GEMINI OBSERVATORY

observing time request summary

Semester: 2025A **Observing Mode:** Fast Turnaround **Gemini Reference:**

Instruments: Flamingos2

Time Awarded: NaN **Thesis:** No **JWST Synergy:** No

Band 3 Acceptable: No

Title: **Spectroscopic Redshift Estimates of SPT-3G-selected DES Quasars**

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

		PI Request		NTAC Recommendation			
Partner	**Lead**	**Time**	**Min**	**Reference**	**Time**	**Min**	**Rank**
	Total Time	*3.15 hr*	*1.89 hr*		*0.00 hr*	*0.00 hr*	

Total Time of Observations

Band	GN	GS
Band 1/2	0.00 hr	3.15 hr
Band 3	0.00 hr	0.00 hr

Abstract

Quasars are some of the brightest known objects in the universe. Thus, they are viewable over a wide range of redshifts---making them valuable probes of cosmology and galaxy evolution. However, this requires accurate measurements of their distances. Photometric methods require less observing time and are therefore more easily obtainable. However, they are intrinsically more inaccurate in measuring redshifts---and therefore distances. Thus, spectroscopic methods are preferrable when distances need to be known precisely. In this proposal, we aim to measure the near-infrared (NIR) spectra of the five brightest DES quasars---in the DES I band---also found in the SPT-3G winterfield millimeter-wave point source catalog. This will allow us to spectroscopically, and therefore more accurately, measure their redshifts. This will serve as a pathfinder for a future proposal in which we repeat this same analysis with the much larger sample of quasars crossmatched between DES and SPT-3G (about 1930).

TAC Category

Active Galaxies, Quasars, SMBH /

Potential Problems

The submitted proposal has 2 observations with a low probability of suitable guide stars.

Scheduling Constraints

No constraints regarding timing or required/impossible dates

Observation Details (Band 1/2)

Observation	RA	Dec	Brightness	Total Program Partner
quasar4	21:36:23.106	-62:24:00.494	14.56 i Vega	0.63 hr 0.38 hr 0.25 hr
Potential problems: Some PAs do not have suitable guide stars (75%) **Conditions:** CC 70%/Cirrus, IQ 85%/Poor, SB 50%/Dark, WV 50%/Median **Resources:** Flamingos2 Longslit JH JH (1.390 um) 8-pix longslit				
quasar3	23:44:48.223	-49:06:40.379	14.44 i Vega	0.63 hr 0.38 hr 0.25 hr
Conditions: CC 70%/Cirrus, IQ 85%/Poor, SB 50%/Dark, WV 50%/Median **Resources:** Flamingos2 Longslit JH JH (1.390 um) 8-pix longslit				
quasar2	20:40:15.751	-51:25:46.931	14.44 i Vega	0.63 hr 0.38 hr 0.25 hr
Conditions: CC 70%/Cirrus, IQ 85%/Poor, SB 50%/Dark, WV 50%/Median **Resources:** Flamingos2 Longslit JH JH (1.390 um) 8-pix longslit				
quasar1	20:59:12.845	-52:00:21.288	14.30 i Vega	0.63 hr 0.38 hr 0.25 hr
Conditions: CC 70%/Cirrus, IQ 85%/Poor, SB 50%/Dark, WV 50%/Median **Resources:** Flamingos2 Longslit JH JH (1.390 um) 8-pix longslit				
quasar0	20:58:26.782	-42:39:00.098	14.16 i Vega	0.63 hr 0.38 hr 0.25 hr
Potential problems: Some PAs do not have suitable guide stars (75%) **Conditions:** CC 70%/Cirrus, IQ 85%/Poor, SB 50%/Dark, WV 50%/Median **Resources:** Flamingos2 Longslit JH JH (1.390 um) 8-pix longslit				

Scientific Justification *Limited to 1 page of text plus 2 pages for figures and references.*

Quasi-stellar objects, also known as quasars or QSOs, are extremely luminous active galactic nuclei (AGN). This phenomenon arises from supermassive black holes (SMBHs), found at the center of nearly every large galaxy in the universe [5, 6], accreting vast amounts of surrounding dusty and gaseous matter. This accretion causes strong emission fluxes across various portions of the electromagnetic spectrum [8]. AGN, along with stars, serve as the two predominant sources of electromagnetic radiation throughout the Universe [8]; the brightest of quasars outshine entire galaxies—having luminosities thousands of times greater than the Milky Way [2, 13].

It is theorized that all AGN generally possess the same substructures. The Unified Theory of AGN asserts that the difference in observed spectral energy distributions (SEDs) can be explained away by a host of reasons, such as obscuration (by the host galaxy or AGN's own dusty torus) due to viewing angle and contamination from nearby star-formation [9, 10]. The supermassive black hole in most galaxies is thought to lie at the nucleus and is encircled by a planar accretion disk consisting of superheated gas, plasma, and dust. Much larger in scale and enclosing the accretion disk is the circumnuclear dusty torus. Biconical outflows of matter jet out in the polar directions for many AGN observed in the local universe [8]. The accretion disk and surrounding corona emits ionizing radiation which photo-ionizes the adjacent dense clouds of gas and dust. This leads to a series of strong emission lines in the UV, optical, and near-IR; examples include Hydrogen recombination line series: Lyman (lower state is the ground state), Balmer (lower state is the first excited state), and Paschen (lower state is the second excited state). These lines are broad due to the velocity dispersions of the aforementioned clouds being several thousands of kilometers per second; hence, this region is known as the Broad Line Region (BLR). Depending on the viewing angle, the BLR may or may not be obscured by the circumnuclear dusty torus [4]. Figure 1 provides a rough pictorial representation of these various substructures.

Quasars being visible over a wide range of redshifts make them valuable cosmological probes [3]. However, to accomplish this, **their redshifts must be known both accurately and to high precision**. Thus, it is preferable that said redshifts are obtained spectroscopically; spectroscopic redshifts are far more accurate and less uncertain than their photometric counterparts. In particular, this study seeks to investigate the evolution of millimeter-selected quasars. A catalog of SPT-3G (the third-generation camera on the South Pole Telescope) winterfield point sources (Archipley, in prep.) has been crossmatched with an optical Dark Energy Survey (DES) quasar catalog [14]. This preferentially selects quasars with strong dust emission—which dominates the millimeter wavelengths of the AGN spectral energy distribution (SED) [8]. We aim to spectroscopically estimate redshifts for these crossmatched sources—allowing for improved statistical analyses, such as quasar number versus redshift, probing quasar evolution through cosmic time.

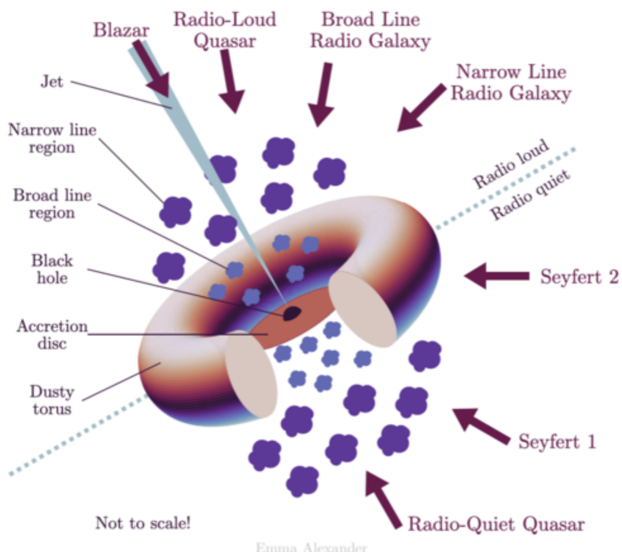


Figure 1: Unified model of AGN adapted from [11]. Figure from [12]

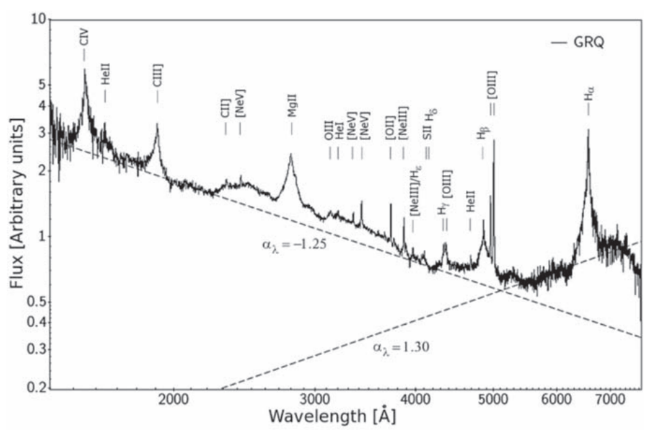


Figure 2: Optical quasar spectrum showing multiple broad and narrow emission lines. Figure from [7].

