Calibrating Interstellar Abundances Using Supernova Remnant Radiative Shocks

Michael Andrew "Mike" Dopita(ANU)

delivered by Ivo Seitenzahl *(UNSW Canberra)*

* 28/10/1946

Kraslice, CZ

† 22/12/2018

Canberra, AUS

***Chania, Greece* 7 June 2019**

PhD STUDENTS

http://www.mso.anu.edu.au/dopitaconference/index.html

Mike has been Supervisor of 26 graduate students, from 1980 to the present, 14 of whom remain in the field.

Martha Cleary 1977
Luc Binette 1983
Ian Wilson 1983
Graeme Smith 1983
Ian Evans 1987
Stephen Metheringham 1988
Micheal Ashley 1989
Roger Brisseenden 1990
Iain Hercus 1989

Gerhardt Meurer 1990
Stephen Russell 1990
Emanuel Vassiliadis 1993
Ralph Sutherland 1993
Stuart Ryder 1993
Sylvie Beaulieu 1996
Anton Koekemoer 1996
Mark Allen 1999
Sung-eun Kim 1999

David Jones 2000
Raven Kaldare 2000
Lisa Kewley 2002
Catherine Drake 2004
Brent Groves 2004
Minh Huynh 2005
Catherine Farage 2012
David Nicholls 2014
Fréd Vogt 2015
+Adam Thomas 2019

Professional Society Memberships

Fellow: Australian Academy of Science

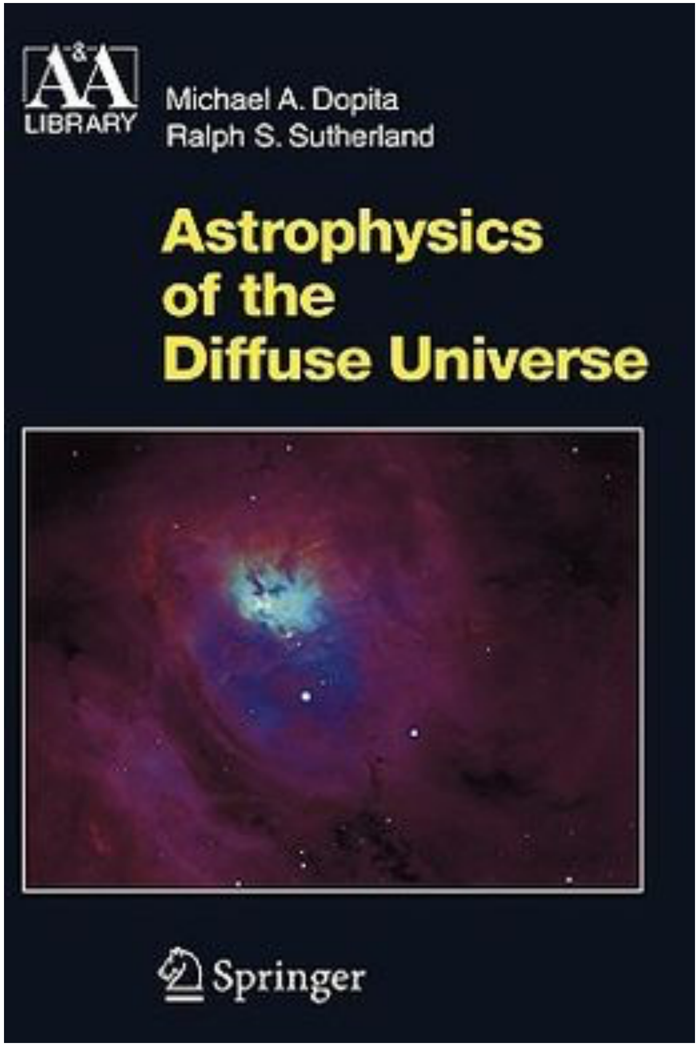
Member: International Astronomical Union,

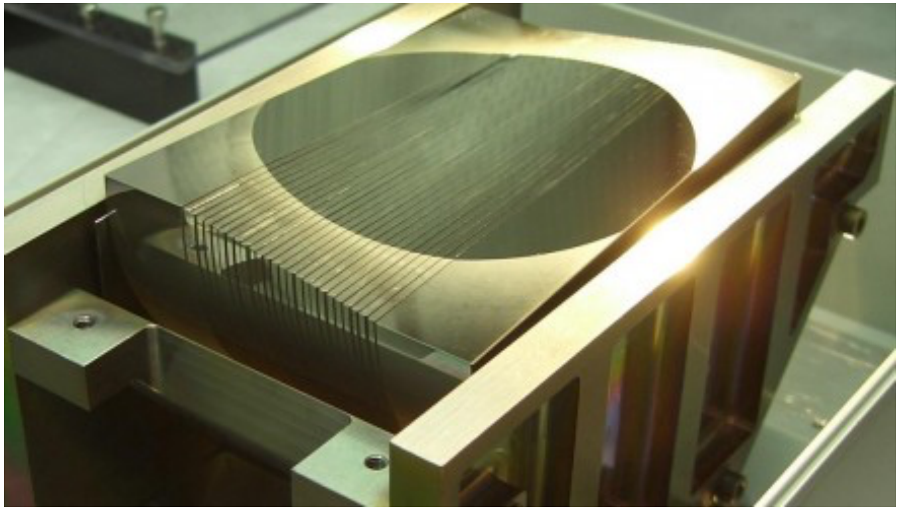
Fellow: Astronomical Society of Australia,

Fellow: American Astronomical Society,

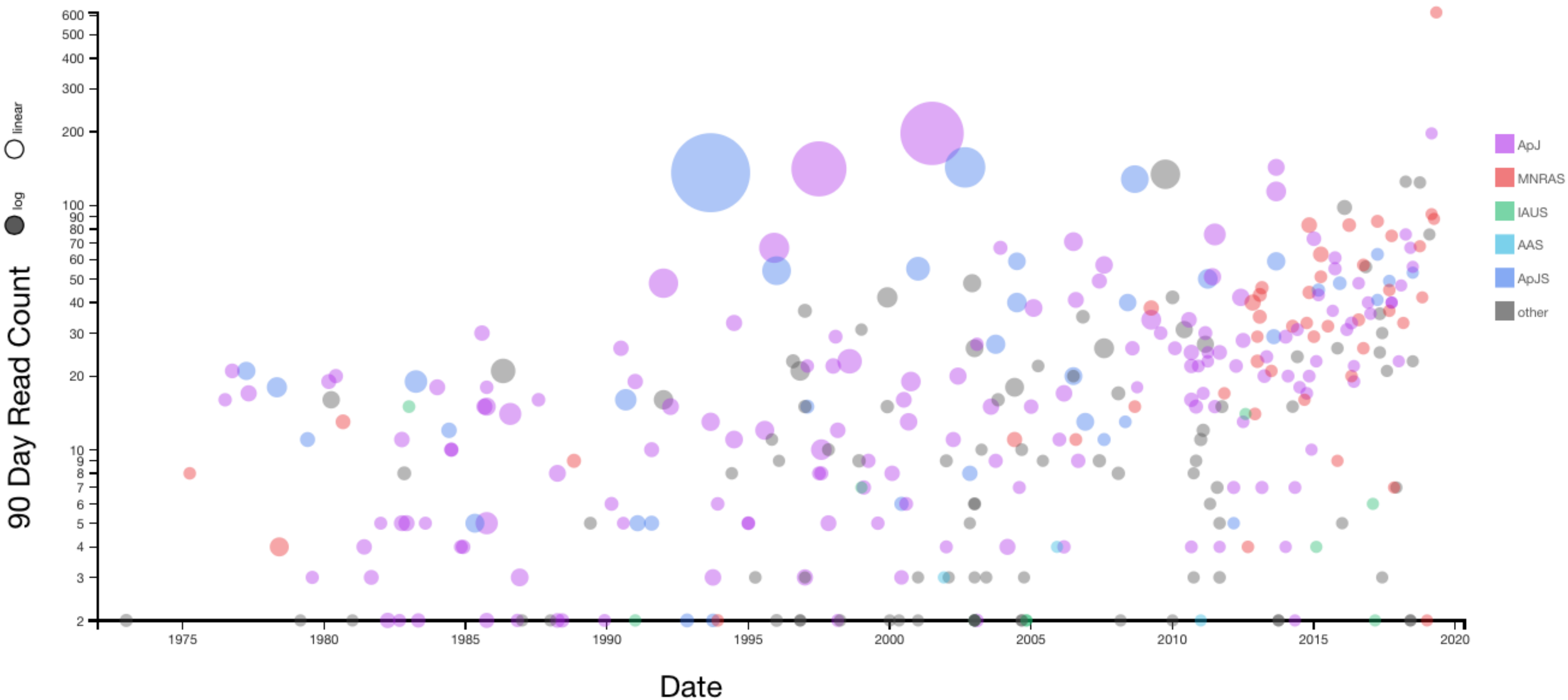
Member: European-Asian Astronomical Society.

