HI Intensity Mapping with MeerKAT & 1/f noise analysis

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2019 SKA Shanghai Meeting, Shanghai, P. R. China

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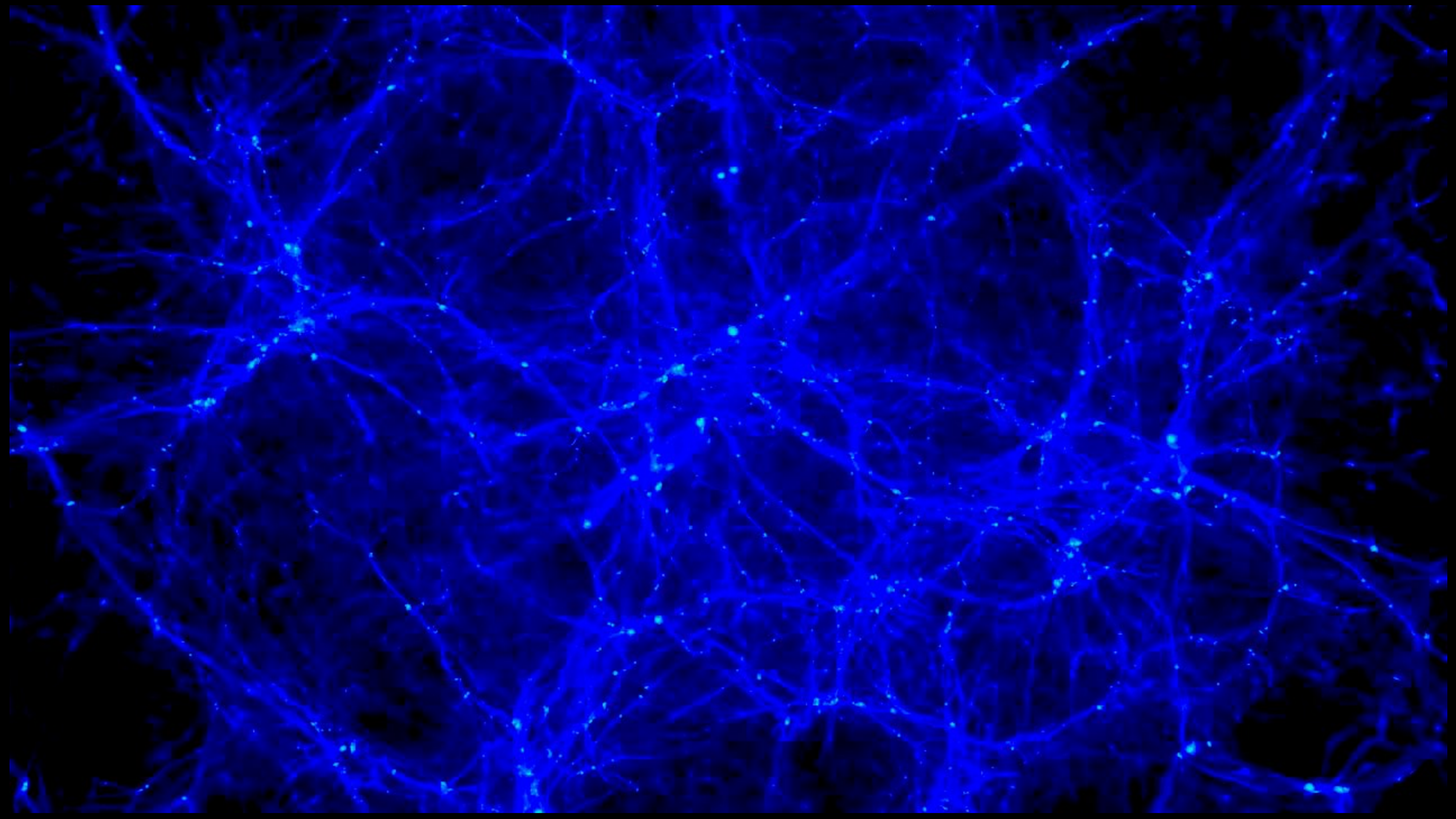
UWC ASTROPHYSICS

NRF National Research Foundation | SARAO South African Radio Astronomy Observatory

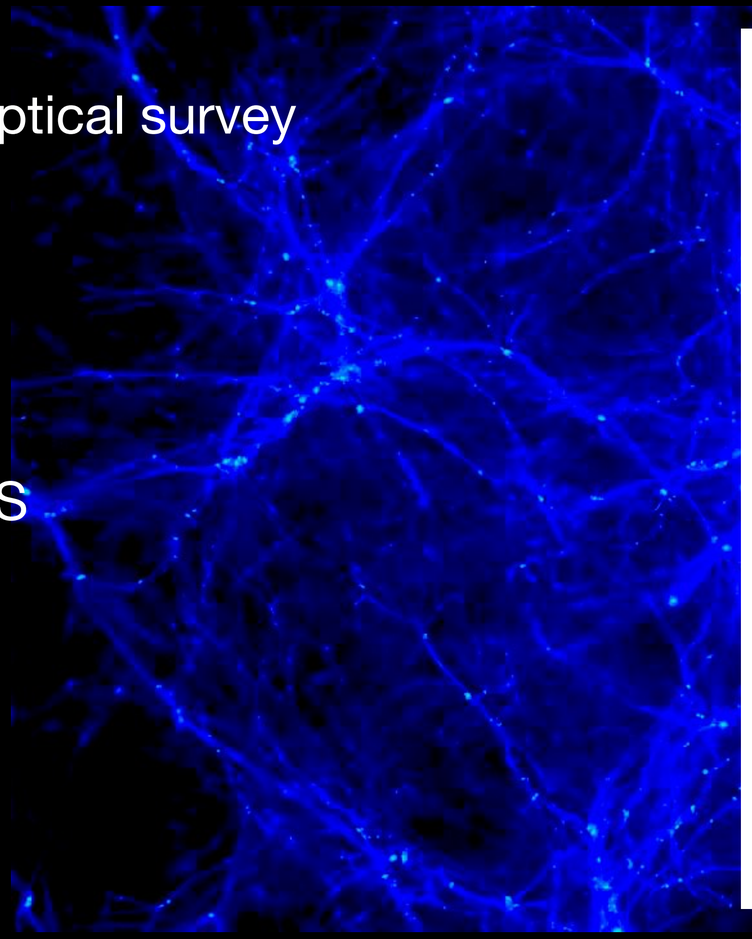
CRC

Large Scale Structure



Large Scale Structure

- CMB
- Galaxy optical survey
  - BOSS
  - DES
  - eBOSS
  - DESI
  - LSST
  - Euclid



