11916 - IR Intrapixel Sensitivity

Cycle: 17, Proposal Category: CAL/WFC3

(Availability Mode: RESTRICTED)

INVESTIGATORS

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VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) OMEGA-CEN-IPSV	WFC3/IR	1	01-Apr-2009 21:01:02.0	yes
02	(1) OMEGA-CEN-IPSV	WFC3/IR	1	01-Apr-2009 21:01:10.0	yes

2 Total Orbits Used

ABSTRACT

In order to characterize the periodic intrapixel sensitivity variation (IPSV) of the WFC3 IR array, we will analyze full-frame IR observations of a star field (in the Omega Centauri globular cluster) in three bandpasses (F110W, F160W, and F098M) dithered on an NxN grid. The measurements will be used to quantify systematic trends in aperture photometry of stars with pixel phase, defined as (x mod 1, y mod 1), where (x,y) is the center of the stellar image at subpixel precision. Grid sizes of N=2 and N=3 are justifed in Additional Comments of Proposal Description.

OBSERVING DESCRIPTION

Two filters in visit 1, F110W and F160W, in full-frame mode, each with a 2x2 subpixel dither box, on a star field suitable for precision aperture photometry of hundreds of stars per amplifier. One short-wavelength filter (F098M) in visit 2 on a 3x3 subpixel grid.

Filters: We select the first two filters (F110W and F160W) for three reasons. 1) C17 GO programs use these two filters often and also so do two programs for which the highest precision of stellar photometry is critical (Program 11677, 47 Tuc; Program 11570, distant SNe). 2) The effective IPSV depends on width of the point spread function (PSF) in pixel units, so two disparate wavelengths are desirable, since the FWHM of the PSF will scale with wavelength. 3) Lauer selected these same two filters for his NICMOS IPSV study. The ~50% narrower bandpass of F098M will produce a sharper PSF, yielding the best opportunity to measure (or set upper limits on) the IPSV.

Dithers: We use a 2x2 or 3x3 grid for the dither pattern with 1/2 or 1/3 pixel pixel shifts in X and Y on the grid, based upon the NxN optimal spacing according to Lauer (1999, PASP 111, 1434) and his statement that N>3 is "highly cumbersome." [More details in Additional Comments.] From the IHB Sect B.3 at field center, the pixel scale is 0.135 arc in X and 0.121 in Y; from Figure B.4 the pixel area varies by +- 4.1%, and the distortion is not very much over the inner 512x512 pixels of the WFC3 IR detector (Figure B.3).

Sample-Sequence: With 8 (for 2x2 grid) or 9 (for 3x3) exposures of equal length per orbit, we will choose exposure times near 5 minutes to take advantage of the full visibility window of ~52 minutes. We use the SPARS25 sample sequence so that the data transfer matches the data acquisition.

Target selection: The star field should be dense enough to produce many hundred stars per WFC3 IR FOV with a S/N > 100 in aperture photometry, but not so dense that aperture photometry will be compromised by blending of stars. Some blending is ok, because we do not need accurate photometry, but instead need precise (relative) photometry of a star compared to dithered versions of itself. For example, if a star has an unresolved companion 0.1 pixel separated from and 0.1 as bright as the star, the aperture photometry (e.g. for an HR diagram) will be inaccurate at 10%, but the centroid will only be inaccurate at 1% of a pixel, so we expect the effect of stellar blending on IPSV estimates to be of "second order." The OMEGA CEN target in this program is selected such that the density of stars is not too high, i.e. a lower-density field of view than those selected for geometric distortion or L-flat. [More justification is given in the comments to the TARGET definition.]

