A New Suite of simulations for the SKA and its precursors

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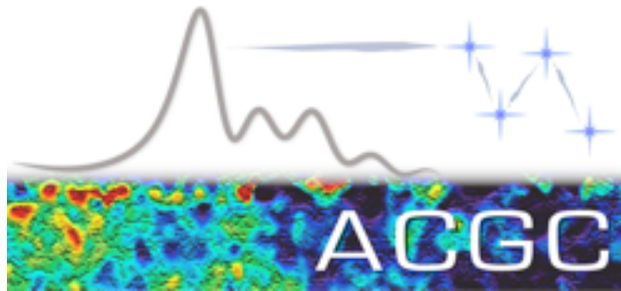


Outline

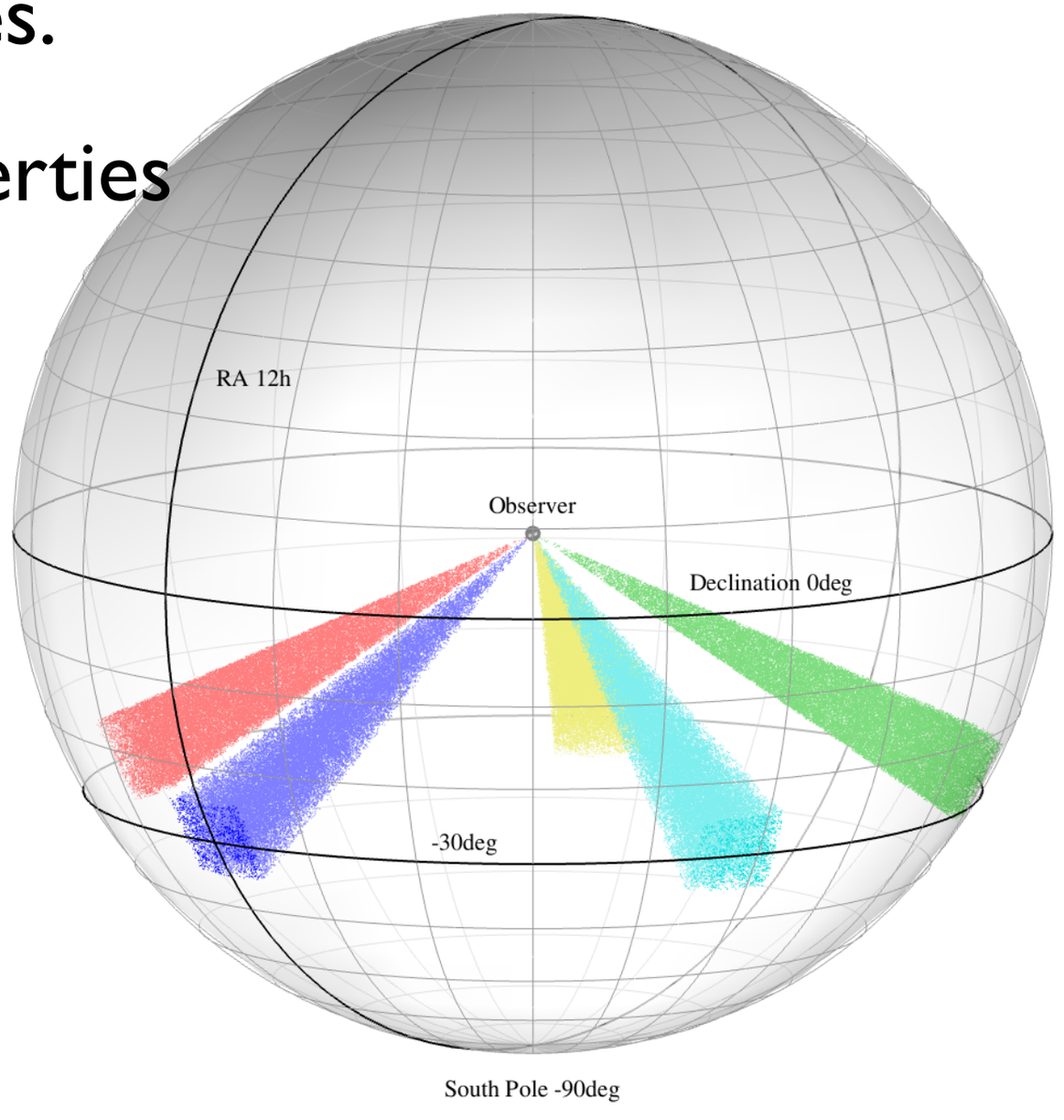
- SKADS: S^3-SAX
- This work: sky models based on S^3-SAX
- Example application
- Future plans

S^3-SAX

- S^3: suite of Semi-Analytic Models (SAMs) delivered as part of the SKADS in 2009.
- S^3-SAX : track the cosmic evolution of HI and H_2 in ~ 3e7 galaxies.
- Based on physical models of Obreschkow et al. (2009).
- Exhaustively tested in > 100 peer-reviewed publications.
- Successfully reproduce HI masses, line profiles, TF relation, clustering & evolution characteristics.
- Used as the basis for SKA performance calculations.

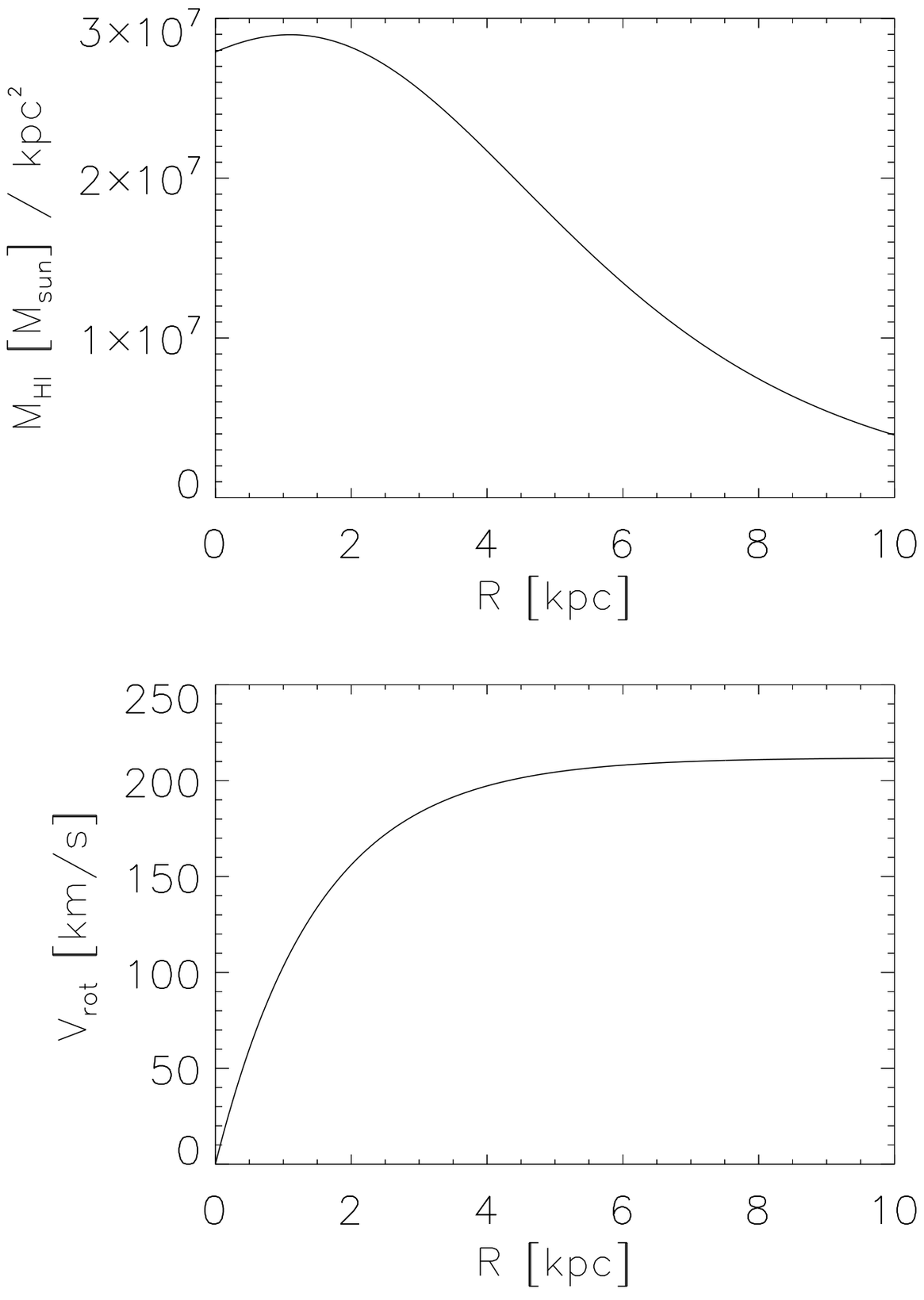
S^3-SAX

- Recently re-released by Obreschkow & Meyer (2014) with added optical properties.
- Catalogue contains 20 properties for each galaxy ...

