13385 - Is there a kicked supermassive black hole in E1821+643?

Cycle: 21, Proposal Category: GO

(Availability Mode: SUPPORTED)

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) E1821+643	ACS/WFC	1	12-Aug-2013 21:26:54.0	yes

1 Total Orbits Used

ABSTRACT

The formation of binary supermassive black holes (BBH) in galaxy centers appears to be an inevitable consequence of hierarchical structure formation. General Relativity predicts that, when a BBH coalesces, the merged SMBH recoils with a velocity that may reach several 1000 km/s. The luminous quasar E1821+643 is one of only 3 SMBH recoil candidates that have been identified via Doppler shifting of emission lines from the retained gas. This case is unique in that the Doppler shift is seen in both direct and scattered light, allowing us to infer a relative velocity of 2100 km/s between the quasar nucleus and host galaxy. By itself, this does not exclude alternative models such as a BBH or anisotropic wind, but follow-up spectroastrometric measurements reveal a relative displacement between the nucleus and the gas emitting the [OIII]4959,5007 lines that is consistent with the recoil hypothesis. The apparent displacement, however, could also be due to an asymmetric circum-nuclear distribution of the [OIII] emission. In order to distinguish

between these two possibilities we propose ACS/WFC ramp filter imaging in [OIII] to map the distribution of narrow-line emission on sub-arcsecond scales. The observations will also allow us to study the relationship between the narrow-line gas and the arcsecond-scale radio source, which has morphological features that may relate to precession in a BBH system, or a "spin-flip" following coalescence. With this modest investment of HST time we will take a key step in establishing the nature of the E1821+643 system, which may ultimately yield direct observational evidence for BBH coalescence and high velocity gravitational recoils.

OBSERVING DESCRIPTION

We propose to obtain high resolution (0.1") ACS/WFC images of the [OIII]4959, 5007 emission lines using the narrow (2% bandpass) ramp filter FR656N set to a central wavelength of 6460A. At the redshift of our target, E1821+643 (z=0.297), the filter bandwidth will comfortably include both [OIII] lines. We will also obtain short exposures with same filter at a central wavelength 6305A, centered on the broad Hbeta line, in order to characterize the quasar PSF. In addition, observations in FR647M, centered at 7300A, will be used for continuum subtraction.

The [OIII] emission line region of our target extends over ~ 5 arcsec, and as described in the science case we are primarily interested in the structure in the central ~1 arcsec, so the smaller field of view of the ramp filters is perfectly suited to our investigation.

As our science goals require mapping the spatial distribution of the [OIII] emission both within the inner arcsec and over the fainter, more diffuse extended region we will use a combination of short exposures to obtain high signal:noise (~100) but unsaturated images of the nucleus and longer exposures to map the extended structure on ~5 arcsec scales (signal:noise ~3-10). All exposures will be dithered to allow removal of hot pixels, cosmetic defects and cosmic rays.

We used the HST ACS ETC for ramp filters to estimate exposure times based on measurements from our Gemini data. The quasar nucleus has a continuum flux density 4.3E-15 erg s-1 cm-2 A-1 at 6614A (5100A rest wavelength). Using the ETC with an uploaded GEMINI/GMOS longslit spectrum of the nucleus and the default extraction aperture we estimate that we will obtain S/N~260 in FR656N with a total exposure time of 20s at both wavelength settings. We will reach a comparable S/N ratio in a total exposure time of 8s in the FR647M filter. The exposure times needed for the extended structure were based on obtaining a S/N ratio ~10 at a radial offset of 2 arcsec from the nucleus. Exposure times were estimated using average fluxes measured from 1" apertures offset 2" E, N, W and S of the nucleus. The average continuum flux density is 1.5E-17 erg s-1 cm-2 A-1 at 6614 A (5100A rest) and the total integrated flux in both [OIII] lines is 1.9E-15 erg s-1 cm-2. For ETC calculation we used Elliptical galaxy template 2 and added emission lines representing [OIII]4959,5007. For a 2x2 aperture, the ETC indicates that we will reach S/N ~7 in FR656N for a total exposure time of 400s. A total exposure time of 200s will yield a comparable S/N ratio in the FR647M filter.

