



## 14669 - Ultramassive Black Holes in Brightest Cluster Galaxies

Cycle: 24, Proposal Category: GO

(Availability Mode: SUPPORTED)

### INVESTIGATORS

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**VISITS**

| <i>Visit</i> | <i>Targets used in Visit</i> | <i>Configurations used in Visit</i> | <i>Orbits Used</i> | <i>Last Orbit Planner Run</i> | <i>OP Current with Visit?</i> |
|--------------|------------------------------|-------------------------------------|--------------------|-------------------------------|-------------------------------|
| 06           | (1) PKS0745-19<br>CCDFLAT    | STIS/CCD                            | 4                  | 09-Nov-2016 11:37:27.0        | yes                           |
| 07           | (1) PKS0745-19<br>CCDFLAT    | STIS/CCD                            | 4                  | 09-Nov-2016 11:37:31.0        | yes                           |
| 08           | (1) PKS0745-19<br>CCDFLAT    | STIS/CCD                            | 4                  | 09-Nov-2016 11:37:34.0        | yes                           |
| 05           | (1) PKS0745-19               | ACS/WFC                             | 2                  | 09-Nov-2016 11:37:36.0        | yes                           |

14 Total Orbits Used

**ABSTRACT**

We have identified an exceptional brightest cluster galaxy (PKS0745-BCG,  $z=0.1028$ ) which stands out as being located in one of the most massive and strong cool clusters known, yet has clear rotation of the gas within the central regions of the galaxy to enable modelling of the black hole mass. Our results imply that the black hole mass should be at least  $2.5 \times 10^{10} M_{\text{sun}}$ , but can be as high as  $10^{11} M_{\text{sun}}$ , placing it well above the observed correlation between central black hole mass ( $M_{\text{BH}}$ ) and bulge stellar velocity dispersion ( $\sigma$ ). It should therefore host the most massive black hole in the Universe, even when compared to other BCGs. We propose to measure its black hole mass using long-slit spectroscopy from STIS onboard HST. There are only four black holes with masses exceeding  $10^{10} M_{\text{sun}}$  known so far. The high-mass end of one of the most fundamental relations in astronomy, the  $M_{\text{BH}}\text{-}\sigma$  relation, therefore remains unconstrained. Careful study of black holes with masses in excess of  $10^{10} M_{\text{sun}}$  is the only way forward to complete our understanding of  $M_{\text{BH}}\text{-}\sigma$  relation. This is the goal of our proposal.

**OBSERVING DESCRIPTION**

We require four observations to measure the black hole mass in PKS0745-BCG.

1) First, we require long-slit spectroscopy from STIS. The idea is to fit the  $H_{\alpha}/[\text{NII}]$  lines in order to measure the velocity, velocity dispersion, and emission-line flux as a function of location along the slit. Once this is accomplished, we will create rotating disk models that account for the gravitational potential of the black hole and the stellar mass distribution. The modelled emission-line profiles from the rotating disk will then be propagated through the telescope and STIS optics to produce synthetic spectra. Measurements of the synthetic spectra will be made in the same manner as the measurements of the observed spectra, which then allow the model and observed velocity fields to be compared.

Detailed description - To accomplish this, we need a slit width of 0.1 by 52arcsec<sup>2</sup> (E1 version, following the recommendations of previous STIS observations to measure BH masses), which allows us to resolve the sphere of influence of our black hole, while allowing for optimum throughput. To probe accurately the sphere of influence, we require observations in 3 different slit positions, which is also needed to determine the gas disk inclination angle and the angle between the STIS slit and the projected major axis of the gas disk, which are two parameters fed in the model.

To optimize the observations, we propose to split the 12 orbits required into 3 visits of 4 orbits each.

For each visit, we will begin the observations with an target acquisition (ACQ) and then a pickup acquisition (ACQ/PEAK). We used the STIS target acquisition simulator and a previously acquired F555W image of the target to determine that the optimal acquisition is a point source acquisition, i.e. the nucleus is bright enough to act as a point source. We use the F28X50LP filter since the target is faint. We have also used the STIS TAC to determine the appropriate exposures for acquisition. For the first visit, we observe the target at POS TARG X=0" and Y=0" for 4 orbits. For the second visit, we observe the target with a +0.1" offset specified with the POS TARG parameter set to X=+0.1" and Y=0" for 4 orbits. Finally, we observe the target in the third visit at -0.1" with POS TARG parameter set to X=-0.1" and Y=0" for another 4 orbits. The total area covered with the 12 orbits is then be 0.3 by 52 arcsec<sup>2</sup>. The exposure times are divided such that the total exposure (including overheads) amounts to 4 orbits per visit. For each pointing, we also include dithering in 2 or 4 back-to-back exposures using the STIS-ALONG-SLIT pattern to help remove bad pixels and cosmic rays. Individual STIS exposures do not exceed 800s in order to keep the number of cosmic-ray hits low. Each orbit also includes auto-wavecal.

We use the G750M grating, which covers the required wavelengths range needed to trace the H<sub>alpha</sub>/[NII] kinematics, while having a dispersion of 0.56Å /pixel (FWHM of 45 km/s at H<sub>alpha</sub>). Although the G750L grating covers our wavelength range, the spectral resolution is too poor for our objectives (dispersion of 4.92Å /pixel equivalent to 400 km/s at H<sub>alpha</sub>). To aid the modelling, we require that the PA of the slits be aligned with the PA of the rotating disk as seen in the Pa-alpha and H<sub>2</sub> rotation fields (North to East: 30 +/- 15 degrees for PKS0745-BCG, or ORIENT=60-90, +/-180). Here, we require a minimum signal to noise of 2 per resolution element (same as Dalla Bonta et al. 2009, resulting in a line S/N of 10). For all observations, we use the ETC calculator and derived estimates using a model spectrum of an elliptical galaxy with H<sub>alpha</sub>/[NII] emission lines, and include an E(B-V) due to our Galaxy of 0.52 mag. The line fluxes (per arcsec<sup>2</sup>) and continuum normalizations are taken from our VLT/VIMOS observations. Note that, the gratings we have chosen will allow us to resolve both the H<sub>alpha</sub>6562 and [NII]6548, 6583 lines. The dynamical modelling will be based on the [NII]6583 line, which is stronger than H<sub>alpha</sub> in PKS0745-BCG (based on our VLT/VIMOS data) and less affected by emission from star-forming regions. However, the additional H<sub>alpha</sub>/[NII]6548 lines will help constrain the measurements of the [NII]6583 line

if fitted simultaneously.

Finally, since we are observing at  $>7000$  Angstrom, we include 2 flat observations in each of the STIS visits.

2) Second, we require a wideband image equivalent to the I-band to extract the stellar surface brightness profiles  $[I(r)]$ , which is converted to a stellar density profile  $[\rho = (M/L)_{\text{star}} * I(r)]$  and used to determine the stellar contribution to the gravitational potential.

Detailed description - Dalla Bonta et al. (2009) used WFPC2[F814W] observations as their I-band image. Since PKS0745-BCG is at a higher redshift, the H<sub>alpha</sub>/[NII] lines are redshifted into this filter. We must therefore choose a filter that excludes the redshifted [NII]6548, 6583, H<sub>alpha</sub>/6562 and [SII]6731 lines. Although WFC3[F105W or F110W] fits this criteria, the pixel size of the IR channel is large (0.13 arcsec /pixel) compared to the best spatial resolution achievable. The best option that also allows for a good throughput is therefore the ACS/WFC with the F850LP filter. To help identify cosmic ray events and achieve optimum sampling of the PSF, we request that the observations be taken as 2 back-to-back exposures with dithering (ACS-WFC-DITHER-LINE). In order to model the stellar density profile accurately, we require a minimum signal to noise of 20 per resolution element based on Dalla Bonta et al. 2009. We also use the WFC1-FIX aperture since the source is extended. Since the dithering will already aid the cosmic ray removal, we do not require a CR-SPLIT and set it to "NO".

