The intriguing field of CSL -1

id est:

evidences for a possible cosmic string?

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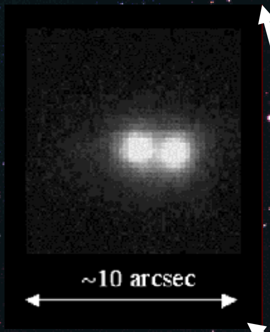
Guess who...

What is CSL-1?

(Capodimonte – Sternberg candidate lens n. 1)

It is a candidate gravitational lens found in the Capodimonte Deep Field (OAC-DF; Alcalà et al. 2004)

Photometry and spectroscopy follow-up’s showed its rather peculiar nature.



The OAC-Deep Field

- OACDF is in three deep broad bands BVR and five intermediate bands in the I region (Alcalà et al., astro-ph/0408220)

Table 1. Coordinates of the OACDF centers.

Field	α(2000)	δ(2000)
OACDF1	12 26 20.4	-12 30 20
OACDF2	12 24 27.0	-12 30 20
OACDF3	12 26 20.4	-13 01 20
OACDF4	12 24 27.4	-13 01 20

Field	obs. run	Filter	# diths	Total exp. time	Seeing arcsec	Airmass	Zero points $ZP^{\dagger}$	Col.Terms
OACDF2 deep	1^{st}	B	12	2.0h	1.24	1.287	24.77	+0.24
OACDF2 deep	1^{st}	V	10	1.7h	1.07	1.184	24.30	−0.14
OACDF2 deep	1^{st}	R	13	3.3h	1.11	1.482	24.63	−0.03
OACDF2 deep	1^{st}-2^{nd}	753nm	9+10	6.5h	0.88	1.512	21.95	
OACDF2 deep	1^{st}-2^{nd}	770nm	9+10	6.0h	0.86	1.544	21.88	
OACDF2 deep	1^{st}-2^{nd}	790nm	9+10	6.5h	0.99	1.084	21.80	
OACDF2 deep	1^{st}-2^{nd}	815nm	9+9	6.8h	0.79	1.044	21.59	
OACDF2 deep	1^{st}-2^{nd}	837nm	9+8	6.6h	0.95	1.468	21.54	
OACDF2 deep	1^{st}-2^{nd}	914nm	10+10	5.6h	0.90	1.046	21.15	
OACDF4 deep*	3^{rd}	B	8	2.0h	0.99	1.095	24.76	+0.22
OACDF4 deep	2^{nd}-3^{rd}	V	7	1.8h	0.95	1.042	24.23	−0.18
OACDF4 deep	2^{nd}-3^{rd}	R	4+14	4.2h	0.99	1.410	24.54	−0.03
OACDF4 deep	2^{nd}-3^{rd}	753nm	5+10	4.8h	0.95	1.042	21.81	
OACDF4 deep	3^{rd}	770nm	7	2.1h	1.33	1.250	21.72	
OACDF4 deep	3^{rd}	790nm	9	3.0h	0.95	1.380	21.65	
OACDF4 deep	2^{nd}-3^{rd}	815nm	5+6	3.5h	0.95	1.110	21.42	
OACDF4 deep	3^{rd}	837nm	7	3.3h	1.20	1.100	21.44	
OACDF4 deep	3^{rd}	914nm	9	2.5h	0.81	1.110	21.05	
OACDF shallow	1^{st}	B	5	20min	0.86	1.078	24.77	+0.24
OACDF shallow	1^{st}	V	5	10min	0.83	1.237	24.30	−0.14
OACDF shallow*	2^{nd}	R	5	10min	1.38	1.320	24.45	−0.03
OACDF shallow	1^{st}	I	5	10min	0.81	1.650	23.31	+0.12

† The reported zero points are those for the first and third observing runs, as the second run was partially non-photometric.
* Due to technical problems it was not possible to calibrate the B-band during the third run. Stars on the OACDF4, calibrated during the first observing run, were used as secondary standards. A similar procedure was applied to the shallow R-band images of the second run.

Filter	Exp. time (h)	PSF (arcsec)	Phot. err.
B	2.0	1.14	±0.11
V	1.7	1.01	±0.13
R	3.3	0.98	±0.21
H^{a}	0.33	0.85	>0.2
753 nm	6.5	0.87	±0.11
770 nm	6.0	0.86	±0.12
791 nm	6.5	0.97	±0.12
914 nm	5.6	0.79	±0.13

[a]The H band covers only the CSL-1 region.

Table 3. Completeness magnitudes vs. wavelengths.

S/N	B_{AB}	V_{AB}	R_{AB}	753	770	791	816	837	915
10	24.6	24.0	24.3	22.8	22.4	22.1	22.5	21.8	21.9
5	25.3	24.8	25.1	23.7	23.3	23.0	23.4	22.7	22.8

Photometry

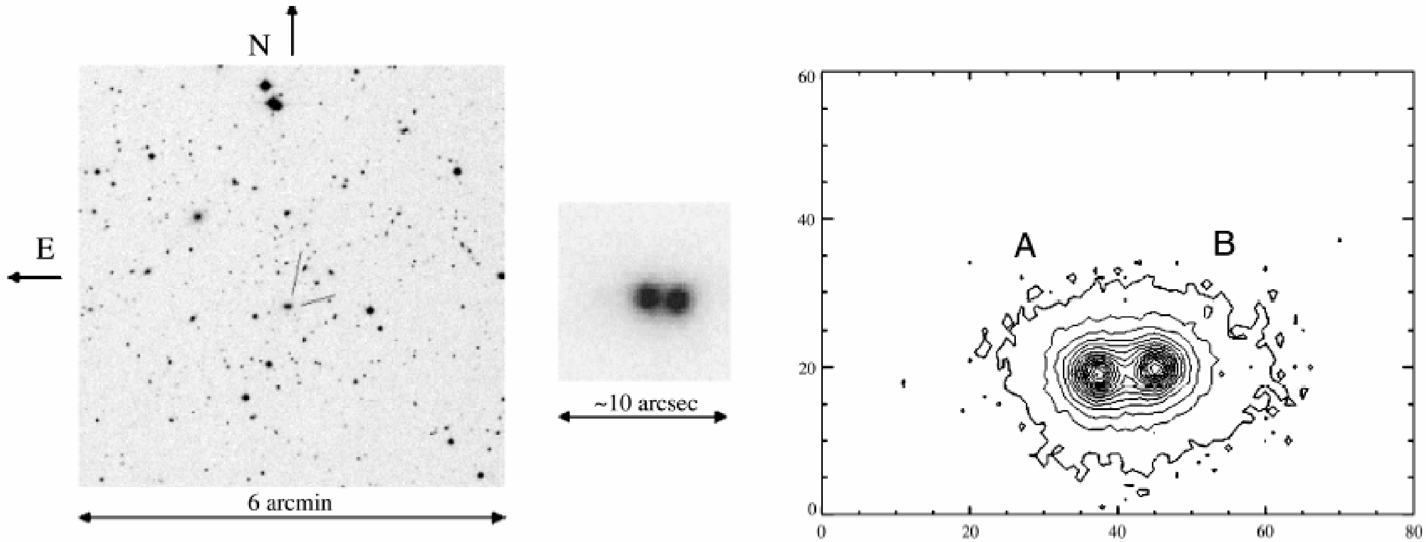


Figure 1. Left-hand panel and central inset: appearance of CSL-1 in the *R* band. Right-hand panel: 2D contours of CSL-1 from the near-infrared (λ914) image. Coordinates are in pixels (1 pixel = 0.238 arcsec) and the two components are labelled A and B as in the text.

Extended and with the same shapes

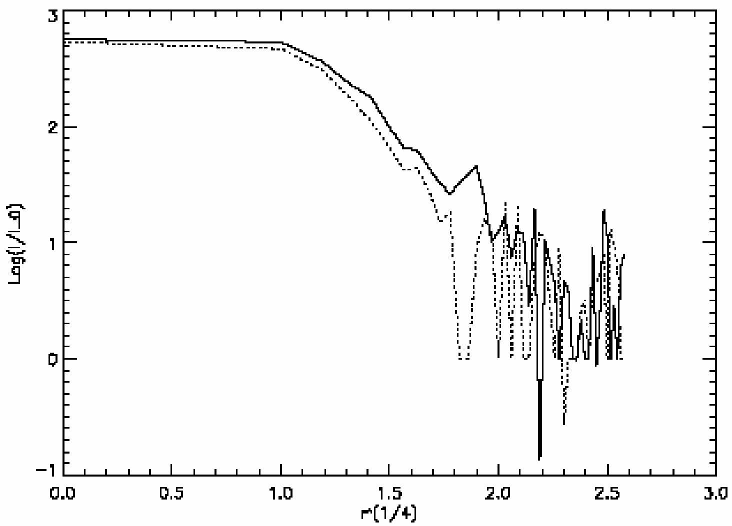


Figure 2. Surface brightness profiles obtained for the the components A (dashed line) and B (solid line) in the 914-Å band. The profiles are normalized to the peak intensity and plotted in $r^{1/4}$ units.

$$M_R = -22.3 \pm 0.1$$

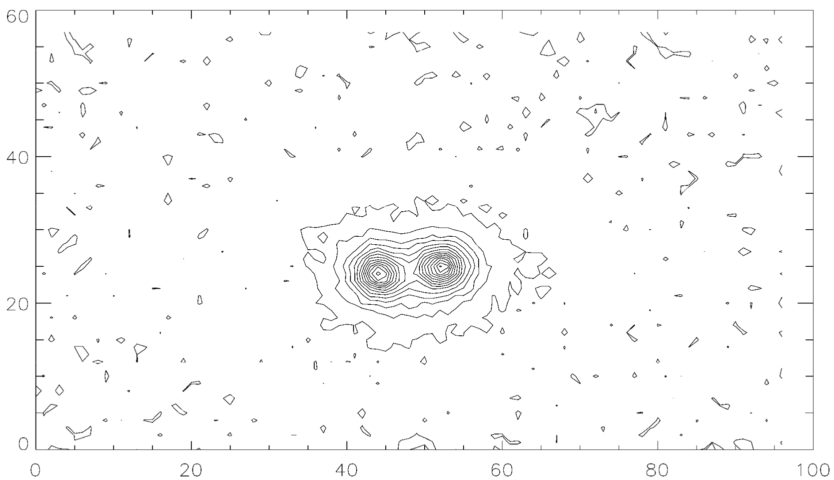
Morphology, shape, absolute luminosity, colors, luminosity profiles all converge toward...

