The multi-wavelength behaviour of PSR B1259-63 during the 2021 periastron passage

B. van Soelen,[1,] M. Chernyakova,[2,3] D. Malyshev[4] S Mc Keague,[2] C. Sobey,[5] S. O'Sullivan[2,] I. Monageng[6,7]

1. Department of Physics, University of the Free State, Bloemfontein, South Africa. 2. School of Physical Sciences and Centre for Astrophysics & Relativity, Dublin City University, Glasnevin, D09 W6Y4, Ireland, 3. Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin 2; 4. Institut für Astronomie und Astrophysik Tübingen, Universität Tübingen, Sand 1, D-72076 Tübingen, Germany, 5. CSIRO Astronomy and Space Science, PO Box 1130, Bentley, WA 6102, Australia, 6. South African Astronomical Observatory, PO Box 9, Observatory, 7935, Cape Town, South Africa. 7. Department of Astronomy, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa

NATURAL AND AGRICULTURAL SCIENCES
UFS

Introduction

Gamma-ray binaries are a rare class of High Mass Binary system, which produce non-thermal emission which peaks in the gamma-ray regime (>1 MeV). All gamma-ray binaries consist of an O or B/Be star, with a compact object in the mass range of a neutron star or black hole. Two scenarios are proposed to explain gamma-ray binaries. In the first, the non-thermal emission is believed to originate from the interaction between a pulsar wind and the stellar wind (pulsar wind scenario) while in the second the systems are powered by accretion and the emission is produced in a relativistic jet (microquasar scenario). However, the compact object is only know for two systems, namely PSR B1259-63 and PSR J2032+4127, both of which contain a fast rotating pulsar.

PSR B1259-63 is a ~48 ms pulsar in a ~1236.7 day orbit around an O9.5Ve star, LS 2883. The orbit is highly eccentric (e~0.87) [1,2] and the majority of the non-thermal emission has been detected around a ~2 month period around periastron [3]. During previous periastron passages, the radio and X-ray light curves showed two maxima, slightly before and after periastron, which is associated with the pulsar passing through the circumstellar disc [3]. A similar structure is hinted at in the TeV light curve [4]. However, the behaviour has been extremely different at GeV energies, where the source has shown a flare starting 30 day after periastron, which has exceeded the spin-down luminosity. The flare peaked between 30-40 days after periastron in 2010 and 2014 and around 60 days during the 2017 periastron passage. During 2017 flares were even detected on minute times scales, see [3] and references therein.

The most recent periastron passage occurred on the 9th of February 2021 (MJD 59254.87), and we organized an extensive multi-wavelength campaign to observe the source at radio, optical, X-ray and GeV energies, from 30 days before until more than 100 days after periastron, providing the most extensive coverage of the source to date. The initial results of this campaign are presented here [5].

Observing campaign

Radio: The Australia Telescope Compact Array (ATCA) observed from 19 February to 13 May 2021 in the 4-cm band using the Compact Array Broadband Backend (CABB), approximately every 2 days.

Optical: The Southern African Large Telescope (SALT) observed from 22 days before, to 80 days after periastron, using the RSS(pg0900) and the HRS in Medium Resolution mode.

X-ray: PSR B1259-63 was monitored by the Swift/XRT and NICER. All available observations between 19 January and 24 May have been analysed.

Gamma-ray: Fermi-LAT data has been analysed between 1 January and 6 June 2021.

