



16649 - The final word on SN 2009ip: is it dead?

Cycle: 29, Proposal Category: GO

(UV Initiative)

(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>
01	(1) SN2009IP	WFC3/UVIS	1	07-Oct-2021 12:00:29.0	yes
02	(1) SN2009IP	WFC3/UVIS	2	07-Oct-2021 12:00:30.0	yes
03	(1) SN2009IP	WFC3/UVIS	1	07-Oct-2021 12:00:30.0	yes
04	(1) SN2009IP	WFC3/IR	1	07-Oct-2021 12:00:31.0	yes

5 Total Orbits Used

ABSTRACT

We propose 10 yr post-explosion UV/optical imaging of the remarkable transient SN 2009ip, in order to determine its ultimate fate. This object was discovered in a non-terminal eruption in 2009, and then appeared to explode in a much more extreme supernova (SN)-like event in 2012. A very

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massive (80 Msun) quiescent progenitor was identified in an archival HST image, and the star had several luminous blue variable (LBV)-like eruptions before 2012. Many SNe IIn are inferred to have LBV progenitors to make their dense circumstellar material (CSM), but SN2009ip is an extraordinary case where the LBV-like progenitor was detected directly, and where spectra of numerous pre-SN eruptions were obtained. No other SN has this treasure trove of detailed information about the progenitor (not even SN1987A). This was one of the most important transient events of the past decade, because if it was a true core-collapse (CC) SN, then it is the first definitive case of a very massive star above 30 Msun that went SN and didn't collapse to a black hole. However, the interpretation of SN2009ip as a true CCSN is controversial for 2 reasons: (1) its lightcurve could also be explained by shell collisions from non-terminal explosive transients, and (2) the tell-tale signs of nucleosynthetic products, if present, were largely masked by CSM interaction. As with all SN progenitor candidates, proof that the star is dead requires that it disappear in late time data. Five years ago the source was only marginally fainter than the progenitor and apparently still fading. Cycle 29 will be 10 years since explosion. Our proposed observations will determine once and for all if the progenitor is gone.

OBSERVING DESCRIPTION

The goal of these observations is to measure the UV/optical/IR spectral energy distribution (SED) and H-alpha emission line strength of the source at SN 2009ip's position at a time of roughly 10 years after its 2012 explosion. If the source at SN 2009ip's position has faded beyond detectability, these observations will place deep-enough upper limits on a late-time source to confirm that the progenitor star is gone. If a detectable source remains, the observations are designed to be able to distinguish between three competing possibilities: (1) A massive luminous blue variable (LBV) progenitor star that survived, possibly obscured by dust that was ejected in the event or returning to a hot state, (2) A SN explosion where the late-time source is dominated by ongoing late-time circumstellar material (CSM) interaction, or (3) A companion star or star cluster that is coincident with the SN position. Of course, the late time source may be due to a combination of these sources, and the UV/optical/IR SED plus H-alpha emission will be able to distinguish them. It is impossible to rule out or distinguish between these possibilities with only optical/IR continuum filters; both the UV flux and the H-alpha emission are essential as well.

Although we have organized the observations into separate visits, they should be executed as close together in time as possible. Whether the lingering source is a SN powered by late-time CSM interaction or a surviving LBV star, it is likely to be variable. LBVs can vary on short (few days) timescales, and late-time CSM interaction luminosity can change quickly if the CSM is clumpy or has shell structure. In order to produce a useful SED to test the various hypotheses, the full continuum broad-band set of filters from UV to IR must be obtained close together in time.

Most importantly, the narrow F657N filter (tracing H-alpha emission) should be obtained as close to quasi-simultaneously with the F555W, F606W,