CALIBRATION JUSTIFICATION

Ground tests of WFC3 IR (TV3) show no measureable IPSV at a level of ~1%, with ~100 observations of a single well-exposed artificial star drifted across ~20 pixels in 0.2 pixel steps, first in X and then in Y (ISR WFC3 2008-29, currently in peer review). A potential limitation of that work was uncalibrated variability of the artificial star; typical stars will be more constant than a lamp. Approximately, 100 pixels per star typically gives good aperture photometry, so with 1M pixels on WFC3 IR, we may expect not more than 10,000 stars per FOV that meet our needs. To be conservative, we estimate that we will use only 1/4 of the stars in the full-frame FOV due to stellar crowding or because we might see different IPSV on each amplifier. With ~2500 stars and 9 dithers compared to TV3 experiment with 1 star and 200 dithers, we expect ~100 times more stellar measurements on orbit in this program as the TV3 experiment, so we may expect ~sqrt(100) = 10x greater precision, or 0.1% measurement uncertainty of the IPSV. If we cannot measure IPSV in this program with multiple filters and dithers on a globular cluster, then we expect that IPSV is not relevant for generic observations with WFC3 IR.

ADDITIONAL COMMENTS

Analysis of IPSV will be as per Lauer (1999) for WFPC2, which used a star cluster. (Lauer's NICMOS analysis used 98 pointings of a single star in the HDFS, but that does not benefit from the multiplexing advantage of a star cluster.)

Anderson & King (2000, PASP 112, 1360) emphasize the need for subpixel dithering to remove the degeneracy between IPSV and stellar locations. In justification of the value of N for the NxN subpixel dither pattern, Lauer (1999) states that "N should be large enough such that in the equation P' = P(x,y) * R(x,y), P' is fully sampled (N=3 for WFCP2 [with F555W] is sufficient)." As the ISPV function R(x,y) can only blur the optical PSF P(x,y), it suffices to have N large enough that P itself is fully sampled. As HST is diffraction limited, and scaling from WFCP2 pixels of 0.1" for which N=3 suffices at 555 nm, then N=2 will suffice at 1060 nm and longer for WFC3 IR pixels (0.128" being the average of the pixel scales in X and Y). On this basis, we select N=2 for F110W and F160W, but choose N=3 for F098M, where we hope to have the most-easily detected IPSV because of the smaller PSF.

Logically, it will make sense to acquire both visits near enough in time that the analyst can examine both data sets simultaneously - this is only to save the human time of the analyst by concentrating on the analysis only once. It also makes sense to complete this analysis prior to, or in

conjunction with, the L-flat analysis (C17 cal program 11928), because uncalibrated IPSV could be a noise term for the L flat. The converse is not true - the L flat is not necessary to determine the IPSV, because each star's individual flux measurements is normalized to the average of the four to nine measurements for that particular star.

The "center" in the definition of pixel phase is not simply the centroid of the star (Anderson & King, 2000).

Visit

Proposal 11916, Visit 01 Thu Apr 02 01:01:14 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: (none)

Comments: F110W and F160W, 2x2 dither each

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=BOX	Coordinate Frame=POS-TARG		(1), (2)
	Purpose=DITHER	Pattern Orientation=0		
	Number Of Points=4	Angle Between Sides=90		
	Point Spacing=0.0675000	Center Pattern=false		
	Line Spacing=0.0605000			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	OMEGA-CEN-IPSV	RA: 13 25 37.6000 (201.4066667d)		V=16.8	Reference Frame: ICRS
		Dec: -47 35 34.30 (-47.59286d)			
		Equinox: J2000			

Comments: The analysis of WFC3 IR imagery will benefit from prior detailed knowledge (e.g. ACS, WFPC2, or WFC3 UVIS imagery) of the positions and brightnesses of stars obtained at higher angular resolution than WFC3 IR. In a simple analysis, stars can be selected as unblended from the ACS imagery, and only those stars used for the IPSV analysis of WFC3 IR imagery. In a more complex analysis, the ACS multi-color data could be used to synthesize models of the WFC3 IR imagery to be used in a Fourier analysis (see Lauer), but perhaps the simpler culling analysis will suffice.

In Lauer's WFPC2 analysis, the pixels were 0.10 arcsec wide, the step size was 0.25 pixel in a 4x5 grid, which he indicates was more than needed, of fields ~13 and ~15 arcmin from the core of Omega Cen. As the pixels for WFC3 IR are 1.64 times larger in area than WFPC2, we should select a field with a stellar density 1.64 times less dense than the one used by Lauer, in order to match the stellar density to the one Lauer had used. We consider a factor of 1.64 not too large, so we stay at ~13 arcmin from the Omega Cen core in order to have a very precise high-resolution WFCP2+ACS image as our template.

