European Organisation for Astronomical Research in the Southern Hemisphere
Observing Programmes Office • Karl-Schwarzschild-Strasse 2 • D-85748 Garching bei München • email: opo@eso.org • Tel: +49 89 3200 6473

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APPLICATION FOR OBSERVING TIME **112.25XB**

IMPORTANT NOTICE

Investigating the Host Environments of 1987A-like Type II Supernovae arising from Blue Supergiants

ABSTRACT

Core-Collapse supernovae (CCSNe) arise from the gravitational collapse of massive stars and are accurate tracers of star formation (SF). Those that retain their hydrogen envelope at the time of explosion result in a Type II SN. These SNe arise from a Red Supergiant (RSG) progenitor star, however, SN 1987A, showed that Blue Supergiants (BSGs) could also explode as Type II SNe despite the lack of such predictions from theoretical stellar models. This proposal aims to investigate the explosion sites of 1987A-like SNe which arise from BSG stars. The study will 1) characterize if 1987A-like SNe arise from a different stellar population than normal Type II SN; 2) whether 1987A-like SNe specifically prefer low-metallicity host environments; 3) determine association of SF in host HII regions of 1987A-like SNe and whether they are indicative of overall SF in the hosts. 4) whether the host environment properties of 1987A-like SNe affect the temporal evolution of its SN.

SCIENTIFIC KEYWORDS

stars: supernovae, galaxies: star formation, galaxies: kinematics and dynamics

RUNS

Run	Period	Instrument	Tel. Setup	Constraints	Mode	Type	Propr. Time	Time Constr.	Req. Time
112.25XB.001 • HostBSGSNe	112	MUSE	UT4	FLI: 100% • Turb.: 100% • pwv: 30.0mm • Sky: Variable, thin cirrus	SM	Normal	12m	×	25h00m

AWARDED AND FUTURE TIME REQUESTS

Time already awarded to this project

- none -

Future time requests to complete this project

- none -

Special Remarks

This project is a ‘filler’ program, with targets across the full RA and DEC range, observable in THN, bad seeing conditions, and during bright nights. We understand that only part of the observations may be completed. Here, we investigate host environments of 1987A-like SNe which result from the explosion of Blue Supergiants and how the stellar population and metallicity differs from hosts of normal Type II SNe.'

DESCRIPTION OF THE PROPOSED PROGRAMME

A- Scientific Rationale

Time Domain Astronomy has experienced significant growth due to the rise in observing facilities, particularly with the advent of the untargeted, large field of view and high cadence sky surveys viz., ASASSN, ATLAS, Gaia, Pan-STARRS, Zwicky Transient Facility (ZTF), Legacy Survey of Space and Time (LSST, upcoming), and others. These surveys have uncovered a diverse zoo of the transient universe, specifically of transients arising in low-luminosity and low-metallicity host galaxies raising important questions about the origins of these explosive phenomena.

Core Collapse supernovae (CCSNe) arise from the gravitational collapse of massive stars. Massive stars that retain their hydrogen envelope at the time of explosion are called Type II SNe. Observational and theoretical studies have shown that Type II SN arises from a Red Supergiant (RSG) progenitor star. However, the closest SN in the past century, SN 1987A, showed that a Blue Supergiant (BSG) could also explode as a Type II SN (see the differences in Fig 1-left). Several attempts have been made to understand how a BSG progenitor undergoes an SN (hereby 1987A-like SNe) since standard stellar models do not predict the explosion of a massive star in the BSG phase (Woosley et al. 2002). Since SN 1987A, there have been further attempts to explore single-star progenitors and binary systems to address this issue (Eldridge et al. 2017, Curtis et al. 2020). Studies of the evolution of massive stars at various metallicities (Woosley et al. 1988) have inferred that low-metallicity could significantly impact the structure of massive stars, mass-loss rates, and ultimately the SN outcome. A decrease in metallicity leads to a decrease in pre-SN radius and a bluer solution in the HR diagram. Rotational mixing has also been invoked to explain stellar evolution towards a BSG star (Weiss et al. 1988). In the case of a binary system, Woosley et al. (2002) ascertained that scenarios involving accretion and merger would lead to the explosion of a massive star as a BSG, even at solar metallicity.

