

GEMINI OBSERVATORY

observing time request summary

Semester: 2007A

Observing Mode: queue

Instruments:
NIRI

Gemini Reference:

Time Awarded:

Title: Adaptive-Optics Imaging of Compact Elliptical Galaxies Discovered in the SDSS
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Partner Submission Details *(multiple entries for joint proposals)*

Partner	Partner Lead Scientist	Time Requested	Minimum Time Requested	Reference Number	NTAC		Rank
					Reco-mmended Time	Minimum Time Reco-mmended	
Brazil	Maia	1.2 hours	1.2 hours		0.0	0.0	
<i>Total Time</i>		<i>1.2 hours</i>					

Abstract:

We request 1.2 hours with Gemini/NIRI and Altair in laser guide star mode to measure Ks-band surface brightness profiles of two compact elliptical galaxies discovered in the Sloan Digital Sky Survey. Compact elliptical galaxies like the prototypes M32, NGC 4486B and NGC 5846A become difficult to distinguish from stars at distances beyond the Virgo cluster. Fortunately, the ugiz colors of compact elliptical galaxies distinguish them from the stellar locus, allowing a dramatic reduction of the otherwise prohibitive foreground contamination. Using this technique we have discovered nine new compact elliptical galaxies including two ultracompact dwarfs. The Gemini observations of two of these newly discovered dwarfs are essential for placing them on the fundamental plane and will yield new insight into the link between compact elliptical galaxies, spiral bulges, and ultracompact dwarfs.

Science Justification

The observed structure of elliptical galaxies motivated early models of galaxy formation and remains one of the definitive tests of modern theory. Relationships among luminosity, surface brightness, effective radius, velocity dispersion and metallicity have played a particularly important role in the development of the cold dark matter model (Faber, Blumenthal & Primack 1984, Dekel & Silk 1986). These scaling relations divide elliptical galaxies into two families with markedly different structural properties (Kormendy 1985, Bender, Burstein & Faber 1992, Graham & Guzman 2003). Among giant ellipticals and spiral bulges, the faintest are the most compact, while the vast majority of dwarf ellipticals (dEs) follow the opposite trend. The rare and extremely compact dwarf ellipticals M32, NGC 4486B, and NGC 5846A are puzzling exceptions to this rule and appear more aligned with the giant-elliptical and bulge scaling relations than with those of typical dEs (Fig. 1a). M32, for example, harbors a central black hole and currently anchors the low-mass end of the relation between black hole mass and bulge velocity dispersion (Merritt & Ferrarese 2001). Their proximity to massive companions suggests that tidal interactions play a role in their formation (King 1962, Faber 1973a, Burkert 1994) and that some may once have been spiral bulges (Nieto 1990, Bekki et al. 2001). Because most low-mass bulges are obscured by bright, dusty disks, compact ellipticals offer unique constraints on the formation of low-mass spheroids.

At distances beyond the Virgo cluster, compact ellipticals are difficult to distinguish from stars in typical seeing conditions. As a result, they are often rejected from deep, wide-field galaxy surveys, and their global abundance is poorly constrained (Disney 1976). Extrapolation of the surface-brightness distribution of early-type galaxies from the Sloan Digital Sky Survey (Fig. 1b) suggests that the population of undiscovered compact ellipticals could be substantial (Shen et al. 2003). Indeed, the recent discovery of two M32 counterparts in HST/ACS imaging of Abell 1689 (Mieske et al. 2005) and the discovery of much fainter, ultra-compact dwarfs in the Fornax and Virgo clusters (Phillips et al. 2001, Hasegan et al. 2005, Jones et al. 2006) suggest that compact stellar systems are, at the very least, under-represented in traditional galaxy surveys.

