A New Public 21-cm EoR Signal Database, and How it Can Make Your Life **sunnier**

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Observatoire de Paris

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The Motivation:

- We know the simulated 21cm signal can vary considerably
- Parameter exploration: Mesinger, Greig & Sobacchi 2016, Cohen et al. 2016, Grieg & Mesinger 2017 Fialkov et al. 2017
- Exploration of a parameter space with high-resolution models
- Necessary for End-to-End simulations
- Many other things we can do with it (we will get back to this)

The goal:

Database of simulations exploring a 3D parameter space

- For each model: high and low (SKA-level) lightcones
- Choose a parameter space
- Derived statistical quantities for each model
  - Power Spectra
  - Pixel Distribution Functions
- Make the whole thing publicly available
- Make life sunnier!

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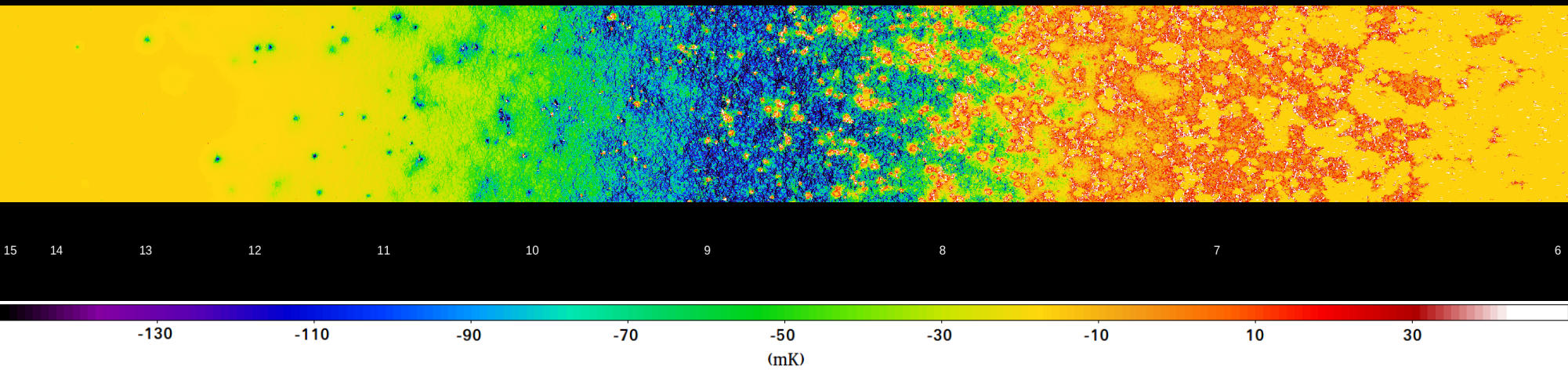
High Resolution Versions

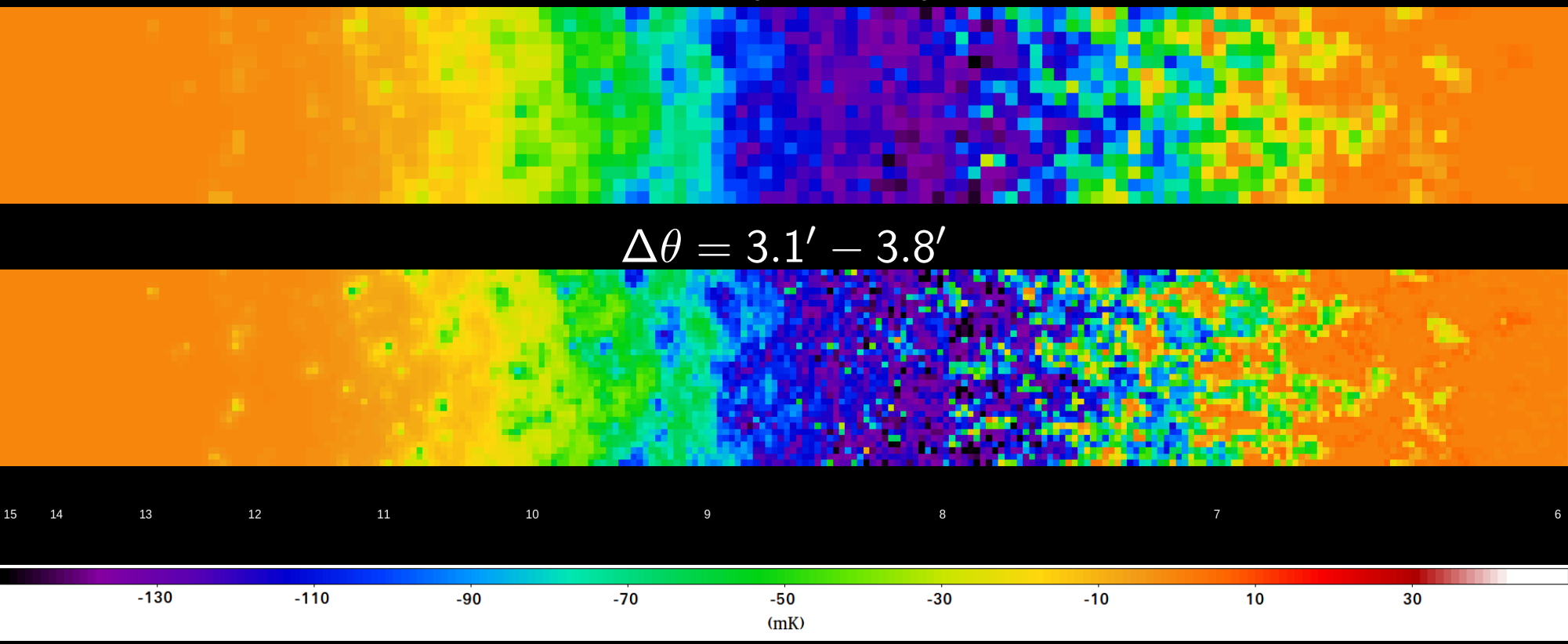


- LICORICE Radiative Hydrodynamic Simulation (Baek, 2009)
- 1024^3 (200 Mpc·h^{-1} box)
- Resolves halos $\approx 10^{10}\mathrm{M}_{\odot}$
- Lightcones at $z \in [6,15]$ ($1024 \times 1024 \times 8192$)

