Cosmic strings: possible candidates on the radio and optical data

Sazhina O.S., Scognamiglio D., Sazhin M.V., Safarova K.M.

Sternberg State Astronomical Institute of Lomonosov Moscow State University and University Federico II (Naples, Italy)

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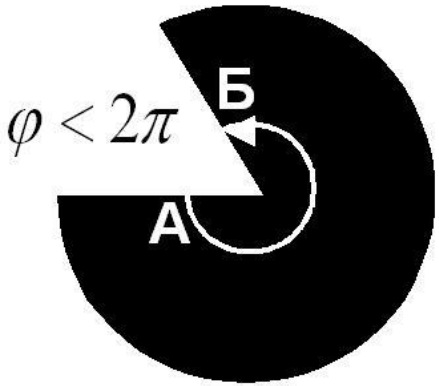
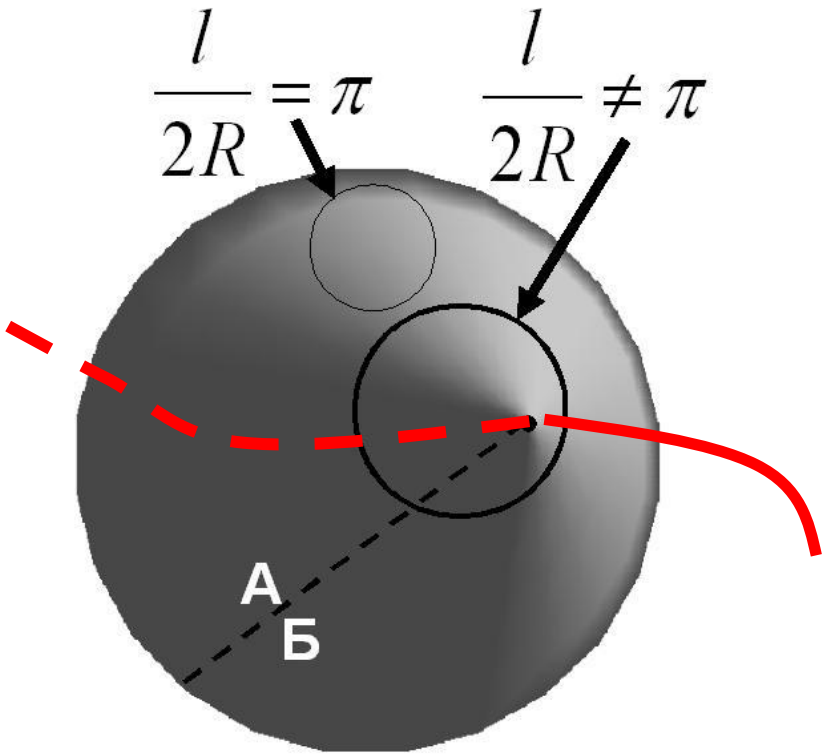
Outline

- Cosmic strings (CS) in astronomy
- Two main methods of CS search
- CS current status
- Possible observational CS parameters
- CS candidates in CMB data
- Search for gravitational lensing events along the “CS candidate No. 1”. Preliminary results from The STScI Digitized Sky Survey
- Deficit angle $\Delta\theta$ of “CS candidate No.1” as statistical characteristic
- ★ Statistical analysis of CMB data to search for “light” CS

Cosmic strings in astronomy



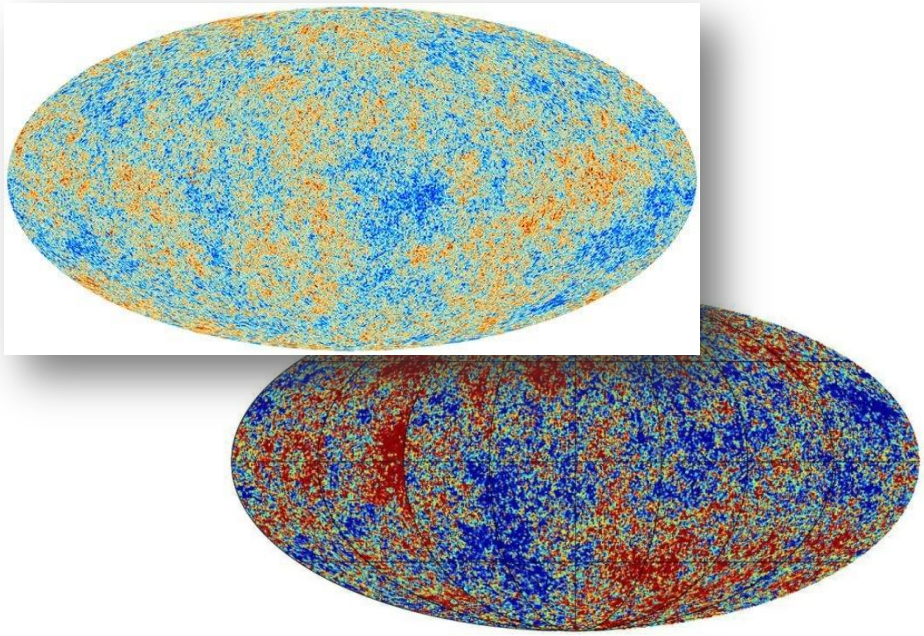


$$\hat{g}_{\mu\nu} = \eta_{\mu\nu} = diag(1,-1,-1,-1)$$

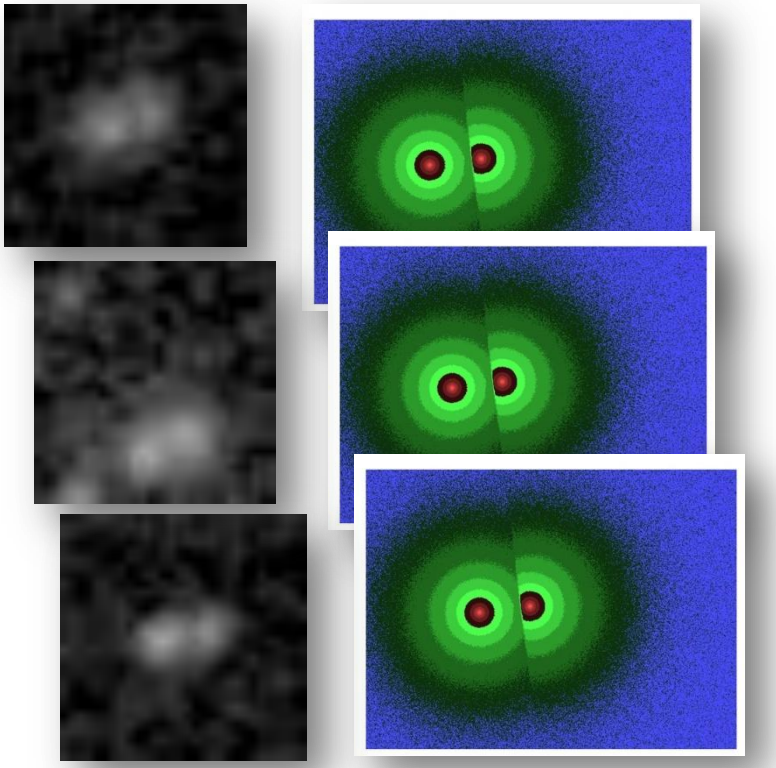
$$0 \le \varphi \le 2\pi - \Delta\theta, \quad \Delta\theta = 8\pi G\mu$$

