GEMINI OBSERVATORY

observing time request summary

Semester: 2012A

Observing Mode: queue

Instruments:
NIFS, Michelle, NIRI, GNIRS

Time Awarded:

Gemini Reference:

Thesis:
yes

Band 3 Acceptable:
Yes

Title: **A sub-arcsecond study of the z~2.284 galaxy IRAS F10214+4724 on 100pc scales**

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Natalie Christopher **(thesis)**: University of Oxford,
Pat Roche: University of Oxford,
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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 *(258 words)*

Since its discovery in 1991 IRAS F10214+4724, has been one of the most heavily investigated extragalactic sources in the Universe. As this strongly-lensed hyperluminous infrared galaxy is a composite starburst+AGN system, spatially resolved emission from the nebular rest-frame optical emission lines reveal key information regarding the broad- and narrow-line emitting regions. As the primary arc is compact (0.7"), it has been challenging to acquire observations high angular resolution in the rest-frame optical from the ground. Together with the LGS/AO system on Gemini, we take advantage of the magnification due to lensing that allows the structure of the host galaxy & line-emitting regions to be studied on <100pc scales adopting our magnification estimate of 10-15x (previous studies have resolution that are 5-10x larger). Recently, through high resolution radio observations we have uncovered observational evidence that F10214's AGN emission undergoes preferential magnification (Deane et al.), a finding that is consistent with the IR SED. We therefore propose NIFS, NIRI and Michelle near diffraction-limited observations of this intriguing source (0.1" & 0.4"). The continuum measurements will allow us to constraint the stellar and AGN contributions to the rest-frame optical light. The NIFS emission line data will allow us to nebular gas diagnostics (Halpha+NII, Hbeta and OIII) from allow us to decouple broad and narrow emission components in this galaxy, assess spatially resolved metallicities and extinction. We may then test how the dynamics and substructures seen in the radio, CO, HCN, or CI maps are related to the stellar continuum to disentangle the nature of this complex system on 100 pc scales.

Science Justification *(1419 words)*

While two decades have passed since the discovery of the hyperluminous infrared (IR) galaxy (HLIRG)) IRAS F10214+4724 (hereafter F10214) (Rowan-Robinson et al. 91), we still lack a clear understanding of the detailed nature and physical properties of this source despite numerous studies. With a luminosity in excess of >1e14 Lsol and at a redshift of z~2.286, this most luminus IRAS source lies 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 believed to play a key role in the evolution 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 [Negrello et al. 20110]. As such, F10214 remains the benchmark source to which he properties of SMGs and dusty quasars at high redshift are often compared. Thus establishing its nature is central to our interpretation of the properties of SMGs and high-z dusty quasars.

HST imaging quickly revealed F10214 to be gravitationally lensed by a foreground galaxy or group of galaxies at z~0.9 [BL95,G96,L98] with magnification estimated to be in the range of 5-100 (e.g. BL95,D95,S95,T95] into an arc (blend of 3 images)+counter image. A significant contribution from ongoing star-formation (AE, SG) was required to explain the rest-frame far-IR emission from this galaxy, but it also displays strong signatures of hosting an obscured active galactic nucleus (AGN) viewed with the torus edge-on (Seyfert 2 optical spectrum [Elston et al. 1994; Lawrence et al. 1993; Soifer et al. 1995; Iwamuro et al. 1995; S95] and highly polarised emission consistent with reflected light from an AGN [REF]. Thus, as with many IR luminous galaxies and SMGs, F10214 hosts a coeval starburst and AGN. The lack of hard X-ray emission suggests that the AGN is compton thick (Alexander et al. 05, Iwasawa et al. XX). The dominance 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 this spectrum showed strong silicate emission (Teplitz et al.), a feature that is predicted for type-1 sources (those where the inner hot torus is exposed). This feature could be explained by the presence of narrow-line region clouds [AE] and preferntial magnification of the central emission associated to the AGN over the extended starburst. Such preferentail magnification (3x REF, [Lacy98,Evans99] Deane) would explain how the source was easily detected by IRAS as the 60 and 100um filters would be sensitive to this hot MIR continuum (10 and 30um rest-frame) that is dominated by the emission from the putative dusty torus surrounding the AGN.

We have made recent developments 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 and Herschel, 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 in the narrow-line region.

2. High resolution radio imaging and molecular line mapping We have recently obtained a 24hr MERLIN 1.6GHz resolved detection of F10214 revealing an extended emission component and a compact core seen in 8GHz (VLA?) maps. The latter is interpreted as emission from the compact AGN, its centre is 0.4" separated from the centre of the "primary arc" seen in the HST image. We believe the extended 1.6GHz emission is a radio jet owing to its morphology and the spectral index. The 8GHz map also indicated an starburst lying along the arc but offset from the core. We have recently analysed high resolution radio and HST data that strongly corroborate this view. From the radio perspective XXX suggests that there is a ... A reanalysis of the HSRT NICMOS data clearly show excess emission N&S of the primary arc, suggesting the extended (starburst) component is differentially magnificed with respect to the compact nueclus that lies close to the caustic.