The influence of host environment metallicity on Type II SNe is apparent in their observed spectra (Anderson et al. 2016), as Dessart et al. (2014) predicted in their spectral modelling. Past studies have also revealed that CCSNe rates differ in low-luminosity host galaxies, which typically tend to have lower metallicities. These studies indicate that progenitor-metallicity affects the later stages of evolution, leading to different outcomes compared to SNe in environments with higher metallicities. As such, investigating the host environments of 1987A-like SNe and their association with low-metallicity environments can provide us valuable insights into the progenitor channels of these SNe. The metallicity estimates in Fig 1(right) show the trend of 1987A-like SNe occurring in low-metallicity environments. But these estimates for the 1987A-like SNe were done using single-slit spectroscopic observations of the host galaxy nucleus inferred by assuming a standard gradient outwards of the nucleus towards the site of the SN. But star-forming regions harbour a lot of CCSNe and can have greatly different metallicity values than a standard gradient. However, MUSE will allow us to investigate stellar populations and accurate metallicity at the explosion sites of these SNe and other HII regions in the host galaxy. It will also help determine if 1987A-like SNe prefer low-Z HII regions compared with all other HII regions in the host galaxies. Additionally, our large sample of 25 1987A-like SNe host environments will help achieve better statistics on the population of these SNe.

While 1987A-like SNe account for only $\sim$1% of the observed Type II SN population (Eldridge et al. 2017), the binary population synthesis from the study predicts that these events are expected to make up only 0.4% of the population, making these SNe extremely rare and warranting a thorough investigation. This proposal aims to investigate stellar population and metallicity at the explosion sites of 1987A-like SNe and to elucidate the progenitor properties that lead to the explosion of a star as a BSG. In addition, the findings of the proposal will be compared with the host environments of normal Type II SNe. We will use archival observations from MUSE for normal Type II SNe; however, there is only one such archival data for 1987A-like SNe. We plan to observe the entirety of 1987A-like SNe from the literature and modern all-sky survey databases with $< 30^\circ$ declination. The targets were selected from the literature with long-term temporal evolution resembling 1987A. Some of the targets were compiled from the works of Taddia et al. (2013) and Pastorello et al. (2012). In addition, we selected 1987A-like candidates from the largest spectroscopic survey of transients, i.e. the Bright Transient Survey (BTS) conducted by the ZTF team. Comparing the sample of host environments of 1987A-like SNe with normal Type II SNe will help us investigate differences in the stellar populations and the metallicity differences that give rise to the rare breed of 1987A-like SNe.

B- Immediate Objective

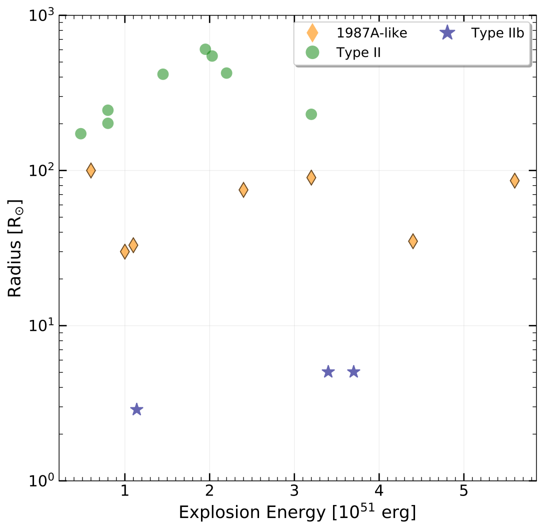
MUSE observations of the host galaxies of 25 1987A-like SNe will be obtained. The observations will allow for the characterisation of these host galaxies on a global scale as well as on an individual parent stellar population scale at the explosion site of the SN. Specifically, we will be targeting the following objectives:

- Characterize the stellar population (specific star formation rate, stellar age, metallicity etc.) at the explosion sites of 1987A-like SNe and compare its differences with that of the observed sample of Type II SNe from archival MUSE observations. We will use penalized PiXel Fitting (pPXF) to estimate stellar population and compute stellar kinematics (Cappellari 2017). We will use absorption and emission line indices for estimating metallicity using line diagnostics at the explosion sites of the SNe.

