NIRISS Guaranteed Time Observations Program Overview

René Doyon, Université de Montréal, doyon@astro.umontreal.ca
NIRISS Principal Investigator

January 26, 2017

Introduction

The Near-Infrared Imager and Slitless Spectrograph (NIRISS) is one of the four science instruments onboard the James Webb Space Telescope. NIRISS is housed together with the Fine Guidance Sensor into a single module provided by the Canadian Space Agency. NIRISS is a near-infrared ($0.6 - 5\,\mu$m) camera featuring four observing modes: broad- and medium-band imaging, wide-field slitless spectroscopy (WFSS), single-object slitless spectroscopy (SOSS) optimized for spectroscopy of transiting exoplanets and Aperture Masking Interferometry (AMI) for high-angular ($0.1 - 0.4''$) resolution observations. More information on the NIRISS instrument and its scientific capabilities can be found here.

NIRISS will be allocated 450 hours (clock time) of Guaranteed Times Observations (GTO), the bulk of it divided into two major ∼200-hr programs, one on wide-field slitless spectroscopy of galaxy clusters and the other on exoplanet transit/eclipse spectroscopy. This document presents an overview of all NIRISS GTO programs. **All targets and time allocated to each program are preliminary and subject to change until submission of the final NIRISS GTO program 15 June 2017.**

NIRISS Science team

The FGS/NIRISS science team includes the following members and affiliation:
René Doyon (U. Montréal),
Chris Willott (NRC-HAA),
Roberto Abraham (U. of Toronto),
Laura Ferrarese (NRC-HAA),
Lisa Kaltenegger (Cornell),
Ray Jayawardhana (York),
Doug Johnstone (NRC-HAA),
John Hutchings (NRC-HAA),
David Lafrenière (U. Montréal),
Michael Meyer (U. Michigan),
Judith Pipher (U. Rochester),
Neil Rowlands (Honeywell),
Marcin Sawicki (St-Mary's),
Anand Sivaramakrishnan (STScI)

The GTO team also includes several collaborators organized in the following four working groups (leader given in parenthesis): high-redshift galaxies and galaxy evolution (Willott), exoplanet spectroscopy (Lafrenière), aperture masking interferometry (Sivaramakrishnan) and substellar initial mass function (Jayawardhana).

NIRISS GTO Program summary

Program title	Lead	Mode	Time
NEAT: NIRISS Exploration of the Atmospheric diversity of Transiting exoplanets	Lafrenière	SOSS	204
The CAnadian NIRISS Unbiased Cluster Survey (CANUCS)	Willott	WFSS	199
The NIRISS Survey for Young Brown Dwarfs and Rogue Planets	Scholz	WFSS	19
Planets in Formation Around Young Stars: NIRISS AMI Observations of Transition Disk Systems	Johnstone	AMI	10
Architecture of Directly-imaged Extrasolar Planetary Systems	Rameau	AMI	7
NGC 1068 as Proving Ground for NIRISS AMI	Ford	AMI	5
Probing the Cloud Properties of the Benchmark Variable T Dwarf SIMP0136	Artigau	SOSS	4
High-Angular Observations of Ultracool Brown Dwarfs	Albert	AMI	3
Exozodiacal Disks: A Theatre for Planetary Gravitational Shadow Plays	Tuthill	AMI	3

The CAnadian NIRISS Unbiased Cluster Survey (CANUCS)

NIRISS GTO *High-redshift galaxies and galaxy evolution* Working Group
Chris Willott, Roberto Abraham, Marusa Bradac, Gabriel Brammer, Pierre Chayer, Van Dixon, René Doyon, Jean Dupuis, Laura Ferrarese, Paul Goodfrooij, John Hutchings, André Martel, Swara Ravindranath & Marcin Sawicki.

Total time : 199 hours — Parallel observations: Yes
Time breakdown by prime instrument: NIRISS 137 hrs, NIRCam 44 hrs, NIRSpec 18 hrs.

Abstract

CANUCS is a JWST slitless spectroscopy and imaging survey of five massive galaxy cluster and ten parallel fields using the NIRISS low-resolution grisms, NIRCam imaging and NIRSpec multi-object spectroscopy. The primary goal is understanding the evolution of low mass galaxies across cosmic time. The resolved emission line maps and line ratios for many galaxies, some at resolution of 100pc, will enable determining the spatial distribution of star formation, dust and metals. Other science goals include the detection and characterization of galaxies within the reionization epoch, using multiply-imaged lensed galaxies to constrain cluster mass distributions and dark matter substructure, and understanding star-formation suppression in the most massive galaxy clusters.