Books and instruments





409 refereed papers



Fe bearing grains destroyed in recombination zone, not cooling zone.

Michael A. Dopita[1,2], Ivo R. Seitenzahl[1], Ralph S. Sutherland[1], Frédéric P. A. Vogt[3], P. Frank Winkler[4], & William P. Blair[5]

Draft version May 10, 2016

ABSTRACT

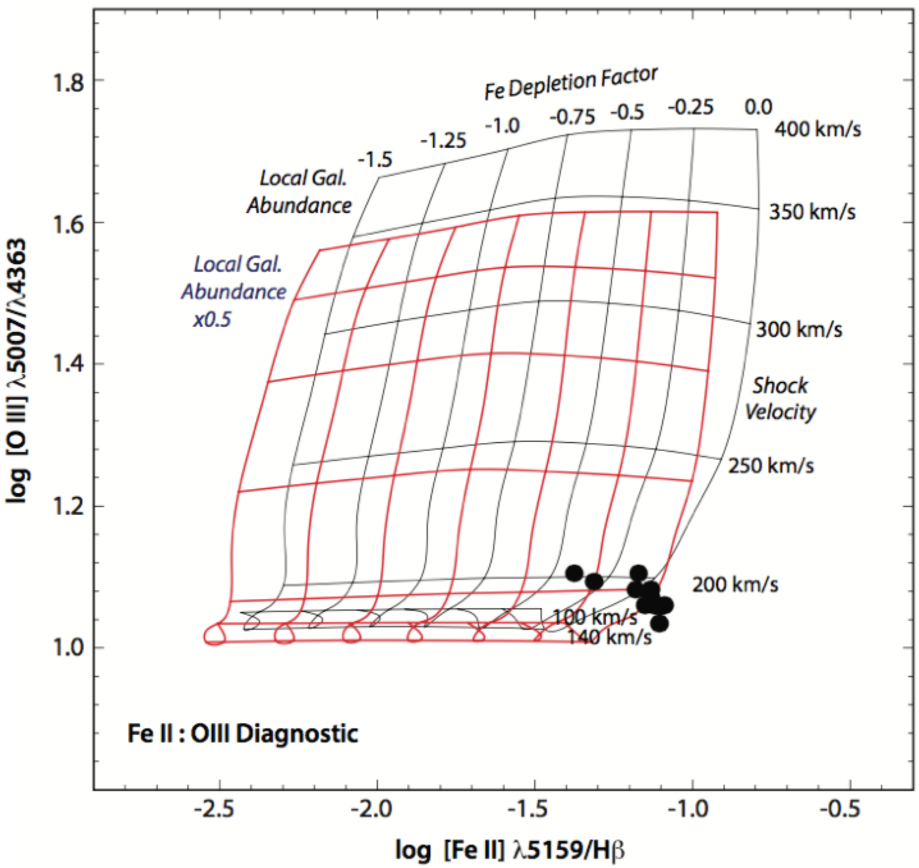
We present results of a complete integral field survey of the bright SNR N49 in the LMC, obtained with the WiFeS instrument mounted on the ANU 2.3m telescope at Siding Spring Observatory. From theoretical shock modelling with the new *MAPPINGS 5.1* code we have, for the first time, subjected the optical Fe emission line spectrum of a supernova remnant to a detailed abundance and dynamical analysis covering 8 separate stages of ionisation. This allows us to derive the dust depletion factors as a function of ionisation stage. We have shown that there is substantial (30% – 90%) destruction of Fe-bearing dust grains in these fast shocks ($v_s \sim 250\,\mathrm{km\,s^{-1}}$), and we have confirmed that the dominant dust destruction is through the non-thermal sputtering and grain-grain collision mechanisms developed in a number of theoretical works.

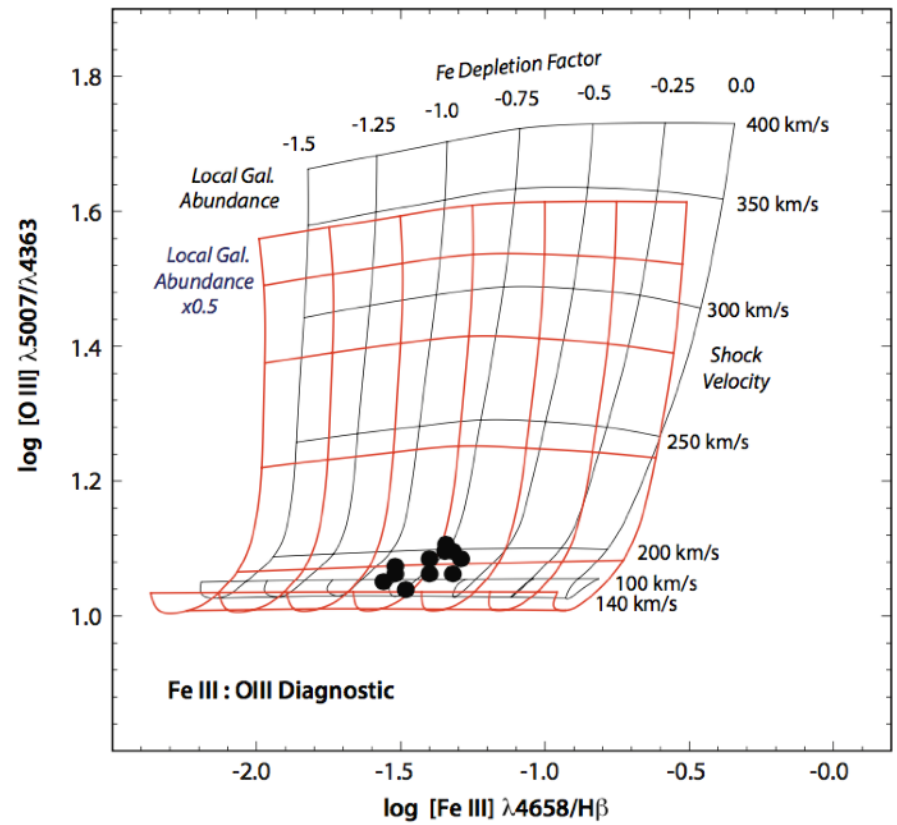
Subject headings: ISM: individual objects (N49) ISM: supernova remnants shock waves Magellanic Clouds dust, extinction

Dust destruction in N49

Fe bearing grains destroyed in recombination zone, not cooling zone.

