



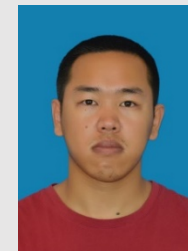
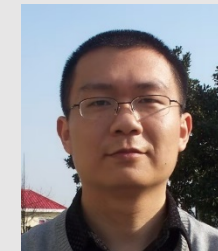
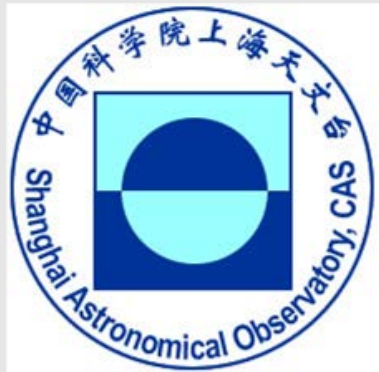
# The simulation of the 21cm interferometer signals for HI gas in galaxies

富坚

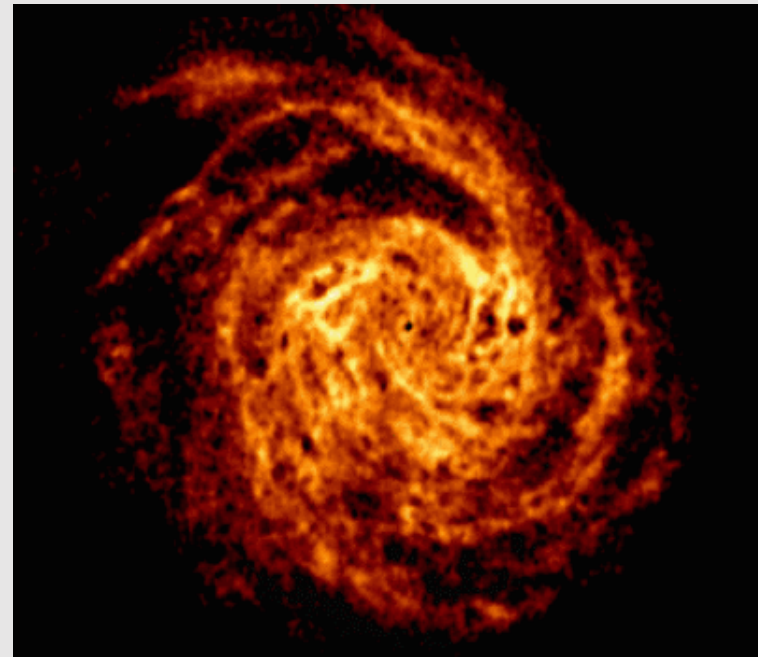
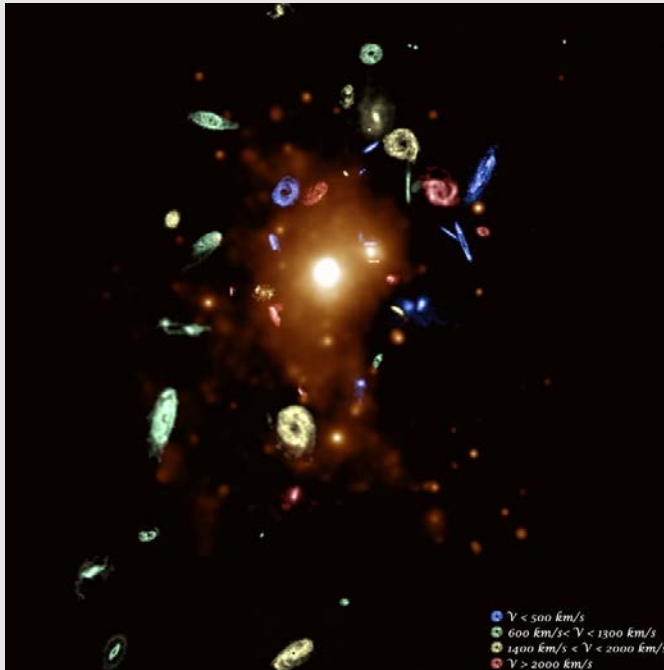
fujian@shao.ac.cn

2023-07-18

Collaborators: 刘磊、王左磊  
东北大学，沈阳

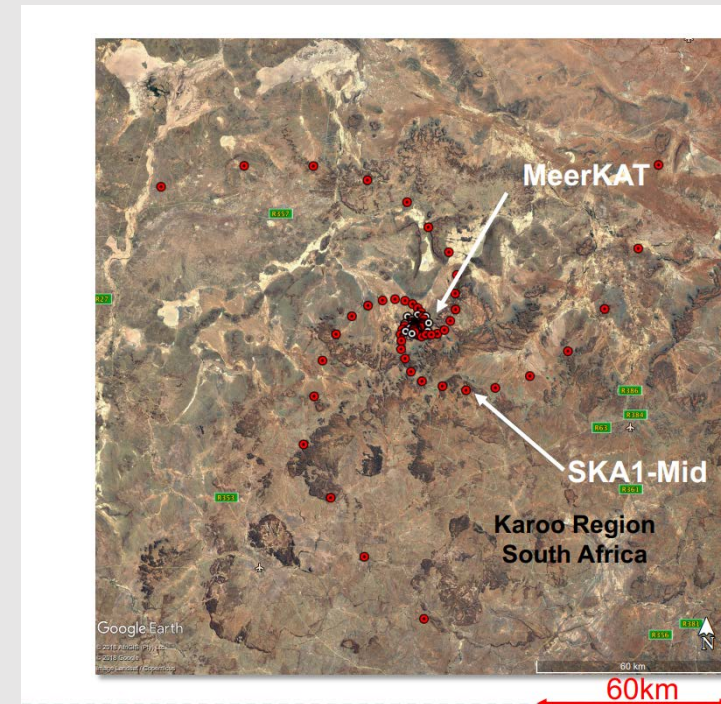


# HI gas in galaxies



# SKA1-mid

- SKA-mid :350 MHz-15.4 GHz
- HI gas in low redshift galaxies~1.42GHz ~0.5" resolution



