GEMINI OBSERVATORY

observing time request summary

Semester: 2012A

Observing Mode: queue

Instruments:
,NIRI,Michelle,NIFS

Time Awarded:

Gemini Reference:

Thesis:
no

Band 3 Acceptable:
Yes

Title: **High spatial resolution spectroscopy in the benchmark HLIRG IRAS F10214+4724**

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Partner Submission Details *(multiple entries for joint proposals)*

				NTAC			
Partner	**Partner Lead Scientist**	**Time Requested**	**Minimum Time Requested**	**Reference Number**	**Reco-mmended Time**	**Minimum Time Reco-mmended**	**Rank**
	Total Time						

Abstract *(181 words)*

*IRAS F10214+4724 is one of the most heavily investigated extragalactic sources in the Universe. This strongly-lensed hyperluminous infrared galaxy is a composite starburst+AGN system. We propose new sensitve observations at unrivalled spatial resolution to investigate the nature of this source in the rest-frame optical using the NIFS-IFU with AO+LGS. We have recently found evidence for a resolved three component model to this source comprising a compact AGN core, an extended starburst and a complex narrow-line region that is likely to lie closest to the caustic of the lens potential causing it to be preferntially magnified. According to our state-of-the art gravitation model these components can be spatially resolved on scales of 0.1-0.4" and thus we propose to test our model by direct observational evidence traced by the optical nebular emission lines **and absoprtion features??**. W will be able to probe velocity structures of ~60km/s and spatial scales of <100pc. We also prpose continuum imaging in the rest-frame NIR-lowMIR to sptailly distinguish images of the extended starburts and the AGN core to definitely constrain the stellar versus re-radiated light in this system.*

Science Justification *(1252 words)*

Despite two decades of studies on the hyperluminous infrared galaxy (HLIRG) IRAS F10214+4724 (hereafter F10214, [RR91], we still lack a clear understanding of the detailed nature and physical properties of this notorious source. With a luminosity in excess of >1e14 Lsol and at a redshift of z~2.286, F10214 is the most luminous IRAS source IRAS discovered, residing at an epoch of the Universe when both star-formation and black-hole activity were at their peaks. While rare locally, such IR luminous galaxies show a rapid increase in number density to z~1-2 and are plasubly the progenitors of present-day massive galaxies. F10214's extreme luminosity is akin to SMGs and dusty quasars that are now being routinely detected in deep surveys conducted by Spitzer, SCUBA and Herschel [N10]. As such, F10214 remains the benchmark source to which the properties of SMGs and dusty quasars at high redshift are often compared. Thus establishing its nature has important consequences on our interpretation of the properties of high-z composite starburst+AGN.

Through HST imaging it became apparent that F10214's high luminosity could be attributed to gravitationally lensing by a foreground galaxy or group of galaxies at z=0.9 [C95,BL95,G96,L98] with magnification estimated to be in the range of 5-100 (e.g. BL95,D95,S95,T95]. While a significant contribution from ongoing star-formation (AE, SG) was required to explain the rest-frame far-IR emission from this galaxy, it also displays strong signatures of hosting an obscured active galactic nucleus (AGN) viewed with the torus edge-on (Seyfert 2 optical spectrum [E94; So95; I95; S95] and highly polarised emission consistent with reflected light from an AGN [L93]. An absence of hard X-ray emission suggests that the AGN is compton thick (Alexander et al. 05, Iwasawa et al. XX). The presence of an obscured AGN was confirmed in the mid-IR by Spitzer/IRS - the spectrum showed a strong MIR continuum and a lack of strong PAH features (commonly seen in starburst galaxies). Curiously, however the IRS spectrum also showed strong silicate emission [T06], a feature that is predicted for type-1 sources (those where the inner hot torus is exposed). The strength of this feature in a type 2 source remains problematic to explain [T06,E06]. Several authors including ourselves purport that the narrow-line region clouds are preferentailly lensed with respect to the starburst [L98,E99,D11].

Recently, our team has made significant progress in understanding the properties of F10214

1. A new hot dust component in IRAS F10214 The difficulty in reconciling the Seyfert 2 optical signature with the silicate emission feature has led us to form a new model for the emission of F10214 in the IR. Together with new data from Spitzer [E11] and Herschel [S10], we are now able to reproduce the full 1-1000um rest-frame SED with multiple components comprising an edge-on tours, a concurrent starburst and three discrete distributions of dust clouds in the narrow-line region [E11]. The SED cannot be explained by a continuous dust distribution suggesting a scenario where there have been episodic outflows of material that forms dust.