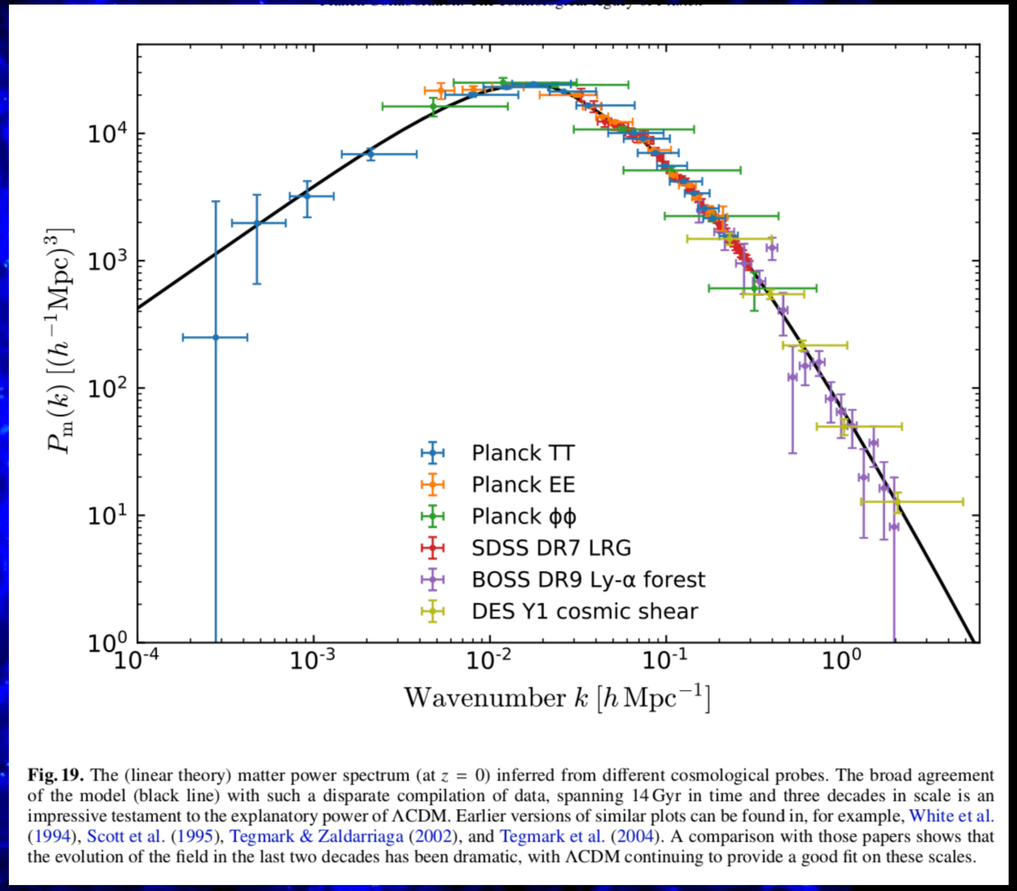


Fig. 19. The (linear theory) matter power spectrum (at $z = 0$) inferred from different cosmological probes. The broad agreement of the model (black line) with such a disparate compilation of data, spanning 14 Gyr in time and three decades in scale is an impressive testament to the explanatory power of ΛCDM. Earlier versions of similar plots can be found in, for example, White et al. (1994), Scott et al. (1995), Tegmark & Zaldarriaga (2002), and Tegmark et al. (2004). A comparison with those papers shows that the evolution of the field in the last two decades has been dramatic, with ΛCDM continuing to provide a good fit on these scales.

Planck 2018

Radio Telescope

- Continue Survey
  - loss redshift info.
- HI Galaxy Survey
  - hard for high redshift
- HI Intensity Mapping Survey

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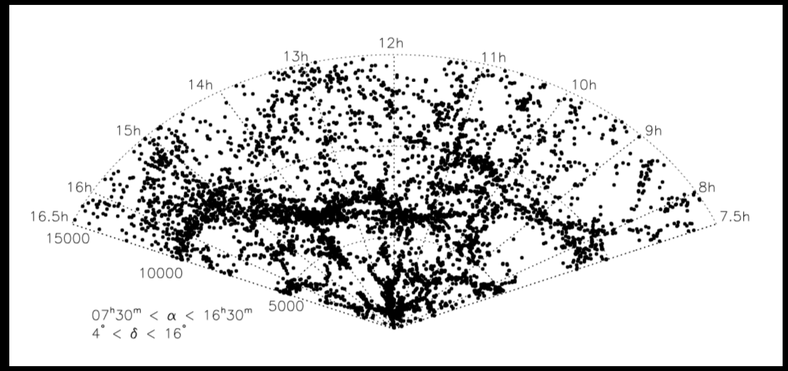

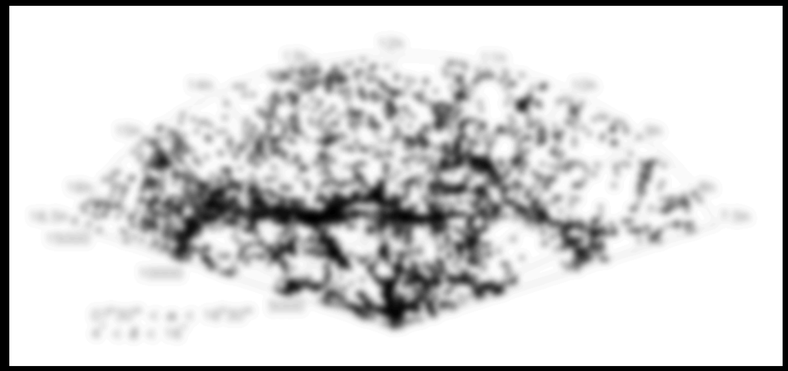

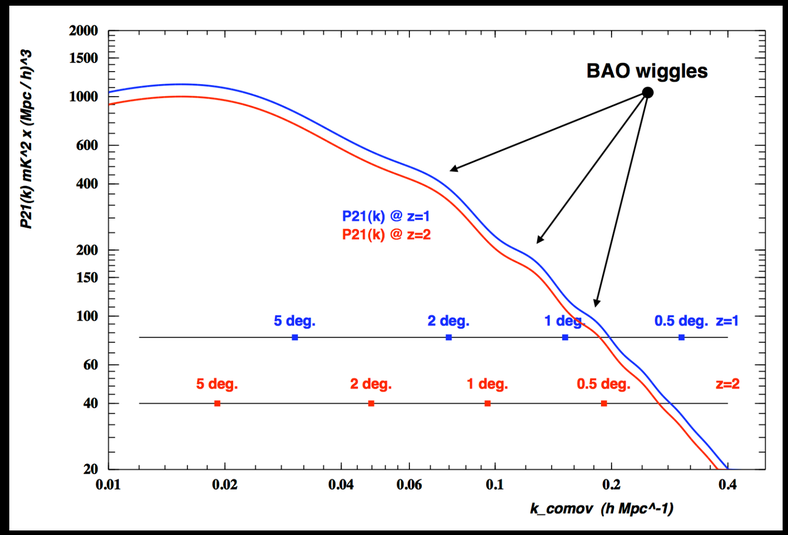

Ansari et. al. 1108.1474

Radio Telescope

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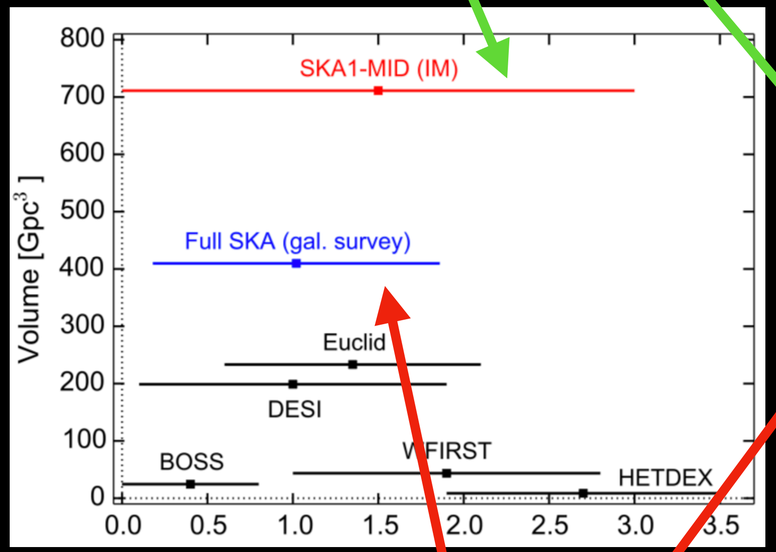
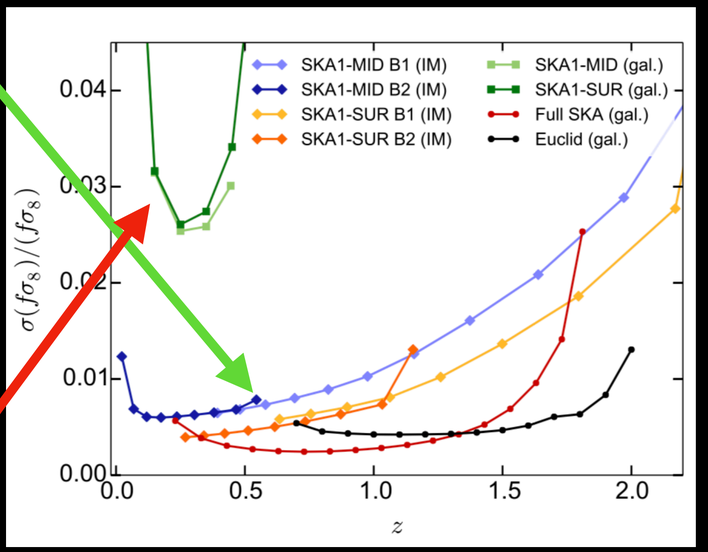
Intensity Mapping Survey