3) Third, we require a wideband image equivalent to the B-band used in combination with the I-band image to obtain color maps, thereby dust corrections.

Detailed description - Dalla Bonta et al. (2009) used ACS/HRC imaging with the F435W filter (equivalent to the Johnson B-band). The equivalent for our higher redshift target is ACS/WFC[F475W] or WFC3/UVIS[F475W] (ACS/HRS is no longer available). We choose the latter for its increased sensitivity. The F475W filter is ideal since it excludes the red-shifted [OIII]5007 line which could cause a problem for the dust corrections around the AGN (i.e. around the most important pixels in our analysis). No prior observations exist, so we request new data taken in 4 back-to-back sets (WFC3-UVIS-DITHER-BOX). Here, we only require a minimum signal to noise for our images of 10 per resolution element (based on Dalla Bonta et al. 2009), since these images will only be used to obtain dust corrections. We select the standard UVIS aperture. Since the dithering will already aid the cosmic ray removal, we do not require a CR-SPLIT and set it to "NO".

4) Finally, we require a narrowband image containing the H<sub>alpha</sub>/[NII] lines to obtain the continuum-subtracted emission-line maps of the ionized gas that is fed into the model.

Detailed description - Here, narrow band ramp filters are ideal to precisely select the wavelength range covering the H<sub>α</sub>/[NII] lines, which are only available for ACS. We choose to use the FR716N filter for PKS0745-BCG. No prior observations exist, so we request new data taken in 3 back-to-back sets (ACS-WFC-DITHER-LINE). For these images, we require good signal to noise of 20 per resolution element (based on based on Dalla Bonta et al. 2009), since these images will be important when modelling the kinematics. We select the standard RAMPQ aperture. Since the dithering will already aid the cosmic ray removal, we do not require a CR-SPLIT and set it to "NO".

Note that we have grouped the ACS/WFC and WFC3/UVIS (2 orbits in total) into one visit to optimise the observations.

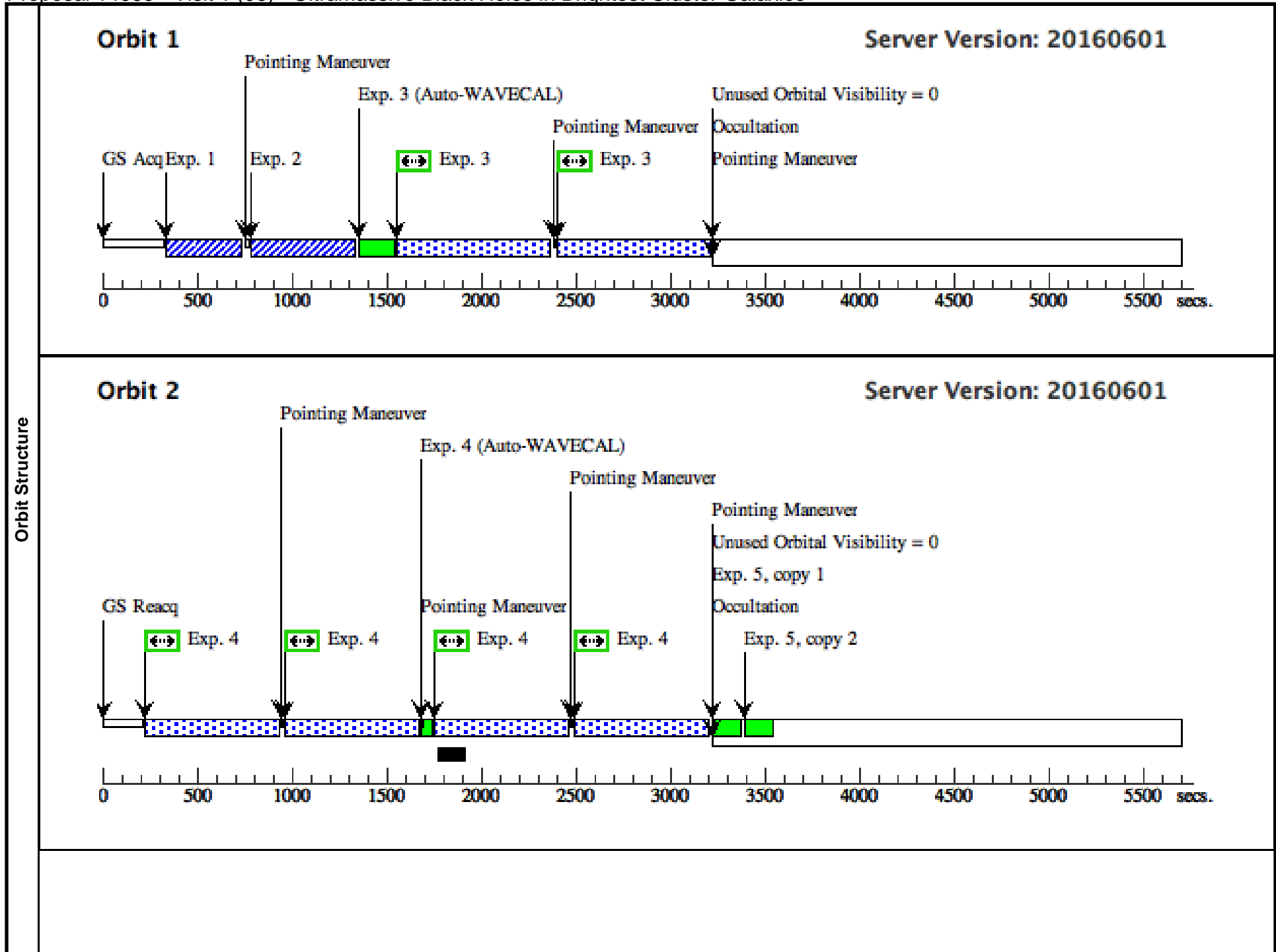
Proposal 14669 - Visit 1 (06) - Ultramassive Black Holes in Brightest Cluster Galaxies

Wed Nov 09 16:37:37 GMT 2016

|                      |  |  |  |                                 |  |                       |
|----------------------|--|--|--|---------------------------------|--|-----------------------|
| <b>Visit</b>         | <b>Proposal 14669, Visit 1 (06), scheduled</b><br><b>Diagnostic Status: No Diagnostics</b><br>Scientific Instruments: STIS/CCD<br>Special Requirements: ORIENT 60D TO 90 D; ORIENT 240D TO 270 D |  |  |                                 |  |                       |
|                      | <b>Patterns</b>  | <b>#</b>   | <b>Primary Pattern</b>   | <b>Secondary Pattern</b>        | <b>Exposures</b>   |                       |
|                      | (2)  | Pattern Type=STIS-ALONG-SLIT      Coordinate Frame=POS-TARG<br>Purpose=DITHER                      Pattern Orientation=90.0<br>Number Of Points=4                  Angle Between Sides=<br>Point Spacing=0.15                  Center Pattern=false<br>Line Spacing= |  | (4), (6), (7)                   |  |                       |
|                      | (7)  | Pattern Type=STIS-ALONG-SLIT      Coordinate Frame=POS-TARG<br>Purpose=DITHER                      Pattern Orientation=90.0<br>Number Of Points=2                  Angle Between Sides=<br>Point Spacing=0.15                  Center Pattern=false<br>Line Spacing= |  | (3)                             |  |                       |
| <b>Fixed Targets</b> | <b>#</b>   | <b>Name</b>  | <b>Target Coordinates</b>  | <b>Targ. Coord. Corrections</b> | <b>Fluxes</b>  | <b>Miscellaneous</b>  |
|                      | (1)  | PKS0745-19<br>Alt Name1: PKS0745-19-<br>BCG  | RA: 07 47 31.3250 (116.8805208d)<br>Dec: -19 17 40.02 (-19.29445d)<br>Equinox: J2000 | Redshift: 0.1028                | V=18.2<br>Flux = 3.7*10 <sup>-14</sup> erg/s/cm <sup>2</sup> at<br>H_alpha (6562 Angstrom) | Reference Frame: ICRS |
|                      | <i>Comments: The V band magnitude was calculated for the core of the galaxy (it does not include the faint extended emission).<br/>                     Extended=YES</i>                         |  |  |                                 |  |                       |

