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JWST Science Exposure Time Variability and its Impact on Science Scheduling

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Abstract

An important consideration for scheduling the James Webb Space Telescope (JWST) is the variation of an observation's exposure time, throughout the JWST orbit, required to achieve a desired signal-to-noise ratio. The variation in exposure time is the result of time-dependent background in the field of view. The JWST science planning and scheduling software must consider this variation in order to maximize the science efficiency of the mission.

Because of the variation of infrared background flux (particularly the zodiacal light) throughout the JWST orbit, exposure times required to achieve a given S/N on a given target can vary by more than a factor of three as a function of observing mode, wavelength and ecliptic latitude. The variation is the greatest for low ecliptic latitudes (in the plane of the zodiacal dust cloud) and for broad-band near and mid-infrared imaging.

The results of this study will illustrate this point, through an examination of exposure times calculated by the JWST Mission Simulator (JMS) for a variety of targets, as a function of wavelength, using the current (JMS 1.0) JWST OTA/Sunshield/Instrument configuration and observations in the JWST ASWG Design Reference Mission (DRM).

The science planning and scheduling software for JWST must account for the variability of exposure times or conversely signal to noise. To schedule observations using the most conservative estimate (longest duration to ensure adequate signal to noise) would, in some cases, produce an inefficient science schedule. Conversely, not considering the variation in time or signal to noise will compromise imaging and low resolution mid-infrared spectroscopy in the ecliptic plane.

Introduction

The JWST Mission Simulator (JMS) currently calculates exposure times taking into account OTA characteristics, science instrument parameters, and observational characteristics. Instead of describing all of the features of the JMS here, the reader may obtain detailed information about the JMS via the web link ***http://www.stsci.edu/jwst/science/jms/help.html***.

If one assumes constant OTA, science instrument, and science detector characteristics, as well as a constant target flux, it is the time-varying background radiation that results in the variation of the exposure time required to achieve a desired S/N. The JMS software models several sources of background contamination, with information on all of them contained in the aforementioned web pages. The dominant variable backgrounds for a given target are the zodiacal light and thermal self-emission from the primary and secondary mirrors, as well as emission from the JWST sunshield that is scattered off the mirror surfaces.

The temporal variations of these background intensities produce significant variation in exposure time throughout the JWST orbit (assumed to be an Earth-Sun L2 halo orbit). To illustrate this point, the observations in the JWST ASWG Design Reference Mission (DRM) were input to the JMS, and the exposure times for each observation were calculated as a function of time (using one hundred evenly spaced time points) over one JWST orbit (365 days). Exposure times were calculated only at time points when the target was within the field of regard, consisting of a target sun angle range of 85 – 155 degrees[1].

The minimum and maximum exposure times, over all time points, were then determined for each observation. The difference score (maximum duration - minimum duration) and the ratio score (maximum duration / minimum duration) were then computed for each observation. Observations with low scores have minimal relative background variations, whereas high score observations have background fluxes that vary more significantly.

The JWST telescope and spacecraft characteristics used for these calculations are specified in the JMS 1.0 Telescope and Spacecraft Characteristics File: ***http://www.stsci.edu/jwst/science/jms/default_inputs/arch_dck_master.txt***.

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[1] The recently revised (2004) sunshield field of regard is 85-135°. A smaller pitch range reduces the variation in exposure times to reach the same signal to noise.

The definition of the science instruments are specified in the JMS 1.0 Requirements Integrated Science Instrument Module Definition File: ***http://www.stsci.edu/jwst/science/jms/default_inputs/isim_dck_rqmts_master.txt.***

The science observations are specified in the JMS 1.0 ASWG DRM File: ***http://www.stsci.edu/jwst/science/jms/default_inputs/drm_dck_aswg_master.txt.***

In addition to using the requirements science instrument parameters, the calculations were repeated using the goals science instrument definitions. The instruments, in the goals case, have improved characteristics relative to the requirements definitions. The goals instrument characteristics are defined in the JMS 1.0 Goals ISIM File: ***http://www.stsci.edu/jwst/science/jms/default_inputs/isim_dck_goals_master.txt.***

Variability studies

Table 1 summarizes the compiled ratio scores over all observations in the ASWG Design Reference Mission (ASWG DRM) using the requirements science instrument parameters. All minimum and maximum exposure times are in seconds. For each Science Instrument Configuration (SI config), data from two observations are shown. The first observation is the Program, Visit, and Line from the DRM with the minimum ratio score for that SI config. The second is the observation with the maximum score for that configuration. SI configurations are ordered by increasing maximum ratio score.