BAO, k ~ 0.074 Mpc^-1
IM 10k hr, 25k deg^2, dz=0.1;
inter. 1k deg^2, dz=0.3



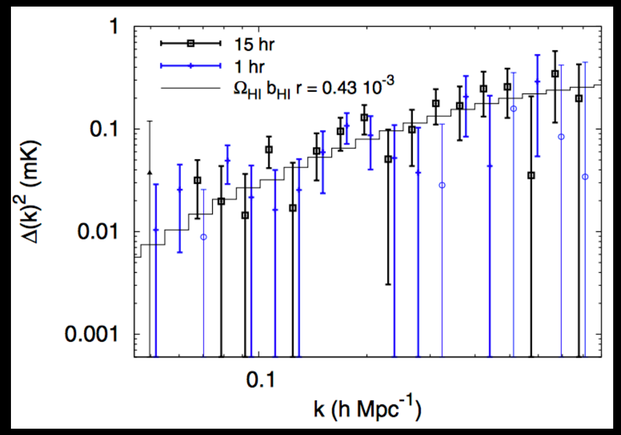


Galaxy Survey

Santos, M G et, al. ArXiv 1501.03989

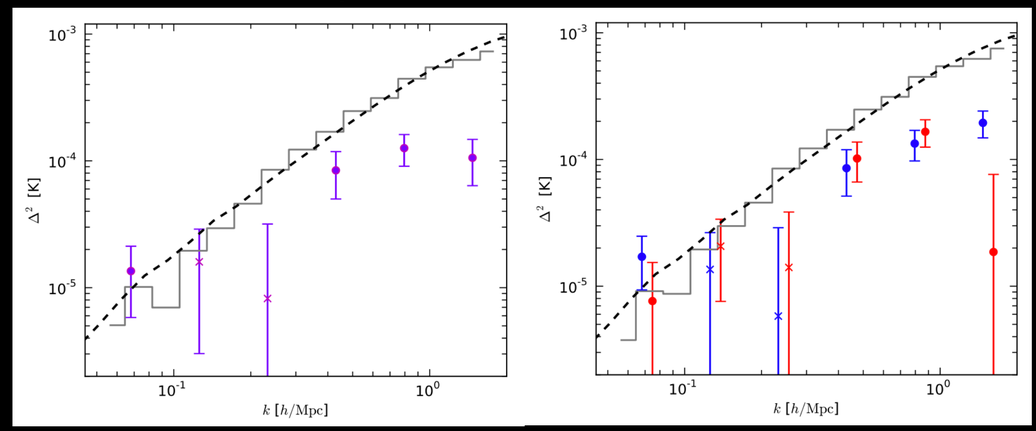
HI Experiments

	Intensity Mapping		Galaxy Survey
Single Dish	GBT Parkes Bingo	FAST	Arecibo *ALFALFA*
interferometry	Tianlai CHIME HIRAX *MeerKLASS*	MeerKAT	ASKAP *WALLABY/DINGO* VLA *CHILES* *MIGHTEE*
Post R.			
EoR	Paper/HERA MWA Lofar 21CMA		
	PRIZM		Edges



GBT x WiggleZ

K. Masui et. al. 2013 ApJ 763L 20M



Parkes x 2dF

C. Anderson 1710.00424

MeerKLASS

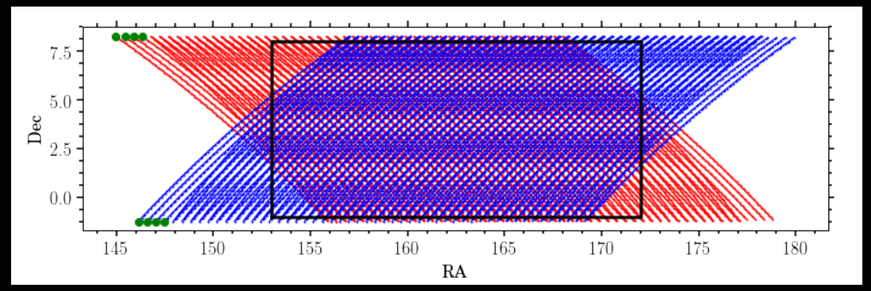
- 64 x 13.5m, max baseline 8km
- **MeerKAT Large Area Synoptic Survey** (MeerKLASS)
  - single dish IM & interferometry galaxy survey
  - 4000 square deg; 4000 hours
  - L-band (0<z<0.58) / UHF-band (0.4<z<1.45)