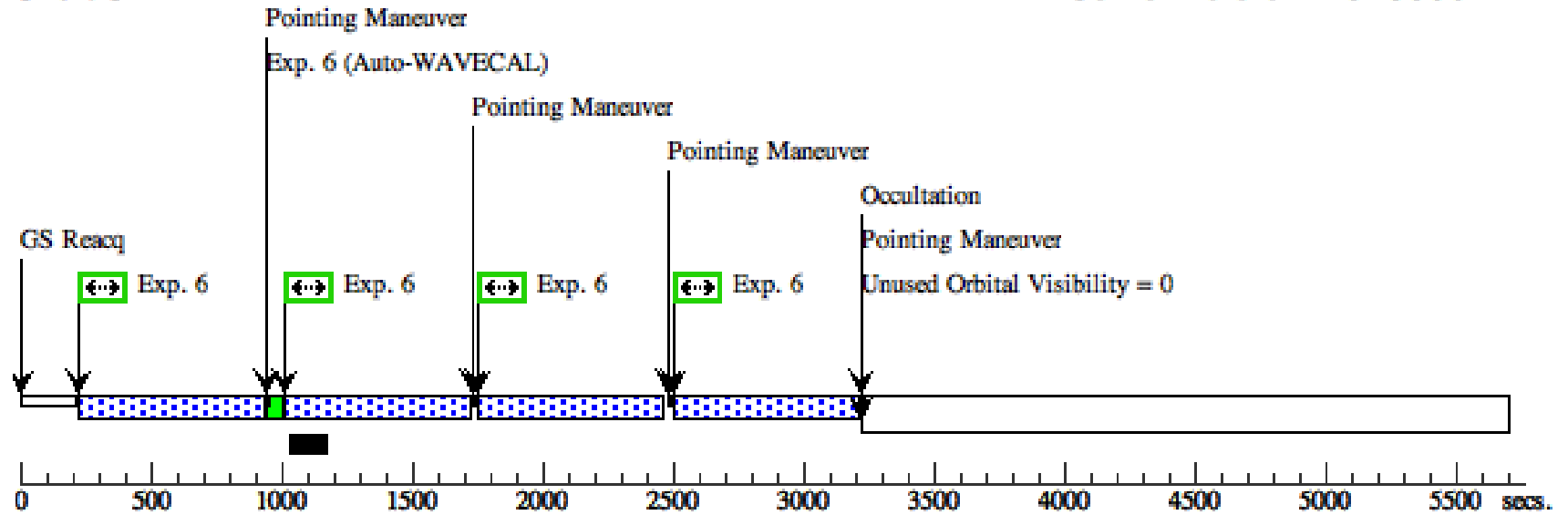
Proposal 14669 - Visit 1 (06) - Ultramassive Black Holes in Brightest Cluster Galaxies

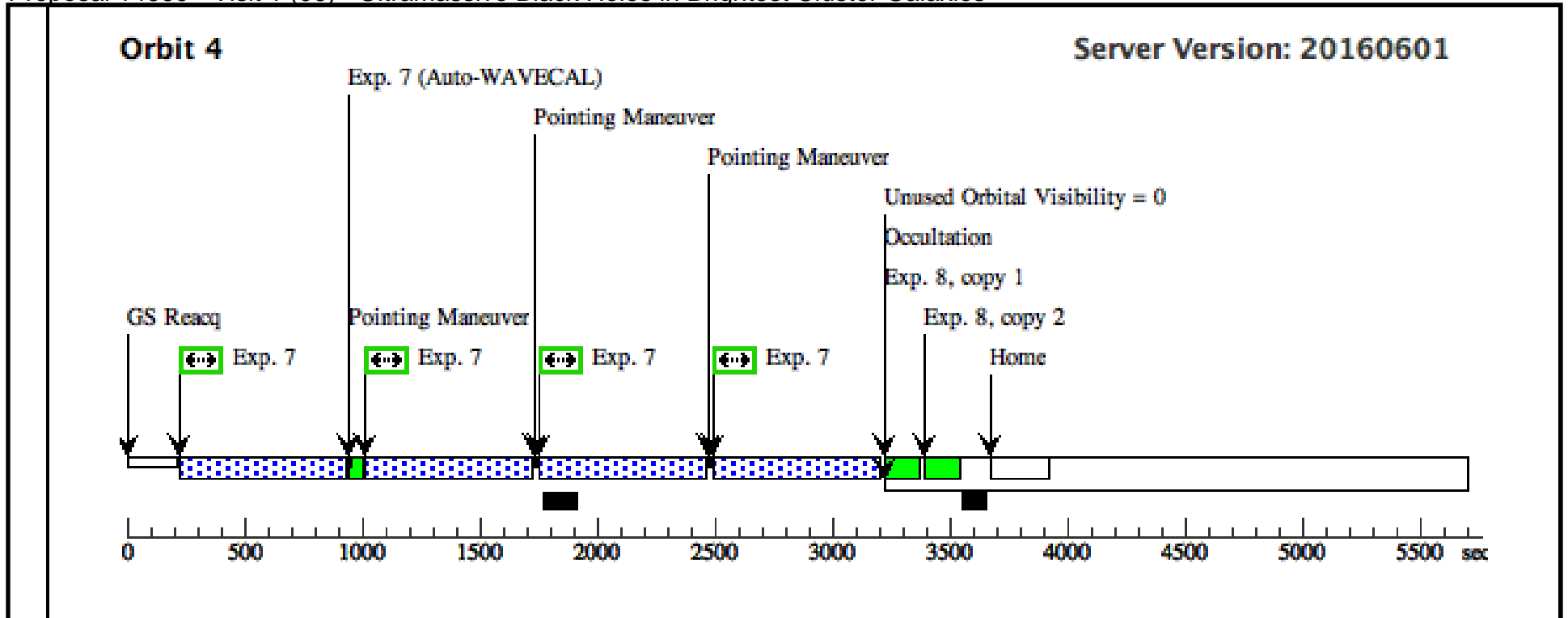
| Exposures | #    | Label          | Target                    | Config,Mode,Aperture         | Spectral Els.   | Opt. Params.  | Special Reqs.                               | Groups                                      | Exp. Time (Total)/[Actual Dur.] | Orbit |
|-----------|------|----------------|---------------------------|------------------------------|-----------------|---------------|---|---|---------------------------------|-------|
|           | 1    | ACQ            | (1) PKS0745-19            | STIS/CCD, ACQ, F28X50LP      | MIRROR          | ACQTYPE=POINT |   |   | 45 Secs (45 Secs)               |       |
|           |      |                |                           |                              |                 |               |   |   | [==>]                           | [1]   |
|           | 2    | ACQ/PEAK       | (1) PKS0745-19            | STIS/CCD, ACQ/PEAK, 52X0.1E1 | MIRROR          |               |   |   | 28 Secs (28 Secs)               |       |
|           |      |                |                           |                              |                 |               |   |   | [==>]                           | [1]   |
|           | 3    | NUC            | (1) PKS0745-19            | STIS/CCD, ACCUM, 52X0.1E1    | G750M<br>7283 A | CR-SPLIT=NO   | POS TARG 0,0                                | Pattern 7, Exps 3-3 i<br>n Visit 1 (06) (7) | 771 Secs (1542 Secs)            |       |
|           |      |                |                           |                              |                 |               |   |   | [==>(Pattern 1)]                | [1]   |
|           |      |                |                           |                              |                 |               |   |   | [==>(Pattern 2)]                |       |
|           | 4    | NUC            | (1) PKS0745-19            | STIS/CCD, ACCUM, 52X0.1E1    | G750M<br>7283 A | CR-SPLIT=NO   | POS TARG 0,0                                | Pattern 2, Exps 4-4 i<br>n Visit 1 (06) (2) | 671 Secs (2687 Secs)            |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 1)]                            | [2]                             |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 2)]                            |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 3)]                            |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>674.0 Secs (Pattern 4)]                 |                                 |       |
| 5         | FLAT | CCDFLAT        | STIS/CCD, ACCUM, 52X0.1   | G750M<br>7283 A              |                 |               |   | [==>(Copy 1)]                               | [2]                             |       |
|           |      |                |                           |                              |                 |               |   | [==>(Copy 2)]                               |                                 |       |
| 6         | NUC  | (1) PKS0745-19 | STIS/CCD, ACCUM, 52X0.1E1 | G750M<br>7283 A              | CR-SPLIT=NO     | POS TARG 0,0  | Pattern 2, Exps 6-6 i<br>n Visit 1 (06) (2) | 671 Secs (2684 Secs)                        |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 1)]                            | [3]                             |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 2)]                            |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 3)]                            |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 4)]                            |                                 |       |
| 7         | NUC  | (1) PKS0745-19 | STIS/CCD, ACCUM, 52X0.1E1 | G750M<br>7283 A              | CR-SPLIT=NO     | POS TARG 0,0  | Pattern 2, Exps 7-7 i<br>n Visit 1 (06) (2) | 671 Secs (2687 Secs)                        |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 1)]                            | [4]                             |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 2)]                            |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>(Pattern 3)]                            |                                 |       |
|           |      |                |                           |                              |                 |               |   | [==>674.0 Secs (Pattern 4)]                 |                                 |       |
| 8         | FLAT | CCDFLAT        | STIS/CCD, ACCUM, 52X0.1   | G750M<br>7283 A              |                 |               |   | [==>(Copy 1)]                               | [4]                             |       |
|           |      |                |                           |                              |                 |               |   | [==>(Copy 2)]                               |                                 |       |