Two main methods of cosmic string search

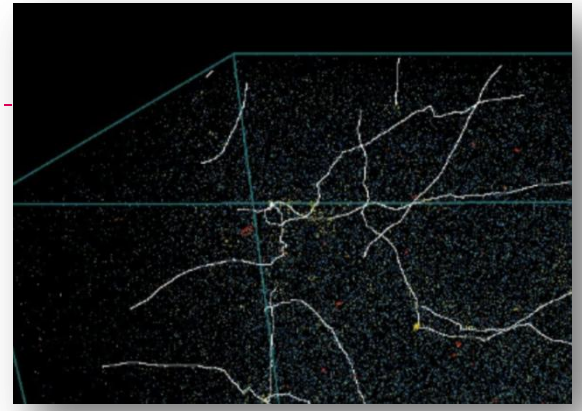
Analysis of anisotropy (and polarization) of Cosmic Microwave Background radiation looking for step-like discontinuities (data from WMAP and Planck space missions)



Analysis of strong gravitational lensing effects by high resolution optical instruments looking for excess of such events and for exotic cuts of isophotes



Current status of cosmic strings



- Simulations of the string network show 80% infinite (long) strings and the rest is in loops with a scale-invariant distribution. This corresponds to 40 infinite strings in any horizon volume
- Restrictions on the CS linear density:

1) cumulative restriction for CS angular power spectrum (Nambu-Goto and semi-local respectively) ["**Planck 2013 results. XXV. Searches for cosmic strings and other topological defects" by Planck Collaboration**]

$$G\mu/c^2 \le 1.5\cdot 10^{-7}$$

$$G\mu/c^2 \le 11.0\cdot 10^{-7}$$

2) direct search for individual strings

a) method based on the assumption that the number density of CS is approximately known [**E. Jeong and G. F. Smoot, Astrophys.J. 624, 21 (2005), astro-ph/0406432**]

$$G\mu/c^2 \le 3.7\cdot 10^{-6}$$

b) method based on Haar convolution **[O.S.Sazhina, D. Scognamiglio , M.V. Sazhin; Eur. Phys. J. C (2014) 74:2972]** got observational evidence to semilocal CS (theoretical justification see in **T.W.B. Kibble, T. Vachaspati "Monopoles on string" 2015**)

$$G\mu/c^2 \le 7.36\cdot 10^{-7}$$

c) statement of Canny algorithm for future CMB experiments [**R. J. Danos and R. H. Brandenberger, Int.J.Mod.Phys. D19, 183 (2010), 0811.2004**]

$$G\mu/c^2 \le 3.0\cdot 10^{-8}$$

Possible observational cosmic string parameters

Amplitude of cosmic string anisotropy

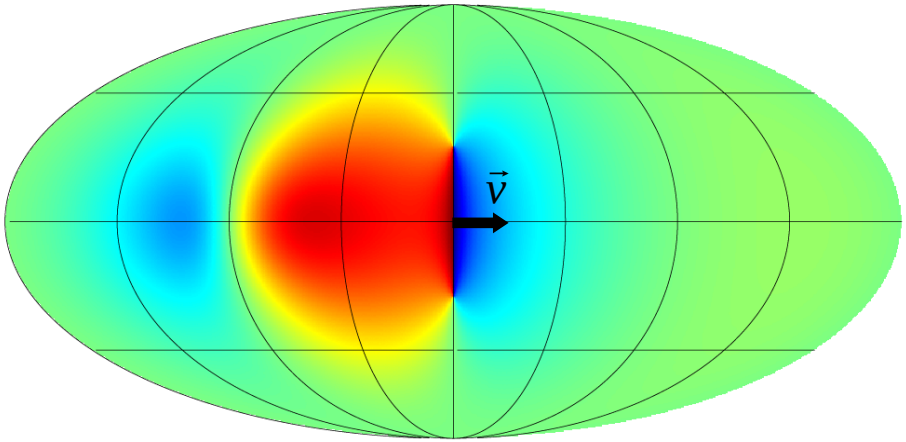
$$\frac{\delta T}{T} \approx 8\pi G\mu\gamma\frac{v}{c}$$

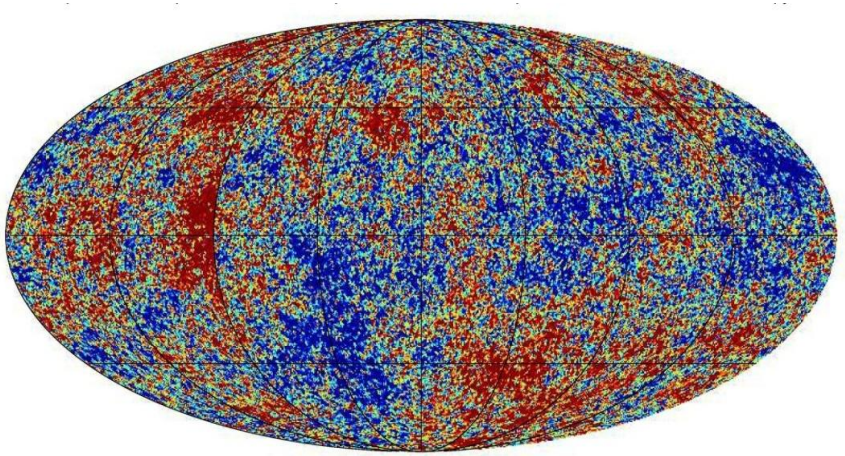
$$\delta T_{\text{string}} = 27\ \mu\text{K}\cdot\frac{\Delta\theta}{2''}\frac{v}{0.9}F(\psi,\varphi,\theta)$$

Simulations: CMBFAST anisotropy (~100 μK) + cosmic string (v ~ 0.9c)

$$\Delta\theta = 6'' \quad \Rightarrow \delta T_{\text{string}} \approx 81\ \mu K$$