- Determine whether 1987A-like SNe prefer low-metallicity host environments as suggested by theoretical studies and how the star formation history at these sites explains the origin of single-star BSG progenitors.
- Determine if 1987A-like SNe occur in solar or supersolar metallicity environments. If yes, does the stellar population at their explosion sites indicate a higher probability of binarity?
- Investigate the association of SF in the host HII regions of 1987A-like SNe compared to other types of CCSNe and determine if they indicate the overall SF activity in the host galaxies.
- To investigate how the host environment properties of 1987A-like SNe affect the temporal evolution of its SN, using the photospheric phase light curve and spectral dataset of 1987A-like SNe. We will use the dataset of 1987A-like SNe from the literature.

The proposed study will provide insights into the evolution of BSG stars, the relationship between SF and Type II SNe, and the effects of the host environment on SN properties. The results will have implications for our understanding of the role of massive stars in galaxy evolution and the cosmic history of SF. A sample of 1987A-like SNe from MUSE will enable these questions to be investigated in unprecedented detail. The observed dataset will provide a gold mine for further galaxy dynamics, stellar populations and chemical evolution studies. We expect many other projects to spawn from the proposed dataset.

Figures



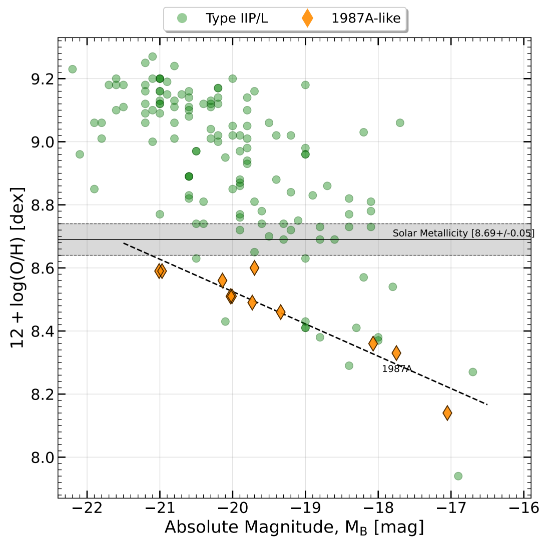


Fig.1 (left) The plot shows the differences in stellar radius of the progenitor of 1987A-like SNe and their differences when compared to the normal Type II SNe. The sample is adapted from Singh et al. (2019b). Fig.2 (right). The plot shows the metallicity estimates for different types of SNe from the estimates of the metallicity of the host nucleus and corrected using an assumed metallicity gradient. The sample is adapted from Taddia et al. (2013).

References

1. Woosley et al. (2002) "The evolution and explosion of massive stars," Reviews of Modern Physics, vol. 74, Issue 4, pp. 1015-1071

2. Pastorello et al. (2012) "SN 2009E: a faint clone of SN 1987A," Astronomy & Astrophysics, Volume 537, id.A141, **3.** Taddia et al. (2013) "A metallicity study of 1987A-like supernova host galaxies," Astronomy & Astrophysics, Volume 558, id.A143

4. Dessart et al. (2014) "Type II Plateau supernovae as metallicity probes of the Universe," Monthly Notices of the Royal Astronomical Society, Volume 440, Issue 2, p.1856-1864

5. Anderson et al. (2016) "Type II supernovae as probes of environment metallicity: observations of host H II regions," Astronomy & Astrophysics, Volume 589, id.A110.

6. Eldridge et al. (2017) "Binary Population and Spectral Synthesis Version 2.1: Construction, Observational Verification, and New Results," Publications of the Astronomical Society of Australia, Volume 34, id.e058

7. Curtis et al. (2020) "When Do Stalled Stars Resume Spinning Down? Advancing Gyrochronology with Ruprecht 147," The Astrophysical Journal, Volume 904, Issue 2, id.140

8. Singh et al. (2019b) "SN 2018hna: 1987A-like Supernova with a Signature of Shock Breakout ," The Astrophysical Journal Letters, Volume 882, Issue 2, article id. L15 (2019).

