

Filament Hunting: HI 21cm Emission from the IGM in Large Scale Filaments

Kooistra et al. (2017)
2017MNRAS.468..857K

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Collaborators:

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IAU Symposium 333: Peering towards Cosmic Dawn
Dubrovnik



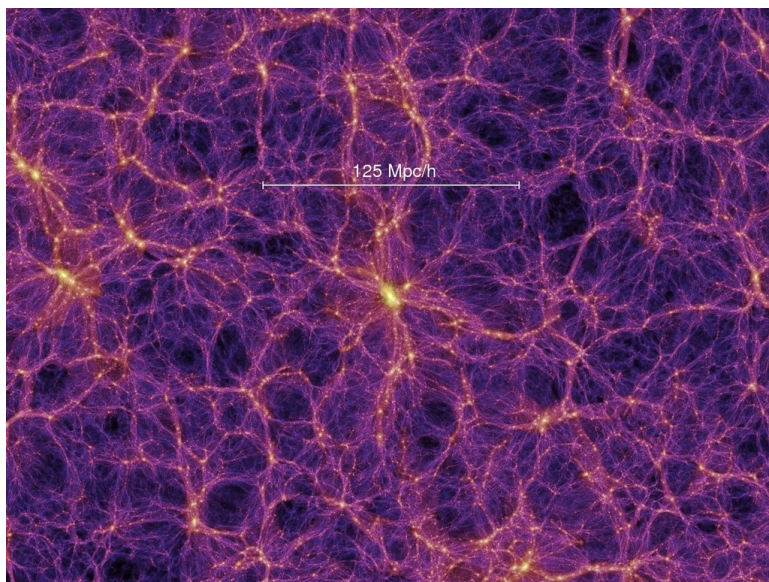
university of
 groningen

faculty of mathematics
and natural sciences

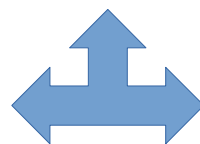
kapteyn astronomical
institute

Motivation

DM



HI gas ?



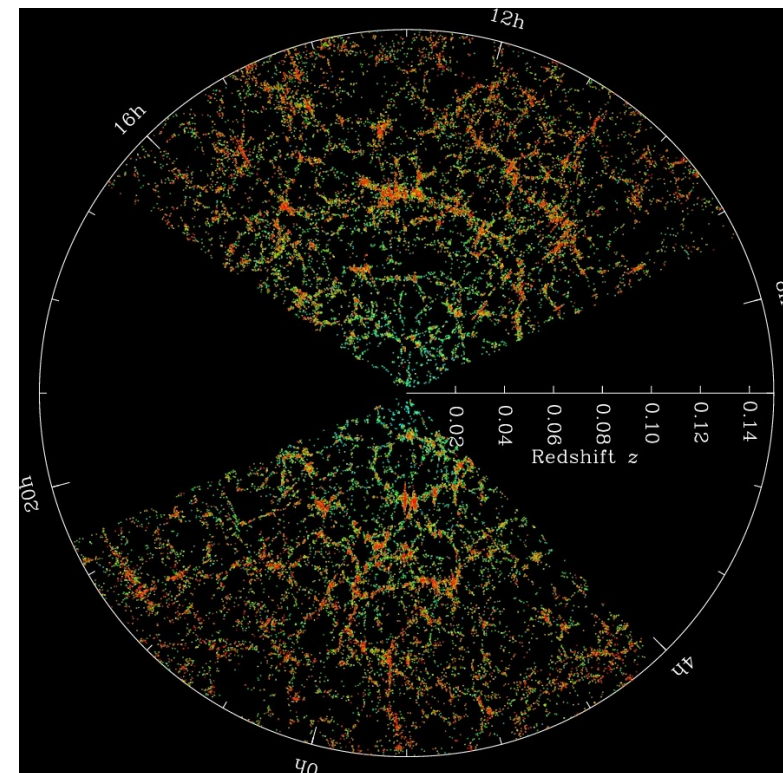
<https://wwwmpa.mpa-garching.mpg.de/galform/virgo/millennium/>

- Large Scale Structure
- Galaxy formation in filaments
 - First large scale structure to form
- UV/X-ray background

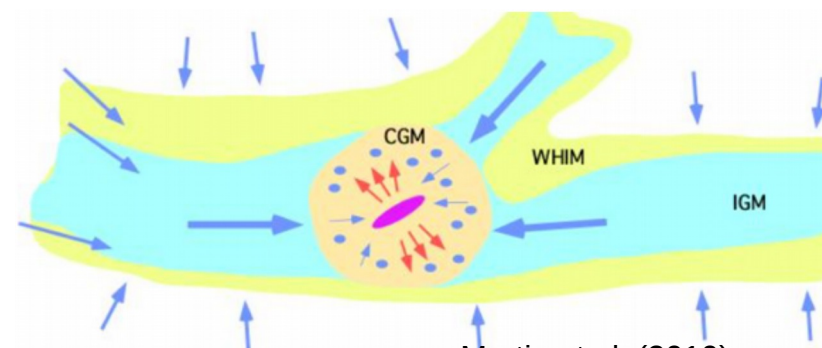
Two main components:

- **Cold IGM ($T_K = 10^2 - 10^5$ K, X-ray/UV-BG dominated)**
- WHIM ($T_K = 10^5 - 10^7$ K, shock heated gas)

Galaxies



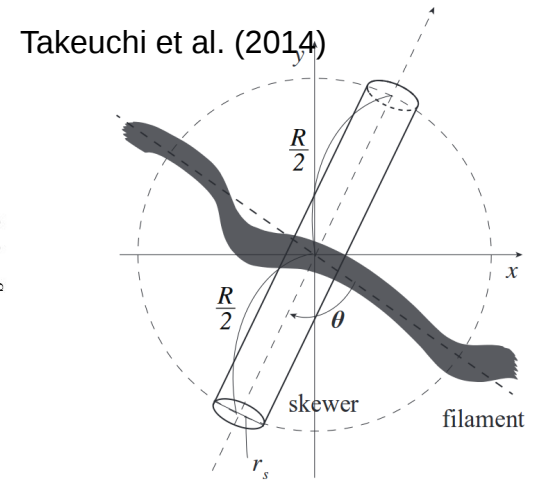
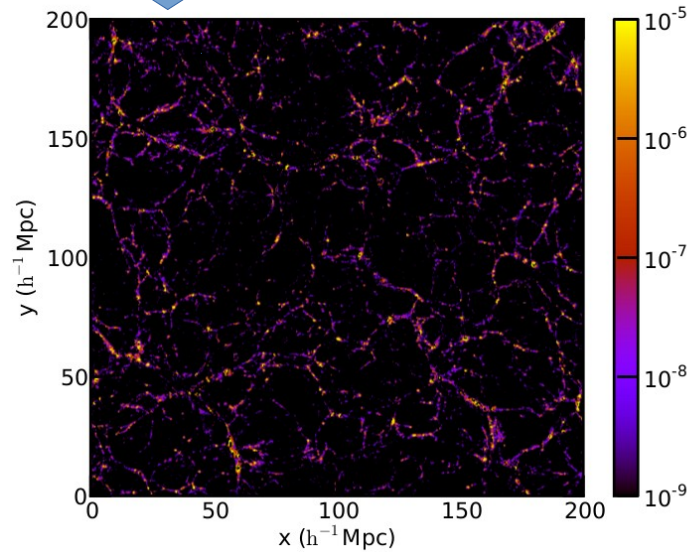
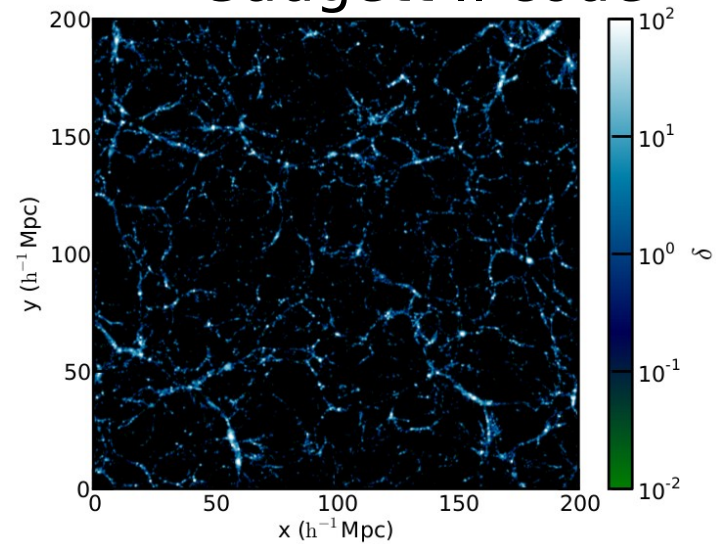
<http://www.sdss.org>



Martin et al. (2010)

Simulation

- Gadget II code



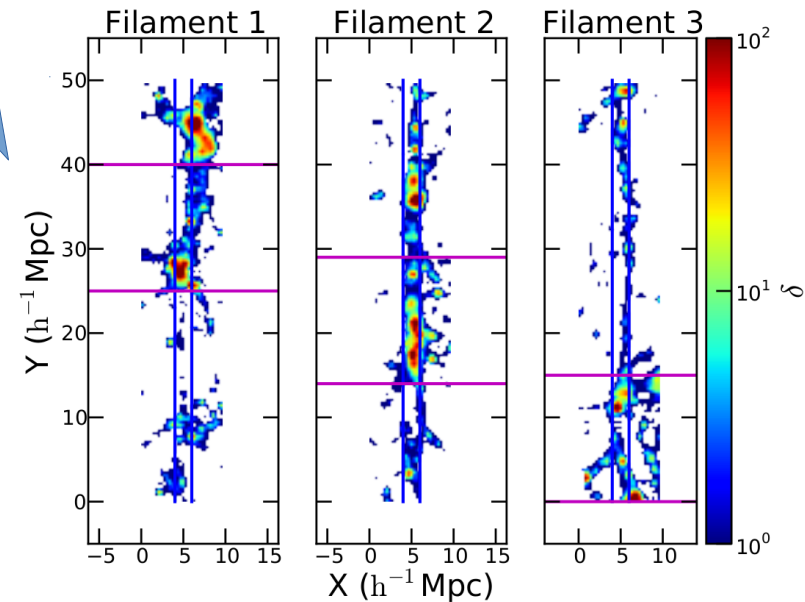
Takeuchi et al. (2014)