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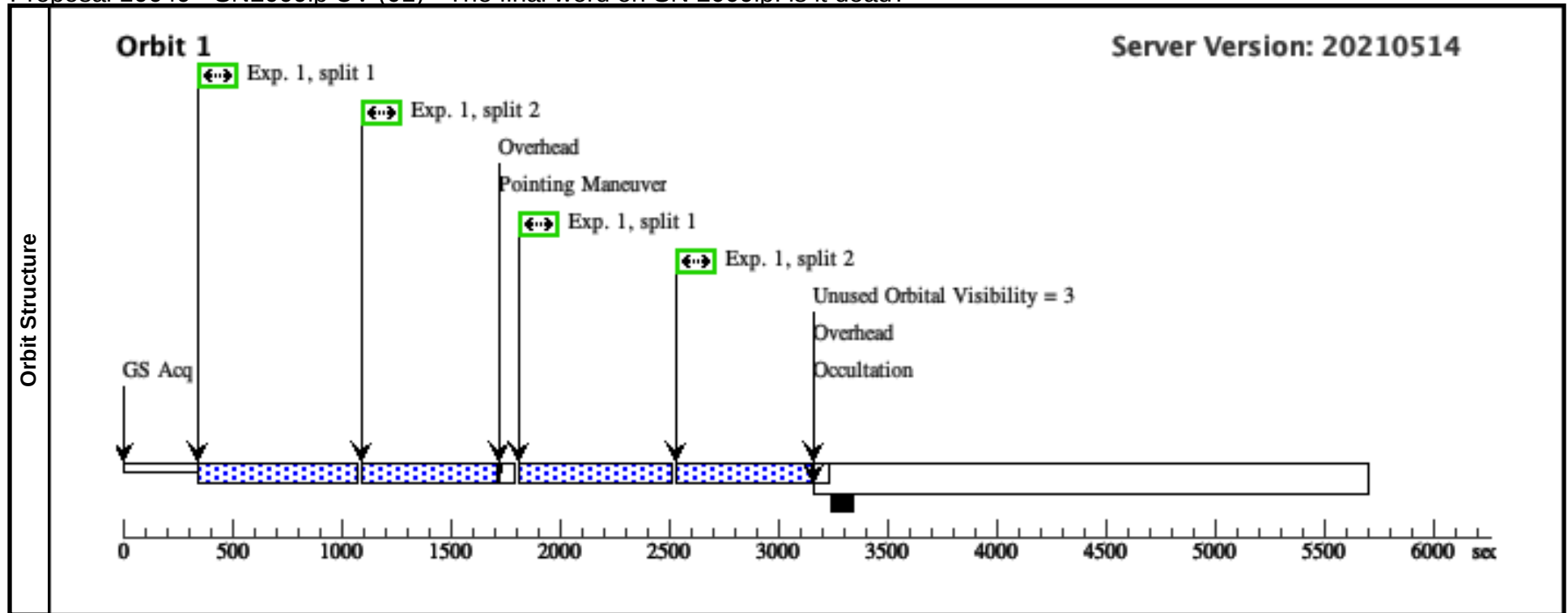
and F814W filter images as possible. The F657N filter will be used to measure the equivalent width of H-alpha emission - but to do this, we need to know the off-line optical continuum emission level measured by the F555W, F606W, and F814W filters at the same time. Both the continuum luminosity and H-alpha emission can be variable (and they may be independently variable). It is impossible to complete the science goals of this program without comparably deep optical continuum filters to subtract from the H-alpha filter.

Also, it will greatly improve the archival value of the images if the F657N and broad continuum filters (at least F555W and F814W) are obtained at nearly the same time, with the SN located at the same position on the detector, and with the same roll angle. This is because well-aligned and simultaneous continuum images are needed to make a continuum-subtracted image of the H-alpha emission. We do not strictly need this spatial alignment to complete the goal of measuring the H-alpha equivalent width from SN 2009ip (we could do this even if the target were at a slightly different position on the detector, as long as the observations were close in time). However this alignment is needed in order to make a continuum-subtracted H-alpha emission map of the surrounding environment in the host galaxy in order to study star forming HII regions or search for emission line stars, for example. It would significantly decrease the archival value if the F657N and broad-band filters were not obtained with the same target position on the detector and a very close roll angle. This is because the differences in distortion correction and pixel resampling are minimized or eliminated when the roll angle and field of view are the same, and obviously, the overlapping area on the sky in the F657N and continuum filters is optimum if they are spatially aligned.

If it turns out that there is a source remaining at SN2009ip's position and that source is consistent with a star cluster contributing to the observed light, the UV/optical/IR SED will be used to constrain the age of that cluster with comparison to population synthesis models. If the remaining light is a combination of a star cluster (presumably not variable) and late-time CSM interaction (variable) then the SED would be corrupted if images in different filters are obtained at significantly different times.

