12611 - Weighing the Low Mass Central Black Hole in NGC404

Cycle: 19, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

Name	*Institution*	*E-Mail*
Dr. Anil C. Seth (PI)	**University of Utah**	**aseth@cfa.harvard.edu**
Dr. Aaron J. Barth (CoI)	University of California - Irvine	barth@uci.edu
Dr. Michele Cappellari (CoI) (ESA Member)	University of Oxford	mxc@astro.ox.ac.uk
Dr. Nadine Neumayer (CoI) (ESA Member)	European Southern Observatory - Germany	nneumaye@eso.org
Dr. Nelson C. Caldwell (CoI)	Smithsonian Institution Astrophysical Observatory	ncaldwell@cfa.harvard.edu
Dr. Benjamin F. Williams (CoI)	University of Washington	ben@astro.washington.edu
Ms. Breanna Binder (CoI)	University of Washington	bbinder@astro.washington.edu

VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) NGC-0404	STIS/CCD	5	06-Jul-2011 21:49:50.0	yes
02	(1) NGC-0404	WFC3/IR WFC3/UVIS	1	06-Jul-2011 21:50:06.0	yes

6 Total Orbits Used

ABSTRACT

The lowest mass black holes occupying galaxy centers are important for understanding the form and causes of the scaling relationship between galaxy and black hole mass. We propose to make the first robust dynamical determination of a central BH with mass below a million solar masses using HST/STIS and WFC3 imaging of the nearby galaxy NGC404. Accretion signatures in this system, including a recent detection of a hard X-ray component, provide strong evidence for the presence of a massive black hole. Using dynamical modeling of high-quality adaptive optics integral

field kinematics from Gemini/NIFS, we have derived a firm upper limit of 1 million solar on the mass of this black hole. However, our current dynamical mass estimates are limited by likely spatial variations in the stellar mass-to-light ratio of the galaxy within the central arcsecond. With the proposed STIS spectroscopy and WFC3 imaging, we will make precision measurements of the mass-to-light ratio to create a stellar mass profile at 0.1" resolution. This mass profile will be combined with the existing kinematic data of both stars and gas to cleanly measure the mass of the black hole. NGC404 is the nearest S0 galaxy and presents a unique opportunity to dynamically measure a sub-million solar mass black hole with currently available instrumentation.

OBSERVING DESCRIPTION

Our observation consists of STIS spectroscopy (5 orbits) and WFC3 imaging (1 orbit) with the goal of measuring the mass-to-light ratio variations within the NGC404 nucleus and enable a more robust mass determination of its black hole. Due to possible variability of the source, we require that the imaging and spectroscopy be done contemperaneously within ~6 hours.

Coordinates of the nucleus:

Using the 2MASS LGA image, we have determined the position of the NGC404 nucleus in the ICRS frame. It agrees with the NED value to within 0.1", and at the brightness of the nucleus, 2MASS positions typically match ICRS to < 0.1".

STIS Spectroscopy:

We will obtain high spatial resolution observations of the stellar populations by obtaining STIS observations with the G430L gratings and the 52 × 0.1slit. Consistent with recommendations in the STIS IHB, we have chosen the E1 aperture to reduce CTE and used exposure times <1000 sec to ensure good cosmic ray rejections. In total, we will obtain 14 science exposures over 5 orbits.

* ACQ preparation -- We have used existing HST data in the F547M band to estimate the ACQ and ACQ/PEAK exposure times, and also used this image to simulate the success of the ACQ centroiding, which with our current parameters centers the nucleus to better than half a pixel. Saturation in the ACQ images should occur in 100s of seconds, and so should not be an issue for our 20s exposure times, but these exposure times should

comfortably exceed the required number of electrons/S/N.

* Exposure Times: Our exposure times are set by the need to have sufficient S/N to resolve changes in stellar populations over small scales within the inner arcsecond of galaxy. With the plan implemented we will obtain 14 exposures of 945s each totaling 13230 seconds, sufficient to obtain S/N > 100 per pixel in the nucleus, and sufficient to obtain M/L estimates out to ~0.5".

* Dithers: We group our exposures in 7 CR-SPLIT=2 exposures with a dither 9 pixels between each 2 exposures. These dithers are large enough to mitigate detector artifacts. Although we would like to use half-pixel dithers to minimize the undulations caused by rectifying the undersampled image, it was unclear (based on the available information and a response from the STIS help desk) whether it really is possible to use multidrizzle to reduce this data. Therefore, to avoid the risk of having no clear path towards combining our exposures, we use integer pixel dithers.

* Orientation: The slit will be oriented within 5 degrees of the major axis.