Low Resolution Versions

$\Delta\theta = 6.1' - 7.6'$

$\Delta\theta = 3.1' - 3.8'$



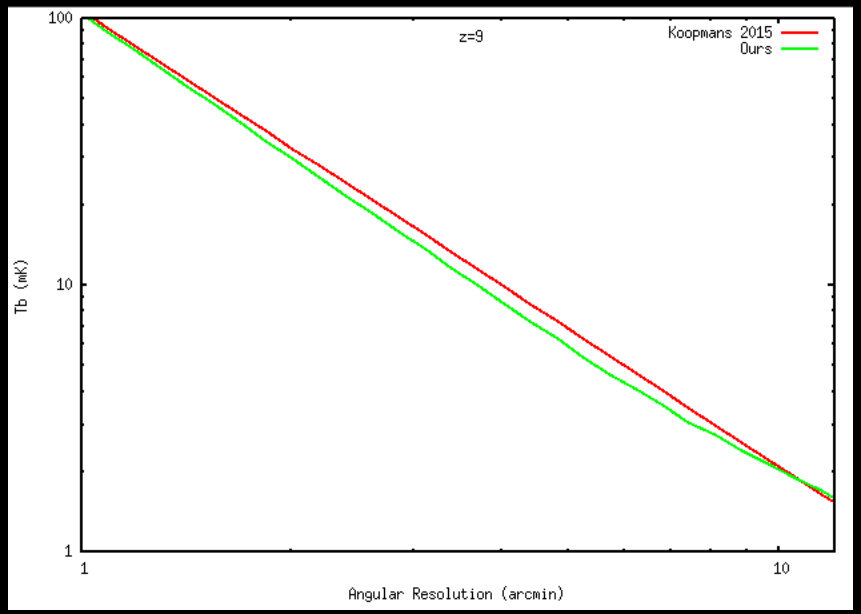
Noise

What we want:

$$\Delta T_b = (\Delta\theta, z)$$

So we made one:

- Full UV modelling of Thermal Noise
- Latest values of Station Layout, Collection Area, etc.
- Agrees with Santos, 2005; McQuinn, 2006; Koopmans, 2015



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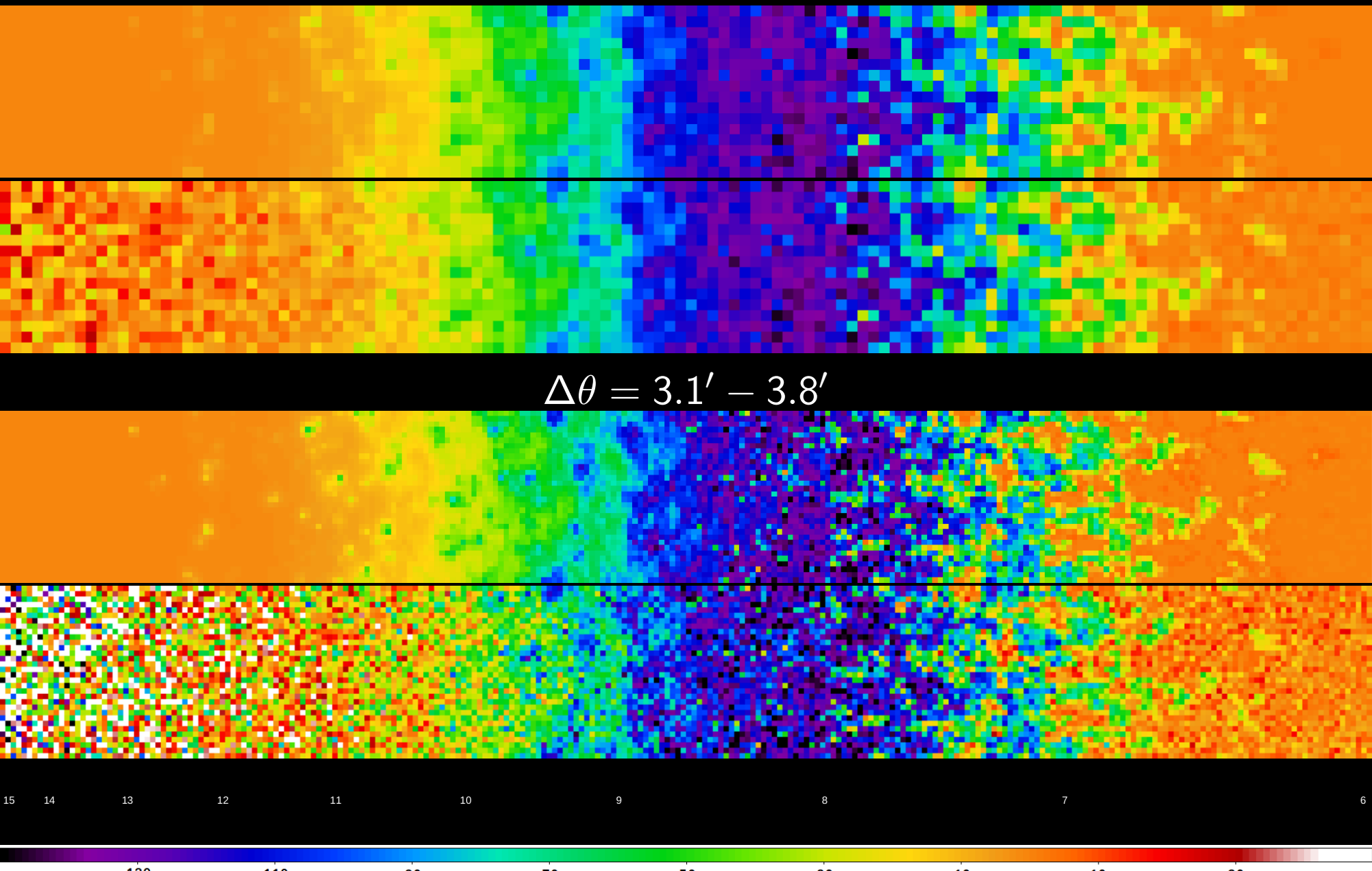