Table 1
Ratio scores using the DRM & SI Requirements

LAT = Target's ecliptic latitude
SPR = Spectral Resolution -- a unit-less quantity, defined as the ratio of the observation' wavelength to the bandpass of the observation.
Lambda = Wavelength of observation
Min Exp = Observation's minimum exposure duration
Max Exp = Observation's maximum exposure duration

SI Config	Program	Visit	Line	LAT (deg)	Lambda (microns)	SPR	Min Exp (sec)	Max Exp (sec)	Ratio Score
NIRSPEC_grating	P017	V0007	056	-74.1	3.5	2000	283389	283502	1.0004
NIRSPEC_grating	P018	V0246	735	06.5	2.1	2000	766318	770312	1.0052
MIRI_ifu_1A	P012	V0026	088	58.9	6.0	6000	716347	718715	1.0033
MIRI_ifu_1A	P012	V0023	078	01.7	6.0	6000	716901	724057	1.0112
NIRSPEC_prism	P026	V0001	001	57.4	1.6	200	257523	258880	1.0053
NIRSPEC_prism	P004	V0002	002	11.8	1.3	200	5924386	6357590	1.0885
MIRI_ifu_2A	P012	V0027	089	58.9	18.0	4000	280752	291077	1.0368
MIRI_ifu_2A	P012	V0006	019	11.8	18.0	4000	269712	307373	1.1396
NIRCAM_sw	P017	V0007	007	-74.1	0.9	4	188318	190807	1.0132
NIRCAM_sw	P003	V0027	133	-00.7	1.1	4	18516	27955	1.5098
MIRI_spec_lores	P020	V0121	321	-49.9	20.0	200	437132	511642	1.1705
MIRI_spec_lores	P020	V0122	323	16.7	20.0	200	310622	550354	1.7718
MIRI_cam	P008	V0016	062	-68.7	10.0	3	2697	3017	1.1184
MIRI_cam	P008	V0027	106	02.3	10.0	3	2922	7662	2.6217
NIRCAM_lw	P017	V0007	023	-74.1	3.6	4	245510	273269	1.1131
NIRCAM_lw	P003	V0027	135	-00.7	4.6	4	8833	26604	3.0118

In addition, scores were also computed using the improved technology goals science instrument parameters. Table 2 shows the comparison, for each SI config, of the requirements and goals score ranges. Note that there is no qualitative difference in the range of ratio scores between the requirements and goals results, though scores significantly greater than 1.00 tend to have a broader range with the low-noise detector goals (e.g. background is a more significant noise source). Because the spectrographs are generally detector-noise dominate, there is relatively little variation in spectroscopic observations.

Also important to realize is that observations with low ratio scores can have significant difference scores (maximum-minimum durations). Consider the near-infrared spectroscopic observation (NIRSPEC_prism SI config) with a ratio score of 1.0885. Though this ratio score is far from the highest, the difference score for this observation is five days.

Table 2
Comparing ratio scores using SI Goals vs Requirements

SI Config	Requirements Score Range	Goals Score Range
NIRSPEC_grating	1.000 – 1.005	1.010 – 1.012
MIRI_ifu_1A	1.003 – 1.011	1.013 – 1.040
NIRSPEC_prism	1.005 – 1.089	1.011 – 1.182
MIRI_ifu_2A	1.037 – 1.140	1.044 – 1.175
NIRCAM_sw	1.013 – 1.510	1.021 – 1.617
MIRI_spec_lores	1.171 – 1.772	1.178 – 1.819
MIRI_cam	1.118 – 2.622	1.119 – 2.625
NIRCAM_lw	1.113 – 3.012	1.142 – 3.192

After the min/max ratio scores for all observations in the ASWG DRM were calculated, another set of hypothetical observations was created (numbering roughly 2000 observations), spanning the entire wavelength range of each SI config, for a variety of target AB Magnitudes (centered on magnitudes typically found in the ASWG DRM for a particular SI config), over all possible ecliptic latitudes, from –90 to +90 degrees, in 10 degree increments. The relevant parameter ranges for these observations, with respect to SI config, wavelength, spectral resolution (SPR), target AB Magnitude, and target S/N values, are summarized in Table 3. These data were created and processed with the JMS to search for potential observations with higher ratio scores than those represented in the ASWG DRM.

