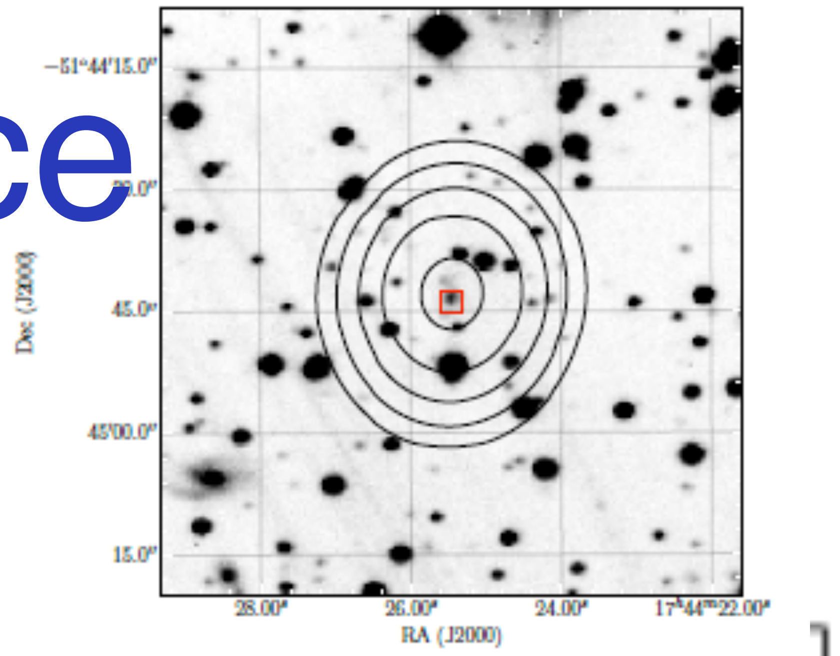
FLASH survey
PI E. Sadler



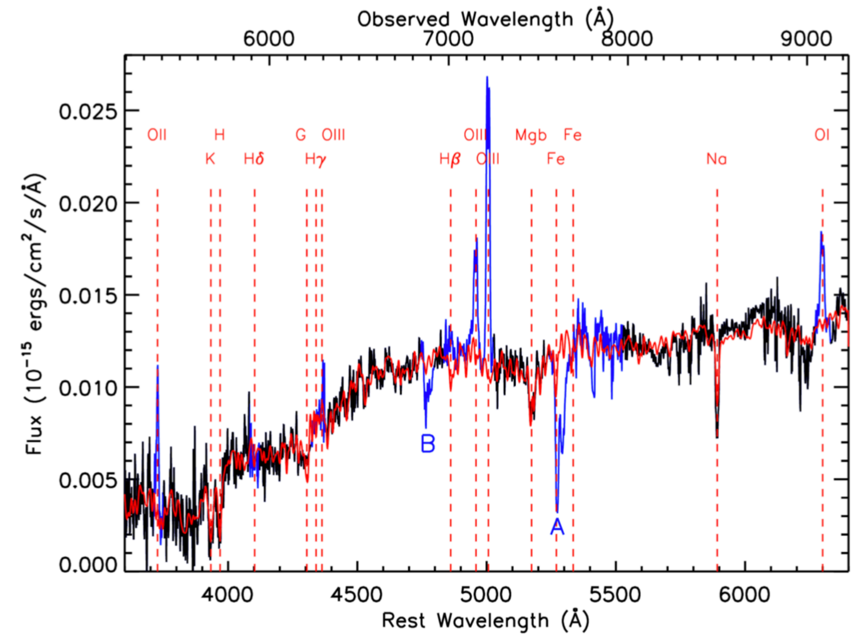
ASKAP discovery of HI in a young source







No existing redshift, only afterwards confirmed by optical spectroscopy



Allison et al. (2016)

ALMA follow up: Allison et al. 2018

Summary…

- HI absorption efficient way to learn about gas in radio AGN: occurrence, kinematics and physical conditions

- HI absorption can trace a variety of absorbing structures: regularly rotating, infalling and fast outflowing gas

- Fast outflows can be driven also by radio jets ➜ HI outflows traced down to pc scale using VLBI

- Expansion at high-z in progress …but challenging!

- Blind surveys from new telescopes will help to reach the necessary statistics to see trends with redshift and type of AGN…