European Organisation for Astronomical Research in the Southern Hemisphere
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Cycle: P114
Type: Normal
Status: Valid
Printed: 29 Jan 2026

APPLICATION FOR OBSERVING TIME **114.26ZM**

IMPORTANT NOTICE

Constraining the fates of very massive stars: Environments of newly discovered peculiar core-collapse supernovae

ABSTRACT

How stellar properties translate to empirical signatures of core-collapse supernovae (SNe) is not yet properly characterised. This is exemplified by the unknown fate of ≥25-50Msun Wolf-Rayet-like stars: thought to be the progenitors of stripped-envelope (SE) SNe, multiple lines of evidence instead show SESNe overwhelmingly-arise from ≤20Msun stars. Recently, a distinct population of broad light-curve SESNe with peculiar host environments was found, greatly expanding the dynamic range of SESN explosion parameters. We propose MUSE observations at the SN sites to characterise the coeval stellar populations and constrain the mass and metallicity of their progenitors, which may be the "missing" high-mass stars. Statistical comparison to existing environmental constraints of regular SESNe will provide the means to ascertain whether or not these are indeed a distinct population of progenitors. Either scenario has ramifications for our understanding of the ultimate fates of high-mass stars.

SCIENTIFIC KEYWORDS

stars: supernovae, galaxies: star formation, galaxies: dwarf

RUNS

Run	Period	Instrument	Tel. Setup	Constraints	Mode	Type	Propr. Time	Time Constr.	Req. Time
114.26ZM.001 • Run 1	114	MUSE	UT4	FLI: 50% • Turb.: 50% • pwv: 30.0mm • Sky: Clear	SM	Normal	12m	×	18h00m

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

Core-collapse (CC) supernovae (SNe) are the explosive end points in the lives of most massive stars ($\gtrsim 8\,\mathrm{M}_\odot$). The explosions drive the chemical enrichment of the Universe, regulate star-formation in galaxies, and are responsible for the production of neutron star and black hole systems. Their astrophysical importance is wide-spread, but exploiting them fully as cosmic beacons driving such phenomena is currently hampered by a lack of understanding of their progenitor systems. This is most critical for *"stripped-envelope"* CC SNe (SESNe) – the explosions of massive stars partially or fully stripped of their H (and He) envelopes – for which direct progenitor constraints are very limited, and where traditional stellar evolution theory is at an impasse to explain the resultant SNe. To better understand the SN-progenitor link for SESNe, this proposal will acquire detailed environmental constraints on the progenitors of an intriguing, and recently uncovered, sub-population.

Where are the very massive stripped-envelope SN progenitors? The nature of SESNe progenitors has long been debated. The favoured progenitor scenario has traditionally been solitary massive Wolf-Rayet (WR) stars ($\gtrsim 25\,\mathrm{M}_\odot$) stripped of their hydrogen and/or helium envelopes by strong mass-loss via line-driven winds. However, observations of the light curves of SESNe reveal mainly narrow-peaked light curves, compatible with low ejecta masses **[1, 2]** – much lower than expectations for a massive WR star exploding. The SESN light curves and spectra are compatible rather with moderately massive progenitors ($\lesssim 20\,\mathrm{M}_\odot$). Although this discrepancy is a conundrum for single stellar evolution (what then *does* happen to those high mass WR stars?), it is backed by other observables, namely a) their high rate compared to hydrogen-rich SNe **[3]**, (known to come from moderately massive supergiants **[4]**), b) a few direct progenitor constraints **[5]**, c) nebular spectroscopic models **[6]**, and d) lightcurve modelling of increasingly large literature SESN samples.

Advances in binary stellar evolution models have now shown that these moderate mass SESN progenitors can be formed via mass-transfer **[7]**. Focus has therefore shifted to how, or even if, massive WR stars manifest themselves in the SESN progenitor population to any appreciable degree. Given currently employed "explodability" criteria for the pre-SN structure of such massive progenitors **[8]**, it is expected for some or most to directly collapse to a black-hole, without a SN-like luminous explosion. Constraints on the nature of any SESNe that *do* match expectations of (potentially solitary) massive WR explosions is therefore of great importance.

