Astro-ph

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Filament Hunting: Integrated HI 21cm Emission From Filaments Inferred by Galaxy Surveys

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ABSTRACT

Large scale filaments, with lengths that can reach tens of Mpc, are the most prominent features in the cosmic web. These filaments have only been observed indirectly through the positions of galaxies in large galaxy surveys or through absorption features in the spectra of high redshift sources. In this study we propose to go one step further and directly detect intergalactic medium filaments through their emission in the HI 21cm line. We make use of high resolution cosmological simulations to estimate the intensity of this emission in low redshift filaments and use it to make predictions for the direct detectability of specific filaments previously inferred from galaxy surveys, in particular the Sloan Digital Sky Survey. Given the expected signal of these filaments our study shows that HI emission from large filaments can be observed by current and next generation radio telescopes. We estimate that gas in filaments of length $l \gtrsim 15$ h^{-1}Mpc with relatively small inclinations to the line of sight ($\lesssim 10°$) can be observed in $\sim 40-100$ hours with telescopes such as GMRT or EVLA, potentially providing large improvements over our knowledge of the astrophysical properties of these filaments. Due to their large field of view and sufficiently long integration times, upcoming HI surveys with the Apertif and ASKAP instruments will be able to detect large filaments independently of their orientation and curvature. Furthermore, our estimates indicate that a more powerful future radio telescope like SKA-2 can be used to map most of these filaments, which will allow them to be used as a strong cosmological probe.

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С одной стороны — n-body моделирование

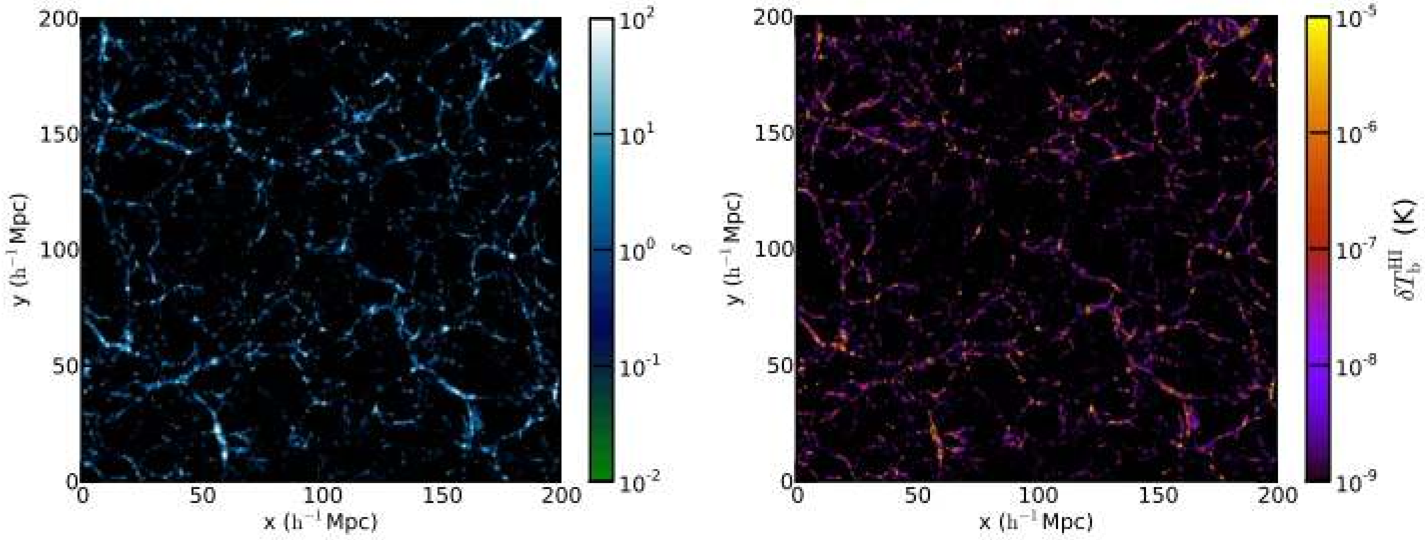

Figure 5. Slice of the simulation box at z = 0.1 with a width of 0.33 h^{-1} Mpc. The left panel shows the overdensity δ and the right panel shows the differential brightness temperature of HI. Cells with overdensities $\Delta_b \geq \Delta_c$ have been masked in the differential brightness temperature box.