References

[1] Stephen Eikenberry et al. "FLAMINGOS-2: the facility near-infrared wide-field imager and multi-object spectrograph for Gemini". In: *Ground-based and Airborne Instrumentation for Astronomy.* Ed. by Ian S. McLean and Masanori Iye. Vol. 6269. Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series. June 2006, 626917, p. 626917. DOI: 10.1117/12.672095. arXiv: astro-ph/0604577 [astro-ph].

[2] Juhan Frank, Andrew King, and Derek J. Raine. *Accretion Power in Astrophysics: Third Edition.* 2002.

[3] J. E. Geach et al. "A Direct Measurement of the Linear Bias of Mid-infrared-selected Quasars at z ≈ 1 Using Cosmic Microwave Background Lensing". In: ApJ 776.2, L41 (Oct. 2013), p. L41. DOI: 10.1088/2041-8205/776/2/L41. arXiv: 1307.1706 [astro-ph.CO].

[4] Timothy M. Heckman and Philip N. Best. "The Coevolution of Galaxies and Supermassive Black Holes: Insights from Surveys of the Contemporary Universe". In: ARA&A 52 (Aug. 2014), pp. 589–660. DOI: 10.1146/annurev-astro-081913-035722. arXiv: 1403.4620 [astro-ph.GA].

[5] John Kormendy and Luis C. Ho. "Coevolution (Or Not) of Supermassive Black Holes and Host Galaxies". In: ARA&A 51.1 (Aug. 2013), pp. 511–653. DOI: 10.1146/annurev-astro-082708-101811. arXiv: 1304.7762 [astro-ph.CO].

[6] John Kormendy and Douglas Richstone. "Inward Bound—The Search For Supermassive Black Holes In Galactic Nuclei". In: ARA&A 33 (Jan. 1995), p. 581. DOI: 10.1146/annurev.aa.33.090195.003053.

[7] Agnieszka Kuźmicz, Sagar Sethi, and Marek Jamrozy. "Giant Radio Quasars: Composite Optical Spectra". In: ApJ 922.1, 52 (Nov. 2021), p. 52. DOI: 10.3847/1538-4357/ac27ad. arXiv: 2109.07825 [astro-ph.GA].

[8] Jianwei Lyu and George Rieke. "Infrared Spectral Energy Distribution and Variability of Active Galactic Nuclei: Clues to the Structure of Circumnuclear Material". In: *Universe* 8.6 (May 2022), p. 304. DOI: 10.3390/universe8060304. arXiv: 2205.14172 [astro-ph.GA].

[9] P. Padovani et al. "Active galactic nuclei: what's in a name?" In: A&A Rev. 25.1, 2 (Aug. 2017), p. 2. DOI: 10.1007/s00159-017-0102-9. arXiv: 1707.07134 [astro-ph.GA].

[10] Cristina Ramos Almeida and Claudio Ricci. "Nuclear obscuration in active galactic nuclei". In: *Nature Astronomy* 1 (Oct. 2017), pp. 679–689. DOI: 10.1038/s41550-017-0232-z. arXiv: 1709.00019 [astro-ph.GA].

[11] C. Megan Urry and Paolo Padovani. "Unified Schemes for Radio-Loud Active Galactic Nuclei". In: PASP 107 (Sept. 1995), p. 803. DOI: 10.1086/133630. arXiv: astro-ph/9506063 [astro-ph].

[12] Wikipedia. *Active galactic nucleus — Wikipedia, The Free Encyclopedia*. https://en.wikipedia.org/w/index.php?title=Active_galactic_nucleus&oldid=1246395769. [Online; accessed 19-December-2024]. 2024.

[13] Xue-Bing Wu et al. "An ultraluminous quasar with a twelve-billion-solar-mass black hole at redshift 6.30". In: Nature 518.7540 (Feb. 2015), pp. 512–515. DOI: 10.1038/nature14241. arXiv: 1502.07418 [astro-ph.GA].

[14] Qian Yang and Yue Shen. "A Southern Photometric Quasar Catalog from the Dark Energy Survey Data Release 2". In: ApJS 264.1, 9 (Jan. 2023), p. 9. DOI: 10.3847/1538-4365/ac9ea8. arXiv: 2206.08989 [astro-ph.GA].

Technical Description *Limited to 1 page of text*

In total, we have identified 1930 DES quasars without spectroscopic redshift measurements found in both ASKAP and SPT-3G. Due to time constraints, we will only look at the five brightest—in the DES I-band—ones to start. This will serve as a pathfinder for a future and more complete follow-up. The five quasars considered here have redshifts ranging from 1 to 1.4; therefore, the near-infrared (NIR) will be the optimal observing window, as it will measure multiple redshifted Balmer emission lines: Hα ($n = 3 \to 2$), Hβ ($n = 4 \to 2$), and Hδ ($n = 5 \to 2$).

For this reason, we will utilize the NIR spectroscopic capabilities of the FLAMINGOS-2 instrument on Gemini South [1]. Specifically, we use the JH filter—which provides sufficient resolution (R=1200) whilst covering a wide enough range of wavelengths (approximately 900 nm to 1800 nm) to guarantee measurement of the redshifted Hα and Hβ emission lines for all five sources along with the Hδ emission line for four of the five sources. We assume median observing conditions (i.e., 70% cloud cover, 50% water vapor, 50% sky background, and an airmass of 1.5) along with poor image quality (i.e., 85%). Quasars are some of the most luminous sources in the universe, so they should be easily observable even during suboptimal terrestrial viewing conditions. For each source, we plan on executing two 60-second exposures. This gives a program time of 22 minutes and 43 seconds for each source—excluding time for baseline calibrations—and a total observing time of three hours and fifteen minutes for all five sources—including time for baseline calibrations. We have requested a minimum time of 1.89 hours, as this will allow us to at least observe three of the five quasars. As illustrated by the ITC examples below, the above experimental setup yields very high SN measurements—upwards of 25 almost everywhere within the JH filter observing window (900 nm to 1800 nm). Thus, we will be able to make extremely high SN measurements of the Hα, Hβ, and Hδ emission lines—which are all prominent features within the quasar optical SED as shown in Figure 2. Quantifying the shift of these three lines via SED template fitting to the observed NIR spectrum will yield the desired accuracy improvement—and uncertainty reduction—in estimating redshifts for the quasar sample.

The integration time per source and number of exposures certainly could have been reduced while still providing very high signal-to-noise (SN) measurements in the desired spectral channels. However, given that the majority of the observing time is dedicated to instrument setup, varying the integration time and number of exposures would have had a very small effect on the total program time. The values chosen still provide very high SN whilst still yielding a very reasonable total program time.

All requested observing time must be conducted at the Gemini South observatory, as the entire sample is located within the southern sky—outside of the declination range available to Gemini North. Beyond this, no specific constraints—scheduling or otherwise—have been requested.

