European Organisation for Astronomical Research in the Southern Hemisphere
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APPLICATION FOR OBSERVING TIME **114.27G5**

IMPORTANT NOTICE

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted.

ALMA + MUSE environment observations to reveal the nature of Type Ic supernova progenitors

ABSTRACT

Core-collapse supernovae (SNe) are the final fate of massive stars (> 8 Msun) as very energetic explosions, injecting significant thermal and kinetic feedback to the interstellar medium, being a key mechanism that models the galaxy formation and evolution. However, it is not clear the nature of progenitor stars for Type Ic SNe and their association to the regions of star formation efficiency (or gas depletion time) because previous observations were not able to reach both molecular cloud and HII region spatial scales (~ 100 pc), and/or were affected by the low statistical sample size. We plan to use ALMA CO(2-1) archival data and achieve VLT/MUSE optical observations to identify Type Ic SN environments at scales of molecular clouds and HII regions for a statistically significant sample in order to constrain their nature.

SCIENTIFIC KEYWORDS

stars: supernovae, ISM: clouds, ISM: HII regions, galaxies: evolution, stars: binaries

RUNS

Run	Period	Instrument	Tel. Setup	Constraints	Mode	Type	Propr. Time	Time Constr.	Req. Time
114.27G5.001 • Run 1	114	MUSE	UT4	FLI: 80% • Turb.: 85% • pwv: 20.0mm • Sky: Variable, thin cirrus	SM	Normal	12m	×	18h31m

AWARDED AND FUTURE TIME REQUESTS

Time already awarded to this project

- none -

Future time requests to complete this project

- none -

Special Remarks

N/A.

DESCRIPTION OF THE PROPOSED PROGRAMME

A- Scientific Rationale

Immediate environments of Type Ic supernovae.

Supernovae (SNe) play a major role in the origin of elements and are the most important component in order to simulate the dynamics of the interstellar medium (ISM; Girichidis et al. 2016). However, the association between progenitor stars and the resulting SNe is poorly understood and one approach to mitigate this is to study in details the properties of the immediate environment. **We propose to test the nature of the progenitors of Type Ic SNe using the multi-phase ISM at spatial scales comparable to giant molecular clouds (GMCs) and star-forming (HII) regions (~ 100 pc) in nearby galaxies for a statistically significant sample**.

Core-collapse SNe (CCSNe) are the fate of massive stars (> 8 $M_\odot$). The spectra of Type II SNe show features of hydrogen and helium lines, whereas for Type Ic these features are not observed (Filippenko 1997). The lack of these lines is because the progenitors' outer layers were stripped. The dominant mechanism responsible for this difference is still a matter of debate with two different processes proposed. It could be due to strong stellar winds from the very massive star itself (Woosley, Langer & Weaver 1995) or due to mass transfer in binary interaction within less massive stars (Podsiadlowski, Joss & Hsu 1992). This distinction has important consequences for the contribution of Type Ic SNe to chemical enrichment and feedback.

Several properties of progenitor stars can be inferred using optical integral field unit spectrographs (e.g. MUSE) from the study of the immediate environment where the SN exploded, such as star formation rate (SFR), metallicity, stellar population age and extinction. Simultaneously, carbon monoxide (CO) observations provide features of molecular gas in GMCs (e.g. ALMA). The availability of both observations make it possible to obtain maps of star formation efficiency/depletion time, together with the star formation (SF) law in a given region, being a direct probe to investigate the physical processes affecting star-forming regions together with GMC formation and disruption.

Previous works attempted to study the SN environments for a large sample (e. g., Anderson et al., 2015; Galbany et al., 2017, 2018). However, the direct connection between a progenitor and SN was not possible to be established due to low spatial resolution not able to resolve the GMC/HII region scales. For high-resolution environmental studies at SN positions, recent works analysed the parent GMCs (Mayker Chen et al., 2023) and the HII regions (Pessi et al., 2023) at spatial scales that resolve these structures, thanks to ALMA and MUSE facilities, respectively. However, their sample sizes of Type Ic SNe were too small to draw any strong conclusions on their progenitors. This motivates us to constrain Type Ic SN progenitor properties, identifying their multi-phase ISM at GMC and HII region scales for a statistically significant sample.