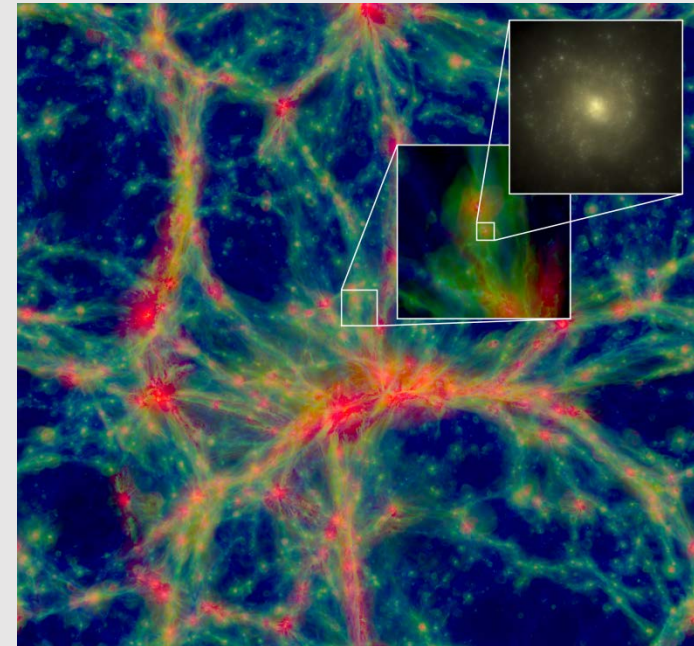
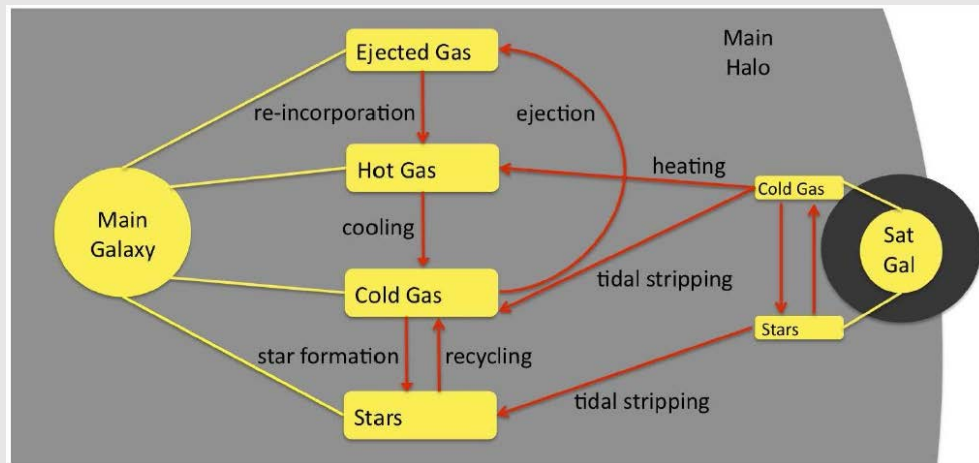
# Galaxies in the Simulated Universe

## Semi-analytic models

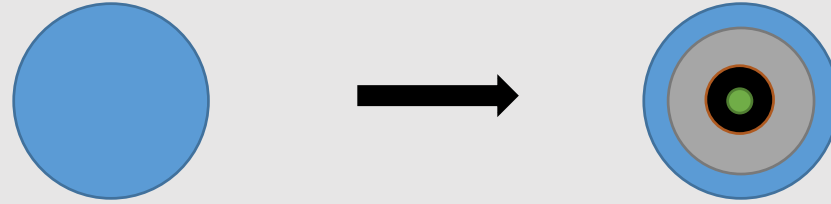
- L-Galaxies 2020
- HI and H<sub>2</sub> prescription by Fu et al. 2013

## Hydrodynamic Simulations

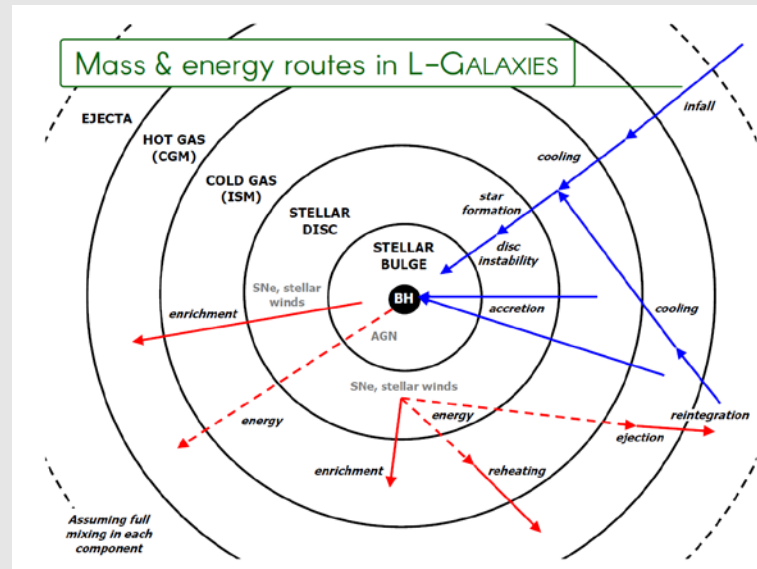
- Illustris (Illustris-TNG)
- HI and H<sub>2</sub> post-processing catalogues by Diemer et al. 2018 in TNG100 box