A new sample of unusual explosions Recent work analysing SESNe in the unbiased Palomar Transient Factory sky-survey has systematically defined an unusual, statistically distinct, broad light curve sample of otherwise ordinary SESNe (**[9]**, **Fig. 1**). The broadness of their light curves, coupled with a spectroscopic normality typical of other SESNe, infers a much larger ejecta mass of these explosions (following analytical diffusion time-scale arguments; **Fig. 1, right**). Such large ejecta masses are the hallmark of very massive SESN progenitors – we expect the stars to have much more massive cores prior to explosion than those of typical, moderately massive, SESN progenitors. The literature identifies only individual such examples (e.g. SN 2011bm, **[10]**). The quantitative methods used to define this sample provides the means to investigate –for the first time– the population statistically, and is able to reveal their relative prevalence at the $\sim 6\%$ level among the SESN population. Simple IMF arguments suggest a larger relative fraction, and indicate other factors may be required to produce SNe from very massive stars.

Environments as probes of SN progenitors Environmental studies of SNe offers alternative means to constrain progenitor properties. Integrated host-galaxy properties such as mass, star-formation rate and metallicity shows crucial independent evidence in the delay-time differences between thermonuclear SNe Ia and CC SNe, as well as metallicity dependence on the production of exceptional SNe, for example. The short lives of many SN progenitors compared to galactic dynamical time-scales means greater insights can be gained by studying their *local* explosion environments. The local, coeval stellar populations can serve as a proxy to obtain constraints on the progenitors themselves – enabled with wide FoV integral-field spectrographs. Spatially-resolved diagnostics of the hosts enables the explosions sites to be properly placed in the context of star formation of the wider galaxy, and enables detailed comparison between SN sub-types to assess the impact of progenitor properties on emergent SN properties (e.g. **[11, 12]**). With exceptional SNe classes, such as super-luminous (SL) SNe and those associated with gamma-ray bursts, there is strong evidence of metallicity dependence in their production (e.g. **[13]**). Integrated galaxy properties hint that broad SESN share more in common with these exceptional classes than regular SESNe **[Fig. 1]**, strongly motivating a detailed investigation on local environment scales, since direct progenitor detections are non-existent and not expected on any reasonable timescale given their rate.

The importance of very massive progenitors Although rare, this newly defined sample of SNe are not an esoteric curiosity. Their inferred rate, and hence mass budget of the IMF, is significant compared to more extreme events such as super-luminous SNe. Most importantly, they show that some very massive WR-like stars *do* produce regular SNe – understanding the progenitor stars can then test stellar evolution theory, which predicts trends in mass and metallicity for direct collapse vs luminous explosion. Additionally, they can produce significant heavy elements as their yields are $\sim 10\times$ regular SESNe, and they may explain the distribution of neutron stars masses **[14]**.

