Towards Lyα Intensity Mapping in *HETDEX*

Shun Saito

MPA in Germany → **Missouri S&T** in US (since Jan 2019)

"Accelerating Universe in the Dark"

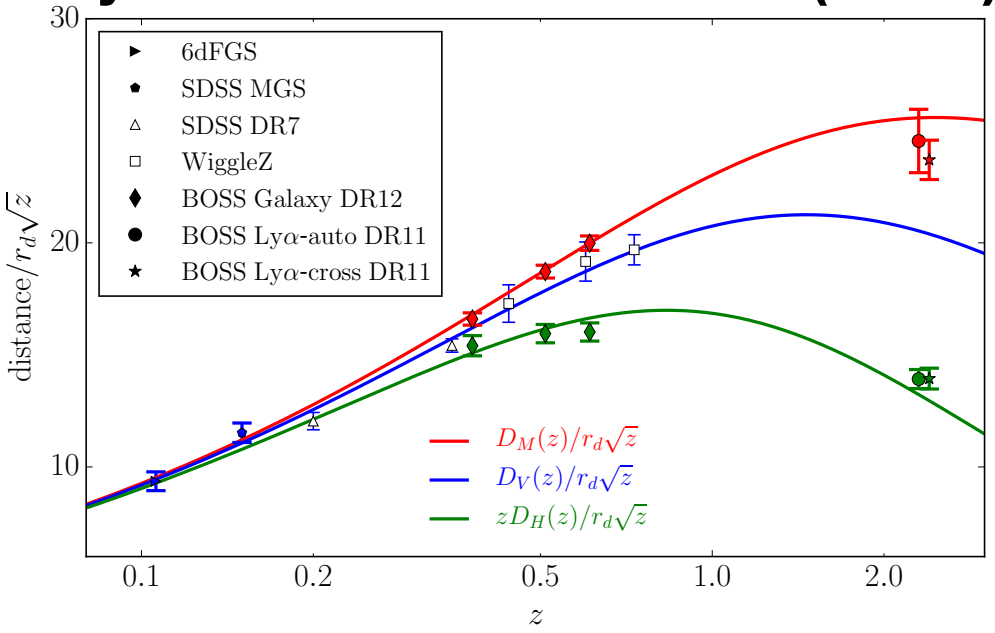
Yukawa Institute, Kyoto, Japan

Mar 5th 2019

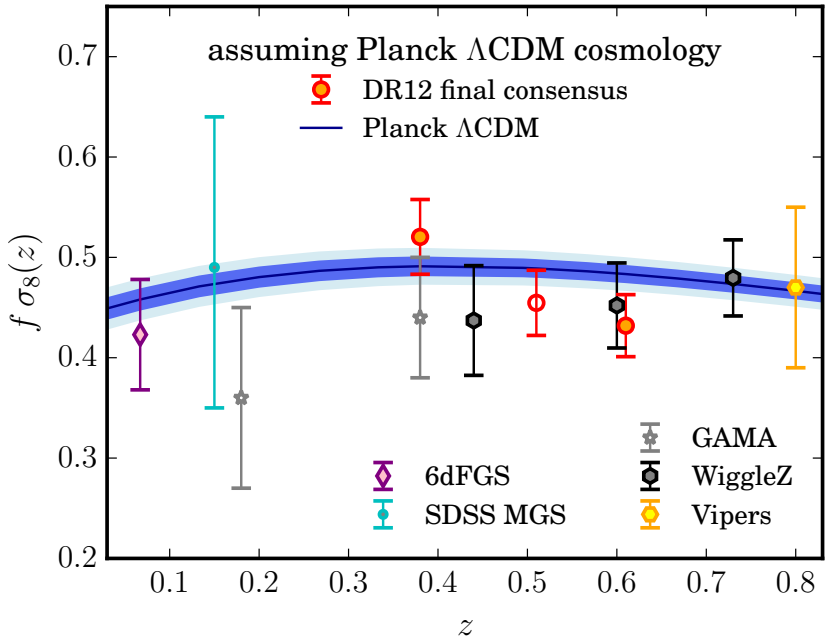
What's next in LSS?

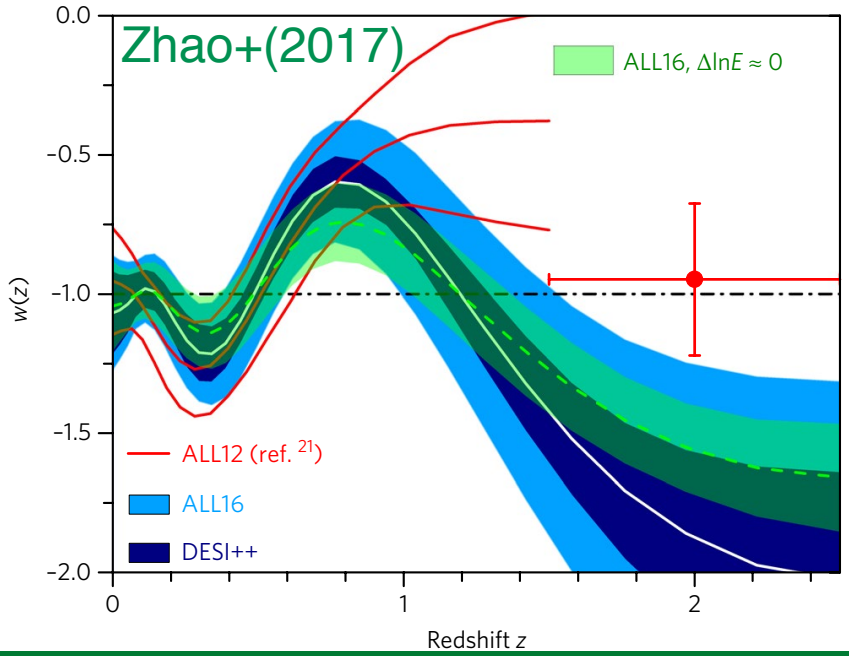
Alam [**SS**+] (2016)

Baryon Acoustic Oscillations (BAOs)



Redshift-Space Distortion (RSD)





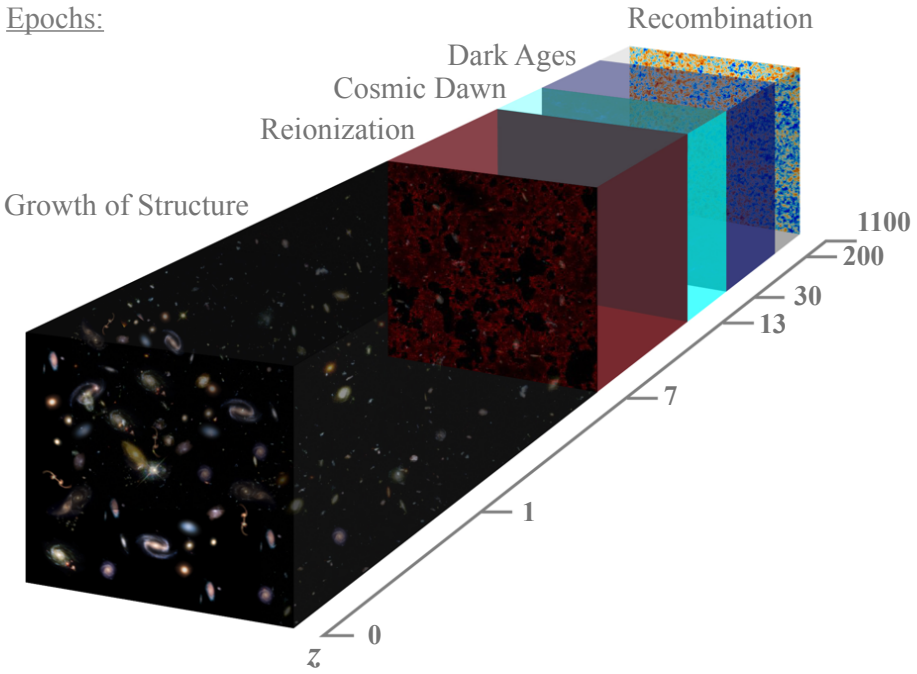
✔ 3D Galaxy clustering ***DONE at z < 1***.

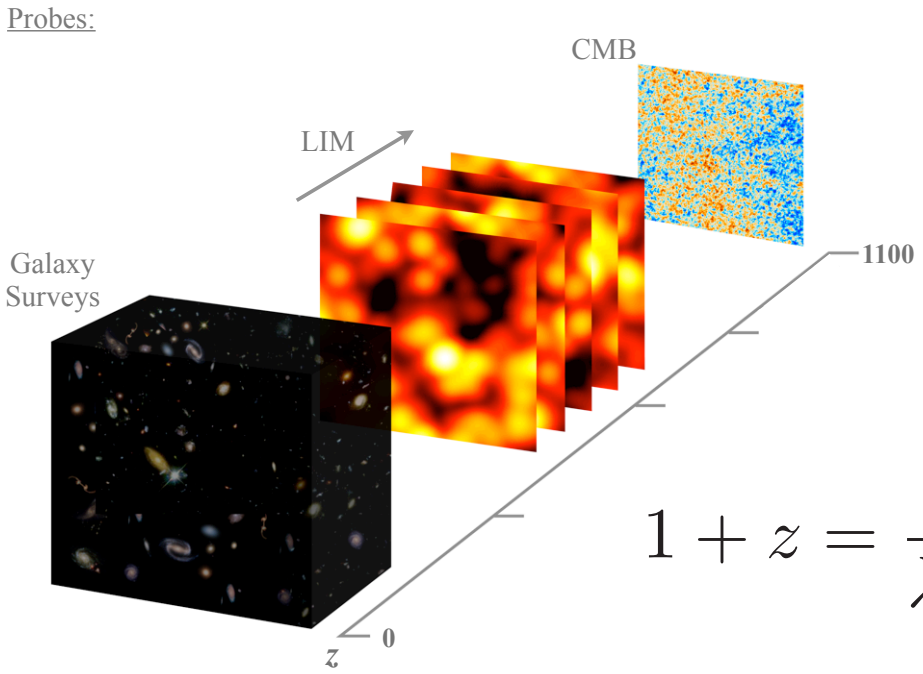
✔ Future surveys go ***towards higher z.***

- unexplored territory
- shed lights on some tensions?
- time-evolving dark energy?

