European Organisation for Astronomical Research in the Southern Hemisphere

OBSERVING PROGRAMMES OFFICE • Karl-Schwarzschild-Straße 2 • D-85748 Garching bei München • e-mail: opo@eso.org • Tel.: +49 89 320 06473

APPLICATION FOR OBSERVING TIME PERIOD: **102Z**

DDT

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.

1. Title Category: **D–5**

Collapsars as a contributor to the Galactic r-process abundances and the case of SN2017iuk.

2. Abstract / Total Time Requested

Total Amount of Time:

The pioneering event that signalled the beginning of multi-messenger astrophysics, GW170817/GRB170817, and the accompanying kilonova, AT2017gfo, have been claimed to be primary source of r-process material in the universe. However, some ultra-faint dwarf galaxies, like Reticulum II, is polluted early in its history by a rare, high-yield source. The time required for a binary star merger and low velocities of the natal kicks poses a problem for the suggestion that a binary neutron star merger is the source. A recent theoretical development suggests that the broad-lines Ic supernovae accompanying Gamma-Ray Bursts could be an additional source of the Galactic r-process. This process would work on a sufficiently rapid timescale, be associated especially with low-metallicity environments, and has suffient r-process yields to explain the inferred abundances. This theoretical model is directly testable in the recent supernovae, SN2017iuk. Only displaced by 163 Mpc from

3.

Run	Period	Instrument	Time	Month	Moon	Seeing	Sky	Mode	Type
A	102	HAWKI	1h	dec	n	0.8	PHO	s	
B	102	XSHOOTER	4h	dec	n	0.8	PHO	s	

4. Number of nights/hours Telescope(s) Amount of time

a) already awarded to this project:

b) still required to complete this project:

5. Special remarks:

Take advantage of this box to provide any special remark using up to three lines

6. Principal Investigator: JSELSING

6a. Investigators:

All CoIs moved to the end of the document.

7. Description of the proposed programme

A – Scientific Rationale:

Since August 2017, the primary source of the r-process elements in the universe is believed to be formed in the merger of two neutron stars (Côté et al. 2018 ApJ 855 99). This is based on the discovery of the first electromagnetic counterpart to a gravitational wave signal and the inferred r-process yields. However, the requirement for prompt r-process enrichment in ultra-faint dwarf galaxies (Ji et al. 2016 Nature, 531, 610), poses a challenge for the neutron star merger scenario, where the delay time between system formation and coalecence is significant. Especially, at early times, there is a need for an additional source of r-process material, which has been suggested to be a rare subtype of supernovae (Côté et al. 2018 arXiv:1809.03525). Recently, Siegel et al. 2018 arXiv:1810.00098, presented a exactly such a new theoretical model, which suggest that the supernovae accompanying long GRBs could play a central role. There is a strong need for direct empirical constraints on the production sites of r-process elements, and only after securely determining the sites and their yields, will we be able to disentangle the relative importance of the suggested r-process production sites.
First localised in gravitational waves (Abbott et al. 2017, Phys. Rev. Lett. 119, 161101), the first optical counterpart to a binary neutron star merger was observed intensely in the entire electromagnetic spectrum (Abbott et al. 2017 ApJl 848, L12). From multi-wavelength imaging (Villar et al. 2017 ApJ 851 21) and spectroscopy covering the entire atmospheric transmission window (Smartt et al. 2017 Nat. 551 75, Pian et al. 2017 Nat. 551 67), constraints can be places on the composition of the emitting material. Based on a comparison between the theoretical brightness as a function of ejecta mass and the observed luminosity of the kilonova, the ejecta mass can be inferred. Assuming a composition of the ejecta and using an estimated neutron star merger rate as a function of time, it estimated that neutron star mergers could potentially be the primary source of r-process elements in the universe (Chornock et al. 2017, ApJL 848 2, Cowperthwaite et al. 2017, ApJL 848 2). The primary evidence for the ejecta being dominated by heavy r-process elements primarily stems from the qualitative agreement between the light curve evolution and spectroscopic evolution, as compared with theoretically synthesised models (Kasen et al. 2017 Nat 551; Tanaka et al. 2017; Metzger 2017 LRR 20 3). Attempts have been made to spectroscopically identify single elements (Smartt et al. 2017), where transitions from Cs I and Te I are suggested to cause observed spectroscopic absorption features. This identification is, however, still not confirmed and the suggested elements are likely not the cause of the observed absorption features (Watson et al. in submitted). One of the reasons for the absence of spectral identifications is the inadequacy of available the atomic data of the heaviest elements (Barnes & Kasen 2013 ApJ 775 18), which causes the spectral modelling to rely on synthetic line-list, known to be discrepant compared to measured line strengths (Waxman et al. 2018, 481, 3, 3423). As a consequence, the existence of r-process material in the neutron star merger of AT2017gfo must still be considered circumstantial, until direct spectroscopic identification of single elements are performed.
GRB171205A/SN2017iuk is a recent, very nearby GRB with an accompanying SN (D'Elia et al. 2018, arXiv:1810.03339). The direct detection of jet cocoon signatures in the early spectra (Izzo et al. 2018, submitted), makes this SN a perfect candidate to test the model by Siegel et al. Additionally, SN2017iuk is the third most nearby GRB/SN discovered after SN1998bw and 2006aj (Cano et al. 2017, Advances in Astronomy, 8929054) and must thus be regarded as a "once-in-a-decade" chance to test the suggest model and to observe the late-time evolution of GRB/SNe.