A and B being

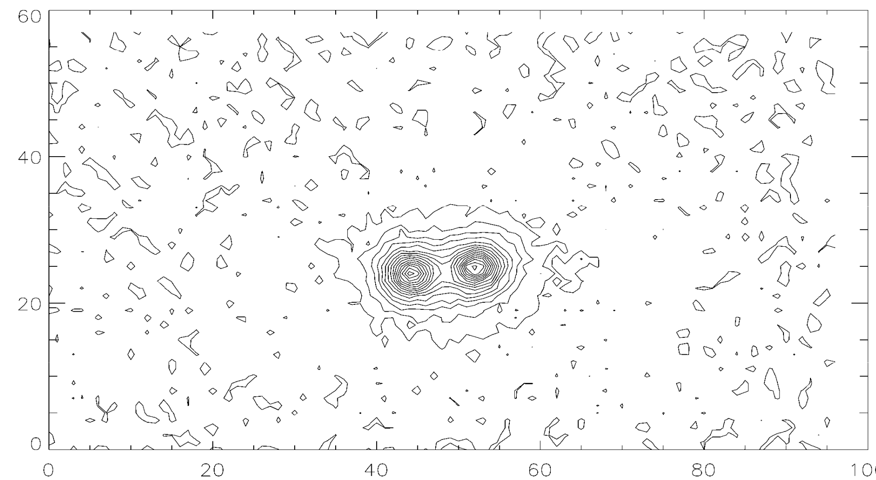
Two giant ellipticals

Band	FWHM A (arcsec)	FWHM B (arcsec)	FWHM PSF (arcsec)	Mag A	Mag B	r_e^A (arcsec)	r_e^A/r_e^B
B	1.59	1.67	1.14	22.73±.15	22.57±.15		
V	1.59	1.67	1.01	20.95±.13	21.05±.13	6.3	1.4
R	1.98	1.98	0.98	19.67±.20	19.66±.20	3.0	2.5
H	1.19	1.11	0.85				
A753	1.11	1.19	0.87				
A770	1.27	1.27	0.86			7.4	0.6
A791	1.67	1.59	0.97				
A914	1.27	1.27	0.79			8.8	1.4

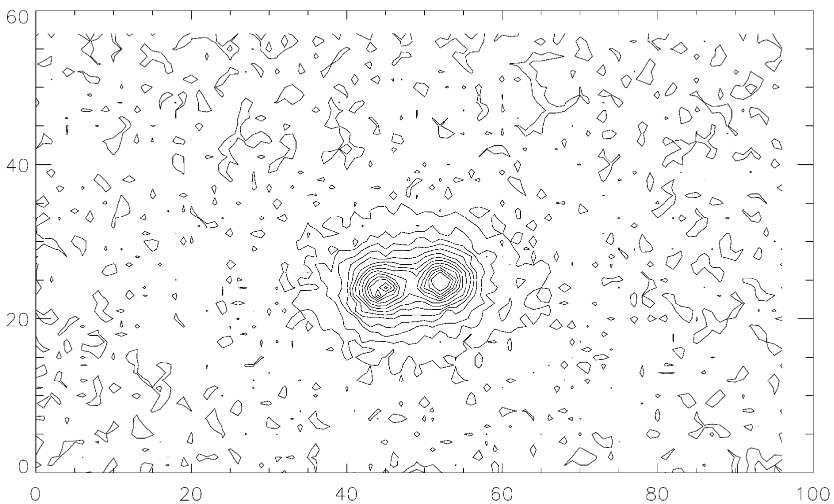
914 nm



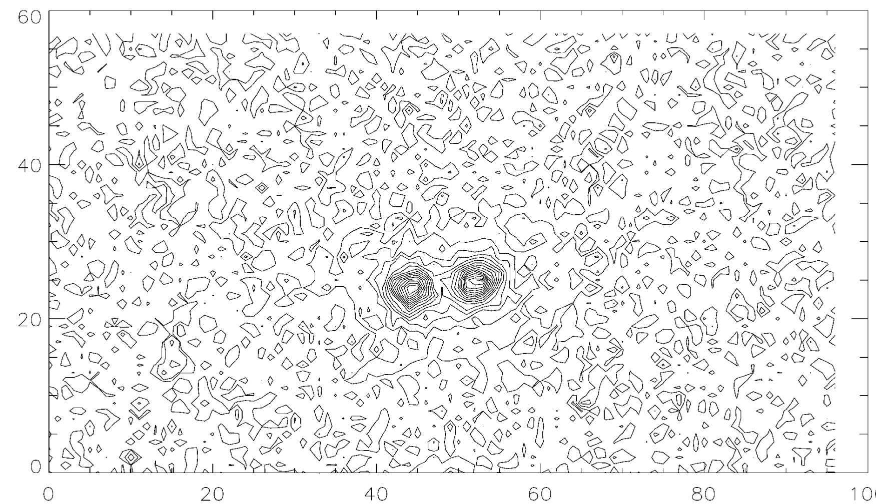
753 nm



B - filter



R - filter



Spectroscopy

Two data sets:

NTT + EMMI

TNG + Dolores

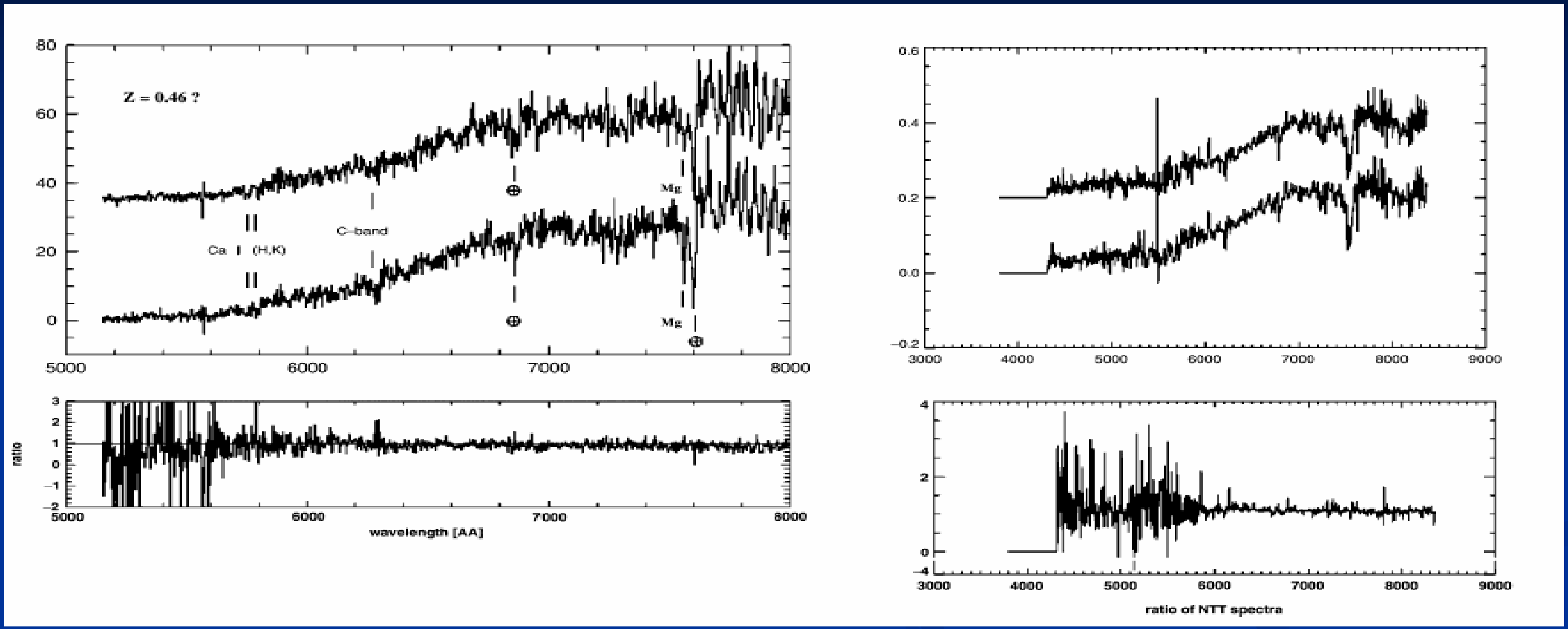
Equipment	Exp. time (h)	Spect. resol.	Spectral range (Å)
TNG+Dolores	1	12.0 Å	5200–7600
NTT+EMMI	2	9.4 Å	4000–8500