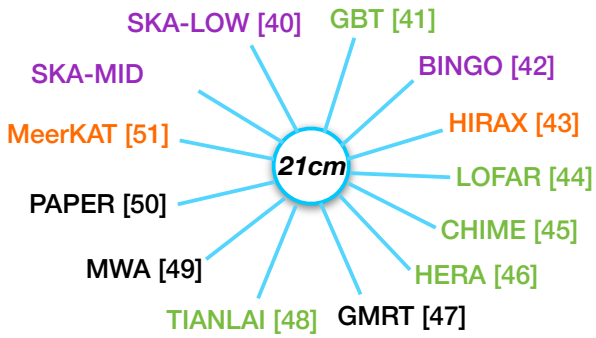
Intensity Mapping is Future

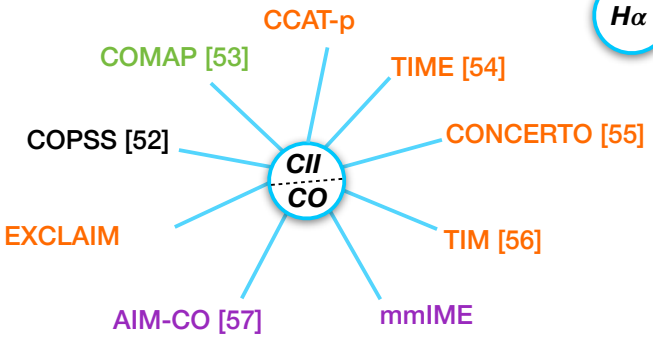
Kovetz, **SS**+, Astro2020, coming soon

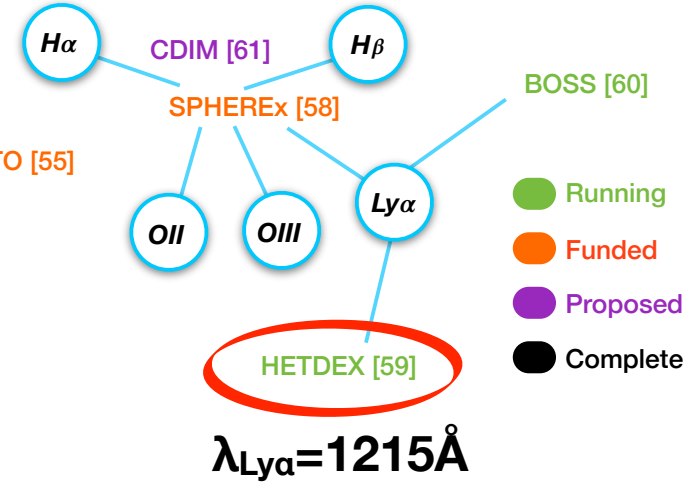




$$1 + z = \frac{\lambda_0}{\lambda_{\rm line}}$$







$\lambda_{Ly\alpha}$=1215Å

HETDEX as a DE survey

◆ ***The Hobby-Eberly Telescope Dark Energy Experiment (2019-2022)***

- Collaboration
  - PI: Gary J. Hill (Univ. of Texas)
  - **~50** people: U Texas, McDonald Obs, Penn State, Texas A&M
    LMU, AIP, MPE/MPA, Gottingen, Oxford, **[*Missouri S&T*]**
- Instrument
  - **10m** Hobby-Eberly Telescope at McDonald Observatory
  - **35k** spectra **(448 fibers/IFU x 78 units)** at one 20mins exposure
  - λ=350–550nm, R~700, a flux sensitivity~a few x 10^{-17} erg/cm^2/s

➡ **~0.8M** Lyman Alpha Emitters (LAEs) over **450deg^2** & **1.9 < z < 3.5**

+ 1M OII-emitters at z < 0.5

First blind survey & First 10Gpc^3-class survey at high z

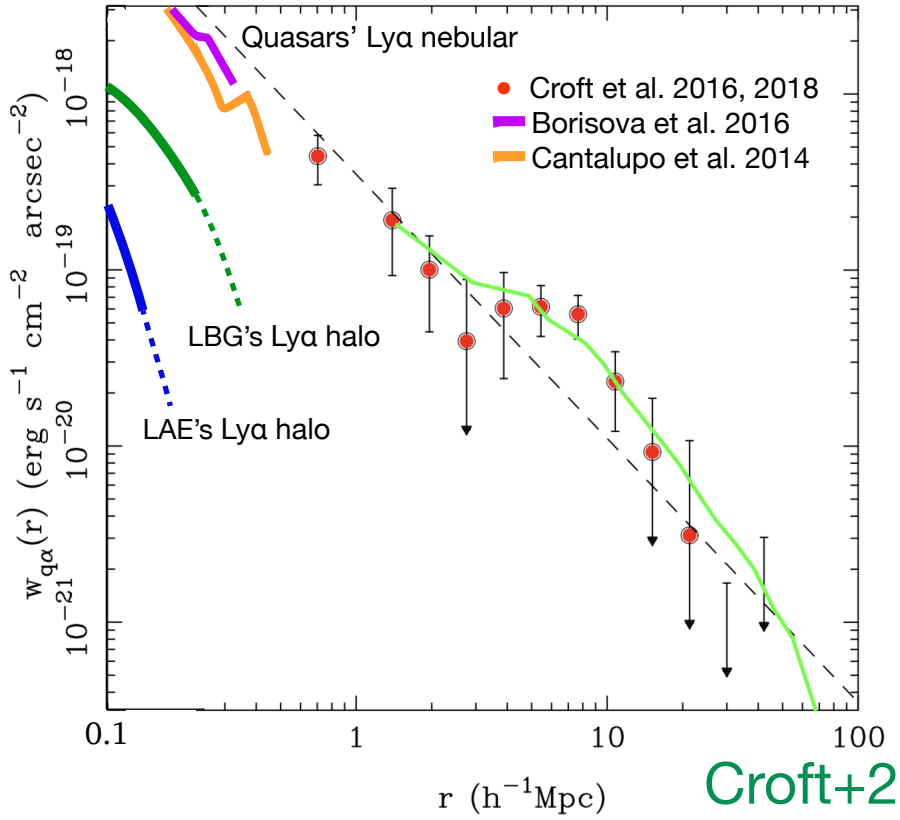
HETDEX as a Lyα IM survey

- ***We can do better than the original plan!***

- More importantly, the ***first blind*** large-scale survey with IFU

➡ Original design: 1.7M/140M fibers, i.e., only 1.2% is used

➡ ***Intensity Mapping***: propose to extract information from 99%.



Croft+2018 & modified by R.Momose

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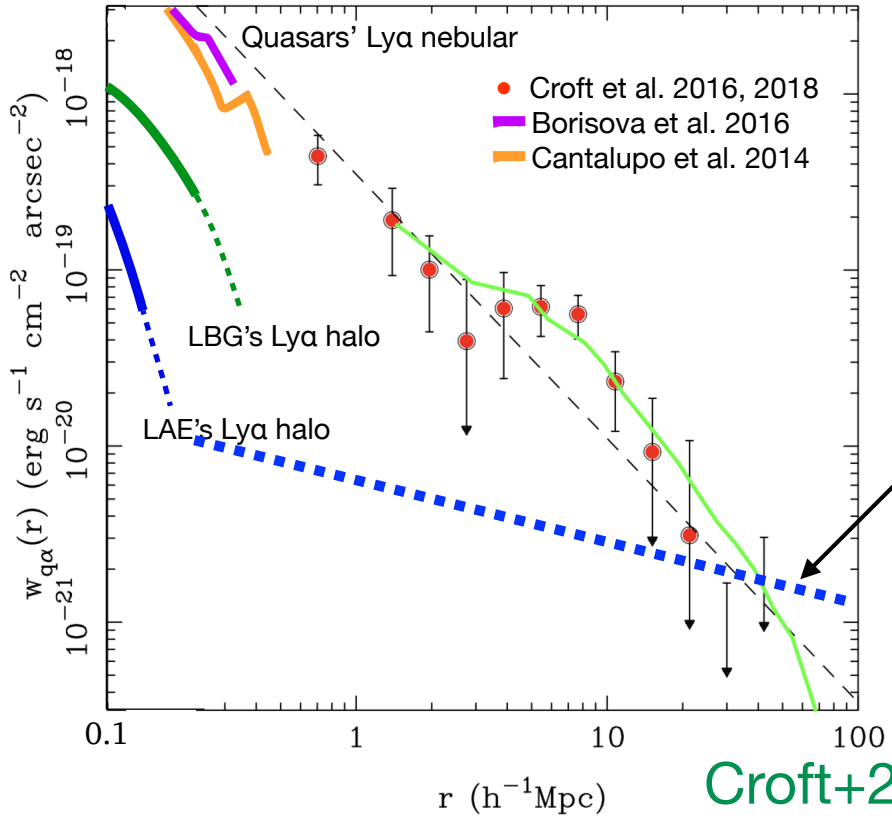


HETDEX's target!

Croft+2018 & modified by R.Momose

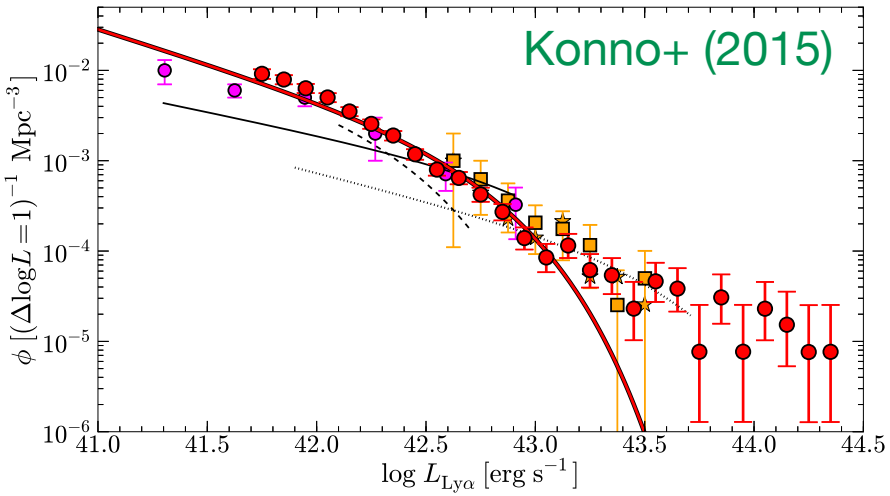
End-to-End Simulation

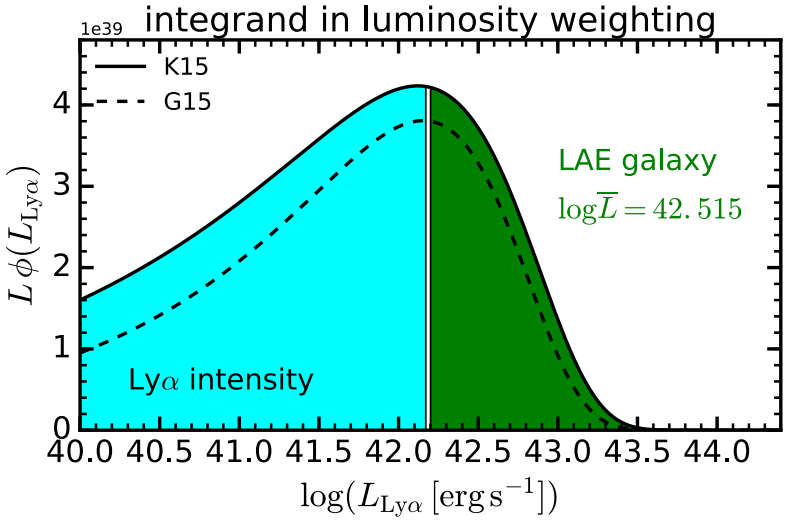
- Simulate something we know *a priori*

  - generate logN density field, given P(k)

    Agrawal, Makiya, Chiang, Jeong, **SS** & Komatsu, JCAP (2017), **SS**+, in prep.