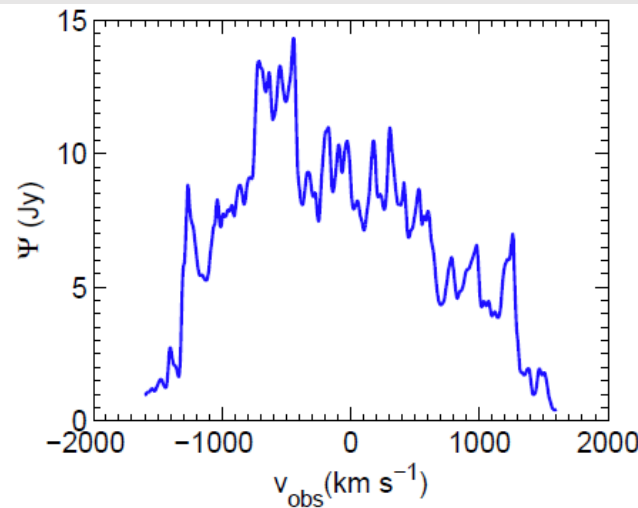
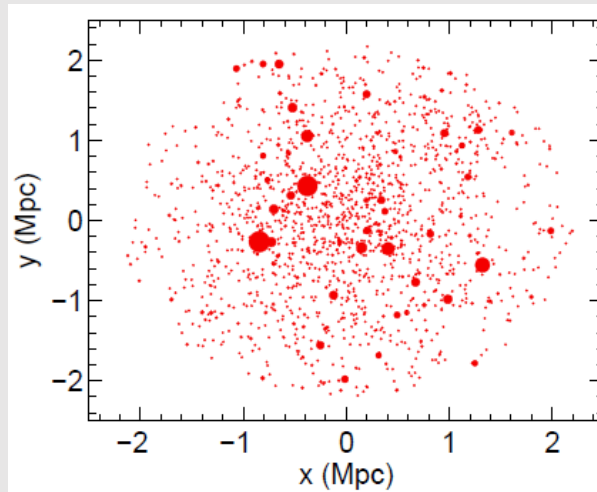
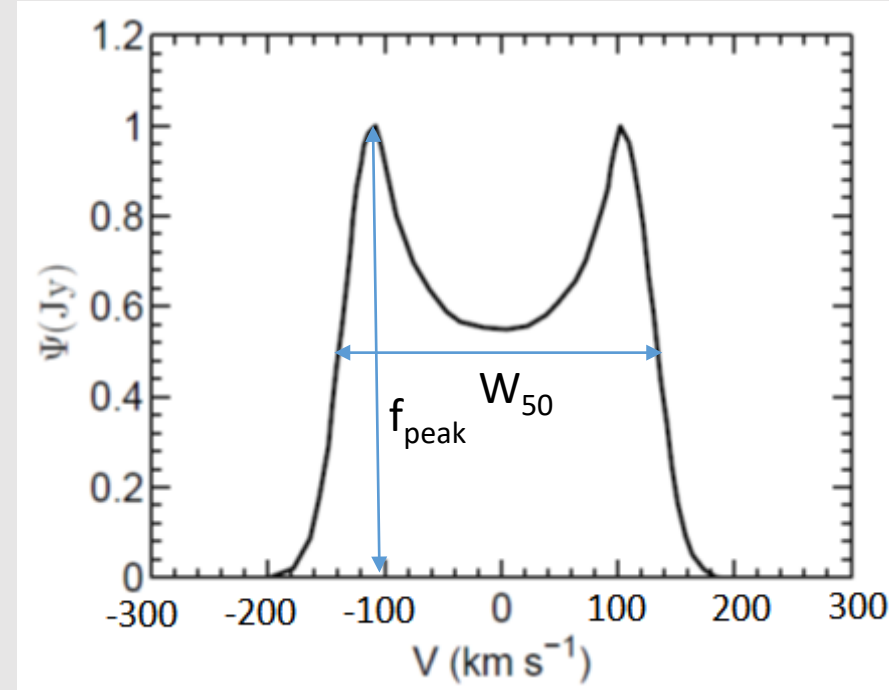
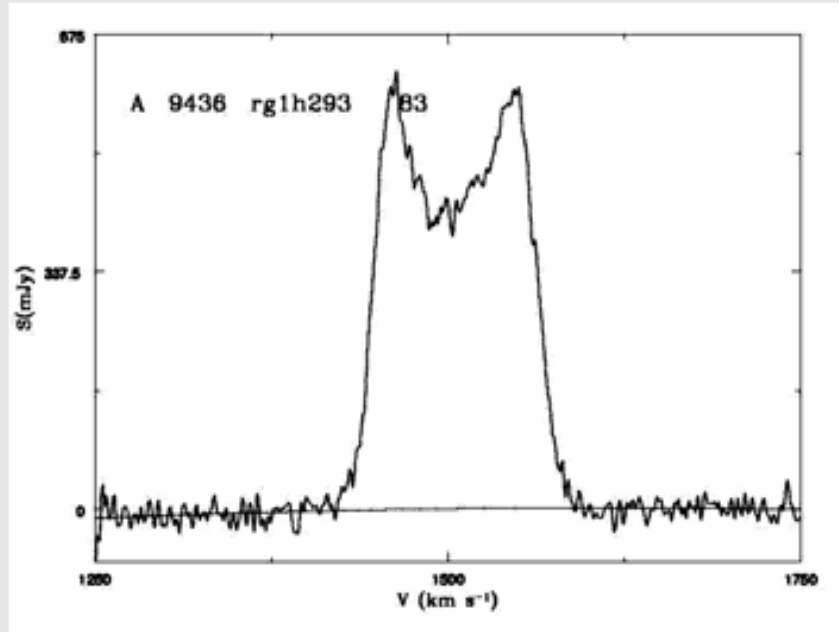
# The HI-H<sub>2</sub> gas prescriptions in L-Galaxies SAMs



