Deep photometry of suspected gravitational lensing events: potential detection of a cosmic string

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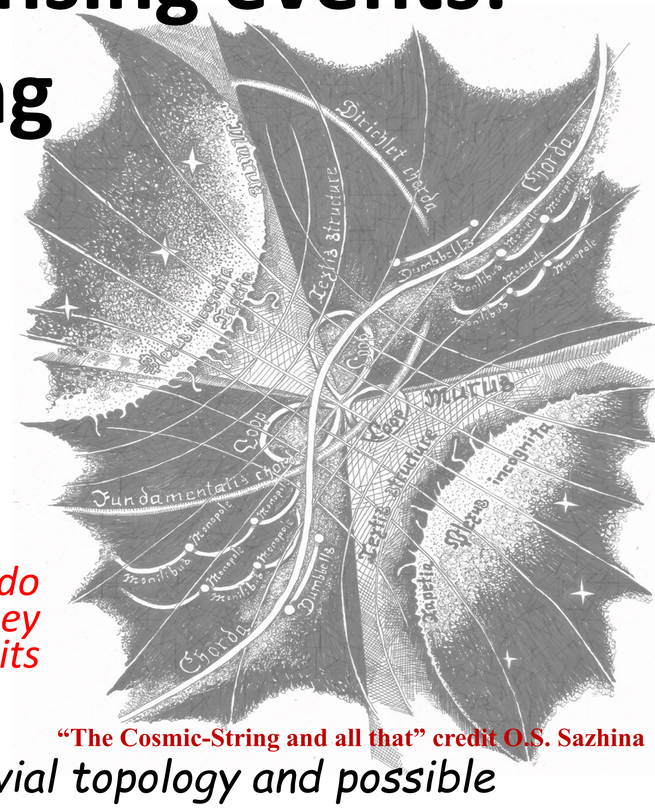

"The Cosmic-String and all that" credit O.S. Sazhina

Defects in Cosmology

Topological:
– zero-dimensional: monopoles
– one-dimensional: cosmic strings
– two-dimensional: domain walls
– hybrid defects: combinations of cosmic strings and monopoles (`dumbbells', `beads', `necklaces');
combinations of cosmic strings and domain walls (`pile')

Non-topological:
– from superstring theory (fundamental, Dirichlet, etc.)

Some topological defects (cosmic strings, monopoles, domain walls) do not contradict Standard Models of cosmology and particle physics. They can originate in early Universe as a result of phase transitions during its expansion and cooling, and can exist today as macro-objects.

References

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Sazhina O.S., et al. (2019). MNRAS, 485, 1876
O.S. Sazhina, V.N. Sementsov, N.T. Ashimbaeva, (2016). Astron. Rep. **58**(1), 16
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Detection of such objects in our Universe would be a unique confirmation of the non-trivial topology and possible multidimensionality of early Universe.

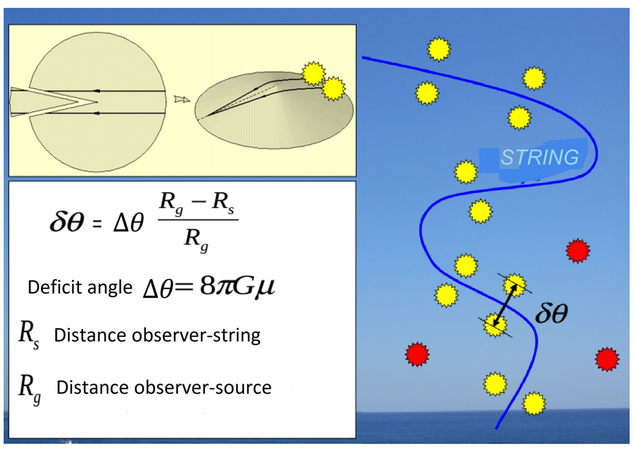
From observational point of view, the presence of monopoles creates the problem of their excessive abundance. Domain walls also appear to be very poor candidates observationally, since they have to be very massive, and thus would generate too high CMB anisotropy.