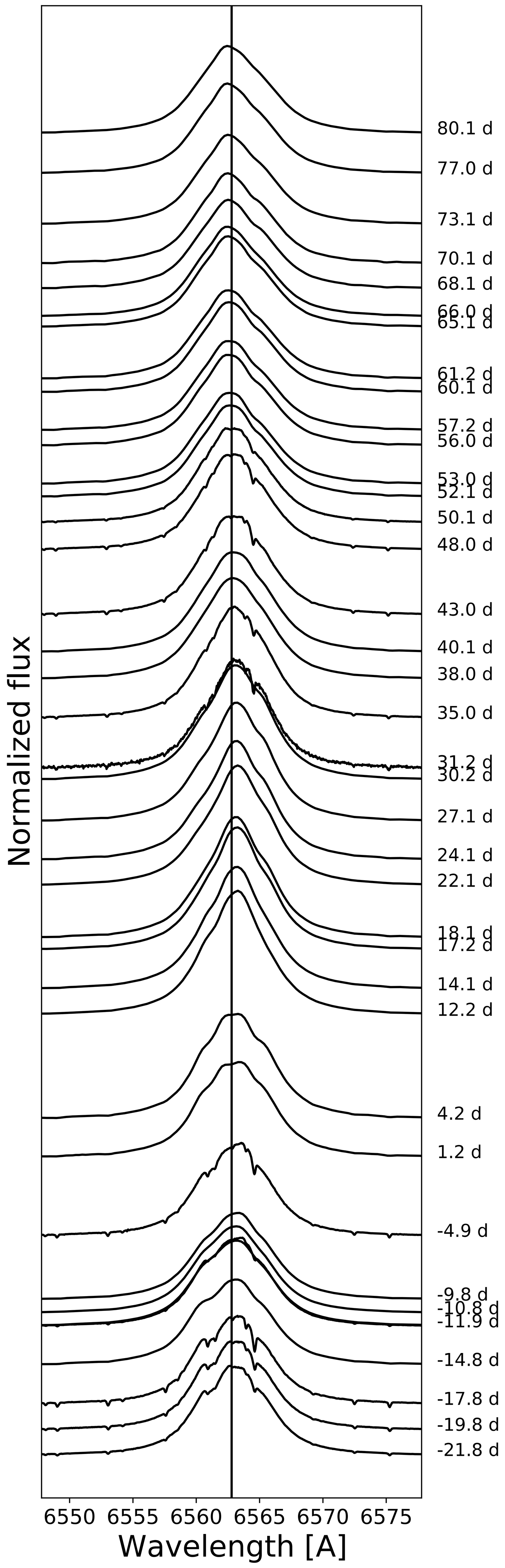
Results

The behaviour of PSR B1259-63 was remarkably different at X-ray and GeV energies during the 2021 periastron passage. While the X-ray emission was similar during the first and second disc crossing (though peaks were slightly lower), the light curve showed a third rise around 30 days after periastron, with no counterpart at other wavelengths. The GeV emission began much later in 2021, with the major increase in GeV activity occurring between 55 - 108 days after periastron.