B – Immediate Objective:

We here propose to observe the evolution of GRB171205A/SN2017iuk, $\sim$ 1 year after the explosion. Our primary science goal is to test the suggestion that GRB-SNe are a important source of r-process elements. Our secondary goal is the observations of the nebular phase of the most nearby GRB-SNe which will allow us to derive detailed constraints on the composition and kinematics of this, most rare subtype of supernovae.
The observations will consist of imaging in the near-infrared to put constraints on the light-curve brightness and spectroscopy to search for the presence of nebular lines. The appearance of the SN, this long after the initial explosion will allow us to put stringent constraints on the possible amount of the r-process element powering, which is one of the key observable predictions of the theoretical models.
The theoretically predicted spectroscopic appearance of the r-process powered transient associated with a long GRB is based on synthetic atomic data, and this appearance is therefore mainly meant to reproduce a qualitative between the theoretical spectra and the observed ones. The observed spectra will then serve as a benchmark going forward, also for the theoretical modelling of these types of transients.
SN2017iuk will be observable in December. Based on the extrapolated light curve from Siegel et al. 2018, it will be brightest in the near-infrared. The imaging will both allow us to put a strong limit on the amount of r-process material, and will provide a precise flux reference to recalibrate the spectra to. The prospect of detecting nebular emission from r-process elements, additionally provides a tantalizing opportunity to find the first direct evidence for the production site.