Michael A. Dopita[1,2], Ivo R. Seitenzahl[1], Ralph S. Sutherland[1], Frédéric P. A. Vogt[3],





Dust destruction in N132D

The Astrophysical Journal Supplement Series, 237:10 (24pp), 2018 July
https://doi.org/10.3847/1538-4365/aac837

CrossMark

Shocked Interstellar Clouds and Dust Grain Destruction in the LMC Supernova Remnant N132D

Michael A. Dopita[1,2], Frédéric P. A. Vogt[3,4], Ralph S. Sutherland[1,2], Ivo R. Seitenzahl[5,6], Ashley J. Ruiter[5,6], and Parviz Ghavamian[7]

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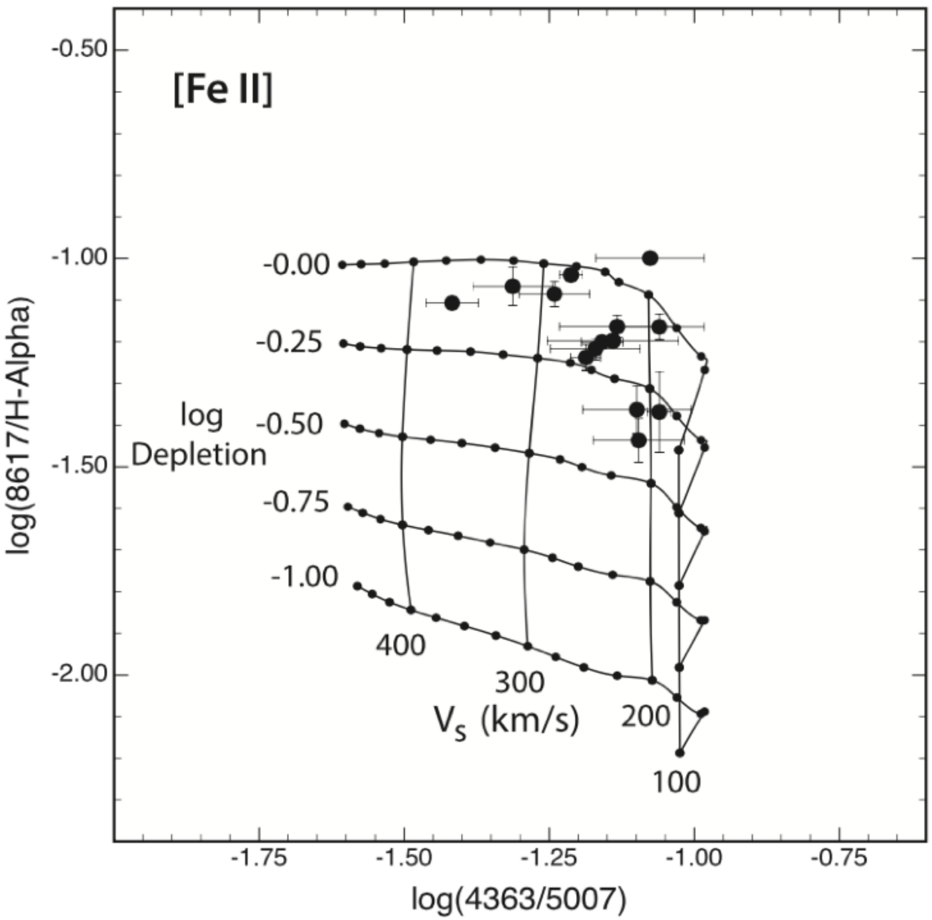
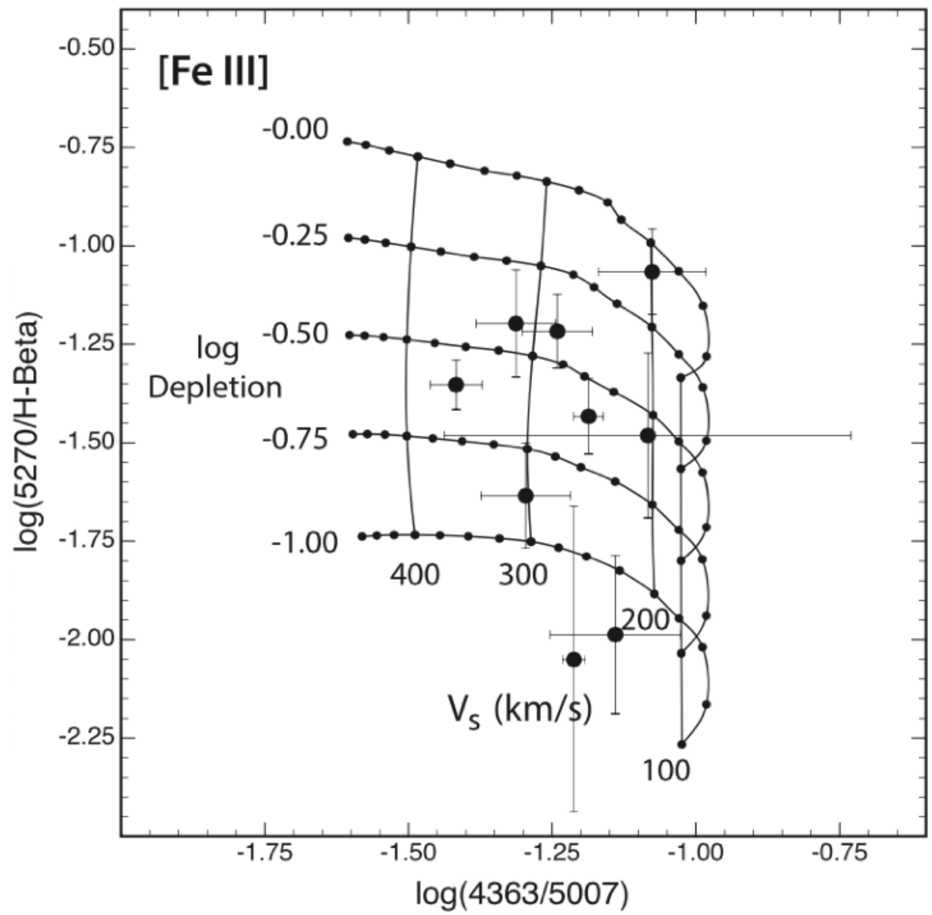
Received 2018 March 12; revised 2018 May 23; accepted 2018 May 24; published 2018 July 10

Dust destruction in N132D





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Fast moving H and O, S, Ar, Cl in 1E0102 with Mappings

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Integral Field Spectroscopy of Supernova Remnant 1E0102–7219 Reveals Fast-moving Hydrogen and Sulfur-rich Ejecta

Ivo R. Seitenzahl[1,2,3], Frédéric P. A. Vogt[4,9], Jason P. Terry[5], Parviz Ghavamian[6], Michael A. Dopita[2], Ashley J. Ruiter[1,2,3], and Tuguldur Sukhbold[7,8]

