

Background-Limited JWST Observations

Observers can assess whether their observations are sensitive to background levels using the JWST Exposure Time Calculator (ETC), and then apply the BACKGROUND LIMITED special requirement in APT to limit scheduling to when the background is relatively low. This special requirement affects the schedulability of observations.

Introduction

Parent article: [JWST Background Model](#)

See also: [How JWST Backgrounds Vary](#), [Backgrounds Tool](#)

Observers can assess the sensitivity of their proposed observations to the JWST background using the [JWST Exposure Time Calculator \(ETC\)](#). If the signal-to-noise ratio of a possible observation depends by more than 5% on the time-variable JWST background levels, then users should consider using the BACKGROUND LIMITED special requirement to request that the observation is scheduled when the background is relatively low. Because this special requirement affects the schedulability of observations, it may be necessary to make a trade-off between background levels and schedulability.

Many observations with JWST will be background limited, meaning that the noise will be dominated by the level of background emission, and not by photon noise from the target or detector read noise. The [JWST Background Model](#) article describes the origins of the background emission and its spectral shape, while [How JWST Backgrounds Vary](#) describes time variable aspects of the various background components.

There are multiple components of the JWST background; the one that varies seasonally is the zodiacal emission, due to the changing path length of solar system dust through which JWST must observe, and the temperature and temperature range of that dust. As a result, for mid-infrared wavelengths where the zodiacal emission peaks, a target may have a low background for only a fraction of all the days when the target is technically observable. For an overview of the backgrounds at a given sky position, consider using the [Backgrounds Tool](#) to visualize the time variability.

The BACKGROUND LIMITED special requirement in APT

See also: [JWST Astronomers Proposal Tool Overview](#), [APT Special Requirements](#)

The JWST ground system has a requirement to schedule the ensemble of background limited observations at times when the background is relatively low, within 10% of the minimum background for those targets. *Users are responsible* for identifying observations that are sensitive to the variable background level to the scheduling system by using the BACKGROUND LIMITED special requirement in APT.

It is often not obvious whether a particular observation needs to use the BACKGROUND LIMITED special requirement. Here are two non-intuitive examples:

1. MIRI imaging at 25.5 μm is background limited, but that background is dominated by emission from the primary mirrors (assumed to be time-independent), not by the time-variable zodiacal emission. As a result, all observable dates may have a background level <10% above the minimum background for a given RA, DEC, and wavelength.
2. While sufficiently deep NIRCcam imaging at 4.4 μm will be dominated by the time-variable zodiacal emission, for shallower observations the SNR will instead be dominated by detector effects. The integration time where that transition occurs is a function of wavelength, brightness, ecliptic latitude of the target, and the chosen filter.

Users should not try to guess whether the BACKGROUND LIMITED special requirement is needed for their observation. Users should calculate whether it is needed, using the method described below.

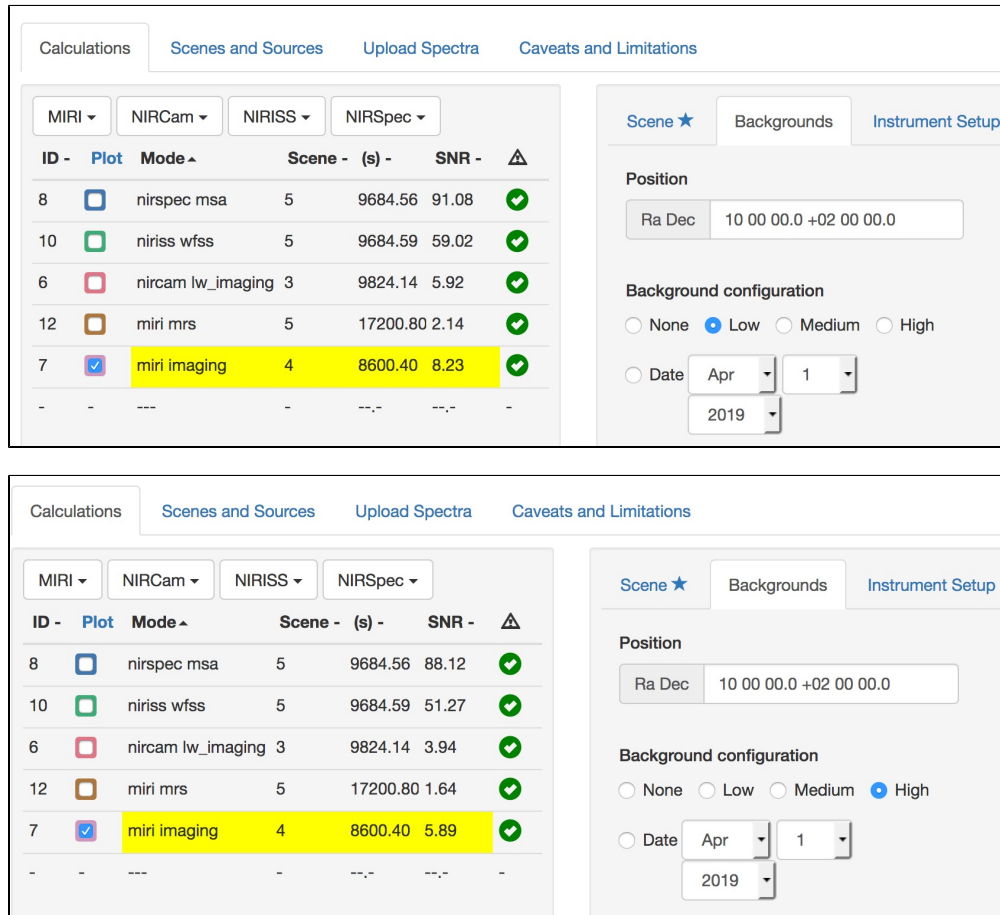
How to determine if an observation needs the BACKGROUND LIMITED special requirement in ETC