Table 3
An augmented range of JWST observations

SI Config	Wavelength Range (microns)	Target AB Mag Range	SPR	Required S/N
NIRCAM_sw	0.6 – 2.3	30 – 32	4, 10	10
NIRCAM_lw	2.3 – 5.0	30 – 32	4, 10	10
NIRSPEC_prism	0.6 – 5.0	29 – 31	200	10
NIRSPEC_grating	1.0 – 5.0	25 – 27	2000	10
MIRI_cam	5.0 – 27.0	26 – 28	3	10
MIRI_spec_lores	5.0 – 27.0	23 – 27	200	10
MIRI_ifu_1A	5.0 – 7.7	18 – 20	6000	80
MIRI_ifu_2A	12.0 – 18.0	14 – 16	4000	1000

The score ranges, for each SI config, calculated using these data, agreed extremely well with the scores calculated for the ASWG DRM observations. *In other words, the observations in the ASWG DRM adequately span the problem domain of exposure time variability for JWST science observations.*

Discussion of results and in depth studies

All further discussion of results assumes the requirements science instrument characteristics and ASWG DRM observations.

Some observations had ratio scores as small as 1.0004, whereas others had scores exceeding 3.0. For many observations with large scores, the exposure times were sufficiently large to result in difference scores (max duration – min duration) on the order of days or weeks, which would be significant for the JWST scheduling system.

As was expected, scores were smaller for observations far from the ecliptic plane because the zodiacal light and the cross section of the sunshield to the Sun do not vary significantly as a function of time. Such observations, therefore, have relative scores closer to unity. Note that most observations that produce a maximal ratio score, within the ASWG DRM, are near the ecliptic plane (see Table 1). In these cases, the shortest duration observations (or best signal to noise for a given observation duration) occur as close as possible to solar opposition.

Computing the scores for a series of observations whose only difference are the ecliptic latitudes of their targets revealed, as expected, an increase in score with decreasing angle from the ecliptic. Table 4 shows an example of this, for both the difference and ratio scores. The sample observation used the NIRCAM_sw SI configuration at 0.6 microns.

Table 4
NIRCam ecliptic latitude study
Observation Data: NIRCAM_sw, S/N=10, SPR=4, Lambda=0.6, AB Mag=30

ECL LAT (degrees)	Min Exp Time (hrs)	Max Exp Time (hrs)	Difference Score (hrs)	Ratio Score
90	17.5	18.4	1.1	1.05
60	17.5	19.0	1.5	1.09
30	18.6	21.1	2.5	1.13
0	20.1	25.7	5.6	1.28

From the data, it can be seen that the score (both absolute and ratio) increases as the target nears the ecliptic. If one considers the above observation, but this time with a fainter target AB magnitude of 31.0, one obtains:

Table 5
NIRCam study with a fainter target
Observation Data: NIRCAM_sw, S/N=10, SPR=4, Lambda=0.6, AB Mag=31

ECL LAT (degrees)	Min Exp Time (hrs)	Max Exp Time (hrs)	Absolute Score (hrs)	Ratio Score
90	108.0	114.0	6.0	1.06
60	108.0	117.0	9.0	1.08
30	115.0	130.0	15.0	1.13
0	127.0	160.0	33.0	1.26

Because the target is fainter for the second observation, the exposure times are accordingly larger. The difference scores therefore increase with decreasing target brightness, but the ratio scores are roughly equivalent between the two targets. The exposure time ratio score is insensitive to target brightness for faint, background-limited observations. Over all observations considered in this study, the ratio scores varied only slightly (at the level of two to three percent) across all target magnitudes for a given pointing and wavelength.

If one computes the exposure time ratio scores for the aforementioned observation (AB Magnitude = 30) at a variety of wavelengths spanning the usable spectral range of the NIRCAM_sw SI config, one obtains the following data. The scores were computed with zero ecliptic latitude, to maximize the score.