WFC3 Imaging:

To enable us to extend the stellar M/L analysis beyond the boundaries of the slit, we are obtaining a single orbit of WFC3 imaging. We proposed for images in four filters (F336W, F547M, F814W, F160W), and will obtain four dithered exposures in each filter to ensure the highest possible spatial resolution for our observations. To enable so many exposures, we utilize subarrays, which will give us information within the central 20" of the galaxy, sufficient for our mass-modeling purposes, and covering the region where the stellar M/L is expected to vary significantly. The required time for these exposures does not completely fill the orbit, so we will also obtain (1) wider field of view exposures in the F160W filter to extend mass modeling to larger radii, and (2) a pair of exposures in the F502N filter to map the [OIII] emission which may originate from the black hole.

* Exposure times were chosen to (1) ensure that we achieve high S/N (~10) out to the edge of the subarray field of (r~10") and (2) to make sure we don't saturate the images. We used a variety of existing HST data and our adaptive optics data to estimate the colors in each band, and our requirements are met using 4x200s exposures in F336W, 4x100s exposures in F547M, 4x50s exposures in F814W, and 4x3.4s exposures in F160W. The use of RAPID mode in the F160W exposures, with a first readout after just 0.3 seconds will ensure that we don't saturate the very bright central regions of the cluster (saturation is expected in ~5 seconds, but could vary as the level of AGN activity varies).

* The full FOV F160W images (2x74s) will be used to analyze the larger scale structure of the galaxy. We expect the central portion of this image to

be significantly saturated, but we will be able to substitute observations from our shorter F160W images in these regions.

* The F502N observations (2x110s) are being added to fill the orbit and do not compromise any of our proposed science. Using the ETC, we have verified that these observations will enable detection of the [OIII] emission around the nucleus, even under the most pessimistic assumptions. This data will be used to verify the apparent jet-like structure seen at lower resolution in ground-based narrow band images in Plana et al. 1998. This observation will help us understand the activity of the NGC404 black hole and thus is directly related to the goal of the proposal.

ADDITIONAL COMMENTS

Due to known variability in the AGN, we want our imaging taken as close in time to our spectroscopic observations as possible. If possible within 6 hours. Low mass black holes are known to be highly variable on day to month time scales. This variability is also the reason for our duplication of previous imaging data.

Visit

Proposal 12611, Visit 01, implementation Thu Jul 07 01:50:12 GMT 2011

Diagnostic Status: No Diagnostics

Scientific Instruments: STIS/CCD

Special Requirements: ORIENT 120D TO 130 D; ORIENT 300D TO 310 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(3)	Pattern Type=STIS-ALONG-SLIT	Coordinate Frame=POS-TARG		(3)
	Purpose=DITHER	Pattern Orientation=90.0		
	Number Of Points=7	Angle Between Sides=		
	Point Spacing=0.45	Center Pattern=true		
	Line Spacing=			

Fixed Targets

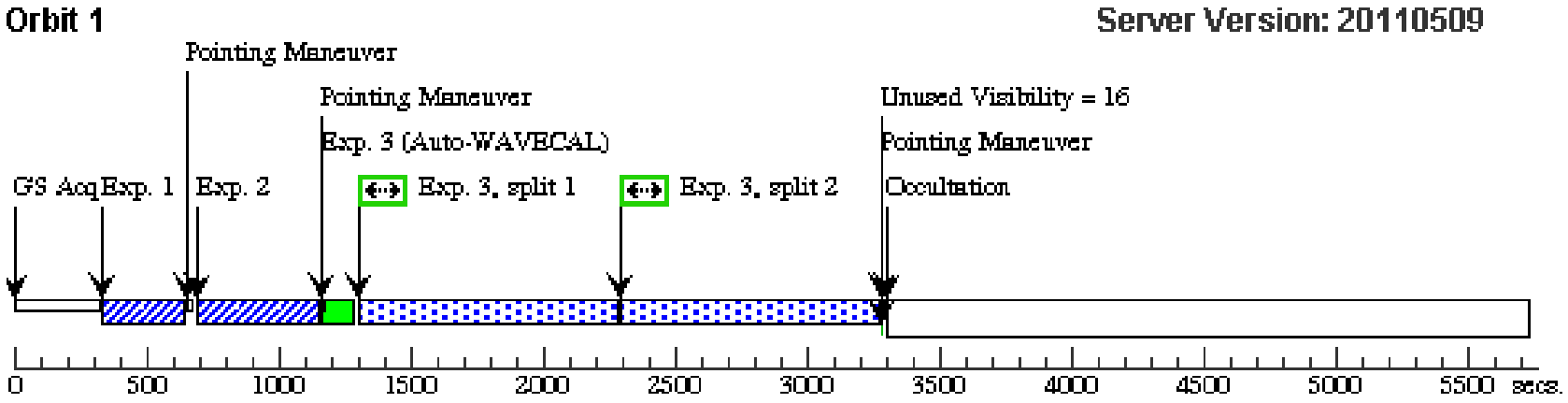
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	NGC-0404	RA: 01 09 27.0159 (17.3625662d) Dec: +35 43 5.14 (35.71809d) Equinox: J2000	Radial Velocity: -48 km/sec	V=15.46+/-0.1 integrated within r=0.5", peak surface brightness at HST resolution in V is 12.6 mag/arcsec^2, V-I~1	Reference Frame: ICRS