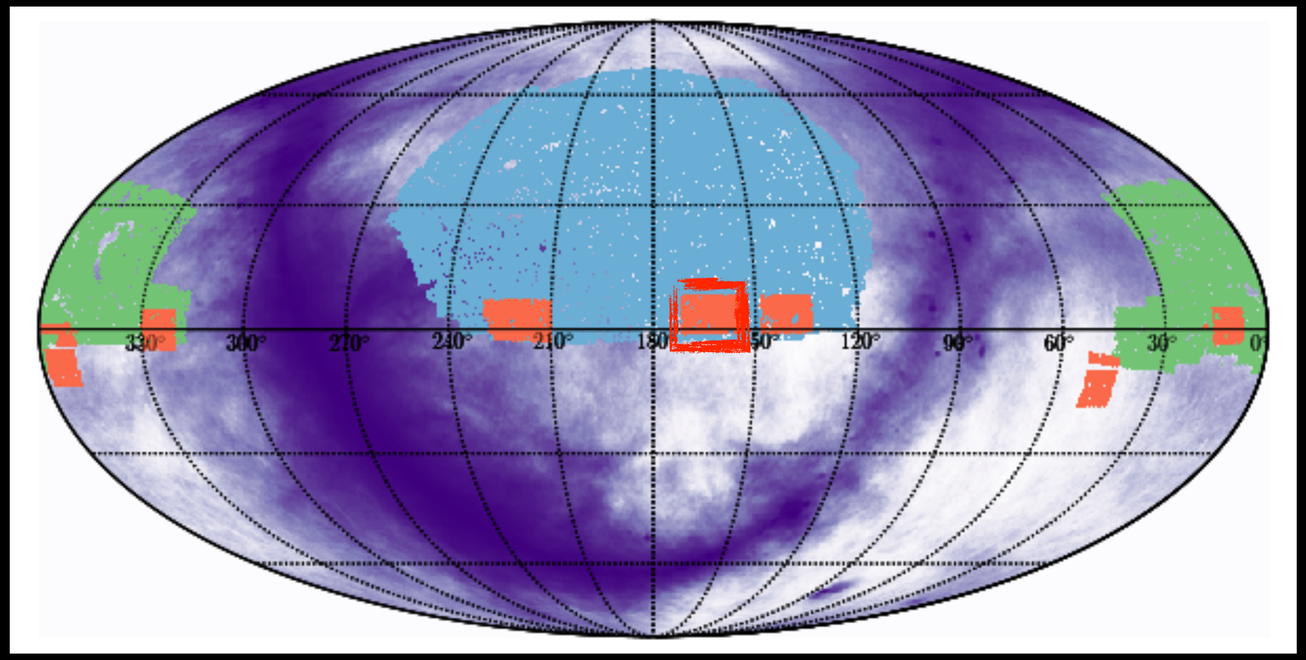
Contents

M. G. Santos et. al. 1709.06099 and references therein

MeerKLASS Pilot Survey

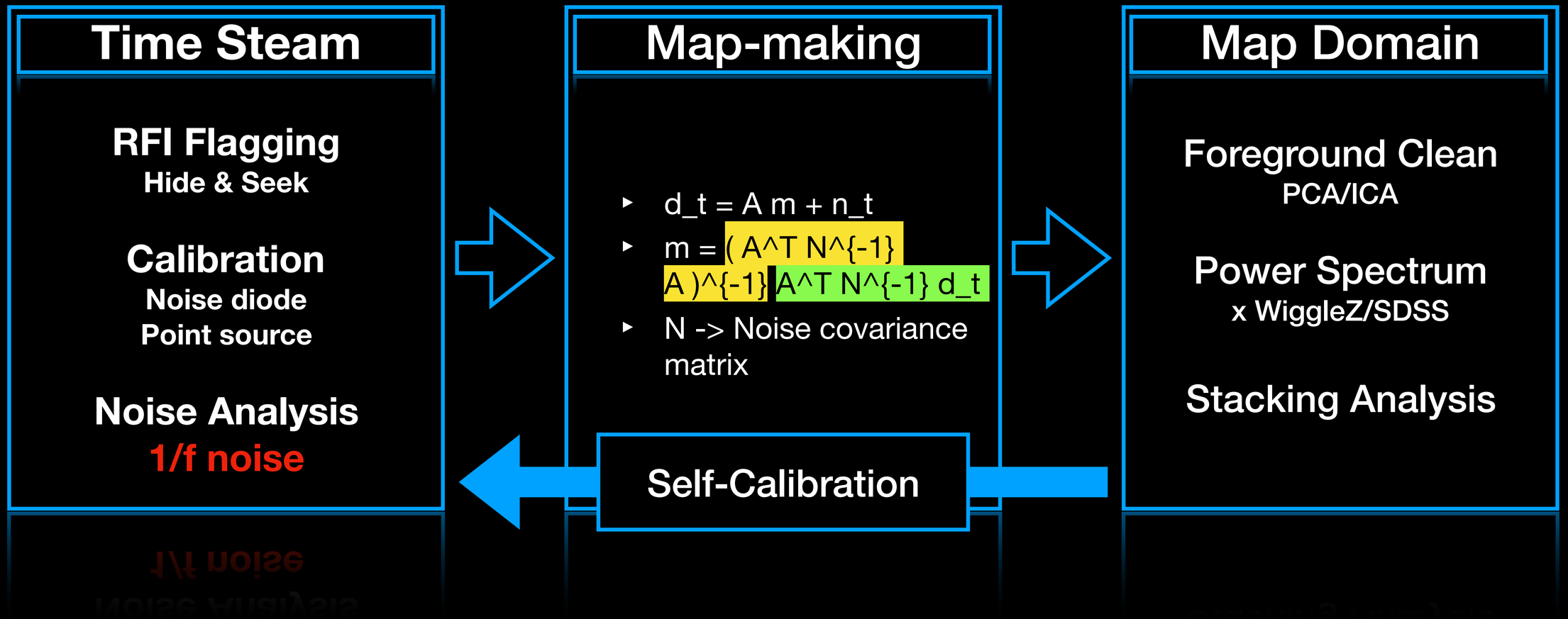
- MeerKAT HI IM Pilot survey
  - 200 square deg, 20 hours,
  - ~60 dishes, Fix Alt ~ 45deg
  - L-band (960MHz - 1.67GHz)
  - Overlap with WiggleZ/SDSS
  - Test system, training pipeline





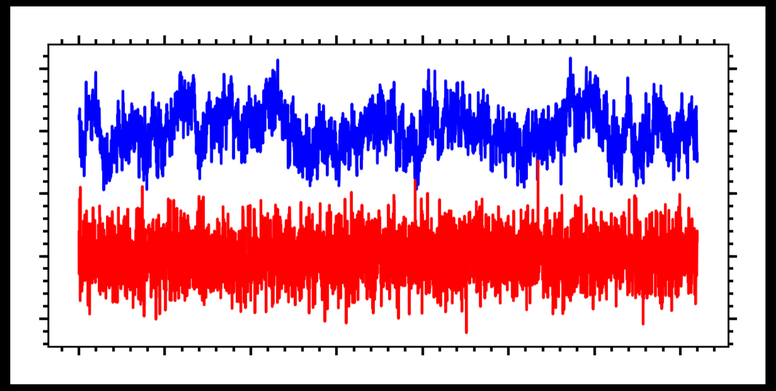
MeerKLASS Pilot Survey

- Data analysis pipeline

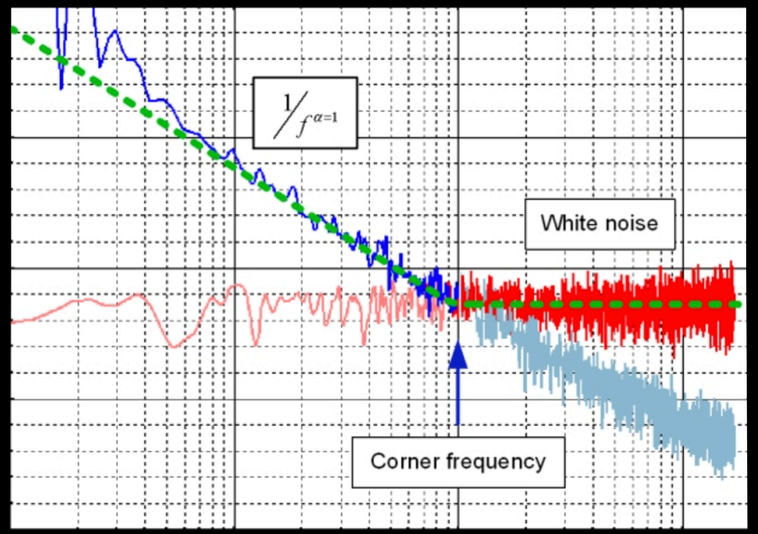


1/f Noise

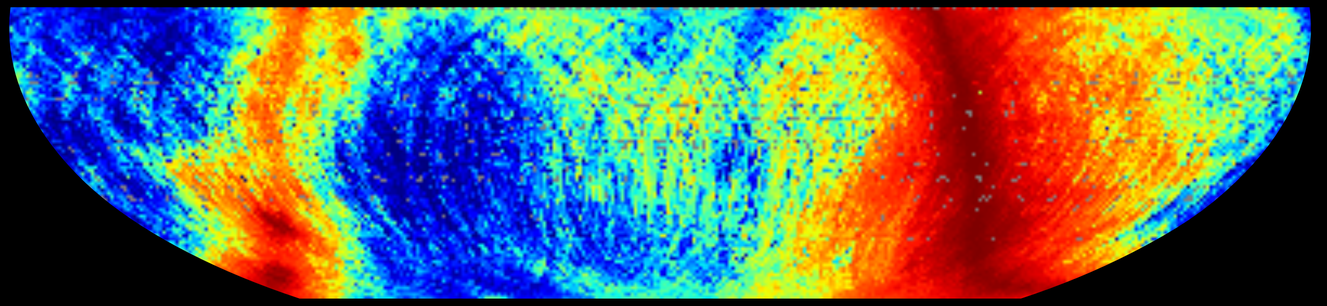
- Correlated noise
  - receiver gain variance