Table 6
NIRCam short wavelength study
Observation Data: NIRCAM_sw, S/N=10, SPR=4, ECL LAT=0, AB Mag=30

Lambda (microns)	Min Exp Time (hrs)	Max Exp Time (hrs)	Zodi Range (counts/pix/sec)	Ratio Score
1.0	20.5	25.7	0.13 – 0.23	1.45
1.5	8.8	12.7	0.13 – 0.23	1.45
2.0	9.5	10.2	0.11 – 0.20	1.43
2.3	10.4	14.5	0.10 – 0.17	1.39

The minimum zodiacal flux (counts/pix/sec) corresponds to the minimum exposure time, the maximum zodiacal flux to the maximum exposure time. Note that the score decreases smoothly toward longer wavelengths. This occurs because the ratio score scales approximately as the ratio of the max/min background flux for background-limited observations. Here, the dominant short-wavelength background, the scattered sunlight, decreases toward longer wavelengths relative to the fixed detector noise, and the ratio scores decrease accordingly.

The thermal zodiacal emission increases with wavelength, and, at approximately 3.5 microns and above, surpasses the scattered zodiacal light as the most important source of background contamination. This thermal emission increases with wavelength. Consider the following observation’s min/max exposure times, as well as min/max zodiacal light fluxes (in counts/pixel/second), as a function of wavelength, across one JWST orbit.

Table 7
NIRCam long wavelength study
Observation Data: NIRCAM_lw, S/N=10, SPR=4, ECL LAT=0, AB Mag=30

Lambda (microns)	Min Exp Time (hrs)	Max Exp Time (hrs)	Zodi Range (counts/pix/sec)	Ratio Score
2.3	7.88	13.0	0.42 – 0.77	1.66
2.5	7.66	12.5	0.38 – 0.68	1.64
3.0	7.13	11.4	0.27 – 0.50	1.62
3.5	7.82	14.1	0.24 – 0.52	1.82
4.0	11.70	27.7	0.31 – 0.89	2.39
4.5	22.10	63.0	0.54 – 1.70	2.85
5.0	47.50	146.0	1.03 – 3.39	3.08

Note the decrease of the ratio score with increasing wavelength, up to 3.5 microns. This, again, corresponds to the decrease in zodiacal dust-scattered sunlight. Below 3.5 microns, thermal emission by the zodiacal dust is relatively unimportant.

At wavelengths longer than 3.5 microns, the thermal zodiacal emission steadily increases relative to fixed detector noise, resulting in progressively larger ratio scores toward longer wavelengths. Clearly, for wideband (SPR = 4.0) NIRCAM imagery, the ratio scores are quite large. These scores are far beyond the variations encountered with HST observations, where a fixed-duration exposure time over the spacecraft orbit is sufficient for achieving, at least approximately, the desired S/N ratio.

Note the difference in the zodiacal flux (counts/pix/sec) between the NIRCAM_sw SI config, at 2.3 microns (see Table 6) and the NIRCAM_lw SI config at that same wavelength (see

Table 7). The zodicacal flux for the NIRCAM_lw config is approximately four times larger than that of the NIRCAM_sw config because the long-wavelength detector pixels are roughly twice as large (in each angular dimension) as those of the short-wavelength detector.

The NIRCAM observations shown above all occur at wavelengths of 5 microns or less. Consider the following MIRI_cam observation at wavelengths ranging from 5 microns to 27 microns. Note, from the data in Table 8, that the score decreases with increasing wavelength. This is because the thermal self-emission of the primary and secondary mirrors, as well as the sunshield, increase with increasing wavelength, and, above 15 or 16 microns, overwhelm the contribution by thermal zodiacal light. The mirror temperatures were taken to be constant, resulting in time independence of the mirror thermal background. The variation in sunshield thermal emission over the JWST orbit causes the score to remain high (~ 1.5) at long wavelengths.

Table 8
MIRI Study
Observation Data: MIRI_cam, S/N=10, SPR=3, ECL LAT=0, AB Mag=26

Lambda (microns)	Min Exp Time (hrs)	Max Exp Time (hrs)	Zodi Range (counts/pix/sec)	Self Emiss Range (counts/pix/sec)	Ratio Score
5.0	0.03	0.1	3 - 10	4e-6 - 3e-05	2.71
10.0	3.3	8.3	94 - 238	2 - 7	2.52
15.0	27.0	56.8	217 - 474	133 - 262	2.10
20.0	136.0	245.0	297 - 480	742 - 1390	1.80
25.0	448.0	706.0	308 - 499	2021 - 3210	1.57
27.0	675.0	997.0	300 - 480	2830 - 4190	1.48

As was stated earlier, the ratio score is approximately proportional to the max/min flux of the dominant source of background contamination. Short of 20 microns, the zodiacal light is the dominant background source, and the ratio of maximum to minimum zodiacal light flux steadily decreases with increasing wavelength, as does the observation's ratio score. At wavelengths beyond 20 microns, the sunshield self-emission dominates the zodiacal light. With increasing wavelength, however, the ratio of maximum to minimum self-emission decreases (even though the self-emission flux increases with wavelength), thereby resulting in a decreasing ratio score with increasing wavelength.