TARGETS

Name	RA	Dec	Coord	Runs	Comment
2004em	19:31:31.31	35:52:25.25	ICRS	1	0.01493|IC 1303
r=13.4					
2019pkh	02:19:27.27	34:04:54.54	ICRS	1	0.02|Anonymous
2004ek	01:09:59.59	32:22:36.36	ICRS	1	0.01742|UGC 724
R=12.75					
2021cwe	15:45:32.32	30:09:30.30	ICRS	1	0.031681|LEDA 214414
r=16.53					
2021wun	15:46:32.32	25:25:45.45	ICRS	1	0.0228049997|SDSS J154631.94+252545.5
r=17.29					
2020xkx	23:20:28.28	22:59:13.13	ICRS	1	0.0415|Anonymous
2021ydc	01:25:18.18	22:23:25.25	ICRS	1	0.055|WISEA J012517.64+222324.8
2018ego	15:52:53.53	19:58:09.09	ICRS	1	0.037|LEDA 1611826
r=16.55					
2020rmk	03:52:55.55	19:19:25.25	ICRS	1	0.025|LEDA 1588264
J=15.04					
2018imj	06:51:06.06	12:55:07.07	ICRS	1	0.013|IC 454
J=12.99					
2006au	17:57:14.14	12:10:59.59	ICRS	1	0.00958|UGC 11057
B=13.56					
PTF12gcx	15:44:17.17	09:57:43.43	ICRS	1	0.04498|LEDA 1372615
r=16.51					
2006V	11:31:31.31	-02:18:10.10	ICRS	1	0.01584|UGC 6510
r=12.93					
2022ymc	03:13:41.41	-01:16:32.32	ICRS	1	0.028|Anonymous
2012gg	04:36:11.11	-05:04:53.53	ICRS	1	0.030485|Anon J043611-0504
r=20.64					
PTF09gpn	03:43:43.43	-17:08:43.43	ICRS	1	0.0154|Anonymous
r=20.08					
2021abnz	02:43:54.54	-20:55:10.10	ICRS	1	0.03|GALEX J024354.4-205511
1998A	11:09:52.52	-23:43:40.40	ICRS	1	0.00697|IC 2627
R=11.4					
2009mw	09:47:15.15	-24:51:03.03	ICRS	1	0.014432|ESO 499-5
R=12.56					
OGLE-2003-NOOS-005	05:55:40.40	-68:55:38.38	ICRS	1	0.03061|2MASX J05553978-6855381
R=15.58					
2021adyl	09:28:04.091	29:59:27.21	ICRS	1	0.02768|IC 2479
r=14.83					
2021adcw	02:04:32.891	-21:07:09.52	ICRS	1	0.017|LEDA 832430
2021aatd	00:59:04.178	-00:12:12.00	ICRS	1	0.015245|SDSS J005904.55-001210.0
r=18.37					
2018anu	17:36:15.551	18:58:39.30	ICRS	1	0.039|GALEXASC J173615.16+185850.6
DES16C3cje	03:28:35.29	-27:09:06.6	ICRS	1	0.0616|2dFGRS TGS243Z257

Name	RA	Dec	Coord	Runs	Comment
R=18.8					

Target Notes

- none -

REMARKS & JUSTIFICATIONS

Lunar Phase and Constraints Justification

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

Our targets can be observed in any lunar phase as this project is a ‘filler’ program.

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.

Our proposed MUSE observations aim to detect and measure the strength of HII region emission lines throughout target galaxies, together with narrow absorption features seen on top of the galaxy continuum. To estimate exposure times, we assume a typical r-band surface brightness of 20.5 mag per arcsec2 for faint HII regions (James et al. 2004). We then use the MUSE ETC to estimate our required exposure times. We assume an ‘Infinitely extended source’ and the HII region template (at a redshift of 0.05) together with an r-band surface brightness of 21 mag per arcsec2 . As a ‘filler’ proposal, we set conditions to 7 days from the new moon with an airmass of 2 and seeing 1.500. In order to remove the edges of each IFU on the detector (artefacts of the image slicer), it is best to combine observations with all four 90-degree angles. With 4×700 second exposures, the ETC gives an S/N of □5 in the continuum, which translates to an S/N of more than 100 for all the emission lines we wish to detect (e.g., Hα, [Nii], [O iii], Hβ). In many galaxy regions, we will obtain much higher S/N in the continuum, and this will allow a more detailed analysis of stellar populations, using absorption line indices as an indicator of stellar metallicities in place of the gas phase values. As the target galaxies are distant and doesn't extend the whole frame, the sky-subtraction will done using the empty pixels. The exposure times along with overheads, will total roughly 1 hr per galaxy. Most galaxies in our sample are covered by one MUSE pointing, so we require 25 hrs to observe our sample of 25 host galaxies. However, as a ‘filler’ proposal, any amount of data obtained will be beneficial to our project.