  - extended for Intensity Mapping: LF & P(k)



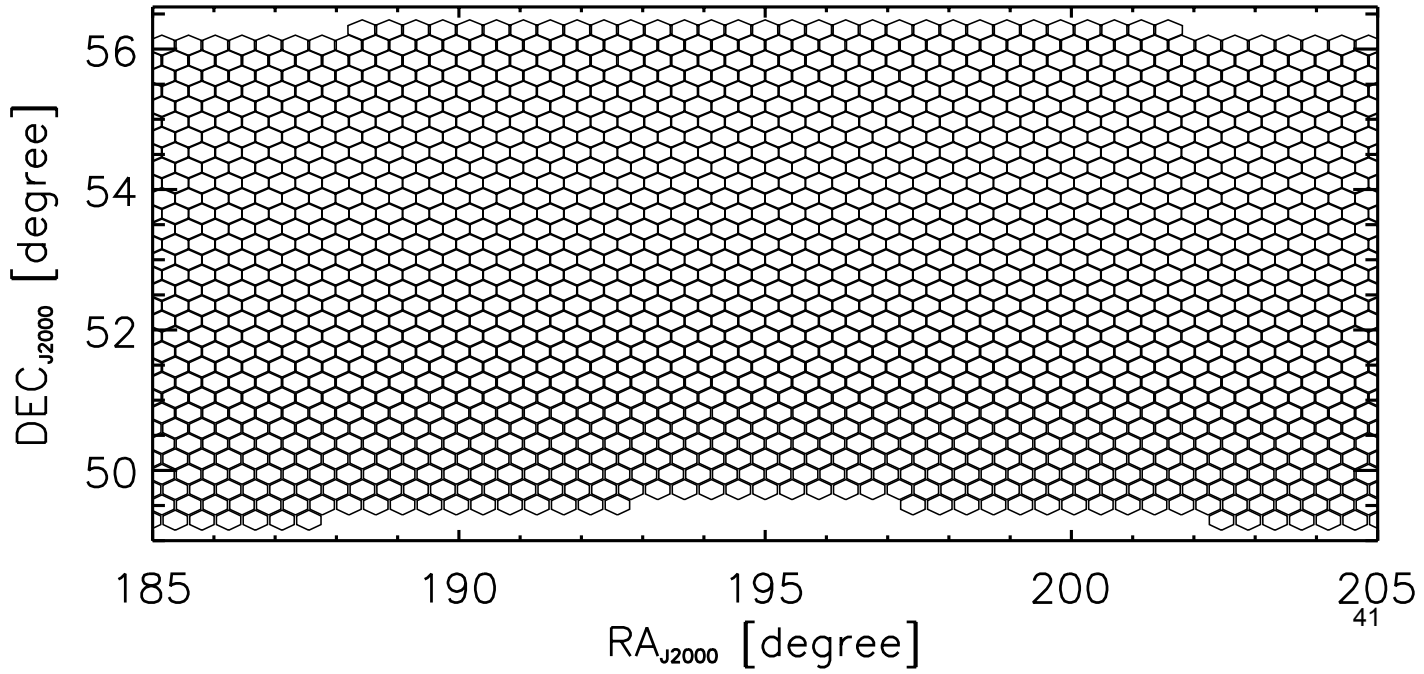


- Useful for two reasons

  - simulate the statistical power of the survey

  - simulate the impact of systematics

Simulating LogN LAE IM



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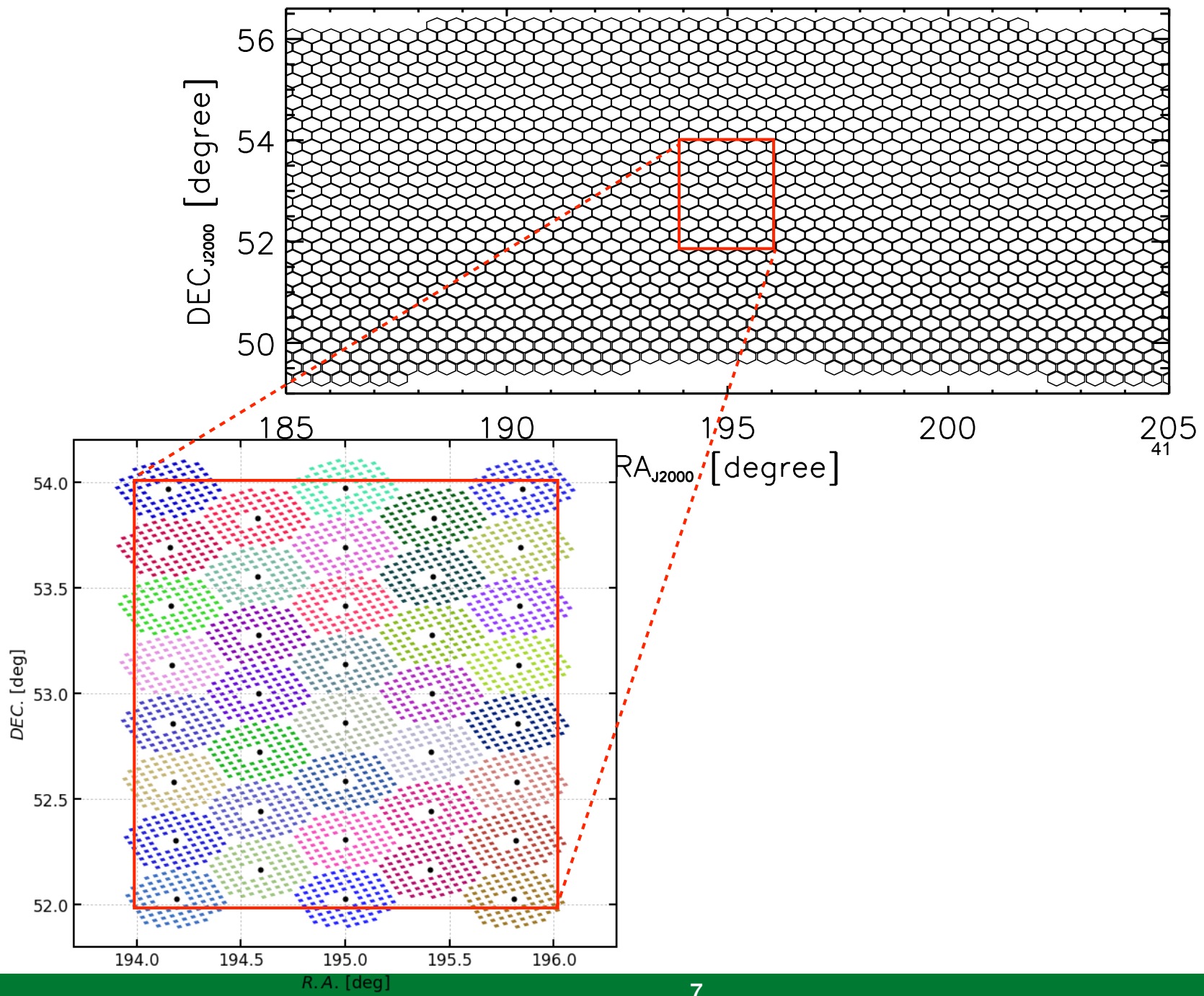

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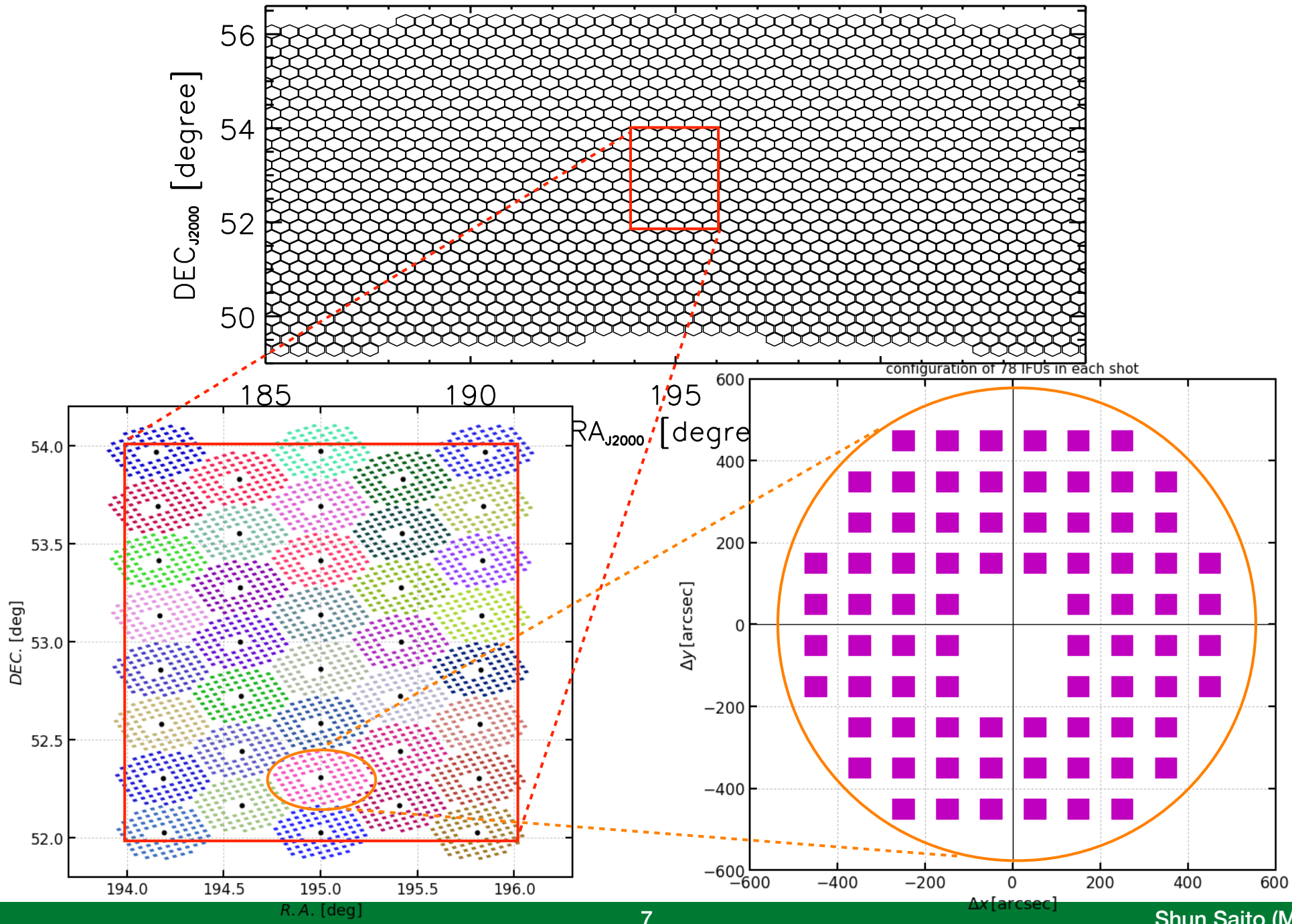