CANUCS Target List

Cluster	RA	DEC	Redshift	Survey	*JWST* Visibility Period
Abell 370	02:39:52.8	-01:34:36	0.375	HFF	24 Jul-16 Sep + 12 Dec-02 Feb
M0416.1-2403	04:16:09.4	-24:04:04	0.395	HFF	12 Aug-09 Nov + 27 Nov-22 Feb
M0417.5-1154	04:17:34.7	-11:54:32	0.443	RELICS	17 Aug-20 Oct + 26 Dec-24 Feb
M1149.6+2223	11:49:35.9	+22:23:55	0.543	HFF	19 Apr-15 Jun + 05 Dec-27 Jan
M1423.8+2404	14:23:47.8	+24:04:40	0.545	CLASH	13 May-24 Jul + 08 Jan-15 Mar

NEAT: NIRISS Exploration of the Atmospheric diversity of Transiting exoplanets

NIRISS GTO *Exoplanet spectroscopy* Working Group
David Lafrenière, Loïc Albert, Étienne Artigau, Björn Benneke, Nicolas Cowan, René Doyon, Joseph Filippazzo, Alex Howe, Ray Jayawardhana, Doug Johnstone, Lisa Kaltenegger, Nikole Lewis, Michael Meyer, Jason Rowe & Anand Sivaramakrishnan.

Total time: 204 hours — Parallel observations: No

Abstract

We propose to obtain NIRISS SOSS transit and eclipse observations of a sample of 14 exoplanets that span the full available range of equilibrium temperatures (300–3000 K) and masses (1 M_{Earth}–2 M_{Jup}) for planets amenable to atmospheric characterization. Our program will thus reveal the full diversity of short-period exoplanet atmospheres. Our observations will also measure the abundance of the molecules and aerosols present in the exoplanets' atmosphere and determine the vertical temperature structure of the hottest targets. These results will allow us to address fundamental issues such as the formation process and formation location of these close-in planets, the presence and characteristics of particulate clouds, and non-equilibrium chemistry effects that might be at play in their atmosphere. Three of our targets are rocky and for these we intend to make the very first detection of an atmosphere, which would then allow us to place the first constraints on the mean molecular weight—and hence bulk composition—of their atmospheres. For one target, we will acquire observations continuously throughout a full orbital period to constrain its temperature-pressure profile as a function of longitude and study how heat is absorbed and redistributed in its atmosphere.

NEAT Targets properties and total observing times

Name	J (mag)	M_p (M_{Jup})	R_p (R_{Jup})	$\log g_p$ ($cm\ s^{-2}$)	T_{eq} (K)	T_{14} (h)	t_{obs} (h)	Notes
GJ 3470b	8.79	0.043	0.346	2.9	600	1.9	6.31	
GJ 436b	6.90	0.0726	0.3767	3.106	680	0.761	3.67	
HAT-P-1b	9.16	0.531	1.242	2.935	1320	2.784	16.72	Tr + ecl
HD 209458 b	6.59	0.689	1.359	2.969	1450	3.065	18.03	Tr + ecl
WASP-39b	10.66	0.284	1.27	2.646	1120	2.803	8.41	
WASP-43b	10.0	1.78	0.93	3.709	1350	1.16	27.7	Phase
WASP-69b	8.03	0.259	1.057	2.762	960	2.230	7.07	
WASP-76b	8.54	0.92	1.83	2.85	2160	3.694	20.94	Tr + ecl
WASP-121b	9.63	1.183	1.865	2.973	2360	2.887	17.20	Tr + ecl
USco1610-1919b	11.1	...	0.45	...	900	4.08	11.37	
TRAPPIST-1 system	11.35	∼0.003	0.0936	∼3	340	0.696	35.2	10 visits
GJ 1132 b	9.25	0.005	0.1036	3.09	580	0.783	18.6	5 visits
K2-18 b	9.76	...	0.2	...	270	2	13.1	2 visits

The NIRISS Survey for Young Brown Dwarfs and Rogue Planets

Aleks Scholz, Ray Jayawardhana, Koraljka Muzic, David Lafrenière, René Doyon, Loïc Albert, Michael Meyer & Doug Johnstone.

