

# The effects of 'on' failures in a MEMS array for the NGST NIRSpec

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V2.2, February 2002 (original V1.0, March 2001)

## ABSTRACT

Any practical MEMS array used to define the input slits for the NGST multi-object spectrograph will have a fraction of elements (facets) which are stuck in either the 'on' or the 'off' position. 'Off' facets in a micro-shutter array will have little effect on performance other than a restriction on object selection. Permanently 'on' facets, however, allow extra unwanted light into the spectrograph which can interfere with the detection of selected sources and reduce the efficiency of the spectrograph. We show that, with the current design parameters and background estimates, an 'acceptable' fraction of 'on' facets is around 0.01% — or just a few hundred facets in a  $2k \times 2k$  MEMS array.

## 1. Introduction

The aim of this report is to establish a useful criterion for determining the maximum number of 'on' failures acceptable in the MEMS array which defines the input slits of the NGST near-infrared multi-object spectrograph, NIRSpec. We define an 'on-failure' to exist when a facet (an individual MEMS element) remains 'on' when commanded to be 'off'.

Such a faulty facet sends extra, unwanted light into the spectrograph, increasing the background noise over a specific region of the detector, i.e., the position of the corresponding spectrum.

The key questions to be answered are:

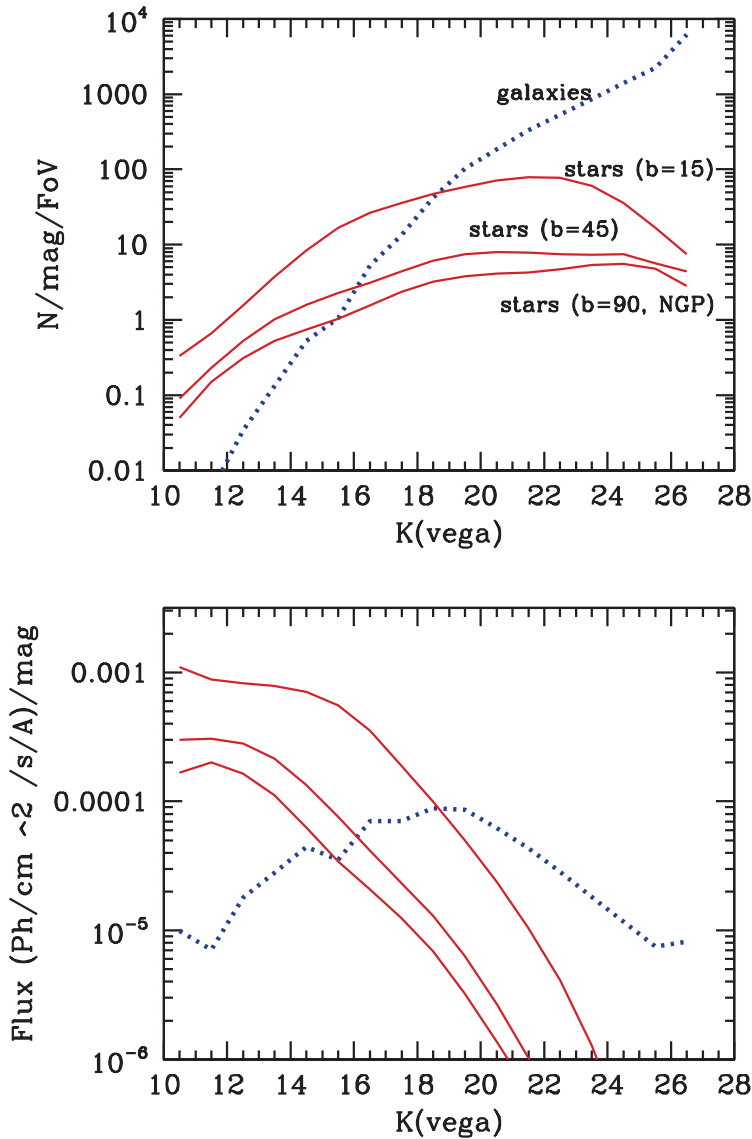
- What is the statistical expectation for the light intensity collected by a single faulty facet?
- How does the resulting extra noise affect the performance of NIRSpec?