In order to constrain SN environments for a statistically significant sample, we collected archival CO(2-1) ALMA data in the local universe (< 55 Mpc, to reach the spatial resolution required), gathering a total of 30 Type II and 21 Type Ic SNe.

Progenitors of Type II SNe have masses between 8–16 $M_\odot$ (Smartt 2015) and under the assumption of very massive single stars as progenitors of Type Ic SNe (for masses of 30–100 $M_\odot$ with lifetimes of 7–3 Myr, respectively; Zapartas et al., 2017), it is expected that the respective parent GMC might not have been dispersed before the SN explosion due to a short progenitor lifetime, and the progenitors would not have enough time to shift away from their birth places significantly. Figure 1 displays the empirical cumulative distribution function (eCDF) for the molecular gas mass surface density ($\Sigma_{\rm mol}$) at the positions of Type II and Ic SNe. The distributions are consistent with each other, suggesting that their progenitors have comparable lifetimes, and hence, similar initial masses, suggesting that the binary interaction model (mass exchange due to a companion) is the main mechanism extracting the outer layers for most of Type Ic SN progenitors.

The cross-match between available ALMA and MUSE data results in a total of 21 Type II and 7 Type Ic SNe. Figure 2 shows the positions of the SNe with respect to the SF law (Kennicutt 1998) from their host galaxies (Leroy et al., 2021; Emsellem et al., 2022). **From this figure it is clear that it is not possible to establish strong conclusions on the similarity or difference of the Type II and Ic SN positions given the low sample size for Type Ic SNe.**

To assess the statistical significance of the sample size, we drawn synthetic samples of Type II SN progenitors and massive stars from the ranges of 6–20 $M_\odot$ and 20–100 $M_\odot$, respectively, weighting by the Kroupa initial mass function (IMF; Kroupa 2001). We randomly assigned an age according to the age probability distribution of SN progenitors for a given initial mass according to the models of Zapartas et al. (2017), that take into account binarity. Figure 3 shows the percentages of p–values below 0.05 (to reject the null hypothesis) for 10 000 Monte Carlo simulations from a Kolmogorov-Smirnov two sample test between the distributions of the 30 random values of Type II SNe and the massive stars, as a function of sample size for such massive stars, in order to test if we can distinguish each simulated pair of sets. For a sample size of 21 Type Ic SNe, we obtained that $\sim 98\%$ of p–values are lower than 0.05. This means that we have statistical significance to correctly reject the null hypothesis and if Type Ic SNe were very massive stars, then we would obtain a lower p–value for virtually all the cases, so our data have enough statistical significance to rule out the very massive star hypothesis. This is the sample size we propose to obtain here.

B- Immediate Objective

The first high-resolution survey of Type Ic supernova environments (ALMA+MUSE).

We aim to increase the current sample of 7 Type Ic SNe with another 14 such sources using MUSE. This is the maximum available sample within the local universe (< 55 Mpc, at HII region spatial scales) having high-resolution ALMA CO observations. This will allow us to characterise the immediate environments of Type Ic SNe: molecular gas mass, SFR, star formation efficiency/depletion time, metallicity, stellar population age, and extinction.

These properties will be compared to Type II SN locations to test if there are any differences between the two SN types. To do so, statistical tests will be used to find if the distributions of the mentioned parameters are drawn from the same parent population, yielding important insights on the properties of progenitor stars. If both types of SNe are located in similar environments, this will prove binary progenitor models for Type Ic SNe. In case there is significant difference from any of the parent population computed, e.g. stronger associations of Type Ic SNe with SFR, this could be explained within a scenario in which: 1) the binarity fraction prefer regions of high stellar density, 2) the binarity fraction prefer more top-heavy initial mass function, or 3) higher initial masses than Type II SNe.

