# Zeropoints

For this work, the calculated zeropoint for a given filter is defined as the magnitude that will produce a signal of 1 ADU/sec within a given aperture and filter on the detector. We use an infinite aperture for our photometry, as final encircled energy curves for NIRCam are not yet available. In order to calculate the zeropoint associated with a given filter, we begin with the measured PCE curve. This curve includes the effects of the JWST Optical Telescope Element (OTE), NIRCam mirrors, dichroic beam splitter, filter, detector quantum efficiency (QE), particulates and contamination on these surfaces. (Hilbert & Stansberry, 2017)

To calculate the zeropoints for a given filter, we follow the steps below. The associated commands used within synphot are given in Appendix A.

For a given filter, we read in the PCE curve, and also set the telescope primary mirror area to 25.326 m2 to match that of JWST. (Lightsey et. al 2012) We first calculate PHOTFLAM and PHOTFNU. Just as the magnitude zeropoint for a given photometric system and filter represents the magnitude of a source which produces 1 ADU/sec on the detector, we also wish to find the flux densities (per unit wavelength and per unit frequency) which produce 1ADU/sec on the detector. For clarity, we follow the HST and JWST convention and refer to these flux density-based zeropoint values as PHOTFLAM and PHOTFNU.

We calculate the PHOTFLAM value for the filter using synphot’s unit\_response function. This is the flux density per unit wavelength () of a source that produces a response of one photon per second in the bandpass. Under the assumption that one incident photon leads to one collected electron, which is true for NIRCam’s detectors and the wavelengths to which they are sensitive (REFERENCE HERE), PHOTFLAM then gives the flux density of a source which produces a signal of one electron per second. However, our final output must translate from one ADU per second. PHOTFLAM therefore must be reduced by a factor equal to the gain of NIRCam’s detectors. The easiest way to accomplish this within synphot’s framework is to reduce the PCE curve by a factor equal to the gain. Gain values used in these calculations are shown in table XX.

|  |  |
| --- | --- |
| **Channel / Module** | **Gain (e-/ADU)** |
| Shortwave / A | 2.071 |
| Shortwave / B | 2.027 |
| Longwave / A | 1.845 |
| Longwave / B | 1.798 |

Table XX: Gain values used in the calculation of the zeropoints.

The equation used to calculate the unit response is shown in equation 5, where *h* is Planck’s constant, *c* is the speed of light, *A* is the telescope mirror area, *P*() is the PCE curve, and  are wavelength values that accompany the PCE curve.

(5)

We also calculate the pivot wavelength of the bandpass at this point. The pivot wavelength is a source-independent measure of the characteristic wavelength of a bandpass. See Tokunaga & Vacca (2005) for details. The equation used to calculate the pivot wavelength is shown in equation XX.

(6)

Using the pivot wavelength, we next convert the PHOTFLAM value to PHOTFNU, which represents the flux density per unit frequency (). Equation XX shows this conversion.

(6)

Returning to the PHOTFLAM value, we next calculate the STMAG zeropoint using equation 3 with PHOTFLAM as the input . In order to calculate the ABMAG zeropoint, we use equation XX, which uses the STMAG zeropoint and pivot wavelength as inputs. Here, is the ABMAG zeropoint, is the STMAG zeropoint, and is the pivot wavelength.

(6)

Finally, we calculate the VEGAMAG zeropoint. For this calculation, we use the Vega spectrum distributed with synphot. This spectrum, shown in figure XX gives the flux density of Vega in units of (). With this curve, the telescope collecting area, and the PCE curve, we calculate the VEGAMAG zeropoint using equation 8, where is the flux from Vega intercepted by the telescope primary mirror.

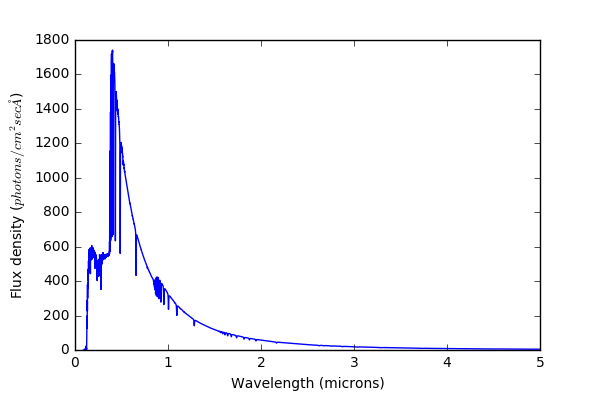


Figure XX: Vega spectrum packaged with synphot, and used for VEGAMAG zeropoint calculations.