Despite the decrease in the ratio score with increasing wavelength, a minimum score of 1.48 still demonstrates a significant variation of exposure time, across the JWST orbit, at 27 microns, due to the variation in the sunshield thermal emission throughout the JWST orbit.

Implications for JWST science scheduling

As to the matter of scheduling science observations with such widely varying backgrounds to achieve a desired S/N, let us consider the following options:

- Use a science scheduling system for JWST that accounts effectively for time-variable exposure times, subject to the constraint that observations should be scheduled, collectively, to maximize the total number of scheduled observations and maximize science efficiency. It therefore follows that such a scheduler would tend to place a particular observation as close as possible to its minimum exposure time (required to achieve the desired S/N). This is how the JMS MET scheduler currently operates.

- Use a science scheduling system that treats exposure time as a constant for a given observation. Two possible alternative implementations of this option are shown below.

- Schedule observations with exposure times set to "worst-case" values, to ensure that a desired S/N would be achieved no matter when the observation was scheduled.

- Schedule observations using the minimum exposure times, within a time-restricted window that ensures that the target S/N remains within some acceptable tolerance of the desired S/N. This time-restricted window would then contain the time point at which the exposure time is minimum.

The first option, accounting for variable-length exposures during science scheduling, treats all observations generically without imposing additional restrictions on the time slots of observations. No matter when the observation is scheduled, the desired S/N would be achieved, thereby ensuring science integrity.

Most observatories operate by defining a reasonable amount of total exposure time for a science program (where the exposure time is calculated based upon the number of targets, their individual brightness, the desired S/N, and the various characteristics of the background sources, telescope, and science instruments). An observer is then granted a certain number of *nights* (for ground-based astronomy), or *orbits* (for HST), or *hours* (generically speaking), as opposed to being guaranteed a certain S/N for each observation. This convention is incompatible with allowing observations to schedule with widely varying exposure durations as a function of time. Also, this first scheduling option (adjustable times) might result in some observations occurring at maximal exposure times (minimum science gain per unit time), thereby significantly reducing the remaining calendar time available for other observations. Such an operation would not be globally optimized since presumably other observations could have used the time more effectively.