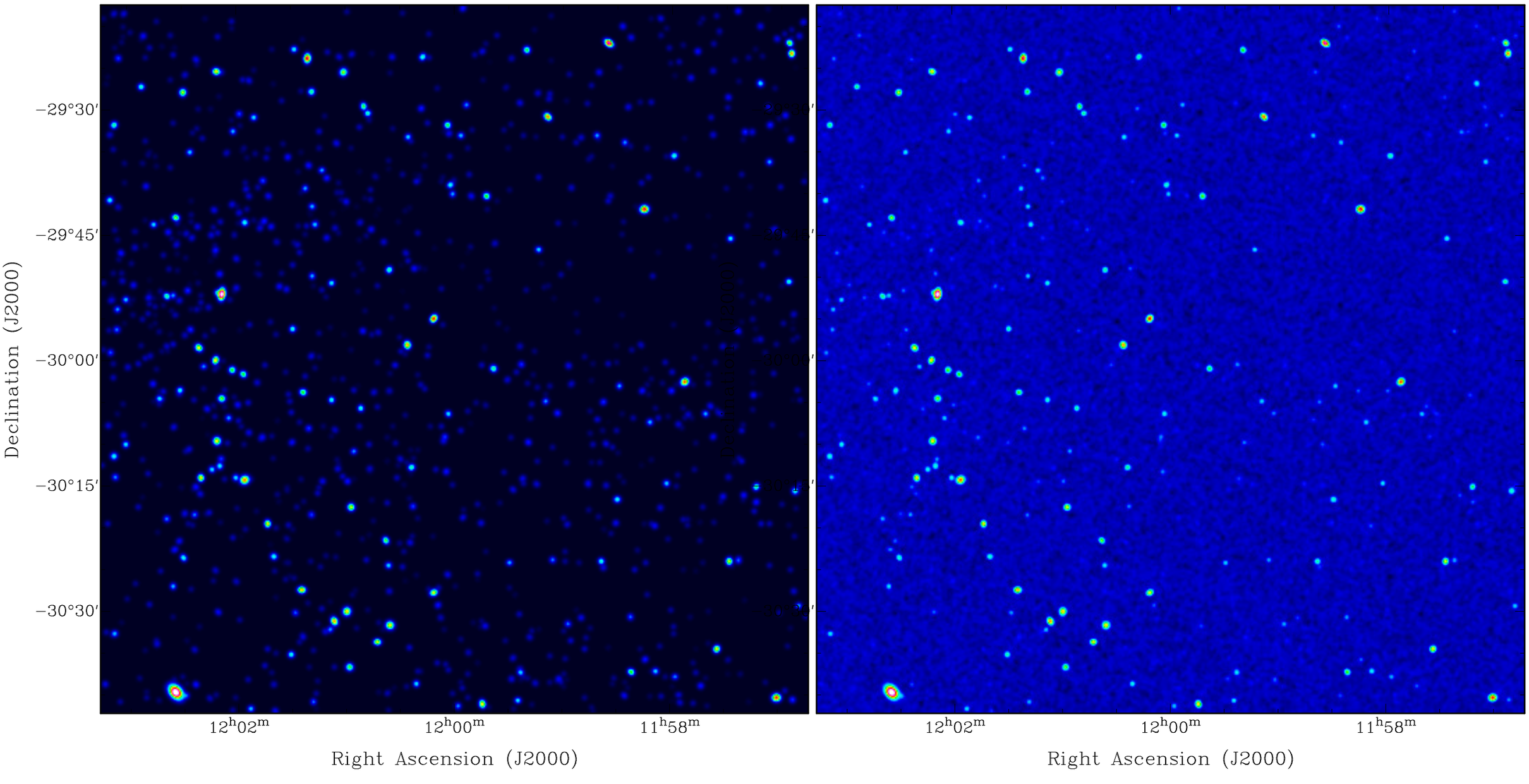


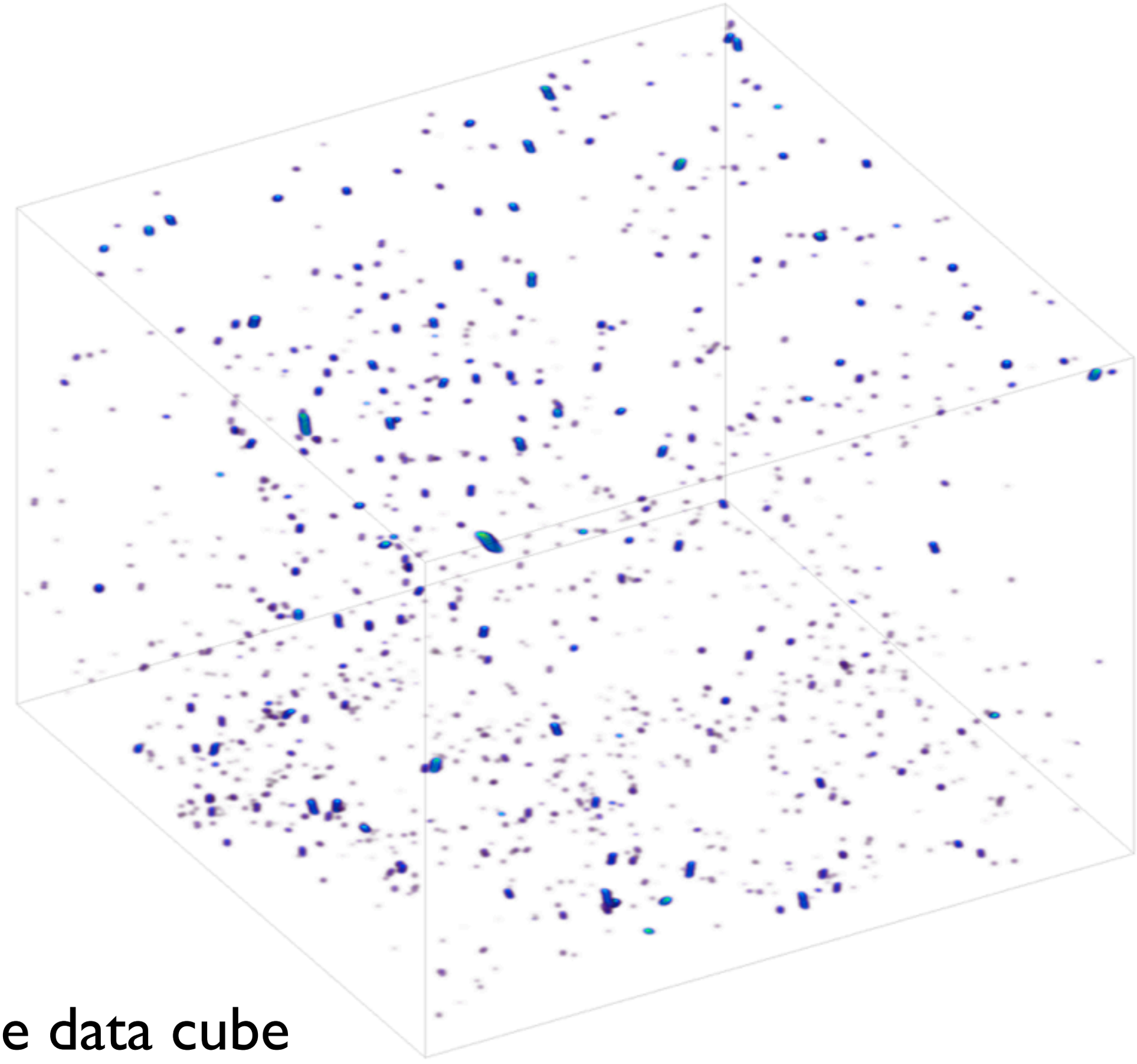
Symbol	Unit	Description
ID	–	Unique galaxy identifier in the Munich Semi-Analytic Model "DeLucia2006a"
RA	deg	Right ascension of galaxy centre
Dec	deg	Declination of galaxy centre
z	–	Apparent redshift of galaxy centre, including the Doppler component due to peculiar motion relative to the Hubble expansion
i	deg	Galaxy inclination defined as the smaller angle ($0° - 90°$) between the line-of-sight and the rotational axis of the galaxy
T	–	Numerical Hubble type ($-6...0$ for ellipticals, $0...10$ for spirals, 99 for morphologically unresolved objects, mostly dwarfs)
M_*	$\mathrm{M}_\odot$	Stellar mass
$M_{\mathrm{H\,I}}$	$\mathrm{M}_\odot$	Mass of neutral atomic hydrogen H I, without helium
$M_{\mathrm{H_2}}$	$\mathrm{M}_\odot$	Mass of molecular hydrogen H_2, without helium
$S_{\mathrm{H\,I}}^{\mathrm{int}}$	$\mathrm{Jy\,km\,s^{-1}}$	Velocity-integrated flux of the redshifted 21 cm H I emission line, with velocity units defined in the galaxy rest-frame
$S_{\mathrm{H\,I}}^{\mathrm{peak}}$	Jy	Peak flux density of the H I emission line; typically the flux density of the 'horns'
$S_{\mathrm{CO}}^{\mathrm{int}}$	$\mathrm{Jy\,km\,s^{-1}}$	Velocity-integrated flux of the redshifted 115.27 GHz ^{12}CO(1–0) emission line, with velocity units defined in the galaxy rest-frame
$S_{\mathrm{CO}}^{\mathrm{peak}}$	Jy	Peak flux density of the ^{12}CO(1–0) emission line; typically the flux density of the 'horns'
$W_{\mathrm{H\,I}}^{50}$	$\mathrm{km\,s^{-1}}$	Width of the H I emission line, in galaxy rest-frame velocity units, measured at 50% of the peak flux density
$W_{\mathrm{H\,I}}^{20}$	$\mathrm{km\,s^{-1}}$	Width of the H I emission line, in galaxy rest-frame velocity units, measured at 20% of the peak flux density
$r_{\mathrm{H\,I}}^{\mathrm{edge}}$	arcsec	Apparent H I radius along the major axis out to a H I disk surface density of $1\,\mathrm{M_\odot pc^{-2}}$, corresponding to a face-on column density of $1.25 \cdot 10^{20}\mathrm{cm^{-2}}$
$r_{\mathrm{H\,I}}^{\mathrm{half}}$	arcsec	Apparent H I half-mass radius along the major axis
M_{R}	mag	Absolute Vega R-band magnitude, corrected for intrinsic dust extinction; 99 if stellar mass and star formation history are insufficiently resolved to compute M_{R}
m_{R}	mag	Apparent Vega R-band magnitude; value 99 if no absolute magnitudes available
r_{e}	arcsec	Effective radius, here approximated as the radius containing half the stellar mass if the galaxy were viewed face-on