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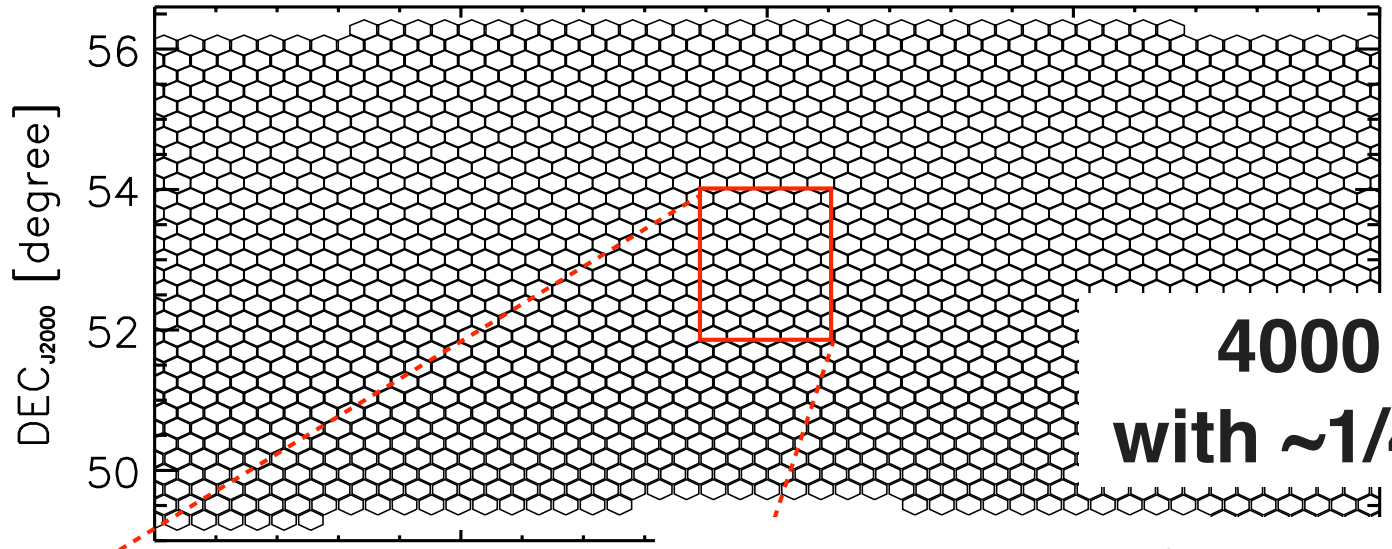
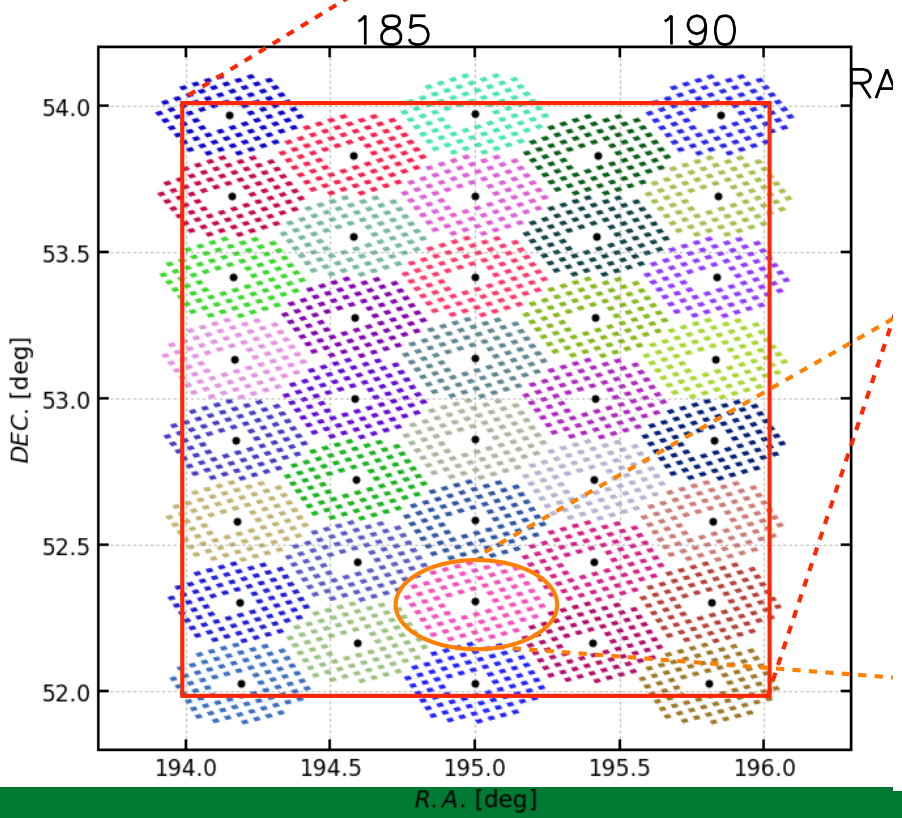
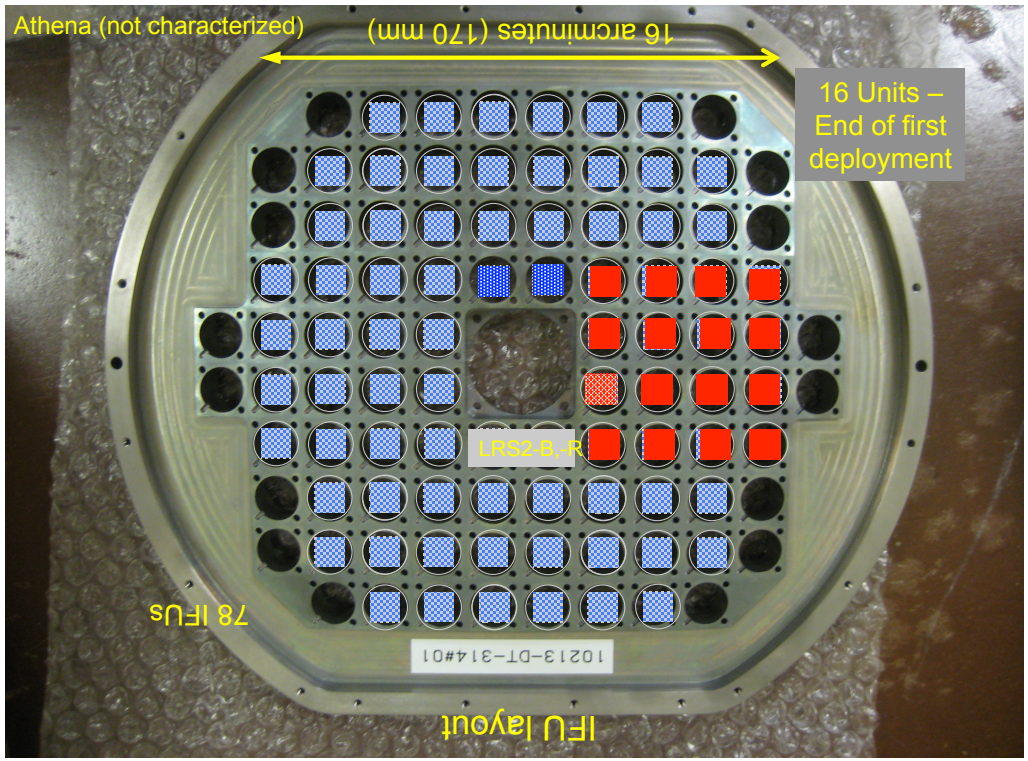