We have previously obtained MUSE data with very similar conditions/observing strategy to that outlined above, and with the above exposure times, we are able to make the necessary measurements. We have already published several papers based on these data (see publications section). Our team has experts on the reduction, analysis and interpretation of IFS galaxy observations; hence, while IFS data and their analysis can sometimes prove somewhat daunting, our team provides all the required knowledge to fully exploit this rich data set. These data will remain in the archive as a legacy for future extra-galactic studies.

Telescope Justification

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

The MUSE instrument at VLT is presently the sole available integral field unit (IFU) that can cover a significant portion of our targets with its field of view (FoV). It boasts high spatial resolution and sensitivity, while also being highly efficient, allowing for observations to be conducted in a relatively short amount of time. It is critical to highlight here that in relatively poor seeing conditions (in which the data will sometimes be observed, given the ‘filler’ nature of our proposal), we will still have the potential to unravel kinematic and population substructure in these galaxies over a large FoV. In fact, even in poor seeing conditions, MUSE data will provide better insight into the characteristics of supernova environments and galaxies than any of the previous or current IFU surveys, such as SAURON, ATLAS3D, CALIFA, SAMI, or MaNGA.

Observing Mode Justification

Please explain the choice of SM, VM or dVM.

Targets are observable throughout the semester, and as this is a ‘filler’ program, service mode (SM) is required.

Calibration Request

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

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.

A few objects requested in the proposal here have been observed photometrically with FORS2 in R and Halpha filter. However, there is no spectroscopic information on the host environments of our target list in the ESO archive. Here we will observe a large extent of the host galaxies of SNe, thus enabling our scientific goals to be met.

GTO Target Duplication Justification

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

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.

1) PI Singh works on observational investigation of CCSNe, primarily 1987A-like SNe.
2) dPI Anderson specializes in studying CCSNe and their host environments and is an experienced FORS2 and MUSE observer.
3) Co-I Kravtsov works with observations on analysis of host galaxy of CCSNe.
4) Co-I Kuncarayakti is an expert in nebular late-time observations of SNe and constraining progenitor parameters through emission line diagnostics.
5) Co-I Lyman specializes in constraining progenitor stars of CCSNe through observations of their explosions and their host environments.
6) Co-I Teja is experienced in hydrodynamical modelling of CCSNe given the initial conditions of the progenitor star.
7) Co-I Galbany works on characterizing local sites of explosion of SNe including their stellar population, star formation rate etc.
8) Co-I Dessart specializes in SN explosion modeling of Blue Supergiants.

REPORT ON PREVIOUS USAGE OF ESO FACILITIES

- none -

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

1. Paulino-Afonso, A., González-Gaitán, S., Galbany, L., et al. (2022) "Systematic errors on optical-SED stellar-mass estimates for galaxies across cosmic time and their impact on cosmology," A&A, 662, A86 - 2022A&A...662A..86P

2. Robleto-Orús, A. C., Torres-Papaqui, J. P., Longinotti, A. L., et al. (2021) "MUSE Reveals Extended Circumnuclear Outflows in the Seyfert 1 NGC 7469," ApJL, 906, L6 - 2021ApJ...906L...6R

3. Dong, Y., Valenti, S., Bostroem, K. A., et al. (2021) "Supernova 2018cuf: A Type IIP Supernova with a Slow Fall from Plateau," ApJ, 906, 56 - 2021ApJ...906...56D

4. Teja, R. S., Singh, A., Sahu, D. K., et al. (2022) "SN 2020jfo: A Short-plateau Type II Supernova from a Low-mass Progenitor," ApJ, 930, 34 - 2022ApJ...930...34T