time



f/f_k



1/f Noise Model

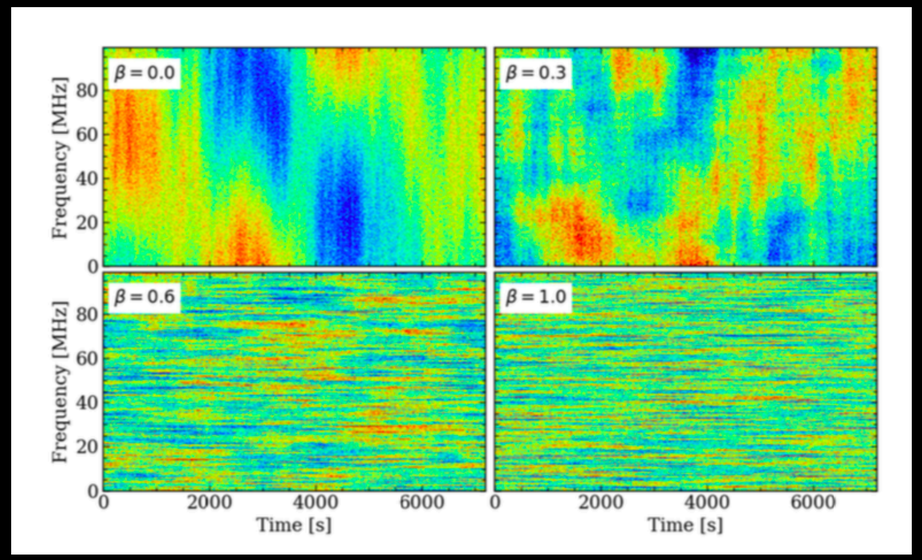
- frequency correlation

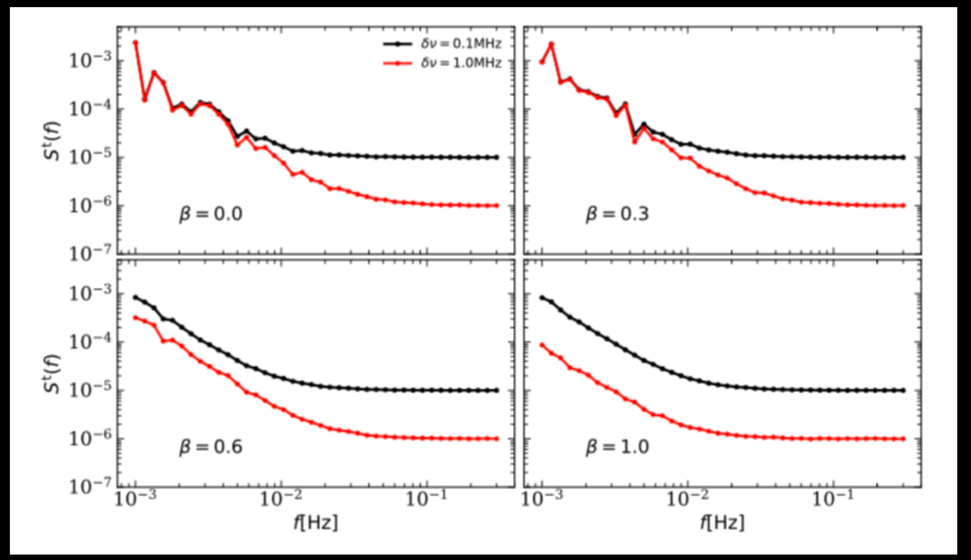
$$S(f,\omega) = A\left(1 + C\left(\frac{f_0}{f}\right)^{\alpha}\left(\frac{\omega_0}{\omega}\right)^{\frac{1-\beta}{\beta}}\right),$$

$$\lg f_0 = \lg f_{\mathrm{k},\delta\nu} - \frac{1}{\alpha}\lg(CK\delta\nu)$$

$$K = \frac{2}{\pi}\int_{\omega_{\min}}^{\omega_{\max}} \mathrm{d}\,\omega \mathrm{sinc}^2(\delta\nu\omega)\left(\frac{\omega_0}{\omega}\right)^{\frac{1-\beta}{\beta}}$$