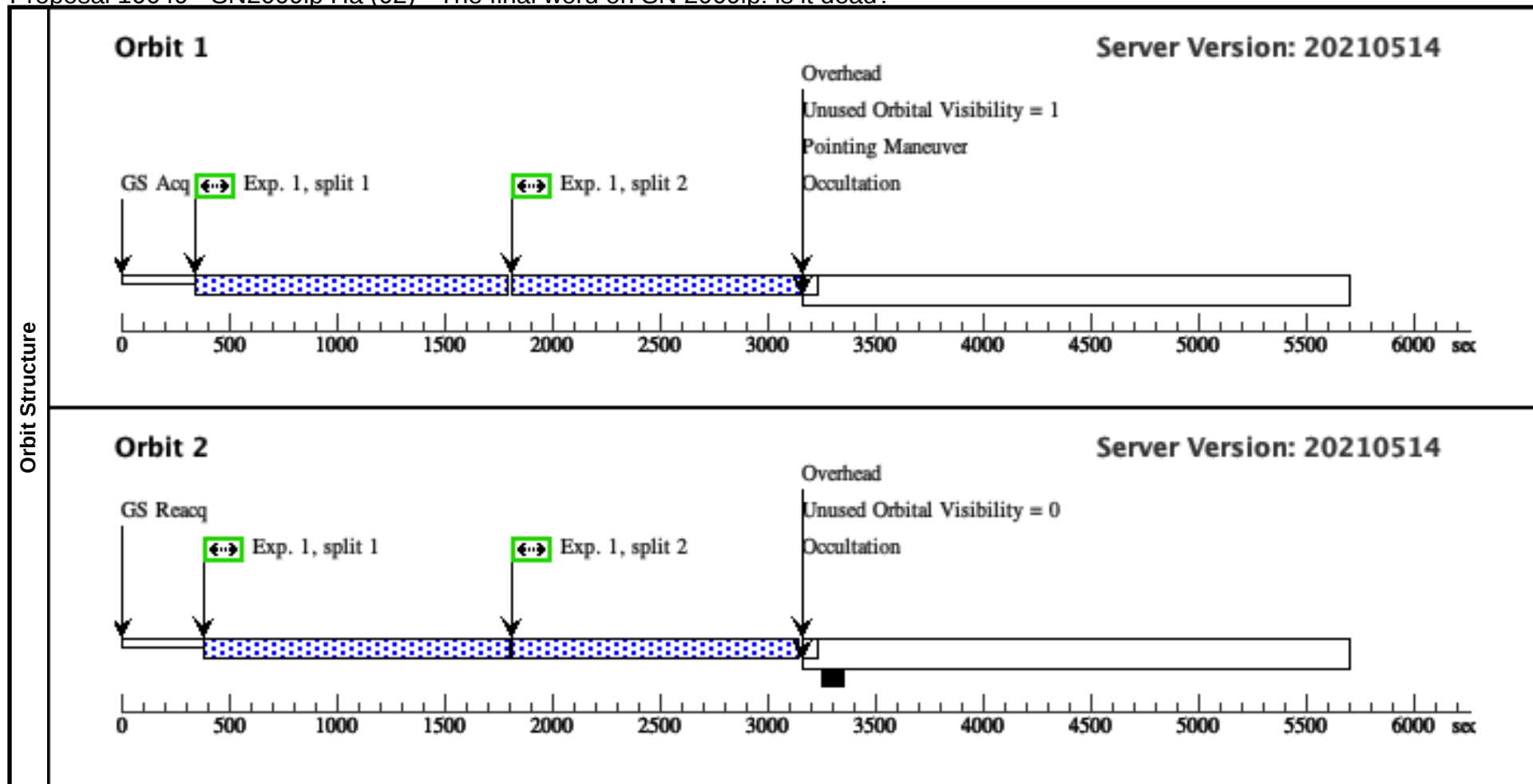
Proposal 16649 - SN2009ip UV (01) - The final word on SN 2009ip: is it dead?

Visit	Proposal 16649, SN2009ip UV (01), implementation										Thu Oct 07 16:00:31 GMT 2021
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: GROUP 01,02,03 WITHIN 1D										
Patterns	#	Primary Pattern				Secondary Pattern				Exposures	
	(2)	Pattern Type=WFC3-UVIS-DITHER-LINE Coordinate Frame=POS-TARG Pattern Orientation=46.84 Purpose=DITHER Angle Between Sides= Number Of Points=2 Center Pattern=false Point Spacing=0.145 Line Spacing=								(1)	
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections		Fluxes		Miscellaneous		
	(1)	SN2009IP	RA: 22 23 8.2600 (335.7844167d) Dec: -28 56 52.40 (-28.94789d) Equinox: J2000		Epoch of Position: 2015.5		V=22		Reference Frame: SIMBAD		
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.										
	Category=STAR Description=[EMISSION LINE STAR, LUMINOUS BLUE VARIABLE, SUPERNOVA TYPE II] Extended=NO										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	UV	(1) SN2009IP	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F275W	FLASH=20; CR-SPLIT=2	GS ACQ SCENARIO BASE1B3	Pattern 2, Exps 1-1 in SN2009ip UV (01) (2)	900 Secs (2480 Secs)		[1]
									[==>620.0 Secs (Pattern 1, Split 1)]		
									[==>620.0 Secs (Pattern 1, Split 2)]		
								[==>620.0 Secs (Pattern 2, Split 1)]			
								[==>620.0 Secs (Pattern 2, Split 2)]			