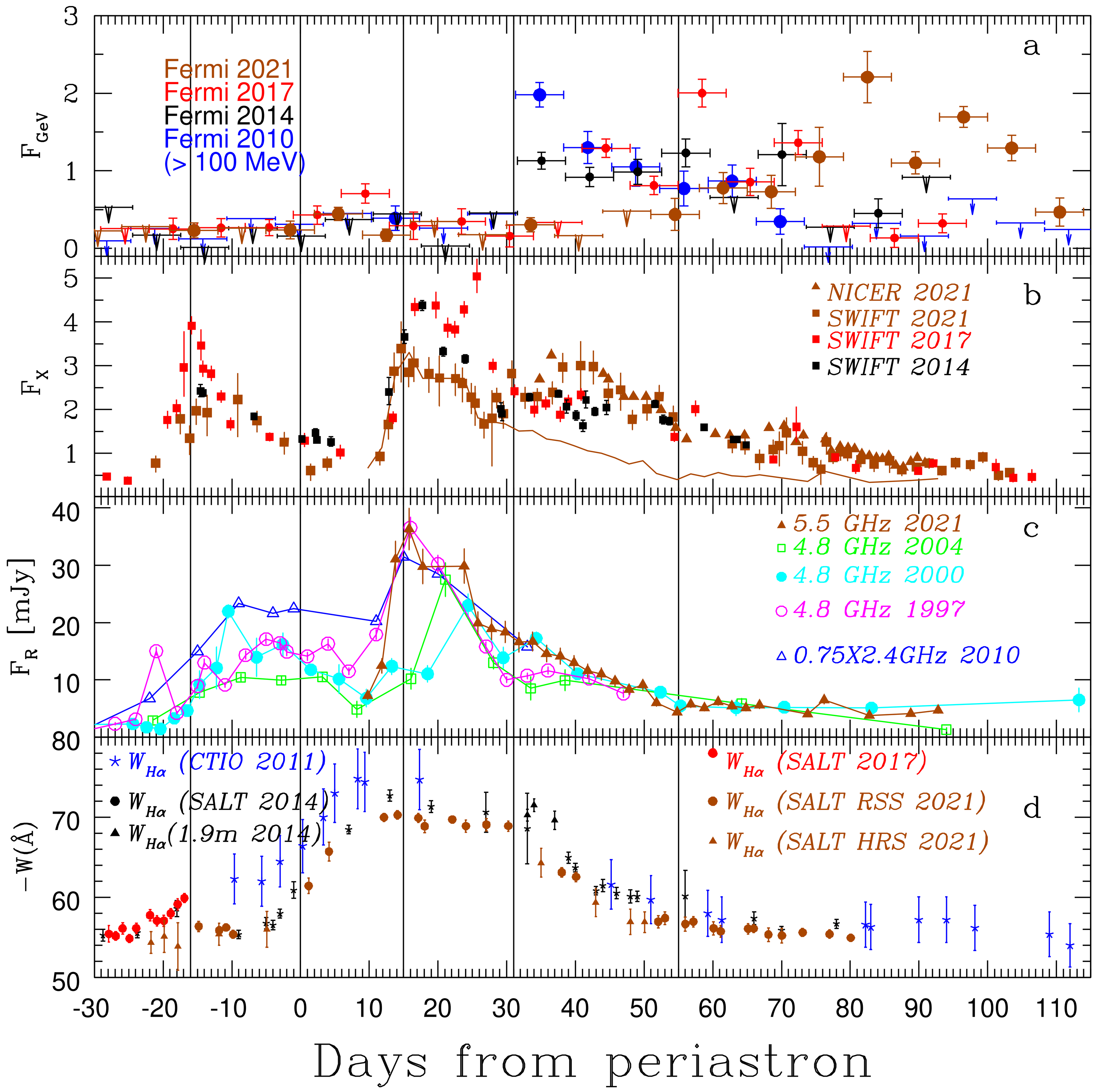
The equivalent width of the H-alpha emission line, which traces the behaviour of the circumstellar disc, is remarkably similar to previous periastron passages, despite the dramatic difference at X-ray and GeV energies, though it is on average slightly lower.

Discussion and Conclusions

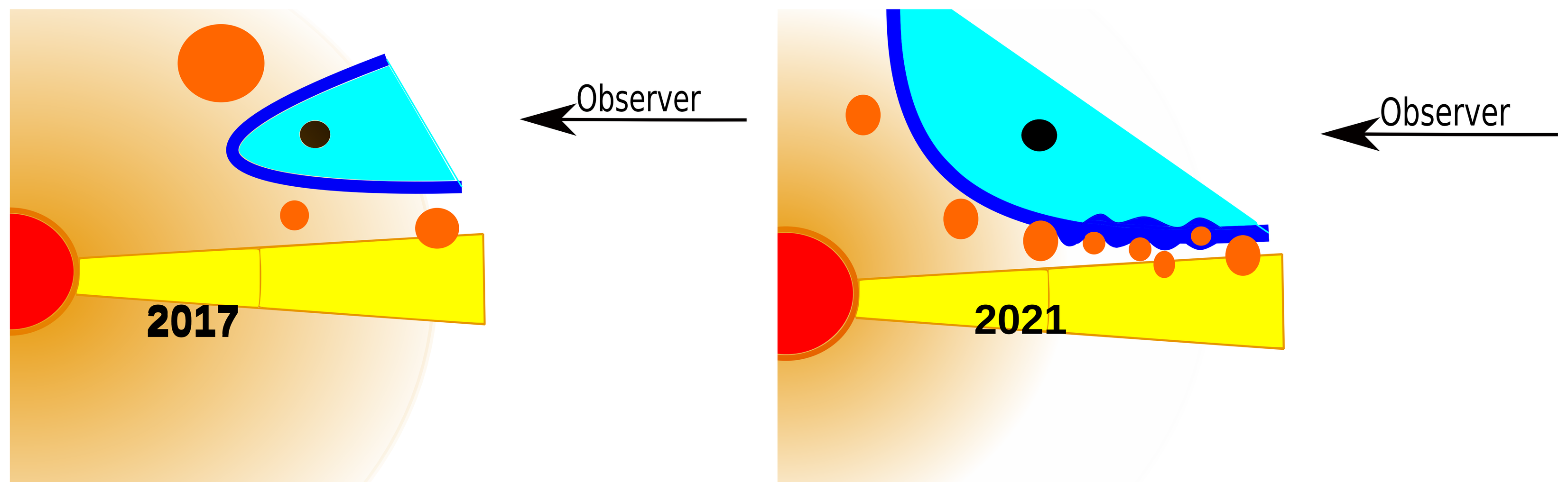
The results from the 2021 periastron can be interpreted in line with the model proposed by [3] where the GeV emission originates from the unshocked pulsar wind which is re-directed along the shock cone. The slightly lower H-alpha equivalent width suggest the outflow may be lower and the cone opening angle larger. This would result in the GeV emission being observed over a longer period. The third peak in the X-ray emission may originate if clumps of material from the disc modify the outflow, which increases the escape time, leading to an enhancement in the X-ray flux.