- **Redshift**
- **Spectral shapes**

$$z = 0.46 \pm 0.008$$

$$\Delta v = 27 \pm 26 \text{ km s}^{-1}$$

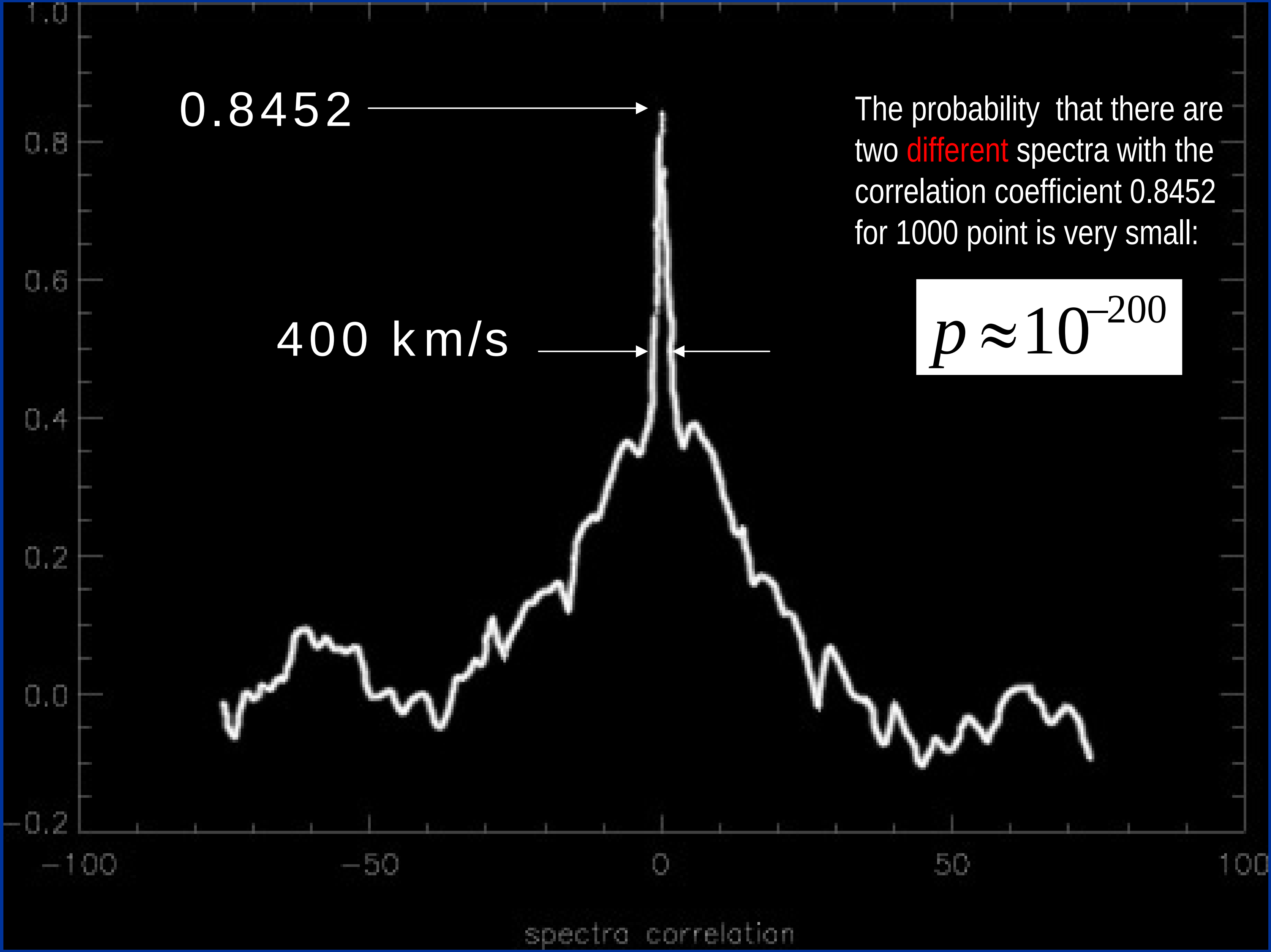
TNG NTT



CSL-1

is a gravitational lens!!

Correlation coefficient of NTT spectra with background removed



The probability that there are two different spectra with the correlation coefficient 0.8452 for 1000 point is very small:

$$p \approx 10^{-200}$$

Other explanations to be rejected. I. - Dust

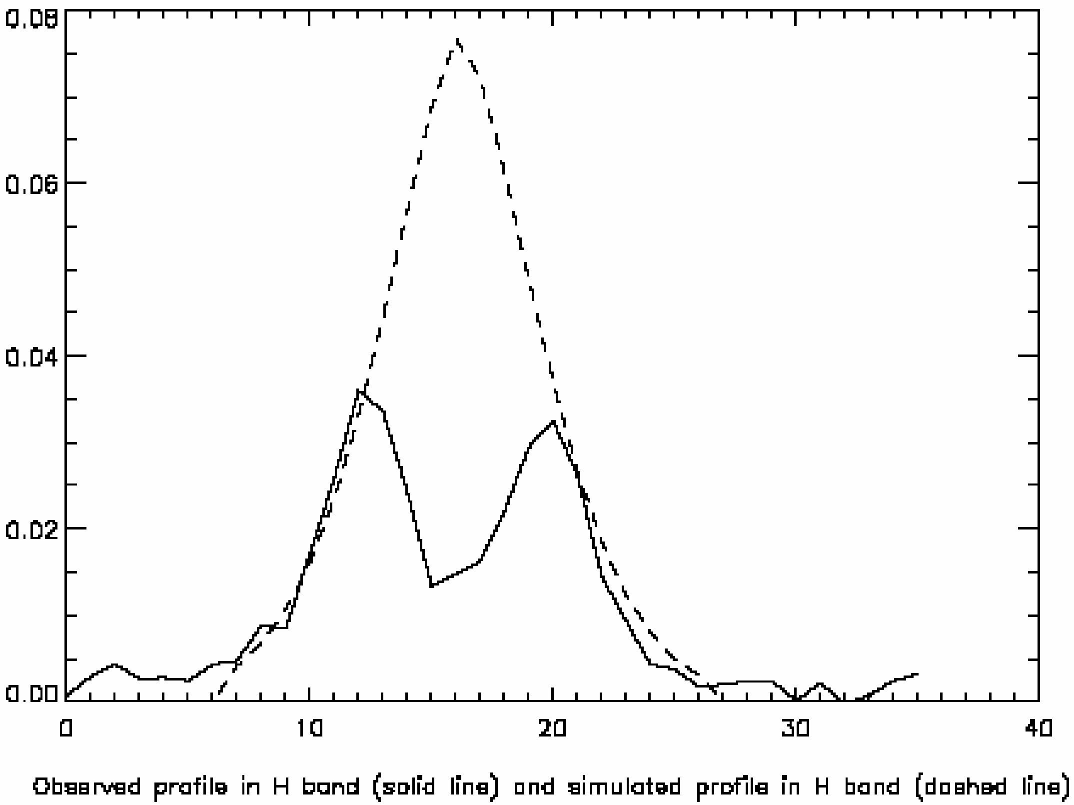
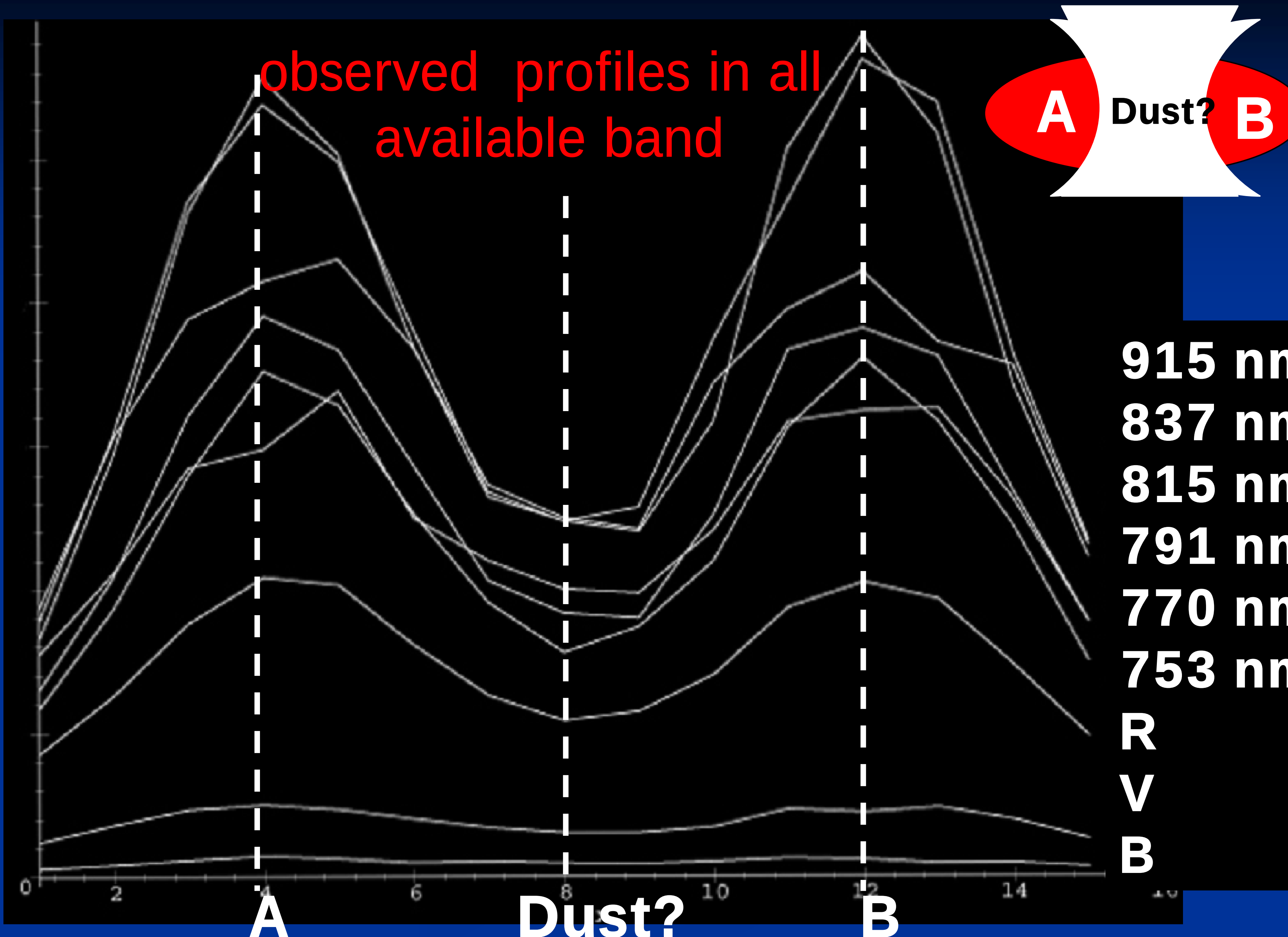


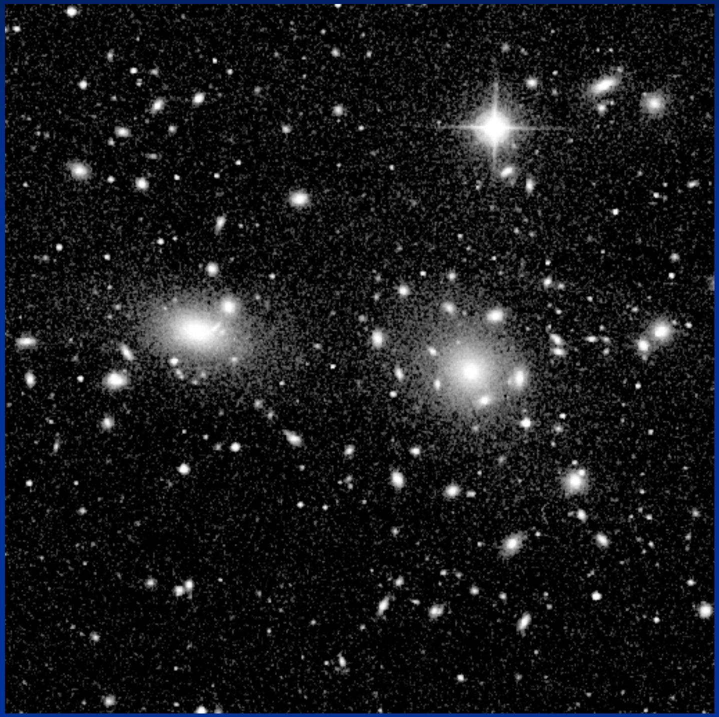
Figure 5. The solid line denotes the observed H band profile for CSL-1. The dashed line denotes the profile expected in the H band following the procedure described in the text (dust index $n = 1$).