- HI-H<sub>2</sub> transition prescriptions
  - 1: Krumholz et al. 2009; Mckee & Krumholz 2010  $f_{\text{H}_2} \left( \Sigma_{\text{gas}}, [Z/H]_{\text{gas}} \right)$
  - 2: Pressure related H<sub>2</sub> fraction recipe (B&R 2006)  $R_{\text{mol}} \equiv M_{\text{H}_2} / M_{\text{HI}} = [P / P_0]^\alpha$
- H<sub>2</sub> proportional star formation law  $\Sigma_{\text{SFR}} = \alpha \Sigma_{\text{H}_2}$



# Synthetic observation for signals of single dish



$$\begin{aligned} & \frac{F_{\text{HI}}}{\text{Jy km/s}} \\ &= \frac{1}{2.36 \times 10^5 D^2} \frac{M_{\text{HI}}}{M_{\odot}} \end{aligned}$$

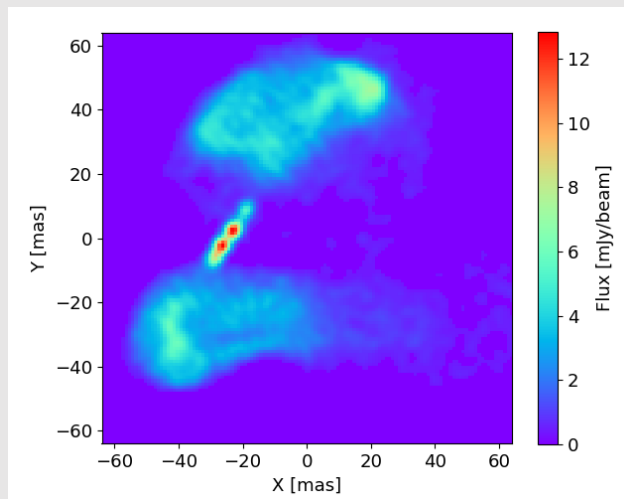
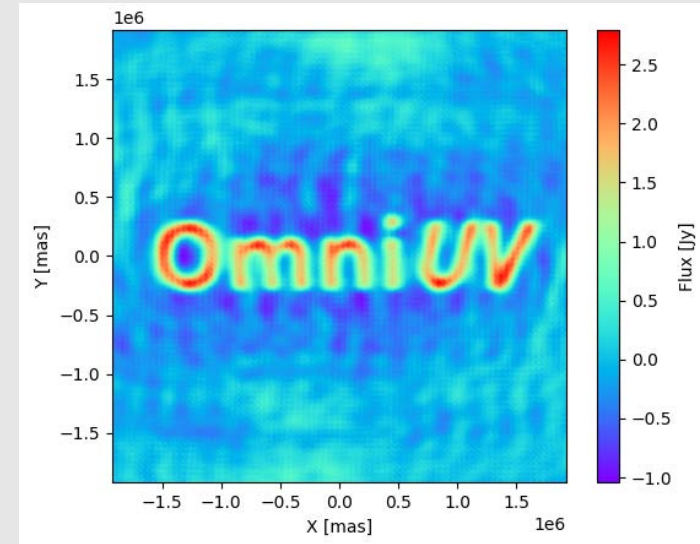
# Simulation softwares for radio interferometer arrays

- OSKAR
- RASCIL
- CASA
- ◦ ◦
- Future plan for SKA1-mid/FASTA
- Observation mode similar to VLBI
- Simulation with long based line
- Co-observation
- Dipole antenna/parabolic antenna
- GPU

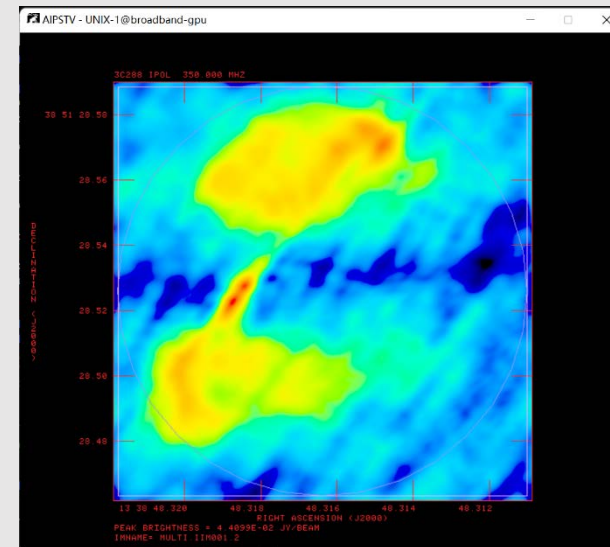
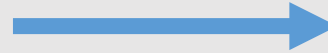


# OmniUV: Omnipotent UV

- Station trajectory calculation
- $UVW$  calculation
- Visibility simulation
- Image/beam reconstruction



OmniUV



Source

Simulated



# OmniUV

- Available on GitHub
- **Codes**, documents, examples
- **Smearing effect**
- **FIT-IDI output**
- **DRO/Halo orbit support**
- **Aperture array beam pattern**
- <https://github.com/liulei/omniuv>