**Orbit 3**

Server Version: 20160601





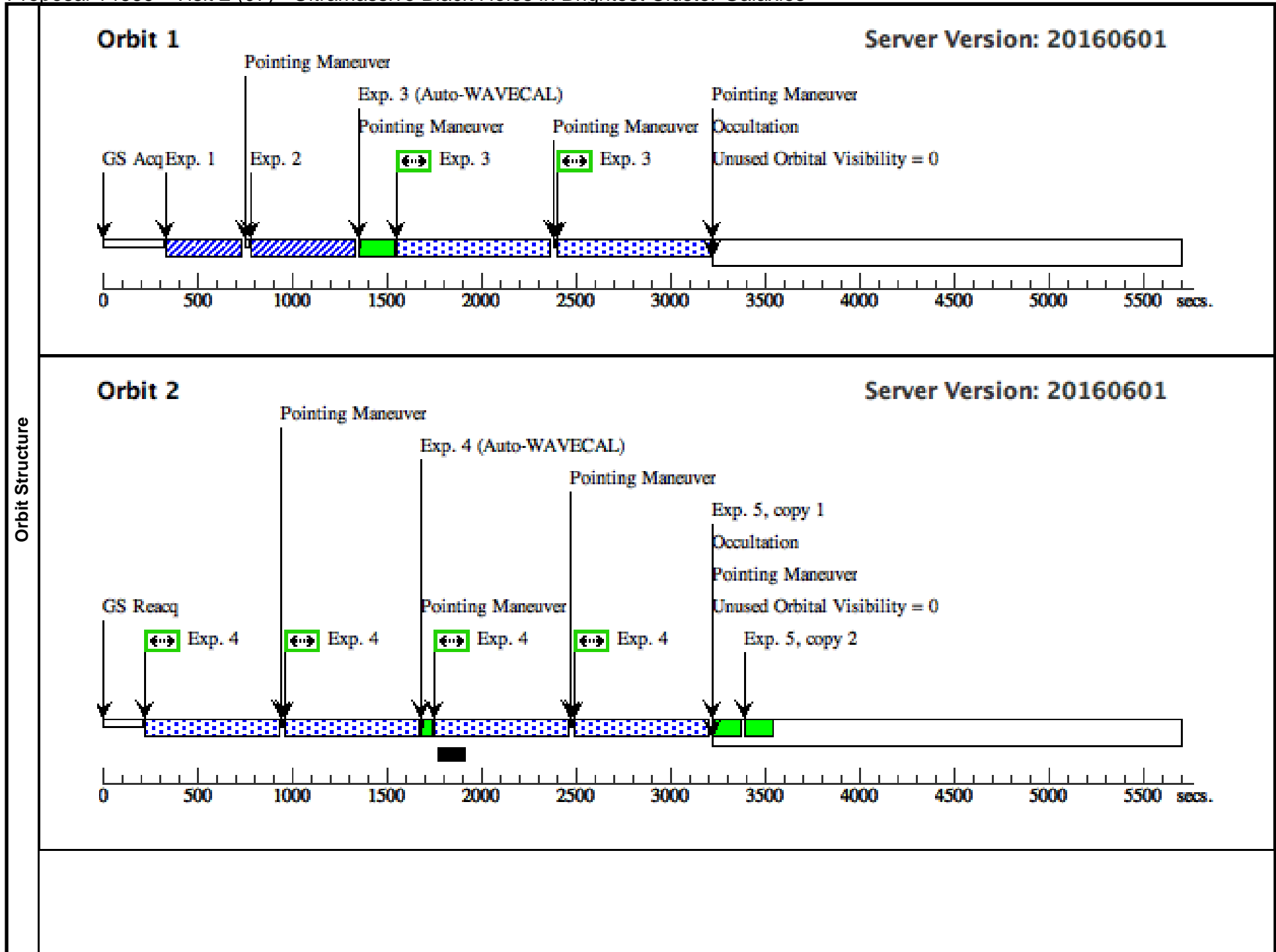
Proposal 14669 - Visit 2 (07) - Ultramassive Black Holes in Brightest Cluster Galaxies