С другой стороны — каталог филаментов, выделенных по данным SDSS Tempel et al 2014

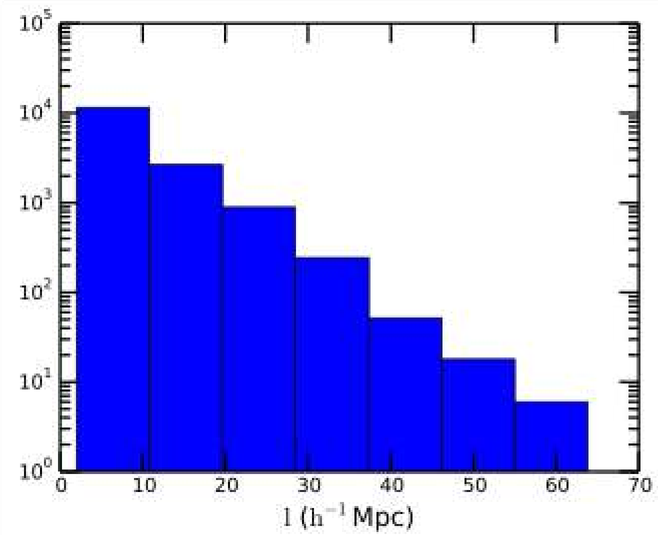

Figure 6. Distribution of the length of the filaments found in the Tempel et al. (2014) catalogue.

Выделили из каталога несколько длинных филаментов, ориентированных вдоль луча зрения

Table 1. Properties of SDSS filaments with small alignment angles. The parameter l is the length of the filament, θ is the alignment angle and N_{gal} is the number of galaxies associated with the filament.

ID	z	d_{com} (h^{-1}Mpc)	l (h^{-1}Mpc)	θ(°)	N_{gal}
1	0.05	175	23.5	5.02	44
2	0.04	130	13.9	5.70	32
3	0.07	227	16.3	4.27	40
4	0.11	333	16.8	1.02	44
5	0.12	356	14.1	2.05	55
6	0.10	282	16.6	2.21	42
7	0.06	180	19.2	5.42	21

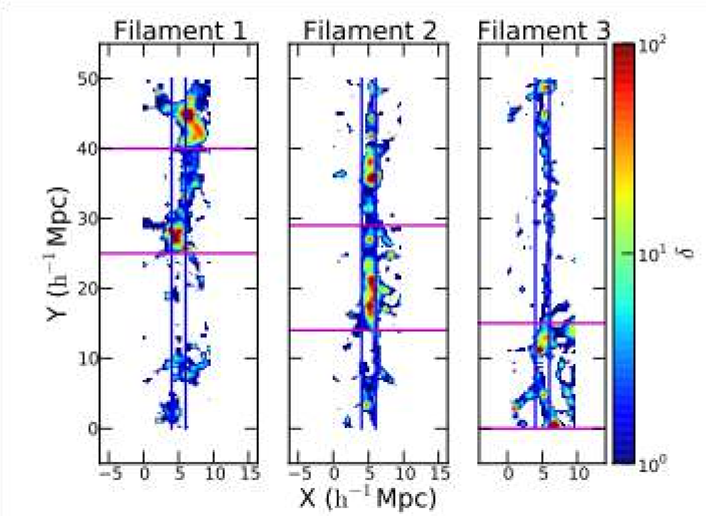

Figure 7. The density fields of the selection of filaments from the simulation. The blue lines denote the observational skewer, whereas the magenta line shows what part would be preferentially detected by SDSS. The colorbar denotes the mean overdensity over the slices in the z-direction.

Затем — выделили из смоделированных филаментов наиболее похожие на реальные (по длине, числу галактик).
Дальше моделировали эти конкретные филаменты — **какой сигнал будет от HI в этих филаментах, какими инструментами можно его детектировать и за какое время?**

Сигнал от ярких галактик при этом должен маскироваться

Table 2. Telescope parameters. Arecibo and FAST are single dish instruments, whereas the others are interferometers. The parameter $D_{\rm dish}$ Dish diameter, $N_{\rm dish}$ denotes the number of dishes, $A_{\rm tot}$ is the total (illuminated) surface area, $\epsilon_{\rm ap}$ gives the aperture efficiency, $T_{\rm sys}$ is the system temperature for the observed frequency band, $D_{\rm max}$ the maximum baseline length, $\theta_{\rm res}$ the angular resolution and $\nu_{\rm res}$ is the minimum possible frequency resolution.