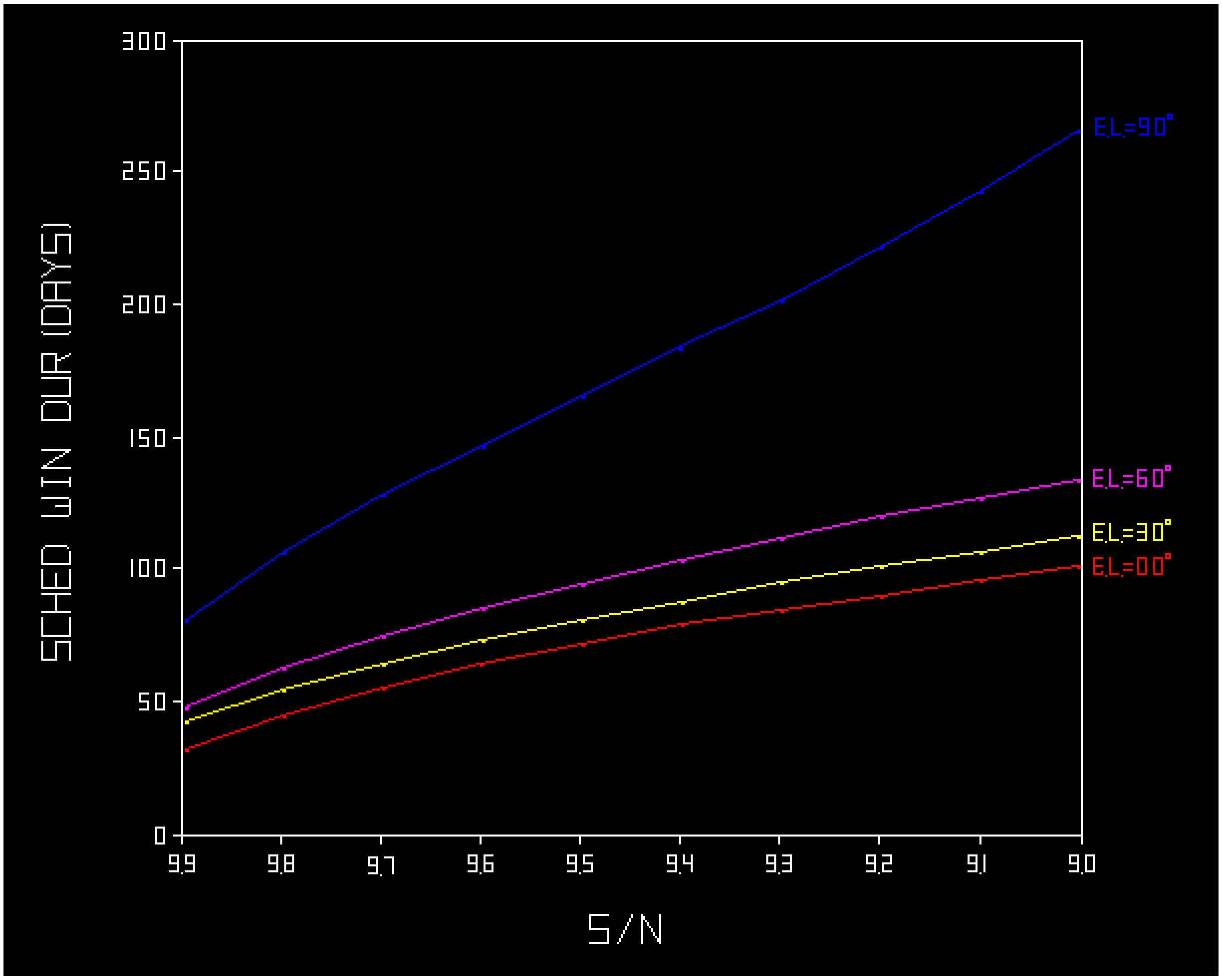
One is then led to one of the two alternatives in the second option, in which exposure times are treated as fixed by the scheduling system or time allocation committee. Considering the first alternative, if one were to allocate the maximum exposure time for every observation to achieve the desired S/N throughout the JWST orbit, how much potential science time would then be wasted by JWST?

Examination of the current sample report JMS Build 1.0 MET scheduling results, at ***http://www.stsci.edu/jwst/science/jms/reports/met_rqmts.out*,** shows that most observations scheduled much closer to their minimum exposure times than their maximum. For example, the total scheduled exposure time of the MET, across all observations, is 4673 days. If these observations were scheduled at their minimum exposure time slots, the total exposure time would be 4619 days. The maximum exposure times, however, total 4931 days. If each observation is scheduled using a worst case (most conservative) exposure time, then 4931 - 4673 = 258 days would be wasted (5.5% -- if SI goals are met, the relative loss is even greater). Considering the goal to have JWST performing science observations at least 70% of the time, these 258 days would translate into about a year (368 days) of calendar time, which is significant.

The second alternative should then be considered, in which exposure times are treated as fixed and the observation is scheduled using the observation's minimum exposure time. The planning system (executed before the scheduling system) could create scheduling constraint windows for each observation. When science scheduling occurs, the observation is then constrained to schedule inside its constraint window. Remaining inside this window ensures that the observation's S/N lies within some tolerance of the desired S/N while also minimizing exposure time.

Figure 1 below shows the constrained scheduling window durations for the highest score observation (most variable) in the ASWG DRM (see Table 1), as a function of S/N and target ecliptic latitude. The observation's ecliptic latitude was varied from 0 to 90 degrees ecliptic latitude, in steps of 30 degrees, with an optimal S/N of 10. Examining the red curve on the graph (ecliptic latitude = 0), one sees that if the observation is scheduled using its minimum exposure time, a scheduling window of 32 days exists if the observer is willing to accept a S/N of at least 9.9. If the observer accepts a S/N of at least 9.0, the scheduling window duration increases to 98 days. If the target is moved from the ecliptic to the north ecliptic pole (latitude = 90 deg, blue curve), a minimum S/N value of 9 results in a scheduling window duration of 258 days.