2. High resolution radio imaging, molecular line mapping and deeper HST 160W data We have recently obtained a 24hr MERLIN 1.6GHz resolved detection of F10214 revealing an extended emission component and a dominant core seen in 8GHz (VLA) maps. The latter is interpreted as scattered quasar light. Deane et al. suggest that the extended 1.6GHz emission is a radio jet owing to its offset from the VLA core and the spectral index. There is also some evidence for weaker extended emission along the arc in the 8GHz map but much weaker than at 1.6GHz. Deane et al. have recently analysed HST F814W and 160W data that both indicate the 8GHz core is not centered on the optical arc. In addition the deep NICMOS 160W clearly shows extended substructure both along and perpendicular to the arc. The bright central arc is attributed to scattered light from the AGN (dominates the 814W map) as well as a more extended lower magnification host galaxy component. This suggests that suggesting the narrlow-line clouds responsible for scattering the quasar light lie close to the caustic and are therefore preferentially magnified.

3. A new detailed lens model for F10214 Co-I Deane has developed a detailed Bayesian MCMC code for deriving a new gravitational lens model of F10214 as well as expalining it's multi-wavelength SED [D11]. This sophisticated model explains the NLR, jet and starburst component images, requiring a neighbouring galaxy to the NE to be included in the lensing potential. The source plane reconstruted image showing the AGN core, radio lobe and scattered light is showin in Fig 2b. The mode suggests the AGN core is magnified by 25x and the starburst by 10x.

These fascinating new results beg the question of whether standard AGN/starburst tracers in the rest-frame optical can elucidate our understanding of this intriguing source

Immediate Objectives:

1. Can we directly spatially resolve the broad-line and narrow-line region using rest-frame nebular emission lines?

Previous spectroscopic studies have shown that the nebular emission lines including Halpha+NII, Hbeta, [OIII]5007,4959 [K96,S98,L98] show complex profiles with broad and narrow components (at a spectral resolution of R~1200 and angular resolution of 1"). The integral field spectrograph NIFS with the laser guide star at Gemini-North offers the opportunity to study this system at 0.1" scales (~80pc in the source-plane for the starburst) and at higher spectral resolution (R~3500-5000). Such spatial scales will allow us to discern the poThe increased spectral resolution will allow us to resolve velocity components of ~57km/s such narrow lines component may originate from the starburst (cf NLR~1000km/s, BLR~fewx1000km/s).

[Note, L98 claim to have already reached 100pc scales however this is based on the previously assumed linear magnification factor of (100) - this has since been revised, our new model suggest factors of 10-25]

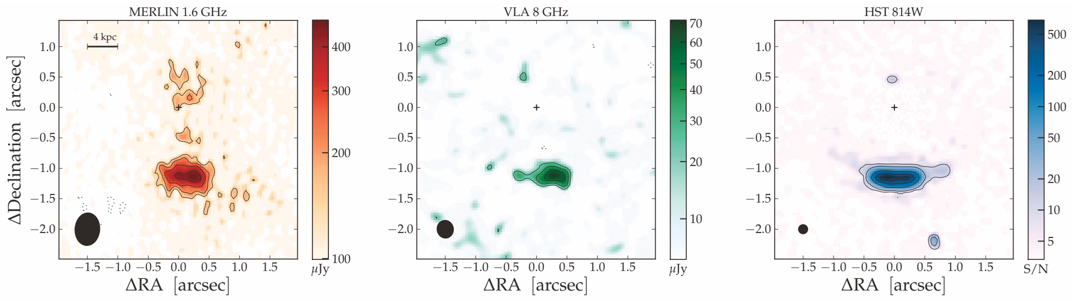
Using the IFS data we will make spectral maps of the broad line, narrow line and potentially starburst regions that we can then compare to the continuum HST, radio and CO line maps. We can test if these corroborate our hypothesis of a core(BLR) & preferentially magnified NLR.

We will also search for extended red or blue wings to the broad and narrow lines and map them - these will be indicative of turbulent gas, shocks and winds, potentially related to the radio jet postualted by Deane et al.