4000 shots with ~1/4.5 filling



Locations of IFUs deployed in IHMP



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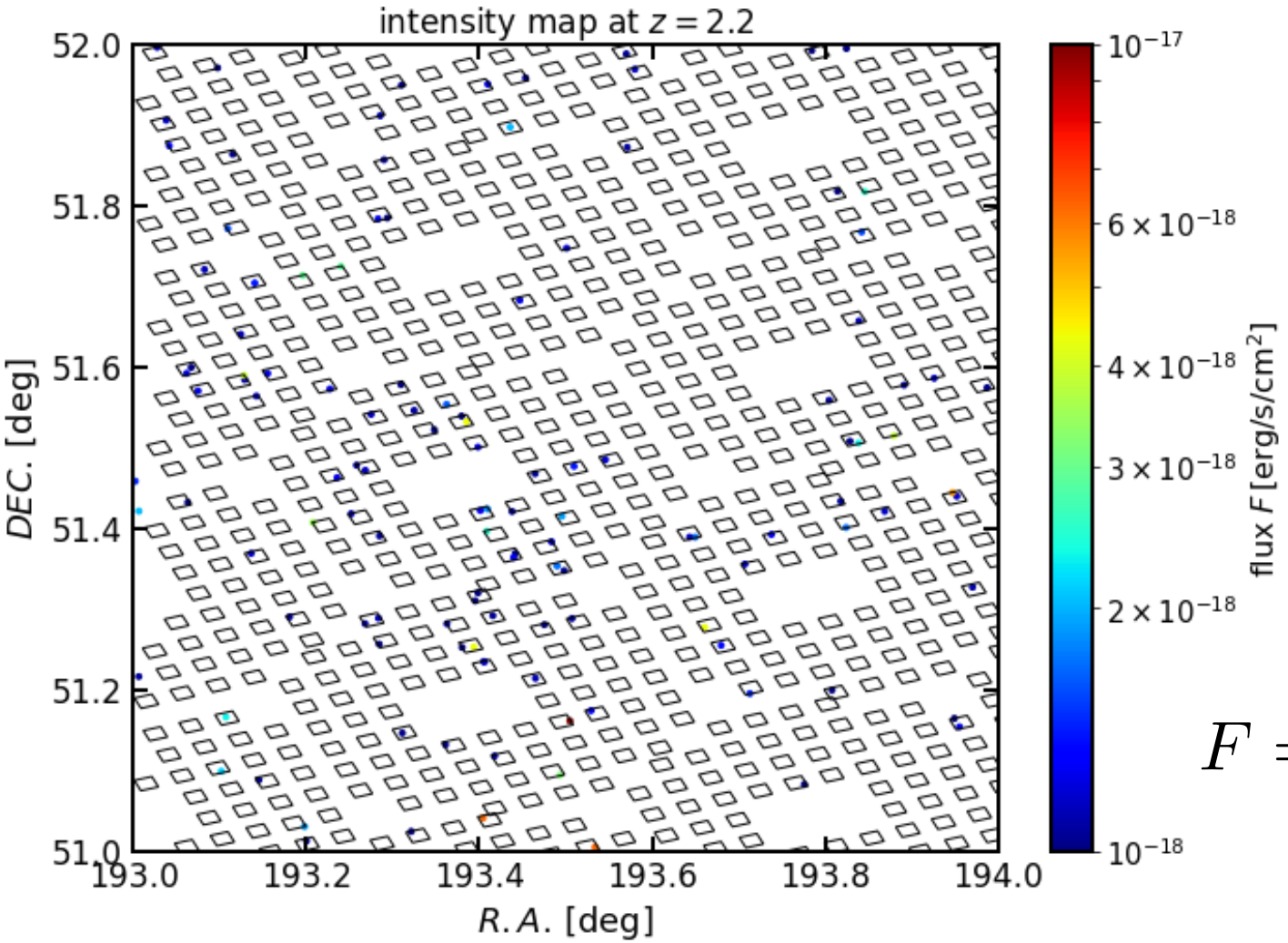
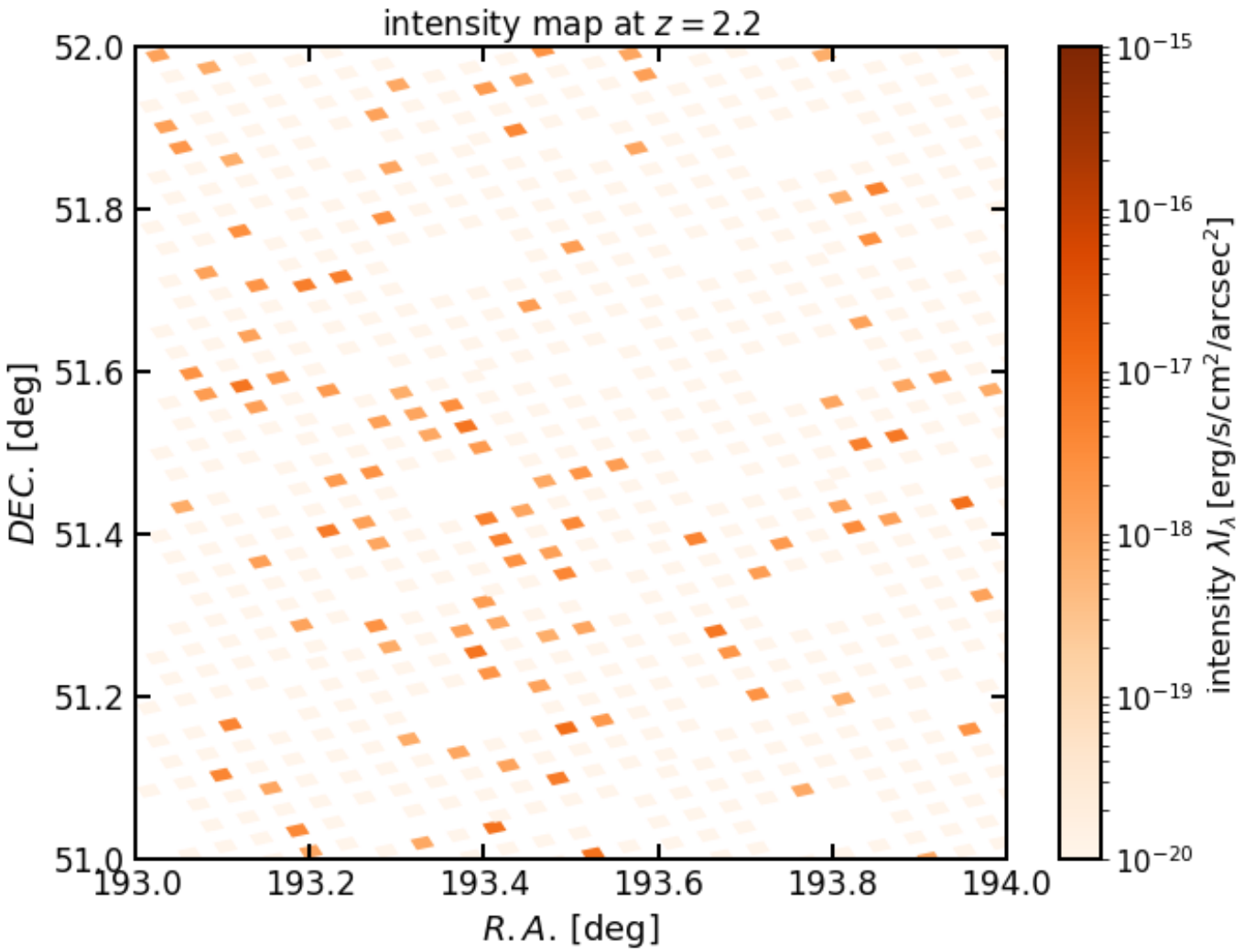


$$F = \frac{L}{4\pi D_L^2}$$

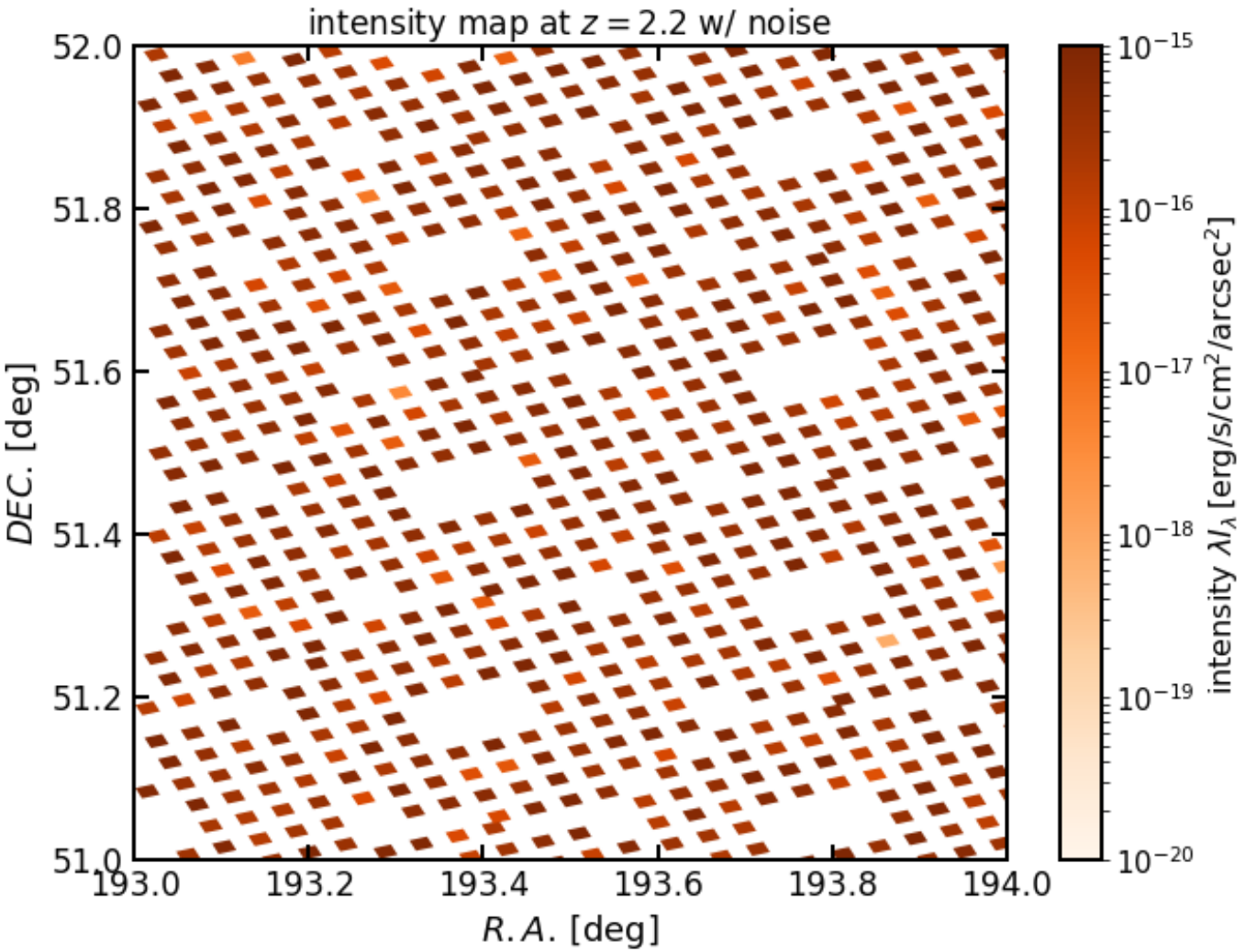
- Luminosity and positions are assigned so that the simulated LogN galaxies recovers ***the input LF & P(k)***.

Simulating LogN LAE IM



$$\lambda I_\lambda = \Delta F \times \frac{\lambda \Delta V_{\rm pix}}{\Delta\Omega\Delta\lambda} = \int dL \frac{dn}{dL} \frac{L}{4\pi D_L^2} \times (1+z)^3 D_A^2 \frac{c}{H}$$