Table 1: Description of the columns of mock catalog in ASCII format.



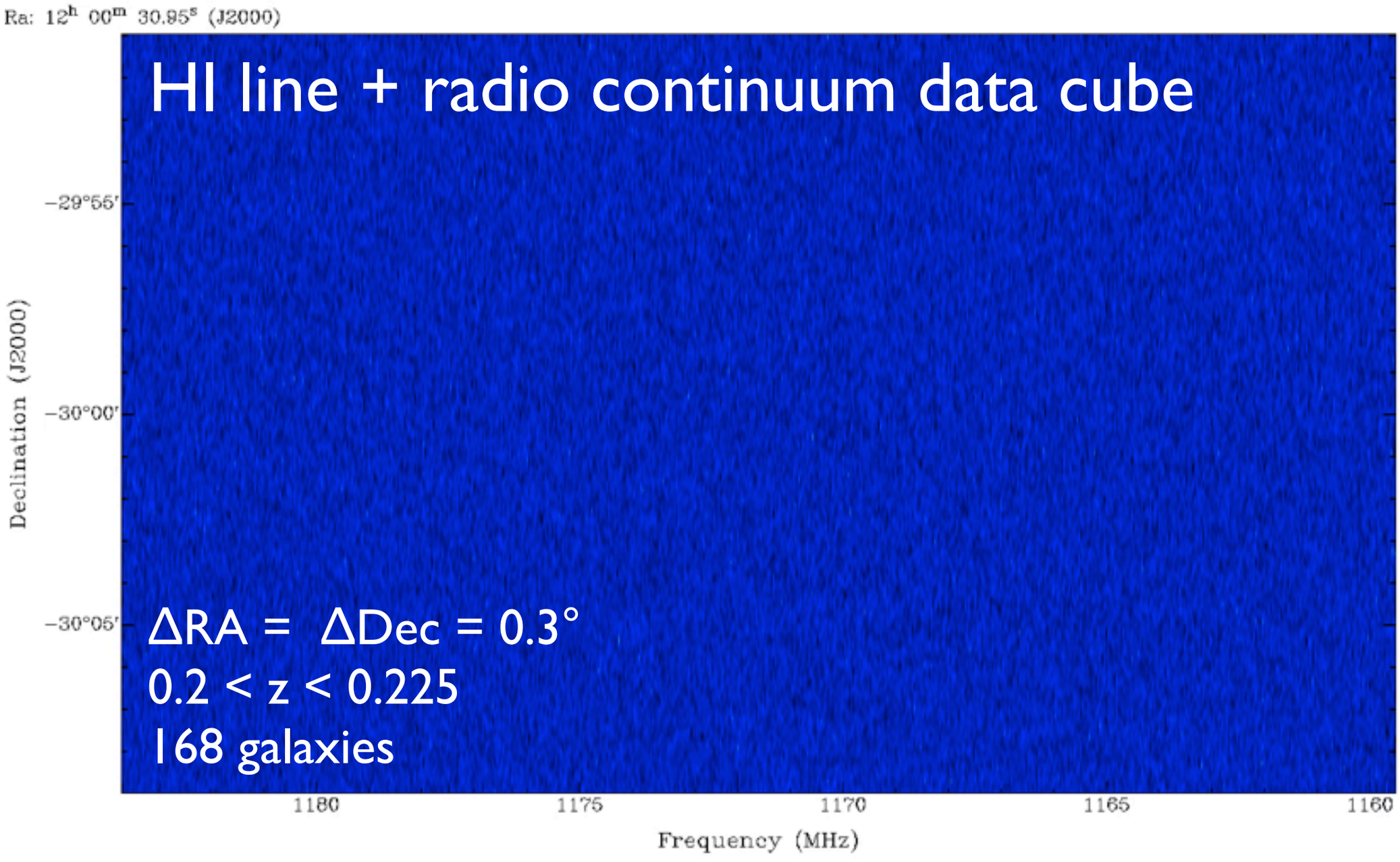
Synthetic HI data cubes based on S^3 - SAX:



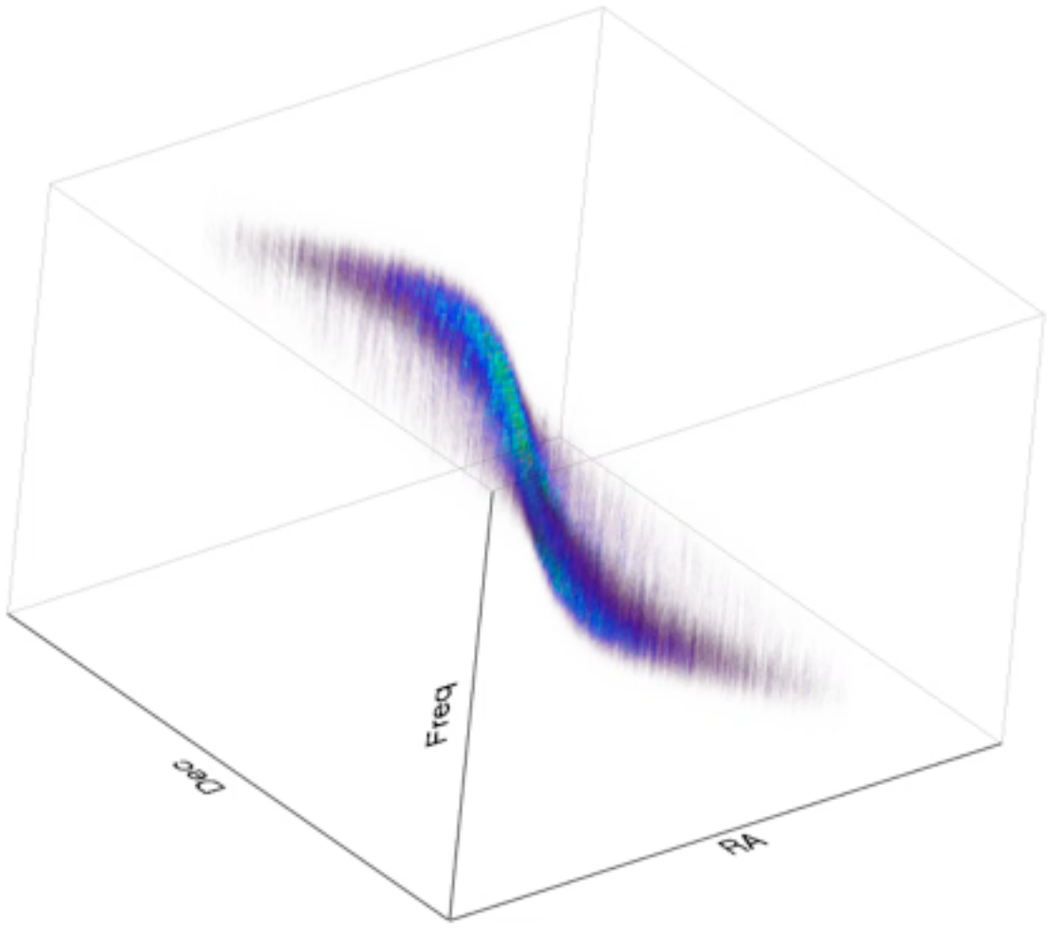


HI line data cube

Synthetic HI data data cubes based on S^3 SAMs:



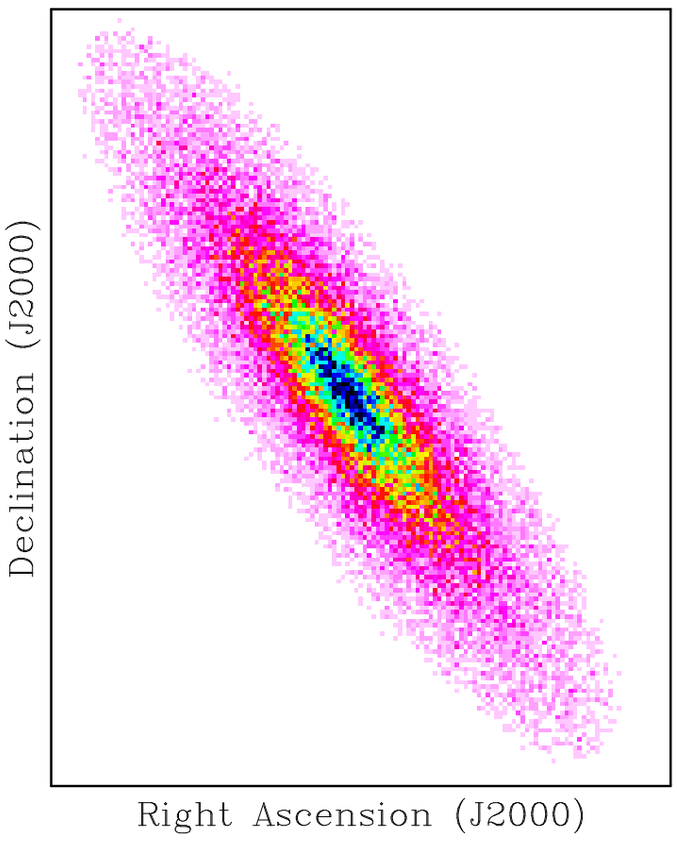
Modeling the HI line emission



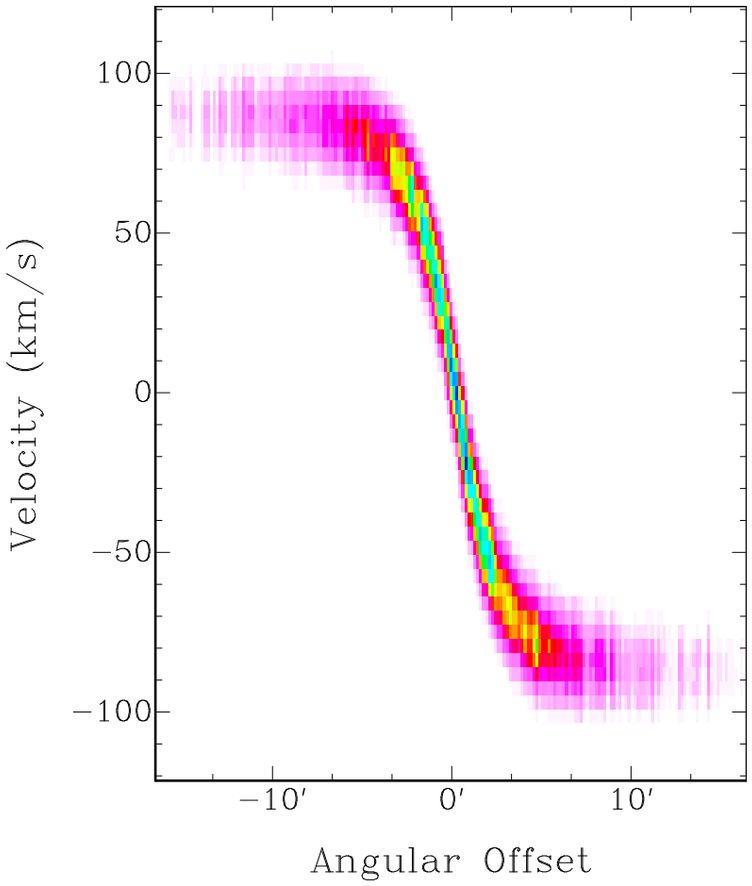
- 3D model generated for each galaxy in simulation sub-volume.
- Unique HI mass distribution, rotation curve, incl, PA, etc.