The end product will be a high resolution map of the [OIII] emission around the nucleus of E1821+643 spanning ~0.1" to ~ 5". The 2-D surface brightness distribution will be used as input data for a code that simulates spectroastrometric displacement measurements for specified combinations

of point source and extended emission components. Given the input [OIII] surface brightness distribution and a point source which has a quasar spectrum (continuum and broad emission lines), we will use this code to generate simulated displacement spectra for cases where (1) the point source is located at the photocenter of the extended light distribution and (2) is offset by different distances from the photocenter (Fig. 4). These simulations will enable us to estimate the extent to which any anisotropies in the [OIII] surface brightness distribution contribute to the measured spectroastrometric displacement in [OIII] and thus determine if the observed displacement indicates gravitional recoil of the SMBH or can be entirely explained by asymmetric [OIII] emission. We will also combine the [OIII] images with archival radio data to investigate interactions between the arcsec-scale radio jets and the extended emission line gas.

Allowing for overheads associated with acquisition, instrument and repositioning overheads, we request 1 orbit for these observations.

Visit

Proposal 13385, Visit 01, implementation Tue Aug 13 01:27:03 GMT 2013

Diagnostic Status: Warning

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Diagnostics

([OIII]-long (01.001)) Warning (Form): POS TARG & PATTERN should be used carefully with ACS ramp or WFC3 quad filters as central wavelengths & transmission efficiencies vary within the apertures.

([OIII]-short (01.002)) Warning (Form): POS TARG & PATTERN should be used carefully with ACS ramp or WFC3 quad filters as central wavelengths & transmission efficiencies vary within the apertures.

(Hbeta (01.003)) Warning (Form): POS TARG & PATTERN should be used carefully with ACS ramp or WFC3 quad filters as central wavelengths & transmission efficiencies vary within the apertures.

(Continuum-long (01.004)) Warning (Form): POS TARG & PATTERN should be used carefully with ACS ramp or WFC3 quad filters as central wavelengths & transmission efficiencies vary within the apertures.

(Continuum-short (01.005)) Warning (Form): POS TARG & PATTERN should be used carefully with ACS ramp or WFC3 quad filters as central wavelengths & transmission efficiencies vary within the apertures.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.146 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=47.17 Angle Between Sides= Center Pattern=false		(1-2), (3), (4-5)