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Parameter Space

- f_α - Lyman Band Emissivity
  - $Ly\alpha$ energy actually emitted by the simulation vs. fiducial
  - $f_\alpha = \frac{E^{\rm eff}(\nu_\alpha, \nu_{\rm limit})}{E(\nu_\alpha, \nu_{\rm limit})}$
  - $f_\alpha \in (0.5, 1, 2)$
- f_X - X-ray Emissivity
  - X-ray luminosity of early SFR
  - $L_X = 3.4 \times 10^{40} f_x \left(\frac{\rm SFR}{1 {\rm M}_\odot \times {\rm yr}^{-1}} \right) {\rm erg\ s}^{-1}$
  - $f_X \in (0.1, 0.3, 1, 3, 10)$
- $r_{H/S}$ - Hard/Soft X-ray Ratio
  - What fraction of X-ray photons originate in XRB
  - $r_{H/S} = \frac{f_X^{\rm XRB}}{f_X}$ (where $f_X = f_X^{\rm AGN} + f_X^{\rm XRB}$)
  - $r_{H/S} \in (0, 0.5, 1)$

For full parameter definitions see Semelin et al. 2017

45 models $\times$ 3 directions $=$ 135 in total.

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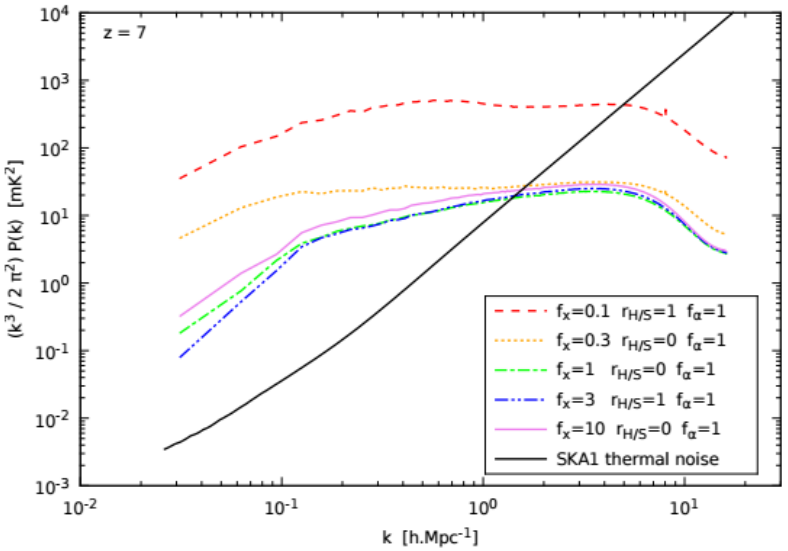
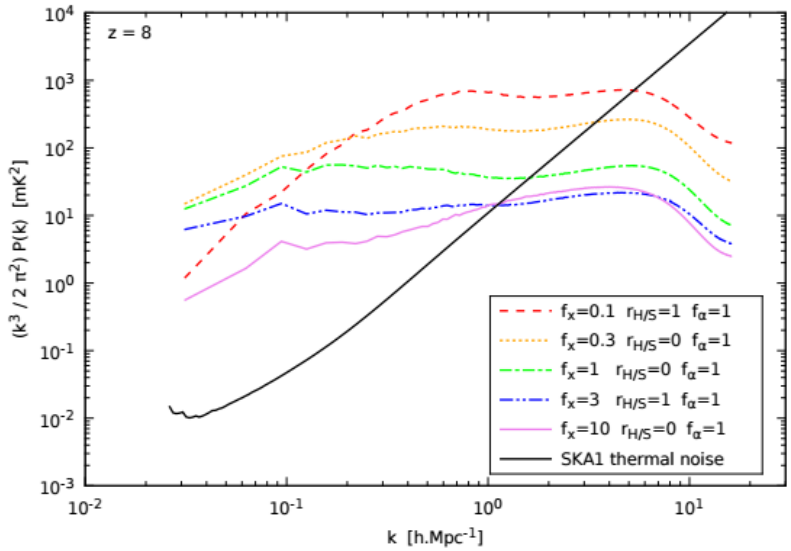
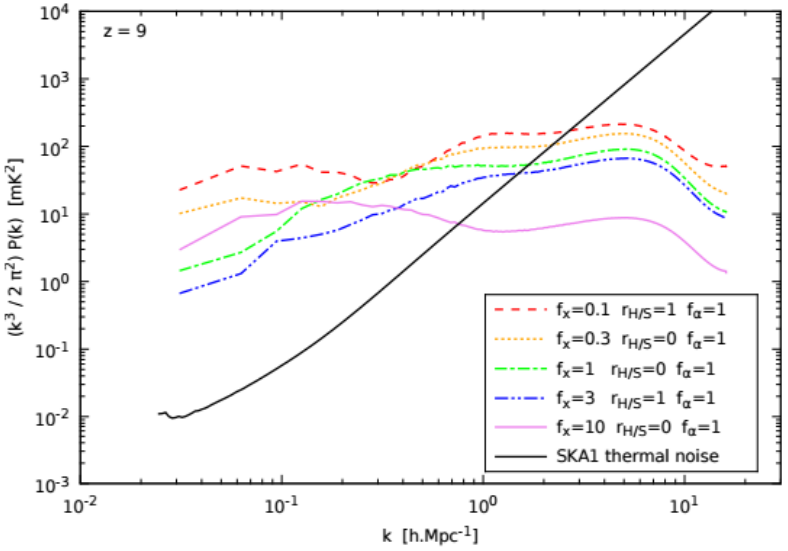
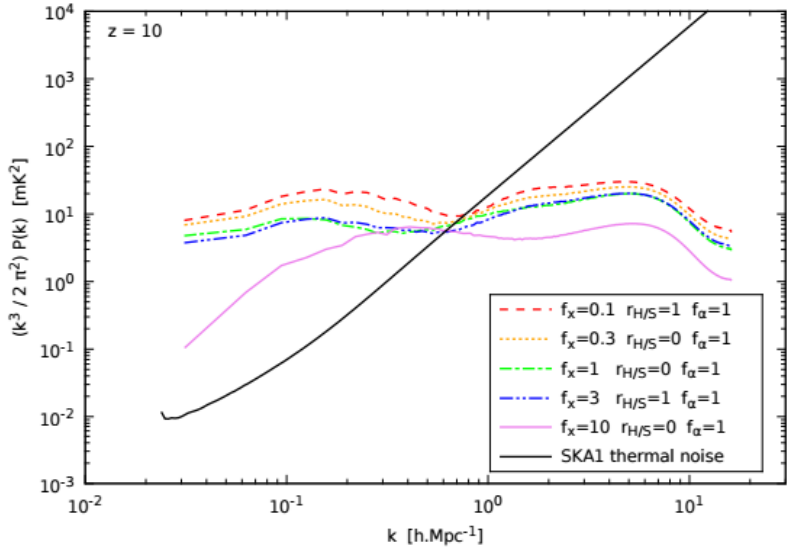
Power Spectra