Modeling the HI line emission

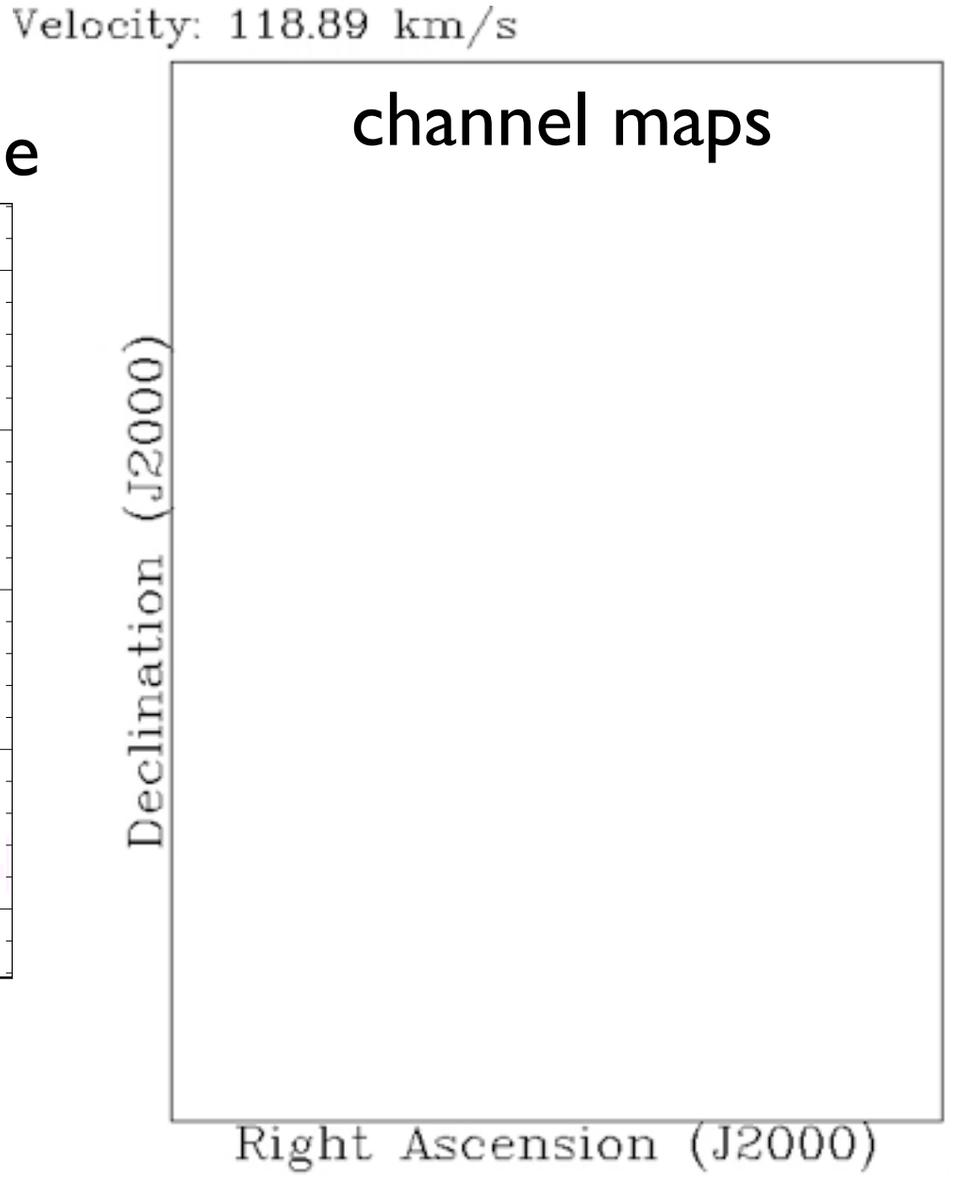
HI total intensity



position-velocity slice

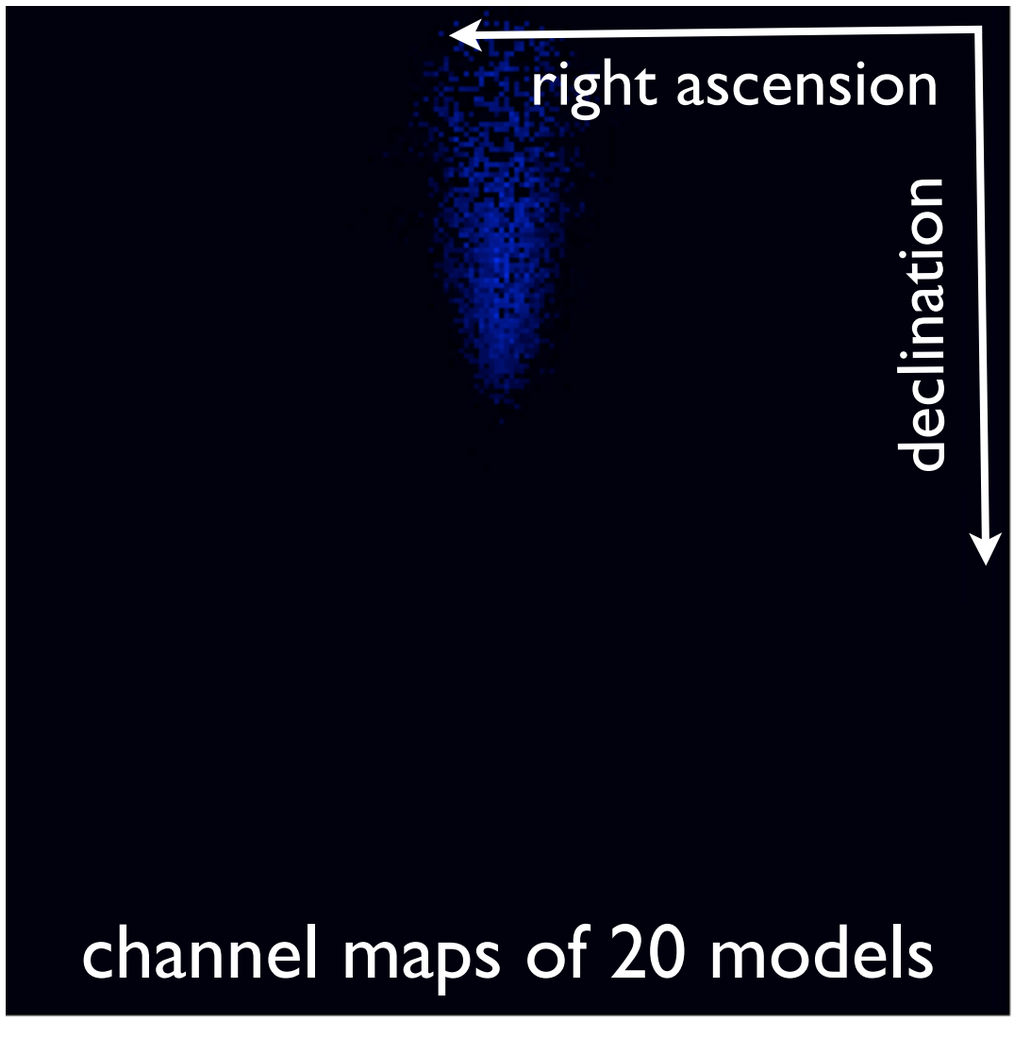


channel maps



Modeling the HI line emission

- Generate a library of > 500 000 unique 3D models of galaxies that sample the S^3-SAX parameter space.
- Fully automated using custom scripts.



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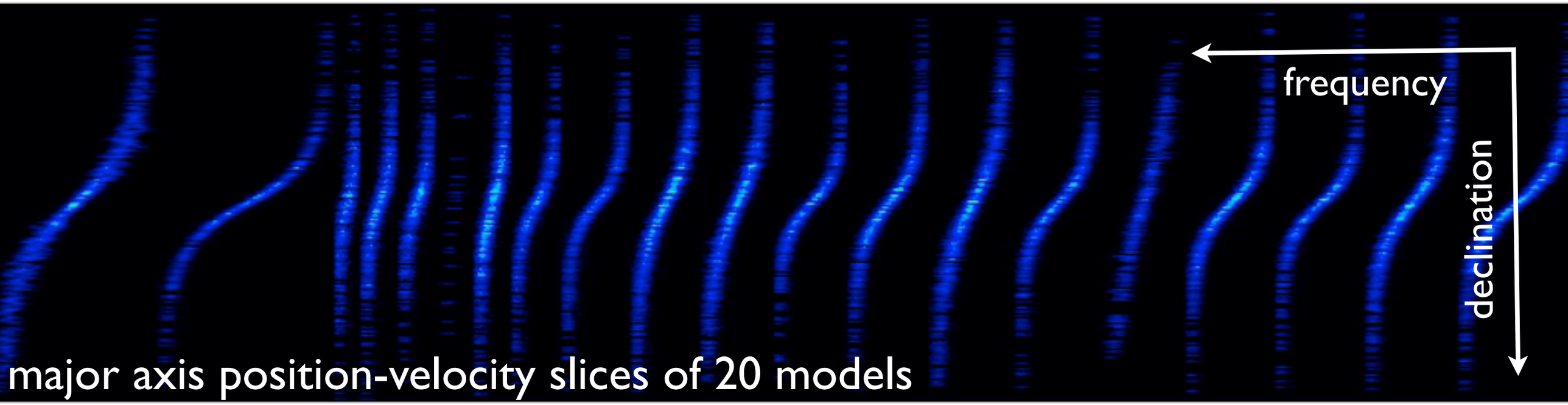
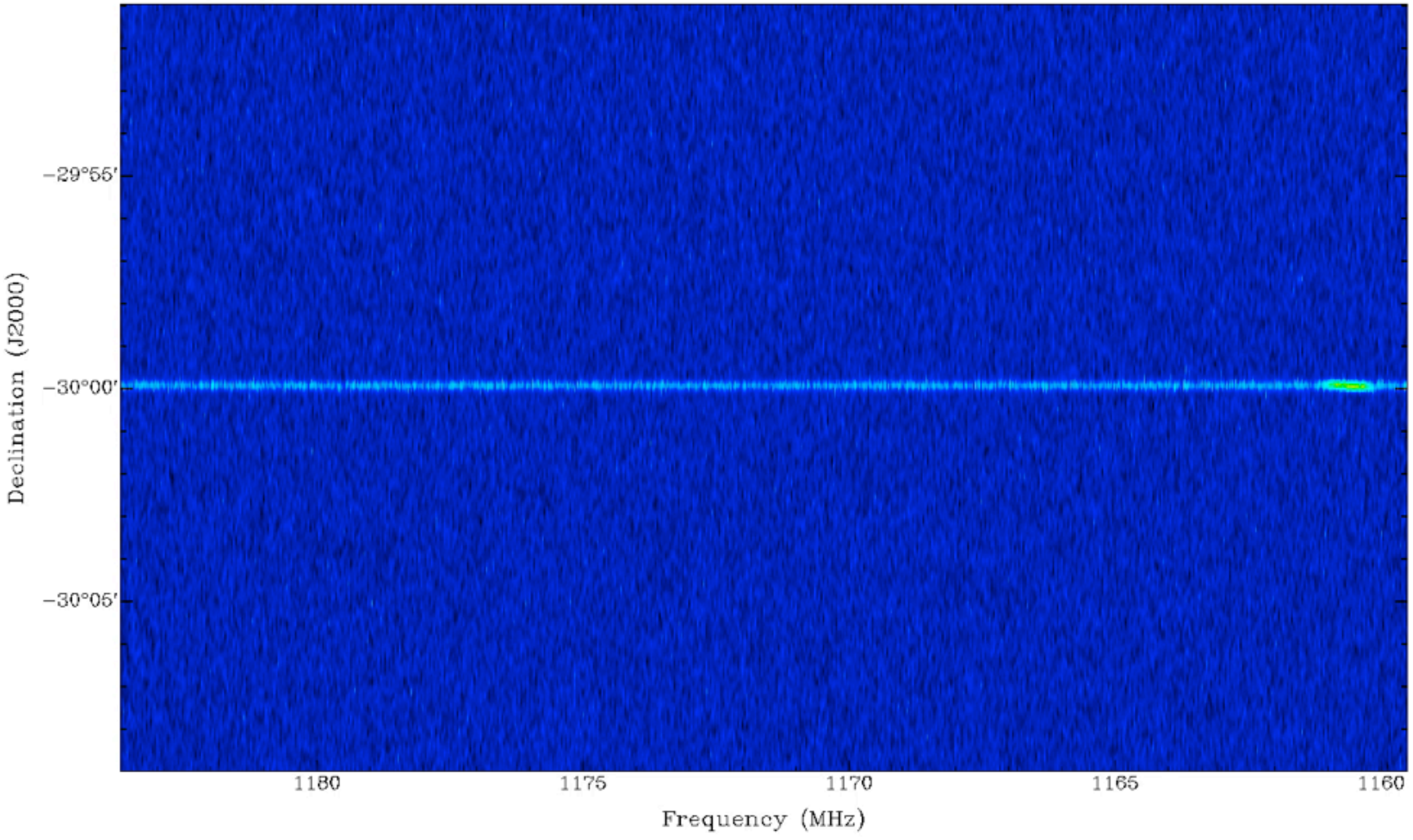
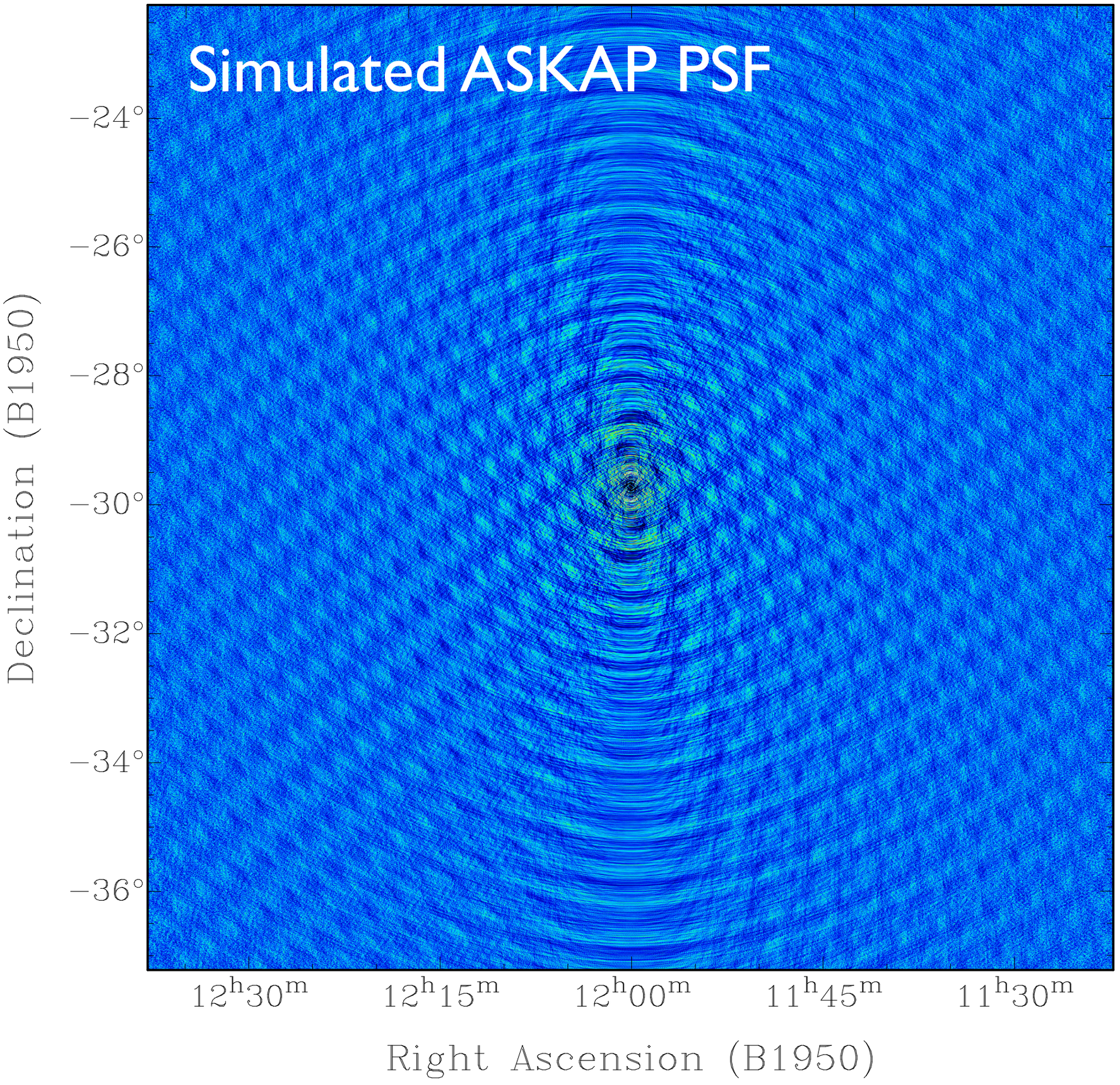