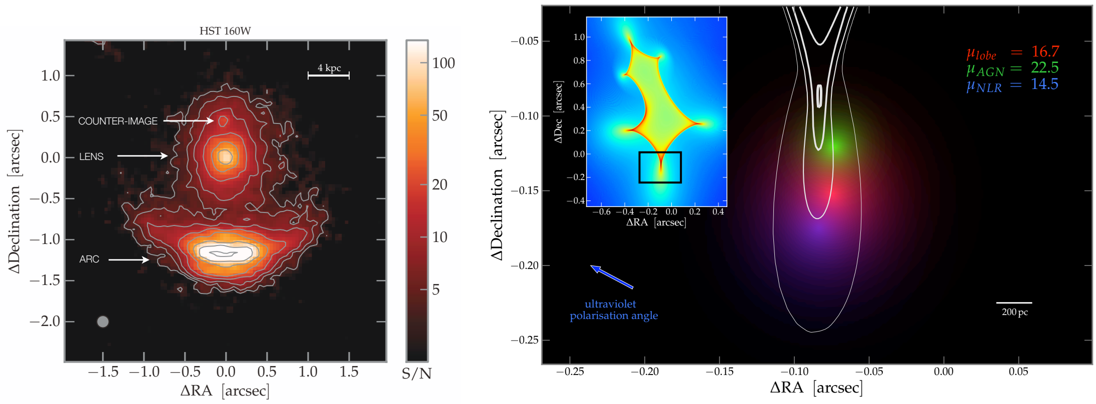
We can also determine spatially resolved extinction via Halpha/Hbeta maps, and investigate the spatial distribution of the gas metallicity using the ratio of Halpha/NII (CAN YOU REALLY DO THIS FOR AGN DOMINATED SYSTEMS?? OR IN THE PRESENCE OF SHOCKS??).

2. Foreground Lens / Group Our data will also give unprecendented measurement of the foreground lens from which we can investigate its detailed dynamics. The Ca triplet absoprtion lines are redshifted into the H-band allowing us to accurately determine stellar velocity dispersion for the lens, and independent measure of the dynamical mass that and can be compared to the total mass derived from our lensing model. SUBSTRUCTURE?? OR DROP??

3. Direct detection of the extended starburst & its physical properties Our SED fits suggest that the (nuclear) starburst or dust close to the AGN dominates the rest-frame NIR however can we probe this directly? 10um imaging offers us the tanatalising possibility to observe this. Corresponding to ~3.6um rest-frame this waveleength probes light close to the transitin between direct stellar light and that reprocessed by dust. As our "core" is offset from the extended arc 0.4" resolution imaging that can be achieved with Michelle can directly corroborate our hypothesis. This resolution supercedes IRAC spatial resolution bty >3x. Do we want to do this???



Left panel: MERLIN 1.6 GHz map with $\sigma \sim 46\ \mu$Jy per 405 × 349 mas^2 beam. **Middle panel:** 8 GHz VLA map with $\sigma\ \sim 11\ \mu$Jy per 292 × 267 mas^2 beam. **Right panel:** HST814W map with counter-image and arc. The integrated arc/counter-image flux density ratio is $\breve{\mu} \sim 75 \pm 25$. The HST PSF through this filter has a FWHM of ∼100 mas, as detailed in Eisenhardt et al. 1996). Note that the lens has been fit using GALFIT and removed from this image. The FWHM of all PSFs are shown in the lower left of each frame. In all panels the cross indicates the centroid of lensing galaxy as measured from the HST160W map.



Left panel:HST 160W map with lensing galaxy, counter-image and the arc. The arc shows two clear components: an extensive, faint arc, as well as a larger, more dominant component. We attribute the latter to the scattered quasar light (that dominates the HST814W map) as well as a more extended, lower magnification host galaxy component. This is supported by the global SED as well as the 4000 Å break first identified by Lacy1998. The integrated arc/counter-image flux density ratio is ∼110 ±30. The HST PSF through this filter has a FWHM of ∼150 mas which is illustrated by the grey circle in the lower left. **Right panel:** Source plane reconstruction of IRAS 10214 showing the AGN core (green), scattered quasar light (blue), and radio lobe (red). The white contours represent lines of equal magnification extending from the caustic at levels μ = 10,20,50,100,150. The inset shows the full lens caustic with colour scale representing magnification and the black rectangle showing the borders of the enlarged region. The magnification of each source could be computed from the convolution of each source with this magnification map. In practice we integrate the model flux in the image plane and the source plane and take the ratio.