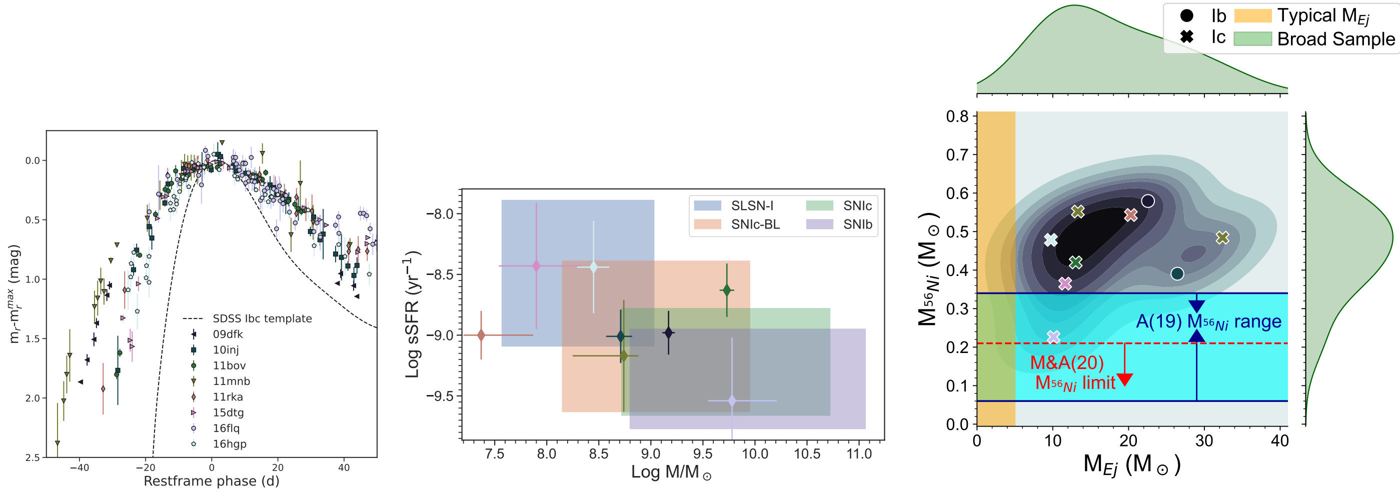

Figure 1: *(Left)* A sub-set of the broad stripped-envelope SN sample **[9]** compared to a "normal" SESN light curve from SDSS (**[2]**). *(Middle)* Integrated global host galaxy properties of the same sub-set compared to other SN types, giving first hints to extreme environments more typical of superluminous SNe (SLSN-I) and gamma-ray burst SNe (SNIc-BL), than of regular SESNe (SN Ib, Ic) hosts. *(Right)* Inferred ejecta (M_{Ej}) and Nickel (M_{56Ni}) masses of the broad SESN sample (markers+contours); cyan and yellow regions show the respective parameter ranges of "normal" SESN – i.e. "normal" SESNe populate the cyan and yellow overlap region of this plot.

B- Immediate Objective

This proposal will obtain integral-field spectroscopic data of the host galaxies and local explosion environments of a newly uncovered population of SESNe with unusually broad light curves; the sample comes from an untargeted wide field survey and is quantitatively defined **[9]**. All 10 visible from ESO will be targeted: environmental analysis is a statistical method and relies on distribution of parameters – sample sizes <10 expose significantly only extreme differences between samples, whereas we are looking for more subtle differences cf. other SESN hosts (e.g. **Fig 1., middle**). We will use spatially-resolved spectroscopy to determine the ages, metallicities, and star-formation properties of the local environments, and perform a statistical comparison to large samples of similar measurements for other SESNe (e.g. **[15]**). Ultimately, **this new sample is the first definition of a collection of SESNe consistent with very-massive progenitors, and we wish to understand if this premise is borne out in analysis of their environments**.

In the data cubes, the bulk analysis will use ratios and fluxes of strong-emission lines (e.g. Hα, Hβ, [OIII], [NII], [SII]) after removing the stellar continuum, fitted with stellar population synthesis models **[16]**. The equivalent-width (EW) of Hα emission indicates relative ages of stellar populations **[17]**. Uncertainties in determining absolute ages are alleviated since our analysis will be comparative to typical SESN explosion sites, to constraint relative ages (initial masses) of the two progenitor populations. We will determine both global *and local* metallicity values for the coeval stellar populations of the progenitors using well established strong-line emission ratios (e.g. O3N2). The move to local metallicity values, determined on small spatial scales (sub-kpc even for the most distant host) is essential to accurately reflect the parent population **[18]**.

These SNe significantly increase dynamic range in the explosion parameters of SESNe (**Fig. 1**), which are typically otherwise closely clustered. The proposed explosion site and host-galaxy data will greatly enhance ongoing work in the joint analysis of supernova and environment properties by providing a crucial link towards answering the fundamental question in stellar evolution: how does the nature of the progenitor star manifest in the observables of the SN signature?