Separation is too large

It would be the brightest spheroid in the universe


observed profiles in all available band
A
Dust?
B
915 nm
837 nm
815 nm
791 nm
770 nm
753 nm
R
V
B
0
2
4
6
8
10
12
14
A
Dust?
B

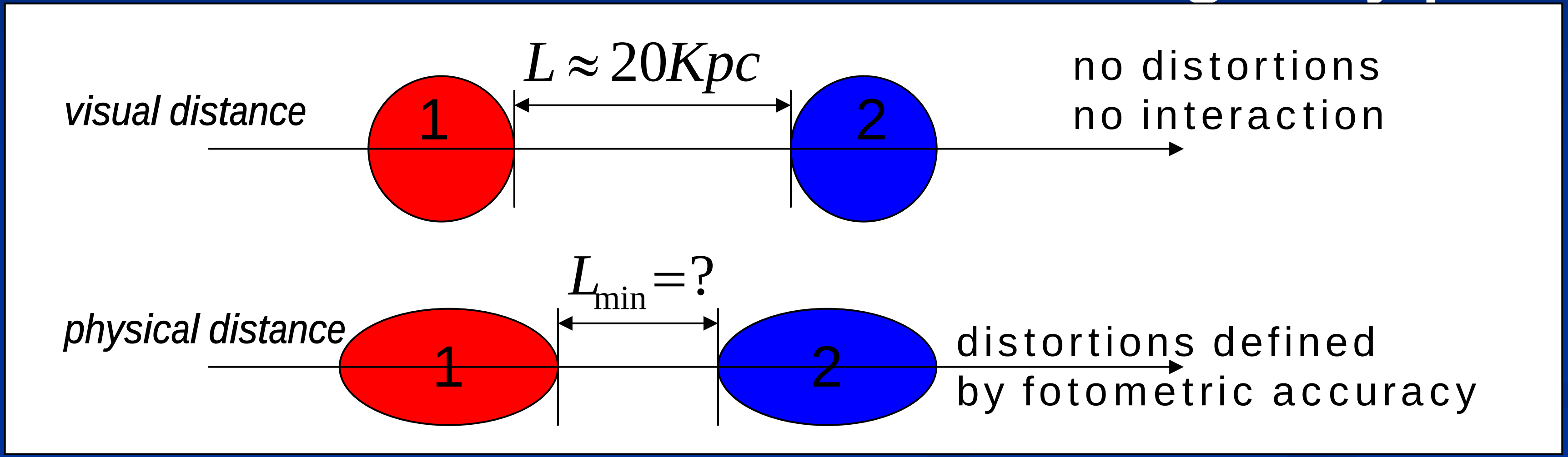
Other explanations to be rejected. II. – Interacting pair of identical ellipticals



- **Separation is too small to prevent from distortions.**
- **There is no cluster of galaxies around and, once more,**
- **It would be the only pair of isolated giant ellipticals in the universe ....**
- **... and it would be rather difficult to explain where they come from...**

Other explanations to be rejected. III. – chance alignment

1. Gravitational tidal interaction of the galaxy pair



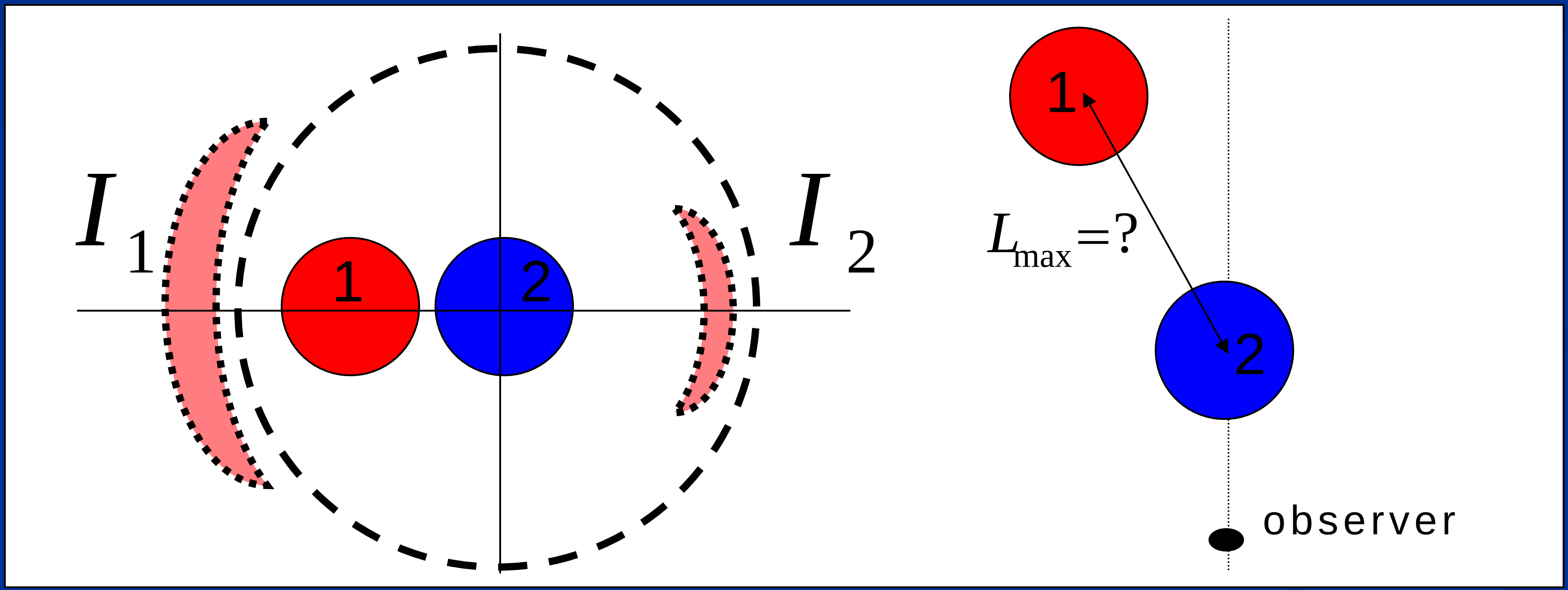
I. Probability smaller than: 10^{-6}

II. Never Observed

III. Where are the clusters?

Other explanations to be rejected. IV. – self lensing

2. Gravitational lensing of the galaxy pair on each other



There are no distorted images

1 would be incredibly luminous

Gravitational lens, but …

why lensed by a cosmic string?

- Because it is extended …

$$\sigma \approx 0.8 \text{ arcsec}$$

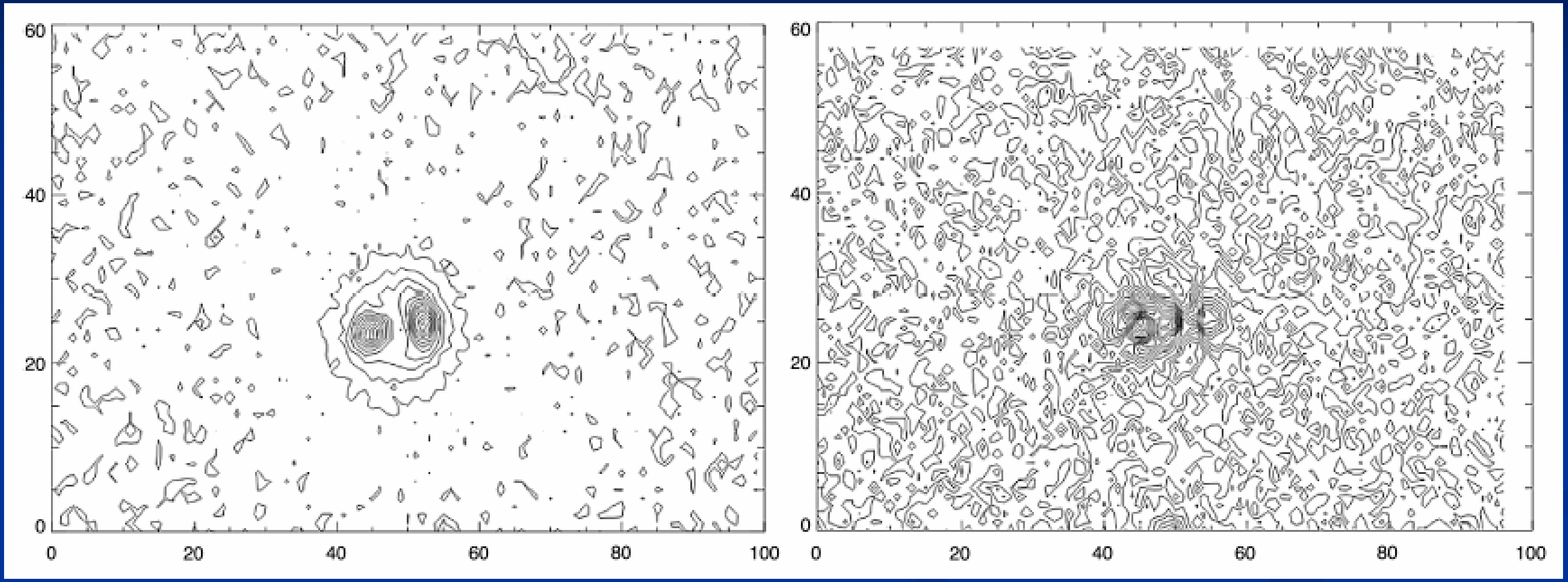
$$R_e = 6 \text{ arcsec}$$

- The two images are identical

- And undistorted !!!

