17208 - Tick Tock, Time's Up: An Alternative to the Supermassive Black Hole Binary Scenario in J1430

Cycle: 30, Proposal Category: GO

(UV Initiative)

(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) 2MASS-J14301603+2303445	COS/FUV COS/NUV	2	11-Aug-2022 17:02:33.0	yes
02	(1) 2MASS-J14301603+2303445 CCDFLAT WAVE	STIS/CCD	1	11-Aug-2022 17:02:34.0	yes

3 Total Orbits Used

ABSTRACT

We propose 3 orbits of optical+UV spectroscopy to test the nature of the "Tick Tock" binary supermassive black hole candidate. J143016+230344 (hereafter J1430) was recently selected based on a rapidly evolving periodicity in its multi-band photometric light curve and is predicted to coalesce within the next 3 years. J1430 is an active galactic nucleus (AGN) and its broad H-alpha line has changed from single peaked with a -2400 km/s velocity offset to double peaked at the systemic velocity. In the binary scenario, this could indicate that the broad line initially traced bulk orbital motion of the secondary and now the newly formed circumbinary broad-line region. We will test the alternative scenario that J1430 is actually a variable single AGN with a perturbed accretion disk. By nearly-simultaneously observing the Ly-alpha, CIV, H-beta, and H-alpha broad emission lines and comparing the shapes of their profiles we can discriminate between (i) bulk orbital motion of the secondary in a binary, (ii) a newly formed circumbinary broad-line region, and (iii) a single black hole with dramatic photometric variability and an emissivity enhancement like a spiral arm in the outer disk where broad lines are produced. This test will arbitrate on the binary nature of J1430.

OBSERVING DESCRIPTION

SCIENTIFIC GOALS AND GENERAL STRATEGY

This program will use quasi-simultaneous optical and UV spectroscopy to test the nature of the binary supermassive black hole candidate J143016+230344 (hereafter J1430). The practical aim is to compare the Ly-alpha, CIV1549, H-beta, and H-alpha broad-line profiles to rule out the single disk alternative. We will observe J1430 for 2 orbits with COS/G140L to detect the broad Ly-alpha and CIV emission lines and determine their shape and velocity offsets relative to the emission lines in a quasi-simultaneous optical spectrum. We will follow with one STIS orbit to obtain coverage of the optical spectrum. This requires three setups: G430L to cover H-beta, and G750M at tilts of 6768A and 7283A to cover H-alpha. We will also obtain complementary ground-based optical spectra in order to look for changes in the broad H-alpha line before and after the HST observations.

TARGET PROPERTIES AND COORDINATES

The target has a redshift of 0.081, galactic E(B-V) value of 0.1, and current ZTF g-band and Swift UVW1 AB magnitudes of 17.466 and 18.8, respectively. Notably, the target brightened substantially since Sloan Digital Sky Survey (SDSS) imaging was taken in 2004. Though J1430 is nominally extended (the SDSS u-band exponential model radius is 0.4") in SDSS, the quasar continuum dominates recent spectra. Therefore, we anticipate that the AGN dominates in imaging in the UV and the morphology has a bright point source (i.e., it is not extended).

We obtained the target coordinates from the SDSS DR16 SkyServer. These coordinates are in the ICRS coordinate system. We computed astrometric

errors by following the prescription described in the SDSS DR16 web pages. In summary, the uncertainties in the astrometric solution of each plate are combined in quadrature with the uncertainties in the centroid of the object. The final uncertainties are listed in the target forms and are better than 0.1 arcsec.

SCHEDULING CONSIDERATIONS

We schedule this program as two visits so that no unnecessary constraints are imposed that might impact scheduling. Given the science requirement that the STIS spectrum be observed immediately before or after COS, we adopt the GROUP WITHIN scheduling constraint set to 1 orbit. This will automatically trigger the minimum time possible between orbits, and they will be taken consecutively.

Coordinated ground-based observations are needed in order to characterize the longer-term trends in the optical spectrum. This places very loose scheduling constraints on the HST observations. Given the coordinates of the target, we can obtain a ground-based spectrum during the period between the start of January and the middle of August.

COS INSTRUMENT SETUP

We will acquire the target with COS using ACQ/IMAGE in the NUV. This approach is recommended for targets with coordinate uncertainties <0.4 arcsec even if the science observations to follow are in the FUV. This is advantageous, because the acquisition exposure time to reach S/N=20 given the current magnitude is much shorter than using ACQ/PEAKXD+ACQ/PEAKD in the FUV. We will carry out the ACQ/IMAGE procedure with PSA+MIRRORB, a conservative choice that prioritizes detector safety if the target is brighter than expected (see below).