REFERENCES:

[A05] Alexander et al., 2005, 357, L16 [BL95] Broadhurst & Lehar, 1995, ApJ, 450, L41 [C85] Close et al, 1995, ApJ, 453, 616 [D11] Deane et al. in prep. [D95] Downes, Solomon & Radford, 1995, 453, L65 [E06] Efstathiou et al. 2006, MNRAS, 371, L70 [E11] Efstathiou et al. in prep. [E94] Elston et al. 1994, AJ, 107, 910 [E99] Evans et al. 1999, ApJ, 518, 145 [G96] Green & Rowan-Robinson, 1995, MNRAS, 279, 884 [I96] Iwamuro et al., 1995, PASJ, 47, 265 [I05] Iwasawa et al. 2005, MNRAS, 362, L201 [K96] Kroker et al. 1996, ApJ, 462, L55 [L98] Lacy, Rawlings & Serjeant, 1998, MNRAS, 299, L1220 [L93] Lawrence et al., 1993, MNRAS, 260, L28 [N10] Negrello M., et al. 2010, Science, 330, 800 [RR91] Rowan-Robinson et al. 1991, Nat. 352, 677 [S95] Serjeant et al., 1995, MNRAS, 276, L9 [So95] Soifer et al. 1995, ApJ, 443, L65 [S10] Sturm et al. 2010, A&A, 518, L36 [T06] Teplitz et al. 2006 ApJ, 638, L1 [T95] Trentham, 1995, MNRAS, 277, 616

Technical Justification *(677 words)*

Fortuitously the redshift of F10214 places the bright emission lines of Halpha+NII, [OII]3727, [OIII]5007,4959 in very "clean" parts of the JH&K bands - free from bright sky lines and low atmospheric absorption. features.

ALTAIR details

We proposal to use the LGS with ATLAIR. A star lies within 13.7" of F10214. It is faint however, R=17.74 & V=18.3 mag based on the SDSS DR8 photometry and conversion of sloan to Johnson for stars (Lupton 05). Therefore this observation will be in the low strehl regime. As a result we have elected to use SB=80% to allow successful guiding on the tip/tilt star. We expect a correction of 10% in the H & K bands and less in the J-band.

NIFS Observations

From exisiting spectroscopic measurements we design our observations based on the MPE3D results from Kroker et al. We base our flux requirement on the faintest broad component seen in the MPE3d images in a 2.5" diameter aperture. The broad component of the Halpha+NII line has a level of 0.2mJy (figure 2 Kroker et al. 96). Assuming this light originates from the the extent of the arc+diffuse emission (~1 sq. arcsec.) this gives a surface brightness of 2e-4 Jy/sq. arcsec (assuming it's uniform over this extent). The assumption of uniform brightness in this aperture is very conservative allowing us to discern even faint broad components. The peak of the line emission will be signficantly brighter than this. This conservative limit just means that we will be sensitive to any diffuse or extended emission from the background host galaxy. We therefore adopt this conservative estimate as our 3-sigma detection limit.

For the purposes ofthe ITC we use

- an extended source with uniform surface brightness of 2e-4 Jy/sq arcsec in the K-band.

- Power-law spectrum (flat) Sv=v^0 IS THIS OK??

- H-K filter+K grating+central wavelength 2.2um,

- very low background

- Altair wavefront sensor with AO guide star sep 13.7" & R=17.74mag, LGS+Field lens IN

- IQ=70, CC=50 (required for LGS observations), WV=Any, SB=80, airmass <1.2 (appropriate for the Dec of this source assuming it is observed close to transit)

- 9x600s integration

- per 1x2 IFU (at centre) - 0.103"x0.084"

gives an SNR of ~2.75 per spectral pixel element for most of the K-band

Thus we will be able to clearly detect any broad components to this depth at a spatial resolution of ~0.1" in 2hrs on source.

For the typical R of NIFS in the K-band this will yield ~60km/s spectral resolution - an unprecendented detailed spectrum of this source. We will be able to adaptively bin the data to achieve signficantly higher SNR on the broad and narrow components by binning over spectral pixels (more IFU elements).

DO WE REALLY NEED 50km/s RESOLUTION FOR THESE LINES? WHAT CAN WE DERIVE FROM HIGH SPECTRAL RESOLUTION? SENSISTIVE TO LOWER MASS NLRS OR SF REGIONS?