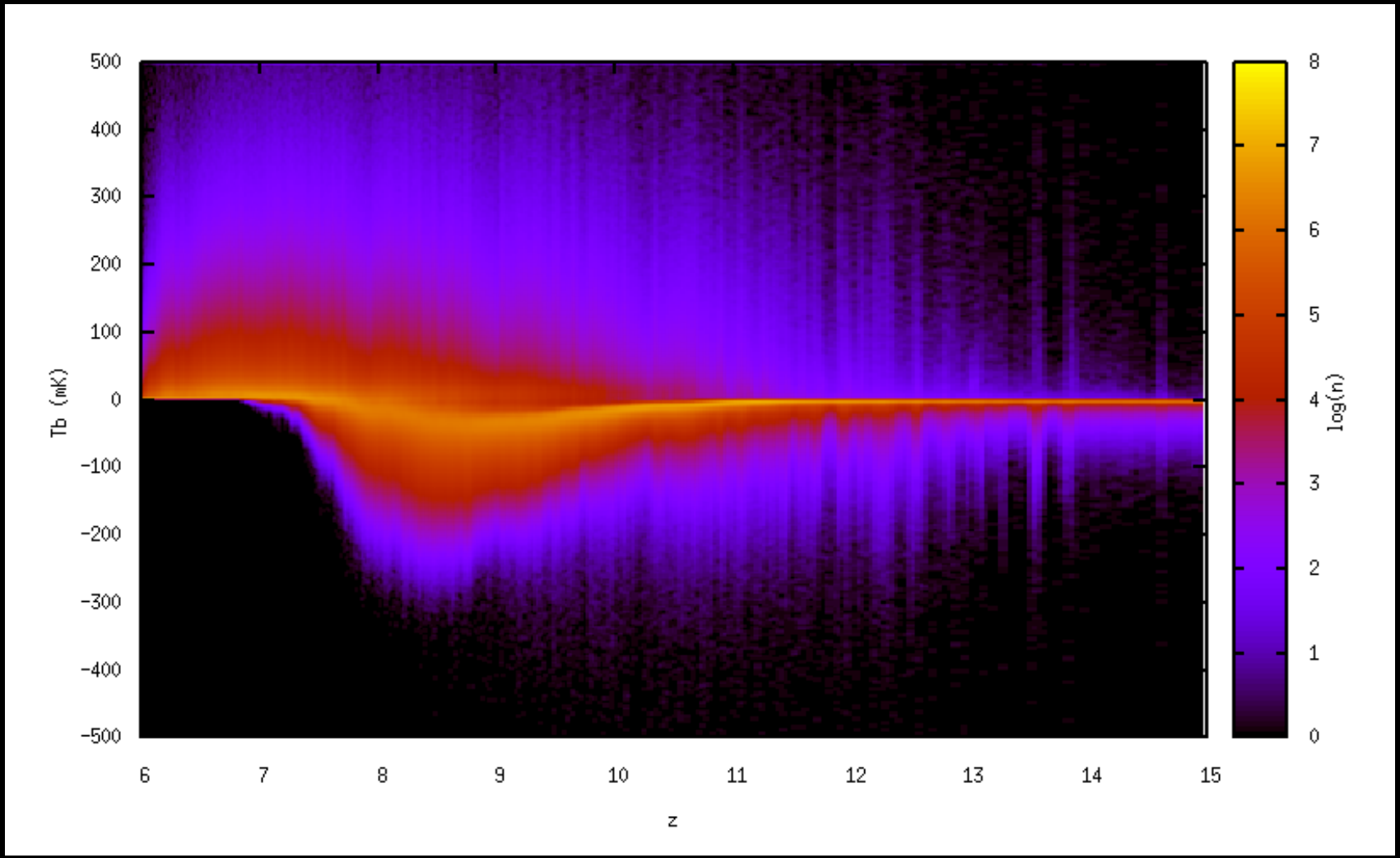








Pixel Distribution Function



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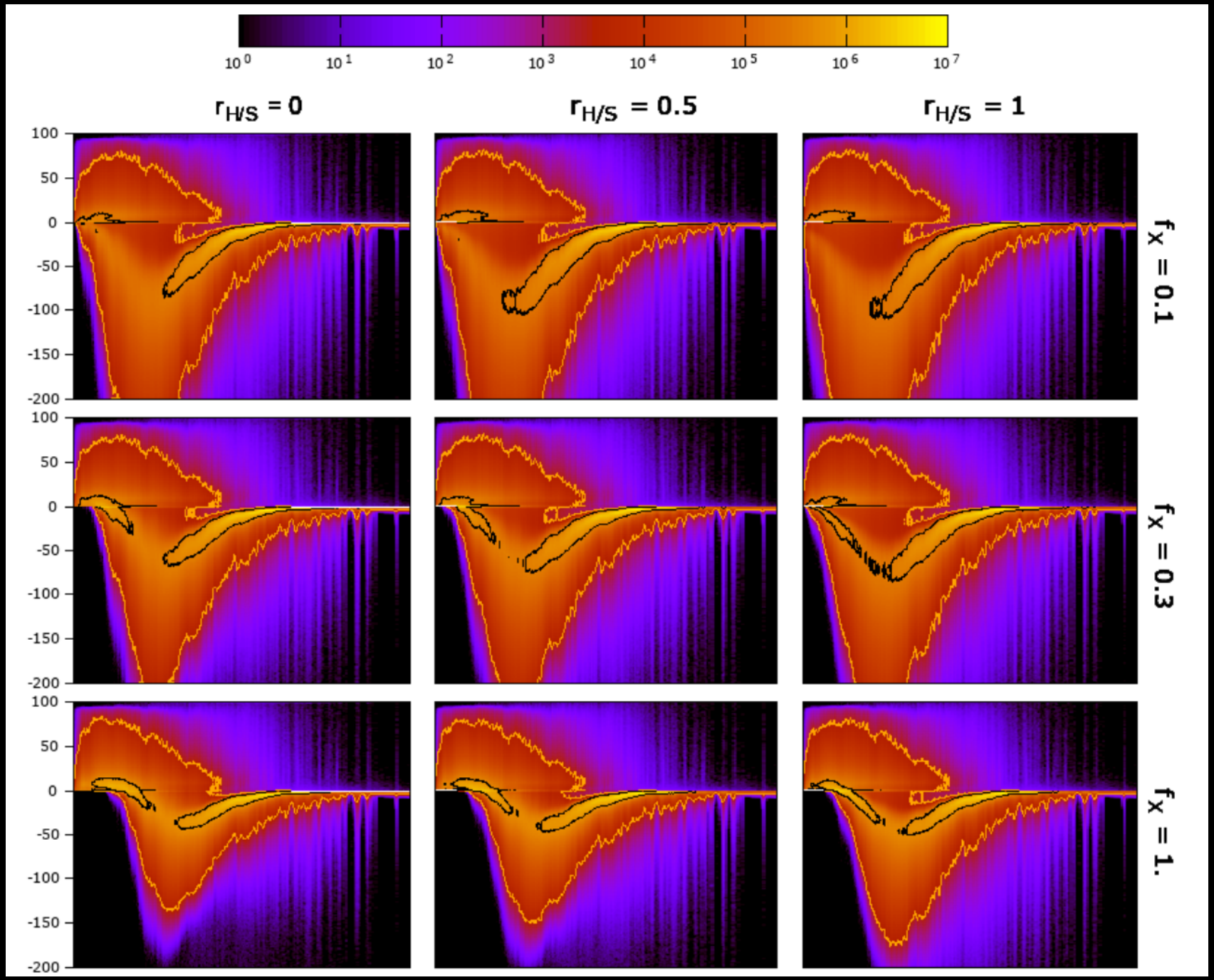