Figure 1
Schedule windows vs S/N criteria



Clearly, with only minor compromises in S/N (9.9 or 9.8 instead of 10), substantial scheduling windows exist even for observations with very high ratio scores. If no deviation in observation S/N was acceptable, and only S/N=10 was allowed, the scheduling window would have zero duration, and the observation would be schedulable at only the time of its minimum exposure duration. One could view the allowed deviation from optimal S/N as a S/N *tolerance*. Because each science program is unique, such a tolerance would have to be chosen carefully. Observations with very low ratio scores (1.001 for example) would have completely non-restrictive scheduling windows with even the most modest of S/N tolerance values.

One disadvantage of using scheduling windows is that it could cause over-subscription of certain time periods throughout the mission, if tight constraint windows overlap each other too closely. This would also make time-critical observations and timing-linked observations more difficult to schedule. Narrow scheduling constraint windows would arise particularly for observations with high ratio scores and rapidly varying exposure times, or for observations with very low S/N tolerances. An advantage of this approach is that an adequate (but perhaps not optimal) S/N would be achieved for all observations, and they would be scheduled at or near their most efficient times, thereby maximizing time available for other observations.

If a S/N of 10 is the desired minimum S/N, a value of 9 might be taken as an absolute minimum. Because exposure time is proportional to the square of the S/N, achieving S/N=9 requires only 81% of the exposure time required to achieve S/N=10. If the minimum exposure time did achieve S/N=10, only observations with ratio scores greater than 1.23 would be potentially problematic in not achieving S/N=9 using the minimum exposure time, if such observations were scheduled at times of greatest background contamination.

Based upon the ratio scores computed with the current ASWG DRM data, the only SI configs containing observations with scores greater than 1.23 are NIRCAM_sw, NIRCAM_lw, MIRI_spec_lores, and MIRI_cam. These four SI config modes can be summarized as the JWST broadband imaging modes and mid-infrared low resolution spectroscopy. Examining the JMS scheduling results, using the ASWG DRM observations, the percentage of total science time for each of these four SI configs is summarized below in Table 9. The total exposure time for the data in Table 9, over all SI Configs, is 4219.2 days.

