GEMINI OBSERVATORY

observing time request summary

Semester: 2012A **Observing Mode:** queue

Instruments: **Time Awarded:** **Gemini Reference:**
NIFS, Michelle, NIRI, GNIRS

Thesis:
yes

Band 3 Acceptable:
Yes

Title:	**A sub-arcsecond study of the z~2.284 galaxy 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 *(218 words)*

Since its discovery in 1991 IRAS F10214+4724, has been one of the most heavily investigated extragalactic sources in the Universe. This strongly-lensed hyperluminous infrared galaxy is a composite system hosting a (super-)starburst and an AGN. Despite its notoriety, relatively little is known about the broad and narrow line emitting regions at high spatial resolution. We take advantage of the magnification due to lensing that allows the structure of the host galaxy & line-emitting regions to be studied in detail. Recently, through high resolution radio observations we have uncovered observational evidence that F10214's starburst and AGN components undergo differential magnification (Deane et al.), a finding that is also required to explain the IR SED (Efstathiou et al.). 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.

Science Justification *(2486 words)*

IRAS F10214+4724 (hereafter F10214), was the first "hyperluminous" infrared galaxy (HLIRG) discovered (Rowan-Robinson et al. 91). At a redshift of z~2.286 its strong 60 and 100um flux suggested an infrared luminosity in excess of >1e14 Lsol. Being the most luminous target discovered in IRAS' faint source catalogue (Moshir et al. 1992), it has been the subject of numerous scientific investigations over the last two decades and remains the archetypal sources to which SMGs and dusty quasars at high redshift are compared. While rare locally, HLIRGs sources are now seen to be common in deep surveys conducted by Spitzer, SCUBA and Herschel [Negrello et al. 20110] with a number density of luminous infrared galazies that strongly increases to the peak star-formation activity in the Universe (z~1-2 REFS). The IR luminous phase has long been plausibly argued to mark the transition phase between major mergers of gas-rich galaxies and the growth of super-massive blackholes (SMBH) eventually emerging from the dusty shell to become optically bright quasar (REFS)s. Thus studying the nature of IR luminous galaxies is key to our understanding of the evolution of the most massive galaxies & SMBHs.

Soon after its discovery, F10214 mammoth flux was revealed to be due to lensing by a foreground galaxy or group of galaxies at z~0.9 [BL95,G96,L98] with wavelength dependent magnification estimated to be in the range of 50-100 (e.g. BL95,D95,S95,T95). While ongoing star-formation in this galaxy is required to explain the rest-frame far-infrared emission from this galaxy, it displays strong signwatures of hosting an obscured AGN (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]. The lack of hard X-ray emission suggests the AGN is compton thick (Alexander et al. 05, Iwasawa et al. XX). The Spitzer/IRS spectrum showed a lack of strong PAH features in the MIR spectrum suggests that the obscured AGN dominated the emission in this wavelength range, masking or diluting any emission from the underlying starburst. Curiously, however it did show strong silicate emission (Teplitz et al.), a feature that is predicted for type-1 sources (those where the inner hot torus is exposed), casuing debate as to it's nature. This enahancement of the silicate feature can be attricbuted to preferntial magnification of the compact AGN torus emission over the extended starburst [] The IR spectral energy distribution, including the silicate emission feature, could be explained by the presence of an edge-on torus, narrow-line region clouds and an aobscured starburst. .While the origin if the silicate feature remains debated, With coeval black-hole activity and ongoing star formation, F10214 continues to be a benchmark template to study the inner workings of IR-luminous galaxies, and we propose to perform diffraction limited imaging, and imaging spectroscopy to study the galaxy on <100pc scales.

Our recent developments in understanding F10214 have promptd this detailed study:

1. A new hot dust component in IRAS F10214 We have recently developed a new model to explain the As well as the excess FIR emission, rest-frame optical spectra and UV polarised light clearly showed signatures of an Seyfert 2 nucleus which is shieded from view. owever, Spitzer IRS spectra revealed for the first-time the presence of silicate emission in F10214. This feature is typically assocaited to type 1 AGN where the system is viewed 'face-on' such that the hot dust emission from either the inner edge of the dusty (clumpy) torus are in view, rather than shielded from view in the 'edge-on' scenario. The diffiulty 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 that suggest a discrete distribution of hot dust component (80K) responsible for the silicate feature, with an underlying starburst component responsible for the longer wavelength emission.