The discovery of ultracompact dwarfs has reinvigorated the discussion about possible links between bright globular clusters, dE nuclei, and compact ellipticals (Meylan et al. 2001, Bekki et al. 2001, Fellhauer & Kroupa 2003). Ultracompact dwarfs appear to be a diverse population with a range of masses and stellar populations (Jones et al. 2006). Compact ellipticals also appear to be a heterogeneous class; M32 has an intermediate-age stellar population (Worthey 2004, Rose et al. 2005) and, like many other low-luminosity ellipticals, it has a power-law core (Lauer et al. 1998). On the other hand, NGC 4486B has a predominantly old stellar population and a well-resolved core that is substantially larger than expected for its luminosity (Kormendy et al. 1997). With only the handful of compact elliptical galaxies identified so far, conclusions about their origin remain highly speculative, and the luminosity range between compact ellipticals and ultracompact dwarfs is currently unexplored.

In order to compile the first statistically meaningful sample of compact elliptical galaxies in the field, we are conducting a redshift survey of compact candidates drawn from the SDSS/DR4 (Adelman-McCarthy et al., 2006). We have selected sources with half-light radii smaller than the seeing FWHM and ugriz colors consistent with low-redshift elliptical galaxies (Fig. 1c). Nine of these are now confirmed to be compact ellipticals, more than doubling the number previously known. Two of the newly detected dwarfs appear in the HST archive. Figure 2a shows the surface brightness profile of one of these dwarfs, which is a companion to the bright Virgo elliptical NGC 4621. The companion, which we call NGC 4621B, is clearly quite compact. Figure 2b shows that the surface brightness profiles of these two newly discovered dwarfs lie between the profile of NGC 4486B and those of the brightest ultra-compact dwarf in the Fornax cluster (de Propris et al. 2005).

Two other galaxies in our confirmed sample have not been observed with HST but are sufficiently close to bright stars to enable AO imaging with Altair. One of these, NGC 4621A, is a second, brighter companion to NGC 4621. Its absolute magnitude lies between the brightest UCDs and the compact elliptical M32 and is the first compact galaxy discovered in this luminosity range. The second galaxy is a brighter, more distant galaxy comparable to the well-studied compact elliptical

NGC 5846A. In order to measure the global structure of these rare galaxies, we request 1.2 hours with Gemini/NIRI using Altair in its laser guide star mode. The high-resolution, Ks-band imaging will provide surface brightness profiles to within ~ 60 pc of the nucleus of the more distant galaxy and to within ~ 10 pc of the nucleus of the nearest galaxy. These measurements of their global structure will be combined with velocity dispersions (measured with the MMT 6.5m Echellette in May 2006) to determine where these galaxies fall in relation to the fundamental plane of elliptical galaxies. These observations represent an important step toward a comprehensive understanding of compact elliptical galaxies and their role in the history of spheroidal stellar systems.

REFERENCES: Adelman-McCarthy et al. 2006, *ApJS*, 162, 38 Bender, R., Burstein, D., & Faber, S. 1992, *ApJ*, 399, 462 Bekki, K., Couch, W., Drinkwater, M., & Gregg, M. 2001, *ApJ*, 557, L39 Burkert, A., 1994, *MNRAS*, 266, 877 Burstein, D., Bender, R., Faber, S., & Nothenius, R., 1997, *AJ*, 114, 1365 Choi, P., Guhathakurta, R., & Johnston, K. 2002, *AJ*, 124, 310 Cote, P. et al. 2004, *ApJS*, 153, 223 Davidge, T. 1991, *AJ*, 102, 896 Davies, R.L. & Thomas, D., 2006, *MNRAS*, 366, 510 de Propris, R., et al., 2005, *ApJ*, 623, L105 Disney, M., 1976, *Nature*, 263, 573 Drinkwater, M.J., et al., 2003, *Nature*, 432, 519 Eisenstein, D., et al., 2001, *AJ*, 122, 2267 Faber, S.M. 1973a, *ApJ*, 179, 423 Fellhauer, M. & Kroupa, P., 2003, *Ap&SS*, 284, 643 Graham, A., 2002, *ApJ*, 568, 13 Graham, A., & Guzman, R., 2003, *AJ*, 125, 2936 Gunn, J., et al., 2006, *AJ*, in press Hasegan, M. et al. 2005, *ApJ*, 627, 203 Jones, J.B. et al. 2006, *AJ*, 131, 312 Kent, S.M., 1987, *AJ*, 94, 306 King, I. 1962, *AJ*, 67, 471 Kormendy, J. 1985, *ApJ*, 295, 73 Kormendy, J., et al., 1997, *ApJ*, 482, 139 Lauer, T. et al. 1998, 116, 2263 Merritt, D. & Ferrarese, L., 2001, *ApJ*, 547, 140 Meylan, G. et al. 2001, *AJ*, 122, 830 Mieske, S. et al., 2005, *A&A*, 430, L25 Phillips, S., et al., 2001, *ApJ*, 560, 201 Rose, J. et al., 2005, *AJ*, 129, 712 Shen, S. et al., 2003, *MNRAS*, 343, 978 Strauss, M.A. et al., 2002, *AJ*, 124, 1810 Wirth, A. & Gallagher, J. 1984, *ApJ*, 282, 85 Worthey, G. 2004, *AJ*, 128, 2826