We select the field (here called target OMEGA-CEN-IPSV) observed very many times by WFPC2 PC and ACS that is 13 arcmin SW of the center of the Omega Cen cluster. The following justifications convince us that in the selected field, we'll obtain more than 100 well-exposed (S/N > 100) stars per amplifier, as desired.

Comparison to TV3 test for IPSV: In ISR WFC3 2008-29, McCullough collects 188,000 e- in an aperture around an artificial star. The WFC3 ETC predicts that the same number of counts will be collected in 303 seconds (SPARS25; NSAMP=13) in F110W or F160W on a G0 V star with Johnson V=19.8 or V=18.8 respectively.

First comparison: The star counts will start to go up rapidly around the turn off point of a globular cluster. The turn off of Omega Cen is V=18.3 and its distance modulus is 13.2. The WFC3 ETC predicts a G0 V star with Johnson V=18.3 will exceed saturation in 303 sec (SPARS25; NSAMP=13) by a factor of 4.2 and 1.4 in F110W and F160W. Some saturation would be ok, because we can use lower NSAMP to get the unsaturated values, and we can choose fainter and more numerous stars as needed to avoid saturation.

Second comparison: Pulone et al 1998 studied a region 7' away from the center of Omega Cen with NIC2. Their Figure 2 (and the -3.7 mag for F160W is in its caption) shows ten stars with m(160) < (21.0-3.7)=17.3 in a 20"x20" NIC2 FOV; those stars have m(110) - m(160) = -0.8, and are G and K stars. WFC3 IR has 40x greater area than NIC2, so there must be ~100 stars per amplifier of WFC3 IR in Pulone et al's region with m(160) < 17.3. The WFC3 IR ETC predicts a 303-sec exposure (SPARS25, NSAMP=13) will be saturated by factors of 3.0 and 0.95 in F110W and F160W on a K0 V renormalized to NICMOS F160W = 17.3 in magnitudes relative to Vega.

V. Castellani et al 2007 ApJ 663 1021 (multi-wavelength catalog combining HST and ground-based observations) has Figure 6, which gives the radial distribution of stars in Omega Cen (with no units); density drops ~2x from 7' to 13' radial distance.