Modeling the HI line emission

- For a user specified:
  - S^3-SAX sub-volume
  - cosmology
  - channel width, pixel scale
  - optical magnitude and HI flux density cuts
  - noise and beam characteristics ...

... we can produce realistic mock data products containing HI line emission (and continuum).


Ra: 12h 00m 29.33s (J2000)
−29°55′
−30°00′
−30°05′
Declination (J2000)
1180
1175
1170
1165
1160
Frequency (MHz)


Simulated ASKAP PSF
−24°
−26°
−28°
−30°
−32°
−34°
−36°
Declination (B1950)
12h30m
12h15m
12h00m
11h45m
11h30m
Right Ascension (B1950)

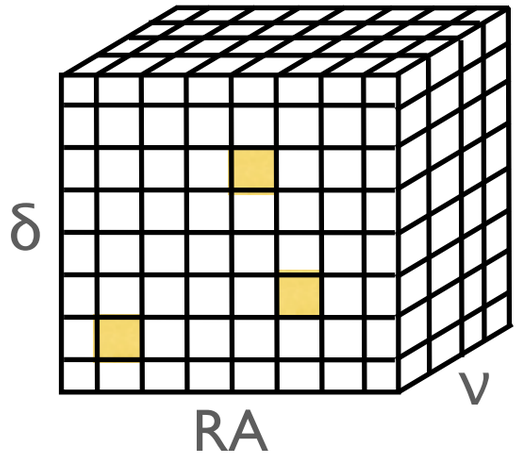
Applications

- Our synthetic data cubes can be used to carry out mock experiments.
- Example: **HI line stacking**
  - Useful method for probing HI content of large samples of distant galaxies ..

HI Stacking

With the poor S/N at the higher redshifts, we will rely on HI spectral stacking to recover average HI properties of galaxies in various samples...

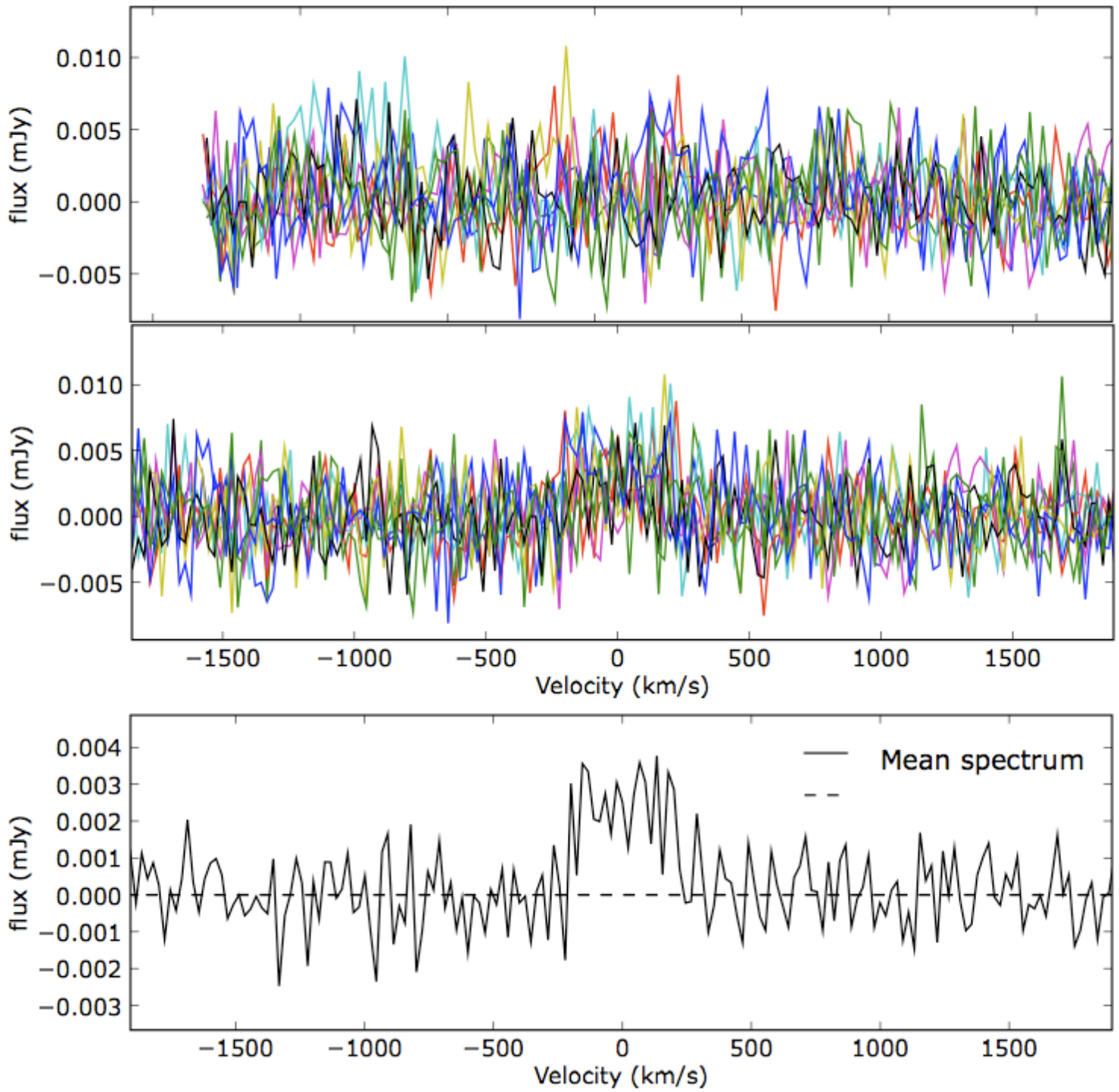
STEP 1: extract spectra using known positions and z



STEP 2: Using known z values, shift all lines to common channel

STEP 3: Co-add spectra

$$M_{HI} = \frac{236}{(1+z)} \left(\frac{S_\nu}{mJy}\right) \left(\frac{d_L}{Mpc}\right)^2 \left(\frac{\Delta V}{km\,s^{-1}}\right)$$



True brightness distrib.