7. Description of the proposed programme and attachments

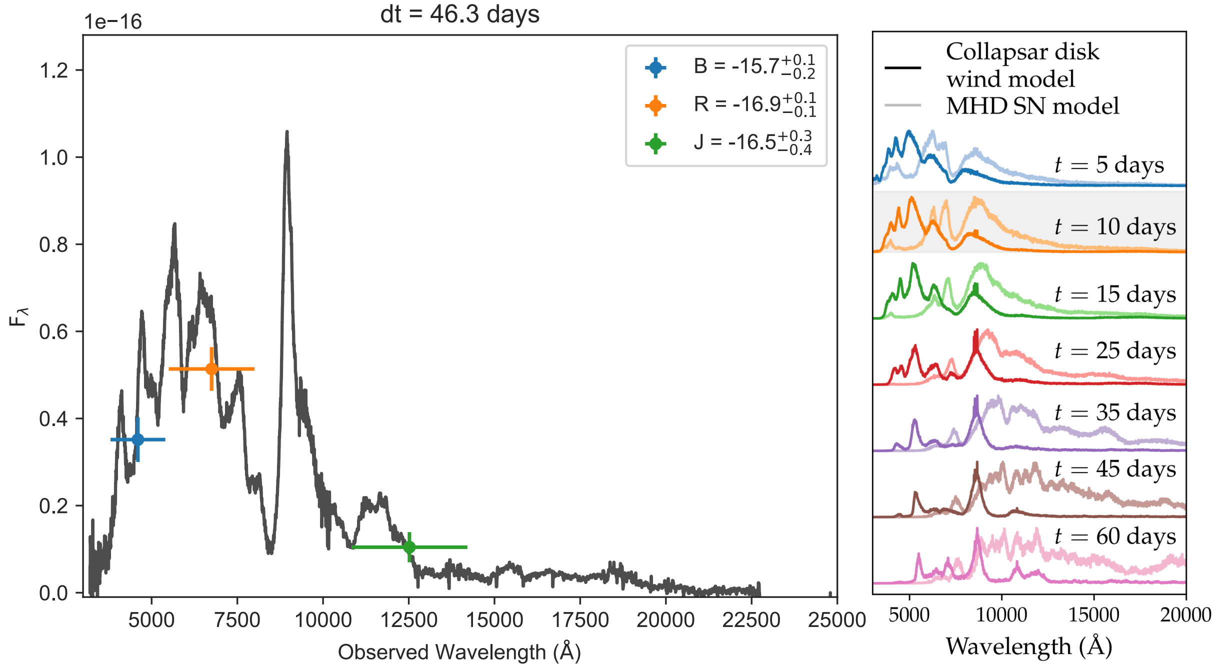

Fig. 1: Comparison between the observed spectrum of GRB171205A/SN2017iuk and the theoretically derived spectra. The left panel shows the spectrum of SN2017iuk 46 days after explosion where synthetic photometry has been overplot. The right panel shows part of Fig. 3 from Siegel et al. (2018), where the synthetic spectra are shown. As can be seen, there is a gross similarity between the two, with significant differences. Late-time spectroscopy will allow constraints on the presence of nebular r-process lines.