No model of compact lens can produce such a morphology

Best example of SIS model

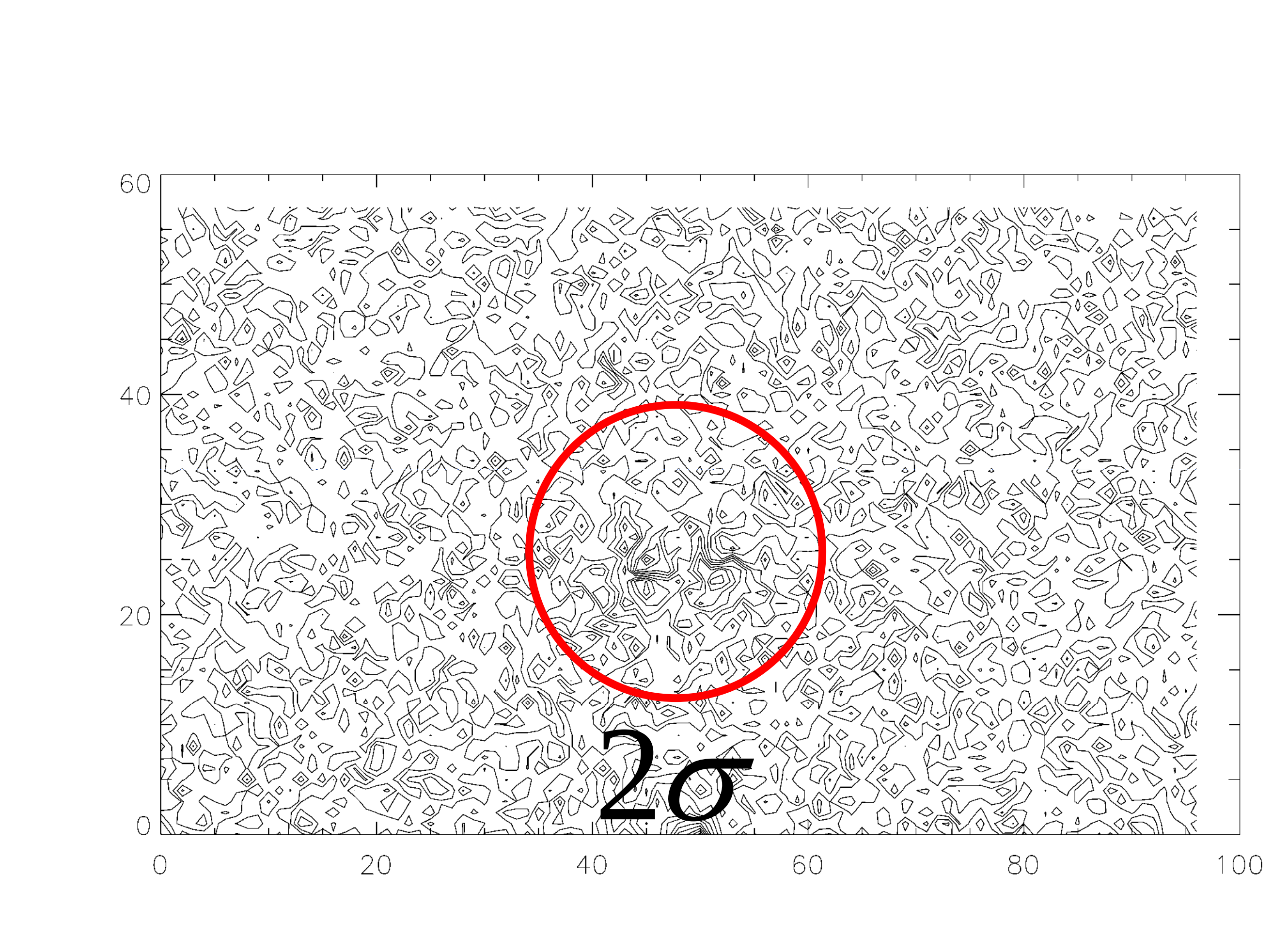


Best fit model convolved with measured PSF

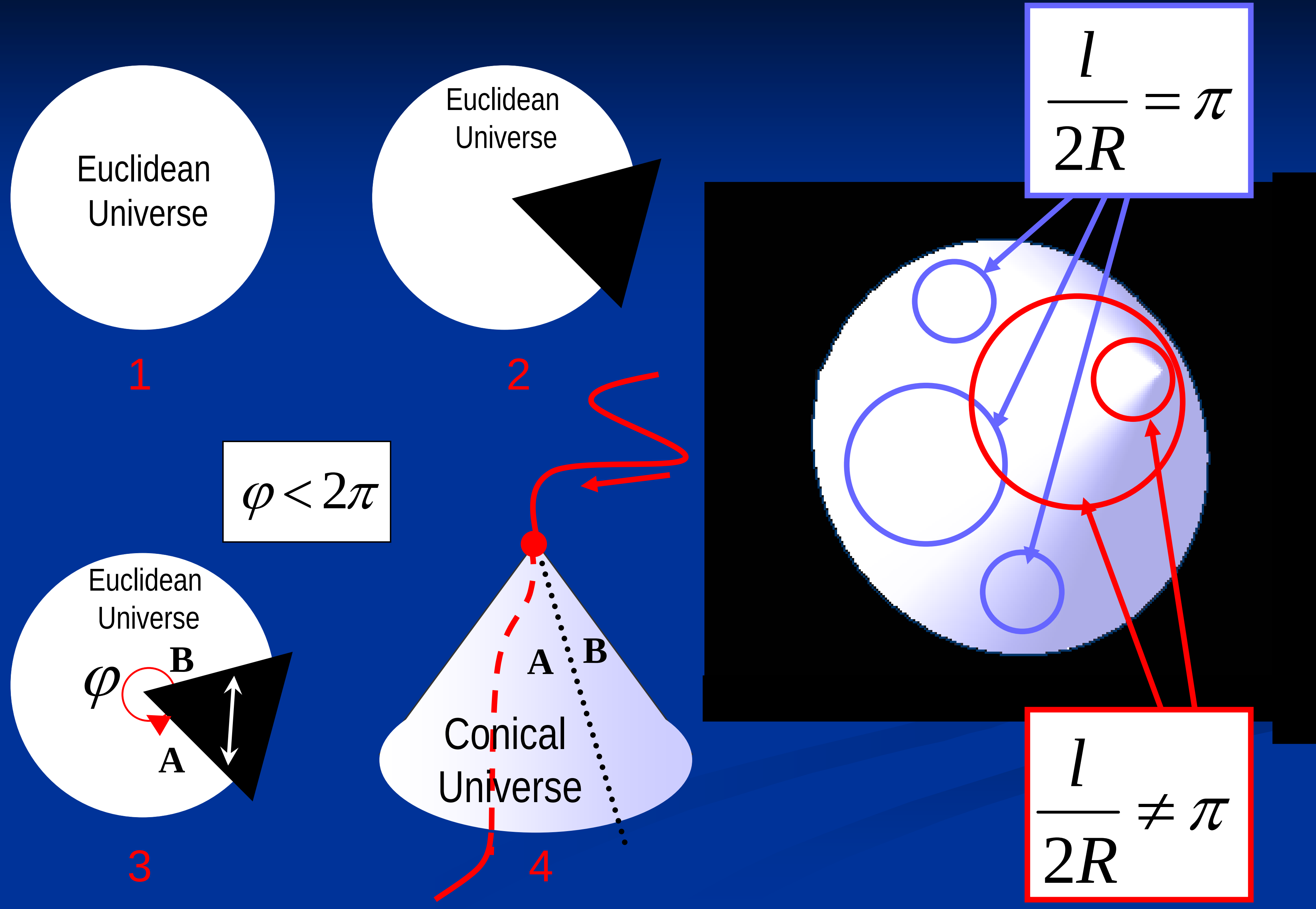
Residuals

Contours = 0.5 σ

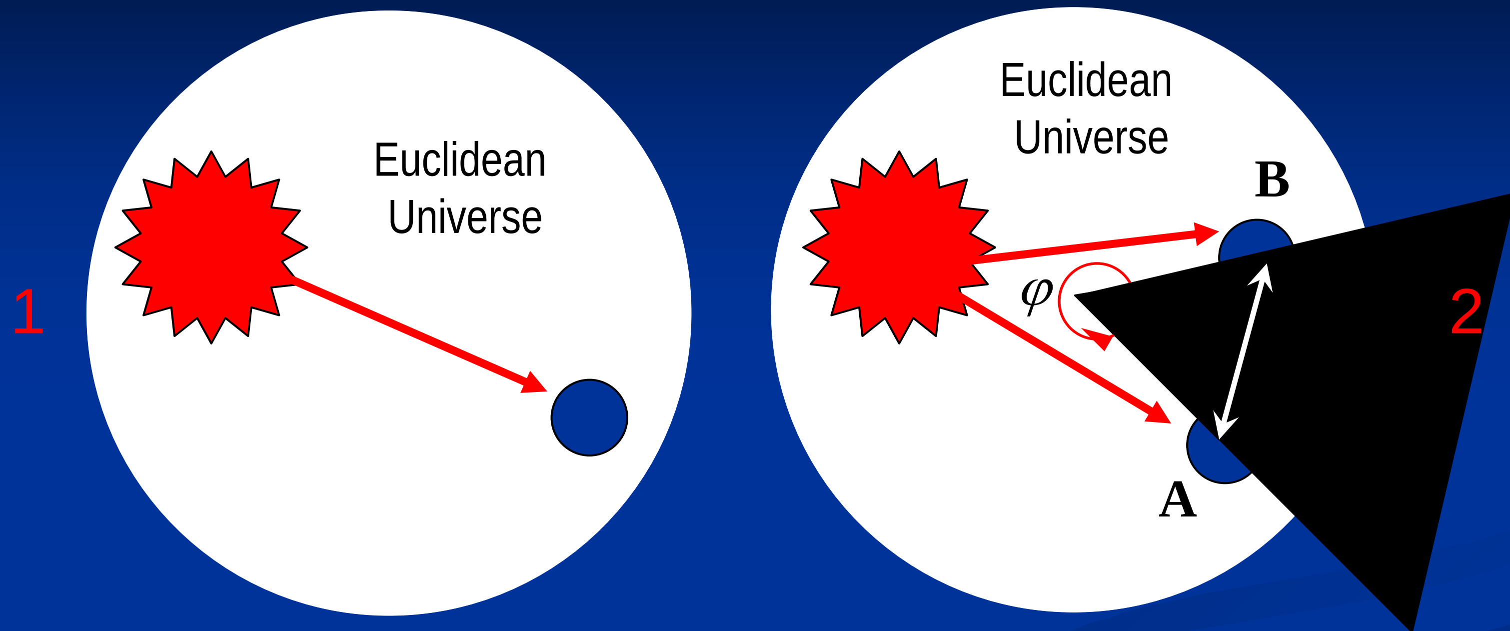
The only explanation we found is lensing by a cosmic string

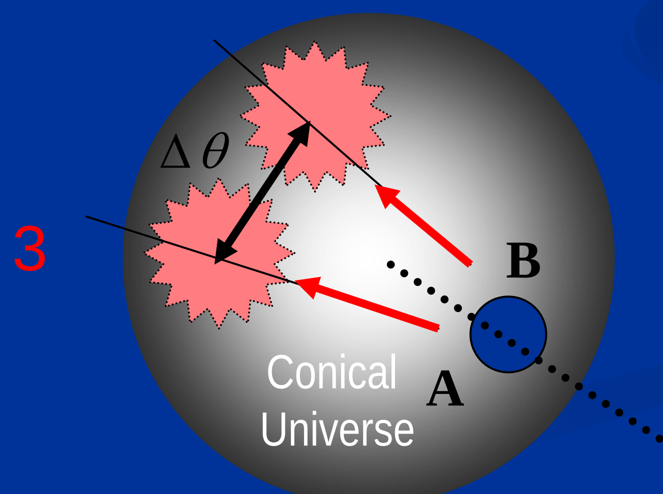


Cosmic string in the Universe



Cosmic string as gravitational lens: schematic model of formation of two images of background source





If the angular distance between the background source and the string is less than

$$D = 2\pi - \varphi$$

the observer sees two images separated by angle

$$\Delta\theta$$

Mon. Not. R. Astron. Soc. **343**, 353–359 (2003)

CSL-1: chance projection effect or serendipitous discovery of a gravitational lens induced by a cosmic string?