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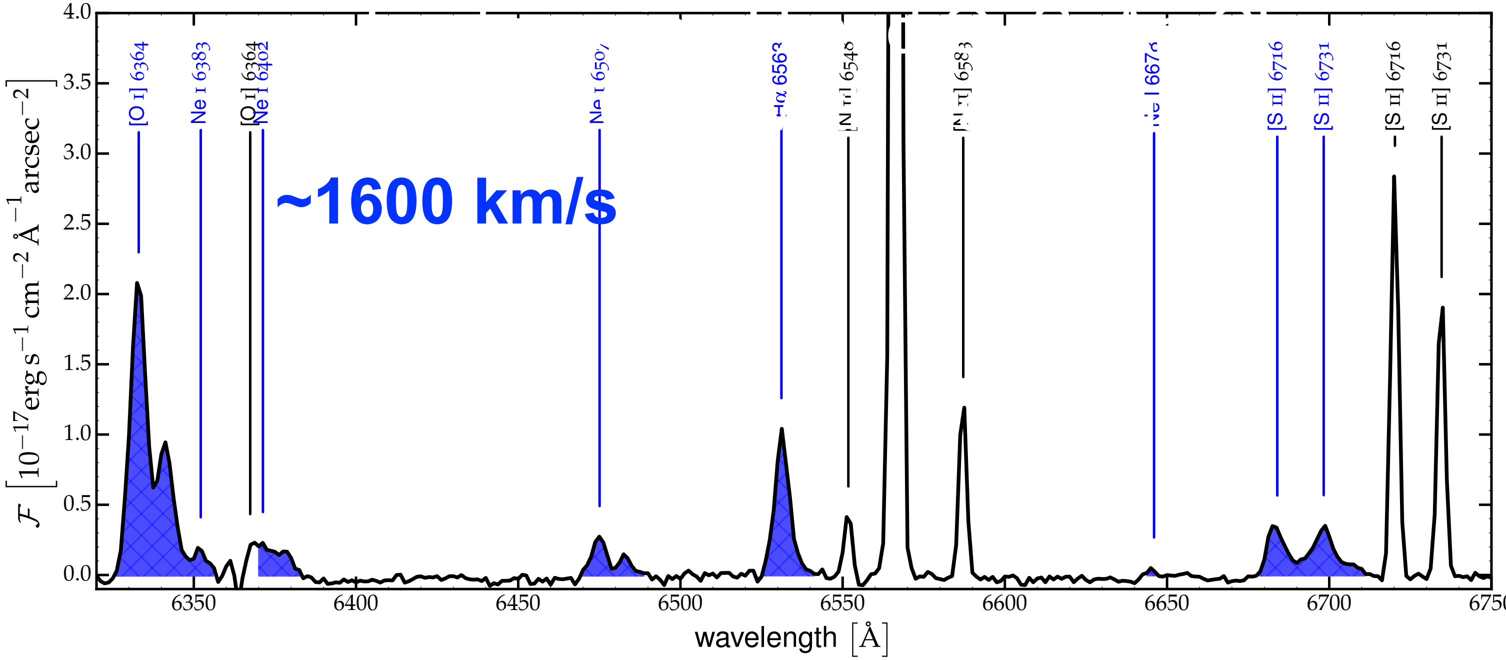
Abstract

We study the optical emission from heavy element ejecta in the oxygen-rich young supernova remnant 1E 0102.2–7219 (1E 0102) in the Small Magellanic Cloud. We have used the Multi-Unit Spectroscopic Explorer optical integral field spectrograph at the Very Large Telescope on Cerro Paranal and the wide field spectrograph (WiFeS) at the ANU 2.3 m telescope at Siding Spring Observatory to obtain deep observations of 1E 0102. Our observations cover the entire extent of the remnant from below 3500 Å to 9350 Å. Our observations unambiguously reveal the presence of fast-moving ejecta emitting in [S II], [S III], [Ar III], and [Cl II]. The sulfur-rich ejecta appear more asymmetrically distributed compared to oxygen or neon, a product of carbon burning. In addition to the forbidden line emission from products of oxygen burning (S, Ar, Cl), we have also discovered Hα and Hβ emission from several knots of low surface brightness, fast-moving ejecta. The presence of fast-moving hydrogen points toward a progenitor that had not entirely shed its hydrogen envelope prior to the supernova. The explosion that gave rise to 1E 0102 is therefore commensurate with a Type IIb supernova.