Wed Nov 09 16:37:37 GMT 2016

|  |  |  |  |                                 |  |                       |
|--|--|--|--|---------------------------------|--|-----------------------|
| <b>Visit</b>   | <b>Proposal 14669, Visit 2 (07), scheduled</b><br><b>Diagnostic Status: Warning</b><br>Scientific Instruments: STIS/CCD<br>Special Requirements: SAME ORIENT AS 06   |  |  |                                 |  |                       |
|  | (Visit 2 (07)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE<br>(Visit 2 (07)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE<br>(Visit 2 (07)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE<br>(Visit 2 (07)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE |  |  |                                 |  |                       |
| <b>Diagnosics</b>  |  |  |  |                                 |  |                       |
|  |  |  |  |                                 |  |                       |
| <b>Patterns</b>  | <b>#</b>   | <b>Primary Pattern</b>   | <b>Secondary Pattern</b>   | <b>Exposures</b>                |  |                       |
|  | (2)  | Pattern Type=STIS-ALONG-SLIT      Coordinate Frame=POS-TARG<br>Purpose=DITHER                      Pattern Orientation=90.0<br>Number Of Points=4                  Angle Between Sides=<br>Point Spacing=0.15                  Center Pattern=false<br>Line Spacing= |  | (4), (6), (7)                   |  |                       |
| (7)  | Pattern Type=STIS-ALONG-SLIT      Coordinate Frame=POS-TARG<br>Purpose=DITHER                      Pattern Orientation=90.0<br>Number Of Points=2                  Angle Between Sides=<br>Point Spacing=0.15                  Center Pattern=false<br>Line Spacing=   |  | (3)  |                                 |  |                       |
| <b>Fixed Targets</b>   | <b>#</b>   | <b>Name</b>  | <b>Target Coordinates</b>  | <b>Targ. Coord. Corrections</b> | <b>Fluxes</b>  | <b>Miscellaneous</b>  |
|  | (1)  | PKS0745-19<br>Alt Name1: PKS0745-19-<br>BCG  | RA: 07 47 31.3250 (116.8805208d)<br>Dec: -19 17 40.02 (-19.29445d)<br>Equinox: J2000 | Redshift: 0.1028                | V=18.2<br>Flux = 3.7*10 <sup>-14</sup> erg/s/cm2 at<br>H_alpha (6562 Angstrom) | Reference Frame: ICRS |
| <i>Comments: The V band magnitude was calculated for the core of the galaxy (it does not include the faint extended emission).<br/>                 Extended=YES</i> |  |  |  |                                 |  |                       |

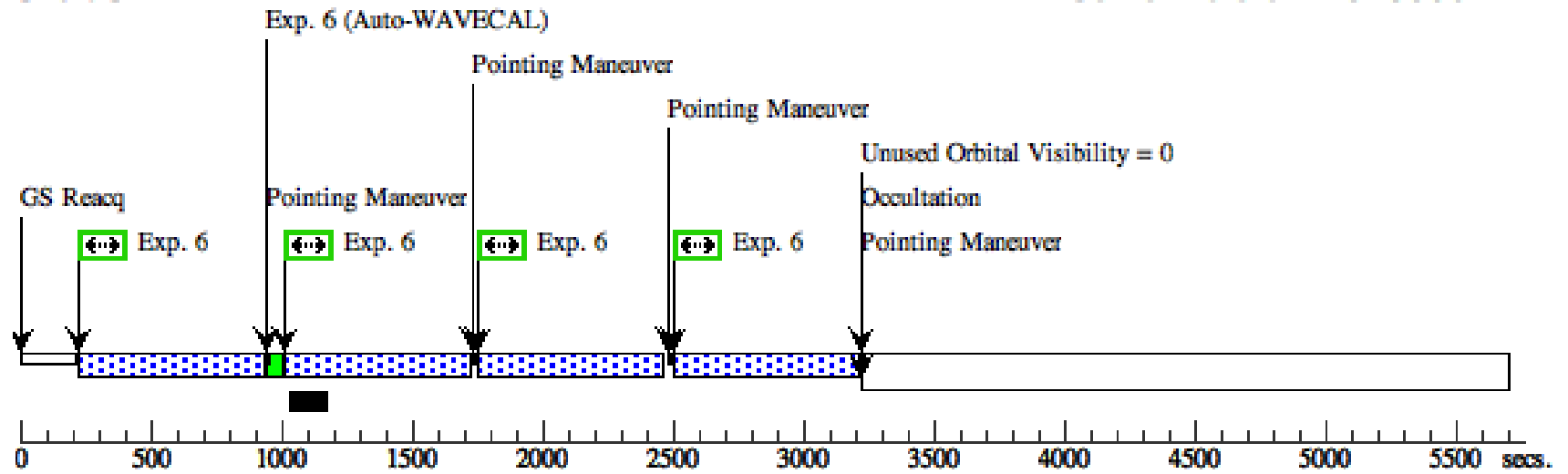
Proposal 14669 - Visit 2 (07) - Ultramassive Black Holes in Brightest Cluster Galaxies

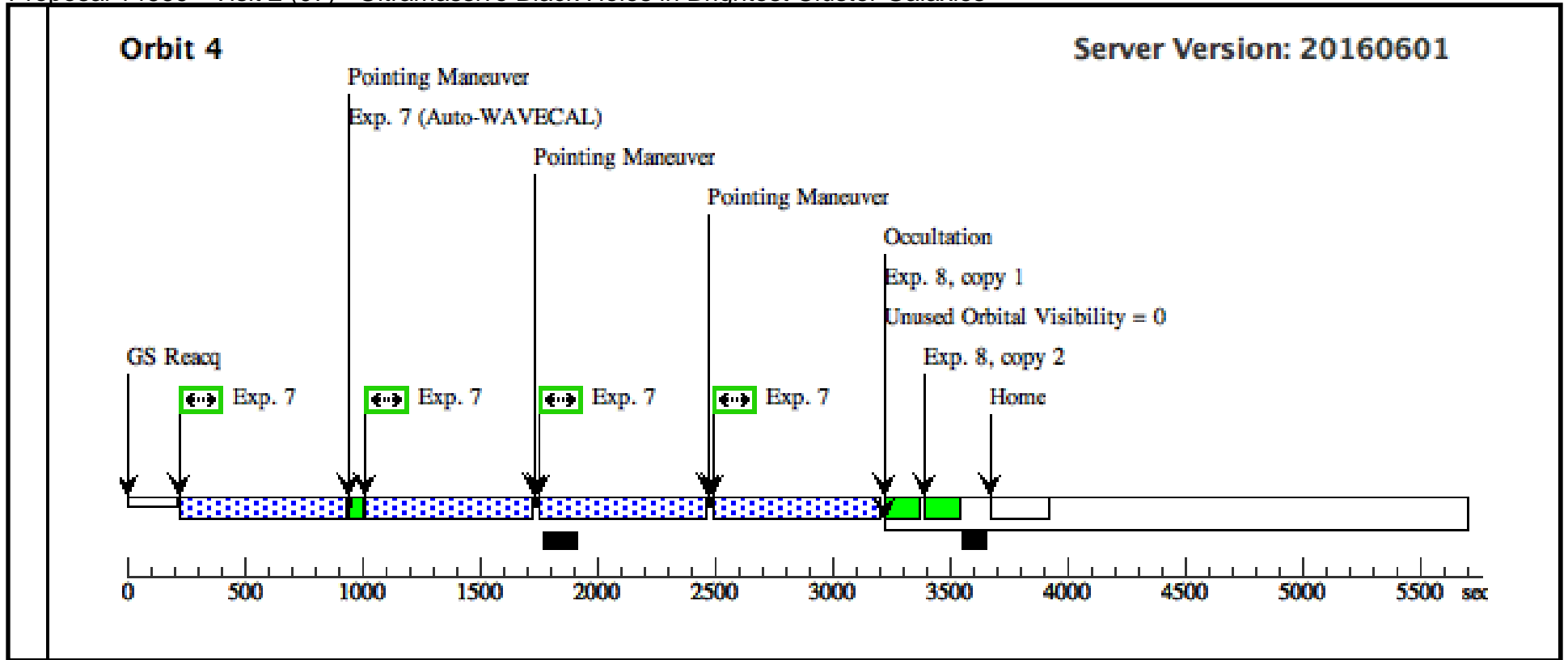
| Exposures | #              | Label          | Target                    | Config,Mode,Aperture         | Spectral Els.   | Opt. Params.    | Special Reqs.                               | Groups                                      | Exp. Time (Total)/[Actual Dur.] | Orbit |
|-----------|----------------|----------------|---------------------------|------------------------------|-----------------|-----------------|---|---|---------------------------------|-------|
|           | 1              | ACQ            | (1) PKS0745-19            | STIS/CCD, ACQ, F28X50LP      | MIRROR          | ACQTYPE=POINT   |   |   | 45 Secs (45 Secs)               |       |
|           |                |                |                           |                              |                 |                 |   |   | [==>]                           | [1]   |
|           | 2              | ACQ/PEAK       | (1) PKS0745-19            | STIS/CCD, ACQ/PEAK, 52X0.1E1 | MIRROR          |                 |   |   | 28 Secs (28 Secs)               |       |
|           |                |                |                           |                              |                 |                 |   |   | [==>]                           | [1]   |
|           | 3              | NUC Orbit<br>1 | (1) PKS0745-19            | STIS/CCD, ACCUM, 52X0.1E1    | G750M<br>7283 A | CR-SPLIT=NO     | POS TARG -0.1,0                             | Pattern 7, Exps 3-3 i<br>n Visit 2 (07) (7) | 771 Secs (1542 Secs)            |       |
|           |                |                |                           |                              |                 |                 |   |   | [==>(Pattern 1)]                | [1]   |
|           |                |                |                           |                              |                 |                 |   |   | [==>(Pattern 2)]                |       |
|           | 4              | NUC Orbit<br>2 | (1) PKS0745-19            | STIS/CCD, ACCUM, 52X0.1E1    | G750M<br>7283 A | CR-SPLIT=NO     | POS TARG -0.1,0                             | Pattern 2, Exps 4-4 i<br>n Visit 2 (07) (2) | 671 Secs (2687 Secs)            |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 1)]                            | [2]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 2)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 3)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>674.0 Secs (Pattern 4)]                 |                                 |       |
| 5         | FLAT           | CCDFLAT        | STIS/CCD, ACCUM, 52X0.1   | G750M<br>7283 A              |                 |                 |   | [==>(Copy 1)]                               | [2]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Copy 2)]                               |                                 |       |
| 6         | NUC Orbit<br>3 | (1) PKS0745-19 | STIS/CCD, ACCUM, 52X0.1E1 | G750M<br>7283 A              | CR-SPLIT=NO     | POS TARG -0.1,0 | Pattern 2, Exps 6-6 i<br>n Visit 2 (07) (2) | 671 Secs (2684 Secs)                        |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 1)]                            | [3]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 2)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 3)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 4)]                            |                                 |       |
| 7         | NUC Orbit<br>4 | (1) PKS0745-19 | STIS/CCD, ACCUM, 52X0.1E1 | G750M<br>7283 A              | CR-SPLIT=NO     | POS TARG -0.1,0 | Pattern 2, Exps 7-7 i<br>n Visit 2 (07) (2) | 671 Secs (2687 Secs)                        |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 1)]                            | [4]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 2)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 3)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>674.0 Secs (Pattern 4)]                 |                                 |       |
| 8         | FLAT           | CCDFLAT        | STIS/CCD, ACCUM, 52X0.1   | G750M<br>7283 A              |                 |                 |   | [==>(Copy 1)]                               | [4]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Copy 2)]                               |                                 |       |