Science observations will be conducted with COS/G140L. As recommended to preserve the life of the detector and improve S/N in the FUV, we will use all FP-POS positions. In order to minimize overheads associated with these small movements, we will observe different positions in different orbits. We aim to keep exposure times in each position similar, but prioritized changing positions during occultation so that no time is lost. Buffer times for each exposure are set to the exposure time for that orbit, because the buffer fill time is extremely long for this target. This approach is advantageous because no data will be lost if the target is brighter than expected from the current magnitudes, which is possible because it is a variable quasar.

The bright object tool (BOT) reveals one unsafe exposure which we investigate further. The culprit is the acquisition exposure of the target itself. The Guide Star Catalog 2 (GSC2) lists the target at V(Vega)=13.89 mag and adopts a stellar spectrum of type OV5 to yield a high count rate per pixel, which triggers the warning. We verify the safety of our acquisition strategy via recent photometry and with further exposure time calculations. Given

recent ZTF g(AB)=17.145 and r(AB)=16.369 magnitudes, the inferred V(Vega)=16.71 is fainter than expected based on the BOT. However, we conservatively adopt MIRRORB for acquisition. This increases the required exposure time, but even if the target does have V(Vega)=13.89 the count rate per pixel will still be acceptable with the exposure time required to reach S/N=20 at g(AB)=17.466 (the latest magnitude from ZTF). This still triggers a warning from the BOT, which is due to the use of the incorrect stellar OV5 spectral shape. We verify in the ETC that usage of the correct SDSS quasar spectrum mitigates this issue.

STIS INSTRUMENT SETUP

To acquire the targets with STIS we will use the standard point-source acquisition sequence with the CCD. Since we are using the 52x0.5 arcsec slit, we will not need an ACQ/PEAK sequence. We adopt a 3-step dither pattern along the slit (step size 0.35 arcsec or 7 pix) to mitigate the effects of hot pixels and cosmic rays. To mitigate the effects of charge-transfer inefficiency, we will place the target at the recommended E1 (or E2 for exposures requiring Fringe Flats) aperture position. For the 52x0.5 slit, the E1 and E2 positions have similar throughput.

We schedule calibration observations to reduce overheads and prioritize science observations during the orbit. For the first STIS/CCD observation we select WAVECAL=NO, which turns off automatic wavelength calibration exposures for the entire visit. We manually include wavelength calibration for each of the G430L, G750M-6768, and G750M-7283 setups, pushing the final wavelength calibration into occultation. Additionally, G750M experiences substantial fringing at wavelengths longer than 7000 A, which could impact the G750M-7283 observations. We schedule the G750M-7283 science observation at the end of the orbit and include a contemporaneous fringe flat exposure during occultation (after the wavelength calibration) to correct fringing effects. All calibration exposures use the 52x0.1 arcsec slit recommended for science with the 52x0.5 arcsec slit.

IMPACT OF REDUCED-GYRO OPERATIONS

Reduced-gyro operations should not have a major impact specific to this program. A potential issue is that reduced gyro observations can impact COS observations if roll angle constraints are present in order to avoid putting the secondary aperture on a bright source when the primary aperture is on the target. No such constraints are required for this program according to the BOT. Other common impacts include the reduction of observing windows (especially for programs with constrains that reduce observability) and difficulty completing coordinated time-domain observations. Neither of these issues apply because we have only one 3-orbit visit with only very loose observing constraints.

Visit

Proposal 17208, Visit 01, implementation

Thu Aug 11 21:02:35 GMT 2022

Diagnostic Status: No Diagnostics

Scientific Instruments: COS/FUV, COS/NUV

Special Requirements: BETWEEN 01-JAN-2022:00:00:00 AND 15-AUG-2022:00:00:00; BETWEEN 01-JAN-2023:00:00:00 AND 15-AUG-2023:00:00:00; BETWEEN 01-JAN-2024:00:00:00 AND 15-AUG-2024:00:00:00; GROUP 01,02 WITHIN 1 Orbits