- $z = 0.1$
- $(1024)^3$ particles
- $L = 200 \text{ Mpc}/h$
- mass resolution: $6.514 \cdot 10^8 M_{\odot}/h$

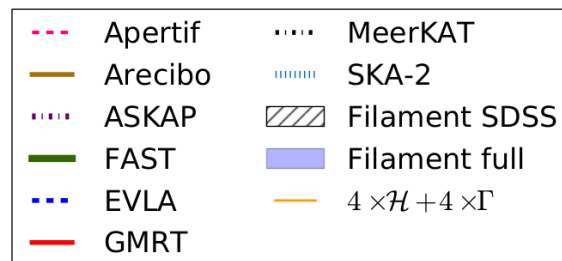
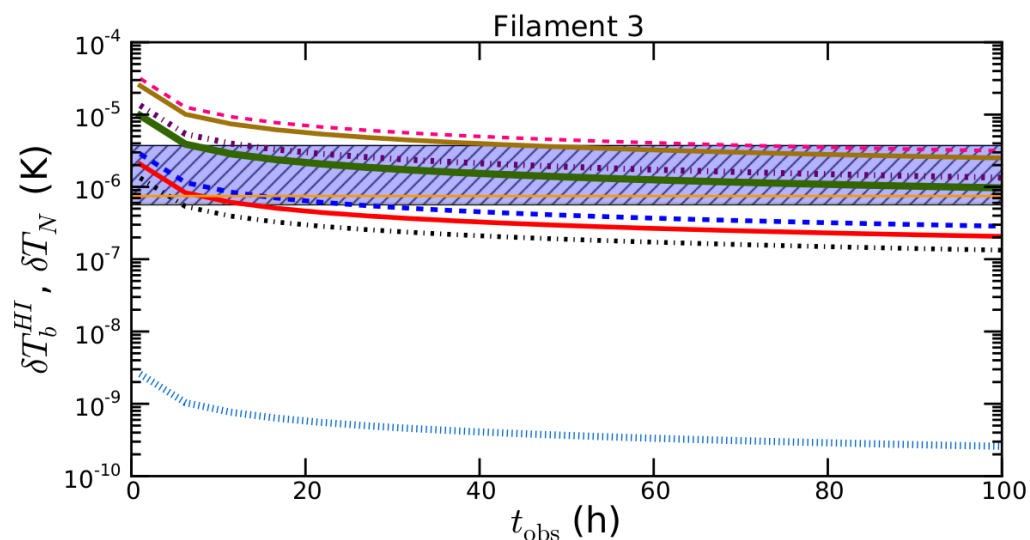
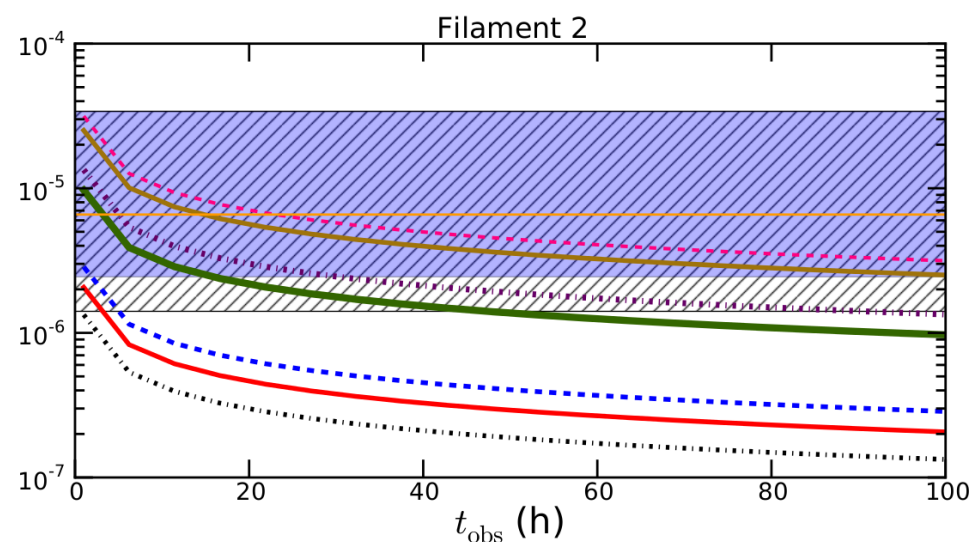
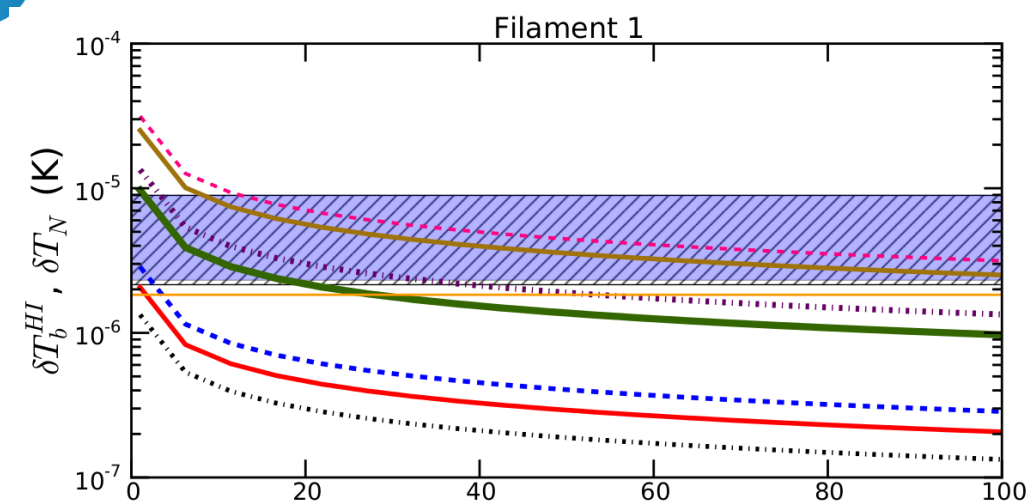
$\Delta\nu = 15 \text{ MHz} \rightarrow R = 50 h^{-1} \text{ Mpc}$
 $\Delta\theta = 10 \text{ arcmin} \rightarrow r_s = 1 h^{-1} \text{ Mpc}$