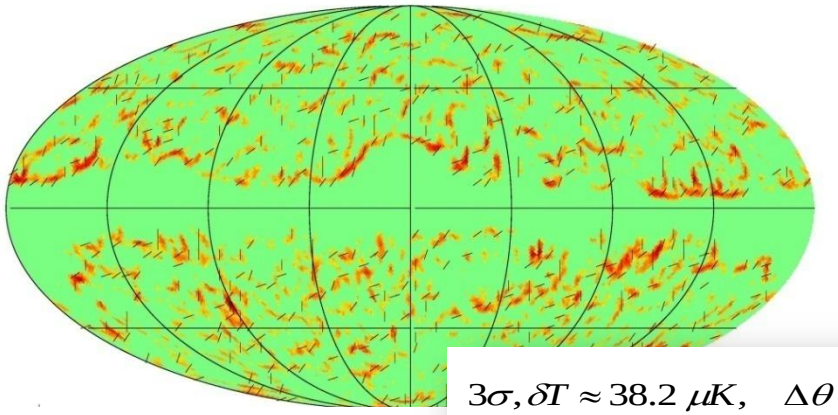
$$\Delta\theta = 0''.1 \quad \Rightarrow \delta T_{\text{string}} \approx 1.5\ \mu K$$



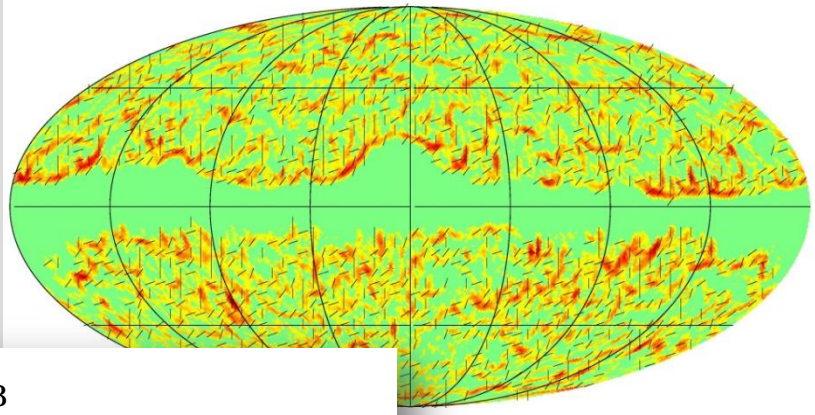


Cosmic string candidates in CMB data (v~0.9.c)

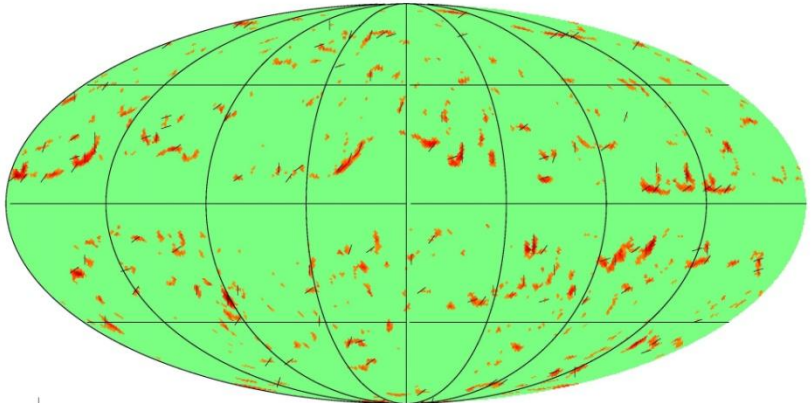
$2\sigma, \delta T \approx 25.3\ \mu K, \quad \Delta\theta = 1''.9$