Independently on the results of these observations, our findings will have essential impact in stellar evolution models of massive stars and how the ISM is affected by them. This can be used to compute the SN metal production, and be implemented in sub-grid processes in order to improve the feedback and chemical mixing in numerical cosmological simulations.

Figures

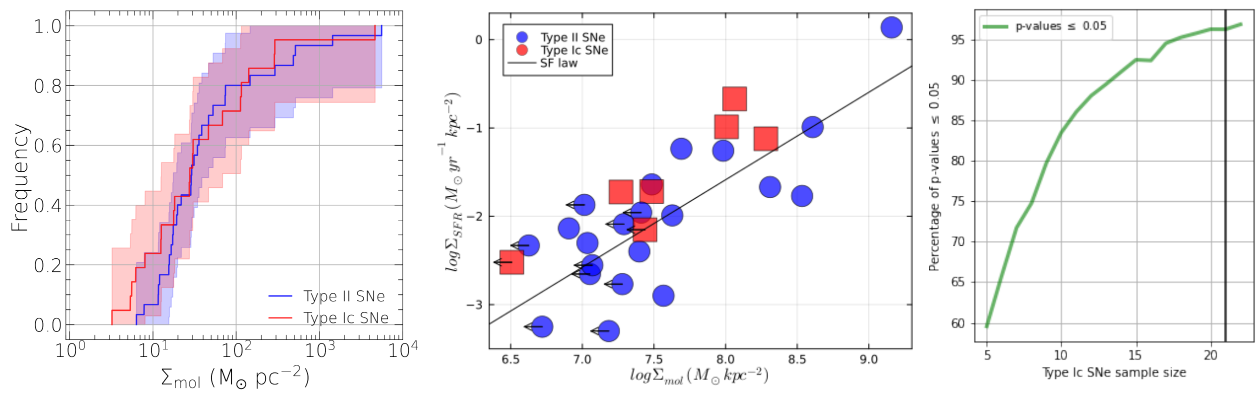

Fig.1 (left) eCDFs of $\Sigma_{\rm mol}$ SN locations for Type II and Ic SNe, in blue and red lines, respectively. The shaded areas represent confidence intervals at 1σ. Fig.2 (middle). Star formation rate (Σ_{SFR}) as a function of molecular surface densities. Type II and Ic SNe are represented as blue circles and red squares, respectively. The black line represents the SF law for their galaxy hosts. In case of non-detections, black arrows are included. Fig. 3 (right) Statistical significance of the sample size. Percentage of p–values below 0.05 as a function of the sample size of Type Ic SNe using 10 000 Monte Carlo repetitions (green line), assuming that they are very massive stars. The vertical horizontal black line is the number of Type Ic SNe used in our sample.

References

1. Anderson J. P., James P. A., Habergham S. M., Galbany L., Kuncarayakti H., 2015, PASA, 32, e019. **2.** Emsellem E., Schinnerer E., Santoro F., Belfiore F., Pessa I., McElroy R., Blanc G. A., et al., 2022, A&A, 659, A191. **3.** Filippenko A. V., 1997, ARA&A, 35, 309. **4.** Galbany L., Mora L., Gonzalez-Gaitan S., Bolatto A., Dannerbauer H., Lopez-Sanchez A. R., Maeda K., et al., 2017, MNRAS, 468, 628. **5.** Galbany L., Anderson J. P., Sanchez S. F., Kuncarayakti H., Pedraz S., Gonzalez-Gaitan S., Stanishev V., et al., 2018, ApJ, 855, 107. **6.** Girichidis P., Walch S., Naab T., Gatto A., Wunsch R., Glover S. C. O., Klessen R. S., et al., 2016, MNRAS, 456, 3432. **7.** Kennicutt R. C., 1998, ApJ, 498, 541.A **7.** Kroupa P., 2001, MNRAS, 322, 231. **9.** Mayker Chen N., Leroy A. K., Lopez L. A., Benincasa S., Chevance M., Glover S. C. O., Hughes A., et al., 2023, ApJ, 944, 110. **10.** Leroy A. K., Schinnerer E., Hughes A., Rosolowsky E., Pety J., Schruba A., Usero A., et al., 2021, ApJS, 257, 43. **11.** Pessi T., Prieto J. L., Anderson J. P., Galbany L., Lyman J. D., Kochanek C., Dong S., et al., 2023, A&A, 677, A28. **12.** Podsiadlowski P., Joss P. C., Hsu J. J. L., 1992, ApJ, 391, 246. **13.** Smartt S. J., 2015, PASA, 32, e016. **14.** Woosley S. E., Langer N., Weaver T. A., 1995, ApJ, 448, 315. **15.** Zapartas E., de Mink S. E., Izzard R. G., Yoon S.-C., Badenes C., Götberg Y., de Koter A., et al., 2017, A&A, 601, A29. doi:10.1051/0004-6361/201629685