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[2]*Sternberg Astronomical Institute, Universitetsky pr., 13, 119992, Moscow, Russia*
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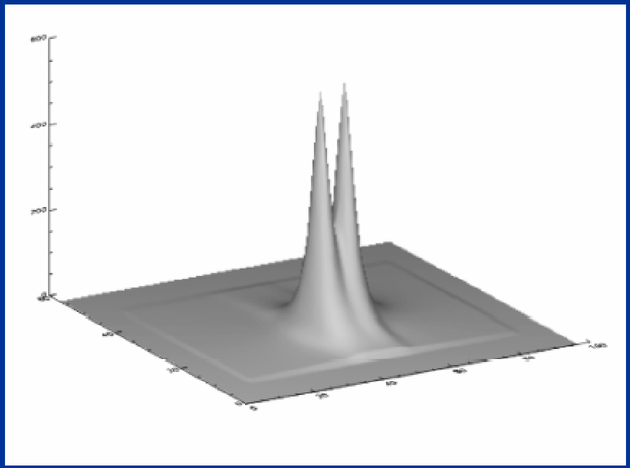
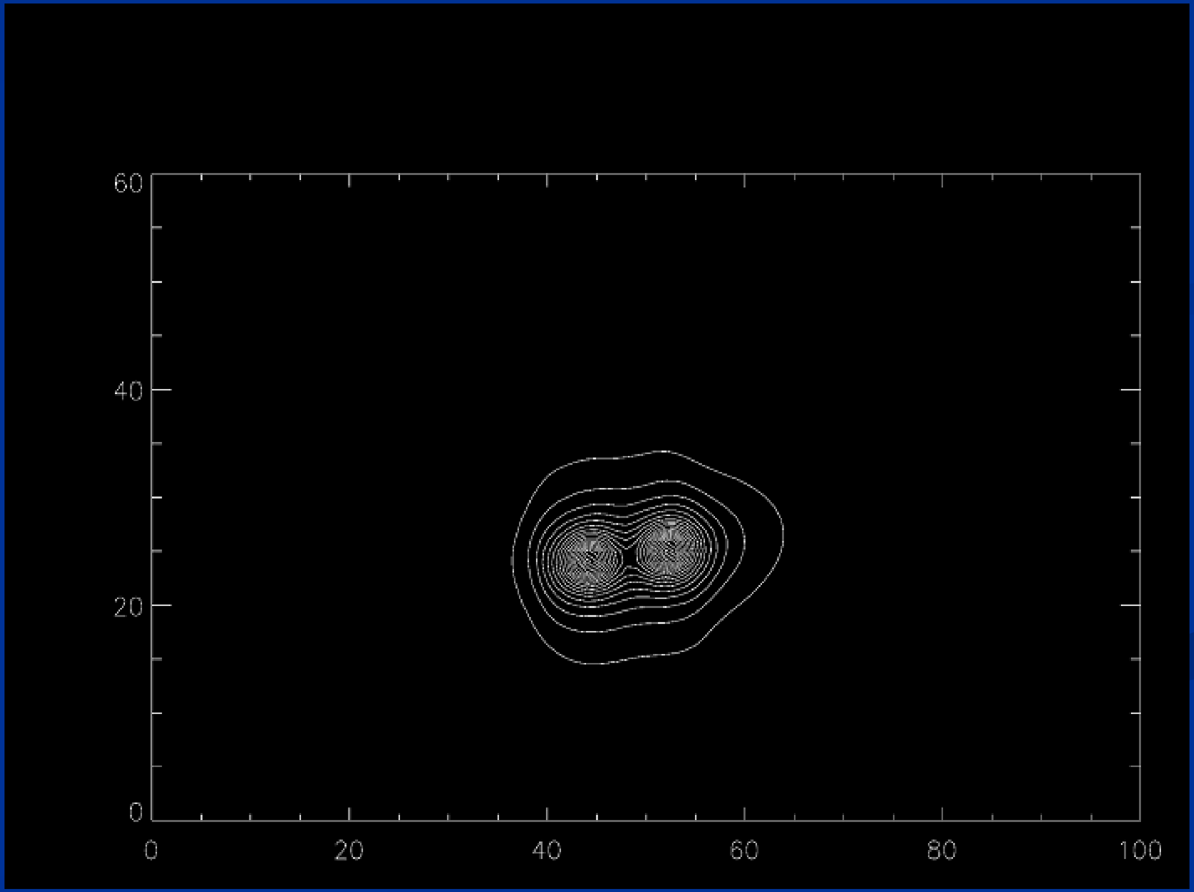
These paper started a debate…

and a long and still ongoing struggle

Possible Tests. I. Morphology

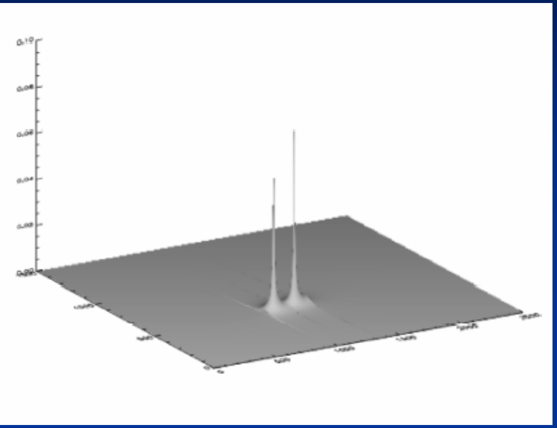
Contours of simulated de Vaucouleurs spheroid after rebinning to the OAC DF pixel size (0.238 arcsec) and convolving with the observed OAC DF PSF (0.98 arcsec)