(8)

Tables 1 and 2 list the zeropoints for all filters in the VEGAMAG, ABMAG, and STMAG systems, as well as the corresponding PHOTFLAM, PHOTFNU, and pivot wavelength values for the filters in both NIRCam modules. Uncertainties were not reported for the PCE curves with which these calculations were made. However the PCE curves do include modeled contamination contributions from non-volatile sources, as well as water. This modeling necessarily introduces uncertainties into the final PCE curves. In addition, uncertainties in the gain values used to convert from units of electrons per second to ADU per second will contribute to the uncertainty of the zeropoints. As these are the same PCE curves that are used in the ETC (REFERENCE), which is stated as being accurate to 10%, we adopt the same uncertainties on the results of these calculations.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Filter** | **Module** | **VEGAMAG** | **ABMAG** | **STMAG** | **FLAM** | **FNU** | **pivot (microns)** |
| F070W | A | 25.9772 | 26.2713 | 26.8198 | 6.7932e-20 | 1.1258e-30 | 0.7049 |
| F090W | A | 26.1481 | 26.6667 | 27.7541 | 2.8732e-20 | 7.8221e-31 | 0.9034 |
| F115W | A | 26.0214 | 26.8046 | 28.4234 | 1.5511e-20 | 6.8896e-31 | 1.1539 |
| F140M | A | 25.0673 | 26.1774 | 28.2252 | 1.8618e-20 | 1.2276e-30 | 1.4060 |
| F150W2 | A | 27.1842 | 28.4170 | 30.8240 | 1.6999e-21 | 1.5603e-31 | 1.6589 |
| F150W | A | 25.8330 | 27.0440 | 29.2325 | 7.3621e-21 | 5.5262e-31 | 1.5001 |
| F162M | A | 24.8751 | 26.2334 | 28.5991 | 1.3194e-20 | 1.1659e-30 | 1.6276 |
| F164N | A | 22.4867 | 23.8848 | 26.2732 | 1.1239e-19 | 1.0141e-29 | 1.6447 |
| F182M | A | 25.0052 | 26.5696 | 29.2078 | 7.5317e-21 | 8.5545e-31 | 1.8453 |
| F187N | A | 22.3569 | 23.9857 | 26.6572 | 7.8907e-20 | 9.2410e-30 | 1.8738 |
| F200W | A | 25.5472 | 27.2296 | 30.0304 | 3.5307e-21 | 4.6578e-31 | 1.9887 |
| F210M | A | 24.5091 | 26.2954 | 29.2096 | 7.5193e-21 | 1.1012e-30 | 2.0953 |
| F212N | A | 22.2830 | 24.0911 | 27.0326 | 5.5840e-20 | 8.3865e-30 | 2.1219 |
| F250M | A | 23.7836 | 25.9067 | 29.2077 | 7.5323e-21 | 1.5753e-30 | 2.5039 |
| F277W | A | 25.0110 | 27.2977 | 30.8023 | 1.7342e-21 | 4.3745e-31 | 2.7500 |
| F300M | A | 23.8323 | 26.2916 | 29.9769 | 3.7088e-21 | 1.1050e-30 | 2.9887 |
| F322W2 | A | 25.5520 | 28.0916 | 31.9460 | 6.0478e-22 | 2.1056e-31 | 3.2307 |
| F323N | A | 21.0475 | 23.6598 | 27.5180 | 3.5711e-20 | 1.2477e-29 | 3.2365 |
| F335M | A | 23.7745 | 26.4596 | 30.3978 | 2.5170e-21 | 9.4659e-31 | 3.3578 |
| F356W | A | 24.5649 | 27.3565 | 31.4242 | 9.7796e-22 | 4.1441e-31 | 3.5642 |
| F360M | A | 23.6649 | 26.5030 | 30.6073 | 2.0753e-21 | 9.0952e-31 | 3.6247 |
| F405N | A | 20.7460 | 23.8340 | 28.1795 | 1.9417e-20 | 1.0627e-29 | 4.0506 |
| F410M | A | 23.4621 | 26.5354 | 30.8923 | 1.5961e-21 | 8.8279e-31 | 4.0720 |
| F430M | A | 22.5456 | 25.7226 | 30.1888 | 3.0512e-21 | 1.8664e-30 | 4.2822 |
| F444W | A | 24.1603 | 27.3505 | 31.8682 | 6.4969e-22 | 4.1668e-31 | 4.3849 |
| F460M | A | 22.1374 | 25.4787 | 30.1168 | 3.2603e-21 | 2.3363e-30 | 4.6350 |
| F466N | A | 20.2299 | 23.6117 | 28.2588 | 1.8050e-20 | 1.3042e-29 | 4.6543 |
| F470N | A | 20.0741 | 23.4446 | 28.1168 | 2.0572e-20 | 1.5212e-29 | 4.7083 |
| F480M | A | 22.0873 | 25.4916 | 30.2030 | 3.0116e-21 | 2.3088e-30 | 4.7941 |

**Table 1: Table of zeropoints for the NIRCam module A filters. Units of PHOTFLAM are erg cm-2 sec-1 Å-1 , and units of PHOTFNU are erg cm-2 sec-1  Hz-1.**

These zeropoints can be used to translate NIRCam instrumental magnitudes into VEGAMAG, ABMAG, or STMAG magnitudes using equation 9, where *s* is the measured signal of the source, *sys* is the photometric system of interest, is the source's magnitude in that system, and is the zeropoint for the filter and photometric system from table 1 or 2.