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## OmniUV: A Multipurpose Simulation Toolkit for VLBI Observation

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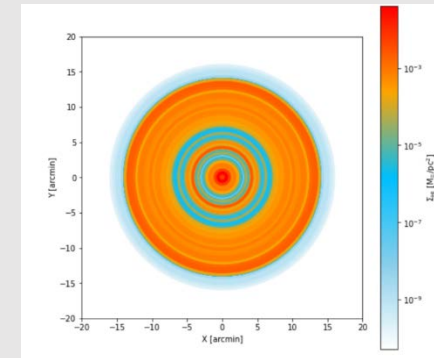
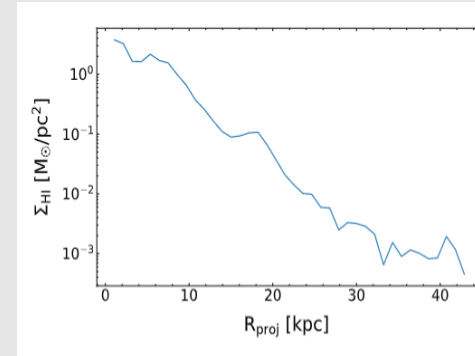
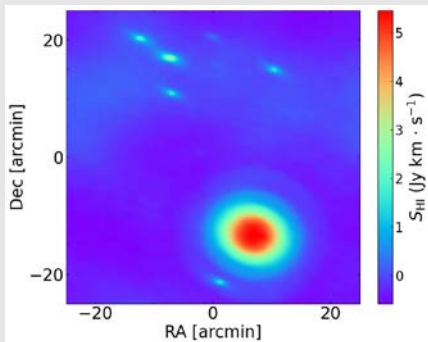
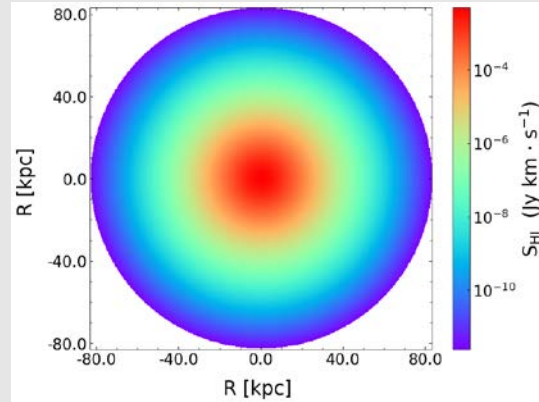
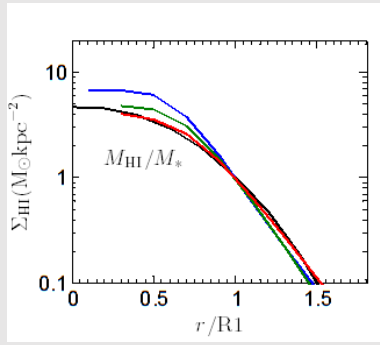
<sup>4</sup> Key Laboratory for Research in Galaxies and Cosmology, Shanghai Astronomical Observatory, Chinese Academy of Sciences, 80 Nandan Rd., Shanghai, 200030, People's Republic of China

*Received 2021 December 17; revised 2022 June 7; accepted 2022 June 9; published 2022 July 25*

# HI gas components in simulated galaxies

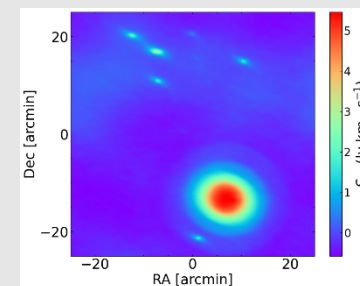
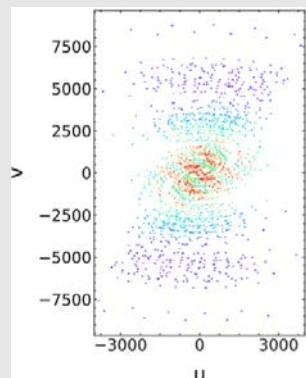
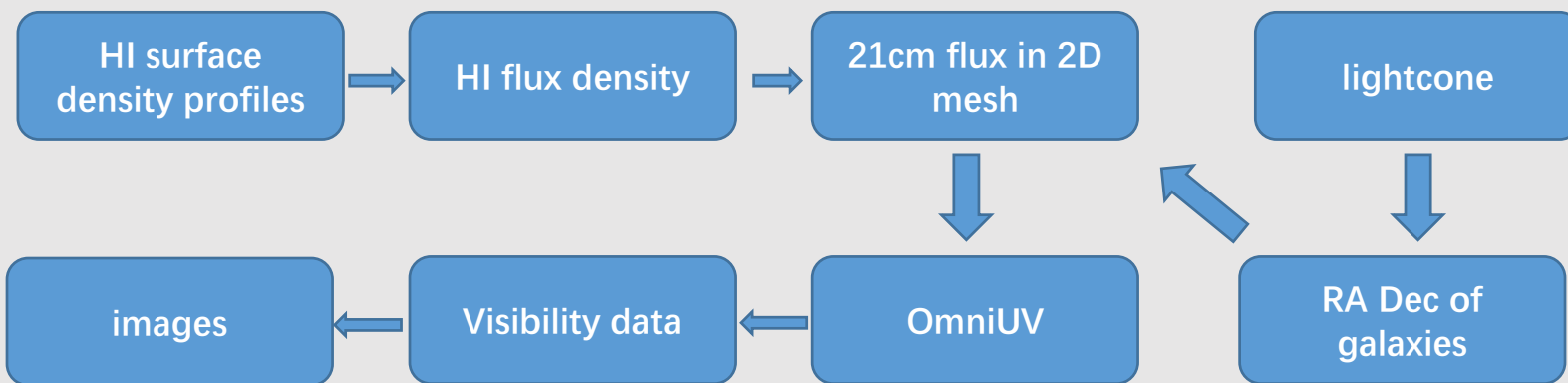
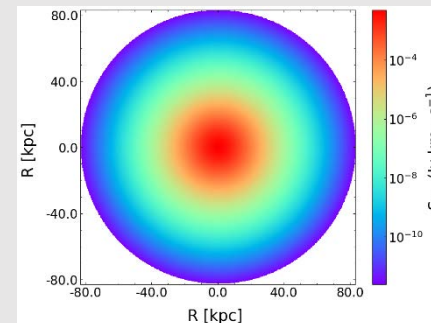
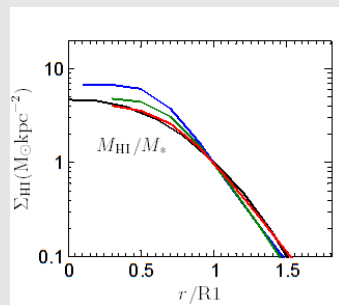
- L-Galaxies 2020 SAMs

