Candidate Cosmic Filament in the GJ526 Field Mapped with the NIKA2 Camera

NIKA2 Science Verification Program GJ526

Jean-François Lestrade (Observatoire Paris) on behalf of the NIKA2 collaboration
Outline

• Initial project: possible dusty circumstellar disk around the nearby red dwarf GJ526

• NIKA2 maps of the GJ525 field: noise characterisation and source extraction

• Spatial distribution of the background sources: candidate cosmic filament
Initial motivation

Proper motion of star GJ526:
\[ \cos \delta \mu_\alpha = +1.77 \text{ arcsec/yr} \]
\[ \mu_\delta = -1.45 \text{ arcsec/yr} \]

Displacement expected in 10 years: 22.6” to south-east

Debris disk around HR8799
Booth et al 2016. ALMA

SNR map of the Field GJ526 with the camera MAMBO/IRAM 30m at 1.2mm, epoch 2007
Contours -3\(\sigma\), -2\(\sigma\), -1\(\sigma\), +1\(\sigma\), +2\(\sigma\), +3\(\sigma\)… Lestrade et al (2009)
Debris disk around HR8799
Booth et al 2016. ALMA

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MAMBO map and NIKA2 maps

MAMBO – 1.2mm

NIK2 epoch 2017 (9.3hours)
Color scale = surface brightness mJy/b
Contours = SNR: -3σ, -2σ, -1σ, +1σ, +2σ, +3σ, ...
1σ=0.6mJy/beam

Lestrade et al 2009

NIK2 – 1.15mm (A1+A3)

NIK2 – 2.0mm (A2)

NIK2 observations : april 2017, february 2018 (9.3hrs)
Map making method : IMCM (Iterative Multi Correlated Modes)
opacity_1mm : 0.20 – 0.45 (2mm : 0.10 – 0.25)
Caracterization of the noise: Jack-knifed maps

1 mm

\[ \text{snr}_{\text{min}} = -3.9 \]
\[ \text{snr}_{\text{max}} = 3.7 \]
\[ \mu = 0.003 \]
\[ \sigma = 1.017 \]

2 mm

\[ \text{snr}_{\text{min}} = -4.0 \]
\[ \text{snr}_{\text{max}} = 3.8 \]
\[ \mu = -0.015 \]
\[ \sigma = 1.038 \]
Statistically, no spurious source with $|\text{SNR}| > 4$ is expected in our 1mm NIKA2 map with its 2630 independent beams ($500''\times500''/(\pi(11''/2)^2)$).

Statistically, 7 spurious sources with $|\text{SNR}| > 3$ are expected.
Statistically, no spurious source with $|\text{SNR}| > 4$ is expected in our 1mm NIKA2 map with its 2630 independent beams ($500'' \times 500'' / (\pi (11''/2)^2)$).

Statistically, 7 spurious sources with $|\text{SNR}| > 3$ are expected, i.e. 3-4 positive sources in the table.

### Point-source extraction and statistics

<table>
<thead>
<tr>
<th>ID</th>
<th>H3</th>
<th>$\alpha_{2000}$</th>
<th>$\delta_{2000}$</th>
<th>NIKA2 $S_{260\text{GHz}}$ (mJy)</th>
<th>SNR</th>
<th>NIKA2 $S_{150\text{GHz}}$ (mJy)</th>
<th>SNR</th>
<th>MAMBO $S_{260\text{GHz}}$</th>
<th>MAMBO cos($\theta$)</th>
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<td></td>
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<td>out$^*$</td>
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<td>13:46:19</td>
<td>14:52:36.8</td>
<td>0.17$±$0.64</td>
<td>0.3</td>
<td>0.49$\pm$0.14</td>
<td>3.4</td>
<td></td>
<td></td>
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<td>n</td>
</tr>
</tbody>
</table>

*(out)=outside the MAMBO map

*(*$^*$)=not detected at snr $\geq$ 4 in the MAMBO map
In the central region (r < 150") : 6 sources (ID 9, 10, 16, 13, 18, 7) are unambiguously detected (SNR >4)

Previous cumulative source count at 1.2mm in the COSMOS field : N(S_\nu > 4\sigma=2mJy )=500 sources/deg^2

Poisson probability with COSMOS source surface density is 1.5% \rightarrow overdensity
Using source number surface density $N(S_\nu > 4\sigma = 2mJy) = 500 \text{ sources/deg}^2$ (COSMOS field) and $\delta = 10^\circ$.

Probability of chance alignment of sources ID 3, 6, 9, 10, 16, 18, (25)

\[
\text{Probability} = \prod_{i=1,6} 500 \text{ sources/deg}^2 \cdot \pi \left( r_i \right)^2 \cdot \left( 2\delta / 360^\circ \right) = 1.5 \times 10^{-6}
\]
SEDs and photometric redshift of SMGs

Adopting the same redshift $z=2.5$ for all sources yields reasonable fits for all SEDs, \textit{i.e.}

\[ 35 \text{ K} < T_{dust} < 60 \text{ K}, \]
\[ 6.5 < L_{bol} < 19 \times 10^{12} \text{ L}_{bol} \]
\[ 1 < \beta < 2 \]

Data: NIKA2 and Herschel/SPIRE photometry

All SMGs with SPIRE data

$$S_{\nu} = \frac{1 + z}{4 \pi D_L^2 L_{bol}} \int f_{\nu'}(1+z) f_{\nu'} d\nu'$$

(Blain et al 2002)
The intersections of filaments become the locations at which galaxy clusters form and evolve. 
(Springel et al 2005)

Narrow streams of cool gas falling along filaments fuel the growth of galaxies at cosmic dawn ($1 < z < 3$).  
(Dekel et al 2009)

Figure 9. Gas in halo 311 of the MareNostrum

$\Lambda$-CDM model **NewHorizon** simulation: snapshot at $z=2$ of projected density (DM and gas) in silver blue and temperature in red.  
(Dubois et al 2014, 2020)

Cosmic web is a vast, foam-like network of filaments and voids stretching throughout the Universe and tracing DM, gas and galaxies.
Candidate Cosmic filament in the NIKA2 map of the GJ526 field

Size = 4.6 Mpc at z=2

Size = 4 Mpc at z=2 (500” x 8.521kpc/’’)

1 cMpc
Proto-cluster SSA22 at $z=3.095$: SMG’s and Ly $\alpha$ emission of two cosmic filaments

Fig. 1. Multi-wavelength images of ADF 22, illustrating the overdensity of galaxies and AGNs in a narrow redshift range at $z=3.09$. Each panel is centered at $(\alpha, \delta) =$

Ly $\alpha$ emission map optimally extracted from the MUSE observations,

Umehata et al 2019
The massive galaxy group RO-1001 at $z=2.91$

Group RO-1001: contours are the Ly$\alpha$ surface brightness. Sources ABC are ALMA SubMillimeter Galaxies and D is a massive Galaxy and quiescent object in the structure.

Daddi et al 2021

Group RO-1001: Ly$\alpha$ image and the three extended filaments labeled.
Concluding remarks

Follow up observations (spectroscopic z of SMGs with CO and Lyman alpha image) to full characterise the candidate cosmic filament(s) of the GJ526 field.

Moderately deep millimeter map (i.e. $1\sigma = 0.5\text{mJy}$) over relative large field ($\sim 100$ arcmin$^2$, i.e. a few Mpc$^2$ at cosmic dawn ($1 < z < 3$) can be conducted efficiently (10hrs) thanks to the high mapping speed of the NIKA2 camera.

This capability could be used to peak up the large scale structure of the Early Univers traced by milliJanky SubMillimeter Galaxies (SMGs).