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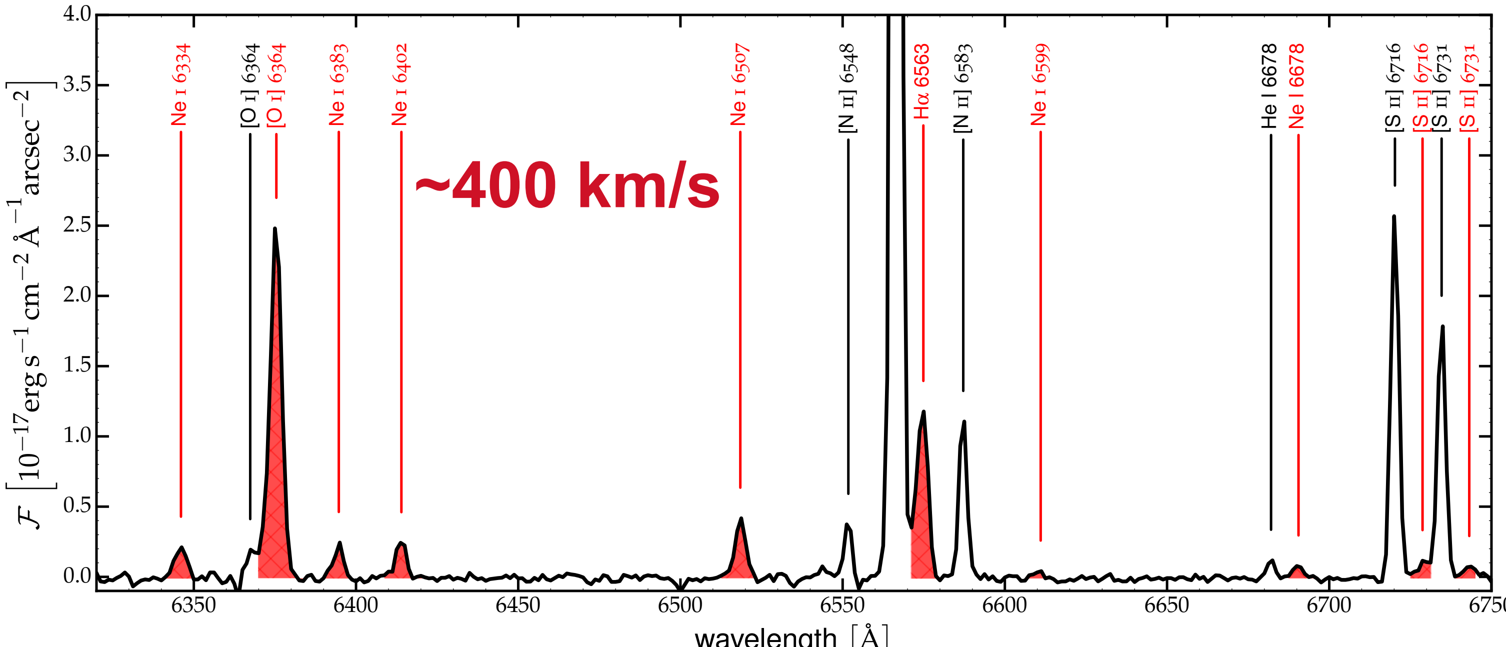
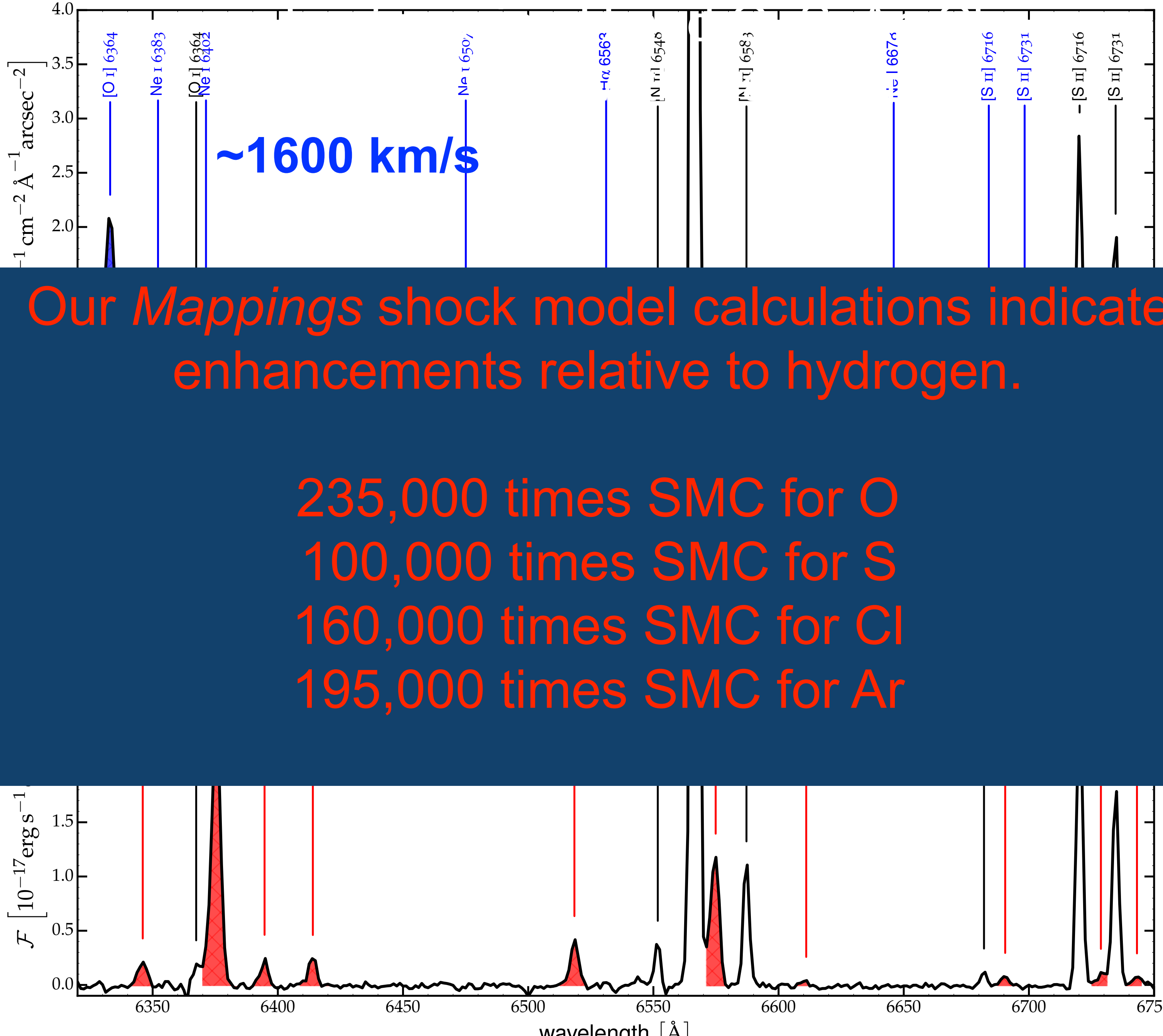
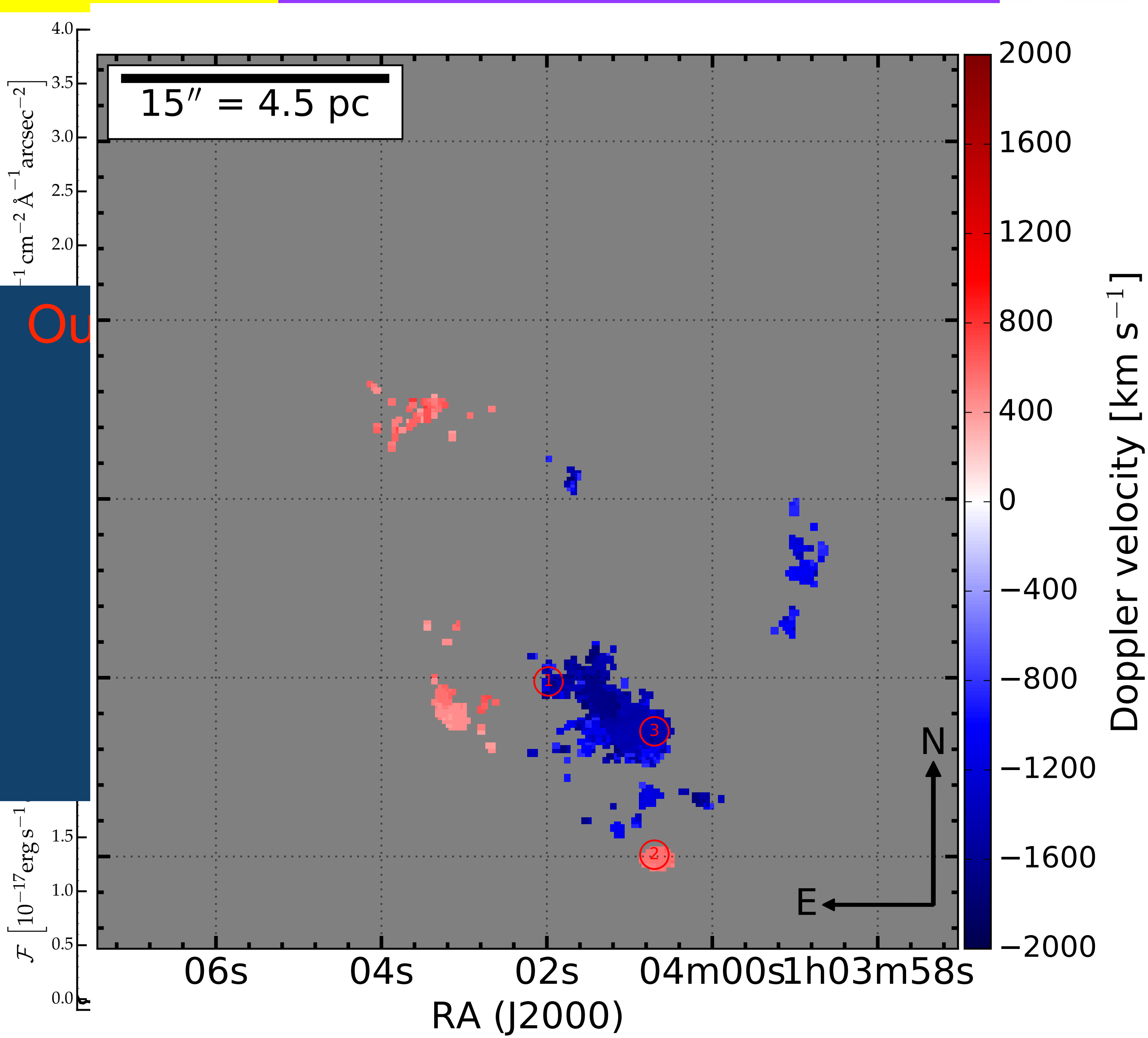


explosion that gave rise to 1E 0102 is therefore commensurate with a Type IIb supernova