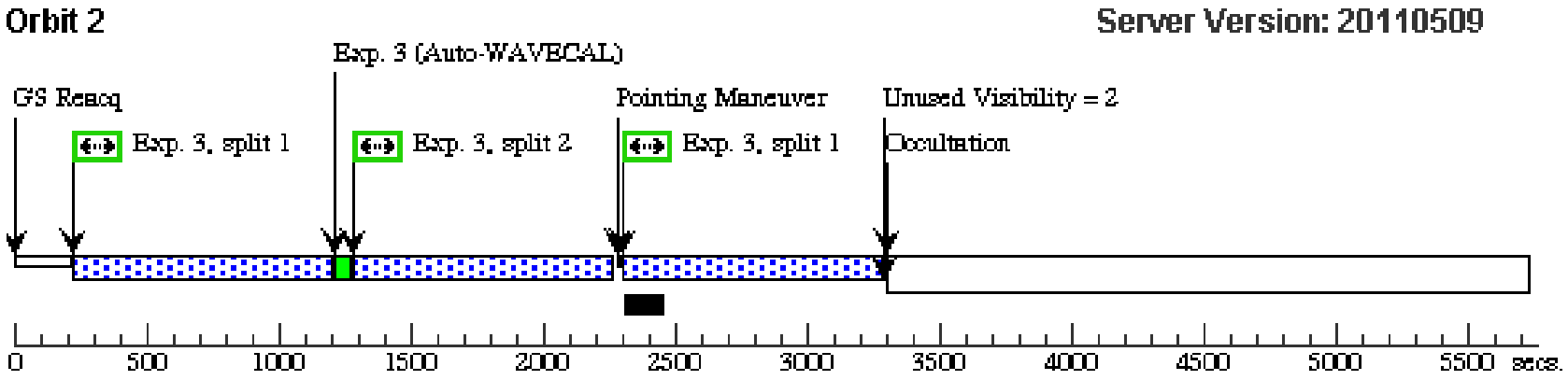
Comments: Distance of galaxy is 3.1 Mpc.
Nucleus position determined from 2MASS LGA images, agrees well with NED.
Magnitude and surface brightness were determined from F547M WPFC2/PC image integrated within a radius of 0.5".