Cosmic strings avoid the problems of single monopoles and domain walls, thus being the most interesting candidates from the point of view of observations. All CS share model-independent properties: extremely long cosmological length and negligibly small cross-section.

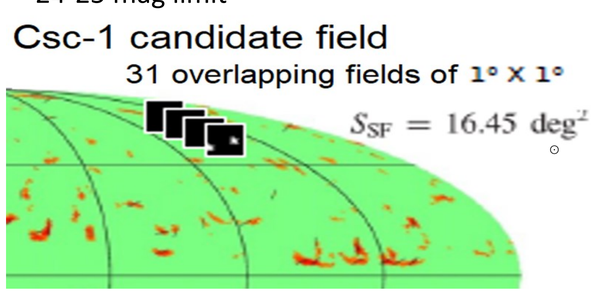
Main methods of observational search for cosmic strings

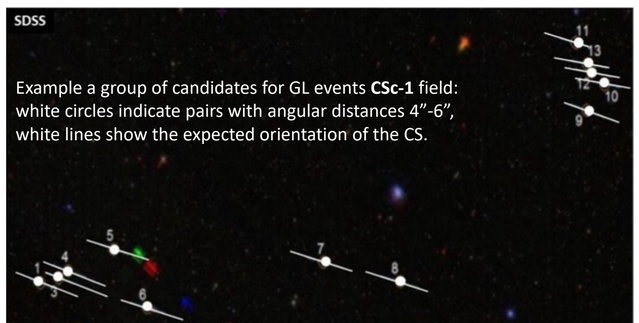
Gravitational Lensing

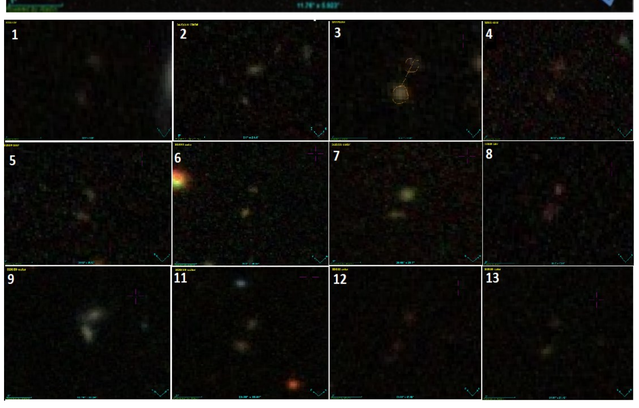
CS always generates gravitational-lens images of background sources, which have a special appearance: pairs of objects of identical morphology and spectrum, with characteristic sharp cuts in isophotes. Moreover, cosmologically long string may produce a strip of multiple images along its path, with characteristic split angle == string deficit angle.



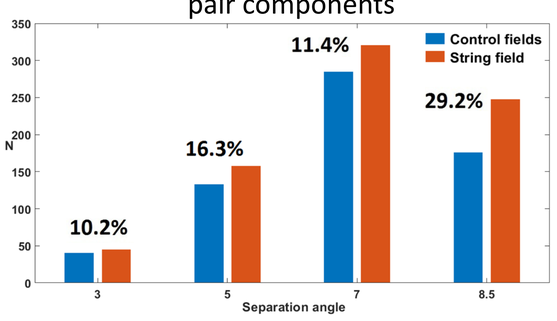
Search parameters of lensing candidates in SDSS-DR12:
- Pairs of galaxies
- 2"–9" separation distance (<=$\Delta\vartheta$)
- Same *z* (<error)
- Same colours (<error)
- 24-25 mag limit