Table 9

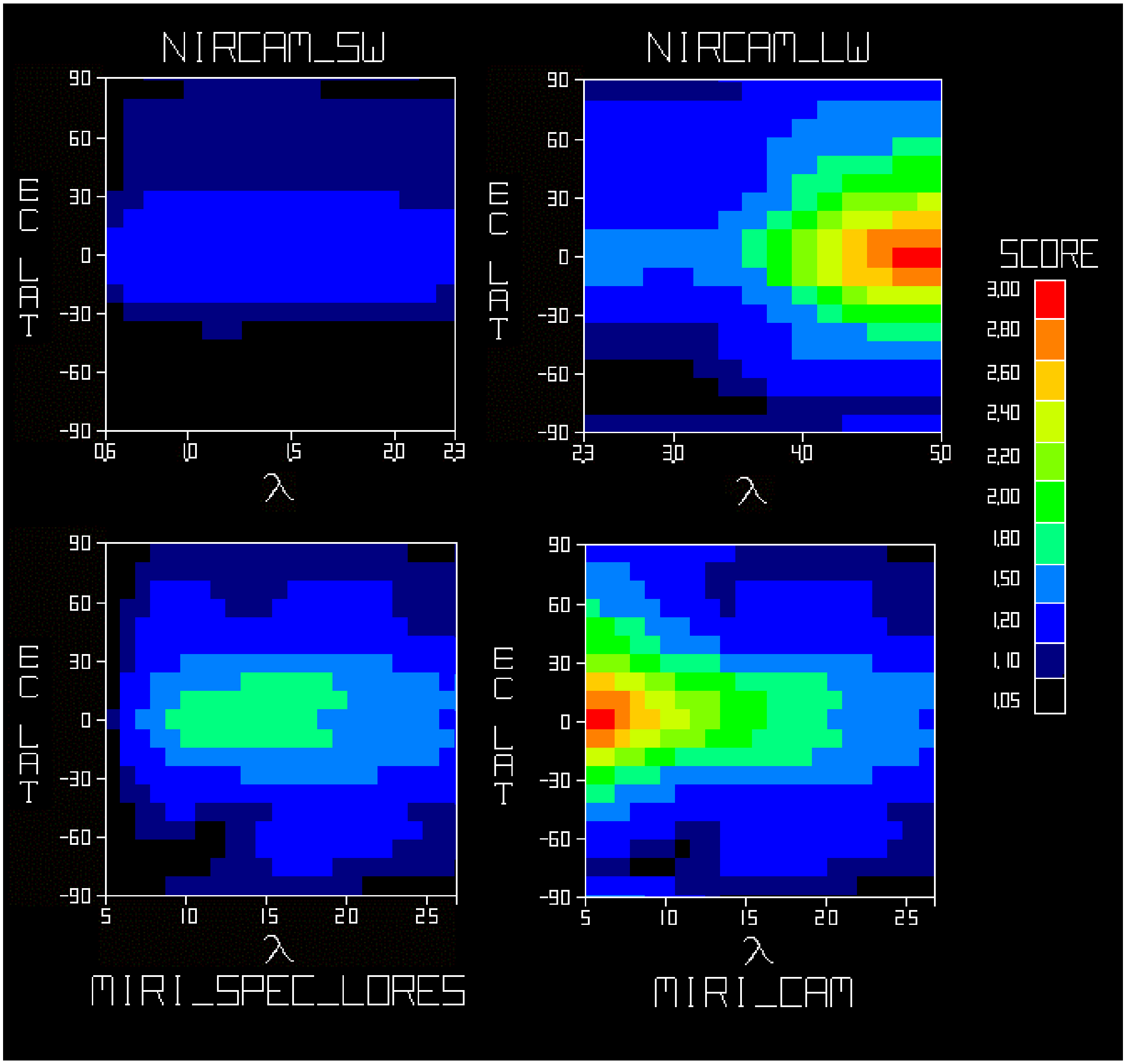
SI configurations with scores > 1.23

SI Configuration	**Total Exposure Time (Days)**	**Percentage of Total Exp Time**
MIRI_cam	39.2	1.05
MIRI_spec_lores	112.7	2.49
NIRCAM_sw	750.4	18.08
NIRCAM_lw	193.2	4.68

In total, these four SI configurations account for 26% of all exposure time.

Figure 2 provides a graphical summary of the maximum ratio scores for each of these four SI's, as a function of target ecliptic latitude and wavelength, using the input data outlined in Table 3 above (the augmented science program). Once again, the dependence of ratio on ecliptic latitude and wavelength is evident. The regions with the highest ratio scores on the plot show that for observational wavelengths of 4-12 microns and target latitudes within thirty degrees of the ecliptic, ratio scores are greatest.

Figure 2
Maximum ratio scores for most sensitive SI configurations



Conclusions

Exposure times for JWST science observations can vary significantly over the JWST spacecraft orbit, due to time-varying sources of background noise that affect the exposure time required to achieve a target S/N value. In particular, wide bandpass imagery, with the near and mid infrared cameras, have significant exposure time variation. Targets near the ecliptic plane are particularly affected, due to the greater variation of zodiacal light intensity and sunshield thermal emission near zero ecliptic latitude. For the sample calculations performed using the JMS 1.0 version of JMS, some ASWG DRM observations have scores as high as 3.0, where the score is the ratio of the max/min exposure time required to achieve S/N=10 over the JWST orbital period. For such observations, it is advantageous for the ground system for JWST to maximize the science efficiency despite the variable nature of the exposure time.

The JWST Operations Concept, at this time, does not envision that the Planning and Scheduling System will guarantee a fixed S/N for all observations (no matter when the observation is scheduled). Instead, the system will treat exposure times as fixed. In that case, scheduling constraint windows (or signal to noise merit functions) should be determined for each observation. Constraint windows would constrain the observation to be scheduled using the fixed exposure time while allowing the S/N to deviate from the optimum value by some policy-defined or observer-specified tolerance. Complications with this method include scheduling conflicts between observations with narrow and closely overlapping scheduling windows, and less ease in implementing additional scheduling features such as time-critical observations and timing linked observations. An advantage of this method is that observations are scheduled to optimize the overall science program efficiency and signal to noise.

Future work

When the new JWST sunshield model has been incorporated into the JMS, a more accurate determination of background intensity variability, with time, can be performed. Additional backgrounds to be considered include the mirror dust-scattered off-axis zodiacal light, starlight, sunshield thermal emission, scattered Moonlight and Earthlight.