TARGETS

Name	RA	Dec	Coord	Runs	Comment
LSQ 13doo	11:48:45.780	-28:17:31.200	J2000	1	
V=15					
SN 1994ai	02:23:06.169	-21:14:09.300	J2000	1	
V=17					
SN 1997dq	11:40:55.900	11:28:45.699	J2000	1	
V=15					
SN 2003aa	10:46:36.820	13:45:32.199	J2000	1	
V=17.6					
SN 2003jg	09:45:38.400	-31:11:19.899	J2000	1	
V=17					
SN 2005lr	07:11:39.030	-26:42:20.199	J2000	1	
V=18.5					
SN 2009em	00:34:44.530	-08:23:57.599	J2000	1	
V=16.6					
SN 2009gd	15:48:22.789	-75:40:47.799	J2000	1	
V=16.3					
SN 2011hp	12:16:25.469	-43:19:46.899	J2000	1	
V=15.7					
SN 2011jl	10:43:02.950	-36:21:52.400	J2000	1	
V=15					
SN 2012ap	05:00:13.720	-03:20:51.200	J2000	1	
B=17.79; V=16.71; R=16.23; I=15.78					
SN 2012cw	10:13:47.950	03:26:02.600	J2000	1	
V=16.5					
SN 2014ad	11:57:44.440	-10:10:15.700	J2000	1	
B=17.787					
SN2018lei	02:33:34.333	-39:02:42.407	J2000	1	
V=16.8					

Target Notes

These targets consist in 14 Type Ic SN environments already observed in ALMA CO(2-1).

REMARKS & JUSTIFICATIONS

Lunar Phase and Constraints Justification

Please justify here the requested lunar phase and other observing constraints. (Anonymized)

To reach the desired S/N ~ 5, using Moon FLI = 90% and Moon FLI = 100%, x1.3 and x4.0 times more of integration time would be needed than for Moon FLI = 80%, justifying an optimal time for our targets for most of the nights, with relatively bad weather conditions (Airmass: 1.8, Turbulence = 85%, PWV = 20 mm, Sky: Variable, thin cirrus) during the cycle.

Time Justification

Please describe here a detailed computation of the necessary time to execute the observations, including time-critical aspects if any. Parameters used in the ETC should be mentioned so the computation can be reproduced. (Anonymized)

We plan to study environments of Type Ic SNe by detecting regions of star formation (HII regions; Hα, Hβ), emission lines from ionised gas to infer metallicity (Hα, Hβ, [NII], [OIII]), stellar population age (Hα + continuuum), galaxy host extinction (Hα, Hβ) using VLT/MUSE. In order to solve the emission lines that we want to detect (e.g. Hα, Hβ, [NIII], [OIII]), and the continuum of the spectra, we estimated the exposure times using the MUSE ETC for a S/N of ~ 5 in the continuum (which is translated in a S/N of ~ 100 for the emission lines aimed to detect).