References

1. Lyman, J. D., et al. (2016) MNRAS, 457, 328 – **2.** Taddia, F., et al. (2018) A&A, 609, A136 – **3.** Smith, N., et al. (2011) MNRAS, 412, 1522 – **4.** Smartt, S. J. (2009) ARA&A, 47, 63 – **5.** Van Dyk, S. D., et al. (2018) ApJ, 860, 90 – **6.** Jerkstrand, A., et al. (2015) A&A, 573, A12 – **7.** Eldridge, J. J., et al. (2013) MNRAS, 1, 774 – **8.** Zapartas, E., et al. (2021) A&A, L19 – **9.** Karamehmetoglu, E., et al. (2022) arXiv:2210.09402 – **10.** Valenti, S., et al. (2012) ApJL, 2, L28 – **11.** Galbany, L., et al. (2016) MNRAS, 4, 4087 – **12.** Lyman, J. D., et al. (2018) MNRAS, 473, 1359 – **13.** Graham, J. F., & Fruchter, A. S. (2017) ApJ, 2, 170 – **14.** Raithel, C. A., et al. (2018) ApJ, 1, 35 – **15.** Galbany, L., et al. (2018) ApJ, 2, 107 – **16.** Eldridge, J. J., et al. (2017) PASA, e058 – **17.** Xiao, L., et al. (2018) MNRAS, 1, 904 – **18.** Niino, Y., et al. (2015) MNRAS, 3, 2706 –

TARGETS

Name	RA	Dec	Coord	Runs	Comment
PTF10qrl V=16.7	23:09:52.831	+13:07:57.252	J2000	1	
PTF11po r=23	09:33:54.300	-22:05:17.664	J2000	1	
PTF11bov V=20	12:56:53.940	+22:22:28.128	J2000	1	
PTF11mnb V=19.2	00:34:13.253	+02:48:31.428	J2000	1	
PTF11rka V=21.2	12:40:44.870	+12:53:21.372	J2000	1	
PTF13aby V=13.8	14:12:15.7	+15:50:31.488	J2000	1	
iPTF15cna V=22.7	23:20:10.951	+28:50:58.092	J2000	1	
iPTF16flq V=16.7	00:28:36.535	-01:33:03.312	J2000	1	
iPTF16hgp V=19.3	00:12:06.413	+32:11:50.892	J2000	1	
iPTF15pz V=19.2	03:08:48.48	-35:13:51.24	J2000	1	
PTF10qrl_TTS R=16.7	23:09:53.193	13:06:52.109	J2000		
PTF11po_TTS R=14.1	09:33:54.669	-22:06:15.617	J2000		
PTF11bov_TTS R=15.9	12:56:51.082	22:23:52.008	J2000		
PTF11mnb_TTS R=14.1	00:34:08.417	02:48:10.895	J2000		
PTF11rka_TTS R=16.8	12:40:50.552	12:53:23.257	J2000		
PTF13aby_TTS R=15.8	14:12:15.722	15:52:17.277	J2000		
iPTF15cna_TTS R=16	23:20:14.747	28:50:01.224	J2000		
iPTF16flq_TTS R=15.9	00:28:31.957	-01:32:51.972	J2000		
iPTF16hgp_TTS R=10.5	00:12:14.528	32:11:28.460	J2000		
iPTF15pz_TTS V=14.9	03:09:01.544	-35:15:01.08	J2000		

Target Notes

The host galaxies of the SNe will be targeted and during P2 the FoV of MUSE will be exploited to maximally cover the SN explosion site and host galaxy at large. TTS are defined for all targets.

REMARKS & JUSTIFICATIONS

Lunar Phase and Constraints Justification

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

We ask for for gray or dark time because the supernova host galaxies extend to faint brightnesses, and we wish to characterise blue-optical emission lines. Good S/N per spaxel in the IFU cubes - required to maintain accurate measurements of environmental parameters at high spatial resolution - would be compromised for these emission lines in bright time, requiring significant extension of the observing blocks. Our turbulence category choice means we will achieve 0.7" angular spatial resolution, this is a limit to ensure the linear spatial resolution at the distances of even the most distant target galaxy is < 1kpc and so allows for the resolving of the local SN environments, and small-scale galactic features (spiral arms, morphological disturbance etc.)