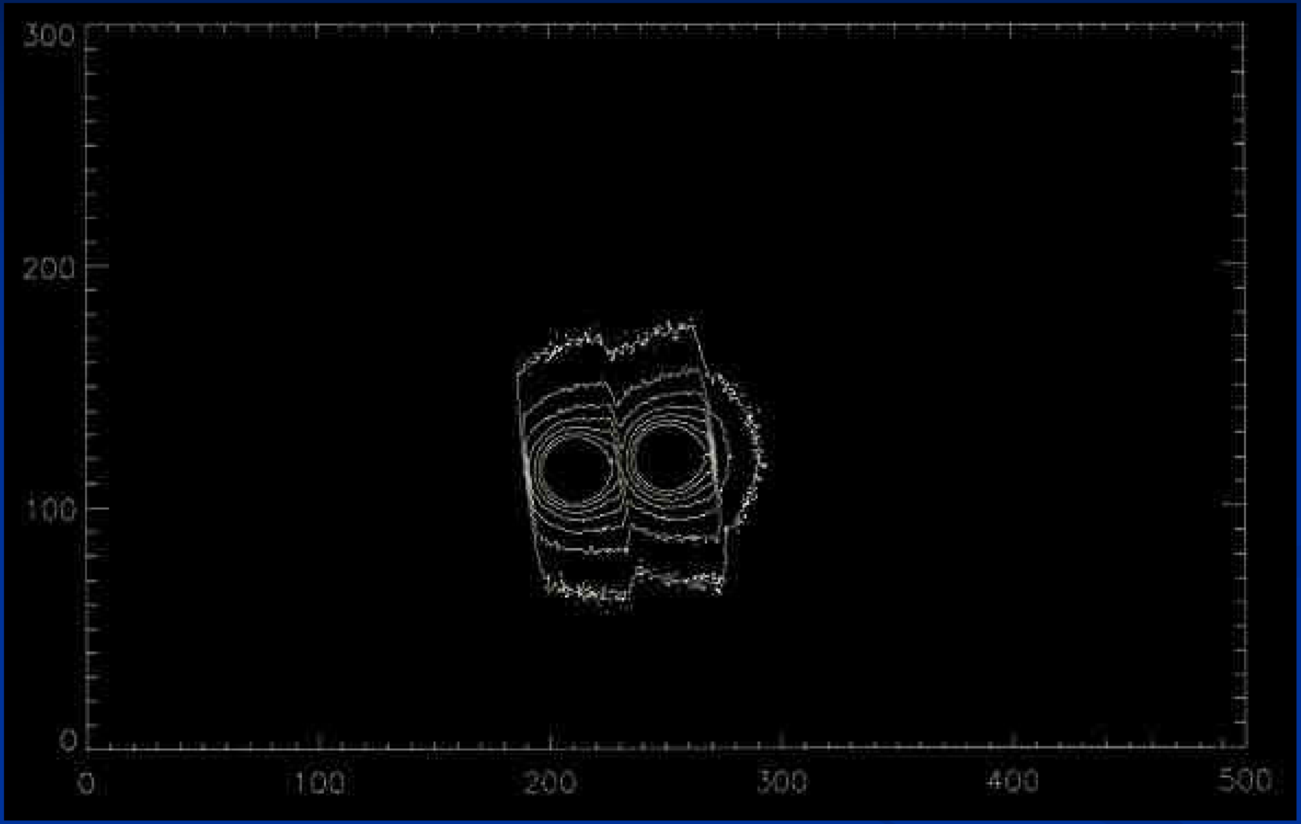




Higher resolution

Contours of simulated image for pixel size 0.05 arcsec and noise

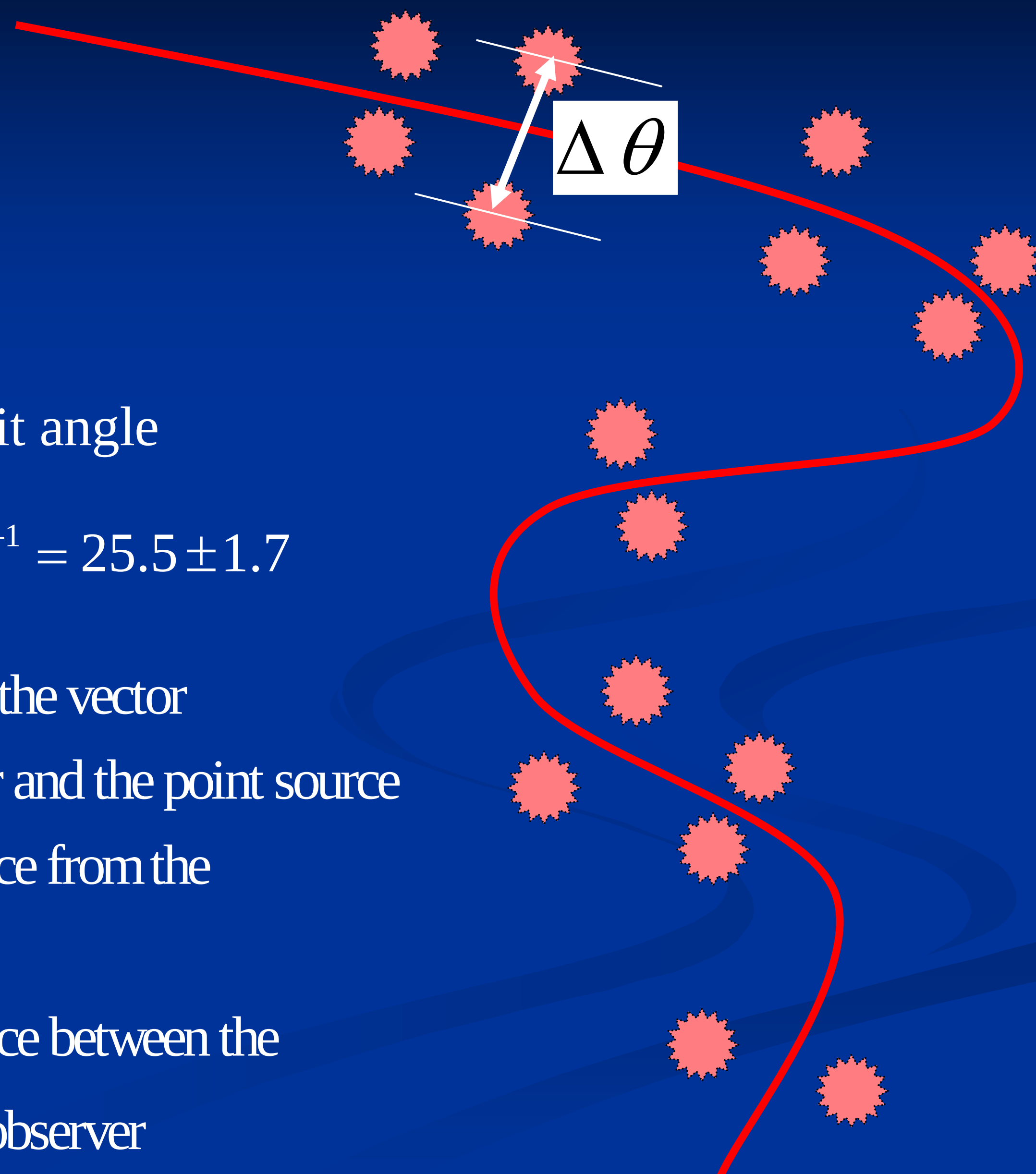




Two possible solutions:

- HST
- Adaptive optics (VLT + CONICA or similar)

Possible Tests. II. "Milky way of lenses"



$$\Delta\theta = D\frac{R_q - R_s}{R_q}\sin\xi$$

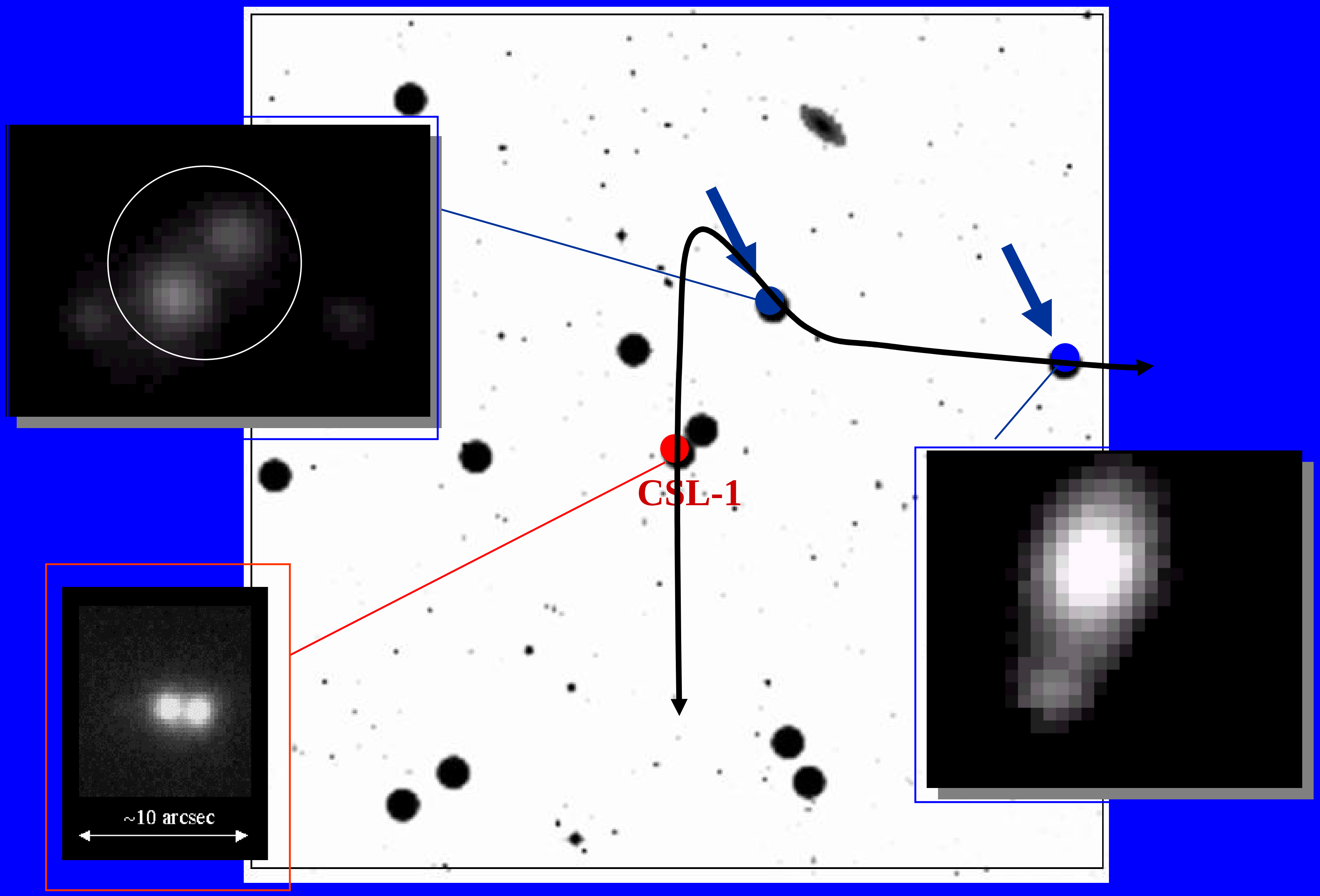
$2\pi - \phi = D = 8\pi\mu$ - deficit angle

$\mu \approx \frac{\mathrm{m}^2}{\alpha}$ string density $\alpha^{-1} = 25.5 \pm 1.7$

ξ - angle between the string and the vector coinciding with the observer and the point source

R_s - angular cosmological distance from the observer to the string

R_q - angular cosmological distance between the background source and the observer


CSL-1
~10 arcsec

Possible Tests. III. CMB signatures

Observation in radio-frequency bands would also be needed. A straight long string induces temperature fluctuation on the cosmic microwave background radiation, and is therefore expected to produce a line-like discontinuity at the place of the string. The amplitude of fluctuation is given by (Kaiser & Stebbins 1984)

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

where v is the velocity of string perpendicular to the line of sight in units of light velocity. Usually the velocity of cosmic string is expected to be close to unity due to stresses which are inside the string. If the velocity is close to unity, we can expect significant anisotropy which will form a strip of $\delta T/T$ along the position of the string with an angular width of the order of 2 arcsec and an amplitude of $\sim$30 μK. This strip would cross the optical images of CSL-1 perpendicularly to the line connecting the two components. Although the expected angular scale is very small, the amplitude is easily detectable with modern radiometers (see, for instance de Bernardis et al. 2002).

Theoreticians like very much the idea!

Appealing for the public

Astronomers like the idea… as long as it remains just an idea !

A few attempts have also been made by others !

Scientific American, February 2005

GPS down here. One by one, the other subs appear—first *Mir 2* and then *Deep Rover 1* and 2. With their acrylic domes, the rovers look like aquariums for people.

All too quickly, five hours go by—about when our 16-volt battery dies: *"Deep Rover 2. Mir 1. Jim, we have to leave. Our 16-volt is out. Call Mission Control. Let them know we're ascending. Over."*

"Roger that. See you at the surface."

Christina Reed, now back in Washington, D.C., was the science coordinator for Aliens of the Deep.

news SCAN

COSMOLOGY

String Revival

ARE COSMIC STRINGS BEHIND UNUSUAL LENSING EFFECTS? **BY GOVERT SCHILLING**

Like haute couture, cosmology has its own fads, fashions and fallacies. Gone are the heydays of galaxy surveys and quasar discoveries; now searches for the universe's first stars and for the nature of dark energy are all the rage. But like miniskirts and

show that all possible explanations for this behavior fail, except for gravitational lensing by a small loop of cosmic string close to our own Milky Way galaxy. The moving cosmic string would have acted as an additional gravitational lens, affecting both quasar im-

Then what?

Proposals submitted in 2003-2004

1. High resolution imaging for “edges”

- Adaptive optics from the ground: TNG and VLT → Rejected : no bright star in the field
- Maidanak → Failed: poor seeing
- HST → Rejected: more observations from the ground are needed

2. Spectroscopical confirmation of other candidates

- TNG → Failed bad weather
- VLT (DDT) → Failed bad weather
- HST → Rejected (ground)

2. Spectroscopical confirmation of other candidates. II. The revenge

- SAO 6 m — 2 candidates done
- VLT + FORS1 (DDT) — 2 candidates done
- HST — Rejected! Need data from the ground

Candidates 1 and 2 are confirmed gravitational lenses !!!