To do so, a HII region template with a Cousins R band of 21/arcsec^2 (Vega) for a redshift of z = 0.05 is used as input in order to indentify the lines of interest + the continuum. An Infinitely Extended Source was choosen for the purpose to extract the most possible information from the surroundings.
The required instrument setup is WFM-NoAO in the nominal wavelength (480-930 nm) with a number of coadded spatial and spectral pixels of 3x3 and 1, respectively.

Sky conditions are as follow, Moon FLI = 0.8, Airmass: 1.8, PWV: 20.0 mm (Probability 95% of realising the PWV ≤ 10.0 mm), Turbulence: 85% (seeing ≤ 1.3"), and Sky = Variable, thin cirrus.
In that way, all targets are observable during the whole cycle for relatively bad weather conditions, for most of nights given the Lunar phase restrictions.
Finally, for the sake of reach the optimal observing time for S/N ~ 5, it is necessary to set NDIT = 2, because the spectrum saturates for NDIT = 1, leading to loss of information.

In this way, we mixed relatively bad weather conditions for an optimal observing time of:
- 2x1800 [s] = 3600 [s] for integration time per target
- 2x220 [s] = 440 [s] of instrument overhead time per target
- 1x360 [s] = 360 [s] of telescope overhead time per target
This yield a total of 18.66 [hrs] (each: 4400 [s], 1.33 [hrs]) for our entire sample of 14 Type Ic SN targets.

Telescope Justification

Please justify why the telescope requested is the best choice for this programme. (Anonymized)

As ALMA CO(2-1) observations, as tracer of molecular gas mass, solve spatial resolution of giant molecular clouds (~ 100 pc), the only current instrument available to cross-match within the regions of star formation (HII regions) and the emission lines required for Type Ic SN environments is the IFU spectrograph VLT/MUSE.

Observing Mode Justification

Please justify the choice of SM, VM or dVM. (Anonymized)

Service Mode is requested, as all targets are observable during the observing period.

Calibration Request

If you need any special calibration not included in the instrument calibration plan, please specify it here. (Anonymized)

Standard Calibration.

Duplication with ESO Science Archive

If observations of the same target(s) using the same instrument(s) already exist in the ESO archive, please justify why this programme requests further observations. (Anonymized)

We looked for duplicated MUSE data in the ESO Science Archive, with the only match for SN2005lr, however the original science goal was to observe SN2009AG and the pointing do not coincide with the position of our SN desired.

GTO Target Duplication Justification

If an instrument GTO team aims at the same target(s), please justify why this programme requests further observations. (Anonymized)

N/A

Background and Expertise

Short description of the background, expertise and roles of the various team members in the context of the science case discussed in the proposal. For small teams the applicants may wish to provide a sentence for the qualifications of each member, while for larger teams (e.g. in Large Programmes), only the leading roles need to be specified.

As the main goal of this project is to constrain the nature of Type Ic supernovae using ALMA CO(2-1) and MUSE optical observations, multidisciplinary knowledge is mandatory to do so and the team is composed with members in expertise from multiple fields as supernovae, stellar evolution, interstellar medium, galaxies, among others.
Is important to highlight that environments of SN locations will be observed, having team members who are within this field since more than 10 years, with very important contributions.
The P.I. is expected to perform most of the data analysis and co-Is to provide substantial contributions to the data interpretation.

REPORT ON PREVIOUS USAGE OF ESO FACILITIES

Run	PI	Instrument	Time	Mode	Comment
106.2104.001	Lluis Galbany	MUSE	53.0h	Service	Data reduced and analyzed. More than 40 papers published.