$1\sigma, \delta T \approx 12.6\ \mu K, \quad \Delta\theta = 0''.9$

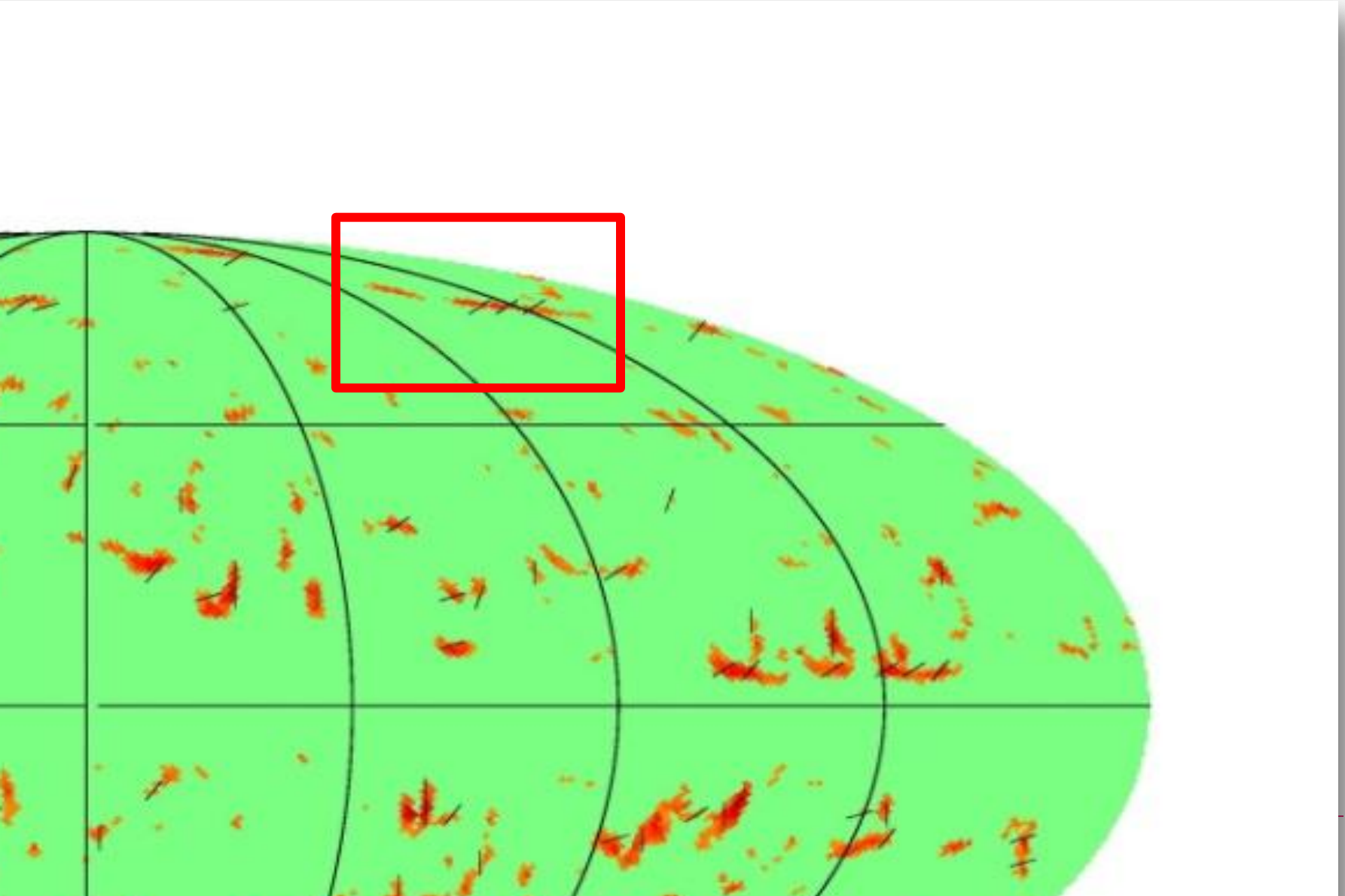


$3\sigma, \delta T \approx 38.2\ \mu K, \quad \Delta\theta = 2''.8$



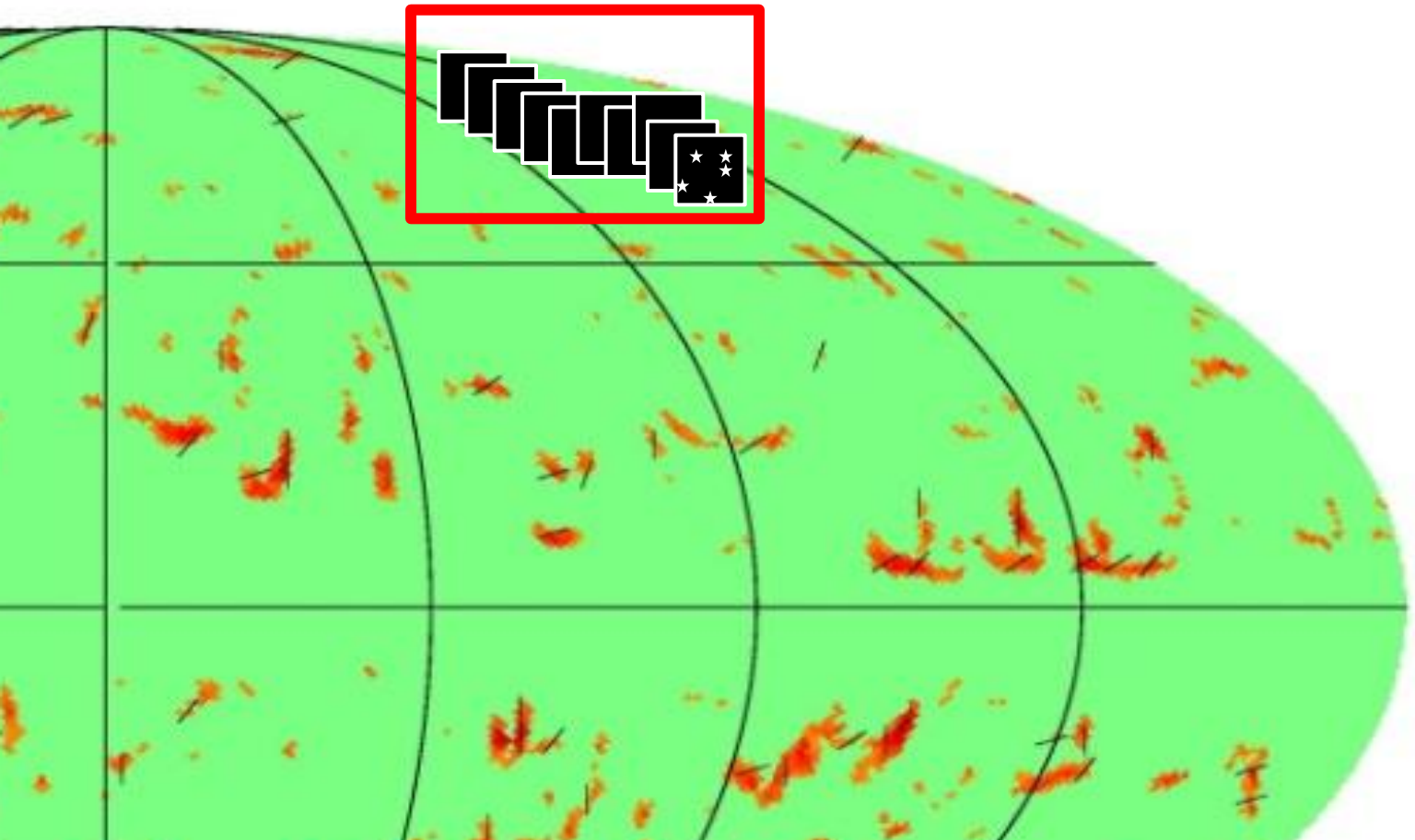
O.S.Sazhina, D. Scognamiglio , M.V. Sazhin; Eur. Phys. J. C (2014) 74:2972

Cosmic string candidate No. 1



Cosmic string candidate No. 1

31 optical fields 1^0 X 1^0 from the STScI Digitized Sky Survey



The STScI Digitized Sky Survey

	“red” = POSS2/UKSTU Red (=POSS-II F)	“blue” = POSS2/UKSTU Blue (=POSS-II J)	“ir” = POSS2/UKSTU IR (=POSS-II N)
Band	5900-7150	3400-5900	7000-9700
Mag	20.8	22.5	19.5
Pixels	1.0”	1.0”	1.0”