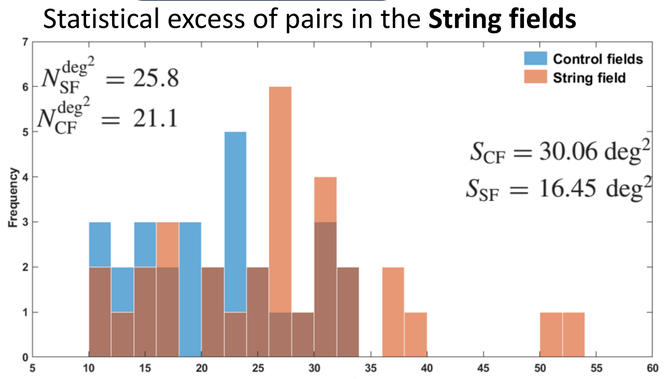
Statistically preferred angle between the pair components



Obj.	sep"	z1/z2(error)	r1/r2
1.	4.453	0.348/ 0.421(+/-0.1)	22.56/22.38
2.	5.999	0.451/0.53(+/-0.14)	22.46/22.16
3.	4.288	0.5/0.448(+/-0.1)	22.42/20.93
4.	5.855	0.684/0.589(+/-0.14)	22.39/21.08
5.	4.092	0.443/0.38(+/-0.13)	21.58/21.73
6.	5.867	0.451/0.432(+/-0.11)	21.80/21.11
7.	4.890	0.384/0.31(+/-0.09)	20.16/22.03
8.	4.309	0.728/0.729(+/-0.06)	22.99/22.2
9.	4.401	0.368/0.555(+/-0.13)	22.09/21.56
11.	5.454	0.337/0.36(+/-0.13)	21.02/21.49
12.	5.195	0.572/0.676(+/-0.1)	22.65/22.15
13.	4.941	0.549/0.5(+/-0.11)	22.56/21.98

425 pairs in CSc-1 field
635 pairs in 29 CFs

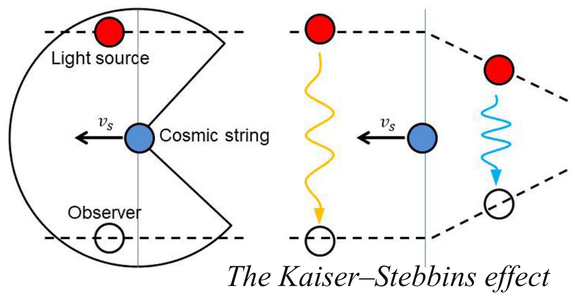
Statistical excess of pairs in the **String fields**



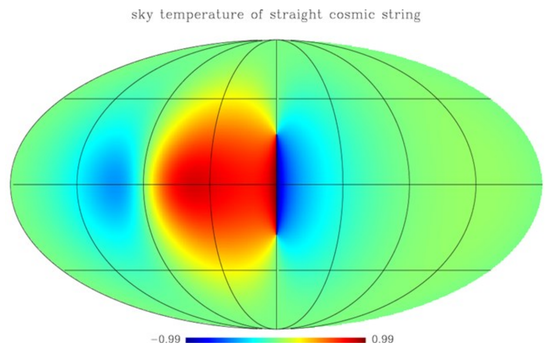
The number of pairs in SF (per 1 sq.deg) is 22% higher than in the CF, excess of 4.6 pairs per 1 sq.deg at 3σ significance level.