**Orbit 3**

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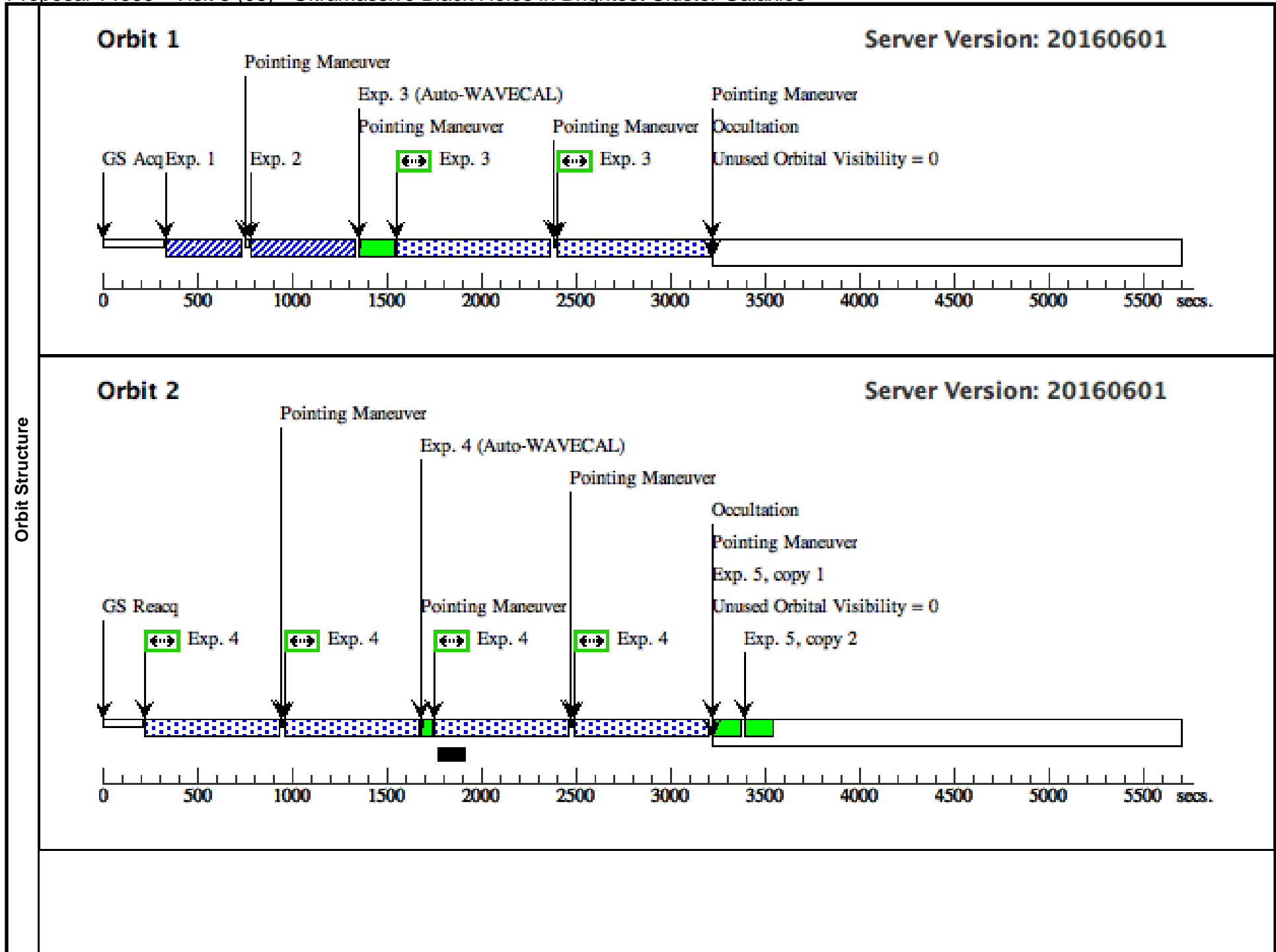
Proposal 14669 - Visit 3 (08) - Ultramassive Black Holes in Brightest Cluster Galaxies