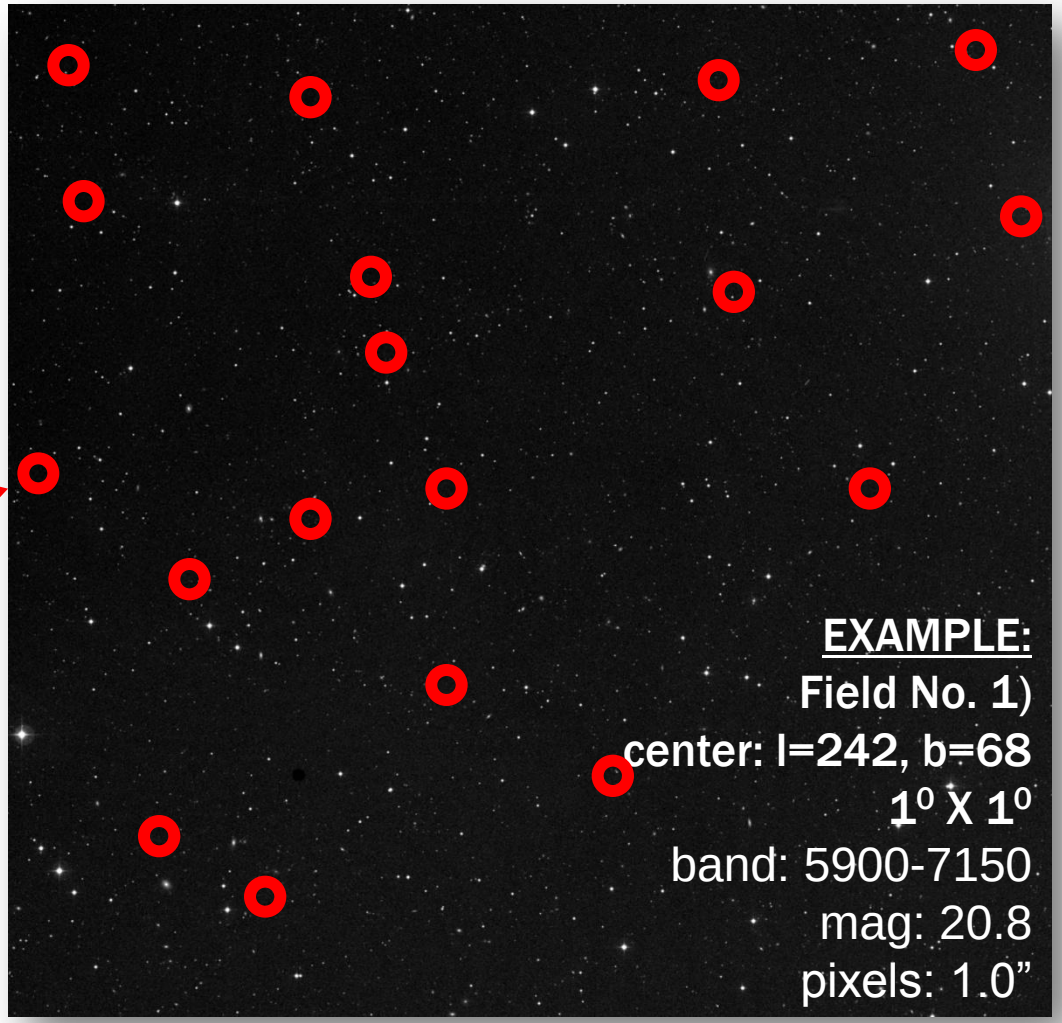
http://gsss.stsci.edu/SkySurveys/Surveys.htm

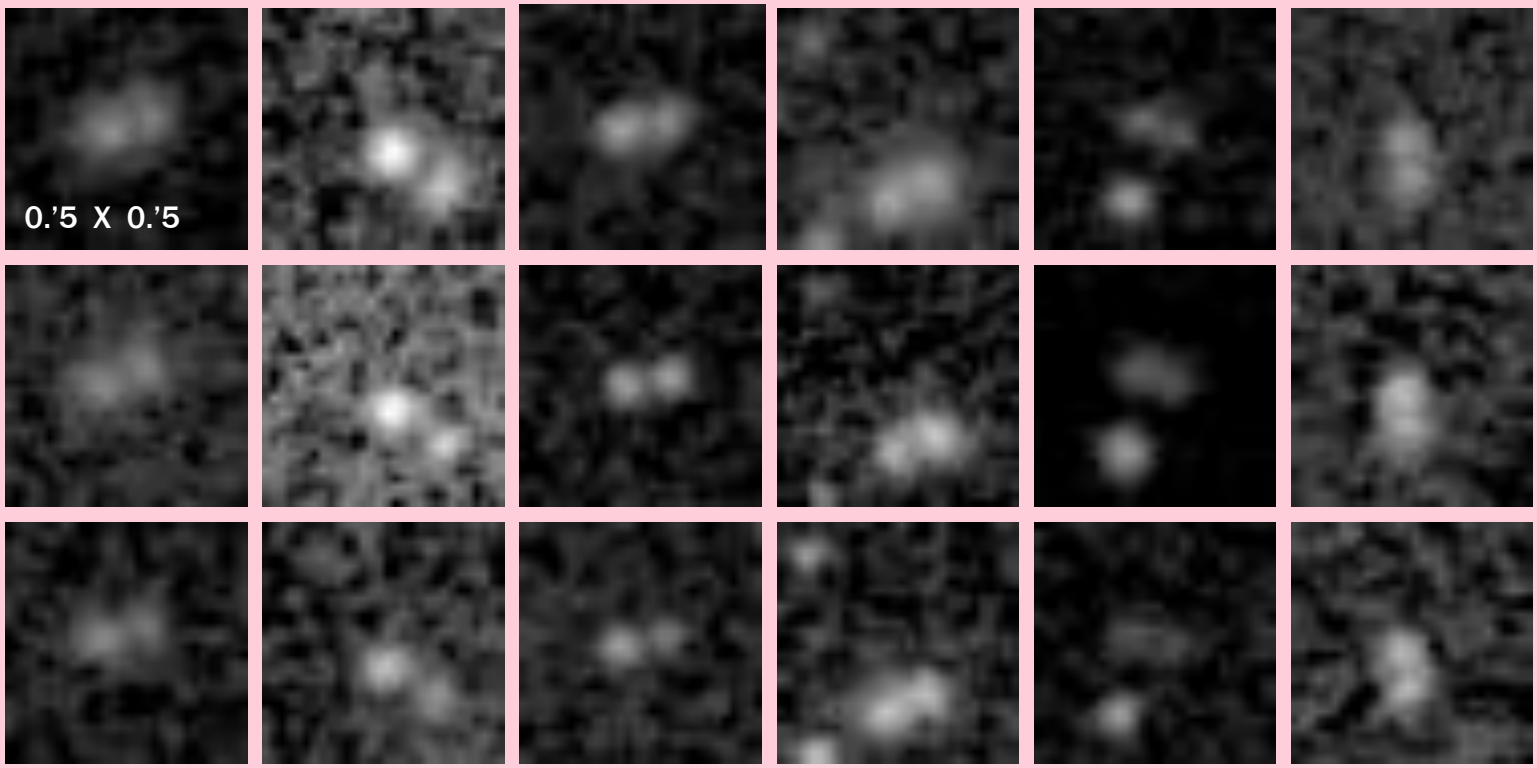
Search for gravitational lensing events along the “CS candidate No. 1”. Preliminary results

Galactic coordinates (l,b)