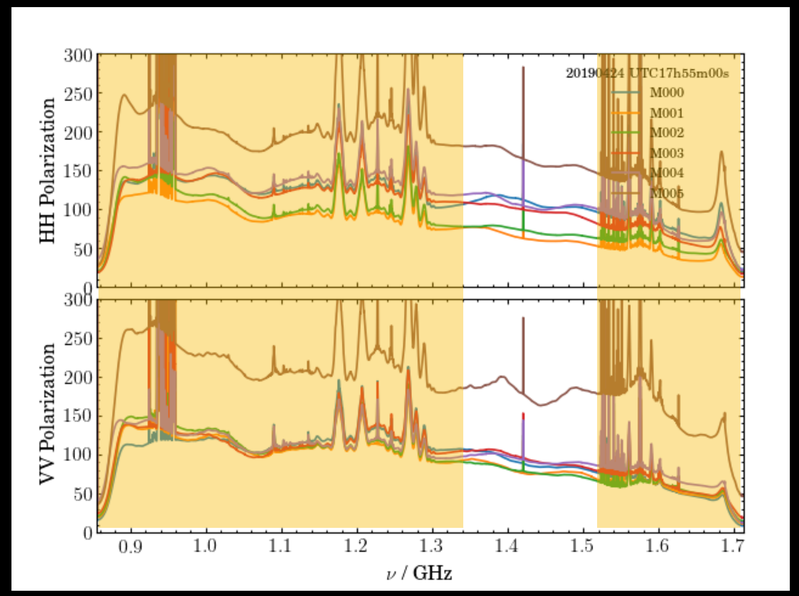
f0 = 1.e-5, alpha = 2

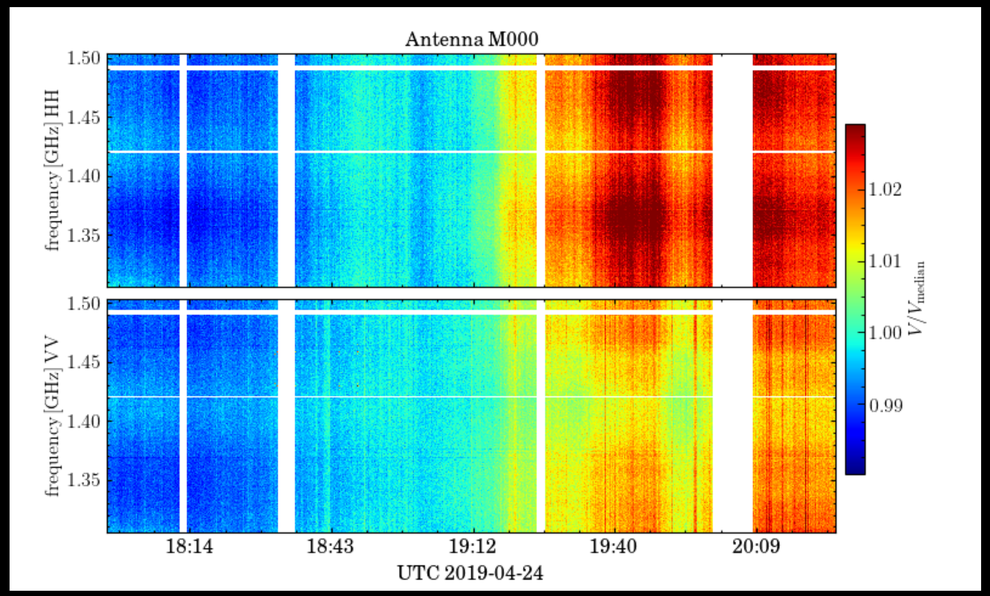




1/f Noise Measurements

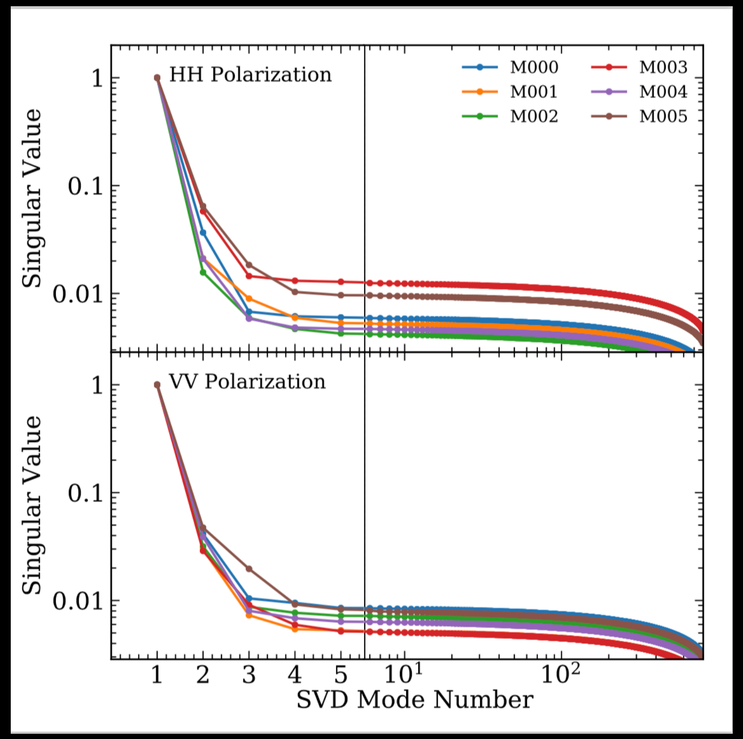
- South Celestial Pole (SCP) observation
  - 64 dishes; 2.5 hours; 2s sampling rate

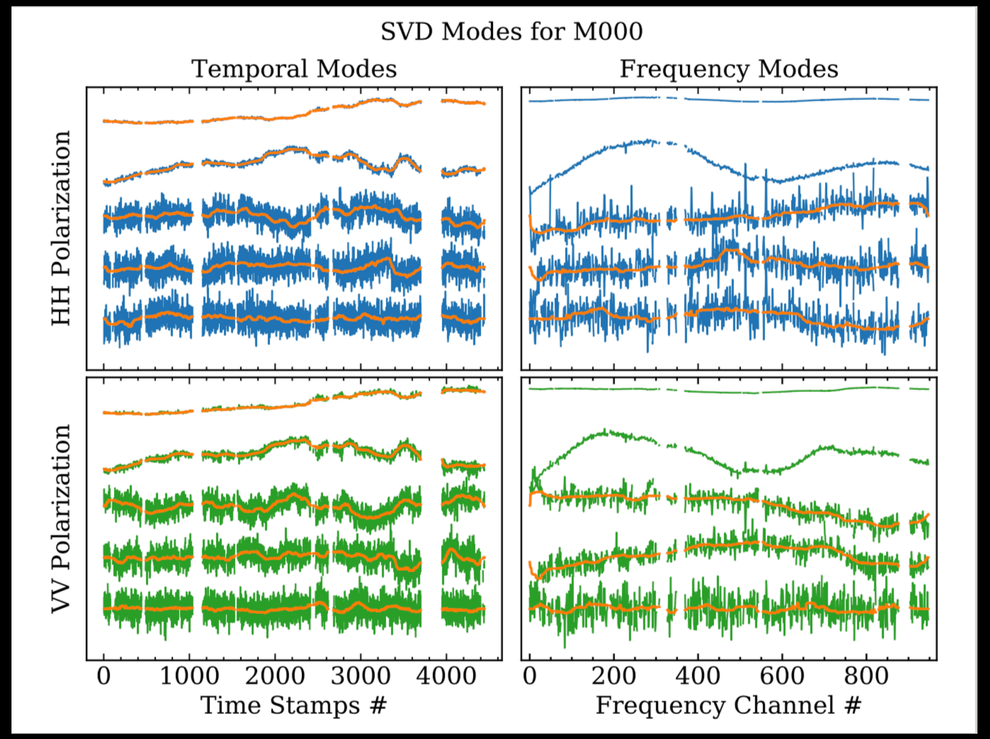




1/f Noise Measurements

- Singular Value Decomposition (SVD)

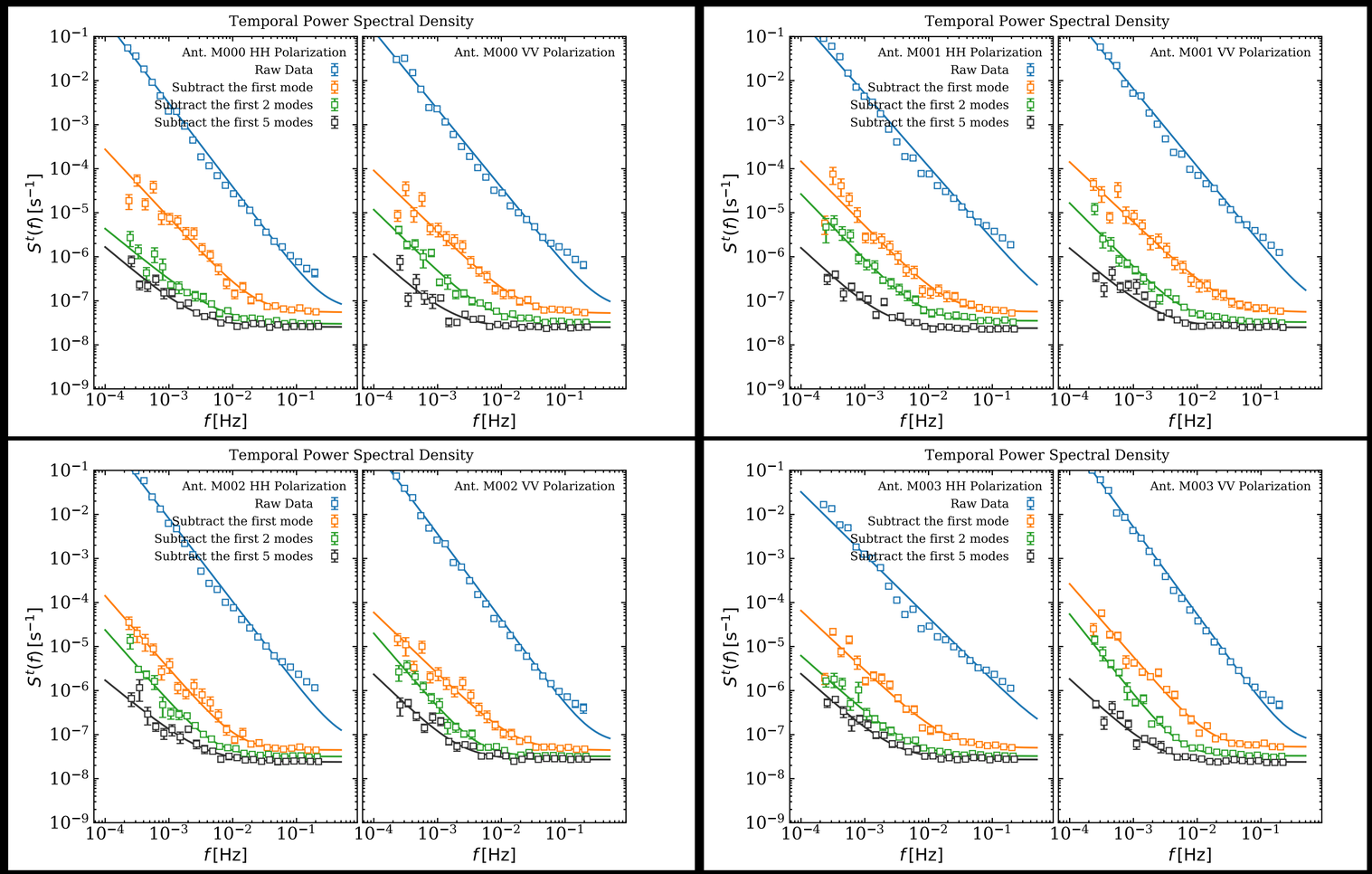




1/f Noise Measurements

- PS estimation

$$\hat{S}^t(f,\nu) = \left| \sqrt{\frac{\delta t}{N}} \sum_{t=1}^{N} d_t(\nu) \exp[-2\pi i f t \delta t] \right|^2$$