Wed Nov 09 16:37:37 GMT 2016

|  |  |  |  |                                 |  |                       |
|--|--|--|--|---------------------------------|--|-----------------------|
| <b>Visit</b>   | <b>Proposal 14669, Visit 3 (08), scheduled</b><br><b>Diagnostic Status: Warning</b><br>Scientific Instruments: STIS/CCD<br>Special Requirements: SAME ORIENT AS 06   |  |  |                                 |  |                       |
|  | (Visit 3 (08)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE<br>(Visit 3 (08)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE<br>(Visit 3 (08)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE<br>(Visit 3 (08)) Warning (Orbit Planner): PATTERN POSITION OUTSIDE APERTURE |  |  |                                 |  |                       |
| <b>Diagnosics</b>  |  |  |  |                                 |  |                       |
|  |  |  |  |                                 |  |                       |
| <b>Patterns</b>  | <b>#</b>   | <b>Primary Pattern</b>   | <b>Secondary Pattern</b>   | <b>Exposures</b>                |  |                       |
|  | (2)  | Pattern Type=STIS-ALONG-SLIT      Coordinate Frame=POS-TARG<br>Purpose=DITHER                      Pattern Orientation=90.0<br>Number Of Points=4                  Angle Between Sides=<br>Point Spacing=0.15                  Center Pattern=false<br>Line Spacing= |  | (4), (6), (7)                   |  |                       |
| (7)  | Pattern Type=STIS-ALONG-SLIT      Coordinate Frame=POS-TARG<br>Purpose=DITHER                      Pattern Orientation=90.0<br>Number Of Points=2                  Angle Between Sides=<br>Point Spacing=0.15                  Center Pattern=false<br>Line Spacing=   |  | (3)  |                                 |  |                       |
| <b>Fixed Targets</b>   | <b>#</b>   | <b>Name</b>  | <b>Target Coordinates</b>  | <b>Targ. Coord. Corrections</b> | <b>Fluxes</b>  | <b>Miscellaneous</b>  |
|  | (1)  | PKS0745-19<br>Alt Name1: PKS0745-19-<br>BCG  | RA: 07 47 31.3250 (116.8805208d)<br>Dec: -19 17 40.02 (-19.29445d)<br>Equinox: J2000 | Redshift: 0.1028                | V=18.2<br>Flux = 3.7*10 <sup>-14</sup> erg/s/cm <sup>2</sup> at<br>H_alpha (6562 Angstrom) | Reference Frame: ICRS |
| <i>Comments: The V band magnitude was calculated for the core of the galaxy (it does not include the faint extended emission).<br/>                 Extended=YES</i> |  |  |  |                                 |  |                       |

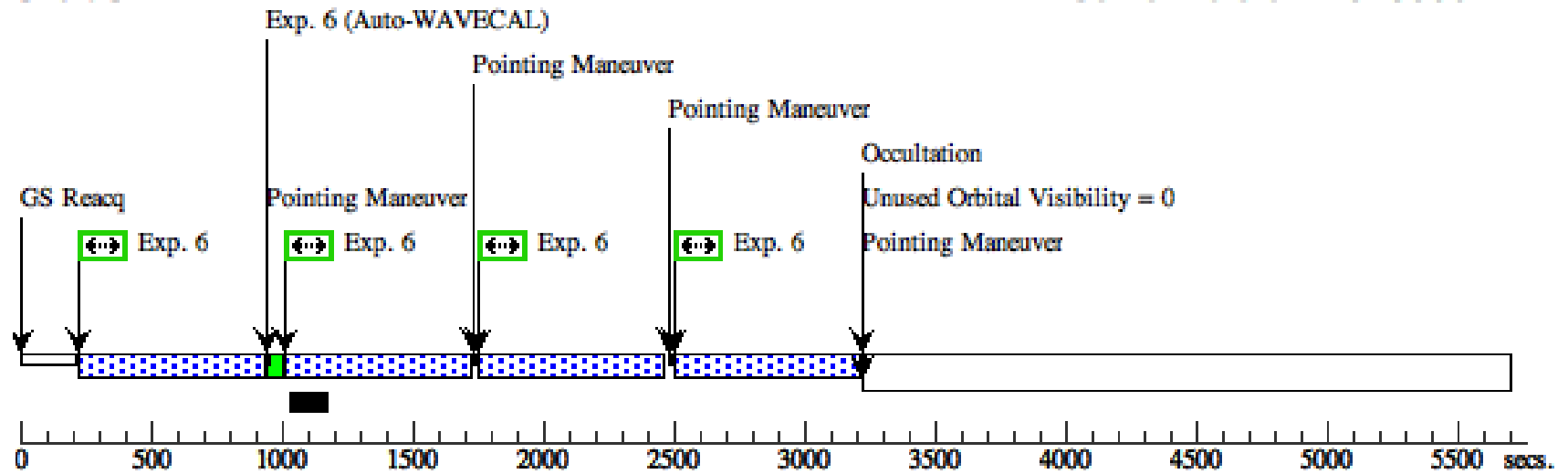
Proposal 14669 - Visit 3 (08) - Ultramassive Black Holes in Brightest Cluster Galaxies

| Exposures | #              | Label          | Target                    | Config,Mode,Aperture         | Spectral Els.   | Opt. Params.    | Special Reqs.                               | Groups                                      | Exp. Time (Total)/[Actual Dur.] | Orbit |
|-----------|----------------|----------------|---------------------------|------------------------------|-----------------|-----------------|---|---|---------------------------------|-------|
|           | 1              | ACQ            | (1) PKS0745-19            | STIS/CCD, ACQ, F28X50LP      | MIRROR          | ACQTYPE=POINT   |   |   | 45 Secs (45 Secs)               |       |
|           |                |                |                           |                              |                 |                 |   |   | [==>]                           | [1]   |
|           | 2              | ACQ/PEAK       | (1) PKS0745-19            | STIS/CCD, ACQ/PEAK, 52X0.1E1 | MIRROR          |                 |   |   | 28 Secs (28 Secs)               |       |
|           |                |                |                           |                              |                 |                 |   |   | [==>]                           | [1]   |
|           | 3              | NUC Orbit<br>1 | (1) PKS0745-19            | STIS/CCD, ACCUM, 52X0.1E1    | G750M<br>7283 A | CR-SPLIT=NO     | POS TARG +0.1,0                             | Pattern 7, Exps 3-3 i<br>n Visit 3 (08) (7) | 771 Secs (1542 Secs)            |       |
|           |                |                |                           |                              |                 |                 |   |   | [==>(Pattern 1)]                | [1]   |
|           |                |                |                           |                              |                 |                 |   |   | [==>(Pattern 2)]                |       |
|           | 4              | NUC Orbit<br>2 | (1) PKS0745-19            | STIS/CCD, ACCUM, 52X0.1E1    | G750M<br>7283 A | CR-SPLIT=NO     | POS TARG +0.1,0                             | Pattern 2, Exps 4-4 i<br>n Visit 3 (08) (2) | 671 Secs (2687 Secs)            |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 1)]                            | [2]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 2)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 3)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>674.0 Secs (Pattern 4)]                 |                                 |       |
| 5         | FLAT           | CCDFLAT        | STIS/CCD, ACCUM, 52X0.1   | G750M<br>7283 A              |                 |                 |   | [==>(Copy 1)]                               | [2]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Copy 2)]                               |                                 |       |
| 6         | NUC Orbit<br>3 | (1) PKS0745-19 | STIS/CCD, ACCUM, 52X0.1E1 | G750M<br>7283 A              | CR-SPLIT=NO     | POS TARG +0.1,0 | Pattern 2, Exps 6-6 i<br>n Visit 3 (08) (2) | 671 Secs (2684 Secs)                        |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 1)]                            | [3]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 2)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 3)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 4)]                            |                                 |       |
| 7         | NUC Orbit<br>4 | (1) PKS0745-19 | STIS/CCD, ACCUM, 52X0.1E1 | G750M<br>7283 A              | CR-SPLIT=NO     | POS TARG +0.1,0 | Pattern 2, Exps 7-7 i<br>n Visit 3 (08) (2) | 671 Secs (2687 Secs)                        |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 1)]                            | [4]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 2)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Pattern 3)]                            |                                 |       |
|           |                |                |                           |                              |                 |                 |   | [==>674.0 Secs (Pattern 4)]                 |                                 |       |
| 8         | FLAT           | CCDFLAT        | STIS/CCD, ACCUM, 52X0.1   | G750M<br>7283 A              |                 |                 |   | [==>(Copy 1)]                               | [4]                             |       |
|           |                |                |                           |                              |                 |                 |   | [==>(Copy 2)]                               |                                 |       |