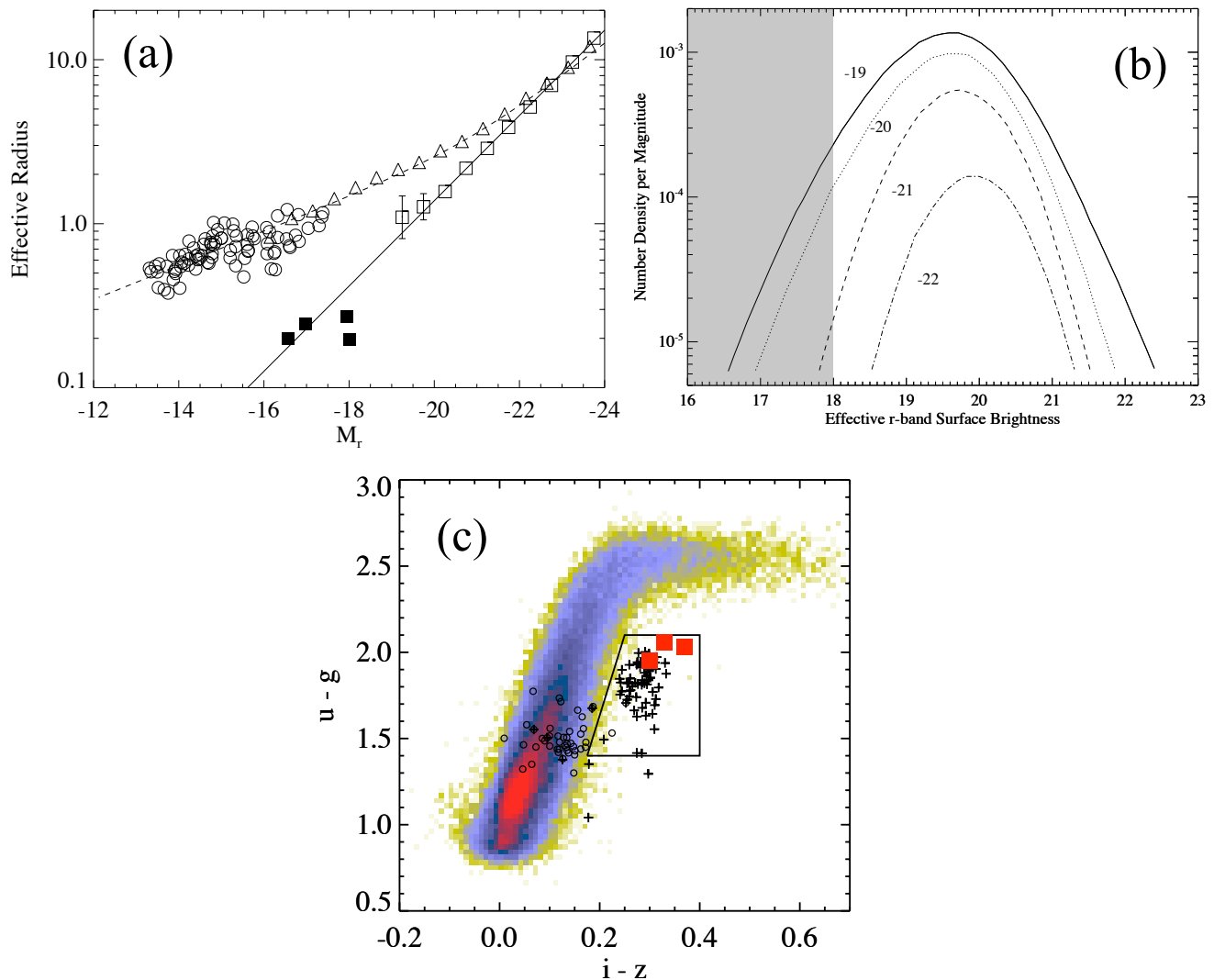


Figure 1: (a) The size-luminosity relation for SDSS galaxies measured by Shen et al. (2003). Open squares represent galaxies with Sersic profiles steeper than $n=2.5$ (predominantly ellipticals); open triangles represent $n < 2.5$ (predominantly disks). We have added Virgo dEs with SDSS imaging (open circles) and known compact ellipticals (filled squares). (b) The distribution of mean surface brightness for early-type galaxies in the SDSS (Shen et al. 2003; the label on each curve indicates mean absolute magnitude). Curves in the shaded region are extrapolations; objects in this region (including most compact ellipticals) are eliminated from the Shen et al. sample by the size cut at $r > 1.6''$. (c) SDSS $ugiz$ colors of previously known compact elliptical galaxies (the three red squares), bright elliptical galaxies from the RC3 (crosses), diffuse Virgo dEs (open circles), and sources identified as stars by the SDSS photometric pipeline (colored density contours). The lines indicate color cuts imposed on our sample of compact candidates.