1/f Noise Measurements

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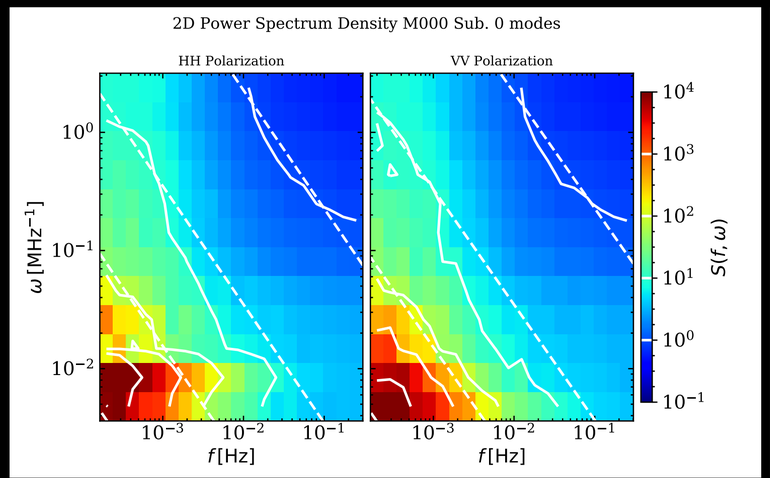
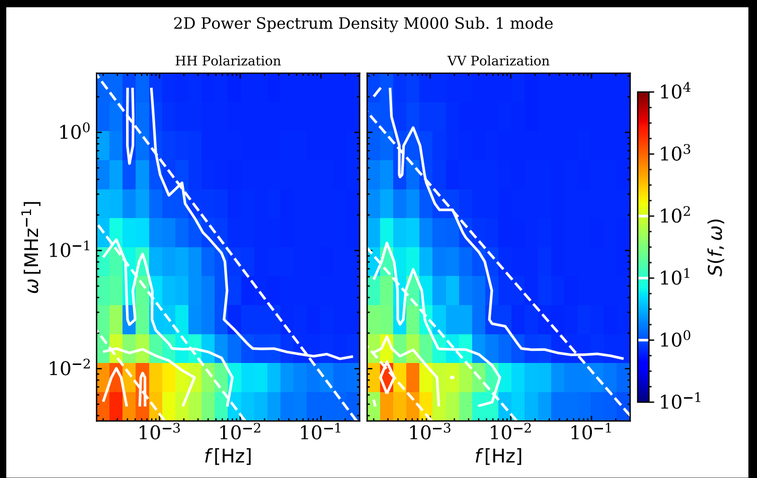
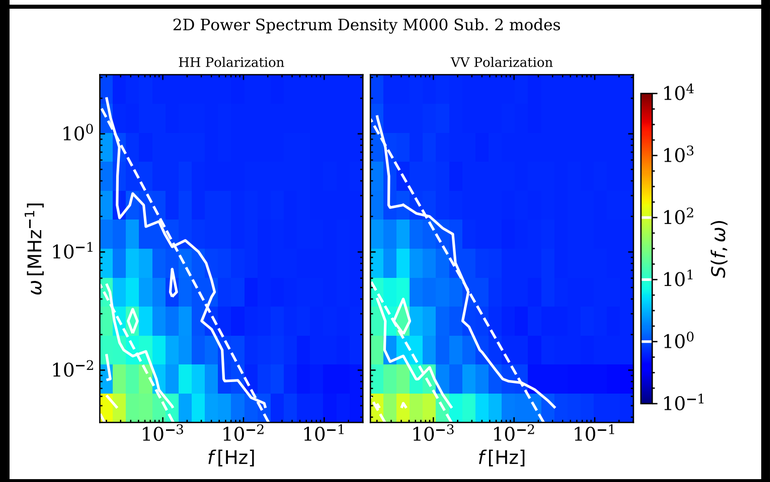
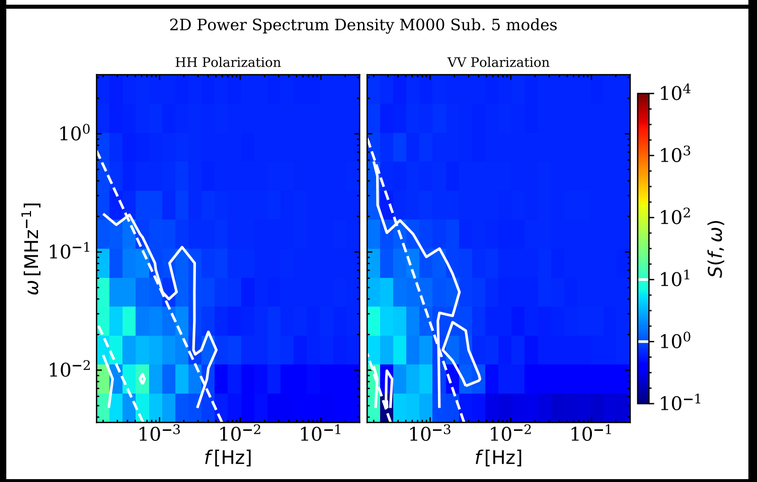
$$\hat{S}(f,\omega) = \left| \sqrt{\frac{\delta t \delta \nu}{N_t N_\nu}} \sum_{t=1}^{N_t} \sum_{\nu=1}^{N_\nu} \exp\left[-2\pi i \left(f t \delta t + \omega \nu \delta \nu\right)\right] \right|^2$$