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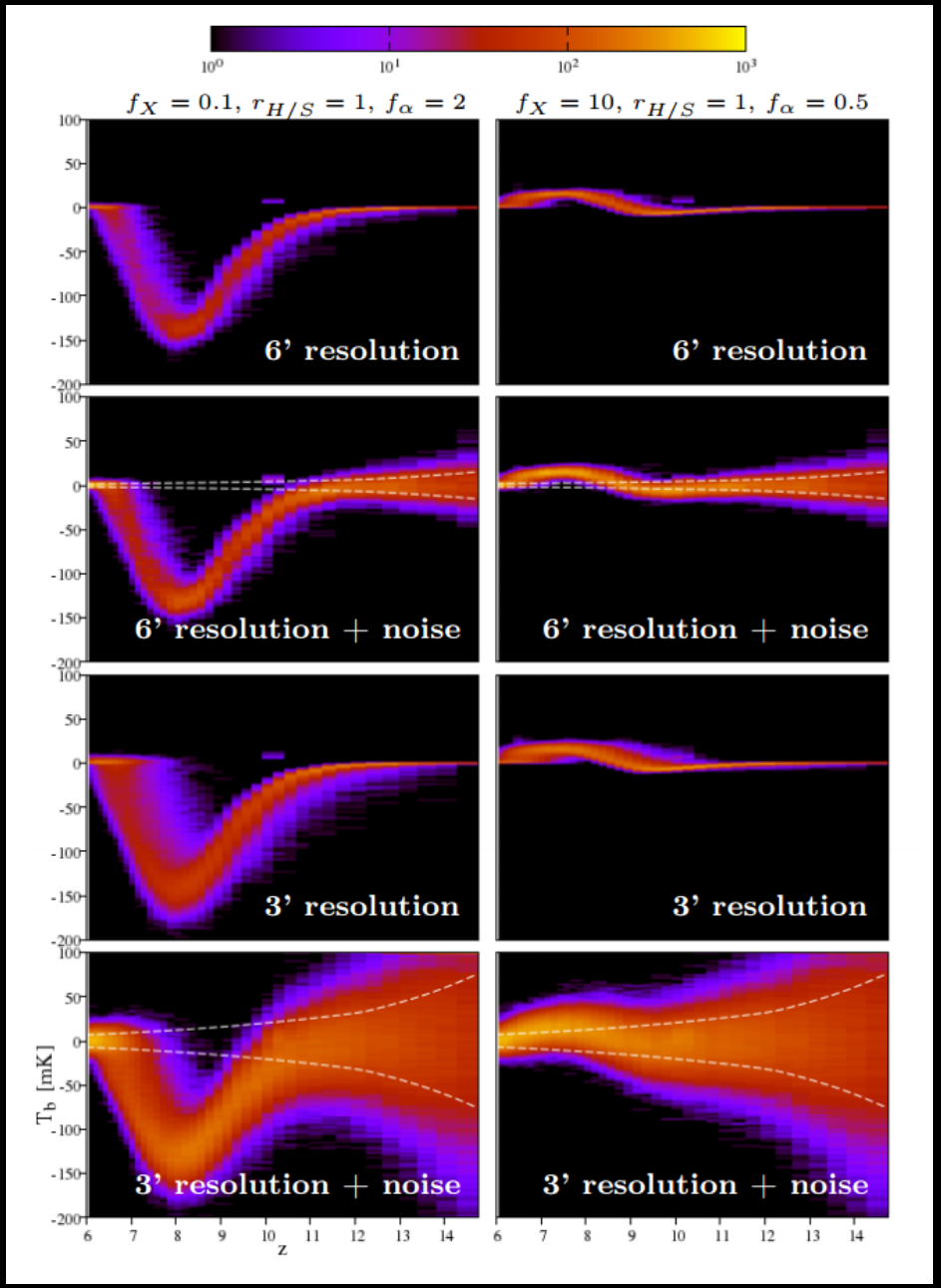

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21SSD: 21CM SIMULATED SIGNAL DATABASE

Description of the project

The 21cm Simulated Signal Database is a publicly available repository of 21cm signal lightcones produced with a number of large radiative-hydrodynamics simulations.

The simulations are described in *21SSD: a public database of simulated 21-cm signals from the epoch of deionization,* Semelin, Eames, Bolgar and Caillat, 2017.

To access the data, register, log in then go to the Data Files menu.

For questions concerning the simulations and the data contact:

benoit.semelin at obspm.fr

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-45 lightcones (high res & SKA level)
-Noisy & Clean
-Noise code
-Corresponding PS
-Corresponding PDF
-Lifetime Warranty

Available at 21ssd.obspm.fr

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Applications:

Some neat things we could do with all this

- Parameter extraction
  - Shimbukuro & Semelin 2017
- PS/Thermal noise templates
- End-to-End Simulations
- Fine tuning semi-numerical simulations
- Train neural networks

Distance Measures

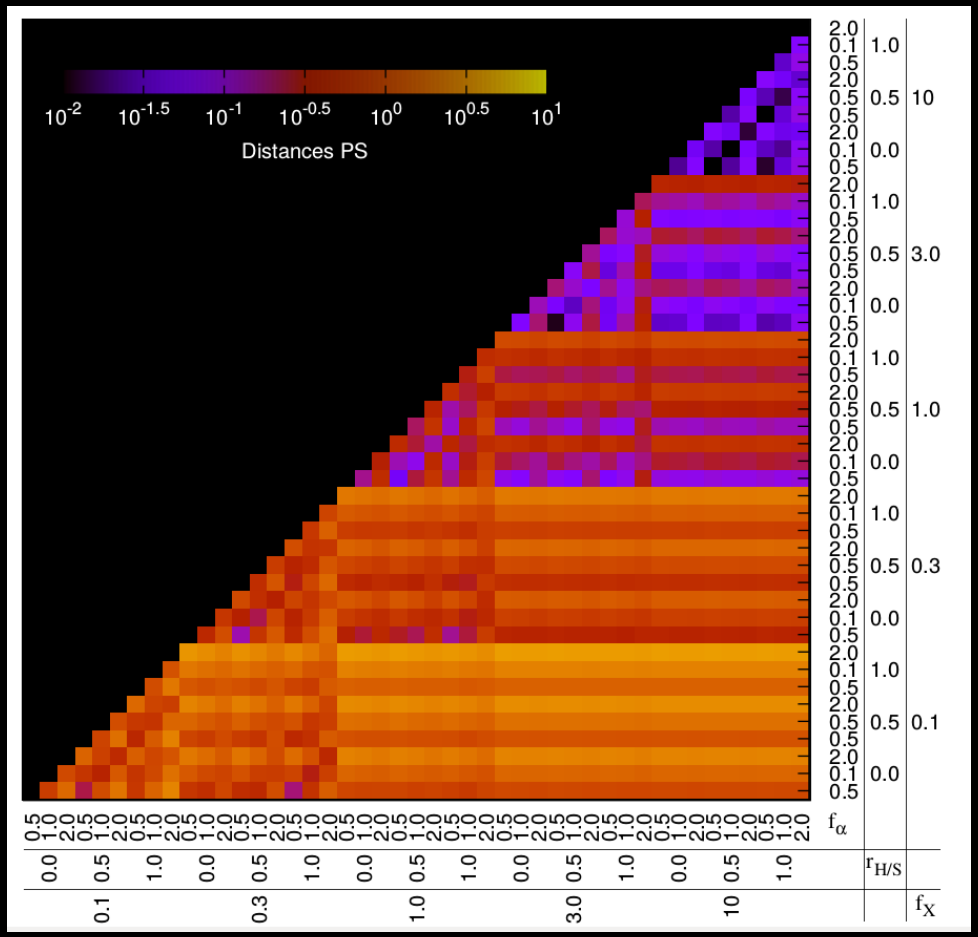
Definition of 'distance' given by the standard L_2 norm:

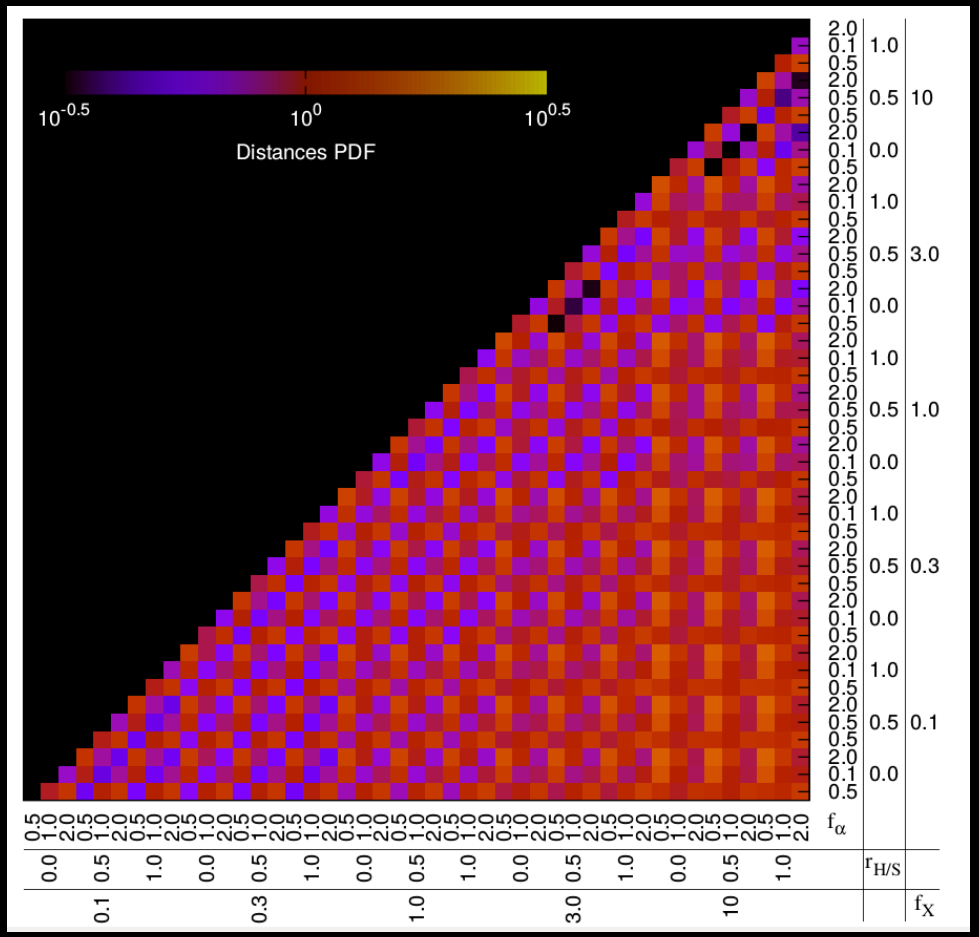
$$D_{i,j}^{PS} = \left(\int (PS_i(k,z) - PS_j(k,z))^2 dkdz \right)^{\frac{1}{2}}$$

$$D_{i,j}^{PDF} = \left(\int (log(PDF_i(T_b,z)) - log(PDF_j(T_b,z)))^2 dkdz \right)^{\frac{1}{2}}$$

PS_i and PDF_i being the Power Spectrum and Pixel Density Function, respectively, of the i^{th} model.

