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The First Calibration of SBF Using Multi-Conjugate Adaptive Optics

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ABSTRACT: We measured Surface Brightness Fluctuations (SBF) in three galaxies, ESO137-G006, NGC 3309, and NGC 5128, using the GeMS Multi-Conjugate Adaptive Optics (MCAO) system on the Gemini South telescope. ESO137-G006 is located in the Norma Cluster, NGC 3309 is located in the Hydra Cluster, while NGC 5128, also known as Centaurus A, is a nearby galaxy with numerous other distance measurements, including Cepheids. These galaxies were observed as a path finder to establish the SBF technique using the MCAO system. The J and Ks-band images taken with MCAO were astrometrically corrected and combined using the THELI software. This method allowed us to accurately account for the distortions of the focal plane when combining the images. The foreground stars as well as the globular clusters were measured to account for their contribution to the SBF. J-Ks color measurements were made to calibrate SBF and determine the stellar populations of the galaxies. The results of these measurements give us an SBF calibration that we can use to measure the distances to much more distant galaxies.

References:

Multi-Conjugate Adaptive Optics:
The GeMS Multi-Conjugate Adaptive Optics (MCAO) system on the Gemini South telescope provides near diffraction limited images at Ks band (2.1 μm) across a ~2 arcmin² field of view. An example of this high resolution is shown in the image of Centaurus A (NGC 5128) below. The image is ~82 x 84 arcsec and the magnified region is ~10 x 8 arcsec. MCAO uses 5 laser guide stars, 3 natural guide stars and 3 deformable mirrors to create a very uniform point spread function (PSF), as shown in the left panel, but also introduces focal plane distortions. We used natural-seeing images and the THELI package to correct for these distortions.

MCAO Image Quality Uniformity: The high resolution and uniformity of the field of view achieved by MCAO is shown in the images below. The field of view of the large image of ESO 137-G006 below is 1.4 x 1.4 arcmin. The smaller stellar images from across the field are 1 arcsec on a side (50 x 50 pix).

Conclusion: MCAO provides uniform, high resolution images for making high-S/N IR SBF measurements of elliptical galaxies. Natural seeing images are very valuable to correct for the geometrical distortions of the focal plane.

SBF Measurements:
- We used natural-seeing reference images taken with other telescopes to map the geometrical distortions in the MCAO focal plane and combine the images using THELI.
- We used a lancoz3 kernel to correct the distortions in the focal plane.
- The galaxy profile fit was subtracted from reduced image to create residual images, like the one shown to the left.
- We used Source Extractor to find and remove foreground stars, background galaxies, and globular clusters.
- We measured the PSF by examining stars from different places in the field of view, as shown in the examples in the left panel.
- The SBF amplitude was then measured by fitting the PSF power spectrum to that of the residual image.
- J-Ks color maps were made from the GeMS data and used to determine the characteristics of the stellar populations.
- The SBF absolute fluctuation magnitude calibration was determined using published distances and our measured J-Ks colors.

Ks Surface Brightness Fluctuation Data

<table>
<thead>
<tr>
<th>Galaxy</th>
<th>Exposure (s)</th>
<th>AO FWHM (arcsec)</th>
<th>Background (mag/arcsec²)</th>
<th>J-Ks (mag)</th>
<th>Preliminary SBF Calibration</th>
<th>Distance source</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGC 5128</td>
<td>150</td>
<td>0.074</td>
<td>12.68</td>
<td>0.60</td>
<td>21.89</td>
<td>Chophes + TRGB²</td>
</tr>
<tr>
<td>NGC 3309</td>
<td>1200</td>
<td>0.082</td>
<td>12.58</td>
<td>1.02</td>
<td>28.39</td>
<td>FP + SBF²,³</td>
</tr>
<tr>
<td>ESO 137-G006</td>
<td>2580</td>
<td>0.082</td>
<td>12.65</td>
<td>1.03</td>
<td>28.90</td>
<td>ν = 4791 km s⁻¹</td>
</tr>
</tbody>
</table>

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