Total time : 19 hours Parallel observations: Yes

Abstract

How far down in mass the stellar initial mass function (IMF) extends is a fundamental, unresolved question in astrophysics. The shape of the IMF at the lowest masses will not only establish the boundary between objects that form 'like stars' and those that form 'like planets', but also distinguish among competing theoretical models for the origin of brown dwarfs. Thanks to extensive surveys by us and others, the IMF is now reasonably well characterised in several nearby star-forming regions down to about 10 Jupiter masses, but not below. While these surveys suggest that free-floating planetary-mass objects are relatively scarce, recent microlensing studies claim they may be twice as common as stars. The stark contrast between the two results could be reconciled if there is a large population of hitherto undetected 1-5 Jupiter mass objects in star forming regions, possibly formed in protostellar disks and subsequently ejected. Here we propose to use NIRISS in the WFSS mode to survey a nearby young cluster to unprecedented depth, in order to (1) establish firmly the shape of the IMF below the Deuterium-burning limit, (2) investigate the fragmentation limit for 'star-like' formation, and (3) quantify the population of isolated planetary-mass objects. Our proposed observations of NGC 1333 will not only identify and confirm objects down to 1-2 Jupiter masses, but also provide a first estimate of their temperature, and thus mass. Follow-up high-resolution spectroscopy with NIRSpec could improve Teff/mass estimates, derive C/O ratios to trace the formation mechanism, look for accretion features, and test atmosphere models, while follow-up MIRI photometry would look for disk emission.

Planets in Formation Around Young Stars: NIRISS AMI Observations of Transition Disk Systems

Doug Johnstone, Michael Meyer, Anand Sivaramakrishan, Alexandra Greenbaum,Samantha Lawler, Julien Rameau, David Lafrenière, René Doyon, Laurent Pueyo & Deepashri Thatte

Total time : 10 hours Parallel observations: No

Abstract

We aim to observe planets in formation around young stars using NIRISS AMI at thermal infrared wavelengths. We focus on Transition Disk systems, in which the natal protoplanetary disk around the young star shows evidence of disruption and gap formation. Such a scenario is expected when a forming planet is dynamically clearing its local environment. We aim to show that planet formation is ubiquitous in Transition Disk systems and that it is responsible for carving the observed large inner cavities. Each detected, and categorized, planet will provide a unique proving ground for theorists modeling disk and planet evolution, disk dispersal, and planet migration. We will observe up to three sources: LkCa 15, HD 100546, and HD 169142.

Architecture of Directly-imaged Extrasolar Planetary Systems

Julien Rameau, David Lafrenière, René Doyon, Étienne Artigau, Anand Sivaramakrishnan, Doug Johnstone, André Martel, Mike Meyer & Deepashri Thatte

Total time : 7 hours Parallel observations: No

Abstract

The Aperture Masking Interferometry (AMI) mode of JWST/NIRISS offers a rare opportunity to probe extrasolar planetary systems with separations from less than 0.1" to 0.4" in the thermal infrared. On the one hand, AO-fed instruments from the ground mostly operate in the near-infrared and offer deep contrast down to 0.2" at best. On the other hand, thermal infrared is a regime in which the spectral energy distribution of young planets peaks, making AMI observations sensitive to planets with masses down to $4M_{\rm Jup}$ around young and nearby stars. Therefore, AMI is an ideal mode that is complementary to ground based direct imaging to probe small angular separations to study the inner part of planetary systems. A complete knowledge of the architecture of extrasolar systems will provide an important observational test to overcome the main limitations of directly-imaged planets. Dynamical studies of multiple systems or systems with planets and disks give independent mass estimates that can be confronted with the model-dependent masses of these planets based on uncalibrated evolutionary tracks. We therefore propose in this project to make use of the AMI performance to help completing the view of the architecture of two directly-imaged extrasolar planetary system, HR8799, HD98086 and a giant planet candidate sculpting the disk of HD115600.

NGC 1068 as Proving Ground for NIRISS AMI

K.E. Saavik Ford, B. McKernan, A.Sivaramakrishnan, A. Martel, J. Hutchings, D. Thatte, K. St.Laurent, L. Mugnier, and the NIRISS AMI Team

Total NIRISS time : 5 hours Parallel observations: No

Abstract

Ground-based imaging of the Narrow Line Region (NLR) of the nearby Seyfert 2 Active Galactic Nucleus (AGN), NGC 1068, reveals substantial near-IR emission aligned along the axis of a biconical outflow. Clear evidence of dust emission at temperatures ∼700K imply a heating mechanism acting locally, at distances of ∼few 10s pc away from the AGN central engine. At larger distances, the near-IR emission is roughly coincident with [OIII] emission observed from HST, and radio emission possibly due to a jet. Thus it has been suggested that a sheath of interacting material around the jet may be providing heating via photoionization. The highest angular resolution near-IR images, however, show a possible arc of emission, probably in the plane orthogonal to the jet, extremely close to the central point source (∼130mas). This is exactly the region where material inflowing from galactic scales may be redirected into an outflow by AGN feedback mechanisms. If real, the arc must be produced by mechanisms operating at the poorly-understood interface between the inflowing reservoir of material supplying the torus and central engine. Only NIRISS AMI observations can unambiguously detect or rule out the presence of the arc structure; we propose NIRISS AMI observations in F380M, F430M and F480M filters, yielding 65-70mas resolution across a sub-arcsecond field of view. We expect to measure the temperatures of a variety of clouds in the field, including the arc, with some objects as bright as L=7.7. The processes governing this region are critically responsible for the balance between inflowing material from the galaxy, outflowing material due to AGN feedback, and accretion onto the black hole itself.