Assume ionization & thermal equilibrium with HM2012 UVB to get x_{HI} and T_g

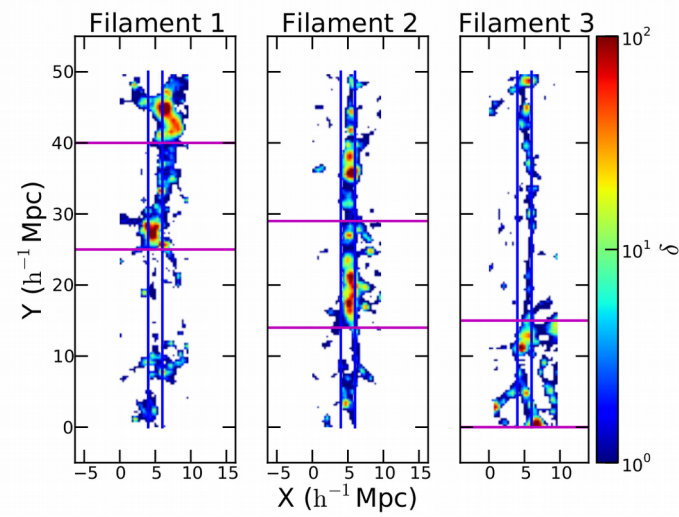
$$\delta T_b^X(z) = \frac{g_1}{g_0 + g_1} \frac{c^3 \hbar A_{10}}{4k_B \nu_{10}^2} \frac{n_X(z)}{(1+z)H(z)} \left(1 - \frac{T_\gamma(z)}{T_s}\right) \left[1 + H(z)^{-1} dv_r/dr\right]^{-1}$$



Signal aligned filaments

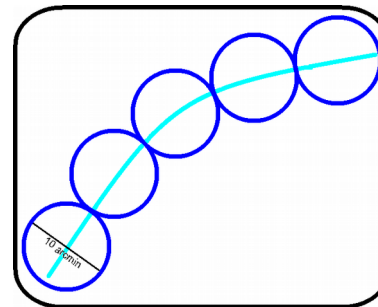
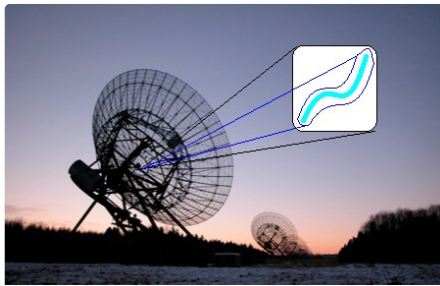


$$\delta T_N \approx \frac{c^2 (1+z)^2}{v_0^2 \Delta \theta^2 \epsilon_{ap} A_{tot}} \frac{T_{sys}}{\sqrt{\Delta \nu t_{obs}}}$$



Signal non-aligned filaments

- Exploit large FoVs
- Integrate along filament
- Filament spine from galaxy surveys