Target galaxy

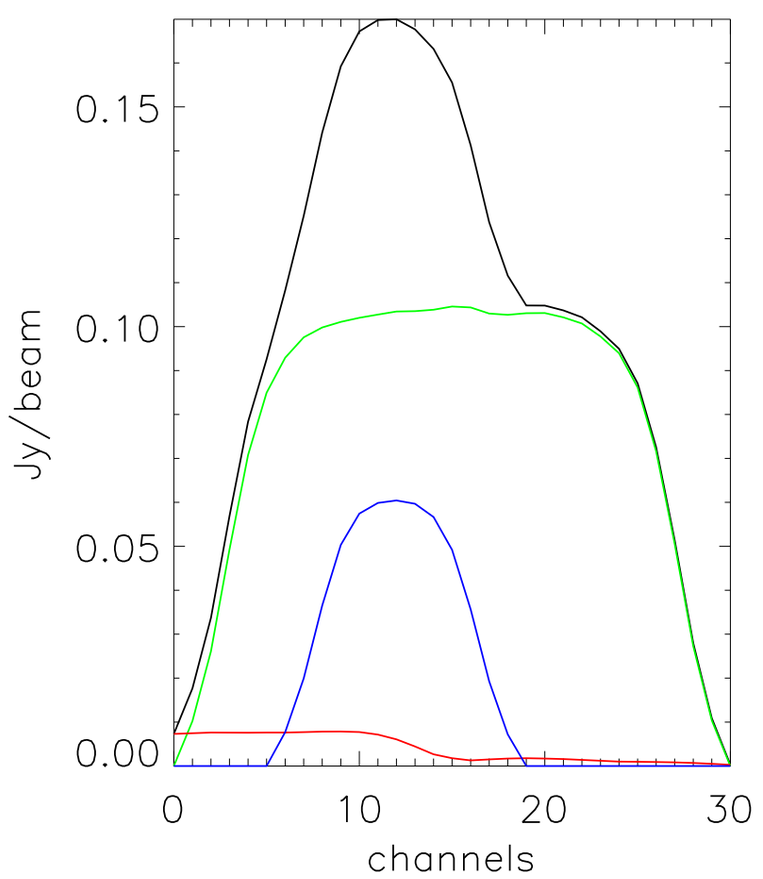
aperture

Observed brightness distrib.
All galaxies.

Observed brightness distrib.
Target galaxy.

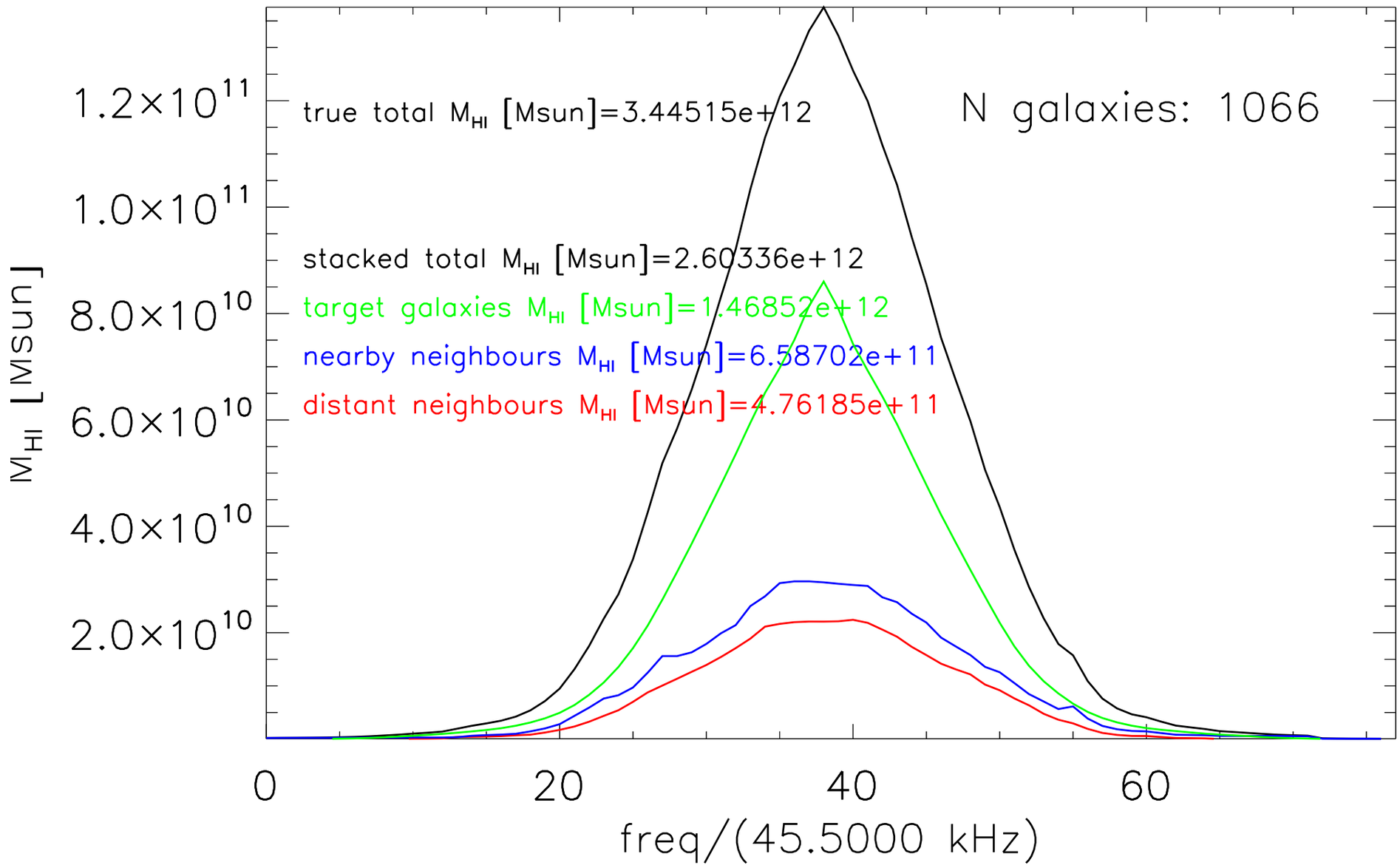
Observed brightness distrib.
Distant neighbours.

Observed brightness distrib.
Nearby neighbours.



Mock Parkes stacking experiment

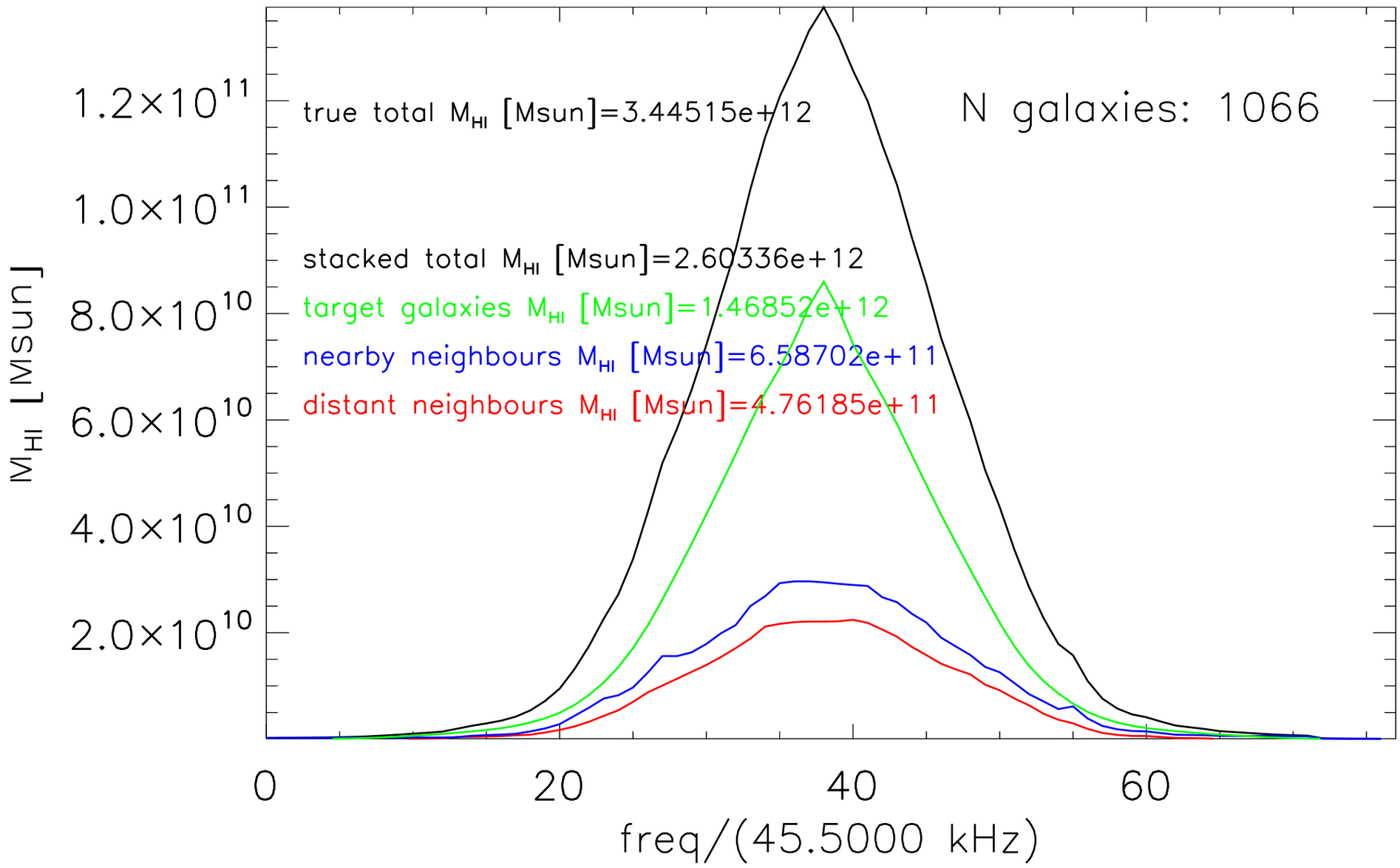
Spatial resolution = aperture size = 15 arc min, z = 0.04 - 0.13



- Significant contributions from distant neighbours (outside of aperture) and nearby neighbours (inside aperture).