- Illustris-TNG 100



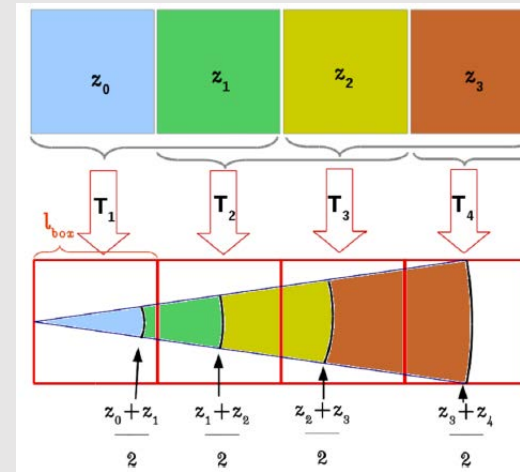
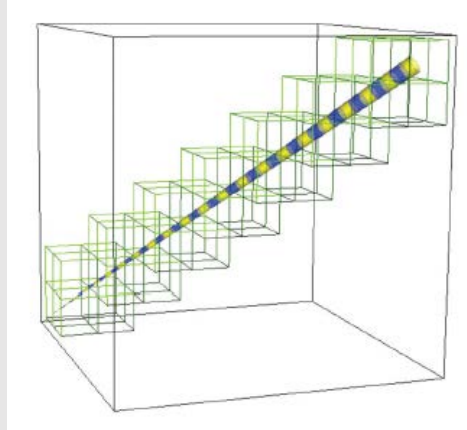
position,  $J$ ,  $v_{\text{HI}}$ ,  $r_{\text{HI}}$ ,  $M_{\text{HI}}$ ,  $\Sigma_{\text{HI}}$