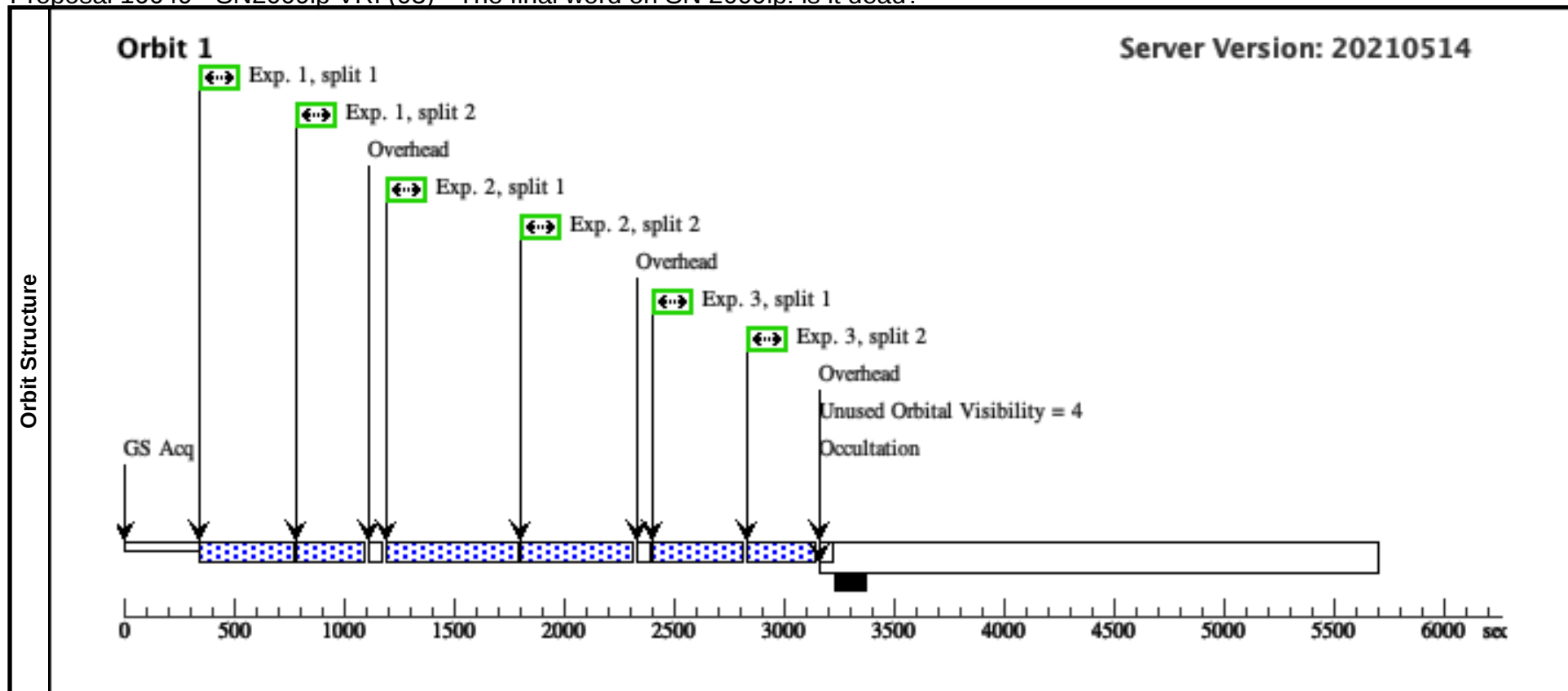
Proposal 16649 - SN2009ip Ha (02) - The final word on SN 2009ip: is it dead?