(9)

Additionally, the values of PHOTFLAM and PHOTFNU from the tables allow the translation between magnitudes and absolute flux densities, as shown in equations 10 and 11. Note that when working with instrumental magnitudes, the zeropoint is 0 by definition.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Filter** | **Module** | **VEGAMAG** | **ABMAG** | **STMAG** | **FLAM** | **FNU** | **pivot** |
| F070W | B | 25.9806 | 26.2733 | 26.8183 | 6.8025e-20 | 1.1238e-30 | 0.7038 |
| F090W | B | 26.2010 | 26.7177 | 27.7997 | 2.7549e-20 | 7.4638e-31 | 0.9012 |
| F115W | B | 26.0279 | 26.8118 | 28.4320 | 1.5389e-20 | 6.8438e-31 | 1.1547 |
| F140M | B | 25.0977 | 26.2063 | 28.2522 | 1.8160e-20 | 1.1953e-30 | 1.4048 |
| F150W2 | B | 27.2060 | 28.4386 | 30.8454 | 1.6666e-21 | 1.5296e-31 | 1.6588 |
| F150W | B | 25.8517 | 27.0641 | 29.2545 | 7.2143e-21 | 5.4246e-31 | 1.5014 |
| F162M | B | 24.9006 | 26.2584 | 28.6231 | 1.2906e-20 | 1.1394e-30 | 1.6269 |
| F164N | B | 22.5142 | 23.9123 | 26.3003 | 1.0962e-19 | 9.8880e-30 | 1.6445 |
| F182M | B | 25.0281 | 26.5922 | 29.2302 | 7.3778e-21 | 8.3777e-31 | 1.8451 |
| F187N | B | 22.3738 | 24.0057 | 26.6774 | 7.7450e-20 | 9.0730e-30 | 1.8740 |
| F200W | B | 25.5630 | 27.2452 | 30.0458 | 3.4809e-21 | 4.5915e-31 | 1.9886 |
| F210M | B | 24.5147 | 26.3016 | 29.2161 | 7.4745e-21 | 1.0949e-30 | 2.0956 |
| F212N | B | 22.2812 | 24.0879 | 27.0280 | 5.6081e-20 | 8.4111e-30 | 2.1204 |
| F250M | B | 23.7108 | 25.8332 | 29.1334 | 8.0658e-21 | 1.6855e-30 | 2.5030 |
| F277W | B | 24.8889 | 27.1944 | 30.7188 | 1.8728e-21 | 4.8113e-31 | 2.7752 |
| F300M | B | 23.7865 | 26.2462 | 29.9324 | 3.8641e-21 | 1.1522e-30 | 2.9898 |
| F322W2 | B | 25.5551 | 28.0941 | 31.9502 | 6.0244e-22 | 2.1008e-31 | 3.2333 |
| F323N | B | 21.0727 | 23.6856 | 27.5444 | 3.4852e-20 | 1.2184e-29 | 3.2374 |
| F335M | B | 23.6981 | 26.3895 | 30.3336 | 2.6703e-21 | 1.0098e-30 | 3.3670 |
| F356W | B | 24.5979 | 27.3927 | 31.4654 | 9.4153e-22 | 4.0083e-31 | 3.5725 |
| F360M | B | 23.6651 | 26.5029 | 30.6066 | 2.0767e-21 | 9.0960e-31 | 3.6237 |
| F405N | B | 20.9103 | 23.9979 | 28.3445 | 1.6680e-20 | 9.1380e-30 | 4.0527 |
| F410M | B | 23.4859 | 26.5697 | 30.9375 | 1.5311e-21 | 8.5534e-31 | 4.0924 |
| F430M | B | 22.6774 | 25.8542 | 30.3194 | 2.7054e-21 | 1.6533e-30 | 4.2803 |
| F444W | B | 24.3658 | 27.5101 | 32.0456 | 5.5176e-22 | 3.5975e-31 | 4.4212 |
| F460M | B | 22.2519 | 25.5891 | 30.2224 | 2.9582e-21 | 2.1104e-30 | 4.6247 |
| F466N | B | 20.3527 | 23.7354 | 28.3826 | 1.6105e-20 | 1.1638e-29 | 4.6545 |
| F470N | B | 20.2270 | 23.5978 | 28.2695 | 1.7873e-20 | 1.3210e-29 | 4.7072 |
| F480M | B | 22.6183 | 25.9498 | 30.6791 | 1.9424e-21 | 1.5138e-30 | 4.8337 |

**Table 2: Table of zeropoints for the NIRCam module B filters. Units of PHOTFLAM are erg cm-2 sec-1 Å-1 , and units of PHOTFNU are erg cm-2 sec-1  Hz-1.**