Justify Target Duplications

The GOA search revealed no duplicate observations.

ITC Examples

Gemini Integration Time Calculator
Flamingos2 - 2025A.1.1.1

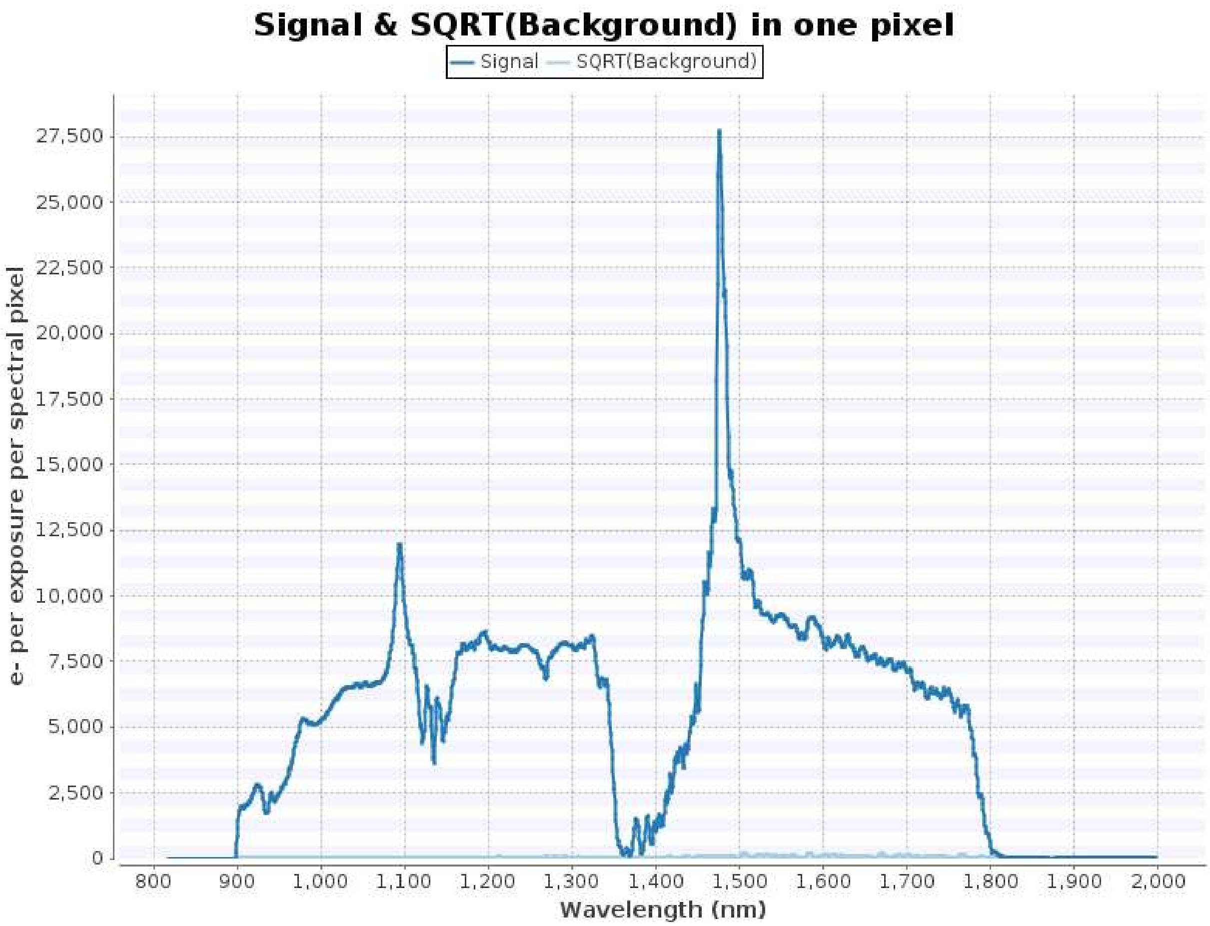
Click here for help with the results page.
derived image size (FWHM) for a point source = 1.08 arcsec.

software aperture extent along slit = 1.52 arcsec
fraction of source flux in aperture = 0.78

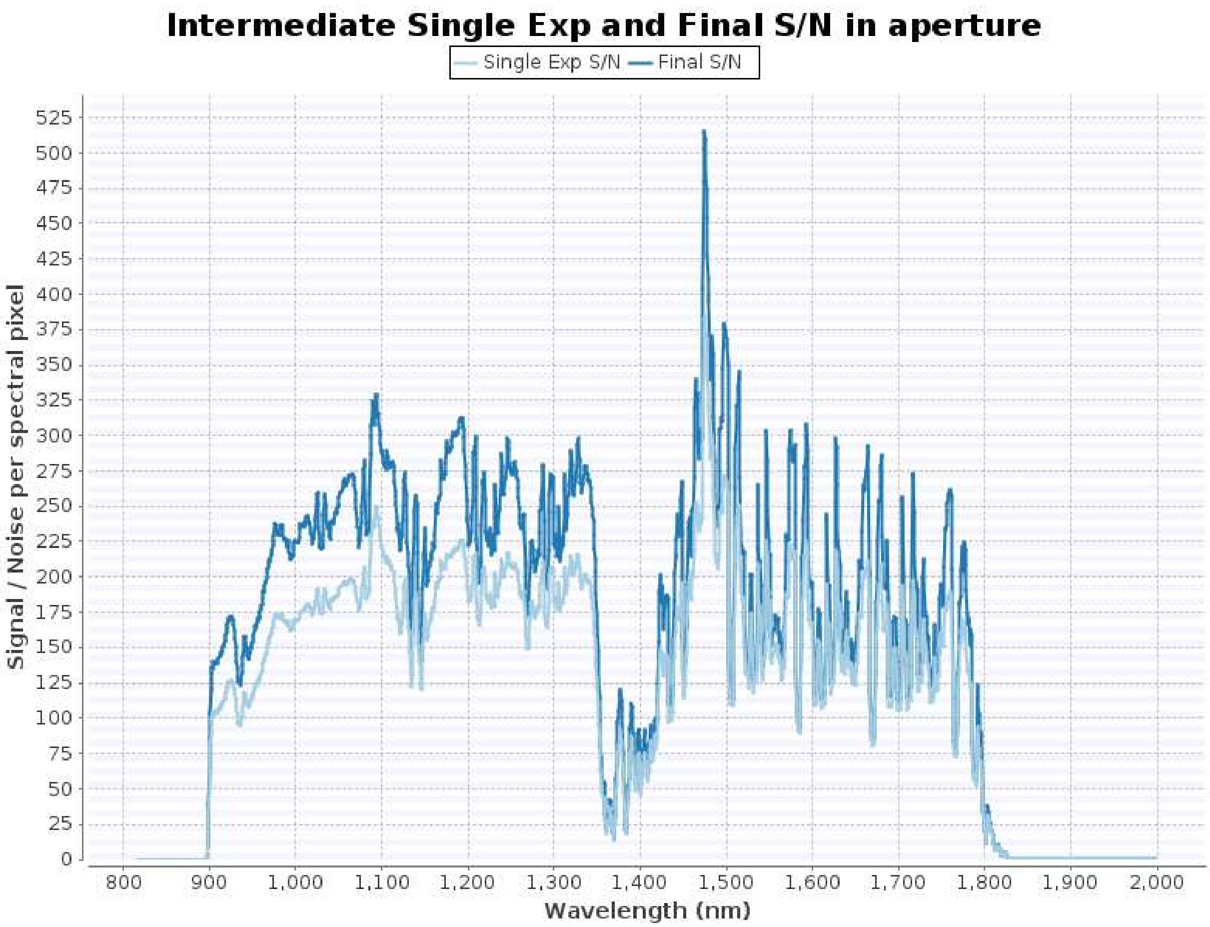
Requested total integration time = 120.00 secs, of which 120.00 secs is on source.