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)

Our observing procedure is driven by that performed in other supernova host galaxy studies with MUSE, which will be our comparison samples for this study. Our main aims are related to detecting and characterising strong emission lines (Hβ λ4861, [OIII] λλ4959, 5007, Hα λ6563, [NII] λ6584, and [SII] λλ6717, 6731), which thus drive our exposure time requirements. MUSE observations of nearby star-forming galaxies, including supernova hosts, have shown that, with 1 hour OBs, good SNR in the emission lines of interest can be achieved to provide the necessary environmental diagnostics. This is possible even in comparatively faint regions by employing adaptive spatial binning techniques and we will employ established techniques to maximally recover a balance between spatial resolution and required SNR. We set here a different strategy for brighter and fainter galaxies. Always using OBs of 4 exposures, following MUSE guidelines to rotate and dither between each in order to combat detector artifacts, we set 4 exposures of 620s (1 OB of 1 hour) for the two brightest galaxies (similar to other nearby galaxies observed with MUSE and available in the arxive) and 8 exposures of 620s (2 OBs of 1 hour) for the other 8 fainter galaxies, which will help increasing the S/N of stellar continuum while keeping emission lines unsaturated. Allowing for overheads, this gives 18 hours total request.

Most fields are sparse enough to use on target observations for sky-subtraction, for those with larger hosts (on-sky) we will reserve 10% of exposing time for dedicated sky-subtraction observations in nearby sparse regions - this will be for the more nearby hosts and so not compromising our SNR targets significantly. With MUSE ETC Version P113, we set turbulence category 50%, airmass to 1.5 and Moon illumination to 0.5 and WFM using AO. We first use a star-forming galaxy template at z = 0.04 (typical of our sample) at R = 21 mag/arcsec2 , appropriate for the presence of faint HII regions (James et al. 2004, A&A, 414, 23). In the pessimistic case of an infinitely extended source, this gives a SNR in the continuum of 10-12 for each spatial element we can resolve (i.e. coadding spatial pixels). This will allow us to properly subtract a continuum model of the stellar population. To characterise the prominent HII regions in the hosts (LHα = 1039 erg/s) we will detect Hα at SNR = 100 and our other lines at ≥ 10 (dependant on metallicity) achieving enough precision on our strong-line metallicity indicators such that statistical uncertainty is not a dominating factor over systematics (0.1 dex). Again, an adaptive spatial binning will allow us to probe lower luminosity regions at a required SNR for our analyses - i.e. primarily measuring equivalent width (characteristic ages) and line ratios (metallicity) of the emission lines.

Telescope Justification

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

To analyse the explosion sites and host galaxies of these supernovae we require statially-resolved characterisation of faint optical emission lines. Only MUSE is capable of providing these data with a good spatial resolution and FoV. Large existing samples of transient host galaxy studies from MUSE data exist and serve an excellent baseline from which to comparison our results.

Observing Mode Justification

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

We ask for service mode observations since our objects can be observed at any opportune time over long time windows, but they are not all well observable at the same time to fit inside a single observing run.

Calibration Request

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

n/a

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)

n/a

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.

The team are experts in the observation and theoretical understanding of astrophysical transients, including core-collapse SNe. They have published extensively on MUSE data of the environments of various transient types and are experts in stellar population measurements.

Galbany & Lyman have extensive experience with using MUSE data to study the host galaxies and environments for various transient types. They have worked on literature samples of stripped-envelope supernovae.

REPORT ON PREVIOUS USAGE OF ESO FACILITIES

Run	PI	Instrument	Time	Mode	Comment
0104.D-0498(A)	Lluis Galbany	KMOS	36.0h	Service	Data reduced and analyzed. More than 30 papers published.
Studying the local environment of type Ia supernovae at low and high redshift with the Dark Energy Survey					
106.2104.001	Lluis Galbany	MUSE	53.0h	Service	Data reduced and analyzed. More than 30 papers published.
Type Ia supernovae in low-luminosity host environments					