Simulating LogN LAE IM



$d\Omega_{fiber} = (1.5''/2)^2 \times \pi$

$d\Omega_{IFU} = (48.96'')^2$

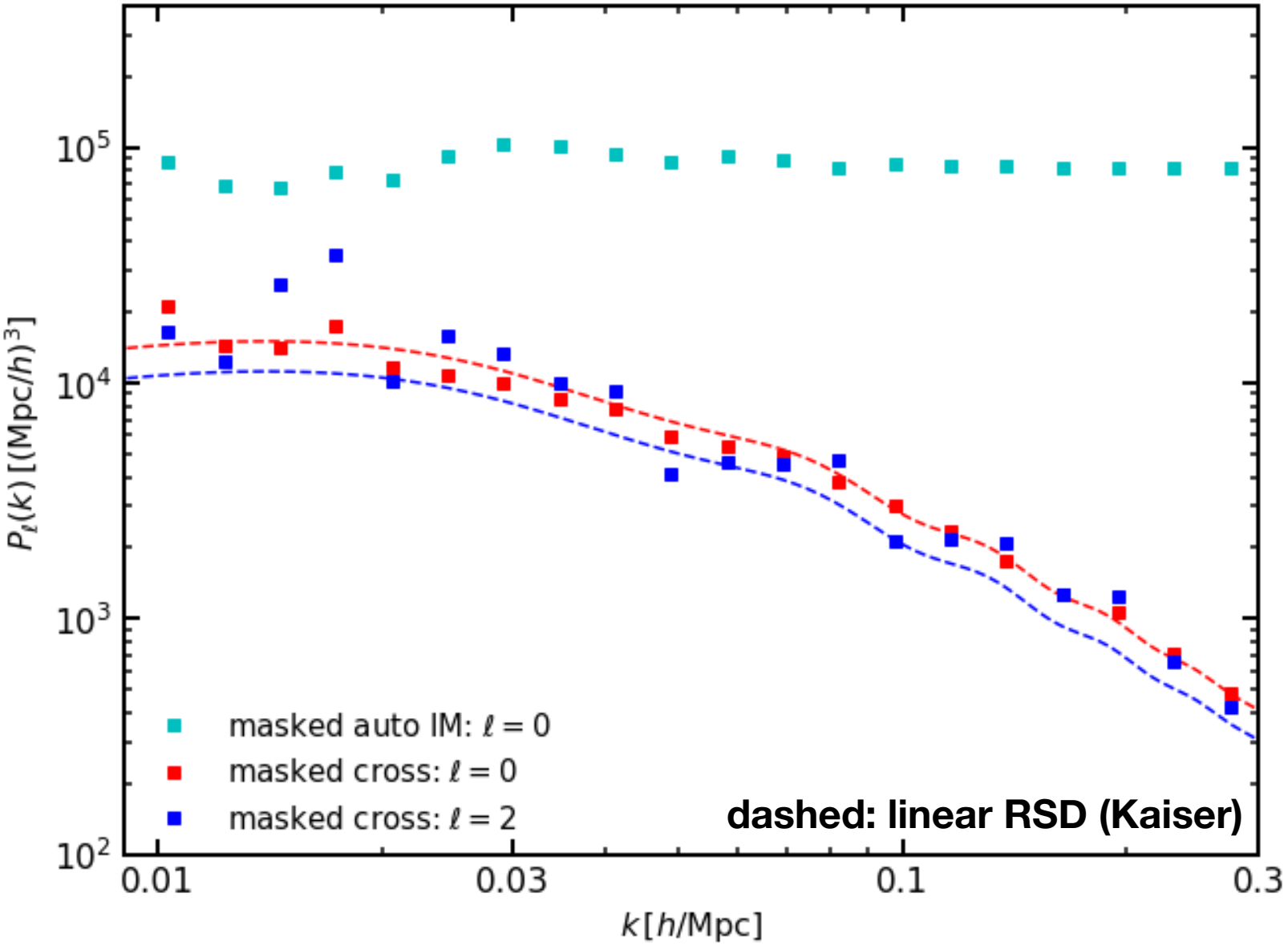
+ HETDEX noise

$$\sigma^{\mathrm{IFU}}_{\lambda I_\lambda} = \sigma^{\mathrm{fiber}}_{\lambda I_\lambda} \sqrt{\frac{d\Omega_{\mathrm{fiber}}}{d\Omega_{\mathrm{IFU}}}}$$

Simulating LogN LAE IM

- Developed P(k) estimator code

Hand+(2017)
c.f. Yamamoto (2000)



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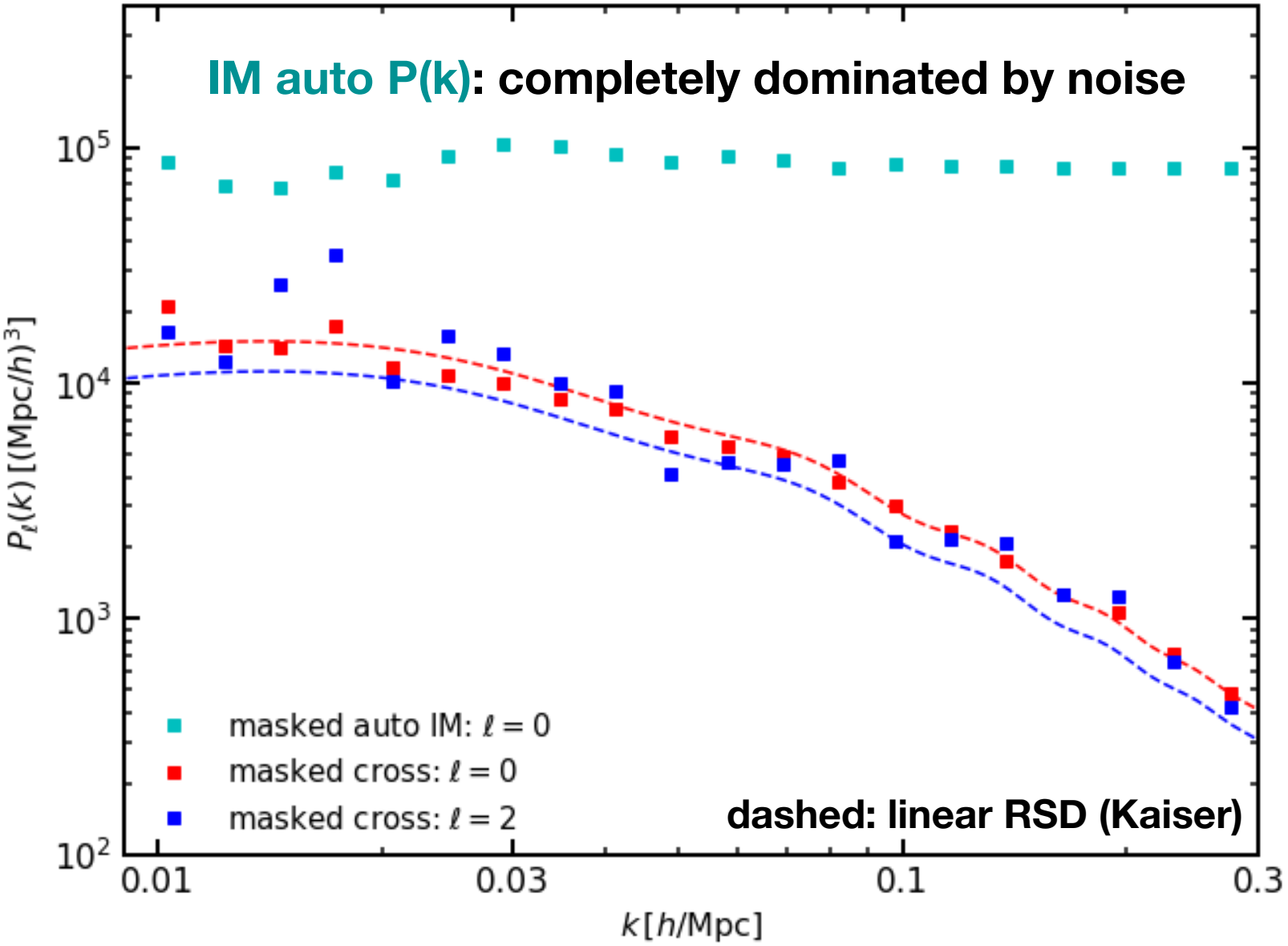

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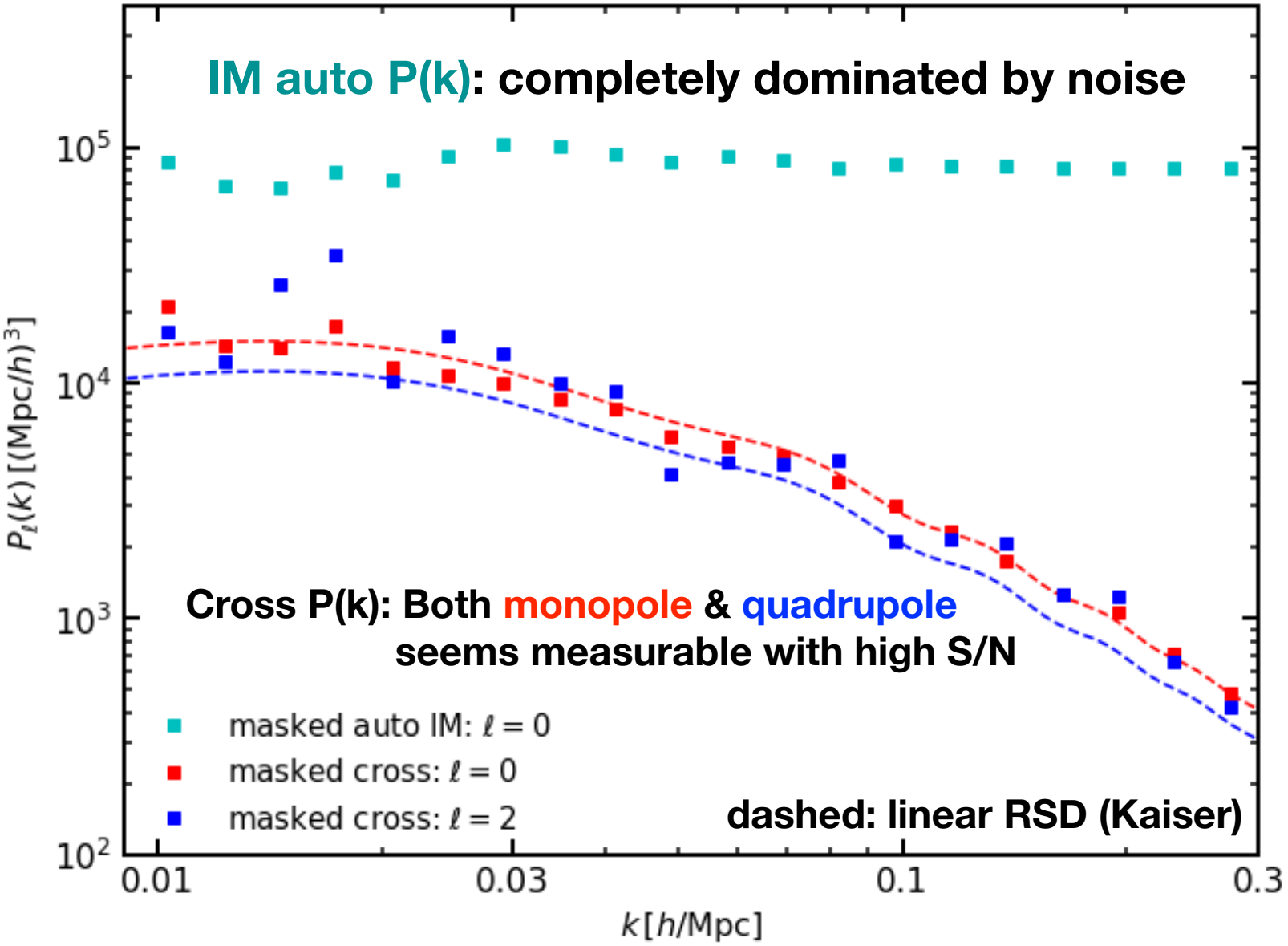
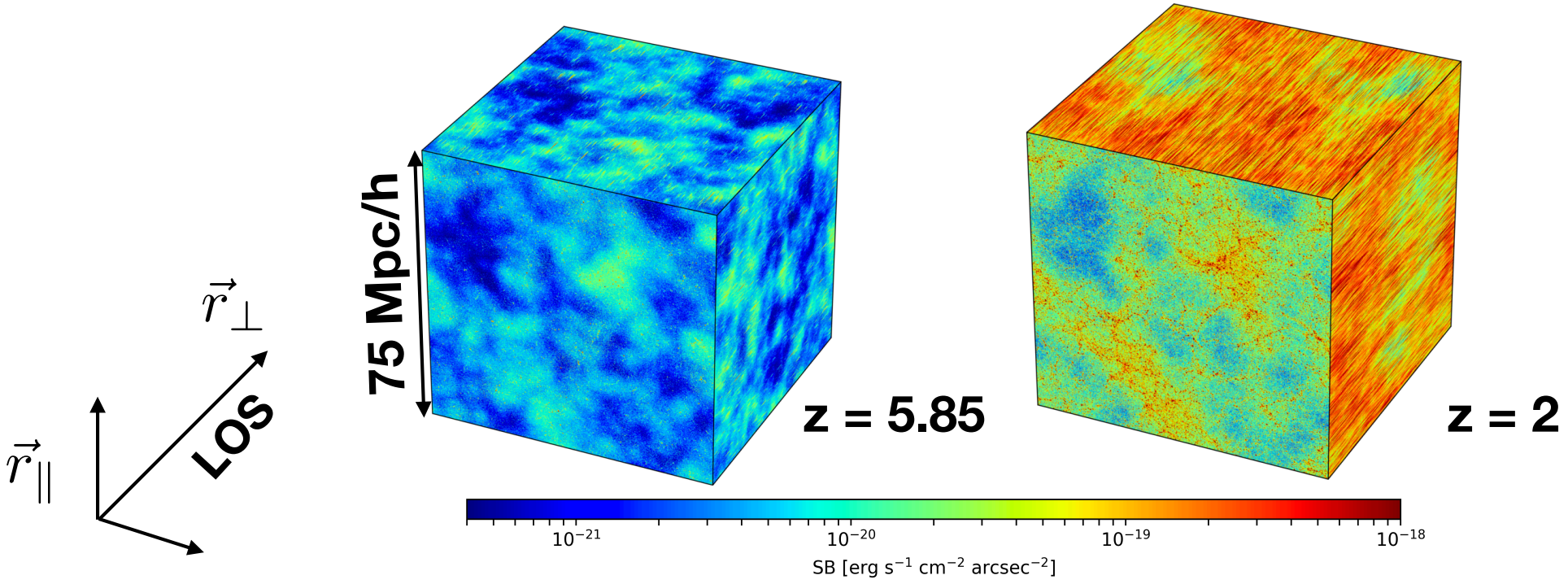