The peak pixel signal + background is 52204 e- (11757 ADU). This is 34% of the full well depth of 155400 e-.

Observation Overheads		
Setup	1200.0 s	
Telescope offset	1 x 7.0 s	assuming ABBA dithering pattern
Exposure	2 x 60.0 s	
Readout	2 x 8.0 s	
DHS Write	2 x 10.0 s	
Program time	**22 mins 43 secs**	



Click here for ASCII signal spectrum.
Click here for ASCII background spectrum.



[Click here for Single Exposure S/N ASCII data.]
[Click here for Final S/N ASCII data.]

Input Parameters:
Instrument: Flamingos 2

Source spatial profile, brightness, and spectral distribution:

The z = 1.25000 point source is a 14.165046 Vega QSO2 in the i band.

Instrument configuration:
Optical Components:
- Filter: JH
- Fixed Optics
- Detector - 2048x2048 Hawaii-II (HgCdTe)
- Grism Optics: R1200JH
- Read Noise: highNoise
- Focal Plane Mask: 8 pix slit

Pixel Size: 0.18

Telescope configuration:
- silver mirror coating.
- side looking port.
- wavefront sensor: oiwfs

Observing Conditions:
- Airmass: 1.50
- Image Quality: 85%   (≤ 0.85" at zenith, ≤ 1.08" on-source)
- Cloud cover: 70%
- Water Vapor: 50%
- Sky Background: 50%

Likelihood of execution: 15%

Calculation and analysis methods:
- Mode: spectroscopy
- Calculation of S/N ratio with 2 exposures of 60.00 secs, and 100.00% of them on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Output:
- Spectra autoscaled.

Gemini Integration Time Calculator
Flamingos2 - 2025A.1.1.1

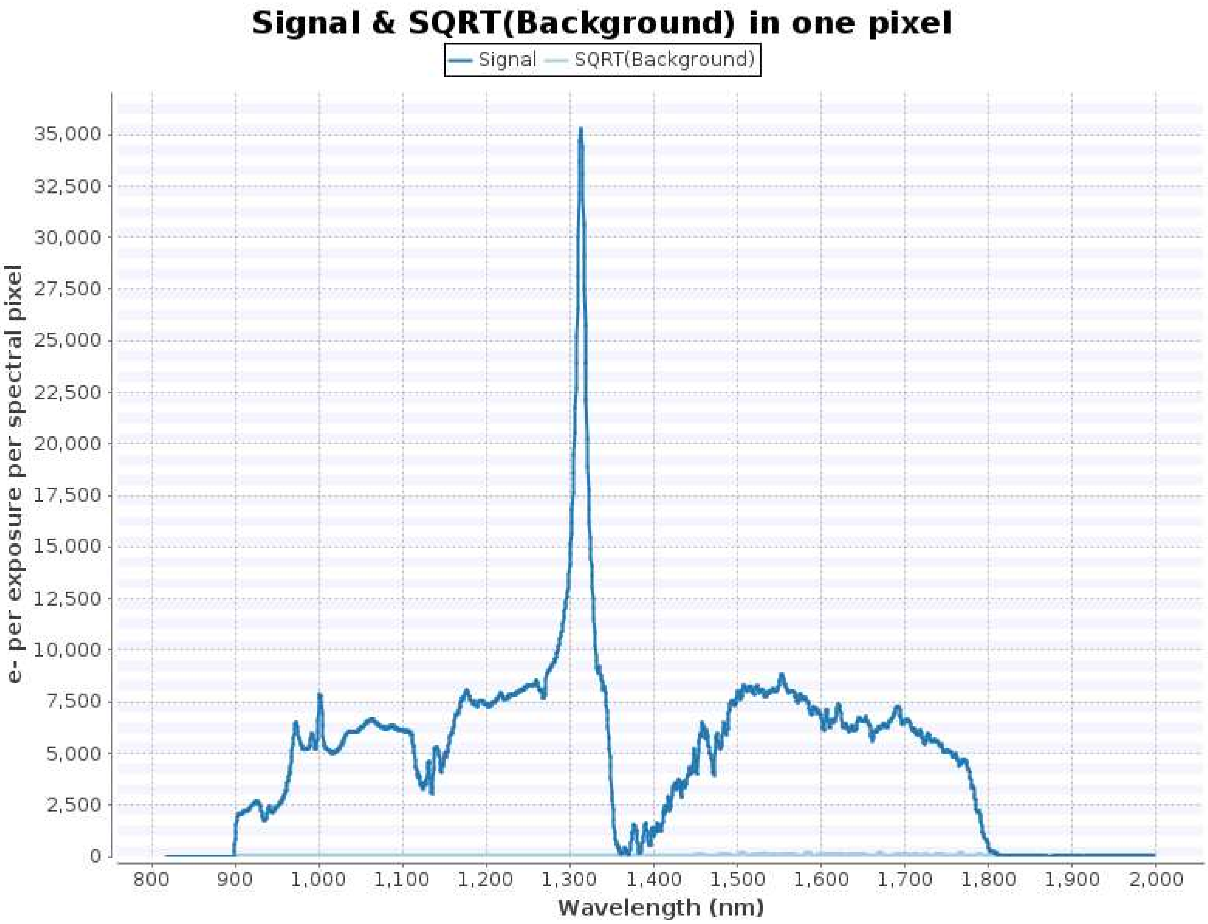
Click here for help with the results page.
derived image size (FWHM) for a point source = 1.08 arcsec.

software aperture extent along slit = 1.52 arcsec
fraction of source flux in aperture = 0.78

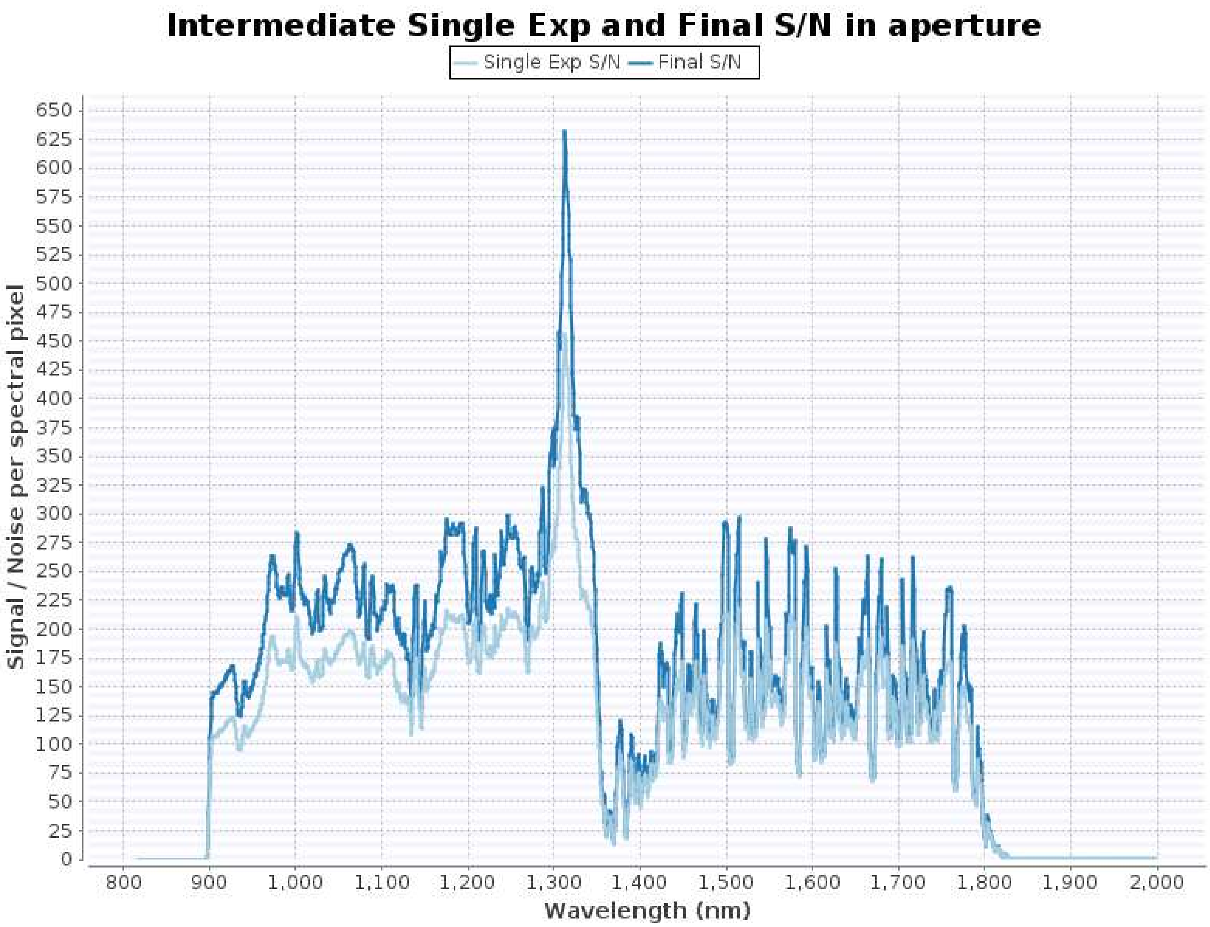
Requested total integration time = 120.00 secs, of which 120.00 secs is on source.