VLT spectra come in next week (ooops!!!)

arXiv:astro-ph/0503120 v1 5 Mar 2005

Signatures of Cosmic Strings in the Cosmic Microwave Background

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6. A Cosmic String Candidate?

Sazhin et al.(2003) reported a discovery of an object which contains two sources of identical isophotes, color, and fitted 2-D light profiles in the Osservatorio Astronomico di Campodimonte Deep Field (OACDF). In addition, spectra of the sources are identical with a confidence level higher than 99%. Morphological arguments led them to propose that this object is a background galaxy lensed by a cosmic string. They have named this object the Campodimonte-Sternberg-Lens candidate 1, or CSL-1. The red-shift of both sources in the object is 0.46 ± 0.008; the separation of the two sources is $2''$.

Precise finder charts for the object were not available. We found this object by visually inspecting the OACDF deep field and comparing it to the Palomar All Sky Survey plates. We found CSL-1 to be located at (J2000) RA 12:23:30.72, Dec -12:38:57.8. There may be some small uncertainty about the location of CSL-1. We examine the WMAP data at this location to see if the Edgefinder can detect a string. As WMAP data had a resolution of 0.23 degrees, by including the four nearest pixels to that coordinate, we believe we have covered this object in our search.

[1] With the $G\mu$ given above, this means for an E.V. = 0.08686 mK, the string needs $\beta\gamma \gtrsim 3.3$, or $v = 0.957c$, to account for the temperature jump. The ranges of string velocity for the E.V. in Table 6 is from $v = 0.941c$ to $v = 0.979c$. These high string velocities makes the case for the existence of cosmic strings at this location more unlikely, as the rms string velocity is $v \sim 0.7c$. We therefore cannot say that we have a significant detection of a cosmic string at the location of CSL-1 in the WMAP data.

RELICT
(Strukov I.A. et al. MNRAS 258 37P 1992)
COBE
(Smoot G.F. et al. Astrophys. J. 396 L1 1992)
BOOMERanG
(de Bernardis P. et al. Nature 404 955 2000)
Archeops

WMAP
(Wilkinson Microwave Anisotropy Probe, http://map.gsfc.nasa.gov)

Current data of microwave background measurements exclude cosmic strings and other topological defects as primary source of primordial density perturbations.

CSL1 fits into 1 WMAP pixel !!!

Plank is needed !!!

From a theoretical point of view: cosmic strings may help to explain

1. The low multipole anisotropy is too small

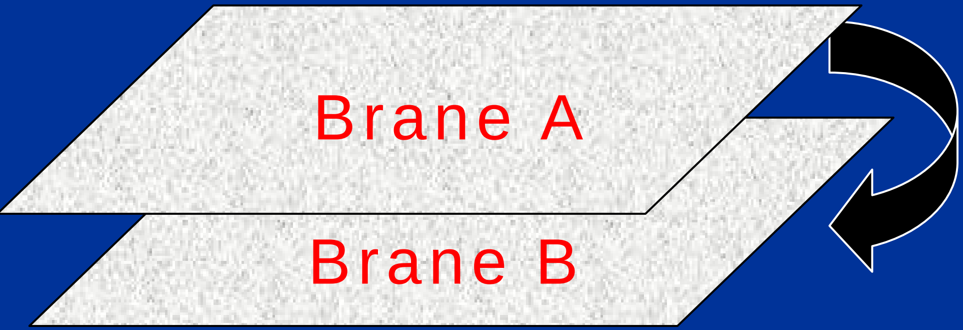
2. First Doppler peak has double peak structure which cannot be explained within standard cosmological model

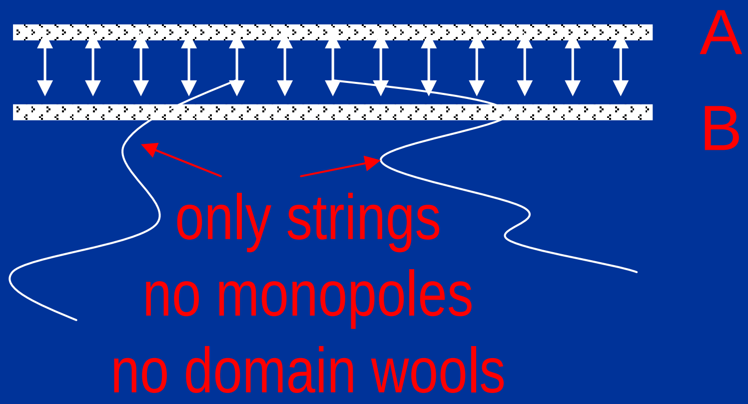
3. The correlation function of galaxies is fitted with broken power-law empirical fit instead of standard power law fit.

One of the possible explanation is that dark matter has complex structure and consists from different type of matter which change both the spectrum of the primordial fluctuation and the transfer function.

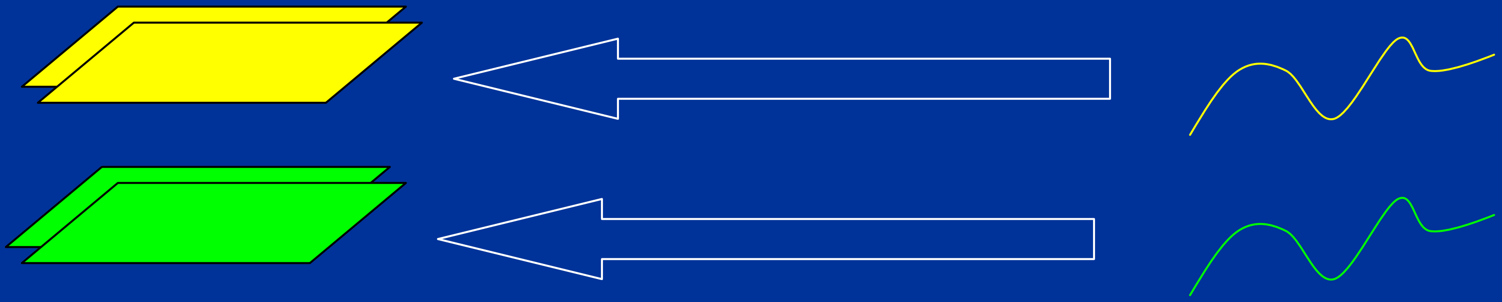
Cosmic string is one among the possible candidates

Branes, which now play key role in superstring theory, can collide and generate cosmic strings. In modern brane cosmology the string production is natural in contrast to monopoles and domain walls production.



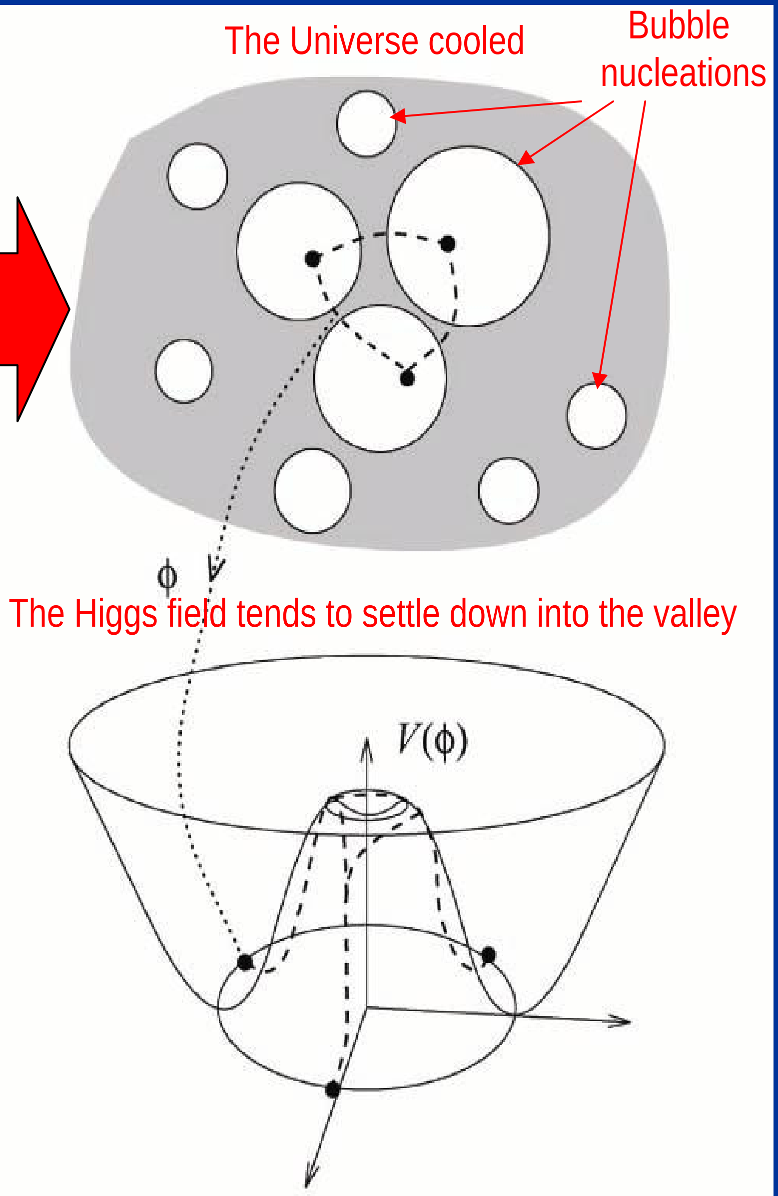


String theory now provides a much richer family of branes with different properties For this reason, if we could discover which kind of cosmic strings exist in our Universe it would tell us a lot about the underlying fundamental theory.



Cosmic string in the Universe

The very hot Universe
is in Symmetric phase.
No strings.



If we accept the interpretation of **CSL-1** as **gravitational lens produced by a cosmic string**, it is possible to derive the scale of energy at which the symmetry breaking occurred.

The distance between the peaks of the two images ~2`` of CSL-1 roughly corresponds to the “deficit angle”. One can therefore estimate the density of the string as

$$G\mu = 4 \cdot 10^{-7}$$

and the **mass scale of symmetry breaking** as

$$2 \cdot 10^{15} GeV$$

CONCLUSIONS ?

AT THE PRESENT TIME: NONE

SEE YOU SOON