1)	242, 68
2)	241, 68
3)	240, 68
4)	239, 68
5)	238, 68
6)	237, 68
7)	236, 68
8)	235, 68
9)	234, 67
10)	233, 67
11)	232, 67
12)	231, 67
13)	230, 67
14)	229, 67
15)	228, 67
16)	227, 66
17)	226, 66
18)	225, 66
19)	224, 66
20)	223, 66
21)	222, 66
22)	221, 66
23)	220, 66
24)	219, 66
25)	218, 66
26)	217, 66
27)	216, 66
28)	215, 66
29)	214, 66
30)	213, 66
31)	212, 65

Candidates to double gravitational lensing images

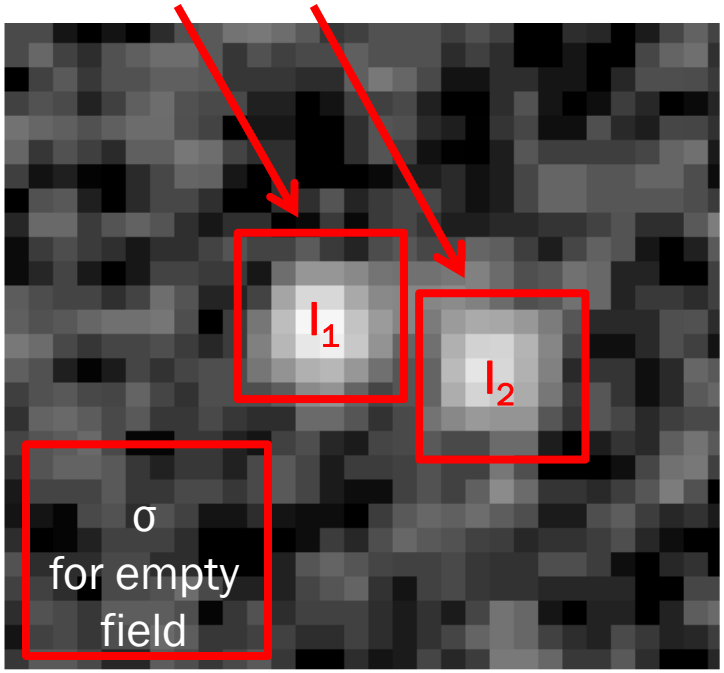


Coordinates of the center of pair (α,δ)	11:22:33.336; +17:56:21.69	11:21:30.725; +17:51:09.90	11:22:20.217; +17:26:34.31	11:21:49.493 ; +17:24:45.91	11:20:46.944; +17:04:14.50	11:19:31.990; +17:05:12.29
Image of pair in red, blue, ir filters. 0.5' X 0.5'						
Angle between the most bright pixels of two components Δθ	3."30	6."07	1."36	2."12	1."44	4."03

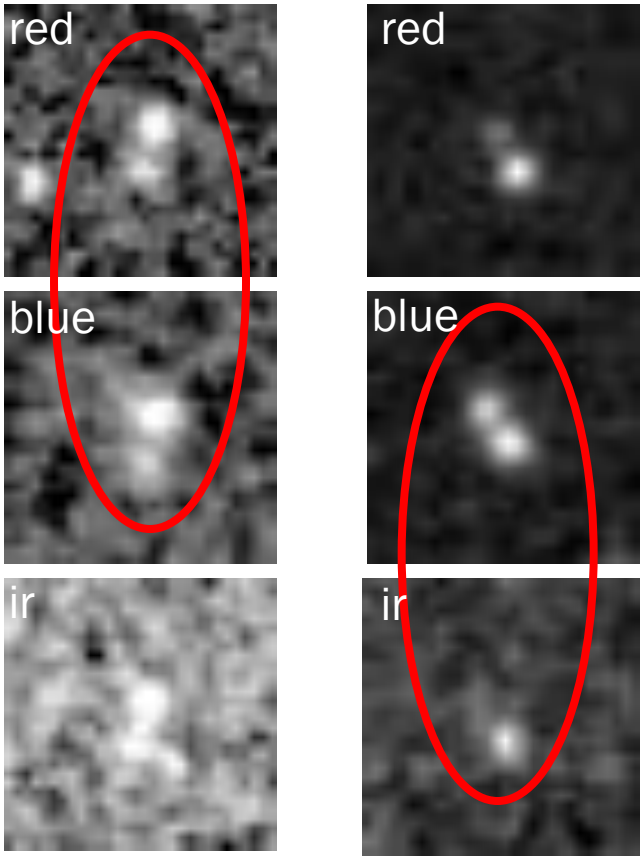
For first 10 fields we found 150 pairs of candidates on lensing system
Now we have complicated multilevel rejection analysis.

First criteria to reject the pair

sum of all intensities up to 3σ

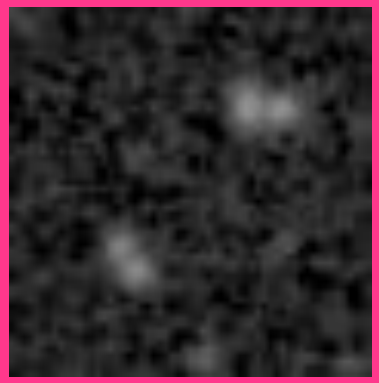


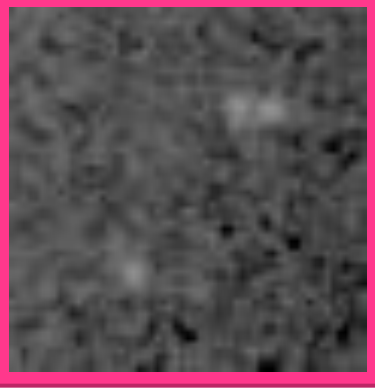
For each pair to construct the estimator E = 1 – I1/I2 * i2/i1