The peak pixel signal + background is 50426 e- (11357 ADU). This is 32% of the full well depth of 155400 e-.

Observation Overheads		
Setup	1200.0 s	
Telescope offset	1 x 7.0 s	assuming ABBA dithering pattern
Exposure	2 x 60.0 s	
Readout	2 x 8.0 s	
DHS Write	2 x 10.0 s	
Program time	**22 mins 43 secs**	



[Click here for ASCII signal spectrum.]()
[Click here for ASCII background spectrum.]()



Click here for Single Exposure S/N ASCII data.
Click here for Final S/N ASCII data.

Input Parameters:
Instrument: Flamingos 2

Source spatial profile, brightness, and spectral distribution:

The z = 1.00000 point source is a 14.297962 Vega QSO2 in the i band.

Instrument configuration:
Optical Components:
- Filter: JH
- Fixed Optics
- Detector - 2048x2048 Hawaii-II (HgCdTe)
- Grism Optics: R1200JH
- Read Noise: highNoise
- Focal Plane Mask: 8 pix slit

Pixel Size: 0.18

Telescope configuration:
- silver mirror coating.
- side looking port.
- wavefront sensor: oiwfs

Observing Conditions:
- Airmass: 1.50
- Image Quality: 85%   (≤ 0.85" at zenith, ≤ 1.08" on-source)
- Cloud cover: 70%
- Water Vapor: 50%
- Sky Background: 50%

Likelihood of execution: 15%

Calculation and analysis methods:
- Mode: spectroscopy
- Calculation of S/N ratio with 2 exposures of 60.00 secs, and 100.00% of them on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Output:
- Spectra autoscaled.

Gemini Integration Time Calculator
Flamingos2 - 2025A.1.1.1

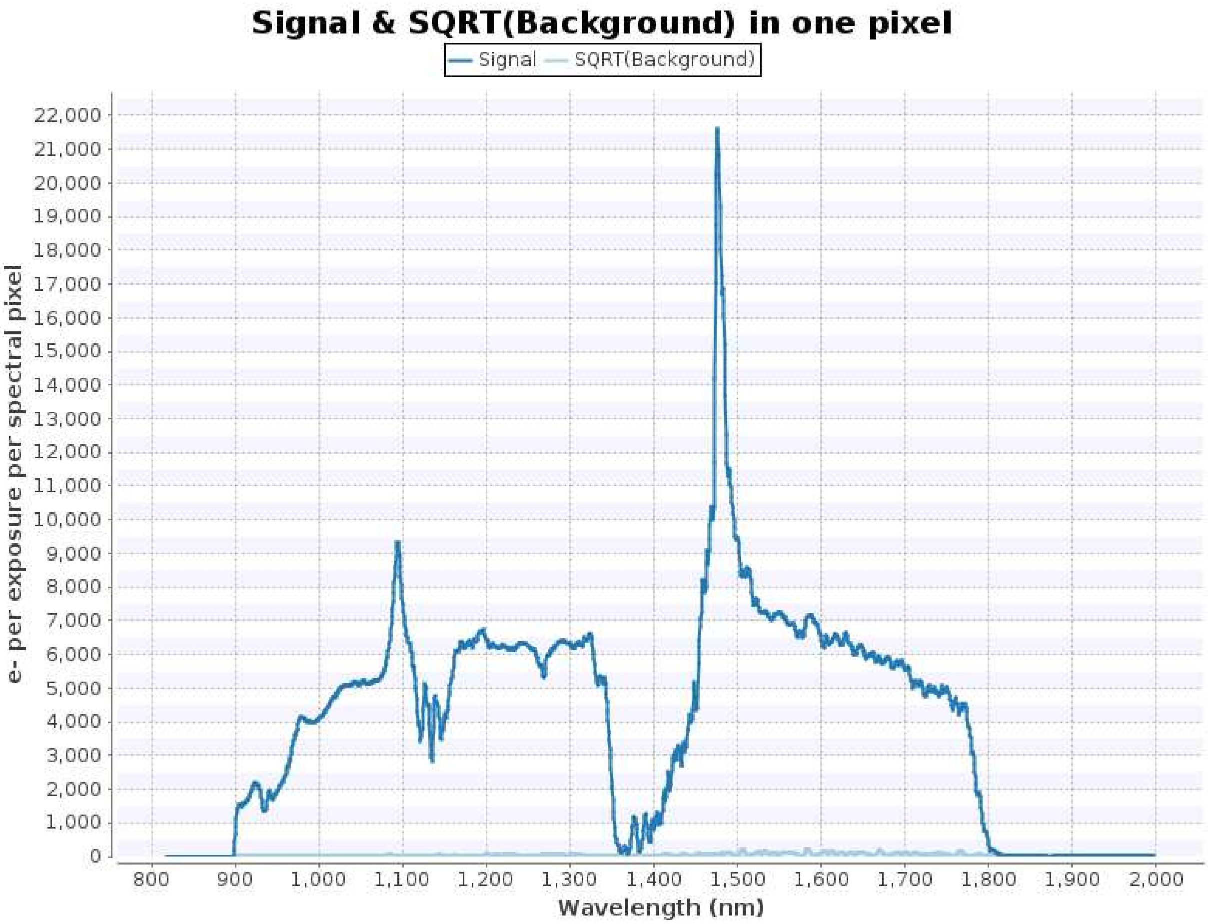
Click here for help with the results page.
derived image size (FWHM) for a point source = 1.08 arcsec.

software aperture extent along slit = 1.52 arcsec
fraction of source flux in aperture = 0.78