# Simulation steps



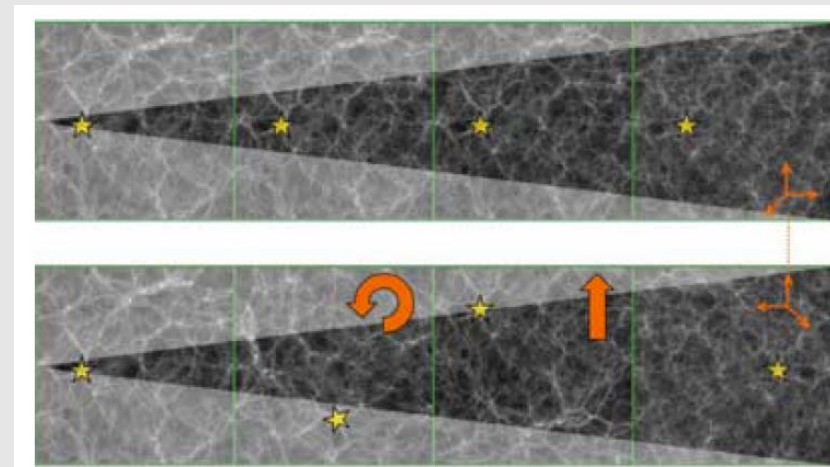
# Light-cones: RA & Dec

- Discrete redshift snapshots  $\longrightarrow$  continuous redshift

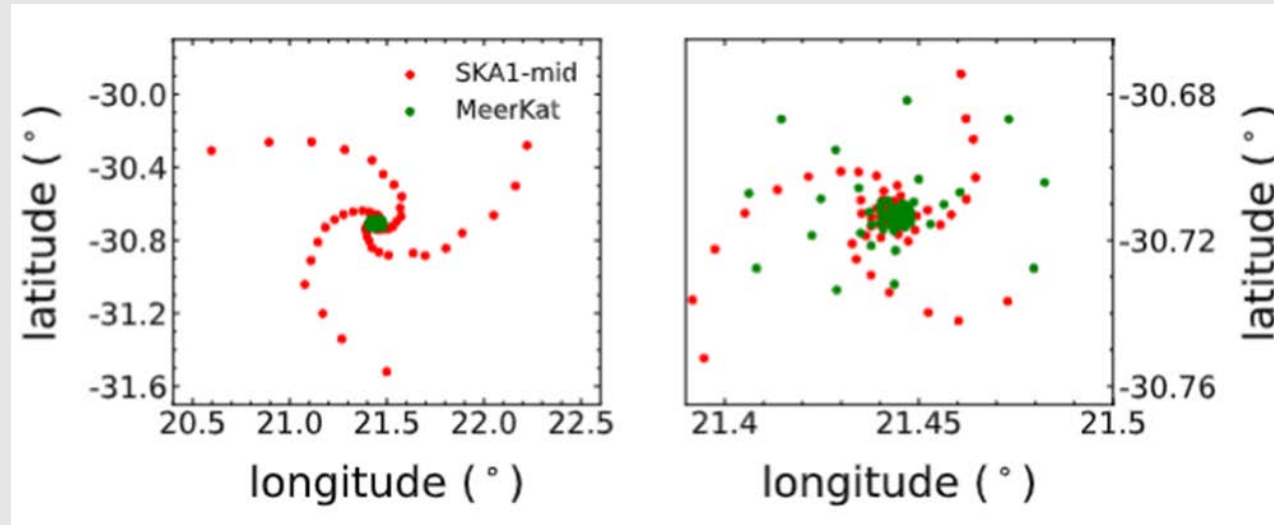


random tiling

- Periodic box  $\longrightarrow$  consistent space



# SKA-1 mid configurations

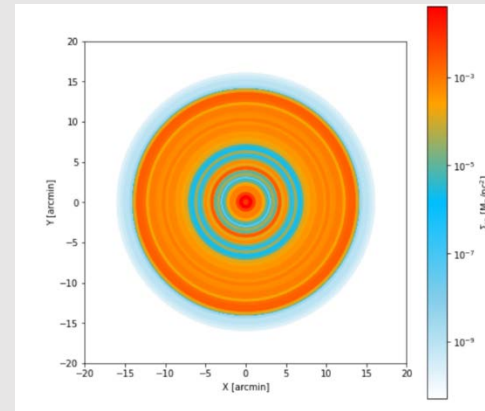


196 dishes:  
133 15m SKA dishes + 64 13.5m MeerKAT dishes

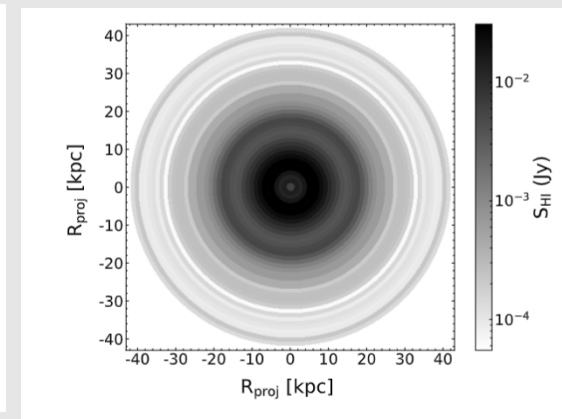
# HI flux and image

$$\frac{S_{\text{HI}}}{\text{Jy}} = \frac{M_{\text{HI},2\text{d}}}{2.35 \times 10^5 M_{\odot}} \left( \frac{D}{\text{kpc}} \right)^{-2}$$

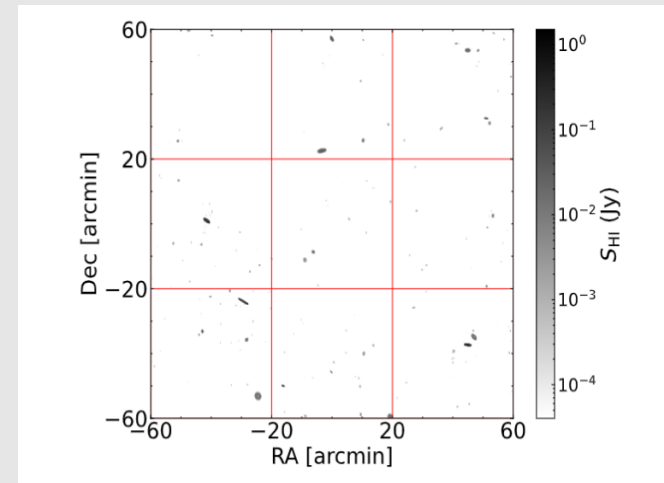
- 1D HI profile  $\rightarrow$  2D mesh image
- 40'  $\times$  40' grid with 0.5'' angular resolution