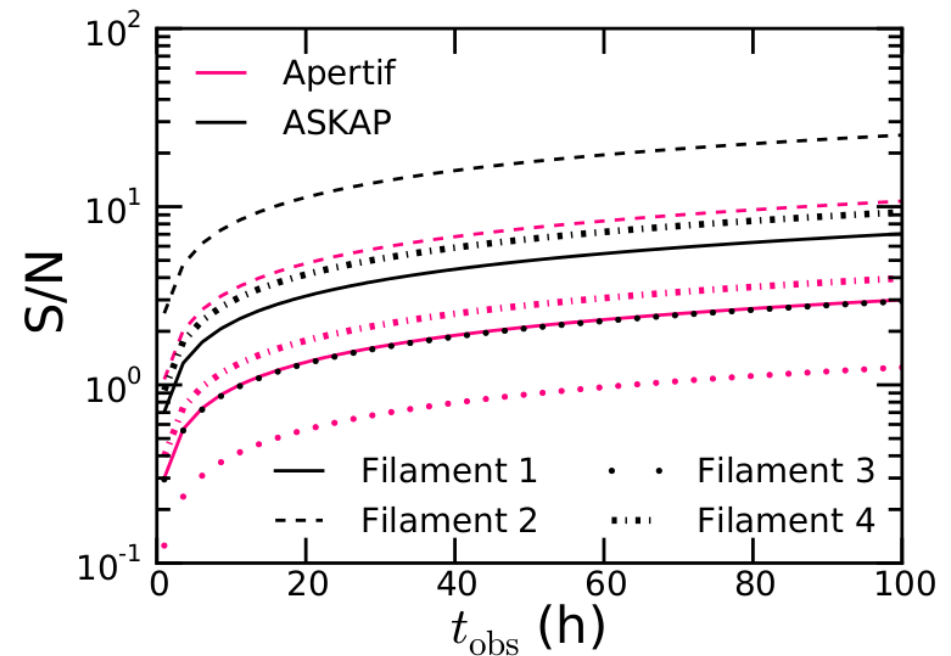
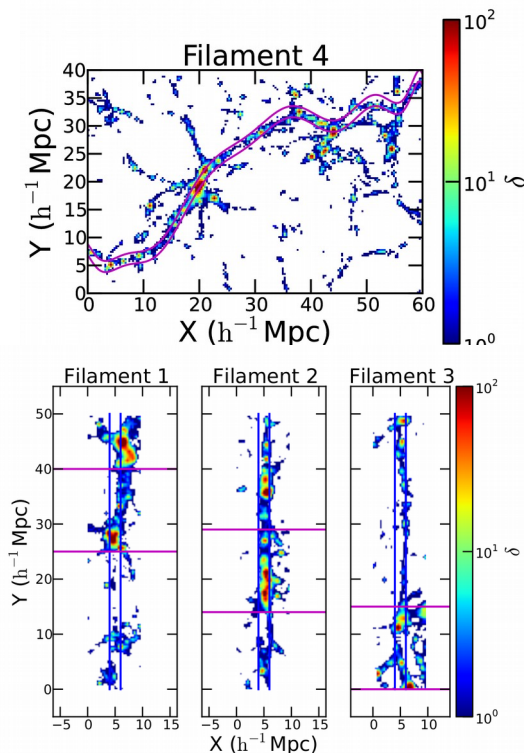
$$\delta T_N \propto \frac{1}{\sqrt{\Delta\nu}}$$

Now: $\Delta\nu \sim 0.6$ MHz vs 15 MHz!