Figure 1

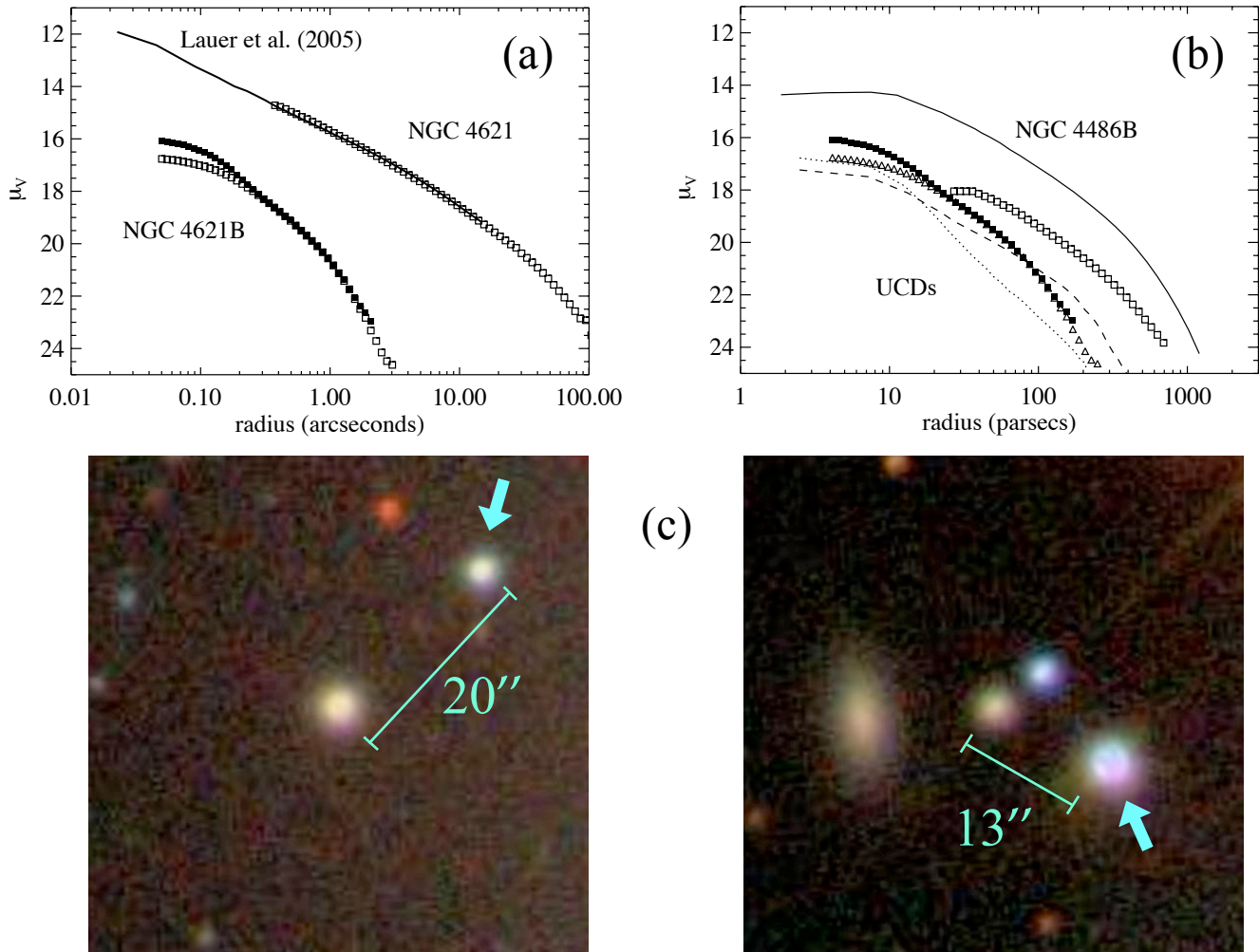


Figure 2: (a) Measured surface brightness profiles of NGC 4621 and of one of its newly discovered compact elliptical companions, NGC 4621B. Open squares are profiles measured from the drizzled F850LP image taken with HST/ACS/WFC. These points are shifted approximately to the V band by matching to the outer profile of NGC 4621 from Lauer et al. 2005 (solid line). Solid squares show measurements after 25 iterations of Lucy-Richardson deconvolution. (b) Surface brightness profiles of compact elliptical galaxies in parsecs. Solid curve is for NGC 4486B (Lauer et al. 2005). The dashed curve is the profile of the brightest ultracompact dwarf in the Fornax cluster measured from STIS imaging without deconvolution (de Propris et al. 2005). The dotted line is the mean UCD profile. Solid squares represent NGC4621B (from left panel); open squares represent another newly discovered compact elliptical, NGC 5846B. (c) SDSS gri images of the two compact elliptical galaxies targeted for AO-imaging in this proposal. NGC4621A is on the left; SDSSJ144049.71+032803 is on the right. The target galaxies lie at the center of each image. AO guide stars are marked with arrows. Note the compactness of the target galaxies and the proximity of the guide stars.

Figure 2

Gemini Integration Time Calculator 4.1

Gemini Integration Time Calculator NIRI version 4.1

[Click here for help with the results page.](#)

$r_0(2183.0\text{nm}) = 1.081 \text{ m}$

Strehl = 0.321

FWHM of an AO-corrected core = 0.062 arcsec

software aperture diameter = 0.07 arcsec

enclosed pixels = 9.00

derived image halo size (FWHM) for a point source = 0.55 arcsec.

Contributions to total noise (e-) in aperture (per exposure):

Source noise = 11.45

Background noise = 167.33

Dark current noise = 16.43

Readout noise = 36.00

Total noise per exposure = 172.32

Total signal per exposure = 131.30

Intermediate S/N for one exposure = 0.76

S/N for the whole observation = 1.70 (including sky subtraction)

Requested total integration time = 1200.00 secs, of which 1200.00 secs is on source.

Observation is background noise limited.

The peak pixel signal + background is 6303. This is 3% of the full well depth of 200000.

Input Parameters:

Instrument: NIRI

Source spatial profile, brightness, and spectral distribution:

The Source is a 24.5 mag elliptical-galaxy at K.