HI surface density



Flux of an HI disk



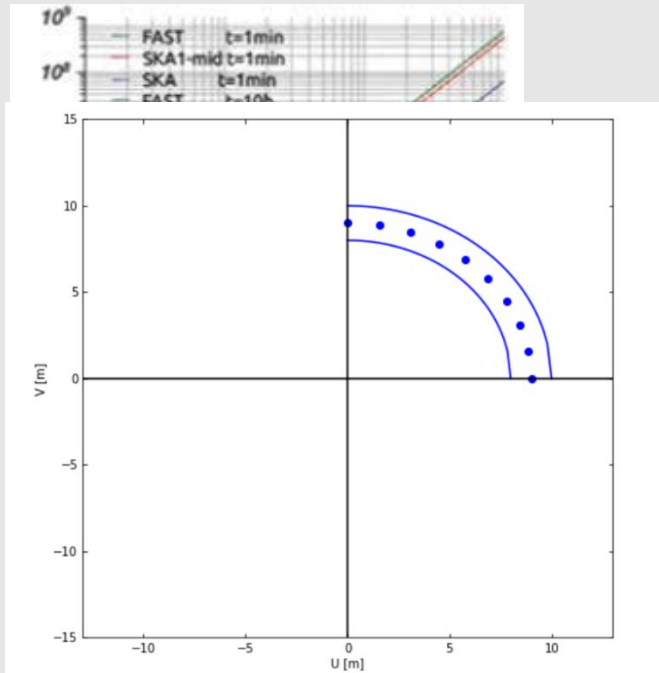
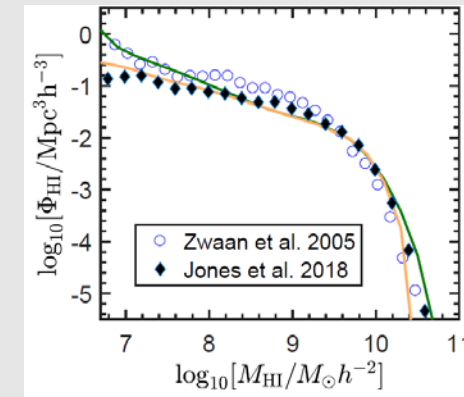
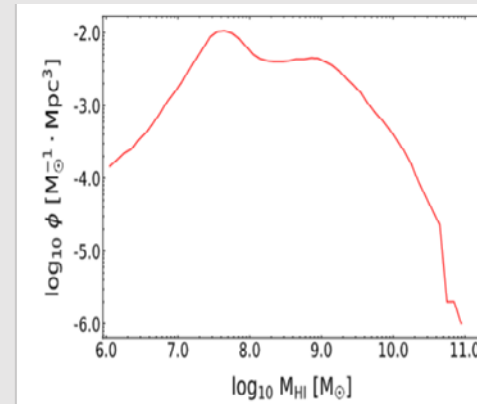
# Simulations for SKA1-mid array

1. Simulation 1:  $M_{\text{HI}} > 10^8 M_{\odot}$

Full box

2. Simulation 2:  $M_{\text{HI}} > 10^6 M_{\odot}$

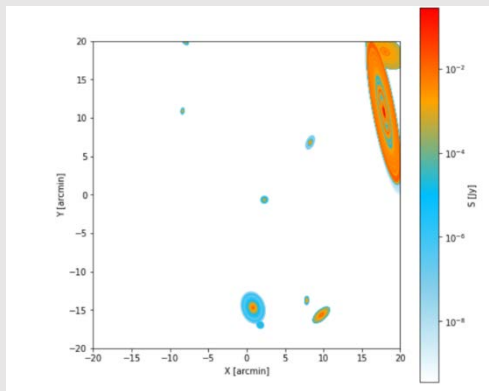
One area with most abundant low mass galaxies



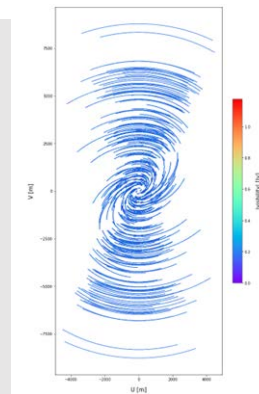
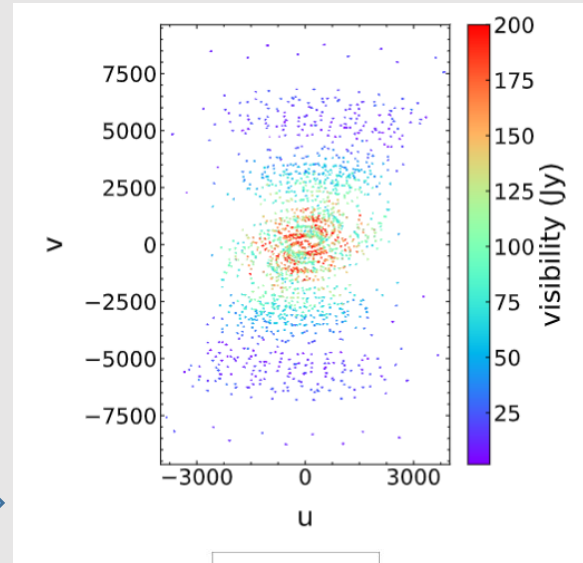
parameters	Simulation 1	Simulation 2
UV coverage time (hour)	6	6
Total integral time (min)	10	360
integral interval time (min)	36	0
Receiver band/GHz	1.36-1.42	
Angular resolution	0.5''	
RA	-30.7°	

# examples

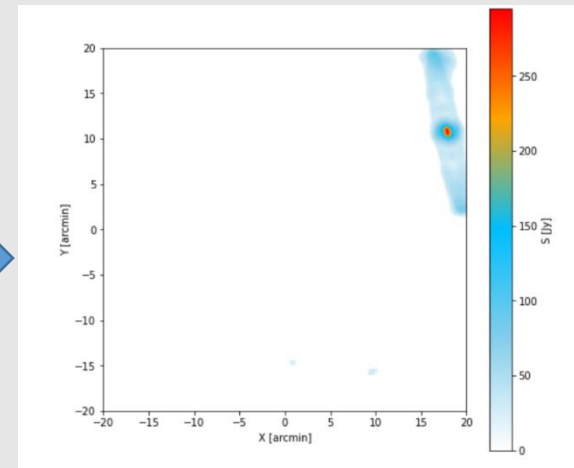
## Simulation 1



input



## Simulation 2



imaging

Wang, Fu, Liu et al. in preparation



# Summary

- OmniUV can be used to simulated the interferometer signals for radio arrays with long base lines.
- We adopt the outputs of HI gas in galaxies from L-Galaxies and Illustris-TNG to construct mock HI flux.
- We simulate the observation of 21cm interferometer signals for SKA1-mid for HI gas, which helps for future observation of HI in nearby universe.
- FASTA, HI gas at high redshift, instrumental effects etc.

Thank you!