Type Ia supernovae in low-luminosity host environments

RECENT PI/CoIs PUBLICATIONS MOST RELEVANT TO THE SUBJECT OF THIS PROPOSAL

1. Agudo, I., Amati, L., An, T., et al. (2023) "Panning for gold, but finding helium: Discovery of the ultra-stripped supernova SN 2019wxt from gravitational-wave follow-up observations," A&A, 675, A201 - 2023A&A...675A.201A
2. González-Díaz, R., Galbany, L., Kangas, T., et al. (2023) "Supernova environments in J-PLUS. Normalized Cumulative Rank distributions and stellar population synthesis, combining narrow- and broad-band filters," arXiv, arXiv:2312.13830 - 2023arXiv2312
3. Grayling, M., Gutiérrez, C. P., Sullivan, M., et al. (2023) "Core-collapse supernovae in the Dark Energy Survey: luminosity functions and host galaxy demographics," MNRAS, 520, 684-701 - 2023MNRAS.520..684G

4. Holmbo, S., Stritzinger, M. D., Karamehmetoglu, E., et al. (2023) "The Carnegie Supernova Project I. Spectroscopic analysis of stripped-envelope supernovae," A&A, 675, A83 - 2023A&A...675A..83H

5. Leśniewska, A., Michałowski, M. J., Kamphuis, P., et al. (2022) "The Interstellar Medium in the Environment of the Supernova-less Long-duration GRB 111005A," ApJS, 259, 67 - 2022ApJS..259...67L

6. Levan, A. J., Ashall, C., Benetti, S., et al. (2023) "Delivering on the promise of multi-messenger astronomy," hst..prop, 17407 - 2023hst..prop17407L

7. Lugo-Aranda, A. Z., Sánchez, S. F., Barrera-Ballesteros, J. K., et al. (2024) "H II regions and diffuse ionized gas in the AMUSING++ Compilation - I. Catalogue presentation," MNRAS, 528, 6099-6118 - 2024MNRAS.528.6099L

8. Moore, T., Smartt, S. J., Nicholl, M., et al. (2023) "SN 2022jli: A Type Ic Supernova with Periodic Modulation of Its Light Curve and an Unusually Long Rise," ApJL, 956, L31 - 2023ApJ...956L..31M

9. Pessi, T., Anderson, J. P., Lyman, J. D., et al. (2023) "A Metallicity Dependence on the Occurrence of Core-collapse Supernovae," ApJL, 955, L29 - 2023ApJ...955L..29P

10. Xiao, L., Szalai, T., Galbany, L., et al. (2023) "The environmental dependence of Spitzer dusty Supernovae," arXiv, arXiv:2312.00562 - 2023arXiv231200562X

INVESTIGATORS

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OBSERVATIONS

In the table below, the repeat factor is applied to the complete observation on that target, including its overhead.

✔ The PI acknowledged that all the telescope times listed below include overheads.

Run 114.27G5.001 • Run 1 • P114 • MUSE • SM — Tel. Time: 18h31m

FLI: 80% • Turb.: 85% • pwv: 20.0mm • Sky: Variable, thin cirrus • Airmass: 1.8

Target • LSQ 13doo • 11:48:45.780 • -28:17:31.200 — Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 1994ai • 02:23:06.169 • -21:14:09.300 — Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 1997dq • 11:40:55.900 • 11:28:45.699 — Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2003aa • 10:46:36.820 • 13:45:32.199 — Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2003jg • 09:45:38.400 • -31:11:19.899 — Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s

Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2005lr • 07:11:39.030 • -26:42:20.199 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2009em • 00:34:44.530 • -08:23:57.599 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2009gd • 15:48:22.789 • -75:40:47.799 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2011hp • 12:16:25.469 • -43:19:46.899 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2011jl • 10:43:02.950 • -36:21:52.400 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2012ap • 05:00:13.720 • -03:20:51.200 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2012cw • 10:13:47.950 • 03:26:02.600 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN 2014ad • 11:57:44.440 • -10:10:15.700 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0

Target • SN2018lei • 02:33:34.333 • -39:02:42.407 Tel. Time: 01h20m

OS 1	WFM-NOAO	Observation
Tel. Time: 2380 s	Instrument Mode: WFM-NOAO-E	Integration Time: 1800 s
Repeat: 2 x	Telescope Overheads: 360 s	Instrument Overheads: 220 s
Total Tel. Time: 4760s		Signal/Noise: 5.0