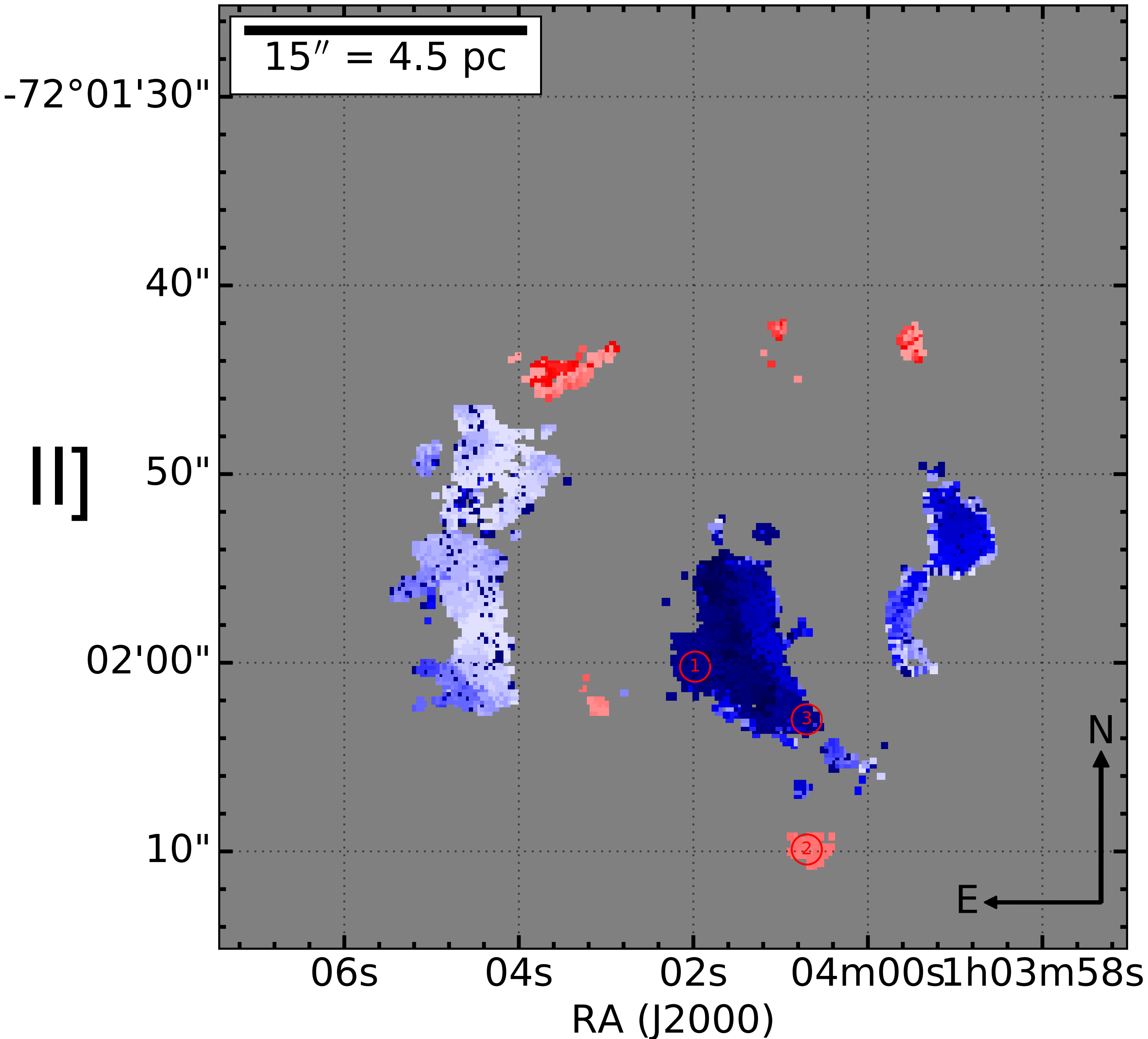
Our *Mappings* shock model calculations indicate enhancements relative to hydrogen.

235,000 times SMC for O
100,000 times SMC for S
160,000 times SMC for Cl
195,000 times SMC for Ar



explosion that gave rise to 1E 0102 is therefore commensurate with a Type IIb supernova

[S II]


15″ = 4.5 pc
-72°01'30"
40"
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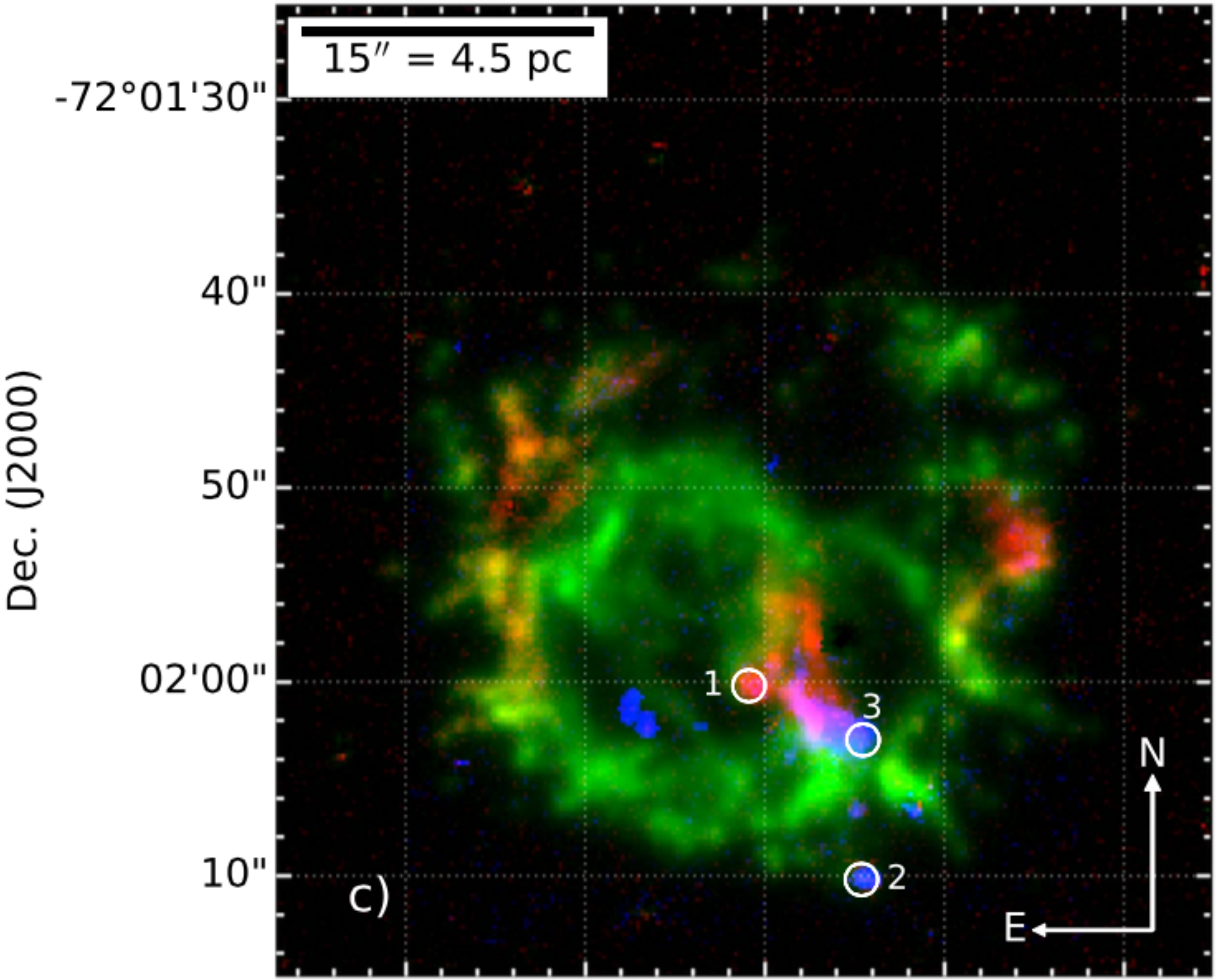