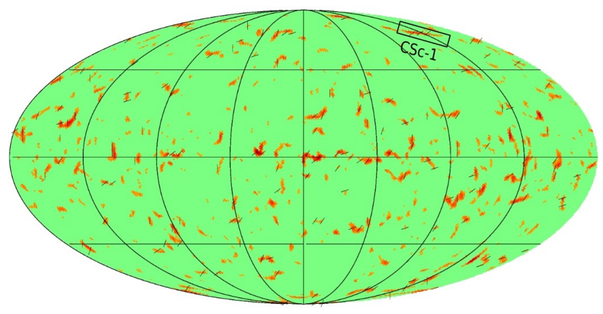
CMB anisotropy

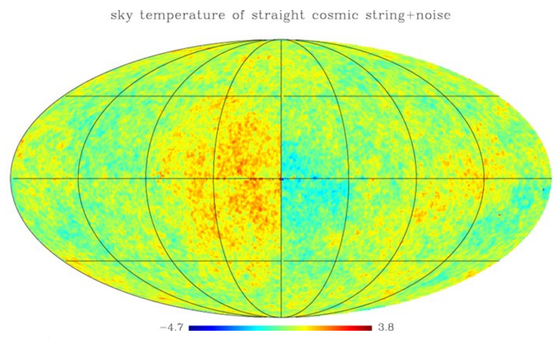
Moving straight long strings create a conical space with a deficit angle, which leads to a step-like change in the CMB anisotropy temperature: a cold spot in front of the CS movement, then a temperature jump and a hot spot, followed by a weaker cold spot – a *Kaiser-Stebbins* effect. CS necessarily creates an increase in CMB temperature behind the moving front.



The Kaiser–Stebbins effect

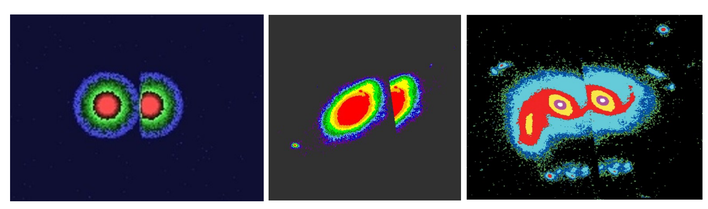






Black strokes indicate the direction of the anisotropy jump

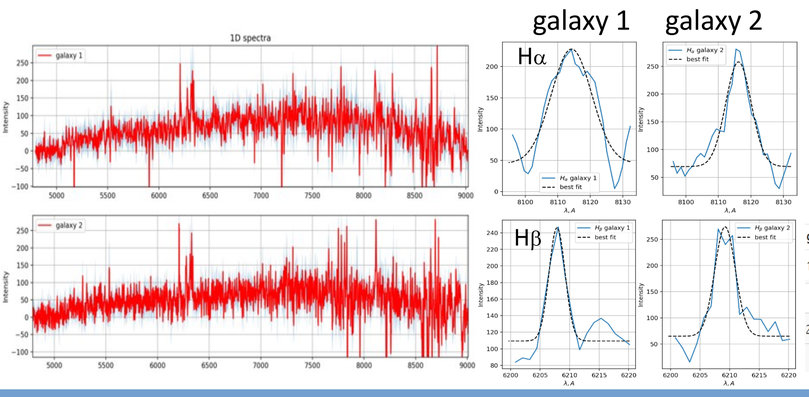
Lensing of extended source results in characteristic sharp edges



CS lens modelling

2021, observations on HCT **obj.9**: *SDSS J110429.61*

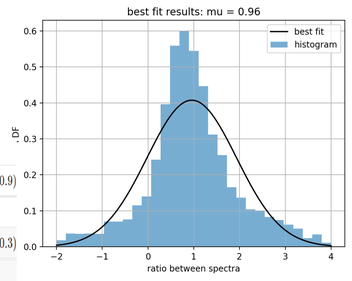
galaxy 1 galaxy 2



Statistical significance both across the entire spectrum and along individual lines:
Correlation ~0.62; χ2/DOF ~ 0.8 by the main lines ($H\alpha$, $H\beta$, $[OIII]$, $[NII]$, etc.)