From this, we can decide on an acceptable number of facet failures.

## 2. Relative importance of zodiacal, galaxy and star light

A facet will always collect zodiacal light, the total amount depending on the field of view of the facet and the ecliptic coordinates of the pointing position on the sky. In addition, there is a finite probability that an astronomical object, a star or galaxy, will fall on the facet.

In Figure 1 (top) the expected number of galaxies and stars is presented for three Galactic latitudes. Figure 1 (bottom) gives their relative flux contributions per unit magnitude. The integrated flux over the complete FoV (assumed to be  $12 \text{ arcmin}^2$ ) of the three compo-



**Figure 1:** top – the number of galaxies and stars (for three Galactic latitudes) in a 12 arcmin<sup>2</sup> FoV per unit magnitude as a function of the K magnitude (Vega system). Bottom – the flux of the total number of galaxies and stars per unit magnitude, as a function of the K magnitude.

nents (i.e., zodi, stars, galaxies) is presented in Table 1.

On average, the effects of foreground galaxies are negligible here, in agreement with previous results by M. Stiavelli (priv. comm.). Even if the number of the faintest galaxies in the field of view is relatively large ( $\sim 10^3$ ), it is still small compared with the number of facets ( $\sim 10^6$ ). In addition the galaxies which contribute more to the total flux are in the range  $18 < K < 20$  mag, and they have even lower densities.

Regarding the stars, the major contribution to the flux is due to the brightest ones. However, their densities are so low that it will very likely be possible to avoid the coincidence of a bright star and a faulty facet for most realistic observational scenarios.

In summary, a faulty facet will collect predominantly only zodiacal light.

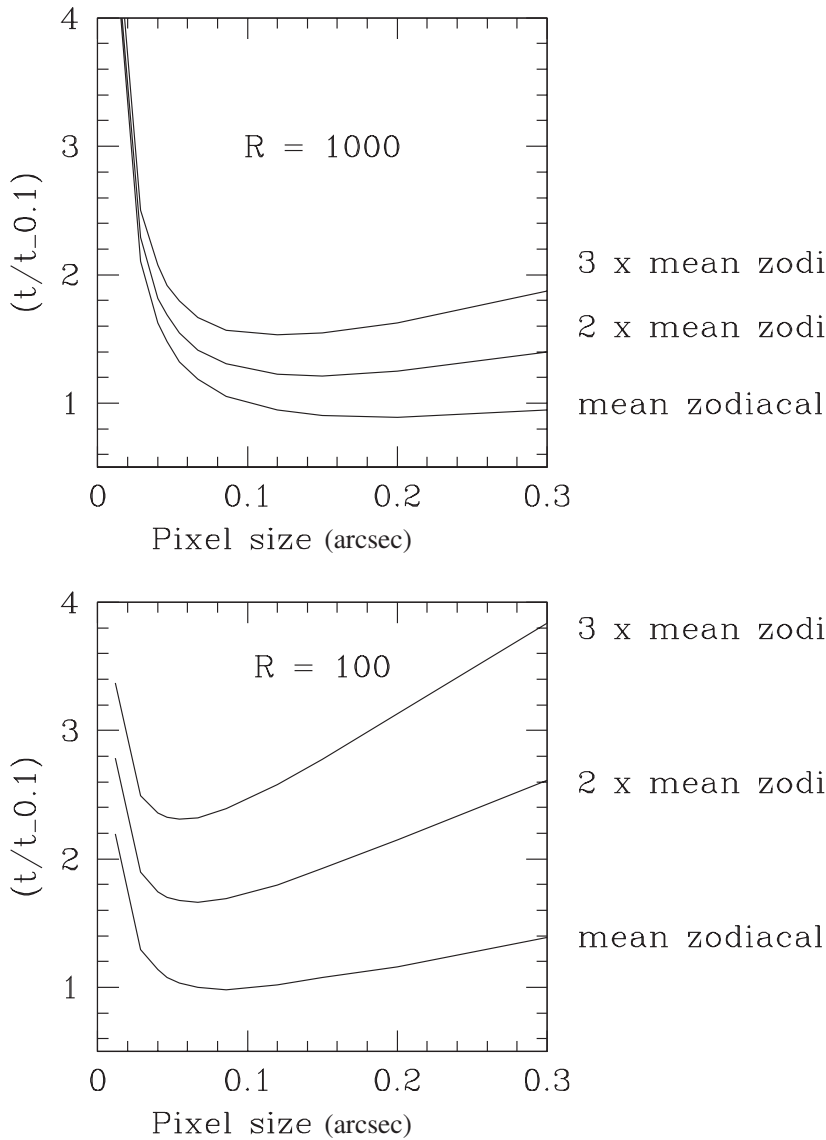
### 3. Effects on the NIRSpec performance