Telescope	$D_{\rm dish}$ (m)	$N_{\rm dish}$	$A_{\rm tot}$ (m^2)	$\epsilon_{\rm ap}$	$T_{\rm sys}$(K)	Spectral range (GHz)	$D_{\rm max}$ (km)	$\theta_{\rm res}$ (′)	$\nu_{\rm res}$ (kHz)	FoV (deg^2)
Arecibo	205	-	32,750	0.7	30	0.047 - 10	0.3	3.24	12.2	0.17
FAST	300	-	70,700	0.55	25	0.070 - 3	0.5	2.9	$\lesssim 0.5$	0.36
Apertif (WSRT)	25	12	5,890	0.75	55	1.13 - 1.75	2.7	0.36	12.2	8
EVLA	25	27	13,300	0.45	26	1 - 50	1 - 36	0.97 - 0.03	31	0.42
GMRT	45	30	47,720	0.4	75	0.05 - 1.5	25	0.04	31	0.13
ASKAP	12	36	4,072	0.8	50	0.7 - 1.8	6	0.5	18.3	30
MeerKAT	13.5	64	9,160	0.8	20	0.580 - 14.5	20	0.05	$\lesssim 18$	1.44
SKA-2	15	1,500	300,000	0.8	30	0.070 - 10	5 (core)	0.19	$\lesssim 18$	1.17