Physical RT Simulation

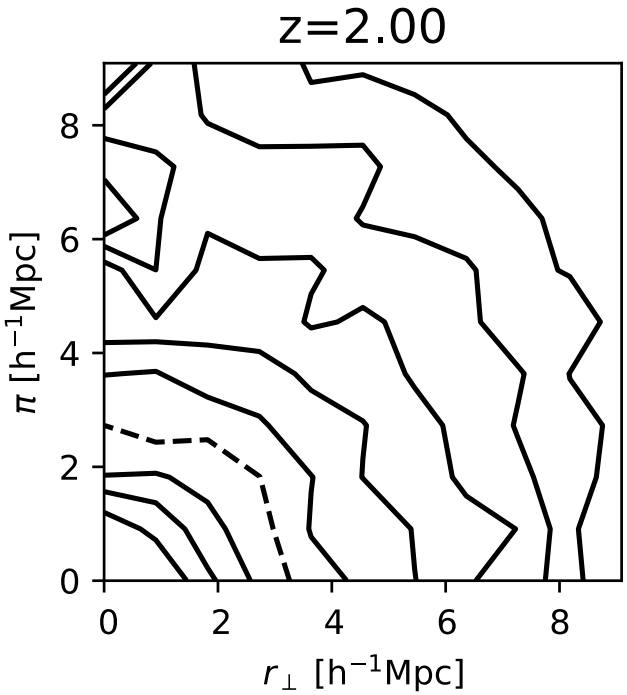
Behrens, Byrohl, **SS**, Niemeyer (2018)

- **Towards a better understanding of LyA**
  - run LyA RT on the ***Illustris*** simulation Vogelsberger+(2014)
  - assumptions (focus on *the large-scale clustering*):
    - initial gaussian profile with virial velocity & $L_{int} = \frac{\mathrm{SFR}}{\mathrm{M}_\odot/\mathrm{yr}} \times 10^{42}\mathrm{erg/s}$
    - + no dust correction → ~~LyA LFs~~

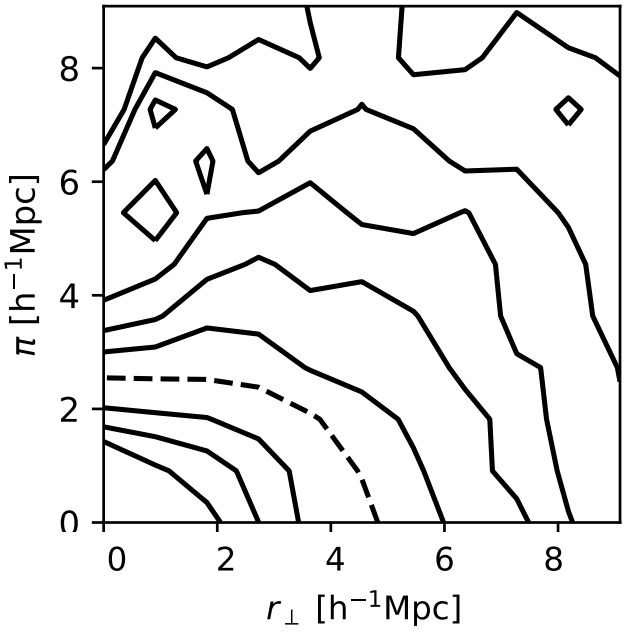


Redshift-Space Clustering

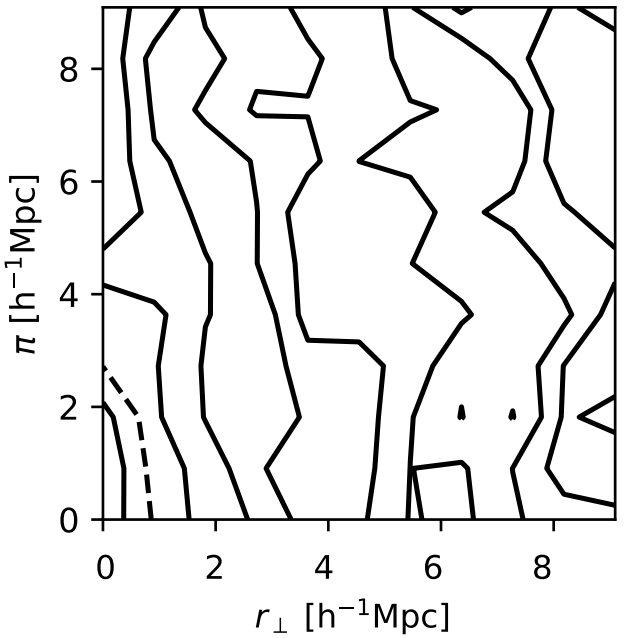
Real Space



Redshift Space w/o RT



Redshift Space w/ RT



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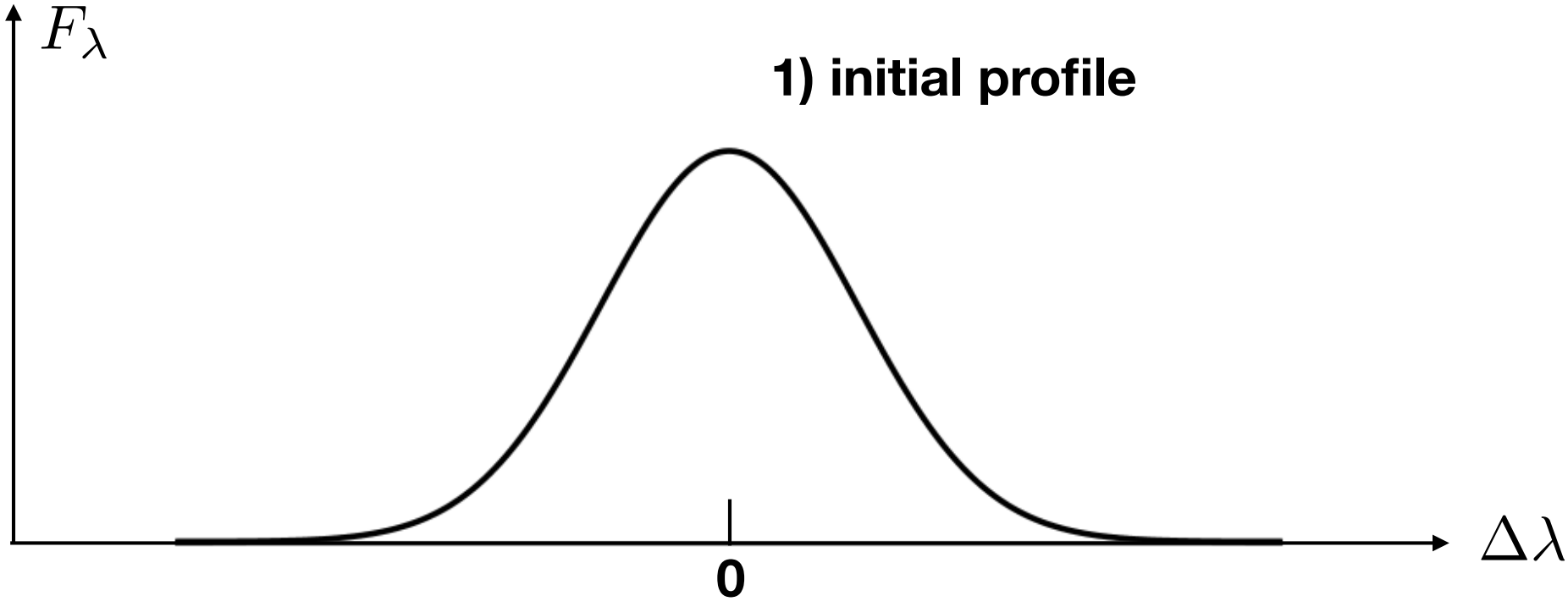
Behrens, **Byrohl, *SS*, Niemeyer**, A&A (2018), **Byrohl, *SS***, Behrens, in prep.