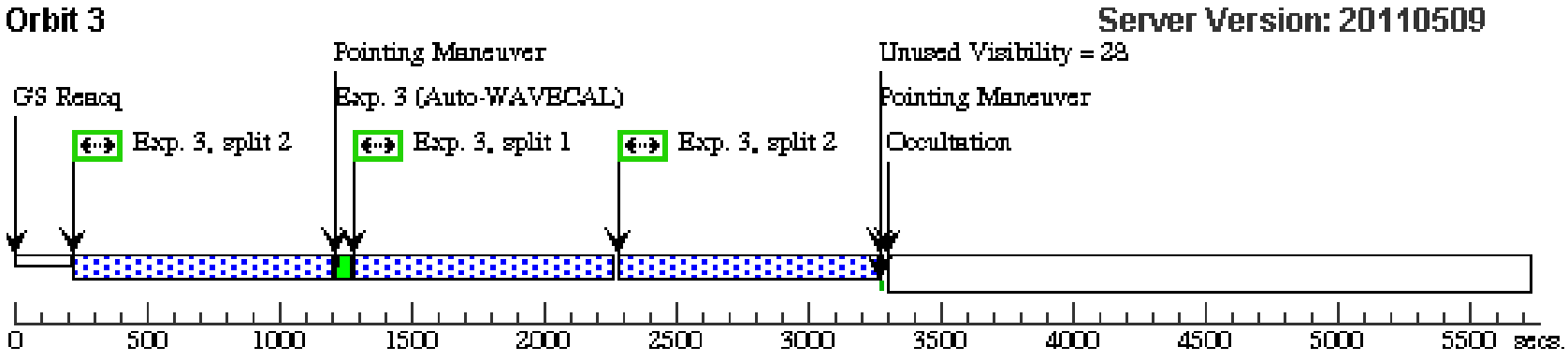
Exposures

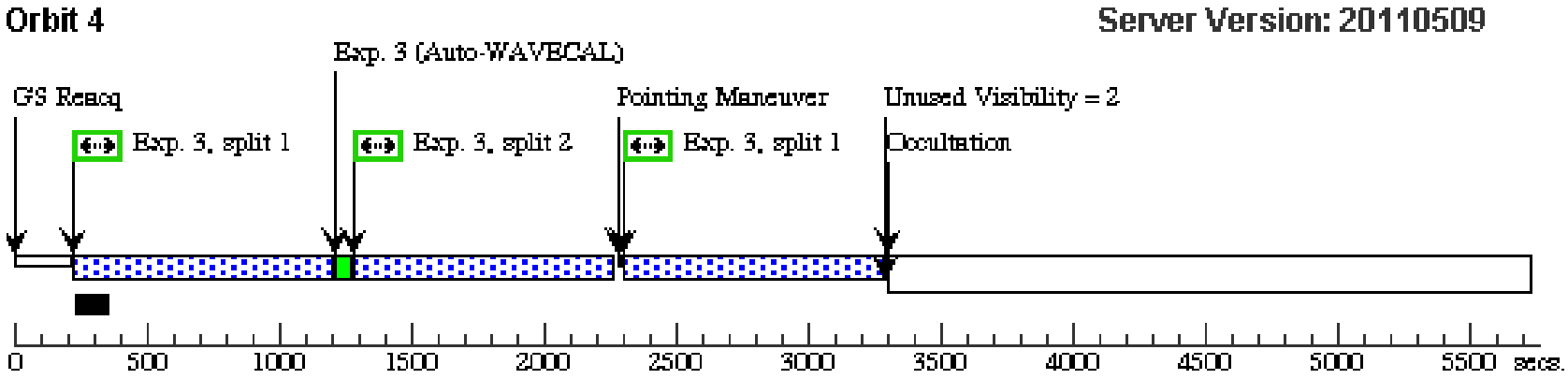
#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1		(1) NGC-0404	STIS/CCD, ACQ, F28X50LP	MIRROR	ACQTYPE=DIFFUSE; DIFFUSE-CENTER=FLUX-CENTROID; CHECKBOX=5	GS ACQ SCENARIO BASE1B3		20 Secs *[==>]*	*[1]*
2		(1) NGC-0404	STIS/CCD, ACQ/PEAK, 52X0.1E1	MIRROR				20 Secs *[==>]*	*[1]*
3		(1) NGC-0404	STIS/CCD, ACCUM, 52X0.1E1	G430L 4300 A	CR-SPLIT=2		Pattern 3, Exps 3-3 in Visit 01 (3)	1890 Secs *[==>(Pattern 1, Split 1)]* *[==>(Pattern 1, Split 2)]* *[==>(Pattern 2, Split 1)]* *[==>(Pattern 2, Split 2)]* *[==>(Pattern 3, Split 1)]* *[==>(Pattern 3, Split 2)]* *[==>(Pattern 4, Split 1)]* *[==>(Pattern 4, Split 2)]* *[==>(Pattern 5, Split 1)]* *[==>(Pattern 5, Split 2)]* *[==>(Pattern 6, Split 1)]* *[==>(Pattern 6, Split 2)]* *[==>(Pattern 7, Split 1)]* *[==>(Pattern 7, Split 2)]*	*[1]* *[2]* *[3]* *[4]* *[5]*