But

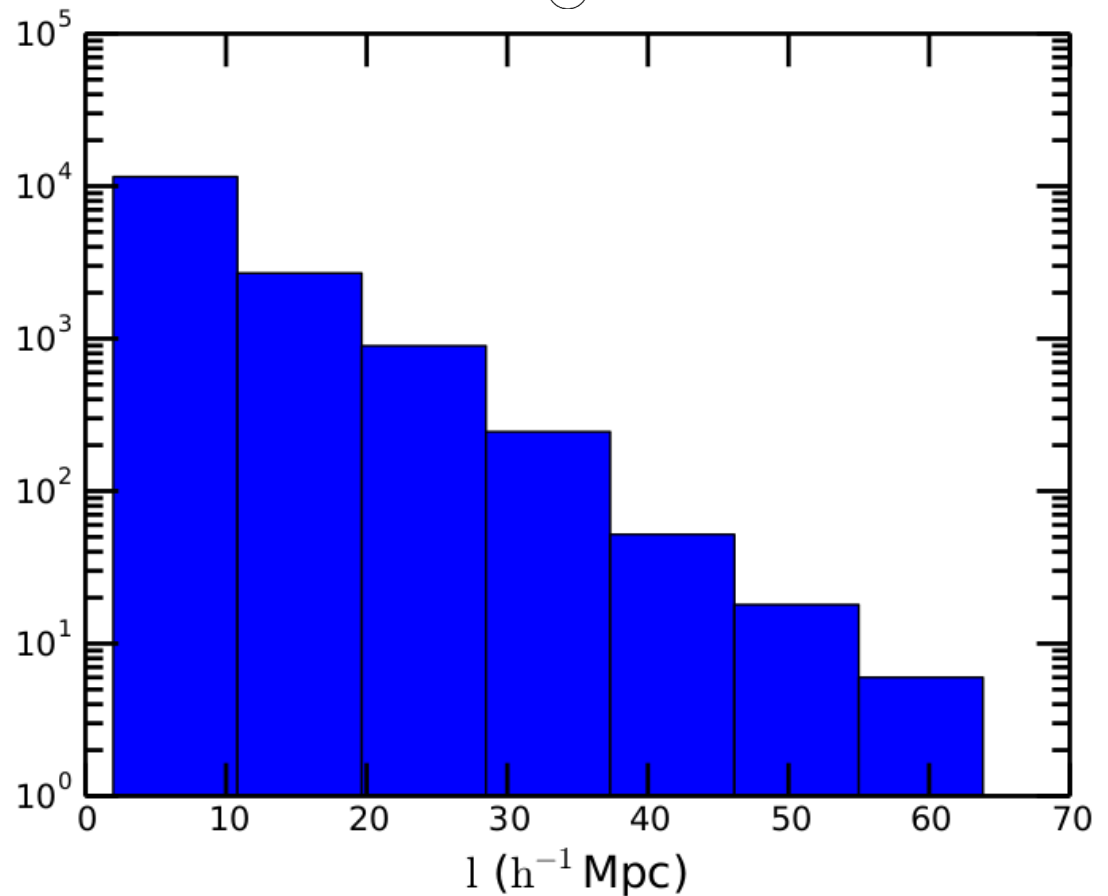
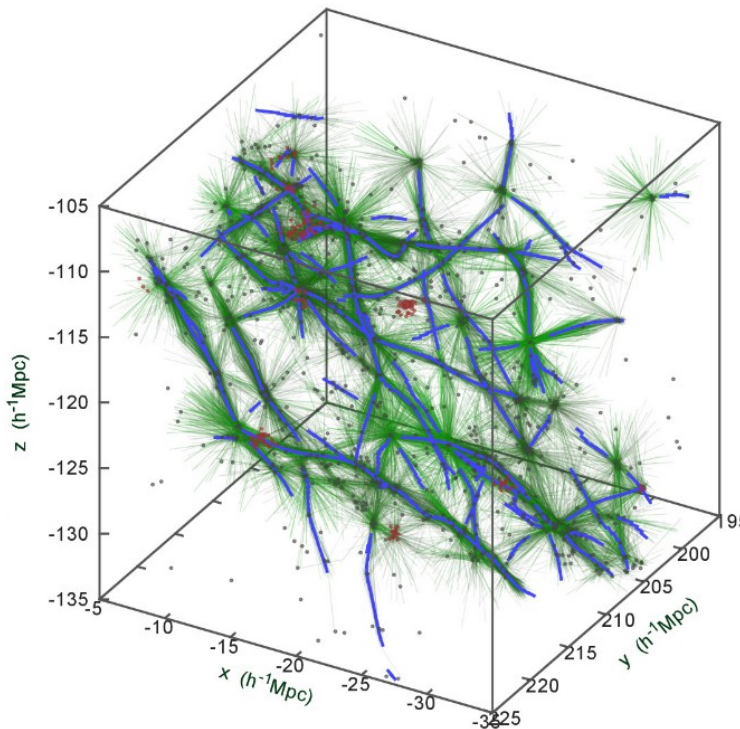
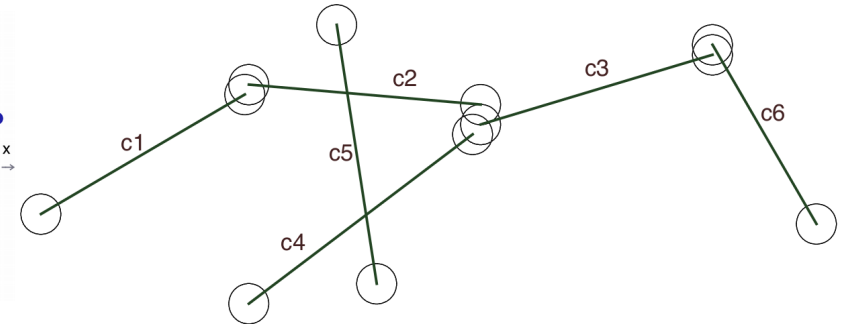
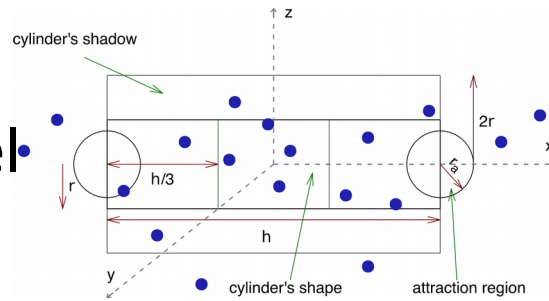
$$\delta T_N \propto \frac{1}{\sqrt{N_{\text{cell}}}}$$