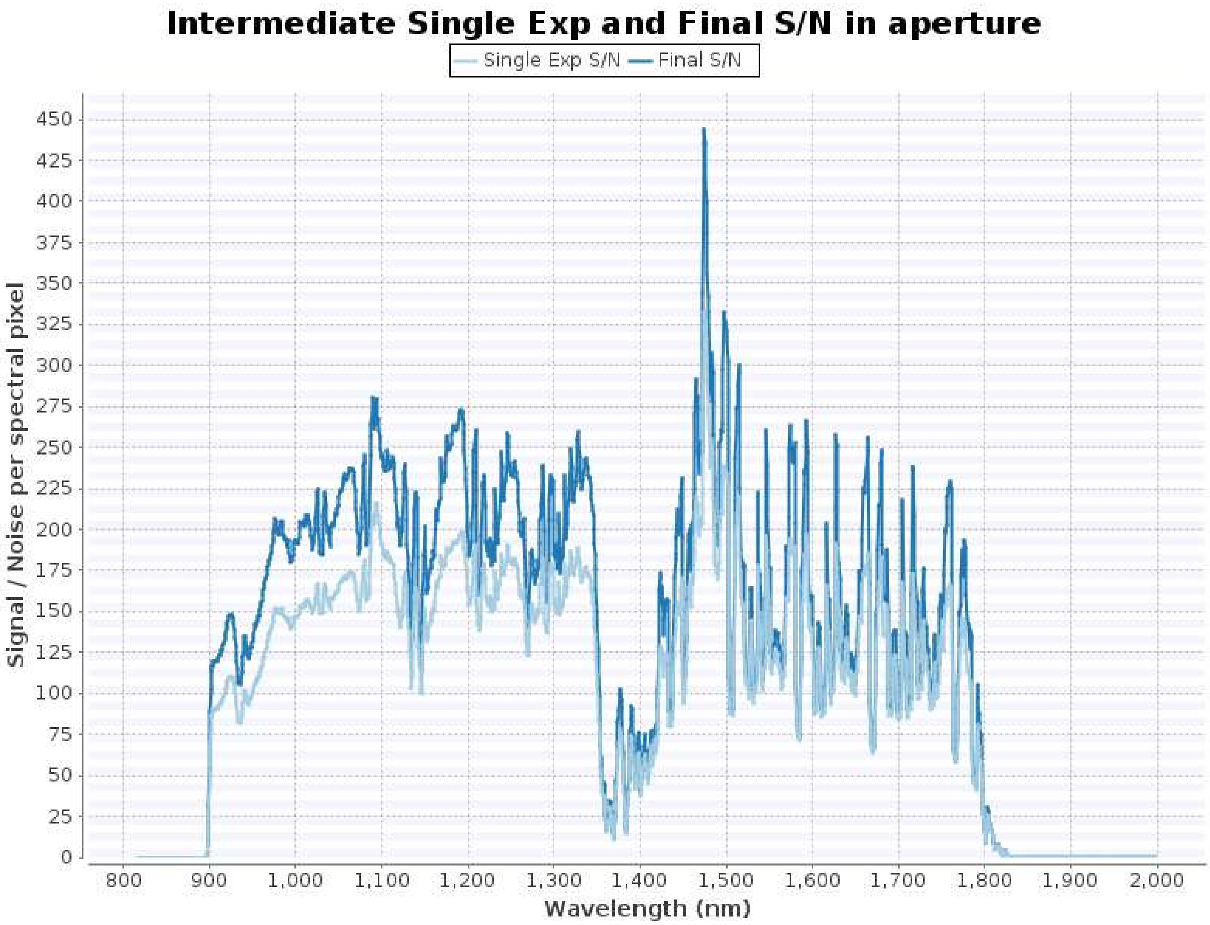
Requested total integration time = 120.00 secs, of which 120.00 secs is on source.

The peak pixel signal + background is 50187 e- (11303 ADU). This is 32% of the full well depth of 155400 e-.

Observation Overheads		
Setup	1200.0 s	
Telescope offset	1 x 7.0 s	assuming ABBA dithering pattern
Exposure	2 x 60.0 s	
Readout	2 x 8.0 s	
DHS Write	2 x 10.0 s	
Program time	**22 mins 43 secs**	



[Click here for ASCII signal spectrum.]
[Click here for ASCII background spectrum.]



Click here for Single Exposure S/N ASCII data.
Click here for Final S/N ASCII data.

Input Parameters:
Instrument: Flamingos 2

Source spatial profile, brightness, and spectral distribution:

The z = 1.25000 point source is a 14.435094 Vega QSO2 in the i band.

Instrument configuration:
Optical Components:
- Filter: JH
- Fixed Optics
- Detector - 2048x2048 Hawaii-II (HgCdTe)
- Grism Optics: R1200JH
- Read Noise: highNoise
- Focal Plane Mask: 8 pix slit

Pixel Size: 0.18

Telescope configuration:
- silver mirror coating.
- side looking port.
- wavefront sensor: oiwfs

Observing Conditions:
- Airmass: 1.50
- Image Quality: 85%   (≤ 0.85" at zenith, ≤ 1.08" on-source)
- Cloud cover: 70%
- Water Vapor: 50%
- Sky Background: 50%

Likelihood of execution: 15%

Calculation and analysis methods:
- Mode: spectroscopy
- Calculation of S/N ratio with 2 exposures of 60.00 secs, and 100.00% of them on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Output:
- Spectra autoscaled.

Gemini Integration Time Calculator
Flamingos2 - 2025A.1.1.1

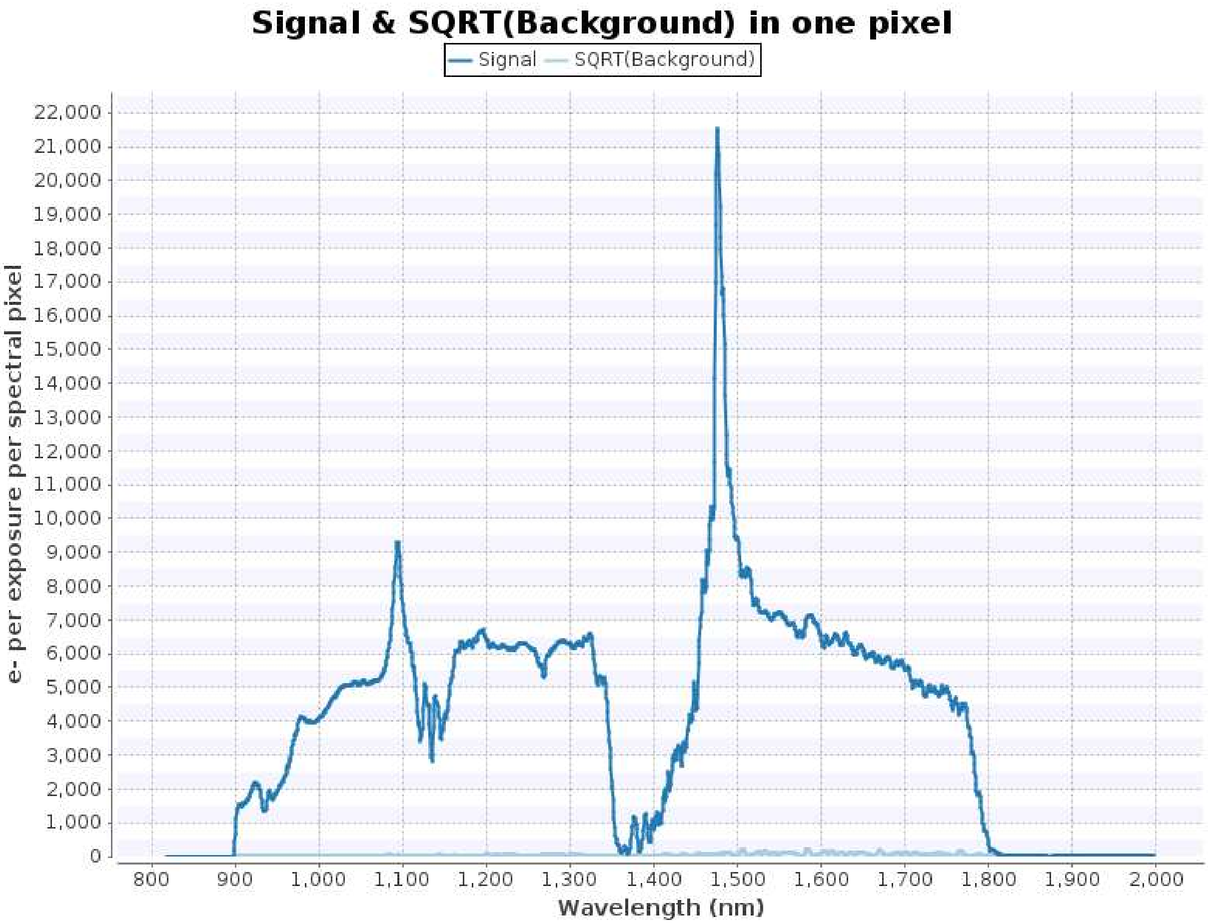
Click here for help with the results page.
derived image size (FWHM) for a point source = 1.08 arcsec.