Visit	Proposal 16649, SN2009ip Ha (02), implementation										Thu Oct 07 16:00:31 GMT 2021	
	Diagnostic Status: Warning											
	Scientific Instruments: WFC3/UVIS											
	Special Requirements: SAME ORIENT AS 01											
Diagnostics	(HalpHa (02.001)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser											
Patterns	#	Primary Pattern					Secondary Pattern				Exposures	
	(2)	Pattern Type=WFC3-UVIS-DITHER-LINE Coordinate Frame=POS-TARG Pattern Orientation=46.84 Purpose=DITHER Angle Between Sides= Number Of Points=2 Center Pattern=false Point Spacing=0.145 Line Spacing=									(1)	
Fixed Targets	#	Name		Target Coordinates		Targ. Coord. Corrections		Fluxes		Miscellaneous		
	(1)	SN2009IP		RA: 22 23 8.2600 (335.7844167d) Dec: -28 56 52.40 (-28.94789d) Equinox: J2000		Epoch of Position: 2015.5		V=22		Reference Frame: SIMBAD		
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.											
	Category=STAR Description=[EMISSION LINE STAR, LUMINOUS BLUE VARIABLE, SUPERNOVA TYPE II] Extended=NO											
Exposures	#	Label	Target	Config,Mode,Aperture		Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	HalpHa	(1) SN2009IP	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB		F657N	FLASH=20; CR-SPLIT=2	GS ACQ SCENARI O BASE1B3	Pattern 2, Exps 1-1 i n SN2009ip Ha (02) (2)	2540 Secs (5344 Secs)		
										[==>1338.0 Secs (Pattern 1, Split 1)] [==>1338.0 Secs (Pattern 1, Split 2)]		[1]
											[==>1334.0 Secs (Pattern 2, Split 1)] [==>1334.0 Secs (Pattern 2, Split 2)]	



Proposal 16649 - SN2009ip VRI (03) - The final word on SN 2009ip: is it dead?

Visit	Proposal 16649, SN2009ip VRI (03), implementation										Thu Oct 07 16:00:31 GMT 2021
	Diagnostic Status: Warning										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: SAME ORIENT AS 01										
Diagnostics	(I (03.001)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser										
	(V (03.002)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser										
	(R (03.003)) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser										
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous					
	(1)	SN2009IP	RA: 22 23 8.2600 (335.7844167d) Dec: -28 56 52.40 (-28.94789d) Equinox: J2000	Epoch of Position: 2015.5	V=22	Reference Frame: SIMBAD					
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.										
	Category=STAR										
	Description=[EMISSION LINE STAR, LUMINOUS BLUE VARIABLE, SUPERNOVA TYPE II] Extended=NO										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1	I	(1) SN2009IP	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	CR-SPLIT=2; FLASH=5	GS ACQ SCENARI O BASE1B3		600 Secs (634 Secs)		
									[==>317.0 Secs (Split 1)]	[1]	
									[==>317.0 Secs (Split 2)]		
	2	V	(1) SN2009IP	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	CR-SPLIT=2			1000 Secs (1034 Secs)		
									[==>517.0 Secs (Split 1)]	[1]	
									[==>517.0 Secs (Split 2)]		
	3	R	(1) SN2009IP	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	CR-SPLIT=2			600 Secs (634 Secs)		
									[==>317.0 Secs (Split 1)]	[1]	
								[==>317.0 Secs (Split 2)]			



Proposal 16649 - SN2009IP IR (04) - The final word on SN 2009ip: is it dead?

Visit	Proposal 16649, SN2009IP IR (04), implementation Thu Oct 07 16:00:31 GMT 2021				
	Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/IR Special Requirements: (none)				
Patterns	#	Primary Pattern		Secondary Pattern	Exposures
	(1)	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			(1-2)
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes
	(1)	SN2009IP	RA: 22 23 8.2600 (335.7844167d) Dec: -28 56 52.40 (-28.94789d) Equinox: J2000	Epoch of Position: 2015.5	V=22
Fixed Targets	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. Category=STAR Description=[EMISSION LINE STAR, LUMINOUS BLUE VARIABLE, SUPERNOVA TYPE II] Extended=NO				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.
	1	(1) SN2009IP	WFC3/IR, MULTIACCUM, IR	F125W	NSAMP=12; SAMP-SEQ=STEP1 00
Exposures					Special Reqs.
					Pattern 1, Exps 1-2 in SN2009IP IR (04) (1)
Exposures					Exp. Time (Total)/[Actual Dur.]
					599.232292 Secs (1198.465 Secs)
Exposures					[==>(Pattern 1)]
					[==>(Pattern 2)]
Exposures					Orbit
					[1]
Exposures	2	(1) SN2009IP	WFC3/IR, MULTIACCUM, IR	F160W	NSAMP=13; SAMP-SEQ=STEP1 00
					Pattern 1, Exps 1-2 in SN2009IP IR (04) (1)
Exposures					Exp. Time (Total)/[Actual Dur.]
					699.232615 Secs (1398.465 Secs)
Exposures					[==>(Pattern 1)]
					[==>(Pattern 2)]
Orbit Structure	Orbit 1 Server Version: 20210514				
	Unused Orbital Visibility = 28				