Figure 2 shows the effects on the exposure time when the zodiacal background is increased by a factors of 2 and 3, for  $R = 100$  and  $R = 1000$  (long exposures of faint objects are assumed). The effects of 'on' failures' (i.e., increase of zodiacal background) are more relevant for the R100 mode.

Origin	Integrated flux (photon/s/Å)		
	low	average	high
zodi (1)	3354	6250	9613
stars (2)	83	262	1492
galaxies (3)	191	191	191

**Table 1:** a FoV of 12 arcmin<sup>2</sup>, a 6.5m telescope and  $\lambda = 2\mu\text{m}$  are assumed. (1) Low, average, high depending on the ecliptic latitude (Giavalisco, 2001, priv. comm.). (2) Based in predictions with SKY model (Cohen et al. 2001, priv. comm.), for  $b = 90^\circ$  (low),  $45^\circ$  (average), and  $15^\circ$  (high).  $l = 90^\circ$  in the three cases. (3) Based in Bershadsky et al. 1998, (AJ, 505, 50) and HDF data (Thompson et al. 1999, AJ, 117,17).

Effects of overlapping / background



**Figure 2:** Exposure time required (normalized to the one for a scale of 0.1 arcsec/pixel, mean background) for one, two, and three times the mean background for  $R = 1000$  and  $R = 100$ .

#### **4. Proposed requirement on the number of 'on' failures**

First we will consider the mode  $R=100$  + Multiplexing capability, which suffers the strictest requirement for the 'ON failures'.

If a typical slit is two facets wide (in the dispersion direction), a faulty facet will increase the zodi background by a factor 1.5. However, taking into account the wavelength/positional dependence of the zodiacal light, let us consider conservatively a factor 2–3. This implies that, for a given S/N, exposure times must be increased by a factor 2 (see Figure 2).

Therefore, under the present assumptions, the effect of a faulty facet can be seen as equivalent as a reduction of 50% in the sensitivity of the corresponding pixels at the detector used for the detection of the spectrum at this position.

If 'on' failures are not to result in a performance reduced by more than 10%, then fewer than 20% of the detector pixels can be affected by the extra zodiacal noise.

The number of acceptable failures that fulfills this criterion is obviously design dependent. Assuming that the spectrum of a single facet uses 2000 detector pixels, only 0.01% of 'on' failures is acceptable (i.e., 400 facets in a  $2k \times 2K$  MEMS array).

If a high multiplexing gain is only needed for the  $R1000$  mode, this requirement can be relaxed. In fact, for  $R = 1000$ , an increase by a factor 2–3 in the background implies exposure times longer by a factor 1.4 (assuming a scale at the detector of  $\sim 0.1$  arcsec/pixel). This is essentially equivalent to the affected detector pixels affected losing 30% of their original sensitivity. Thus, if we want to preserve the whole detector above 90%, no more than about 35% of the detector pixels can be affected by this extra background. With the same hypothesis about the design as above, this implies that only  $\sim 0.0175\%$  of failures are acceptable (i.e., 700 facets in a  $2k \times 2K$  MEMS array).