software aperture extent along slit = 1.52 arcsec
fraction of source flux in aperture = 0.78

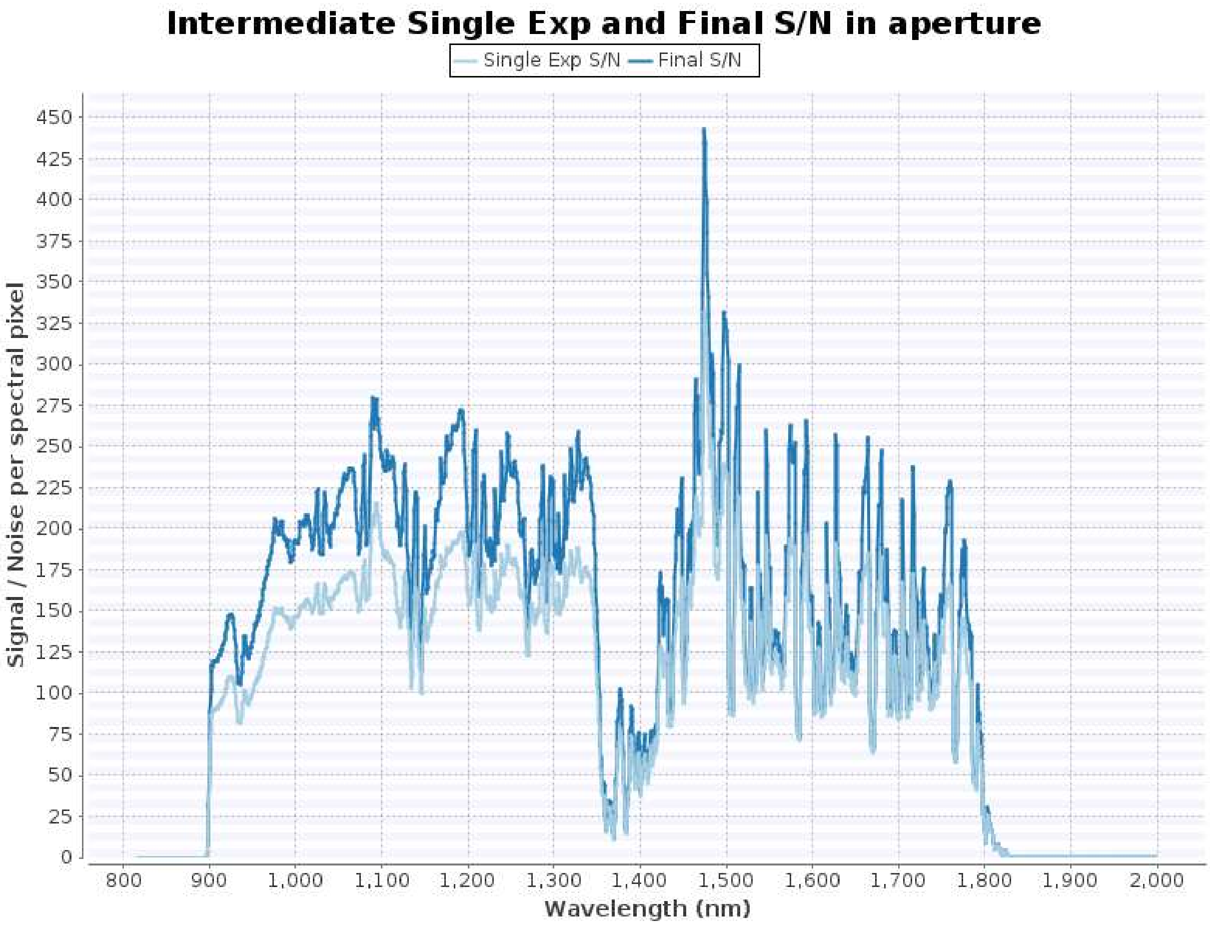
Requested total integration time = 120.00 secs, of which 120.00 secs is on source.

The peak pixel signal + background is 50162 e- (11297 ADU). This is 32% of the full well depth of 155400 e-.

Observation Overheads		
Setup	1200.0 s	
Telescope offset	1 x 7.0 s	assuming ABBA dithering pattern
Exposure	2 x 60.0 s	
Readout	2 x 8.0 s	
DHS Write	2 x 10.0 s	
Program time	**22 mins 43 secs**	



[Click here for ASCII signal spectrum.]
[Click here for ASCII background spectrum.]



Click here for Single Exposure S/N ASCII data.
Click here for Final S/N ASCII data.

Input Parameters:
Instrument: Flamingos 2

Source spatial profile, brightness, and spectral distribution:

The z = 1.25000 point source is a 14.438916 Vega QSO2 in the i band.

Instrument configuration:
Optical Components:

- Filter: JH
- Fixed Optics
- Detector - 2048x2048 Hawaii-II (HgCdTe)
- Grism Optics: R1200JH
- Read Noise: highNoise
- Focal Plane Mask: 8 pix slit

Pixel Size: 0.18

Telescope configuration:

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

Observing Conditions:

- Airmass: 1.50
- Image Quality: 85%   (≤ 0.85" at zenith, ≤ 1.08" on-source)
- Cloud cover: 70%
- Water Vapor: 50%
- Sky Background: 50%

Likelihood of execution: 15%

Calculation and analysis methods:

- Mode: spectroscopy
- Calculation of S/N ratio with 2 exposures of 60.00 secs, and 100.00% of them on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Output:

- Spectra autoscaled.