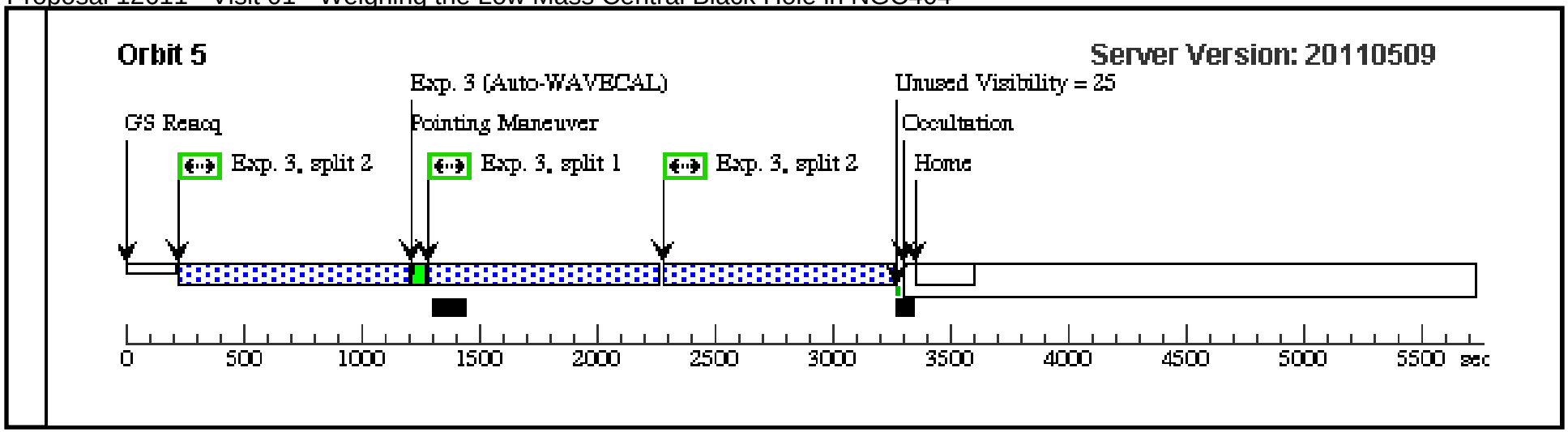
Orbit Structure






Orbit 3
Server Version: 20110509
GS Reacq
Exp. 3, split 2
Pointing Maneuver
Exp. 3 (Auto-WAVECAL)
Exp. 3, split 1
Exp. 3, split 2
Unused Visibility = 28
Pointing Maneuver
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
secs.


Orbit 4
Server Version: 20110509
Exp. 3 (Auto-WAVECAL)
GS Reacq
Exp. 3, split 1
Exp. 3, split 2
Pointing Maneuver
Exp. 3, split 1
Unused Visibility = 2
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
secs.


Orbit 5
Server Version: 20110509
Exp. 3 (Auto-WAVECAL)
Unused Visibility = 25
GS Reacq
Pointing Maneuver
Occultation
Exp. 3, split 2
Exp. 3, split 1
Exp. 3, split 2
Home
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec

Visit

Proposal 12611, Visit 02, implementation Thu Jul 07 01:50:13 GMT 2011

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR, WFC3/UVIS

Special Requirements: GROUP 02,01 WITHIN 6H

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-IR-DITHER-BOX-MIN Purpose=DITHER Number Of Points=4 Point Spacing=0.572 Line Spacing=0.365	Coordinate Frame=POS-TARG Pattern Orientation=18.528 Angle Between Sides=74.653 Center Pattern=false		(5)
(2)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1), (2), (3)
(4)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(4)
(5)	Pattern Type=WFC3-IR-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.636 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=41.788 Angle Between Sides= Center Pattern=false		(6)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	NGC-0404	RA: 01 09 27.0159 (17.3625662d) Dec: +35 43 5.14 (35.71809d) Equinox: J2000	Radial Velocity: -48 km/sec	V=15.46+/-0.1 integrated within r=0.5", peak surface brightness at HST resolution in V is 12.6 mag/arcsec^2, V-I~1	Reference Frame: ICRS

Comments: Distance of galaxy is 3.1 Mpc.
Nucleus position determined from 2MASS LGA images, agrees well with NED.
Magnitude and surface brightness were determined from F547M WPFC2/PC image integrated within a radius of 0.5".

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1		(1) NGC-0404	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F336W	CR-SPLIT=NO	GS ACQ SCENARIO BASE1B3	Pattern 2, Exps 1-1 in Visit 02 (2)	200 Secs *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***
2		(1) NGC-0404	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F547M	CR-SPLIT=NO		Pattern 2, Exps 2-2 in Visit 02 (2)	100 Secs *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***
3		(1) NGC-0404	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F814W	CR-SPLIT=NO		Pattern 2, Exps 3-3 in Visit 02 (2)	50 Secs *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***
4		(1) NGC-0404	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F502N	CR-SPLIT=NO		Pattern 4, Exps 4-4 in Visit 02 (4)	110 Secs *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***
5		(1) NGC-0404	WFC3/IR, MULTIACCUM, IRSUB256	F160W	SAMP-SEQ=RAPID; NSAMP=12		Pattern 1, Exps 5-5 in Visit 02 (1)	*[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***
6		(1) NGC-0404	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=STEP25; NSAMP=7		Pattern 5, Exps 6-6 in Visit 02 (5)	*[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***

Orbit Structure