Instrument configuration:

Optical Components:

- Filter: Kshort
- Fixed Optics
- Camera: f32

Gemini Integration Time Calculator 4.1

- Detector - 1024x1024-pixel ALADDIN InSb array

Pixel Size: 0.022

Telescope configuration:

- silver mirror coating.
- side looking port.
- wavefront sensor: altair

Observing Conditions:

- Image Quality: 70.00%
- Sky Transparency (cloud cover): 50.00%
- Sky transparency (water vapour): 50.00%
- Sky background: 100.00%

Frequency of occurrence of these conditions: 17.50%

Calculation and analysis methods:

- mode: imaging
- Calculation of S/N ratio with 10 exposures of 120.00 secs, and 100.00 % of them were on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Gemini Integration Time Calculator 4.1

Gemini Integration Time Calculator NIRI version 4.1

[Click here for help with the results page.](#)

$r_0(2183.0\text{nm}) = 1.081 \text{ m}$

Strehl = 0.251

FWHM of an AO-corrected core = 0.062 arcsec

software aperture diameter = 0.07 arcsec

enclosed pixels = 9.00

derived image halo size (FWHM) for a point source = 0.55 arcsec.

Contributions to total noise (e-) in aperture (per exposure):

Source noise = 10.26

Background noise = 167.33

Dark current noise = 16.43

Readout noise = 36.00

Total noise per exposure = 172.25

Total signal per exposure = 105.31

Intermediate S/N for one exposure = 0.61

S/N for the whole observation = 1.36 (including sky subtraction)

Requested total integration time = 1200.00 secs, of which 1200.00 secs is on source.

Observation is background noise limited.

The peak pixel signal + background is 6299. This is 3% of the full well depth of 200000.

Input Parameters:

Instrument: NIRI

Source spatial profile, brightness, and spectral distribution:

The Source is a 24.5 mag elliptical-galaxy at K.

Instrument configuration:

Optical Components:

- Filter: Kshort
- Fixed Optics
- Camera: f32

Gemini Integration Time Calculator 4.1

- Detector - 1024x1024-pixel ALADDIN InSb array

Pixel Size: 0.022

Telescope configuration:

- silver mirror coating.
- side looking port.
- wavefront sensor: altair

Observing Conditions:

- Image Quality: 70.00%
- Sky Transparency (cloud cover): 50.00%
- Sky transparency (water vapour): 50.00%
- Sky background: 100.00%

Frequency of occurrence of these conditions: 17.50%

Calculation and analysis methods:

- mode: imaging
- Calculation of S/N ratio with 10 exposures of 120.00 secs, and 100.00 % of them were on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Technical Justification

Compact elliptical galaxies and ultracompact dwarfs are difficult to distinguish from stars in ground-based imaging. Detailed studies of their structure and kinematics thus require significantly higher resolution than can be attained with standard, ground-based facilities. The laser guide star mode of Gemini/Altair offers the only opportunity to study these sources from the ground. Of the nine newly-discovered compact ellipticals and UCDs, two lie within 30" of bright stars. The first, NGC 4621A (the brighter of the companions to NGC 4621) is approximately 20" away from an $r=16.6$ mag star. The second, SDSSJ144049.71+032803, is within 13" of an $r=14.4$ mag star. Both stars are bright enough and close enough to the target galaxies to achieve ~25% Strehl ratio using the laser guide star option with NIRI/Altair. Neither target has been observed with HST.