5. Li, Z., Wisnioski, E., Mendel, J. T., et al. (2023) "Spatial metallicity distribution statistics at □100 pc scales in the AMUSING++ nearby galaxy sample," MNRAS, 518, 286-304 - 2023MNRAS.518..286L

6. Onori, F., Cannizzaro, G., Jonker, P. G., et al. (2022) "The nuclear transient AT 2017gge: a tidal disruption event in a dusty and gas-rich environment and the awakening of a dormant SMBH," MNRAS, 517, 76-98 - 2022MNRAS.517...76O

7. López-Cobá, C., Sánchez, S. F., Lin, L., et al. (2022) "Exploring Stellar and Ionized Gas Noncircular Motions in Barred Galaxies with MUSE," ApJ, 939, 40 - 2022ApJ...939...40L

8. Espinosa-Ponce, C., Sánchez, S. F., Morisset, C., et al. (2022) "H II regions in CALIFA survey: II. The relation between their physical properties and galaxy evolution," MNRAS, 512, 3436-3463 - 2022MNRAS.512.3436E

INVESTIGATORS

Avinash Singh, Hiroshima University, Japan (PI)
Joseph Anderson, ESO Chile, ESO (Delegated PI)
Rishabh Singh Teja, Indian Institute of Astrophysics, India
Timo Kravtsov, ESO Chile, ESO
Luc Dessart, Institut d'Astrophysique de Paris/CNRS and Sorbonne University, France
Joseph Lyman, University of Warwick, United Kingdom
Lluis Galbany, Institut d'Estudis Espacials de Catalunya - Barcelona, Spain
Hanindyo Kuncarayakti, Turun yliopisto, Finland

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 112.25XB.001 • HostBSGSNe • P112 • MUSE • SM — Tel. Time: 25h00m

FLI: 100% • Turb.: 100% • pwv: 30.0mm • Sky: Variable, thin cirrus • Airmass: 2.0

Target • 2004em • 19:31:31.31 • 35:52:25.25 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2019pkh • 02:19:27.27 • 34:04:54.54 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2004ek • 01:09:59.59 • 32:22:36.36 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2021cwe • 15:45:32.32 • 30:09:30.30 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2021wun • 15:46:32.32 • 25:25:45.45 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2020xkx • 23:20:28.28 • 22:59:13.13 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2021ydc • 01:25:18.18 • 22:23:25.25 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2018ego • 15:52:53.53 • 19:58:09.09 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2020rmk • 03:52:55.55 • 19:19:25.25 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2018imj • 06:51:06.06 • 12:55:07.07 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2006au • 17:57:14.14 • 12:10:59.59 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • PTF12gcx • 15:44:17.17 • 09:57:43.43 Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2006V • 11:31:31.31 • -02:18:10.10 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2022ymc • 03:13:41.41 • -01:16:32.32 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2012gg • 04:36:11.11 • -05:04:53.53 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 0 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • PTF09gpn • 03:43:43.43 • -17:08:43.43 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2021abnz • 02:43:54.54 • -20:55:10.10 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 1998A • 11:09:52.52 • -23:43:40.40 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 0 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2009mw • 09:47:15.15 • -24:51:03.03 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • OGLE-2003-NOOS-005 • 05:55:40.40 • -68:55:38.38 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2021adyl • 09:28:04.091 • 29:59:27.21 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2021adcw • 02:04:32.891 • -21:07:09.52 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2021aatd • 00:59:04.178 • -00:12:12.00 — Tel. Time: 01h00m

WFM-NOAO	WFM-NOAO	Observation
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 0 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s

Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • 2018anu • 17:36:15.551 • 18:58:39.30 Tel. Time: 01h00m

WFM-NOAO	**WFM-NOAO**	**Observation**
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 2800 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0

Target • DES16C3cje • 03:28:35.29 • -27:09:06.6 Tel. Time: 01h00m

WFM-NOAO	**WFM-NOAO**	**Observation**
Tel. Time: 3600 s	Instrument Mode: WFM-NOAO-N	Integration Time: 0 s
Repeat: 1 x	Telescope Overheads: 360 s	Instrument Overheads: 0 s
Total Tel. Time: 3600s		Signal/Noise: 0.0