Distance Measures

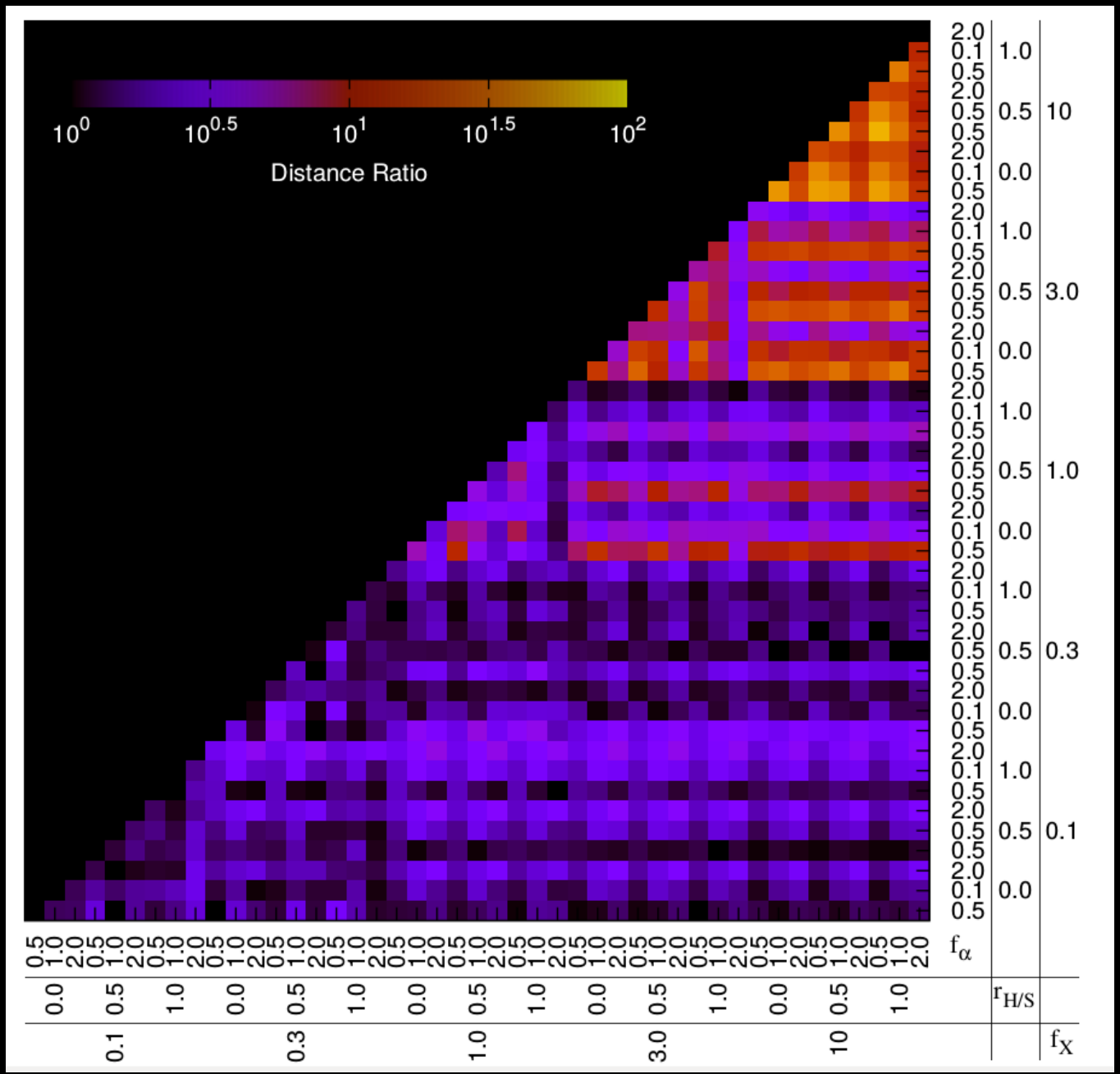




Distances Between Peruvian Cities

Ciudades	Abancay	Arequipa	Ayacucho	Cajamarca	Cerro de Pasco	Cusco	Chachapoyas	Chiclayo	Huancavelica	Huancayo	Huánuco	Huaraz	Ica	La Oroya	LIMA	Moquegua	Moyobamba	Piura	Pucallpa	Pto. Maldonado	Puno	Tacna	Trujillo
Abancay																							
Arequipa	713																						
Ayacucho	399	1078																					
Cajamarca	1759	1860	1394																				
Cerro de Pasco	910	1312	511	1154																			
Cusco	198	515	597	1957	1108																		
Chachapoyas	2094	2195	1729	335	1489	2292																	
Chiclayo	1672	1773	1307	260	1067	1870	622																
Huancavelica	661	1374	262	1291	395	859	1626	1204															
Huancayo	656	1308	257	1150	254	854	1485	1063	141														
Huánuco	1017	1419	618	1261	107	1215	1596	1174	502	361													
Huaraz	1316	1417	951	857	711	1514	1192	770	848	707	818												
Ica	605	706	372	1154	606	803	1489	1067	634	602	713	711											
La Oroya	781	1183	382	1025	129	979	1360	938	266	125	236	582	477										
LIMA	955	997	556	856	305	1153	1186	763	445	299	410	517	303	174									
Moquegua	851	138	1216	1998	1450	653	2333	1911	1478	1446	1557	1555	844	1321	1140								
Moyobamba	2287	2388	1922	528	1682	2445	193	815	1819	1678	1789	1385	1682	1553	1471	2526							
Piura	1881	1982	1516	496	1276	2079	831	209	1413	1272	1383	979	1276	1147	973	2120	1024						
Pucallpa	1388	1790	989	1620	478	1586	1967	1545	873	732	371	1189	1084	607	781	1928	2160	1754					
Puerto Maldonado	731	1048	1130	2490	1641	533	2825	2403	1392	1387	1748	2047	1336	1512	1637	1186	3018	2612	2119				
Puno	587	326	986	2186	1638	389	2573	2099	1248	1243	1604	1743	1032	1509	1542	464	2714	2308	2116	922			
Tacna	997	284	1396	2144	1596	799	2479	2057	1366	1592	1703	1701	990	1467	1293	146	2672	2266	2074	1332	610		
Trujillo	1465	2022	1100	294	860	1663	629	207	997	856	724	563	860	731	557	1704	822	416	1338	2196	1892	1850	
Tumbes	2164	2265	1799	750	1559	2362	1114	492	1696	1555	1666	1262	1559	1430	1299	2403	1307	283	2037	2895	2591	2549	699

Parameter Extraction



Future Projects

- Finding an Optimal Parameter Space
  - Create a parameter space (21cmFAST)
  - Calculate the distances between all simulations
  - Calculate the 'Density Gradient' of the database
  - Adjust parameters and recreate database until 'Density' is uniform
  - *Coming Spring 2018!*
- Train neural networks
  - Will require more models
  - Hayato?

Thanks!

also my phd ends in 10 months so...