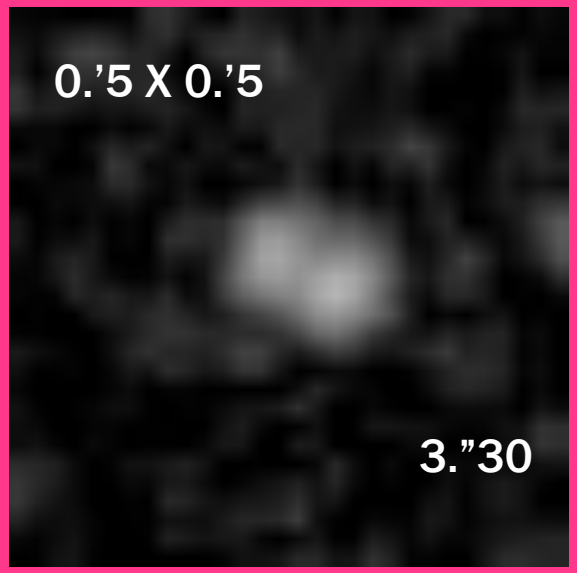


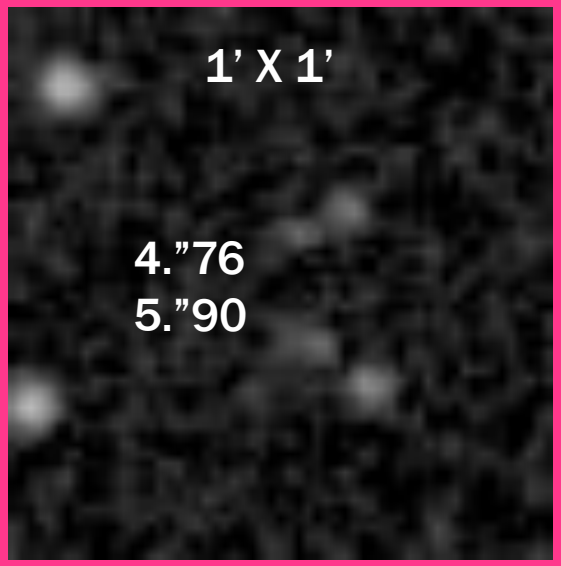
Different ratio of intensities of two components in different bands

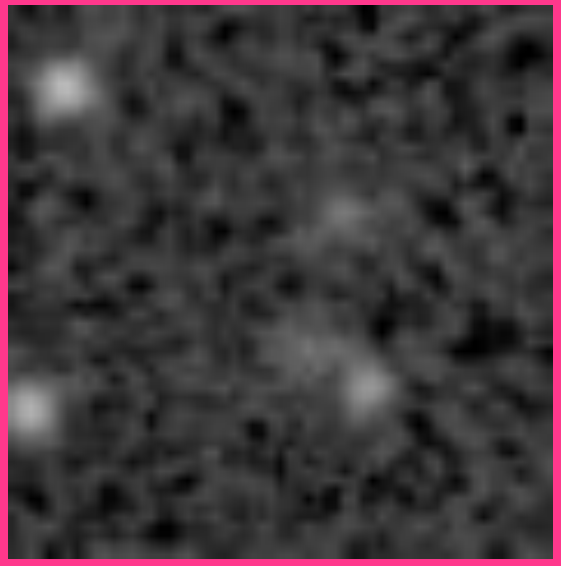

1’ X 1’
1.”17
4.”02



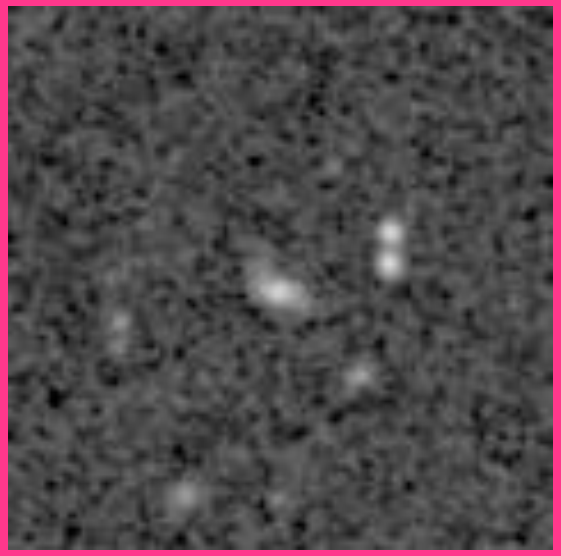


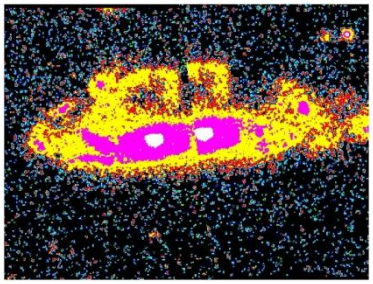

0.’5 X 0.’5
3.”30

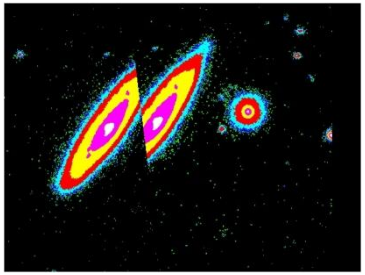

1’ X 1’
4.”76
5.”90

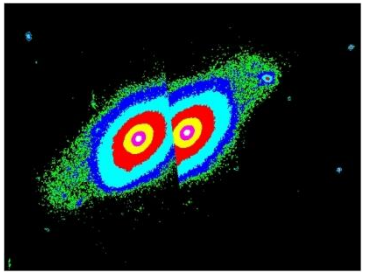



2’ X 2’









Future work

- For sample of 79 pairs:

  <Δθ> = 4.69''

  s.d. = 1.63''

  v_{string} = 0.54 c

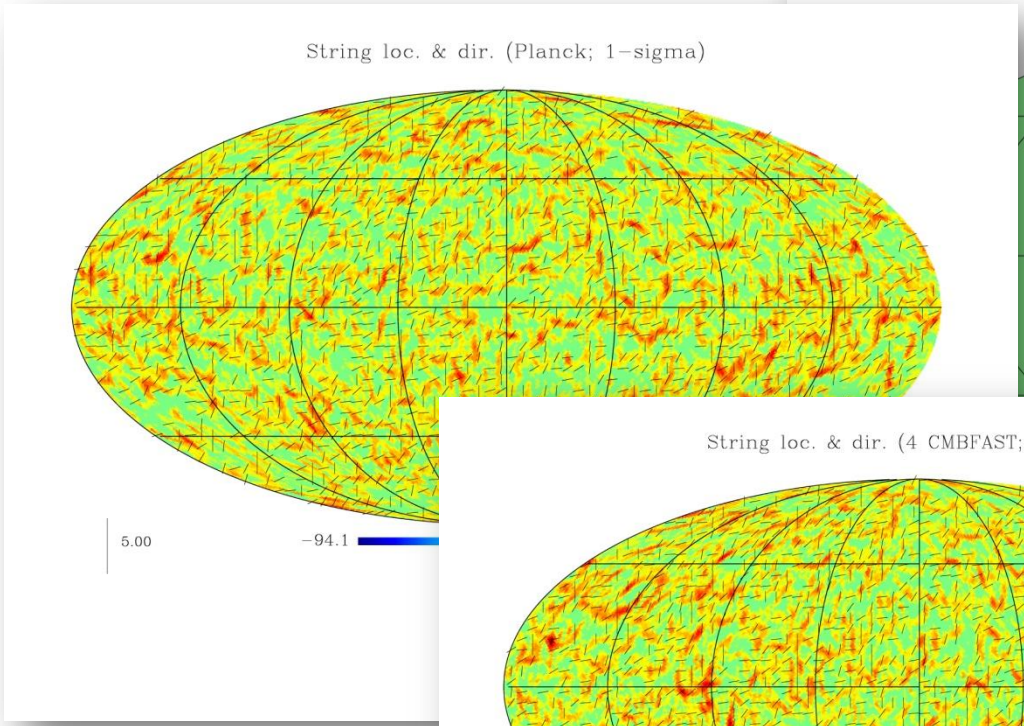
$$\frac{\delta T}{T} \approx 8\pi G \mu \gamma \frac{v}{c}$$