Gemini Integration Time Calculator
Flamingos2 - 2025A.1.1.1

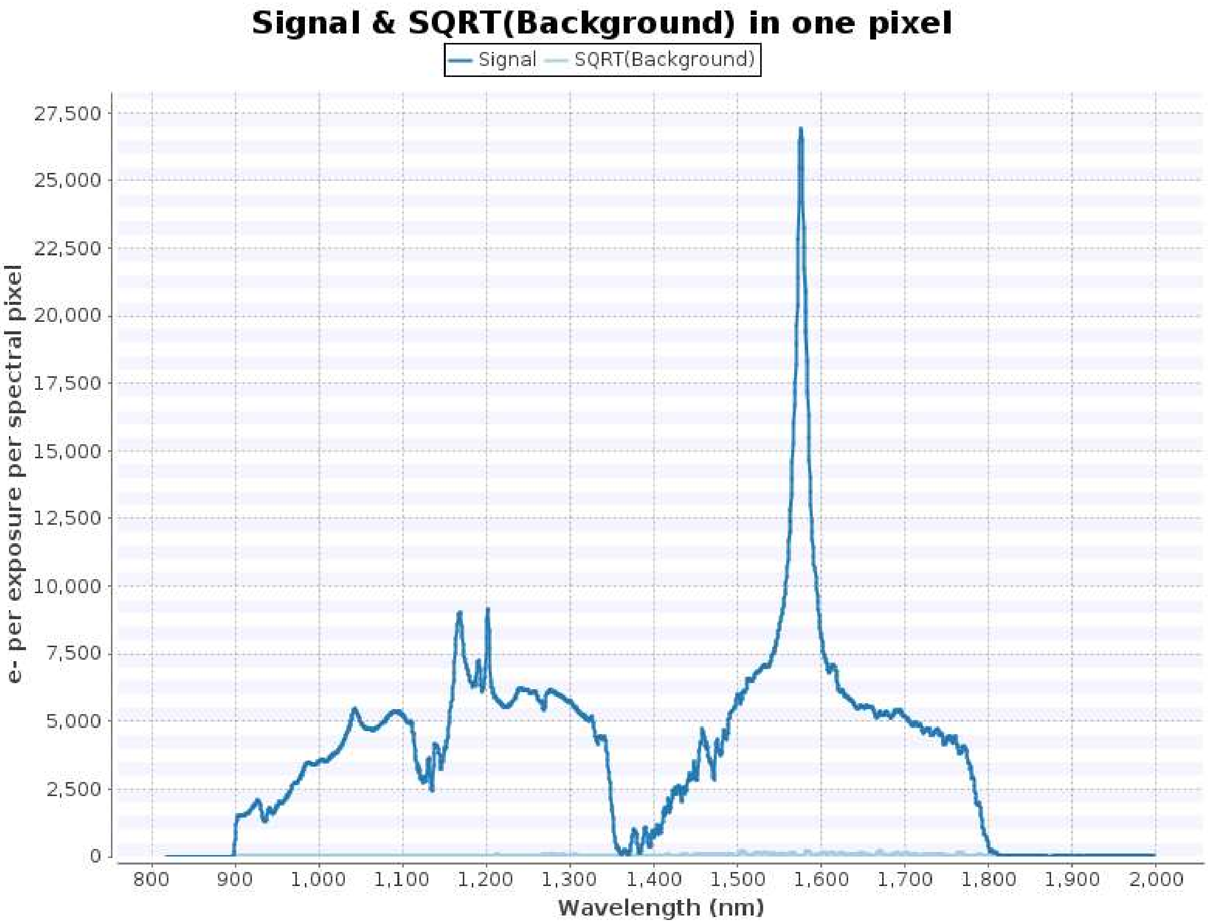
Click here for help with the results page.
derived image size (FWHM) for a point source = 1.08 arcsec.

software aperture extent along slit = 1.52 arcsec
fraction of source flux in aperture = 0.78

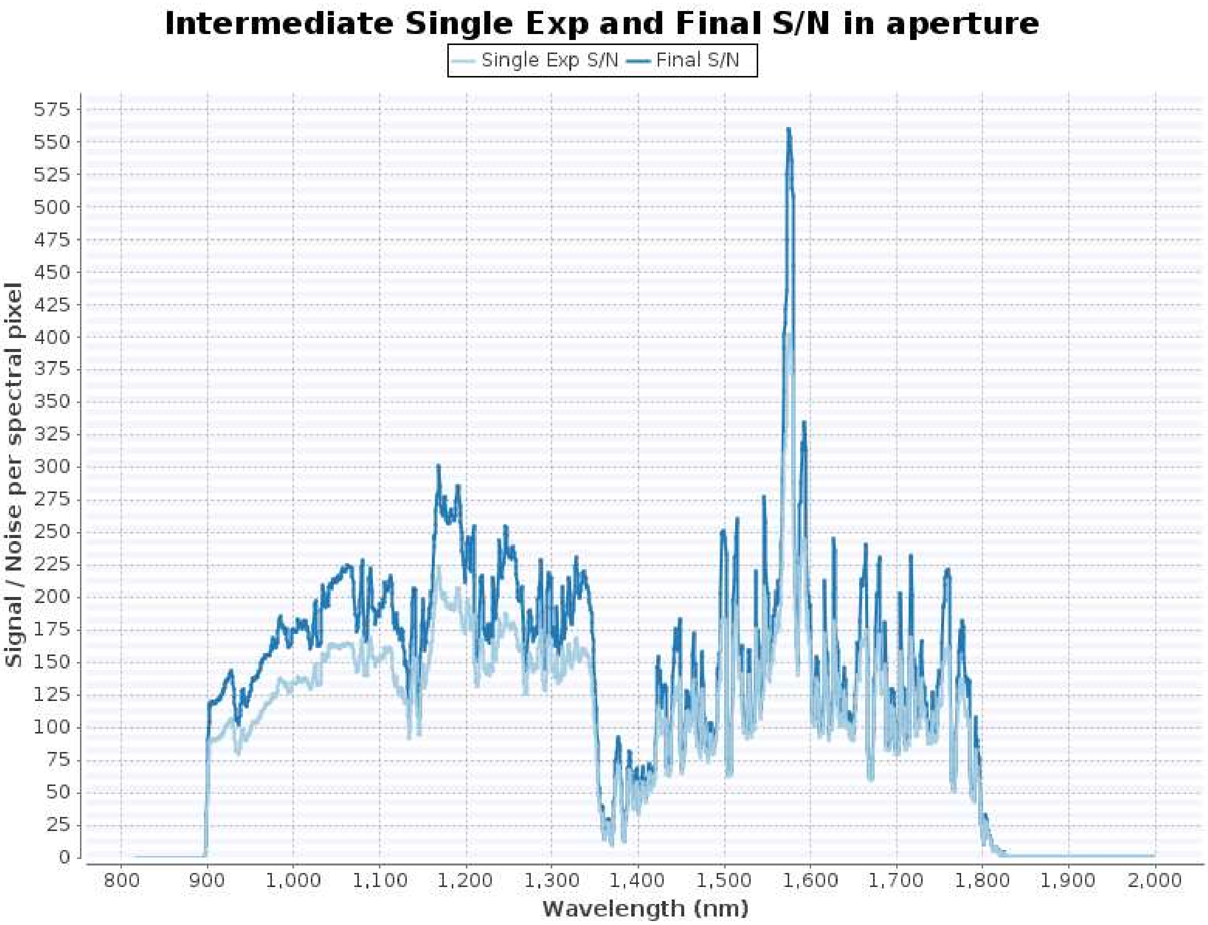
Requested total integration time = 120.00 secs, of which 120.00 secs is on source.

The peak pixel signal + background is 58534 e- (13183 ADU). This is 38% of the full well depth of 155400 e-.

Observation Overheads		
Setup	1200.0 s	
Telescope offset	1 x 7.0 s	assuming ABBA dithering pattern
Exposure	2 x 60.0 s	
Readout	2 x 8.0 s	
DHS Write	2 x 10.0 s	
Program time	**22 mins 43 secs**	



Click here for ASCII signal spectrum.
Click here for ASCII background spectrum.



Click here for Single Exposure S/N ASCII data.
Click here for Final S/N ASCII data.

Input Parameters:
Instrument: Flamingos 2

Source spatial profile, brightness, and spectral distribution:

The z = 1.40000 point source is a 14.561196 Vega QSO2 in the i band.

Instrument configuration:
Optical Components:
- Filter: JH
- Fixed Optics
- Detector - 2048x2048 Hawaii-II (HgCdTe)
- Grism Optics: R1200JH
- Read Noise: highNoise
- Focal Plane Mask: 8 pix slit

Pixel Size: 0.18

Telescope configuration:
- silver mirror coating.
- side looking port.
- wavefront sensor: oiwfs

Observing Conditions:
- Airmass: 1.50
- Image Quality: 85%   (≤ 0.85" at zenith, ≤ 1.08" on-source)
- Cloud cover: 70%
- Water Vapor: 50%
- Sky Background: 50%

Likelihood of execution: 15%

Calculation and analysis methods:
- Mode: spectroscopy
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- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Output:
- Spectra autoscaled.