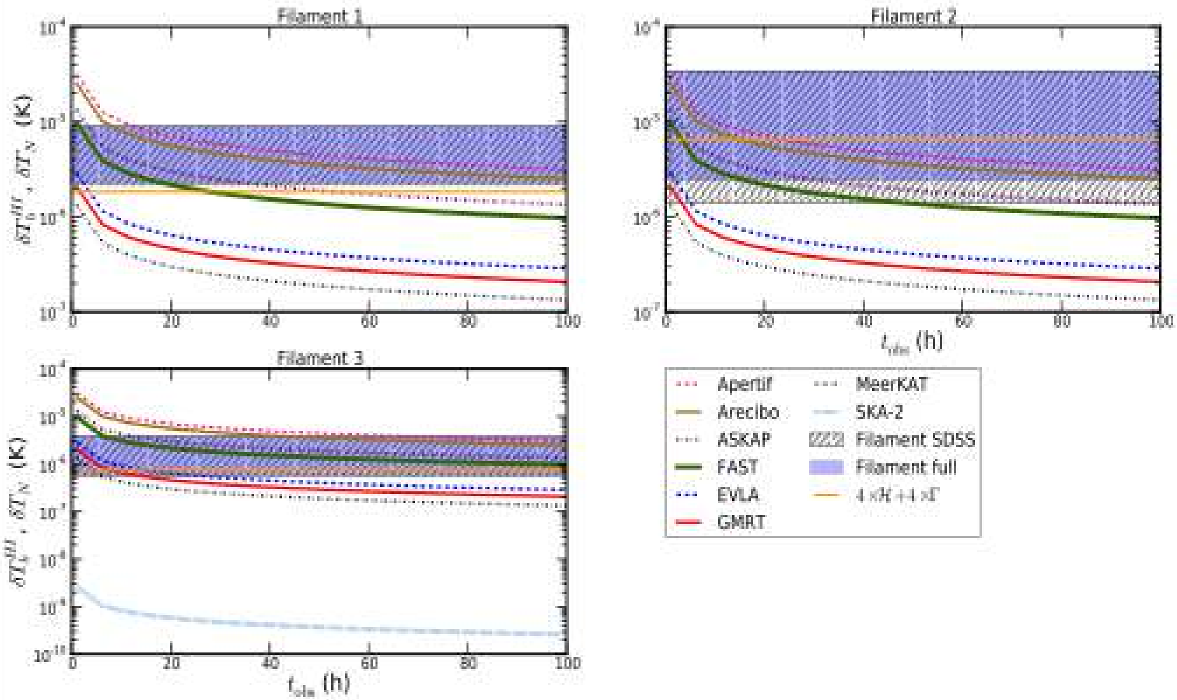

Figure 8. The expected signal of the three filaments in this study (see Figure 7) together with the noise temperatures for the different instruments being considered. The shaded blue area shows the signal for the full filament, where the top and bottom denote the minimum and maximum signal when rotating the observational skewer -5 to +5 degrees. The white striated shaded area shows the same, but for the case where the filament is only as long as expected from SDSS data. The colored lines denote the noise level of the instruments described in Table 2 for $\Delta\theta = 10$ arcmin, $\Delta\nu = 15$ MHz. The orange solid line shows the maximum signal of the filament after increasing the heating and the photoionization by a factor of 4.

Даже при помощи уже существующих инструментов можно находить такие филаменты с суммарным временем накопления в пределах 100 часов

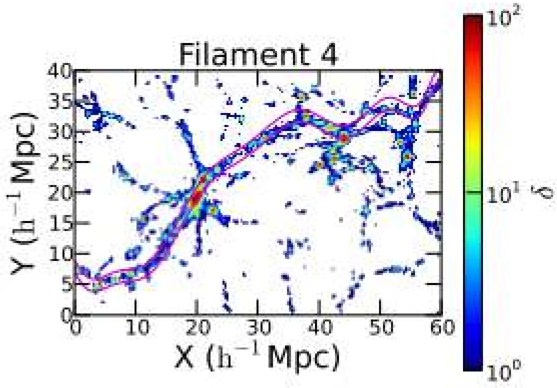

Figure 9. The density field of the selected curved filament from the simulation. The magenta lines show the observational skewer over which the integration was performed with an angular resolution of 10 arcmin and a frequency bandwidth of 0.6 MHz, corresponding to a filament radius of $\sim 1\ h^{-1}$Mpc. The colorbar denotes the mean overdensity over the filament in the z-direction.

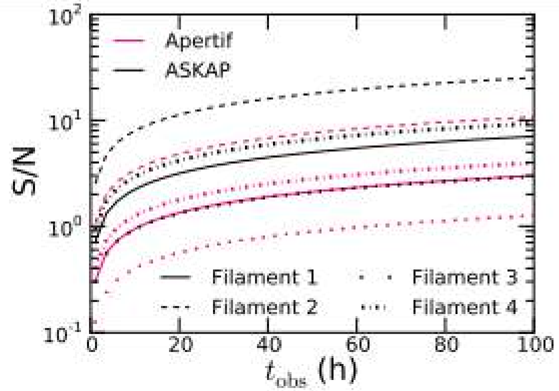

Figure 10. Expected signal to noise of the simulated filaments with the HI survey instruments Apertif and ASKAP. We assume an angular resolution of 10 arcmin and a frequency bandwith of 0.6 MHz. The color of the lines denotes the instrument and the linestyle shows for which filament it is.

Из доклада Carignan на конференции в Венеции.

MeerKAT. 64*13.5м, максимальная база 8км. Конец 2017 года
→ MHONGOOSE 30 галактик по 200 часов

Дальше - SKA

Table 1. Expected sensitivities of different telescopes at 5σ.

Telescope Array(s)	Integration hours	resolution km s^{-1}	beam arcsecs	sensitivity cm^{-2}	Expected date
VLA (THINGS)	10	5	30	5.0×10^{19}	
KAT-7	100	5	210	5.0×10^{18}	
WSRT (HALOGAS)	120	5	30	5.0×10^{18}	
KAT-7 + WSRT	100	16	210	1.0×10^{18}	
MeerKAT	200	16	90	5.0×10^{17}	2017
SKA_1-MID	100	5	30	7.5×10^{17}	2023
SKA_2	10	5	30	2.5×10^{17}	2030
SKA_2	100	5	30	7.5×10^{16}	2030

Carignan 2016:

However, in the near future (2017), the best combination to study low column density HI with a good spatial resolution will be to combine the sensitivity of FAST with the spatial resolution of MeerKAT. The combination of the data from those two telescopes will allow, 6 years before SKA_1-MID, to do "cosmic web" research to levels $< 5.0\times10^{17}$ cm^{-2}, close to 10^{16} cm^{-2}, densities that would normally only be accessible to the full SKA around 2030. It is at those densities that we expect the galaxies to connect with the surrounding cosmic web.