15″ = 4.5 pc
-72°01'30"
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10"
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1
2
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c)
N
E

[Fe XIV] and [Fe XI] behind the forward shock in 1E0102

[Fe XIV] and [Fe XI] reveal the forward shock in SNR 1E 0102.2-7219

Frédéric P. A. Vogt[1,⋆], Ivo R. Seitenzahl[2,3,4], Michael A. Dopita[2], and Parviz Ghavamian[5]

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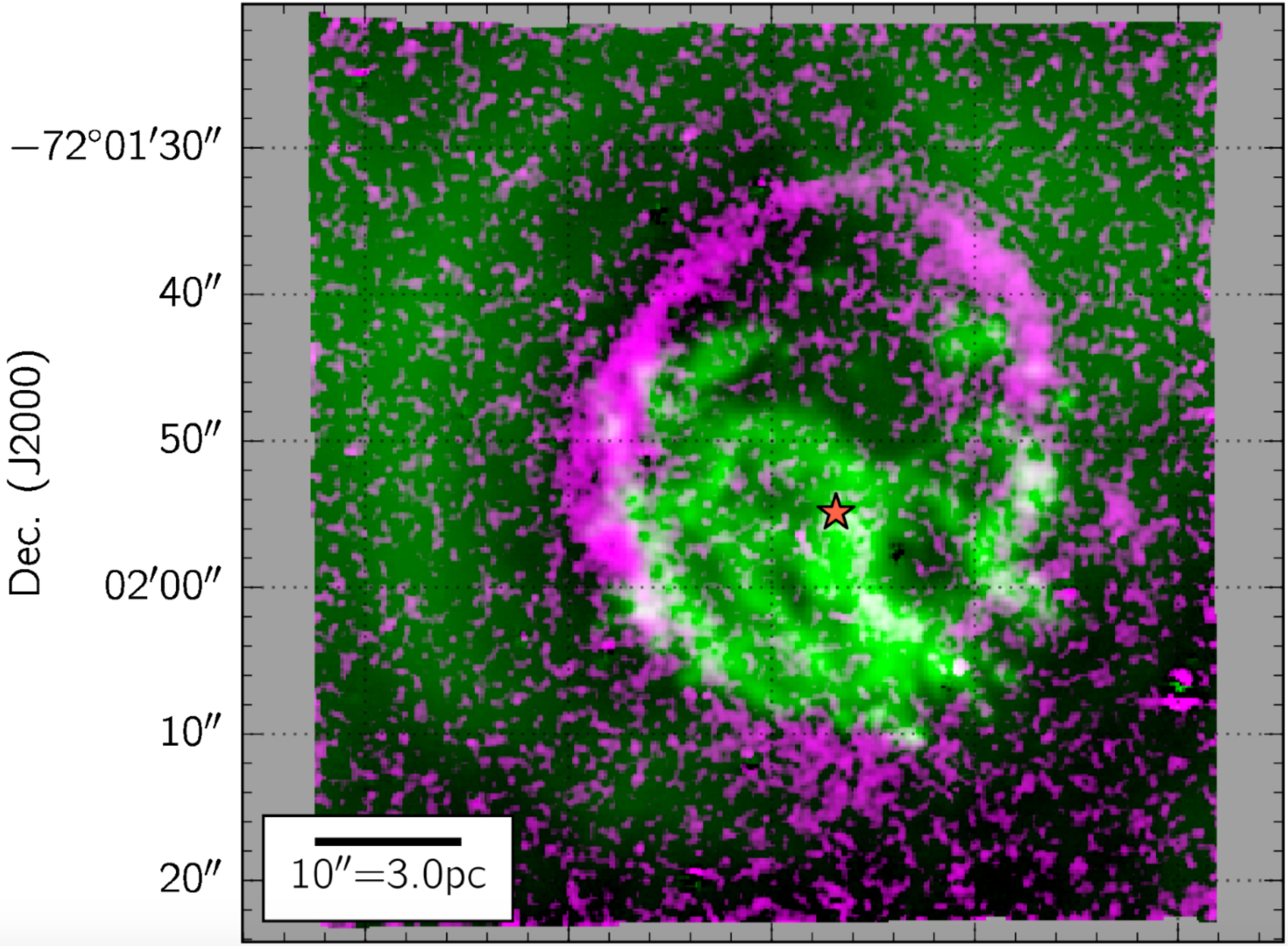
ABSTRACT

Aims. We study the forward shock in the oxygen-rich young supernova remnant (SNR) 1E 0102.2-7219 (1E 0102 in short) via optical coronal emission from [Fe XIV] and [Fe XI]: emission lines that allow for the use of an alternative method to X-rays for this purpose.
Methods. We have used the Multi-Unit Spectroscopic Explorer (MUSE) optical integral field spectrograph at the Very Large Telescope (VLT) on Cerro Paranal to obtain deep observations of SNR 1E 0102 in the Small Magellanic Cloud. Our observations cover the entire extent of the remnant with a seeing limited spatial resolution of $0.7'' \equiv 0.2$ pc at the distance of 1E 0102.
Results. Our MUSE observations unambiguously reveal the presence of [Fe XIV] and [Fe XI] emission in 1E 0102. The emission largely arises from a thin, partial ring of filaments surrounding the fast-moving O-rich ejecta in the system. The brightest [Fe XIV] and [Fe XI] emission is found along the eastern and north-western sides of 1E 0102, where shocks are driven into denser ISM material, while fainter emission along the northern edge reveals the location of the forward shock in lower-density gas, possibly the relic stellar wind cavity. Modeling the eastern shocks and the photoionization precursor surrounding 1E 0102, we derive a pre-shock density $n_{\mathrm{H}} = (7.4 \pm 1.5)\,\mathrm{cm}^{-3}$, and a shock velocity $330\,\mathrm{km\,s^{-1}} < \upsilon_{\mathrm{s}} < 350\,\mathrm{km\,s^{-1}}$.



−72°01′30″
40″
50″
Dec. (J2000)
02′00″
10″
20″
10″=3.0pc

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Balmer-dominated shocks in N103B

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THE ASTROPHYSICAL JOURNAL, 847:122 (12pp), 2017 October 1 https://doi.org/10.3847/1538-4357/aa83b8

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Integral Field Spectroscopy of Balmer-dominated Shocks in the Magellanic Cloud Supernova Remnant N103B

Parviz Ghavamian[1], Ivo R. Seitenzahl[2,3,4], Frédéric P. A. Vogt[5,10], M. A. Dopita[2], Jason P. Terry[6], Brian J. Williams[7,8], and P. Frank Winkler[9]