- ***Blue*** part can be redshifted and attenuated by CGM/IGM.
  Laursen+(2011)
  - low RT resolution = underestimate the attenuation by CGM.
  - low redshift: unlikely to be attenuated by CGM/IGM

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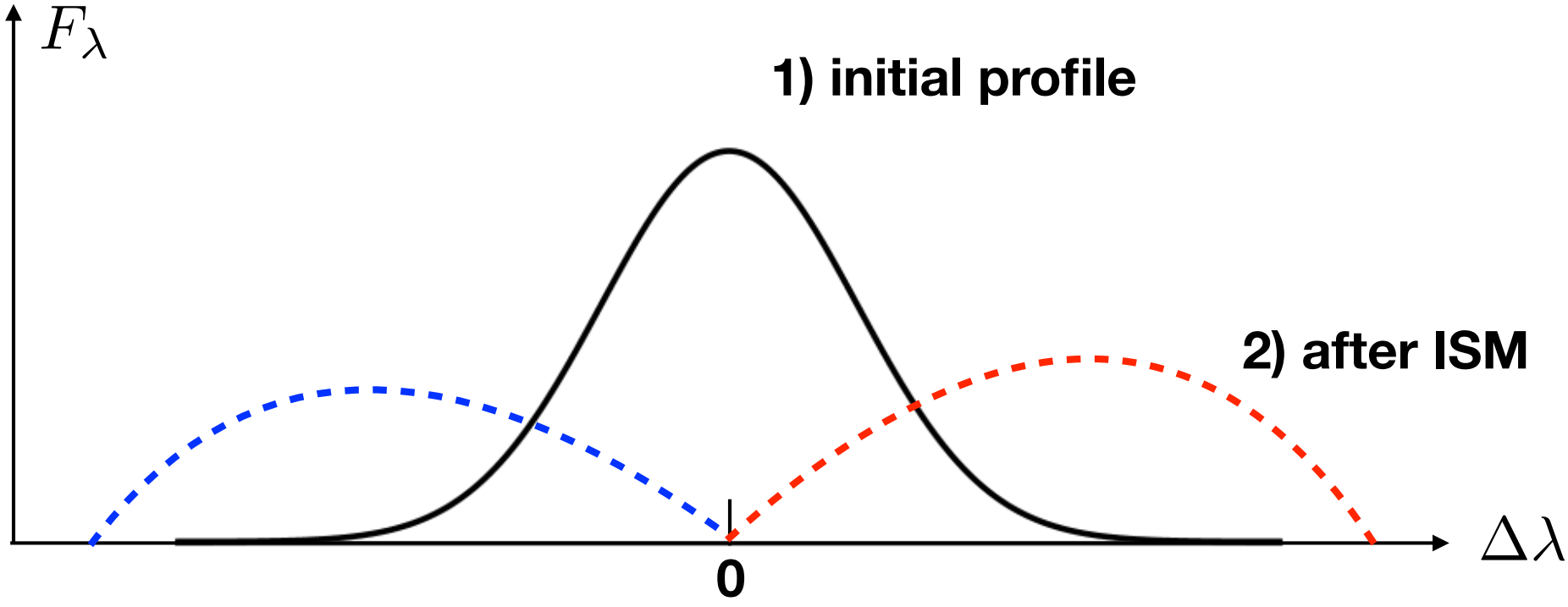

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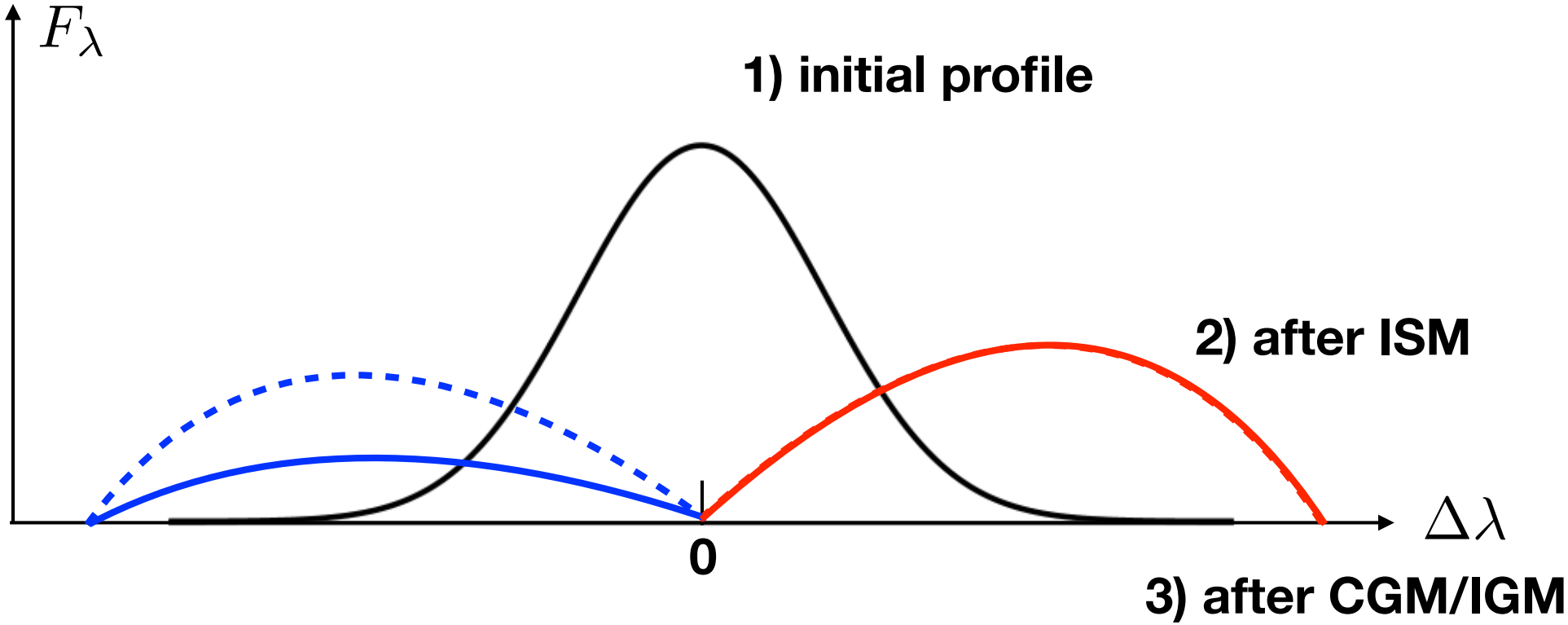

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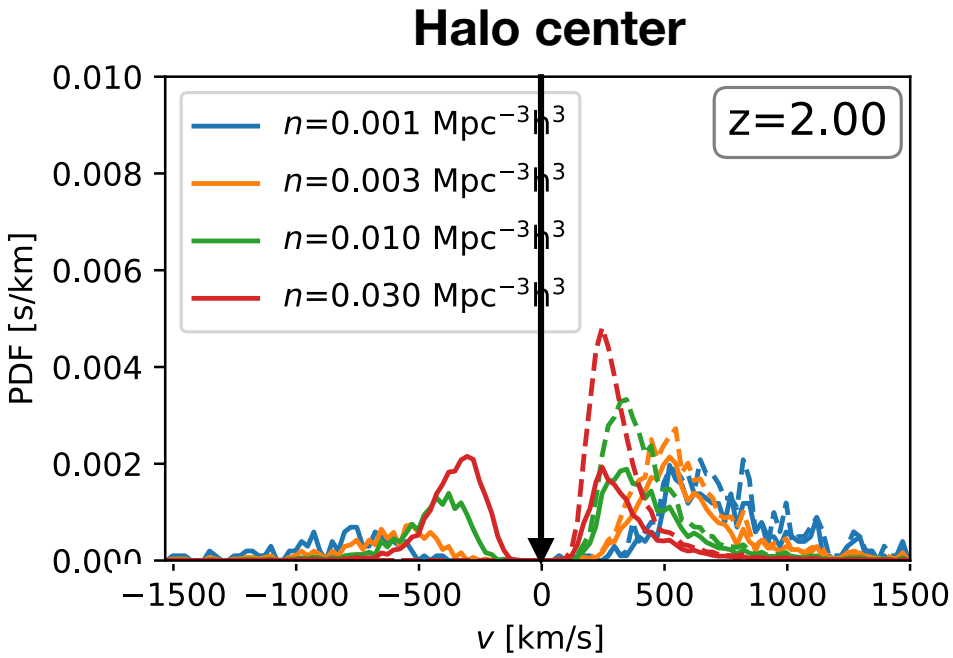
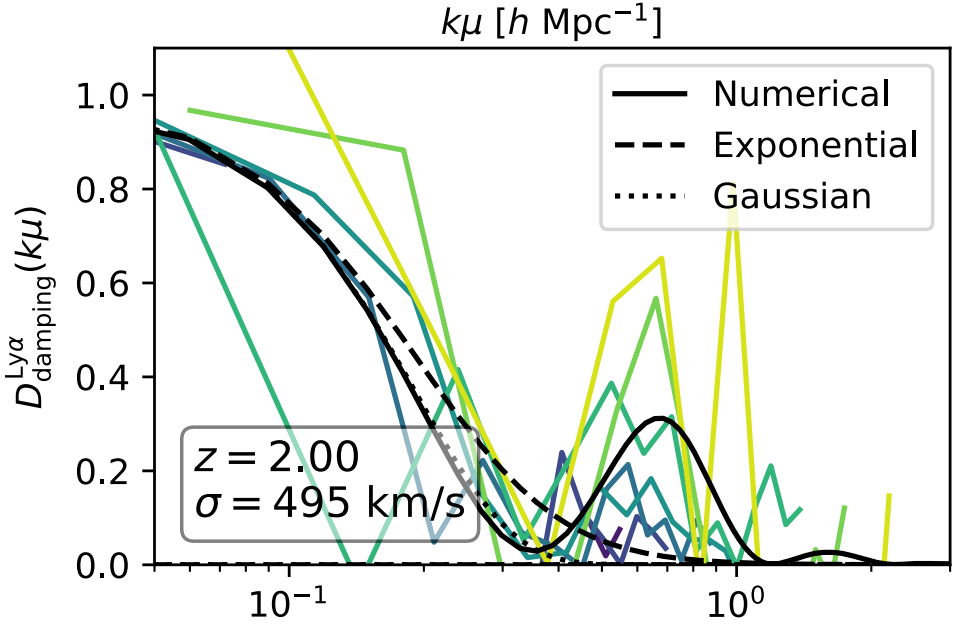
Physical RT Simulation

Byrohl, *SS*, Behrens, in prep.

- Find a new *Finger-of-God* damping due to RT.
  - double peak leads to the oscillation in the damping.



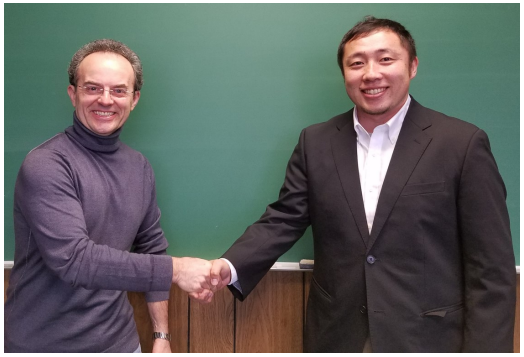


Summary

- ***HETDEX as a Lyα IM survey***
  - Fully make use of its **blind** nature.
  - First results with 77M(!) spectra coming soon!

- ***Preparing analysis & simulation pipeline***
  - End-to-End Log-Normal simulation
  - Physical Radiative Transfer simulation

S&T Physics opens a window to the sky



Marco Cavaglia, Shun Saito

Starting in January, two new faculty, Marco Cavaglia and Shun Saito, will work to unravel the mysteries of the universe at S&T. Cavaglia, who joins the department after 15 years at the University of Mississippi, is an expert on gravitational physics and multi-messenger astrophysics. Saito, from the Max Planck-Institute for Astrophysics in Germany, works on observational cosmology. They will collaborate to develop a new astrophysics program at S&T. Detailed faculty profiles for Marco Cavaglia and Shun Saito will be published in the next edition of the newsletter.

Multi-messenger astrophysics and precision cosmology are research areas at the forefront of today's physics. Multi-messenger astrophysics studies celestial phenomena through different physical carriers (electromagnetic waves, gravitational waves, particles and cosmic rays). Cosmology studies the origin and large -scale structure of the Universe.

Join our new astro group if interested in working on *HETDEX* and/or *LIGO*!

S&T Physics News Letter 2019