The evolution of the H-alpha emission line. The line remains in emission during all observations with a general shift in the peak from red to blue wavelengths.



The multi-wavelength behaviour of PSR B1259-63 over multiple periastron passages. ***Panel a:*** *Fermi-LAT flux in the E>100 MeV energy range in weekly bins, in units of 10^{-6} cm^{-2} s^{-1}.* ***Panel b:*** *X-ray flux between 1-10 keV in units of 10^{-11} erg cm^{-2} s^{-1}.* ***Panel c:*** *Radio flux,* ***Panel d:*** *The H-alpha equivalent width.*



The suggested difference in the bow shock structure between 2017 and 2021. The Be star and disc are indicated by the red circle and yellow wedge. The out flow and clumps are indicated in orange. The unshocked pulsar wind is shown in cyan, with the shock indicated in blue.

Acknowledgements

This paper uses observations made at the South African Astronomical Observatory (SAAO). This paper uses observation Some of the observations reported in this paper were obtained with the Southern African Large Telescope (SALT) under program 2018-1-MLT-002 (PI: B. van Soelen). The Australia Telescope Compact Array is part of the Australia Telescope National Facility which is funded by the Australian Government for operation as a National Facility managed by CSIRO. We acknowledge the Gomeroi people as the traditional owners of the Observatory site. The authors acknowledge support by the state of Baden-Württemberg through bwHPC.

References

1. Johnston S., Manchester R. N., Lyne A. G., Bailes M., Kaspi V. M., Qiao G., D'Amico N., 1992, ApJ, 387, L37
2. Shannon R. M., Johnston S., Manchester R. N., 2014, MNRAS, 437, 3255
3, Chernyakova M., Malyshev D., Mc Keague S., van Soelen B., Marais J. P., Martin-Carrillo A., Murphy D., 2020, MNRAS, 497, 648
4. H. E. S. S. Collaboration et al., 2020, A&A, 633, A102
5. Chernyakova, Maria ; Malyshev, Denys ; van Soelen, Brian ; O'Sullivan, Shane ; Sobey, Charlotte ; Tsygankov, S. ; Keague, Samuel Mc. ; Green, Jacob ; Kirwan, Matthew ; Santangelo, Andrea ; Pühlhofer, Gerd ; Monageng, Itumeleng M., 2021, submitted to Universe, arXiv:2106.03759

vansoelenb@ufs.ac.za | www.ufs.ac.za
UFSUV UFSweb UFSweb

SAIP 2021 – Virtual Conference

UFS·UV
NATURAL AND AGRICULTURAL SCIENCES
NATUUR- EN LANDBOUWETENSKAPPE