2. High resolution radio imaging and molecular line mapping We have recently obtaines 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 core, it's centre is 0.4" separated from the centre of the "primary arc" seen in the HST image. The extended 1.6GHz emission is interepreted as a radio jet owing to it's morphology and the spectral index.

The comapct 8Ghz distinct emisson components, a compact nucleus and extended starburst in the primary arc (blend of three images). This result strongly corroborates the AGN and starburst undergo differntial magnification as suggested by XX (factor of 3). This is consistent with the IR SED model that suggests enhanced magnificatin (FACTOR) of the compact AGN in order to explain the unusually strong silicate emission feature. We also have high resolution (0.1") CO(1-0) line maps showing the molecular gas extent to be XXpc (unlensed).

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 brghtness of the brightest image of the compact core, the extended star-forming region as well as the counter image. In order to

In this scheme the compact AGN lies on a caustic line, explaining the enhancement of the silicate emission feature relative to the continuum emission from the starburst. Our model predicts the compact emission offset of the AGN core from from the centre of the starburst hence we need to probe spatial resolutions <0.4". The availability of the integral field spectrograph NIFS with the laser guide star at Gemini-North offers this opportunity. We propose to conduct a study of the spatial distribution broad and narrow emission line regions in this galaxy at 0.1" scales. 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. Furthermore we already have a handle on the emission line strengths from observations with the MPE3D and CGS4 instuments (Kroker et al. 96, Lacy et al. 98). While these 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") that is insufficient to resolve the primary arc of F10214, our near-diffiraction limited observations will yield 0.1" resolution which corresponds to (XXpc in the source-plane). Please note Lacy et al. 98 claim to reach 100pc scales however this is based on the previously assumed linerar magnification factor of (XX) that has since been revised and for our new lens model is (XX). In addition, the previous spectroscopic observations are of 2-3x lower spectral resolution than will be achievable by NIFS (R~5000), which may help to resolve the issue of the apprent an=bsence of

Can we corroborate the findings in the radio with spatially resolved rest-frame optical to mid-infrared tracers of the AGN and starburst at high spatial resolution? High resolution HST and Keck-imaging (().1" and 0.4", respectively, EGL95) have notably corroborated the lensing hypothesis of this source, higher resolution still is needed to discern the compact AGN and extended starburst regions. We propose a multi-instrument study of this galaxy using the to spatially resolve the starburst and AGN using spatially resolved channel maps of Halpha, OIII and OII shifted into the NIR. We also propose to

Is it possible to disentangle the emission from active star-froamtion and the elusive active nucleus? As well as the brightness amplification that lensing offers, the magnification of the structure makes this potentially intersting provding there is sufficient spatial resolution to differentiate the components. Several authors have suggested that the system is undergoing differential magnification [Lacy98,Evans99]. 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.

Thus, we apply for a bechmark study of IRAF F10214, on the fienst spatial scales possible from the ground to elucidate the nature of this composite AGN+starburst.

The amplification and magnification due to lensing allows us to study to fainter intirinsic depths and to access greater spatial resolution than would normally be possible.

Despite two decades of active research we are still intrigued by this object, and we are fast approaching a deep understanding of its complex nature.

We therefore propose to corroborate these findings with high spatial resolution studies with Gemini. We aim to measure the stellar continuum using NIRI/MICHELLE. And perform spatially resolved integral field spectroscopy with NIFS to reveal both the compact nucleus and the extended starburst using near-diffraction limited performance with Gemini. Due to the presence of a suitable bright tip/tilt star (V=18.3mag) within 13.7" of the science target, we are able to exploit the gain in sensitivity though enhanced strehl ratios as well as the spatial resolution improvement with LGS-assisted observations.

Immediate Objectives & observational tests:

1. Spatial distribution and Kinematics of the broad-line and narrow-line regions

From previous spectroscopy ideas we find the 1. Spatially resolve the broad and narrow-line emitting regions for comparisn to our new high-res radio data. If, our hypothesis of a preferentailly maginfied AGN is correct we will

see enahnced BLR emission at the Search for and determine the presence of turbulent gas in both the BLR and NLR lines that are indicate blue or redwings suggestive of outflows. Determine the distribtuin and fractional flux The NLR lines may show blue wings i ndicative of outflows due to winds or inflows to the accretin disk gas (L98) which we will be able to trace the spatial variation of across the primary image.