cancels



Finding filaments from galaxies: SDSS Filament Catalogue

- Tempel+14
→ Bisous model
- $m_r < 17.77$
- $0.009 > z > 0.155$



Filaments with Apertif

Bisous Model Filaments with
 $z \leq 0.1$
 $\ell \geq 10 h^{-1} \text{ Mpc}$

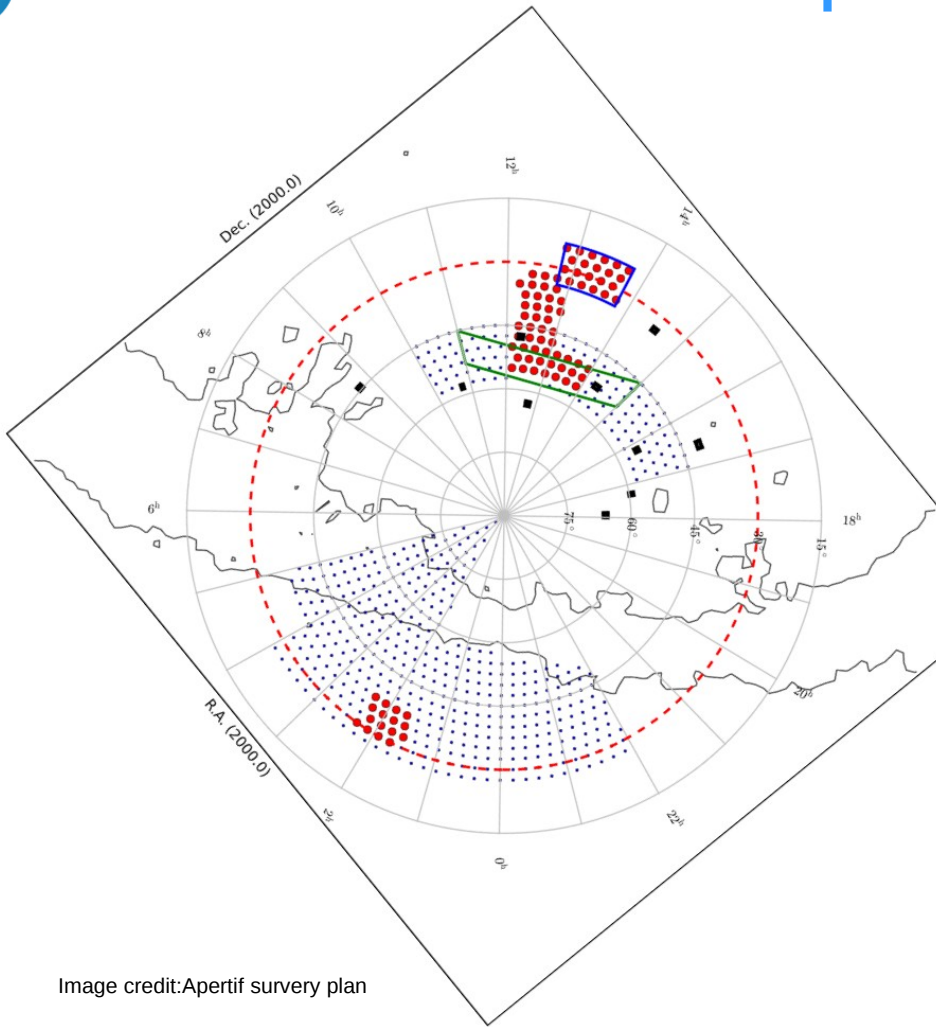
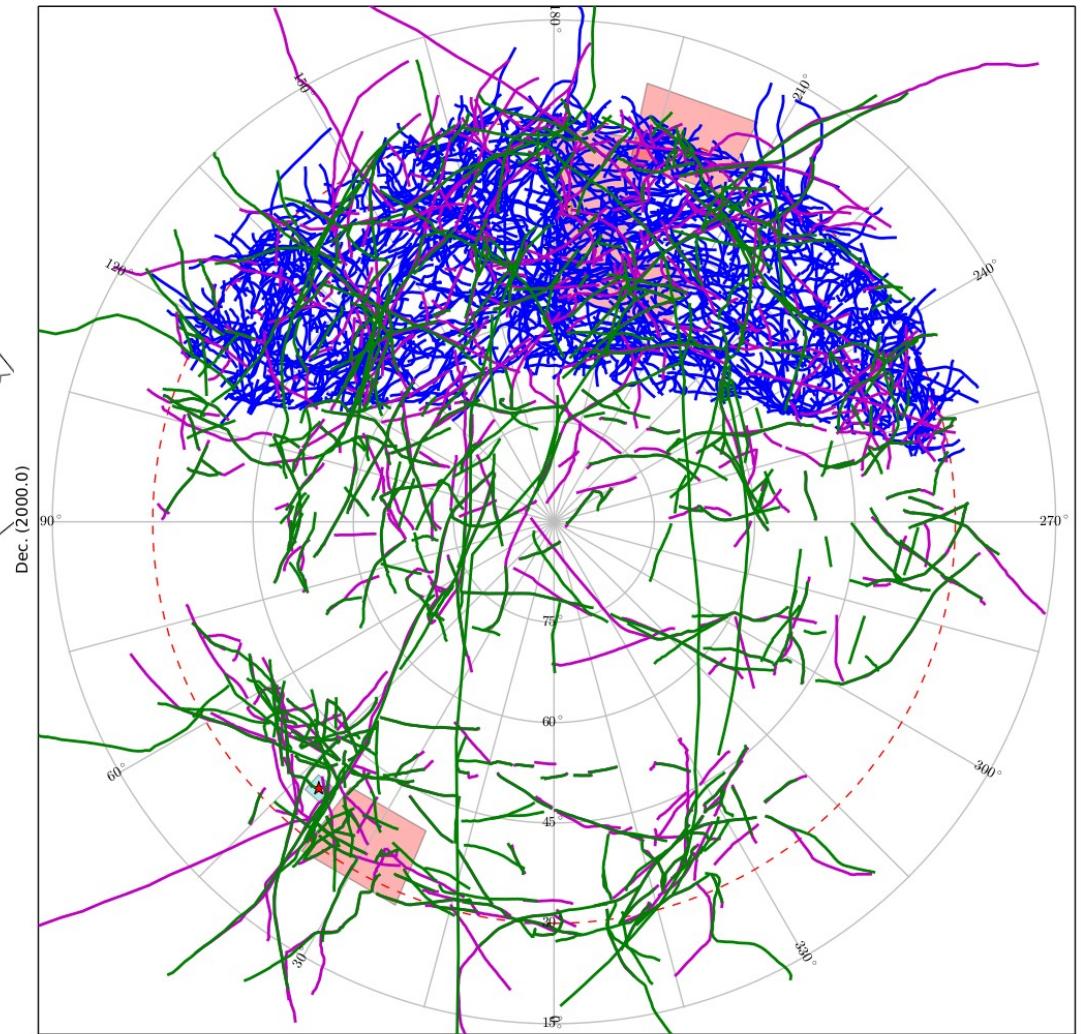