Mock Parkes stacking experiment

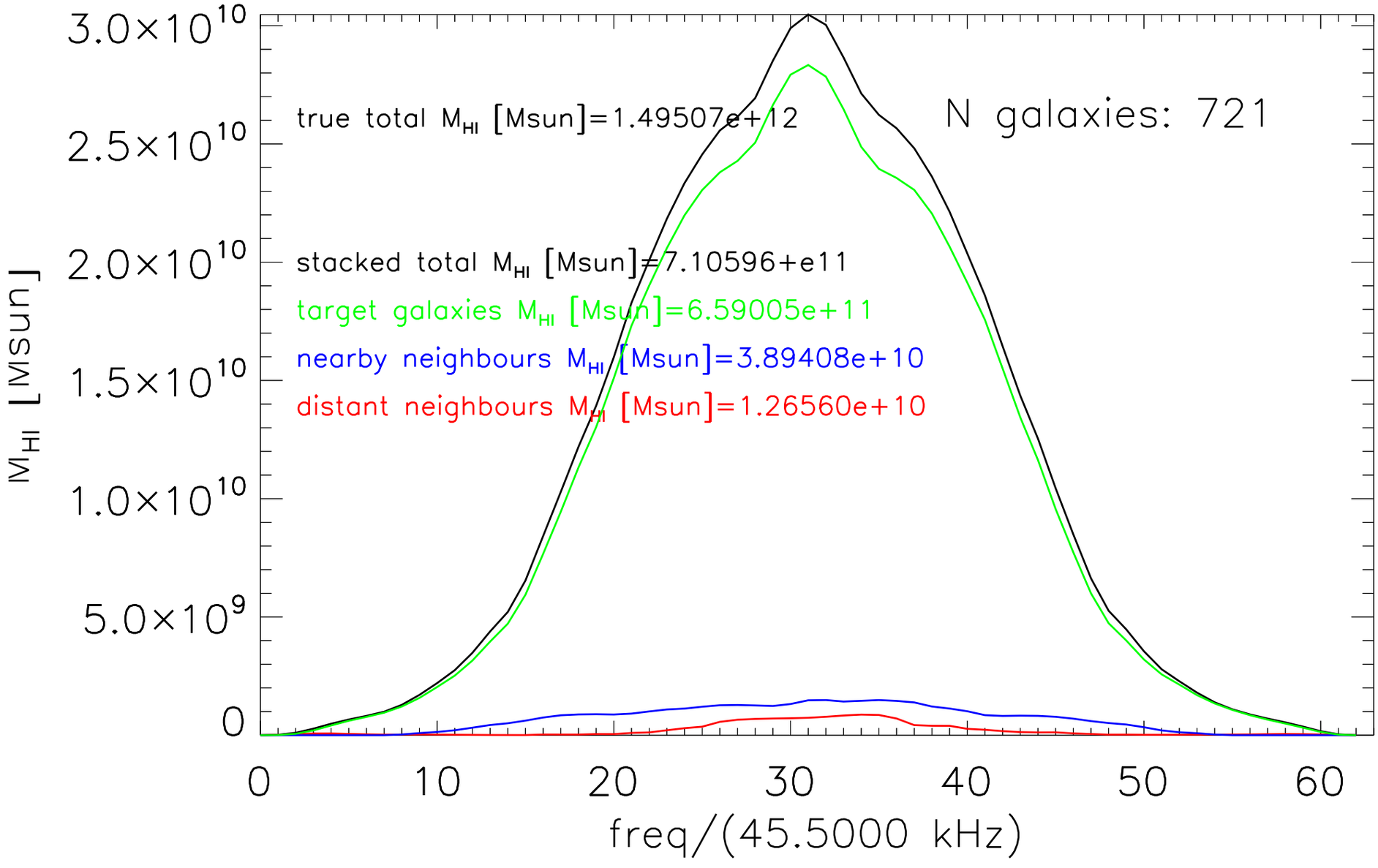
Spatial resolution = aperture size = 15 arc min, z = 0.04 - 0.13



- Target galaxy emission constitutes only ~55% of stacked spectrum.

Mock ALFALFA stacking experiment

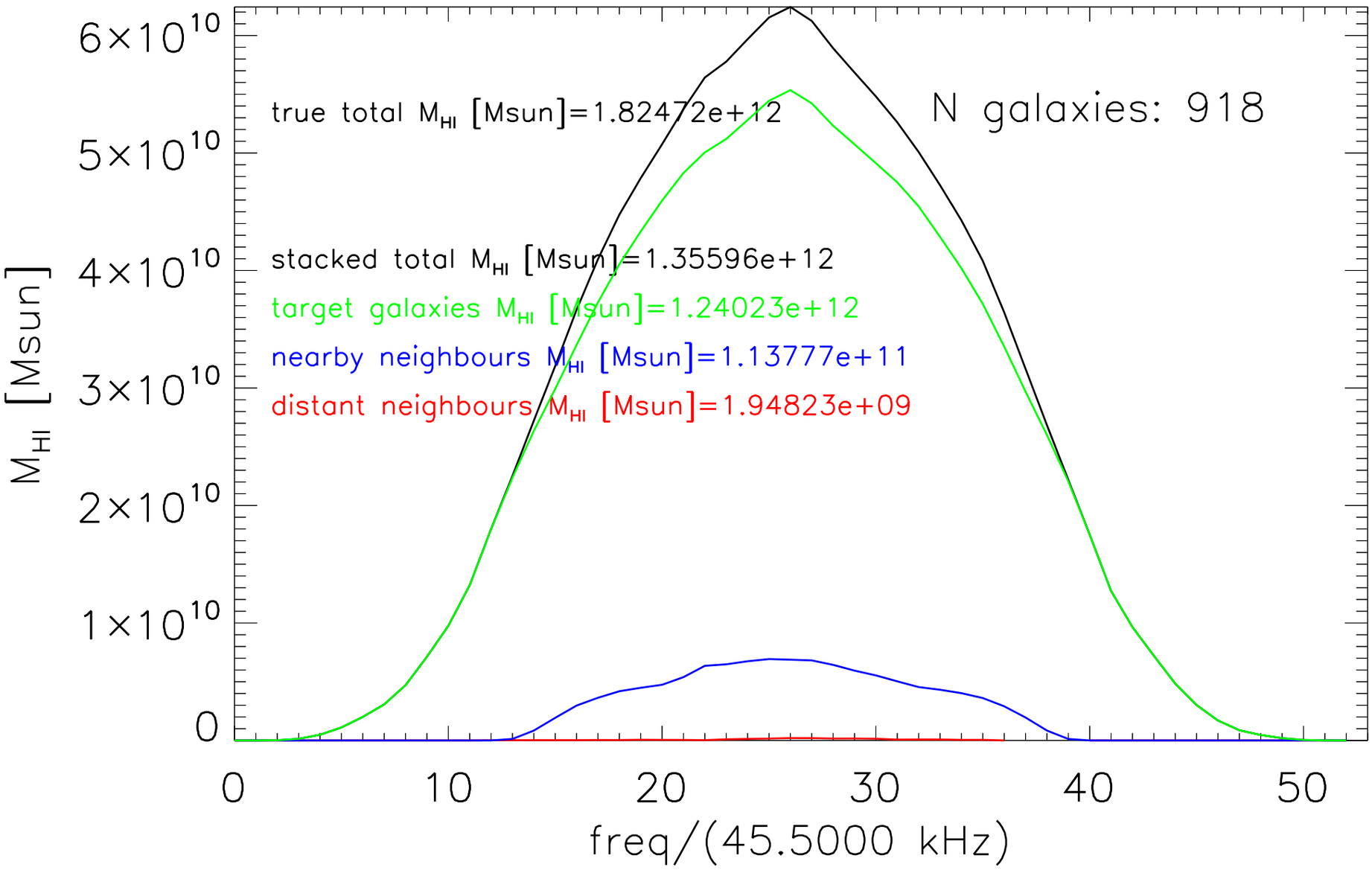
Spatial resolution = aperture size = 3.5 arc min, z = 0.025 - 0.05



- Target galaxy emission constitutes ~ 93% of stacked spectrum.

Mock LADUMA stacking experiment

Spatial resolution 15 arc sec, aperture size = 30 arc sec, z = 0.1 - 0.15



- Target galaxy emission constitutes ~92% of stacked spectrum, yet for a much higher redshift shell (more crowding).

Applications

- Other potentially useful applications:
  - Low-mass end of HI mass function
  - Cosmic variance
  - Data reduction and/or visualization pipelines
  - Data analysis pipelines (e.g. V_{rot} modeling)
  - Calibration
  - ...

Summary

- We have developed the infrastructure to convert S^3-SAX catalogues into realistic mock data products.
- Our methods accurately model the spatial and spectral distribution of HI line and radio continuum emission.
- Mock experiments allow us to better interpret our SKA-era data and results.
- For more info or for some mock products: drelson.e.c@gmail.com