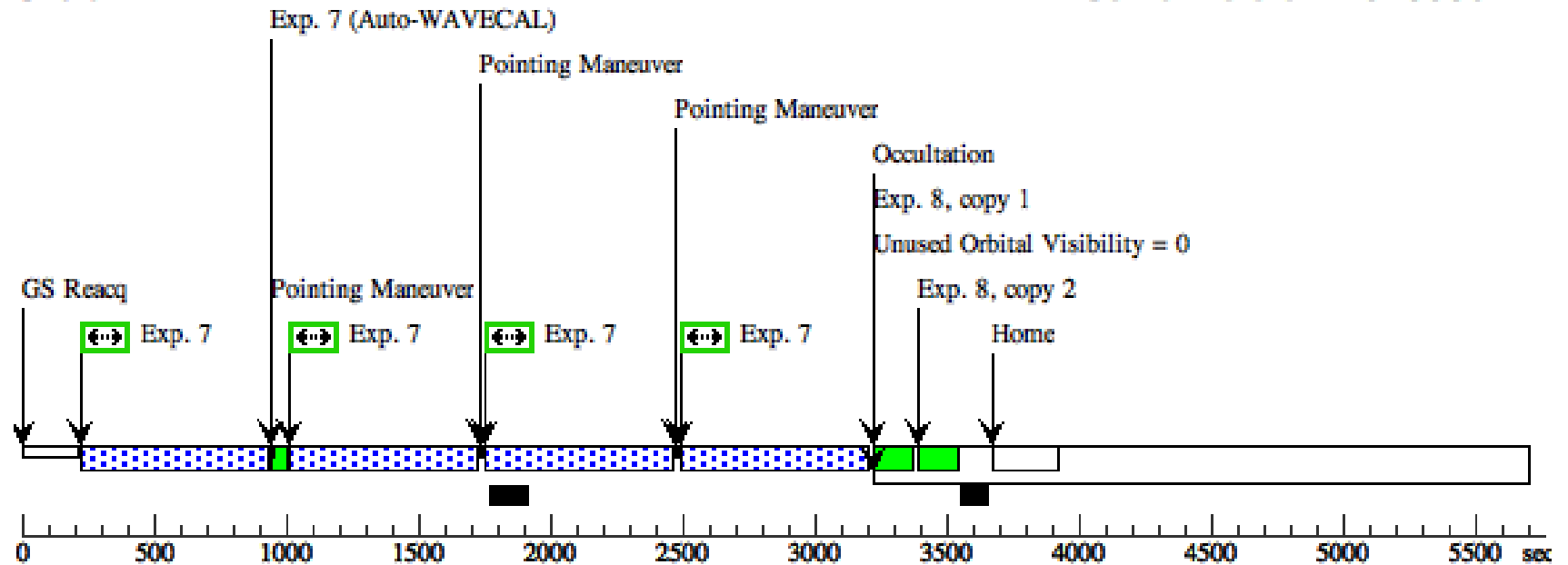
**Orbit 3**

Server Version: 20160601



**Orbit 4**

Server Version: 20160601



Proposal 14669 - Visit 4 (05) - Ultramassive Black Holes in Brightest Cluster Galaxies

Wed Nov 09 16:37:37 GMT 2016

|  |  |  |  |                                 |   |                       |
|--|--|--|--|---------------------------------|---|-----------------------|
| <b>Visit</b>   | <b>Proposal 14669, Visit 4 (05), implementation</b><br><b>Diagnostic Status: Warning</b><br>Scientific Instruments: ACS/WFC<br>Special Requirements: (none)  |  |  |                                 |   |                       |
|  | (FR716N (05.001)) Warning (Form): POS TARG & PATTERN should be used carefully with ACS ramp filters as central wavelengths & transmission efficiencies vary within the apertures.  |  |  |                                 |   |                       |
| <b>Patterns</b>  | <b>#</b>   | <b>Primary Pattern</b>   | <b>Secondary Pattern</b>   | <b>Exposures</b>                |   |                       |
|  | (5)  | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=1.5<br>Line Spacing=<br>Coordinate Frame=POS-TARG<br>Pattern Orientation=140<br>Angle Between Sides=<br>Center Pattern=false     |  | (1)                             |   |                       |
|  | (6)  | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=3.034<br>Line Spacing=<br>Coordinate Frame=POS-TARG<br>Pattern Orientation=85.29<br>Angle Between Sides=<br>Center Pattern=false |  | (2)                             |   |                       |
| (8)  | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=3.034<br>Line Spacing=<br>Coordinate Frame=POS-TARG<br>Pattern Orientation=85.29<br>Angle Between Sides=<br>Center Pattern=false |  | (3)  |                                 |   |                       |
| <b>Fixed Targets</b>   | <b>#</b>   | <b>Name</b>  | <b>Target Coordinates</b>  | <b>Targ. Coord. Corrections</b> | <b>Fluxes</b>   | <b>Miscellaneous</b>  |
|  | (1)  | PKS0745-19<br>Alt Name1: PKS0745-19-BCG  | RA: 07 47 31.3250 (116.8805208d)<br>Dec: -19 17 40.02 (-19.29445d)<br>Equinox: J2000 | Redshift: 0.1028                | V=18.2<br>Flux = $3.7 \cdot 10^{-14}$ erg/s/cm <sup>2</sup> at<br>H_alpha (6562 Angstrom) | Reference Frame: ICRS |
| <i>Comments: The V band magnitude was calculated for the core of the galaxy (it does not include the faint extended emission).<br/>                     Extended=YES</i> |  |  |  |                                 |   |                       |

Proposal 14669 - Visit 4 (05) - Ultramassive Black Holes in Brightest Cluster Galaxies

| Exposures | #      | Label          | Target                   | Config,Mode,Aperture           | Spectral Els.    | Opt. Params. | Special Reqs.                               | Groups                                      | Exp. Time (Total)/[Actual Dur.] | Orbit |
|-----------|--------|----------------|--------------------------|--------------------------------|------------------|--------------|---|---|---------------------------------|-------|
|           | 1      | FR716N         | (1) PKS0745-19           | ACS/WFC, ACCUM,<br>WFC1-IRAMPQ | FR716N<br>7260 A | CR-SPLIT=NO  |   | Pattern 5, Exps 1-1 i<br>n Visit 4 (05) (5) | 350 Secs (1050 Secs)            |       |
|           |        |                |                          |                                |                  |              |   |   | [==>(Pattern 1)]                | [1]   |
|           |        |                |                          |                                |                  |              |   |   | [==>(Pattern 2)]                |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 3)]                            |                                 |       |
| 2         | F850LP | (1) PKS0745-19 | ACS/WFC, ACCUM, WFC1-FIX | F850LP                         | CR-SPLIT=NO      |              | Pattern 6, Exps 2-2 i<br>n Visit 4 (05) (6) | 438 Secs (1314 Secs)                        |                                 |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 1)]                            | [1]                             |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 2)]                            |                                 |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 3)]                            | [2]                             |       |
| 3         | F475W  | (1) PKS0745-19 | ACS/WFC, ACCUM, WFC1-FIX | F475W                          | CR-SPLIT=NO      |              | Pattern 8, Exps 3-3 i<br>n Visit 4 (05) (8) | 433 Secs (1732 Secs)                        |                                 |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 1)]                            | [2]                             |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 2)]                            |                                 |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 3)]                            |                                 |       |
|           |        |                |                          |                                |                  |              |   | [==>(Pattern 4)]                            |                                 |       |

Orbit 1

Orbit Structure