We use the measured surface brightness profile of the fainter companion to NGC 4621 (NGC 4621B) to set surface brightness limits for our NIRI/Altair imaging of NGC 4621A. In order to measure the surface brightness profile of NGC 4621A within the region that is compromised by typical seeing, we set our surface brightness limit to the expected surface brightness at 1.2". At this radius, the surface brightness of NGC4621B is approximately 21.6 mag / sq arcsec. The optical colors of both NGC4621A and NGC4621B are consistent with those of brighter elliptical galaxies, which have V-Ks ~ 3.1. In the Ks band, the surface brightness at 1.2" is then expected to be 18.5 mag / sq arcsec. Based on the NIRI/Altair exposure-time calculator, we expect SNR=2 per 3x3 pixel bin in a 20-minute exposure using the f/32 camera. In their cores, the brightest compact elliptical galaxies like NGC 4486B reach 14 mag / sq arcsec in V (Lauer et al. 2005), corresponding to approximately 11 mag / sq arcsec in Ks. In their cores, the S/N ratio will be several hundred but the total counts (signal + background) are still a factor of five below saturation in 120-second exposures.

To estimate these SNR limits, we used the NIRI+Altair integration time calculator, which does not automatically account for laser guiding. According to the Altair documentation, the laser guiding mimics a natural guide star that is four times closer and three magnitudes brighter than the actual guide star used for tip-tilt correction. For NGC 4621A, the effective angular offset for the ITC is then 5", and the effective R magnitude is 13.6. For SDSSJ144049.71+032803, the effective angular offset is 3.25", and the effective R magnitude is 11.4. The expected Strehl ratios are ~25% for NGC 4621A and 32% for SDSSJ144049.71+032803. Finally, the NIRI+Altair ITC treats point sources only. In order to estimate the SNR at the chosen limiting surface brightness of 18.5 mag / sq arcsec at K, we calculated the SNR per 3x3 box using a point source of magnitude $18.5 + 6 = 24.5$ mag, where the 6 magnitudes represent the fraction of a square arcsecond covered by the nine-pixel box.

Beyond the radius we are targeting with AO, the expected surface brightness of NGC 4621A becomes low enough that the background contribution from the halo of NGC 4621 is no longer negligible. In order to follow the surface brightness profile to larger radii (where AO is not required), we will be complementing the NIRI/Altair imaging with deep, wide field, Ks-band imaging using the MMT and SWIRC. This imaging will cover a wide enough field to enable careful modeling and subtraction of the halo of NGC 4621. Preliminary modeling can already be done using available SDSS imaging in gri. We note that this background contribution is quite small in the region of interest for this proposal.

Our second target is nearly seven times more distant, but because its absolute luminosity is also more than nine times brighter, its expected surface brightness at 1.2" is quite similar to that of NGC 4621A. This brighter galaxy is comparable to the prototypical compact elliptical NGC 4486B, whose surface brightness profile is shown in Fig 2b. At the redshift of the second target, $z=0.028$, 1.2" corresponds to approximately 650 pc, where the surface brightness of NGC 4486B is again approximately 21.5 mag / sq arcsec in V. Because of this similarity, we set the same surface brightness limit for both targets. Our total exposure request for the two targets combined is then 40 minutes. Following the NIRI/Altair documentation, we add 15 minutes overhead per pointing (for slewing and setup on the guide star) and 5 seconds overhead for each of the 10 dithers within a pointing. The total observing time with overhead is then 72 minutes.

Observation Details

Observation	RA	Dec	Brightness	Total Time <i>(including overheads)</i>
NGC 4621A	12:42:11.04	11:38:41.2	Sloan r = 16.08 (AB)	36.0 minutes
N1202200127(wfs)	12:42:06.932	11:44:05.15	99.90 Fmag	separation 5,49
Observing conditions: Global Default		resources: NIRI		
NGC 4621A	12:42:11.04	11:38:41.2	Sloan r = 16.08 (AB)	36.0 minutes
N1210011238(wfs)	14:40:30.683	3:23:00.65	15.24 Fmag	separation 1.828,15
Observing conditions: Global Default		resources: NIRI		

Observing Conditions

Name	Image Quality	Sky Background	Water Vapor	Cloud Cover
Global Default	70 %	Any	Any	50 %

Resources

- Gemini North
NIRI

Scheduling Information

Scheduling constraints and non-usable dates

- (impossible):
- (optimal):
- (synchronous):

Additional Information

Keyword Category: extraGalactic
Keywords: Dwarf galaxies
Elliptical galaxies
Galaxy morphology