See also: [JWST Exposure Time Calculator Overview](#)

1. In the ETC **Backgrounds** tab, specify the RA and DEC of the target (see Figure 1).
2. Select **Low** background. Click **Calculate** (bottom right of the panel, not visible in Figure 1) and make note of the signal-to-noise ratio (SNR).
3. Select **High** background. Click **Calculate** and, again, note the SNR.
4. On your own, calculate the fractional change in the SNR, X, where
$$X = [\text{SNR}(\text{low bkg}) - \text{SNR}(\text{high bkg})] / \text{SNR}(\text{low bkg}) \quad (\text{Equation 1})$$
5. If $X > 0.05$, then the SNR of this observation depends by more than 5% on the variable background level. You *should use* the BACKGROUND LIMITED special requirement in APT, at the default value of <10% above the minimum background, [unless you have a good reason not to do it](#).
6. If $X < 0.05$, then your observation is not sensitive to the time-variable background. You *should not use* the BACKGROUND LIMITED special requirement in APT.

The threshold value of $X = 0.05$ was chosen for consistency with the ground system requirements. Proposers are encouraged to mention the results of this calculation in their technical justification, especially if they select the BACKGROUND LIMITED special requirement.

Figure 1. How to determine whether an observation needs the BACKGROUND LIMITED special requirement



Screenshots showing an ETC calculation to determine whether the BACKGROUND LIMITED special requirement should be used. In the upper panel, the Backgrounds tab of the ETC is open, the RA and DEC have been set (step 1), in this case for the COSMOS extragalactic deep field on the ecliptic plane. The dateless background has been set to Low (step 2). The resulting SNR column shows the signal-to-noise for the low background case (the 10th percentile lowest background for that target over all observable dates). In the lower panel, the SNR has been recalculated using the High background case (90th percentile highest background for that target over all observable dates).

Figure 1 shows 5 worked examples of this method. For the examples in Figure 1, calculation #8 (NIRSpec MSA) has $X = 0.03$, so the BACKGROUND LIMITED special requirement should not be used. The other observations have $X > 0.05$, and therefore should use the BACKGROUND LIMITED special requirement.

How to apply the BACKGROUND LIMITED special requirement in APT

The BACKGROUND LIMITED special requirement is available in APT 25.4, released in November 2017.

The BACKGROUND LIMITED special requirement has a variable: the maximum permitted background for the RA, DEC, and wavelength of an observation. The default value is <10% above the minimum background for that RA, DEC, and wavelength. Higher values may be chosen to increase schedulability when there are competing constraints.

The [APT Special Requirements](#) page provides guidance on how to use APT to apply the BACKGROUND LIMITED special requirement to an observation.

The BACKGROUND LIMITED special requirement affects schedulability

Since the BACKGROUND LIMITED special requirement limits the schedulability of an observation to times when the background is relatively low, it is effectively a scheduling constraint. For targets at low ecliptic latitude, the BACKGROUND LIMITED special requirement may restrict the schedulable window to 10–20 days per year. Thus, users should apply the BACKGROUND LIMITED special requirement only if scientifically justified.

However, applying *both* the BACKGROUND LIMITED special requirement and another scheduling requirement (for example, one of the aperture position angle special requirements) may make an observation impossible to schedule. Users will have to decide which constraints are more important to the science goals, and relax constraints until the observation becomes schedulable. Within the BACKGROUND LIMITED special requirement, the user may select an acceptable background level higher than the default of 10% above the minimum to improve the schedulability.

Best practices

1. Users should assess whether the signal-to-noise estimates of their observations are sensitive to the level of the time-variable background, using the ETC method described above. If yes, then the BACKGROUND LIMITED special requirement should be added to the observation, to request scheduling when the background is relatively low.
2. *Proposers should not use the BACKGROUND LIMITED special requirement when it is not justified.* Doing so decreases schedulability but only negligibly improves the signal-to-noise ratio for cases where the noise is dominated by factors other than the background (for example, target shot noise or detector read noise).
3. Users should exercise caution when adding any additional scheduling requirements to an observation that has the BACKGROUND LIMITED special requirement. This is especially true for targets at low ecliptic latitude. Multiple scheduling requirements may make the observation impossible to schedule.
4. Users should be aware that a constraint on the aperture position angle can be incompatible with the BACKGROUND LIMITED special requirement since both are effectively scheduling constraints.