Probing the Cloud Properties of the Benchmark Variable T Dwarf SIMP0136

Étienne Artigau, Stanimir Metchev, Loïc Albert, René Doyon, Jason Rowe, David Lafrenière & Björn Benneke

Total time : 4 hours | Parallel observations: No

Abstract

SIMP0136 is one of the nearest isolated brown dwarfs to the Sun; this early-T dwarf lies in the temperature range where dust-bearing clouds, more typical of L dwarfs, sink below the photosphere. The inhomogeneous cloud coverage on its surface leads to rotation-induced variability at the $2-7\%$ level over its 2.4 h rotation. Furthermore, the evolution of cloud patterns leads to a modulation of the light-curve over timescales of a few days. We propose GTO observations to obtain time-resolved SOSS spectroscopy of this benchmark variable brown dwarf over a complete rotation. This observation will detect variability at the 10-70σ level per spectral channel over the entire SOSS wavelength domain. By probing different heights in the atmosphere, variability of different chemical species will trace the vertical extent of dust-clouds and upwelling processes in ultra-cool atmospheres. This work will have a strong bearing on the study of hot exoplanets; at a temperature of $\sim$1200 K, SIMP0136 is similar to numerous hot Jupiters. Proper description of dust behavior is key in understanding transit spectroscopy data as dust clouds can readily mask the lower layers of an otherwise clear atmosphere.

High-Angular Resolution Observations of Ultracool Brown Dwarfs

Loïc Albert, Thomas Roellig, Charles Beichman, David Barrado Navascuès, Catarina Alves de Oliveira, Doug Johnstone, René Doyon, David Lafrenière, Étienne Artigau & Mike Meyer.

Total time : 3 hours | Parallel observations: No

Abstract

The ultracool dwarfs of the Y spectral type discovered with WISE are not only very cool ($250-600$ K), they are likely of very low masses ($5-30M_{Jup}$) for only the least massive brown dwarfs can cool down to such temperatures within the thin disk lifetime. This is why, by clustering at the low-end of the initial mass function, the population of known Y dwarfs (~ 25) probably constitute the extreme product of turbulent cloud core fragmentation. Although, it may also be that the lowest-mass Y dwarfs belong to an entirely different population of ejected planets whose existence is supported by gravitational lensing studies. However, contrary to ejected planets which are not expected to come as binaries, objects formed through core fragmentation can be produced as binary systems. Any companion found around a Y dwarf would therefore push further down the limits at which the core fragmentation scenario can form objects. This short program will use NIRISS/AMI to search for companions around 2 Y dwarfs with contrasts of Δmag$\approx$ 3 at the peak of the SED in the F480M filter. At the Y dwarfs distances ($\leq$ 10 pc) and the separations probed by NIRISS/AMI ($0.1-0.3''$), a significant fraction of the orbit could be traced within the lifetime of JWST and masses of Y dwarfs directly measured for the first time.

We will choose the brightest few Y dwarfs having low estimated mass and/or over-luminosity. We will likely choose between W0350, W1828, W0855 and W1738.

Exozodiacal Disks: A Theatre for Planetary Gravitational Shadow Plays

Peter Tuthill, James Lloyd, Anand Sivaramakrishnan, Christophe Pinte & Alexandra Greenbaum

Total time : 3 hours Parallel observations: No

Abstract

Disks of dust and debris are ubiquitous in the circumstellar environment. Due to its large surface area, even a modest structure such as our solar system's interplanetary dust emits orders of magnitude more radiation across the optical and infrared than all the planets combined as the zodiacal light. Characterization of exozodiacal disks remains in specifying future missions, driving the aperture requirements for resolving planets from exozodiacal light. Particularly at scales corresponding to the inner solar system (and habitable zones), present technologies are only able to detect the densest debris systems.

This proposal directly addresses this critical blind spot in our knowledge. Furthermore, at the sensitivities available to JWST, the flux from bright exo-zodiacal disks can be used to prospect for signatures of embedded planets. Gravitational shepherding of the dust by any orbiting massive bodies will reveal telltale signatures that are orders of magnitude larger, and easier to detect, than the bodies themselves. This proposal will target the bright system η Crv to demonstrate the capabilities of NIRISS/AMI for imaging dust signatures of exoplanetary systems.