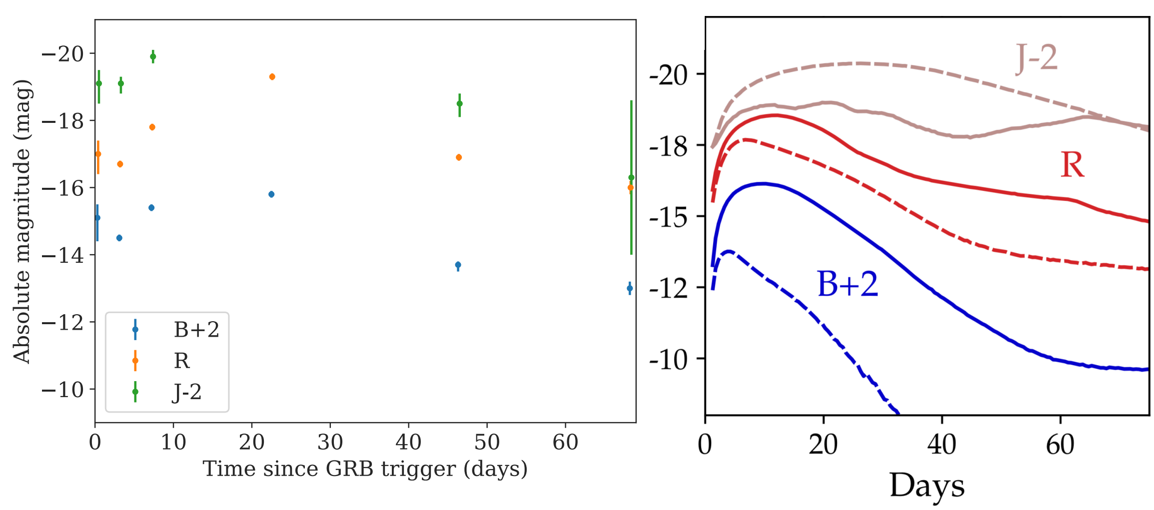

Fig. 2: Comparison between the observed light curve and the synthetic one. On the left panel is the light curve based on the synthetic photometry of the spectra. The right panel shows the theoretical light curve from Fig. 3 in Siegel et al. (2018). Generally, the observed light curve of SN2017iuk is bluer than what is predicted by the model, however late-time observations will provide the needed leverage to confirm or reject the model.

8. Justification of requested observing time and observing conditions

Lunar Phase Justification: These are ToO observations primarily targeting the near-infrared, and thus the lunar phase is a secondary concern.

Time Justification: (including seeing overhead)

HAWK-I imaging: To calculate the required exposure time we use the HAWK-I Exposure Time Calculator Infrared Imaging Mode Version P103.3. Based on the extrapolated light-curve and assuming the Planck 2018 cosmology, the transient is expected to be around $J \sim 24$mag. In order for us to confidently reject or confirm the model, a $\sim 10\sigma$ detection is required and for that we need 3000 s exposure, which including overhead totals 3600 s.

8a. Telescope Justification:

Justification for the use of the selected telescope (e.g., VLT, NTT, etc...) with respect to other available alternatives.

8b. DDT Justification:

Justification of the need for DDT.

8c. Calibration Request:

Special Calibration - Adopt a special calibration

9. Report on the use of ESO facilities during the last 2 years

Report on the use of the ESO facilities during the last 2 years (4 observing periods). Describe the status of the data obtained and the scientific output generated.

9a. ESO Archive - Are the data requested by this proposal in the ESO Archive (http://archive.eso.org)? If so, explain the need for new data.

Are the data requested in this proposal in the ESO Archive (http://archive.eso.org)? If yes, explain the need for new data.

9b. GTO/Public Survey Duplications:

Specify whether there is any duplication of targets/regions covered by ongoing GTO programmes. If so, please explain the need for the new data here. Details on the protected target/fields in these ongoing programmes can be found at:
GTO programmes: http://www.eso.org/sci/observing/teles-alloc/gto/index.html

10. Applicant's publications related to the subject of this application during the last 2 years

Name1 A., Name2 B., 2001, ApJ, 518, 567: Title of article1

Name3 A., Name4 B., 2002, A&A, 388, 17: Title of article2

Name5 A. et al., 2002, AJ, 118, 1567: Title of article3

11. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	NGC 253	00 47 33.1	-25 17 17.8	4	8		Seyfert gal.	
B	NGC 253	00 47 33.1	-25 17 17.8	4	8		Seyfert gal.	

Target Notes: This is a note about targets.

12. Scheduling requirements

This proposal involves time-critical observations, or observations to be performed at specific time intervals.

3. Unsuitable period(s) of time

Run	from	to	reason
A	15-jan-19	18-jan-19	Insert reason here
B	15-jan-19	18-jan-19	Insert reason here

12. Scheduling requirements contd...

4. Specific date(s) for time critical observations:

Run	**from**	**to**	**reason**
A	12-nov-18	14-nov-18	insert reason for time-critical observations.
B	12-nov-18	14-nov-18	insert reason for time-critical observations.

13. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
102	XSHOOTER	B	300-2500nm	SLT
102	XSHOOTER	B	SLT	1.0,0.9,0.9JH
102	XSHOOTER	B	SLT	100k-1x2,100k-1x2 VIS,NDR
102	HAWKI	A	PRE-IMG	Y,J,H,Ks
102	HAWKI	A	IMG	Y,J,H,Ks

6b. Investigators:

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D.	Watson	14042
D.	Malesani	14042
J.	Bolmer	1261
P.	Schady	1496