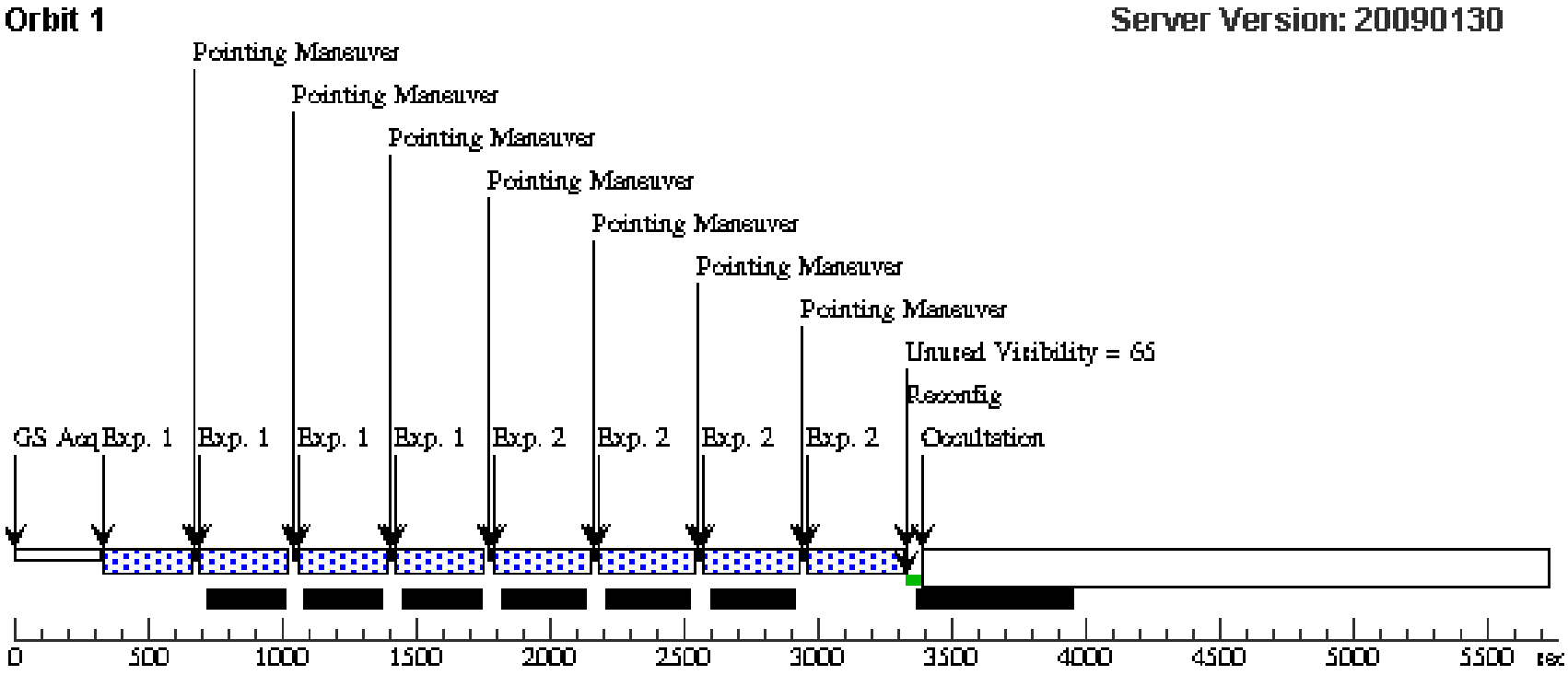
Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	F110W	(1) OMEGA-CEN-IPSV	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS25; NSAMP=13	POS TARG 0,0	Pattern 1-1 (1)	*[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***

Exposures (continued)

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
2	F160W	(1) OMEGA-CEN-I PSV	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS 25; NSAMP=14	POS TARG 0,0	Pattern 2-2 (1)	*[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***

Orbit Structure



Visit

Proposal 11916, Visit 02 Thu Apr 02 01:01:15 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: ORIENT -20DD TO 20DD FROM 01; GROUP 02,01 WITHIN 28D

Comments: F098M, 3x3 dither grid

GROUP requirement: Schedule both visits within 4 weeks to facilitate simultaneous analysis of the entire dataset at one time. Additionally, this should make it easier for the ORIENT requirement to be satisfied.

ORIENT requirement: Within +/- 20 deg of ORIENT of Visit 01, to facilitate selection of the same stars for analysis. If necessary THIS REQUIREMENT MAY BE RELAXED to make scheduling easier.

Patterns

#	Primary Pattern		Secondary Pattern		Exposures
(2)	Pattern Type=LINE	Coordinate Frame=POS-TARG	Pattern Type=LINE	Coordinate Frame=POS-TARG	(1)
	Purpose=DITHER	Pattern Orientation=0	Purpose=DITHER	Pattern Orientation=0	
	Number Of Points=3	Angle Between Sides=	Number Of Points=3	Angle Between Sides=	
	Point Spacing=0.045	Center Pattern=false	Point Spacing=0.040333	Center Pattern=false	
	Line Spacing=		Line Spacing=		

Fixed Targets

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Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	F098M	(1) OMEGA-CEN-I PSV	WFC3/IR, MULTIACCUM, IR	F098M	SAMP-SEQ=SPARS 25; NSAMP=12	POS TARG 0,0	Pattern 1-1 (2)	*[==>(Pattern 1,1)]* *[==>(Pattern 1,2)]* *[==>(Pattern 1,3)]* *[==>(Pattern 2,1)]* *[==>(Pattern 2,2)]* *[==>(Pattern 2,3)]* *[==>(Pattern 3,1)]* *[==>(Pattern 3,2)]* *[==>(Pattern 3,3)]*	***[1]***

Orbit Structure