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

1. Lyman, J. D., Galbany, L., Sánchez, S. F., et al. (2020) "Studying the environment of AT 2018cow with MUSE," MNRAS, 495, 992-999 - 2020MNRAS.495..992L
2. Larsson, J., Sollerman, J., Lyman, J. D., et al. (2021) "Clumps and Rings of Ejecta in SNR 0540-69.3 as Seen in 3D," ApJ, 922, 265 - 2021ApJ...922..265L
3. Karamehmetoglu, E., Fransson, C., Sollerman, J., et al. (2021) "The luminous and rapidly evolving SN 2018bcc. Clues toward the origin of Type Ibn SNe from the Zwicky Transient Facility," A&A, 649, A163 - 2021A&A...649A.163K
4. Karamehmetoglu, E., Sollerman, J., Taddia, F., et al. (2022) "A population of Type Ibc supernovae with massive progenitors; broad lightcurves not uncommon in (i)PTF," arXiv, arXiv:2210.09402 - 2022arXiv221009402K
5. Stritzinger, M. D., Taddia, F., Holmbo, S., et al. (2020) "The Carnegie Supernova Project II. Early observations and progenitor constraints of the Type Ib supernova LSQ13abf," A&A, 634, A21 - 2020A&A...634A..21S
6. Kool, E. C., Karamehmetoglu, E., Sollerman, J., et al. (2021) "SN 2020bqj: A Type Ibn supernova with a long-lasting peak plateau," A&A, 652, A136 - 2021A&A...652A.136K
7. O'Neill, D., Kotak, R., Fraser, M., et al. (2021) "Revisiting the progenitor of the low-luminosity type II-plateau supernova, SN 2008bk," A&A, 645, L7 - 2021A&A...645L...7O
8. Barbarino, C., Sollerman, J., Taddia, F., et al. (2021) "Type Ic supernovae from the (intermediate) Palomar Transient Factory," A&A, 651, A81 - 2021A&A...651A..81B
9. Castrillo, A., Ascasibar, Y., Galbany, L., et al. (2021) "The delay time distribution of supernovae from integral-field spectroscopy of nearby galaxies," MNRAS, 501, 3122-3136 - 2021MNRAS.501.3122C
10. Galbany, L., de Jaeger, T., Riess, A., et al. (2022) "An updated measurement of the Hubble constant from near-infrared observations of Type Ia supernovae," arXiv, arXiv:2209.02546 - 2022arXiv220902546G

INVESTIGATORS

Lluis Galbany, Institut d'Estudis Espacials de Catalunya - Barcelona, Spain (PI)

Joseph Lyman, University of Warwick, United Kingdom

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 114.26ZM.001 • Run 1 • P114 • MUSE • SM — Tel. Time: 18h00m

FLI: 50% • Turb.: 50% • pwv: 30.0mm • Sky: Clear • Airmass: 1.5

Target • PTF10qrl • 23:09:52.831 • +13:07:57.252 — Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	PTF10qrl_TTS	23:09:53.193	13:06:52.109	J2000	

Target • PTF11po • 09:33:54.300 • -22:05:17.664 Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	PTF11po_TTS	09:33:54.669	-22:06:15.617	J2000	

Target • PTF11bov • 12:56:53.940 • +22:22:28.128 Tel. Time: 01h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 1 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 3600s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	PTF11bov_TTS	12:56:51.082	22:23:52.008	J2000	

Target • PTF11mnb • 00:34:13.253 • +02:48:31.428 Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	PTF11mnb_TTS	00:34:08.417	02:48:10.895	J2000	

Target • PTF11rka • 12:40:44.870 • +12:53:21.372 Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	PTF11rka_TTS	12:40:50.552	12:53:23.257	J2000	

Target • PTF13aby • 14:12:15.7 • +15:50:31.488 Tel. Time: 01h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 1 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 3600s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	PTF13aby_TTS	14:12:15.722	15:52:17.277	J2000	

Target • iPTF15cna • 23:20:10.951 • +28:50:58.092 Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	iPTF15cna_TTS	23:20:14.747	28:50:01.224	J2000	

Target • iPTF16flq • 00:28:36.535 • -01:33:03.312 Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s

Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	iPTF16flq_TTS	00:28:31.957	-01:32:51.972	J2000	

Target • iPTF16hgp • 00:12:06.413 • +32:11:50.892 Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	iPTF16hgp_TTS	00:12:14.528	32:11:28.460	J2000	

Target • iPTF15pz • 03:08:48.48 • -35:13:51.24 Tel. Time: 02h00m

AO	WFM-AO	Observation
Tel. Time: 3600 s	Perform acquisition with TTS: true	Integration Time: 0 s
Repeat: 2 x	Instrument Mode: WFM-AO-N	Instrument Overheads: 0 s
Total Tel. Time: 7200s	Telescope Overheads: 360 s	Signal/Noise: 0.0

Reference Targets

Type	Name	RA	Dec	Coord	Comment
TTS	iPTF15pz_TTS	03:09:01.544	-35:15:01.08	J2000	