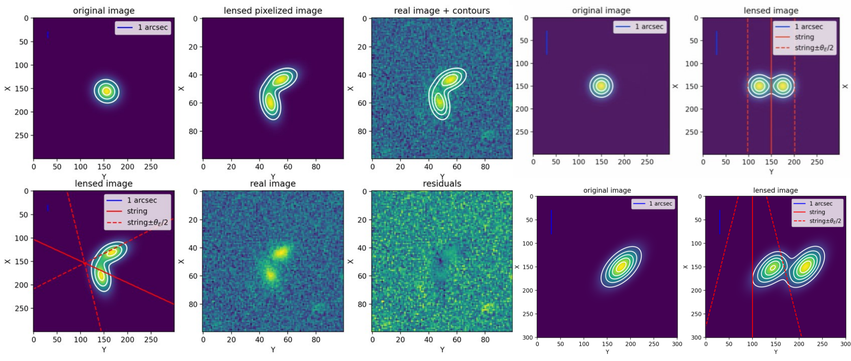
galaxy	H_α	H_β
1	$\lambda = (8114.2 \pm 0.5)A$	$\lambda = (6207.9 \pm 0.2)A$
	$z = 0.236$	$z = 0.277$
2	$\lambda = (8116.2 \pm 0.2)A$	$\lambda = (6209.2 \pm 0.3)A$
	$z = 0.236$	$z = 0.277$

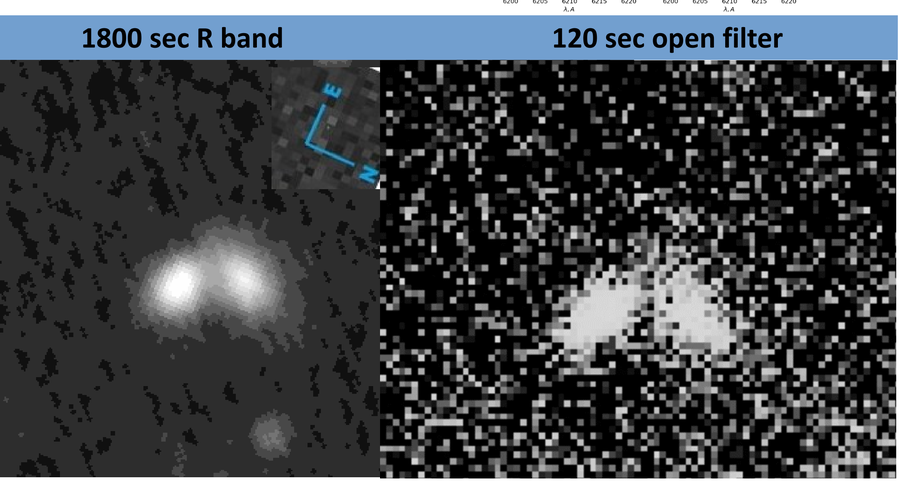
galaxy	[OIII]	[OI]]	[NII]	[SII]λ6718	[SII]λ6733
1	$\lambda = (6328.8 \pm 0.7)A$	$\lambda = (7782.6 \pm 0.8)A$	$\lambda = (8155.0 \pm 0.5)A$	$\lambda = (8283.7 \pm 0.3)A$	$\lambda = (8317.1 \pm 0.9)$
	$z = 0.264$	$z = 0.235$	$z = 0.239$	$z = 0.233$	$z = 0.235$
2	$\lambda = (6330.0 \pm 0.4)A$	$\lambda = (7781.6 \pm 0.4)A$	$\lambda = (8155.2 \pm 0.5)A$	$\lambda = (8283.8 \pm 0.2)A$	$\lambda = (8313.9 \pm 0.3)$
	$z = 0.264$	$z = 0.235$	$z = 0.239$	$z = 0.233$	$z = 0.235$



Obj.9 *lensing on string lying nearly in the line of sight i*= 89.9995°

String lying in image plane





Conclusions

The string GL scenario of obj.9 is statistically significant

- Two independent methods: CMB data and statistical significance excess of double galaxies
- Correlation between the spectra – possible GL nature of the pair
- Simulations show that observed angle between the components of the pair is reproduced by the string strongly inclined to the line of sight

The sign of the sharp isophotal edge in one image along with the CMB and spectral data strongly suggests the possibility of a CS detection