IFS SPECTROSCOPY

IFS measurements of F10214 exist (K98), however these data were taken by me with the first IR IFS MPE-3D at Calor Alto in conditions of 1" and a spectral resolution of 1100. From these data it was only possible to analyse spatially integrated spectral line profiles (but despite the poor resoultion, these observations were able to demonstrate the nearby companions were likely not lensed images due to the lack of detections of Halpha+NII in any of the companions). These obs did reveal interesting differences in the line and continuum extents. Instead we propose to observe spatially resolved signatures in F10214 at higher spatial and spectral resolution. The data in K09 provide us with spectral line fluxes that effectively demonstrate that the experiment proposed here WILL deliver sufficient SNR that bypasses any study conducted on F10214 thus far, and will be sufficient to resolve the spectral signatures we are seeking. The redshift of F10214 places the galaxy in regions of the NIR bands that are free from bright sky lines and atmospheric absoroption features. 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.

2. Direct detection of the extended starburst continuum and AGN core

While HST imaging is available in the archive, the brightness of F10214 means that Gemini is able to probe longer wavelengths than the HST, where the stellar continuum will be intrinscially brighter. We propose to image the galaxy with NIRI in the L'-band, corresponding to the rest-frame J-band a sensitive measure of the stellar continuum. The archival HST data suggest that the rest-frame optical emission is dominated by scattered light from the obscured nucleus, in the NIR, the galaxy will dominate. (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 SENSITIVITY WITH MICHELLE 1HR+OVERHEADS

Previous spectroscopy clearly shows multiple components line profiles. W

2. Probe the rest-frame J-band to (a) resolve the core and extended starburst and derive a constraint of the galaxies stellar mass 3. Direct detection of the hot infrared emission from the obscured AGN at a wavelength beyond the stransition from direct stellar to re-radiated light and that probr the "hot" continuum emission from the AGN itself in the MIR (rest-frame 3um). where the active nucleus and starburst regions undergo lower extinction than in the observed-frame optical. In the rest-frame optical IMAGING

and thus know the required exposure times. We note that the proposed AO-assisted observations will improve the spatial resolution of the resultant spectral maps (0.1" versus 1") the data will also be at higher spectral resolutin aiding the ability to discern the broad and narrow line components in this source. We note there are alos CGS4 long-slit observations (lacy et al. 98) - from these observations

and Halpha allow us to probe the spatial extent of the broad and narrow emitting line regions. If, our hypothesis of a differentially maginfied AGN

The composite nature of F10214 is founded i Since its discovery, F10214 has been known to host coeval starburst and AGN components that were both required to explain its FIR SED. The AGN alone could not be responsble for the all the IR emission, rather components of cool "cirrus" dust and ongoing star formation are necesary to explain the galaxy's FIR-mm SED. This is corroborated by the large mass of molecular and atomic gas in this galaxy [V04,], providing ample fuel for the intense starburst. Furthermore, H

and

In addition the IR-luminous phase is also argued to be a stepping stone between the transitions from major mergers of gas rich disks - to quasars - to present-day massive galaxies. Both Spitzer and Herschel have revealed the importance of the IR luminous galaxies, with their number density increasing to higher redshifts with a peak coinciding with the peak of activity in the star-formation history of the Universe. Moreover, there is growing evience for the i number density of IR-luminous galaxies increases to high-redshift coinciding with the peak of activity seen in the star-formation hostory of the universe.

The IR-luminous phenomenon at high-z pin-points the most massive dark matter halos, and is plausibly a ubiquitous stage in the evolution of massive present-day galaxies.

Compton-thick quasar? Alexander 2005MNRAS.357L..16A, xray em consistent with starburst

Technical Justification

Band 3 Information

Requested time in case of band 3 allocation: 0.0 hours

Minimum required time for a usable band 3 allocation: 0.0 hours

Use the following conditions for band 3 only:

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

Observation Details

Observation	RA	Dec	Brightness	Total Time *(including overheads)*
IRAS F10214+4724	10:24:34.56	47:09:9.59	N~	
GSC0343500222(wfs)	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	N~	
GSC0343500222(wfs)	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	N~	
GSC0343500222(wfs)	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	N~	
GSC0343500222(wfs)	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: NIFS		

Observing Conditions

Name	Image Quality	Sky Background	Water Vapor	Cloud Cover
Band 3 Observing Conditions	Any	Any	Any	Any
Global Default	Any	Any	Any	Any

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