Fixed Targets

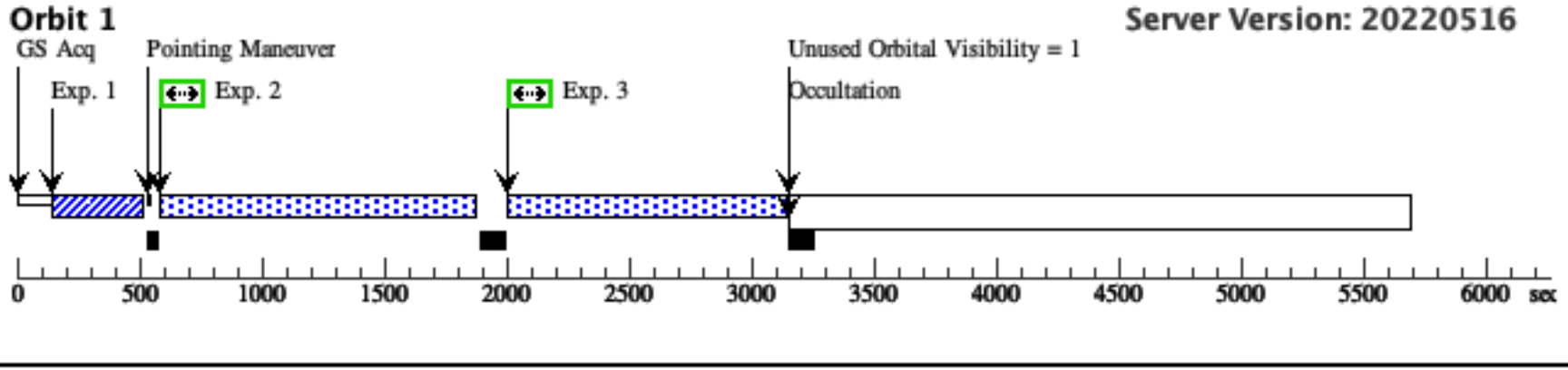
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	2MASS-J14301603+2303445	RA: 14 30 16.0538 (217.5668908d) Dec: +23 03 44.43 (23.06234d) Equinox: J2000	Proper Motion RA: -2.262009886373391 mas/yr Proper Motion Dec: 2.044207925416694 mas/yr Epoch of Position: 2016 Redshift: 0.081	V=16.7115+/-0.01 ZTF_g(MJD=59769)=17.466+/-0.023, Swift_UVW1(MJD~59300)~18.8	Reference Frame: ICRS

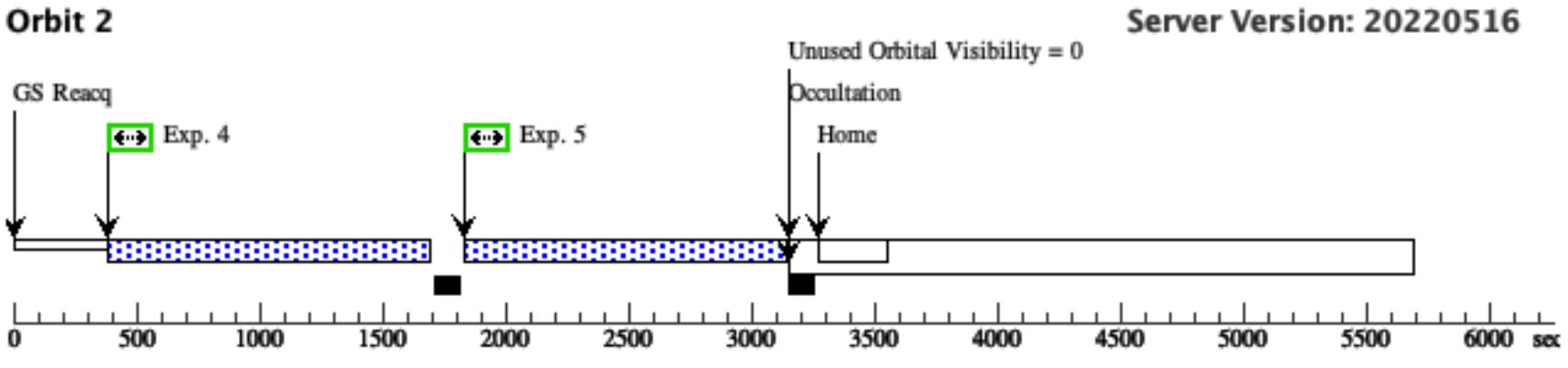
Comments: Target is variable AGN, latest magnitudes estimated from ZTF and Swift in 2022.
Category=GALAXY
Description=[SEYFERT]
Extended=NO