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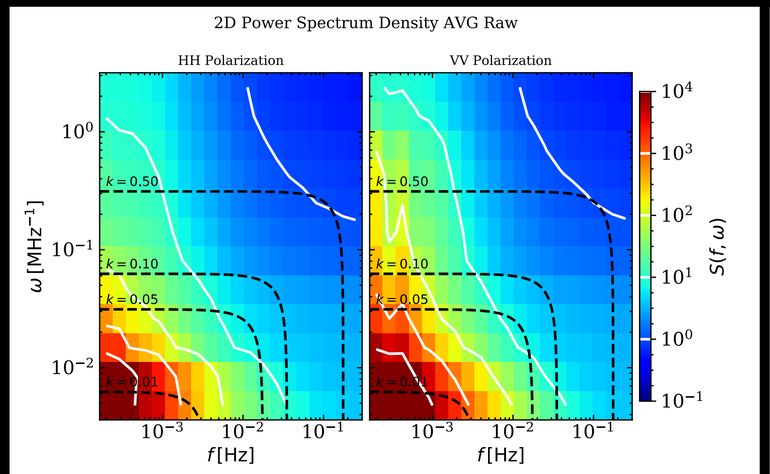
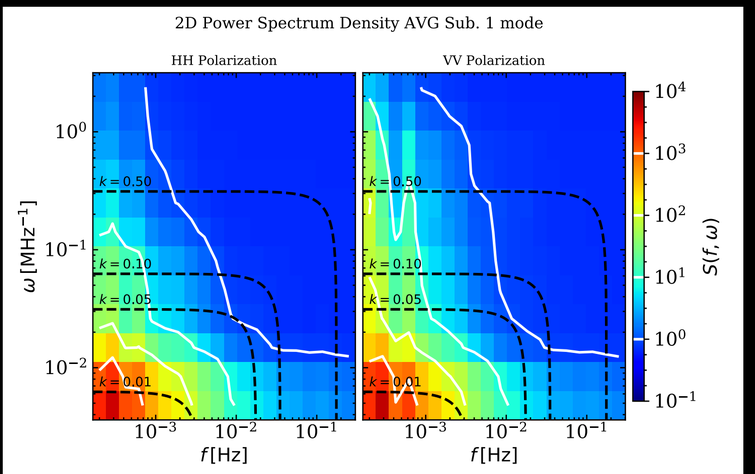
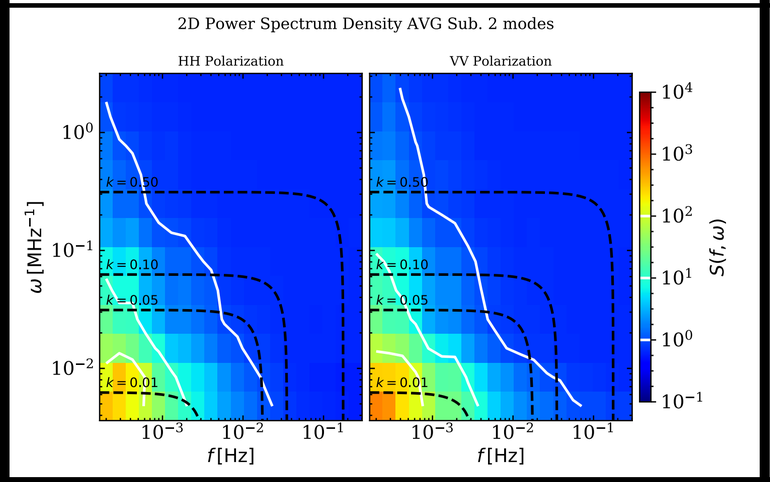
$$\omega = \frac{\nu_0}{\nu_{\rm obs}^2} \frac{c}{H(z)} \frac{k_\parallel}{2\pi}, \quad f = \frac{k_\perp \chi(z) u}{2\pi},$$

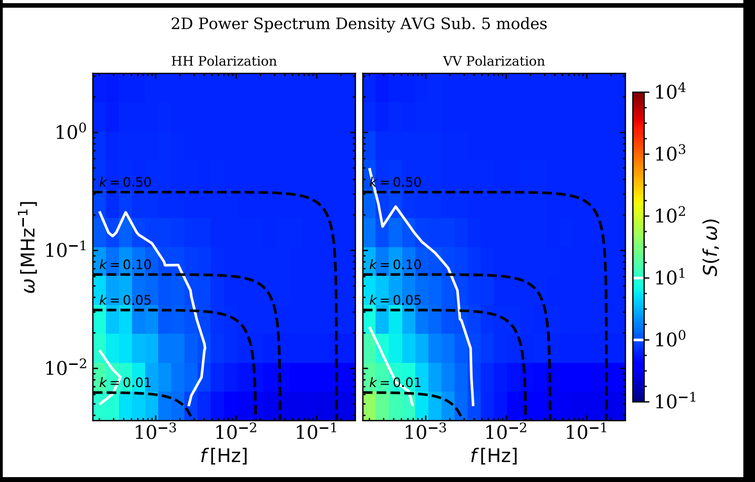
$$\text{and } k^2 = k_\parallel^2 + k_\perp^2$$

v=900MHz, u=5arcmin/s









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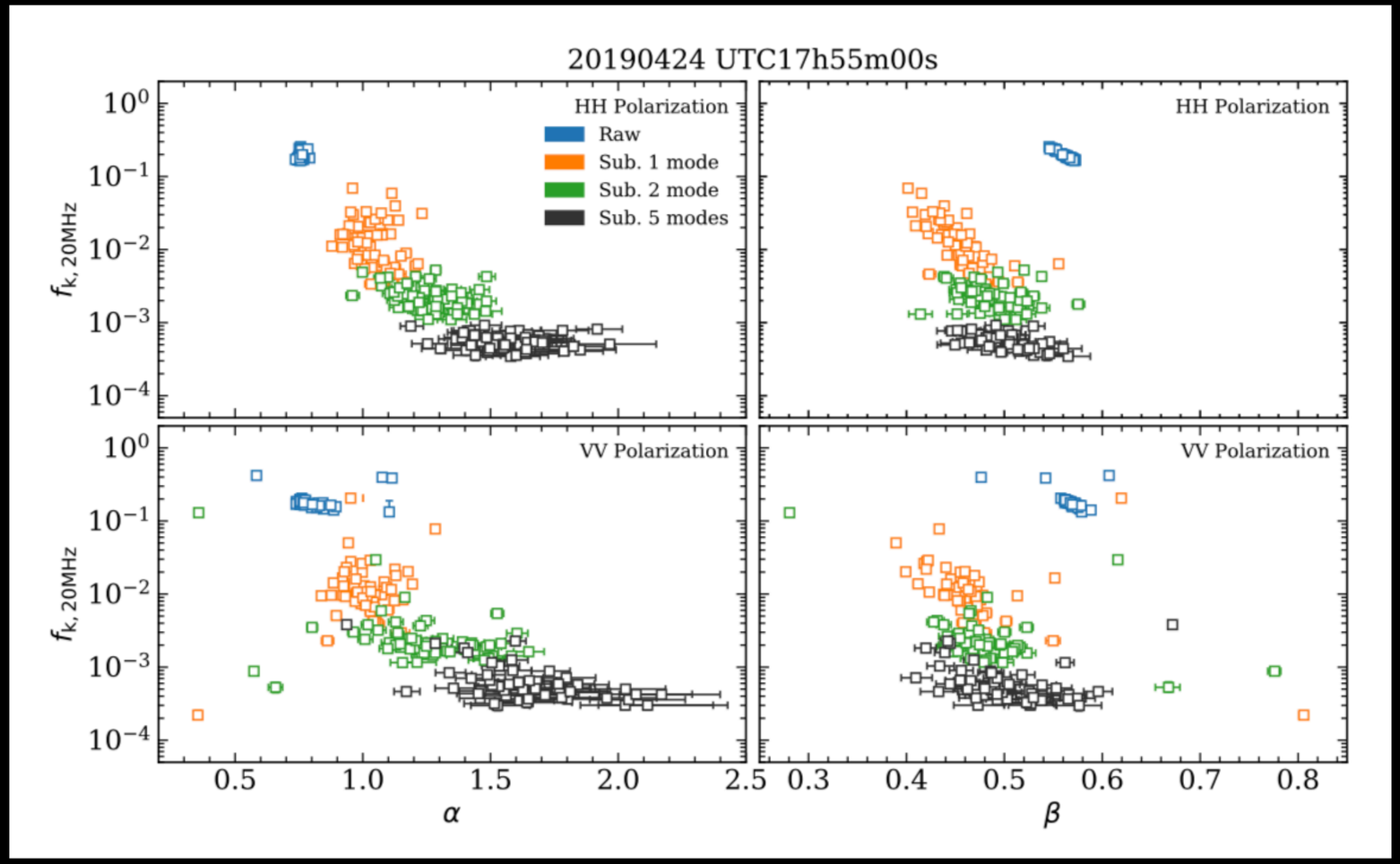

Summary

- HI IM is considered promising as a probe of cosmological LSS
- It has been test with GBT/Parkes
- We proposed a HI IM project with MeerKAT
- 1/f noise analysis for MeerKAT

Thanks !