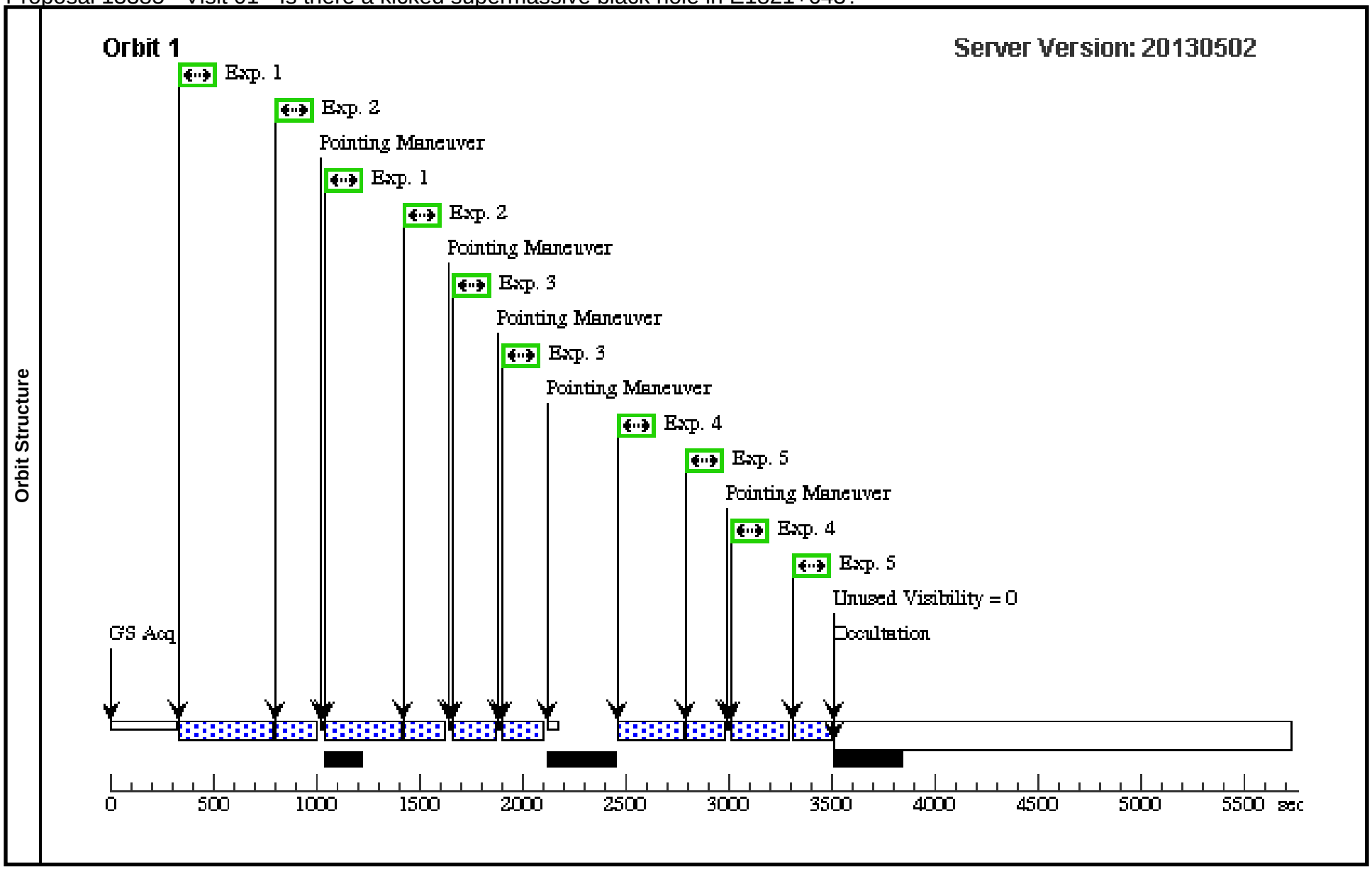
Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	E1821+643 Alt Name1: IRAS18216+6418 Alt Name2: H1821+643	RA: 18 21 57.2365 (275.4884854d) Dec: +64 20 36.23 (64.34340d) Equinox: J2000	Redshift: 0.297	V=14.24+/-0.1 nucleus continuum flux density 4.3E-15 erg s-1 cm-2 A-1 at 5100A (rest wavelength); average [OIII]4959+5007 flux = 1.9E-15 erg s-1 cm-2 in 1 arcsec aperture offset 2 arcsec from nucleus	Reference Frame: J2000

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	[OIII]-long (516902)	(1) E1821+643	ACS/WFC, ACCUM, WFC1-MRAMPQ	FR656N 6460 A			Pattern 1, Exps 1-2 in Visit 01 (1)	200 Secs (400 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***
2	[OIII]-short (516941)	(1) E1821+643	ACS/WFC, ACCUM, WFC1-MRAMPQ	FR656N 6460 A			Pattern 1, Exps 1-2 in Visit 01 (1)	25 Secs (50 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***
3	Hbeta (516964)	(1) E1821+643	ACS/WFC, ACCUM, WFC1-MRAMPQ	FR656N 6305 A			Pattern 1, Exps 3-3 in Visit 01 (1)	20 Secs (40 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***
4	Continuum-long (516884)	(1) E1821+643	ACS/WFC, ACCUM, WFC1-IRAMPQ	FR647M 7300 A			Pattern 1, Exps 4-5 in Visit 01 (1)	100 Secs (200 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***
5	Continuum-short (516974)	(1) E1821+643	ACS/WFC, ACCUM, WFC1-IRAMPQ	FR647M 7300 A			Pattern 1, Exps 4-5 in Visit 01 (1)	9 Secs (18 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***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Server Version: 20130502
Orbit Structure
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Exp. 2
Pointing Maneuver
Exp. 1
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Pointing Maneuver
Exp. 3
Pointing Maneuver
Exp. 3
Pointing Maneuver
Exp. 4
Exp. 5
Pointing Maneuver
Exp. 4
Exp. 5
Unused Visibility = 0
Occultation
GS Acq
0
500
1000
1500
2000
2500
3000
3500
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4500
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sec