Image credit: Apertif survey plan

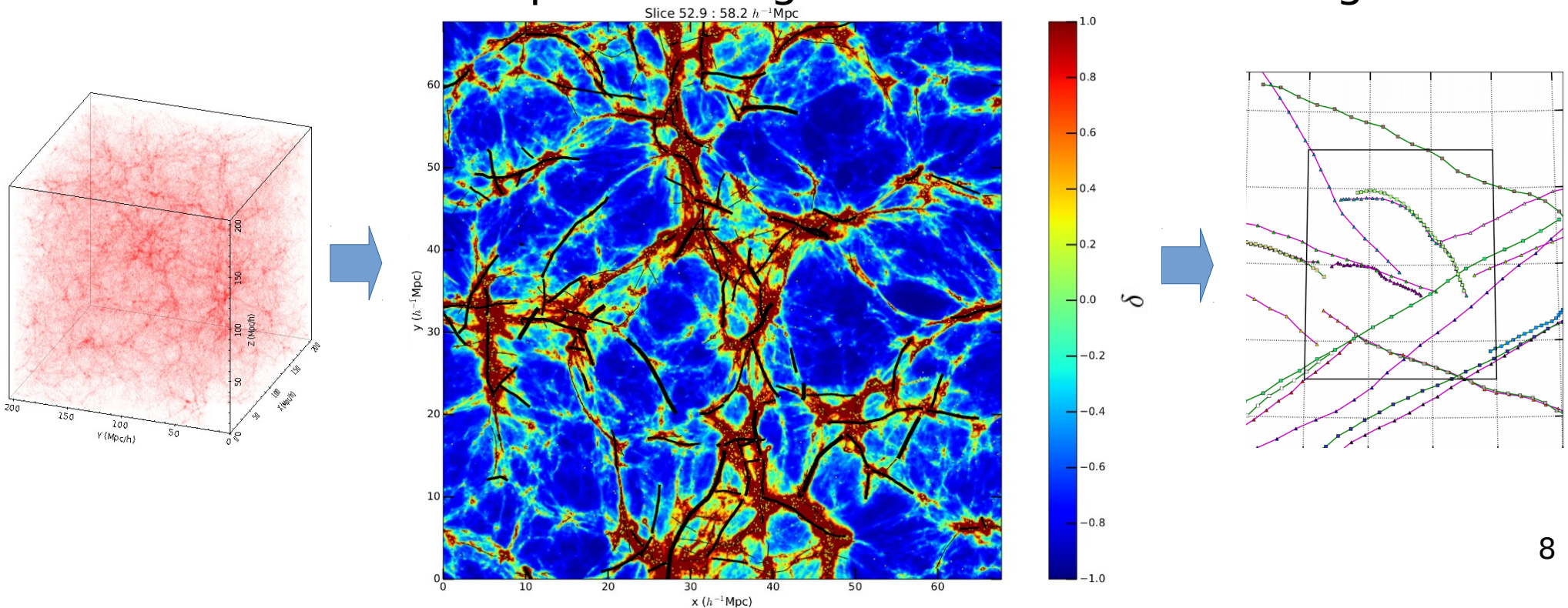
medium-deep (84 h)
shallow (12h)



R.A. (2000.0)
SDSS
2MRS
2MRS + 6dFGS

Stacking of filaments

- Apply Bisous model to simulation boxes → “template”-filament signal
- Apply template on target field and calculate S/N
- Stack multiple filaments
- How well does Bisous model work?
- Use EAGLE 100 Mpc³ box to get better estimate for signal



Conclusions

- HI 21 cm signal of filaments within reach of current and future radio telescopes
- SKA able to map and resolve filaments
- Instruments with large FoV allow for stacking
- Ongoing:
 - finding strongest filaments with Bisous model
 - Predictions for Apertif observations with stacking
 - Predictions for mapping with SKA
 - Cross-correlation galaxies and IGM