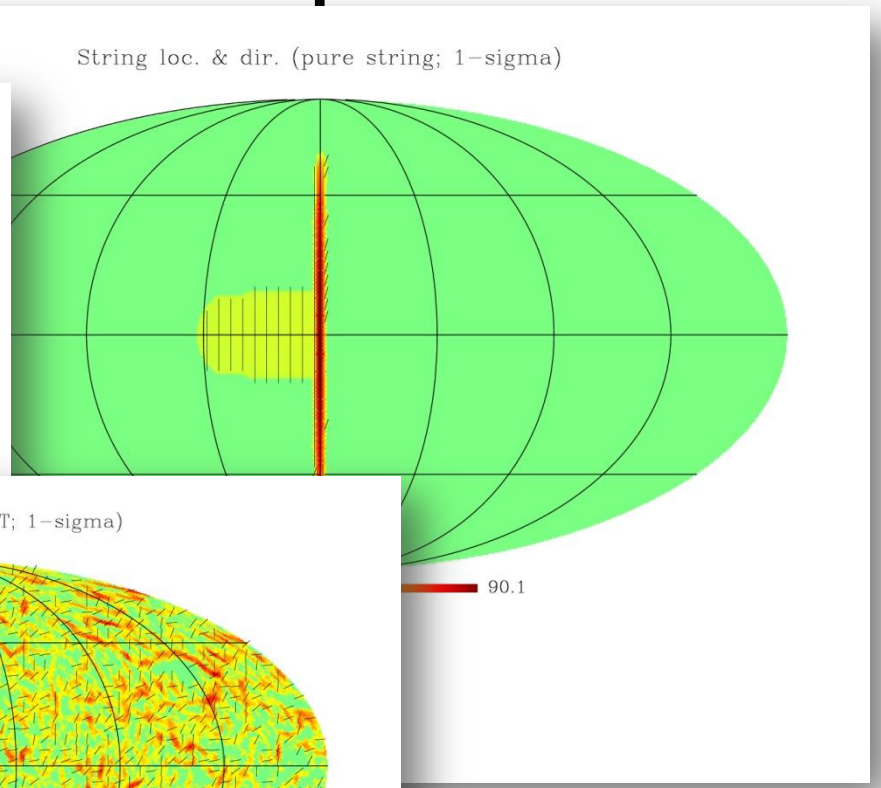
$$\delta T_{\text{string}} = 27\ \mu\text{K} \cdot \frac{\Delta\theta}{2''} \frac{v}{0.9} F(\psi, \varphi, \theta)$$

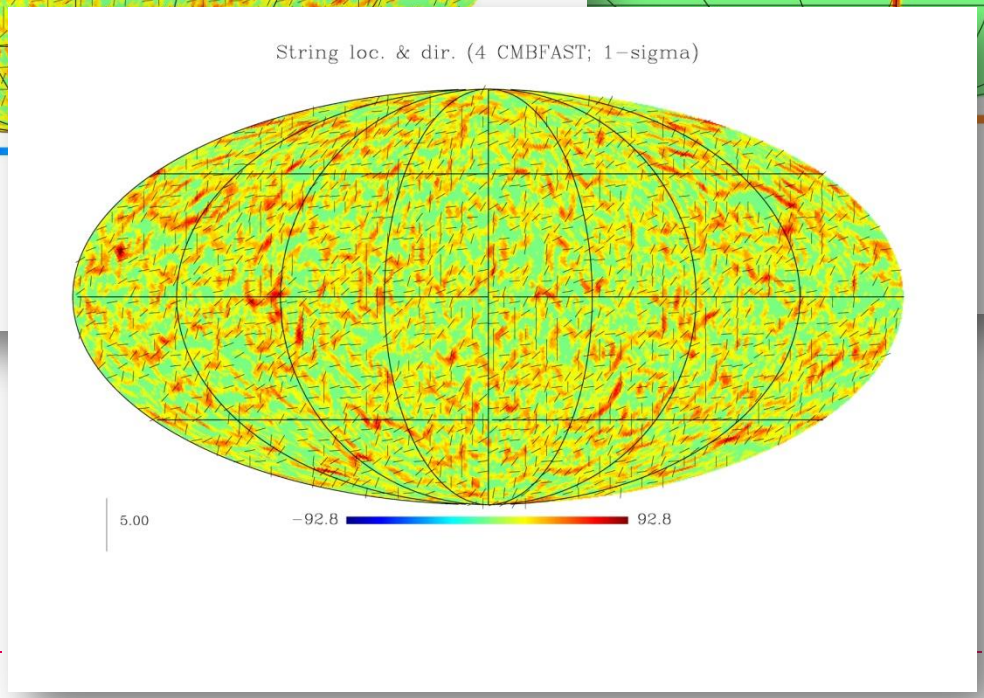
Epoch	Radiation		Matter	
Properties	Bennet & Bouchet, 1990	Allen & Shellard, 1990	Bennet & Bouchet, 1990	Allen & Shellard, 1990
v	0.66 c	0.62 c	0.61 c	0.58 c

From "Cosmic strings and Other Topological Defects" A. Vilenkin, E.P.S. Shellard 1994

Statistical analysis of 1σ-level maps







Conclusions

- There are no cosmic strings with $\delta T > 40\ \mu K$ ($G\mu/c^2 > 7.36 \cdot 10^{-7}$) from two independent data set by WMAP and Planck);
- There at least from 1 up to 6 heavy semilocal cosmic string candidates which have to be confirmed by independent optical data;
- There are neither Nambu-Goto nor Abelian-Higgs cosmic strings (under simple assumption of homogeneous distribution of cosmic strings).

NEW!

Optical analysis of string candidate No.1

Statistical analysis of “light string” sector