3. A new detailed lens model for F10214 Co-I Deane has developed a detailed Bayesian statistical method for deriving a new gravitational lens model of F10214 (Deane et al. in prep.) this simultaneously predicts the location and brIghtness of the brightest image of the compact core, the extended star-forming region as well as the counter image. In this model the AGN lies close to the caustIc boosting its flux relative to the extended starburst.

Immediate Objectives:

1. Can we directly spatially resolve AGN signatures?

Previous spectroscopic studies have shown that the nebular emission lines including Halpha+NII, [OII]3727, [OIII]5007,4959 (Kroker et al., Serjeant et al., lacy et al.) show complex profiles with broad and narrow components that trace the broad and narrow-line regions associated to the AGN and the starburst. Spatially resolved spectroscopy at high angular resolution will allow us to probe these regions directly and their distribution across the arc at 0.1" scales, i.e. 80pc in the source plane. The availability of the integral field spectrograph NIFS with the laser guide star at Gemini-North offers this opportunity. While previous spectroscopic studies have given us important and plausible explanations of the physical properties of F10214, it is important to note that both of these studies are at significantly poorer spatial resolution (>1") and at 3-4x lower spectral resolution (R~1200, versus R~3500-5000 NIFS). The increased spectral resolution will allow us to perform detailed analysis on the structure of the line profiles to discern the broad and narrow components. [Note, Lacy et al. 98 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 and for our new lens model is 10-15.] Fortuitously the redshift of F10214 plces 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.

If, our hypothesis of a preferentailly maginfied AGN is correct we will see enahnced BLR emission in the centre of the arc with narrow lines arising from the starburst around the arc (extended N-S , see figure XX). 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.

MT ADD MORE PHYSICS HERE IE.E SPEARATAION OF BRAID AND NARROW LINE COMPONENTS ALREADY SHOWN IN KROHKER. RESOLVING HALPH/NII GIVES A METALLICITY ESTIMATE THAT KROKER COULDNT RESOLVE THE LINES. HBETA/HALPHA GIVES EXTINCTION. THEY KEY TIE IN IS WHETHER THE EXTENSION SEEN N/S IN THE NICMOS 160W IMAGE CAN BE RESOLVED FROM THE BRIGHTER PLAUSIBLY NUCLEAR ARC - roger can you confirm if 0.1" is enough to see a separation?

add benefits of doing OII and OIII - can use BPT diagnostics note NV much stronger than OII in J-band see lacy

2. Direct detection of the extended starburst & its physical properties

Gemini's instrumentation suite, where the stellar continuum of the host galaxy will be intrinscially brighter. We therefore propose to perform sensitive L-band imaging to reach the rest-frame J-abdn eemission of the stellar continuum. As L-band+ALTAIR gives 0.1" resolution we will be able to assess the extent and brightness of the L-band emission including tracing the compact and diffuse emission suggested by the HST images. XX has suggested the rest-frame optical is dominated by scattered light - our high reolution observations will test this asserion. Furthermore the foreground lens and arc are separated by XX" - we also have IRAC constraints (fig XX) but the IRAC data is not of sufficient spatial resolution to discern emission from the 0.9

MT/RD ARE WE GOING TO BE ABLE TO RESOLVE THE LOWER STARBUST EXTENSION SEEN IN THE NICMOS IMAGE WITH 0.25" DIFFRACTION LIMITED PERFORMANCE WITH MICHELLE 10UM IS 3UM REST-FRAME, BUT DIFFLIM IS 0.26" AT 10UM, IQ - IQ=20% GIVES US 0.31-0.34" FWHM IQ=70 0.37"?) NIRI GIVES US 0.1" IN L' (1.15UM RES-FRAME) BUT THERE'S A BIG HIT IN SENSITIVITY BECUASE OF ALTAIR IN IQ=20% WE GET 0.35" FWHM WITH ALTAIR WE GET 0.1") WHAT DO WE WANT - BETTER IQ AND BETTER SENSITIVITY? WITH NIR TAKES 1HR WITHOUT AO, 1.5HR WITH AO OR BRIGHTER EMISSION BUT POORER RESOLUTION & SENSITIVITY WITH MICHELLE 1HR+OVERHEADS

Technical Justification *(556 words)*

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 - 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?

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

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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)

Band 3 Information

Requested time in case of band 3 allocation: 2.0 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 *(31 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

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: GNIRS		
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

GNIRS
- Disperser order
  - L (order 2)
  - XD (cross-dispersed X-K)

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