As the source encompasses the NIFS FoV it is not possible to nod on IFU therefore we will perform an equal number of sky observations. Assuming the 40% offsetting efficiency recommended on the NIFS web pages this results in a total observation time of 3.75 hours - assuming the target is visited 2 times we add 2x25min of acquistion/setup overhead giving a total of 4.6hr.

WHY DO WE DO HALPHA+NII RATHER THAN OIII (BRIGHT) OR OII (FAINT) NEED MORE PHYSICAL MOTIVATION

We similarlly perform H-band observations to target the bright [OIII] doublet STILL NEED TO DO H-BAND CALCIULATIONS & TOTAL TIME ESTIMATE . While the strong nebular lines of NeV are available in the J-band our priorities are for Ha+NII and OIII that dominate the NIR spectrum and where sky-line varaibility is less of an issue.

Our minimum time corresponds to observations of Halpha only in the K-band. ---------------------------

components by binning over

For the OIII and OII lines in the J and H band we make similar estimates usinf the Z-J filter+Jband grating and J-H filter with the H-band grating (lacy lines fluxes OII 1.23um 2e-19, OIII164.5 53e-19)

NOTE WE CANT DO ABSORPTION FEATURES LIKE LACY AS WE HAVE SNR<0.01 IN THE CONTINUUM

Band 3 Information

Requested time in case of band 3 allocation: 4.6 hours

Minimum required time for a usable band 3 allocation: 2.0 hours

Use the following conditions for band 3 only:

Name	Image Quality	Sky Background	Water Vapor	Cloud Cover
Band 3 Observing Conditions	85 %	Any	Any	80 %

Band 3 Consideration Comments *(49 words)*
In the event the main program using LGS cannot be awarded band 1 or 2 time, we request GNIRS XD observations of the companion galaxies of F10214 that lie within the

THEY ARE TOO FAINT FOR GNIRS U NEED A LOWER RESOLUTION WIDE SPECTROGRAPH SO THIS WILL BE REMOVED

Observation Details

Observation	RA	Dec	Brightness	Total Time *(including overheads)*
IRAS F10214+4724	10:24:34.56	47:09:9.59		
GSC0343500222(oiwfs)	10:24:00.991	47:08:43.19	13.34 mag	separation 5.72
U1350_07766563(aowfs)	10:24:35.837	47:09:10.08	17.5 mag	separation 5.72
Observing conditions: Global Default		resources:		
IRAS F10214+4724	10:24:34.56	47:09:9.59		
GSC0343500222(oiwfs)	10:24:00.991	47:08:43.19	13.34 mag	separation 5.72
U1350_07766563(aowfs)	10:24:35.837	47:09:10.08	17.5 mag	separation 5.72
Observing conditions: Global Default		resources: NIRI		
IRAS F10214+4724	10:24:34.56	47:09:9.59		
GSC0343500222(oiwfs)	10:24:00.991	47:08:43.19	13.34 mag	separation 5.72
U1350_07766563(aowfs)	10:24:35.837	47:09:10.08	17.5 mag	separation 5.72
Observing conditions: Global Default		resources: Michelle		
IRAS F10214+4724	10:24:34.56	47:09:9.59		4.6 hours
U1350_07766563(aowfs)	10:24:35.837	47:09:10.08	17.5 mag	separation 0.22
Observing conditions: NIFS/LGS		resources: NIFS		

Observing Conditions

Name	Image Quality	Sky Background	Water Vapor	Cloud Cover
Band 3 Observing Conditions	85 %	Any	Any	80 %
Global Default	Any	Any	Any	Any
NIFS/LGS	70 %	80 %	Any	50 %

Resources

- Gemini North
  - NIRI
    - Camera
      - f/6 (0.12 arcsec)
      - f/32 (0.02 arcsec)
    - Filter
      - Broad-Band

- L' (3.78 um)
- Adaptive Optics
  - Altair
  - Field lens
  - Laser guide star
- NIFS
  - Disperser
    - Z-grating
    - J-grating
    - H-grating
    - K-grating
  - Filter
    - ZJ
    - JH
    - HK
  - Adaptive Optics
    - Altair
    - Field lens
    - Laser guide star
- Michelle
  - Filter
    - N' 11.2um (semi-broad)
  - Disperser
    - Mirror

Scheduling Information

Scheduling constraints and non-usable dates

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

Additional Information

Keyword Category:	extraGalactic
Keywords:	Active galaxies Dust Dynamics Emission lines Gravitational lensing IR-luminous galaxies Seyfert galaxies Starburst galaxies