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	COS-ACQ (1814942)	(1) 2MASS-J14301603+2303445	COS/NUV, ACQ/IMAGE, PSA	MIRRORB				33 Secs (33 Secs) *[==>]*	***[1]***
2	COS-G140L-800-FP1 (1814307)	(1) 2MASS-J14301603+2303445	COS/FUV, TIME-TAG, PSA	G140L 800 A	BUFFER-TIME=1083; FLASH=YES; FP-POS=1			1138 Secs (1083 Secs) *[==>1083.0 Secs]*	***[1]***
3	COS-G140L-800-FP2 (1814307)	(1) 2MASS-J14301603+2303445	COS/FUV, TIME-TAG, PSA	G140L 800 A	BUFFER-TIME=1083; FLASH=YES; FP-POS=2			1138 Secs (1083 Secs) *[==>1083.0 Secs]*	***[1]***
4	COS-G140L-800-FP3 (1814307)	(1) 2MASS-J14301603+2303445	COS/FUV, TIME-TAG, PSA	G140L 800 A	BUFFER-TIME=1260; FLASH=YES; FP-POS=3			1279 Secs (1260 Secs) *[==>1260.0 Secs]*	***[2]***
5	COS-G140L-800-FP4 (1814307)	(1) 2MASS-J14301603+2303445	COS/FUV, TIME-TAG, PSA	G140L 800 A	BUFFER-TIME=1260; FLASH=YES; FP-POS=4			1279 Secs (1260 Secs) *[==>1260.0 Secs]*	***[2]***

Orbit Structure





Visit

Proposal 17208, Visit 02 Thu Aug 11 21:02:35 GMT 2022

Diagnostic Status: No Diagnostics

Scientific Instruments: STIS/CCD

Special Requirements: BETWEEN 01-JAN-2022:00:00:00 AND 15-AUG-2022:00:00:00; BETWEEN 01-JAN-2023:00:00:00 AND 15-AUG-2023:00:00:00; BETWEEN 01-JAN-2024:00:00:00 AND 15-AUG-2024:00:00:00; GROUP 02,01 WITHIN 1 Orbits

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=STIS-ALONG-SLIT	Coordinate Frame=POS-TARG		(3), (5), (6)
	Purpose=DITHER	Pattern Orientation=90.0		
	Number Of Points=3	Angle Between Sides=		
	Point Spacing=0.35	Center Pattern=true		
	Line Spacing=			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	2MASS-J14301603+2303445	RA: 14 30 16.0538 (217.5668908d) Dec: +23 03 44.43 (23.06234d) Equinox: J2000	Proper Motion RA: -2.262009886373391 mas/yr Proper Motion Dec: 2.044207925416694 mas/yr Epoch of Position: 2016 Redshift: 0.081	V=16.7115+/-0.01 ZTF_g(MJD=59769)=17.466+/-0.023, Swift_UVW1(MJD~59300)~18.8	Reference Frame: ICRS

Comments: Target is variable AGN, latest magnitudes estimated from ZTF and Swift in 2022.
Category=GALAXY
Description=[SEYFERT]
Extended=NO

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	STIS-ACQ (1814331)	(1) 2MASS-J14301603+2303445	STIS/CCD, ACQ, F28X50LP	MIRROR	ACQTYPE=POINT			2 Secs (2 Secs) *[==>]*	***[1]***
2	G430L wavecal	WAVE	STIS/CCD, ACCUM, 52X0.1	G430L 4300 A				*[==>]*	***[1]***
3		(1) 2MASS-J14301603+2303445	STIS/CCD, ACCUM, 52X0.5E1	G430L 4300 A	CR-SPLIT=NO; WAVECAL=NO		Pattern 1, Exps 3-3 in Visit 02 (1)	67 Secs (180 Secs) *[==>60.0 Secs (Pattern 1)]* *[==>60.0 Secs (Pattern 2)]* *[==>60.0 Secs (Pattern 3)]*	***[1]***
4	G750M-6768 wavecal	WAVE	STIS/CCD, ACCUM, 52X0.1	G750M 6768 A				*[==>]*	***[1]***
5		(1) 2MASS-J14301603+2303445	STIS/CCD, ACCUM, 52X0.5E1	G750M 6768 A	CR-SPLIT=NO		Pattern 1, Exps 5-5 in Visit 02 (1)	189 Secs (546 Secs) *[==>182.0 Secs (Pattern 1)]* *[==>182.0 Secs (Pattern 2)]* *[==>182.0 Secs (Pattern 3)]*	***[1]***
6		(1) 2MASS-J14301603+2303445	STIS/CCD, ACCUM, 52X0.5E2	G750M 7283 A	CR-SPLIT=NO		Pattern 1, Exps 6-6 in Visit 02 (1)	209 Secs (606 Secs) *[==>202.0 Secs (Pattern 1)]* *[==>202.0 Secs (Pattern 2)]* *[==>202.0 Secs (Pattern 3)]*	***[1]***
7	G750M-7283 wavecal	WAVE	STIS/CCD, ACCUM, 52X0.1	G750M 7283 A				*[==>]*	***[1]***
8	FRINGE-FLAT-7283	CCDFLAT	STIS/CCD, ACCUM, 52X0.1	G750M 7283 A				*[==>(Copy 1)]* *[==>(Copy 2)]*	***[1]***

Orbit Structure