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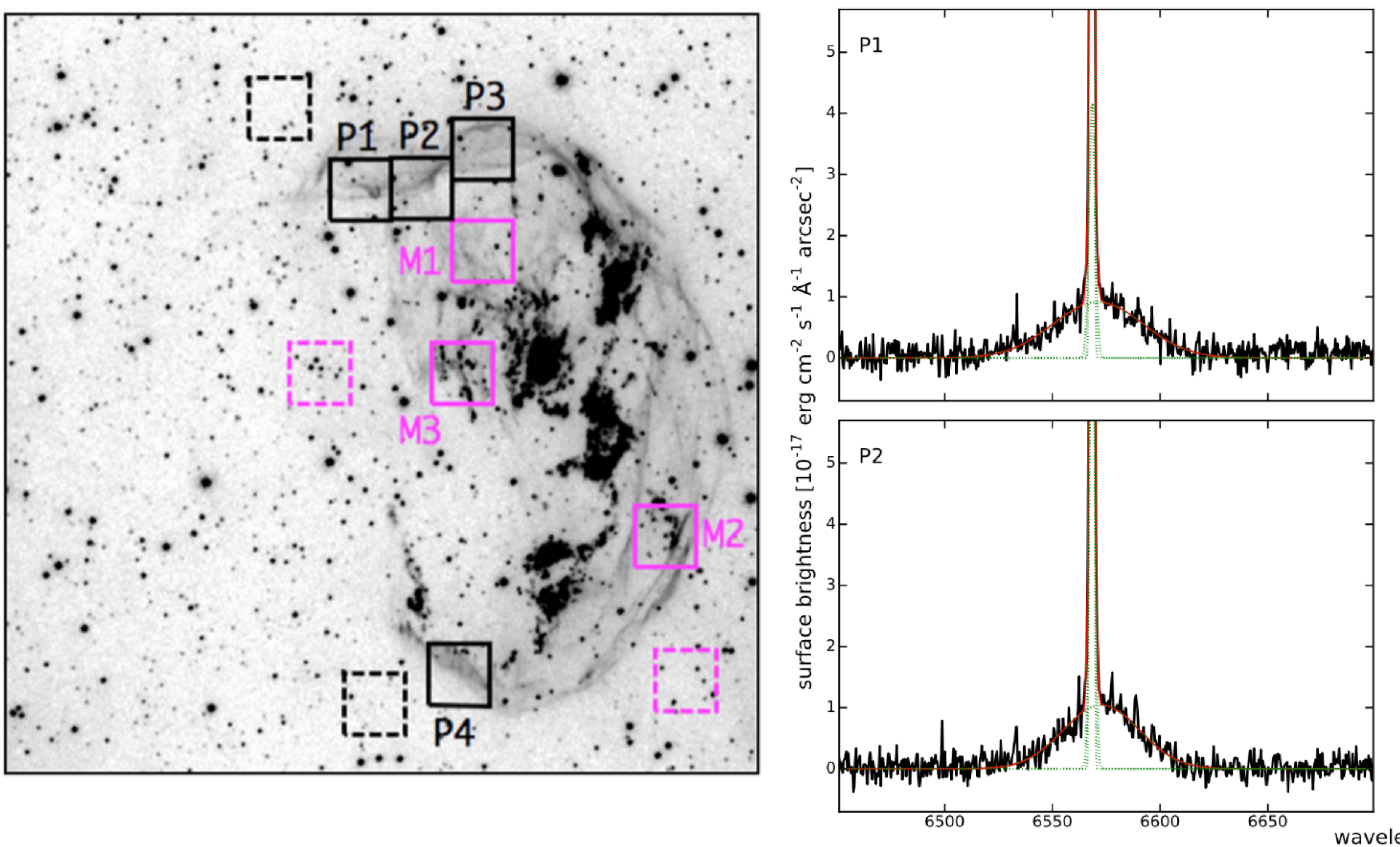
Balmer-dominated shocks in N103B



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extragalactic NS in 1E0102.2-7219

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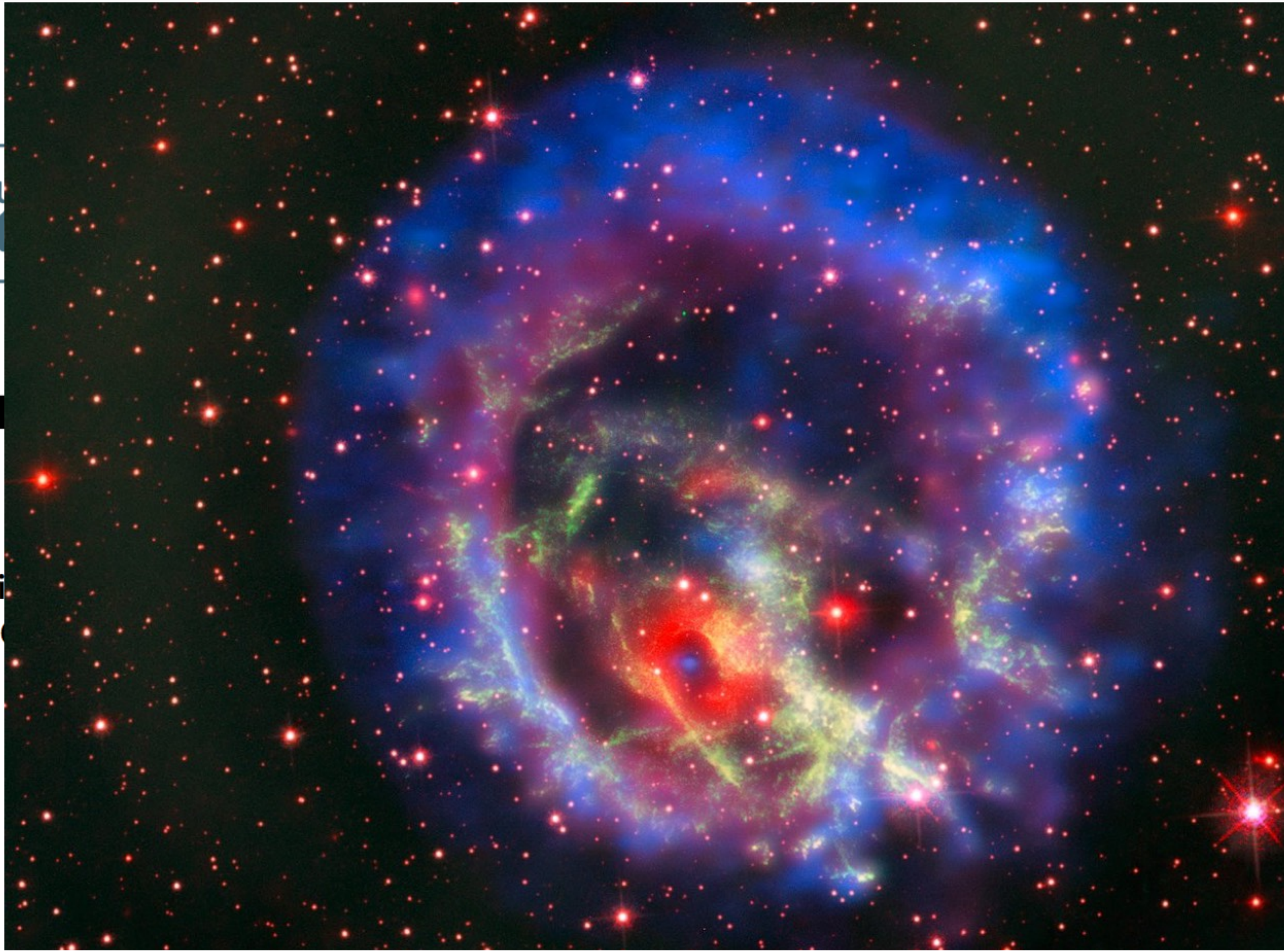
nature astronomy

LETTERS

https://doi.org/10.1038/s41550-018-0433-0

Identification of the central compact object in the young supernova remnant 1E 0102.2-7219

Frédéric P. A. Vogt[1*], Elizabeth S. Bartlett[1], Ivo R. Seitenzahl[2,3], Michael A. Dopita[3], Parviz Ghavamian[4], Ashley J. Ruiter[2,3] and Jason P. Terry[5]



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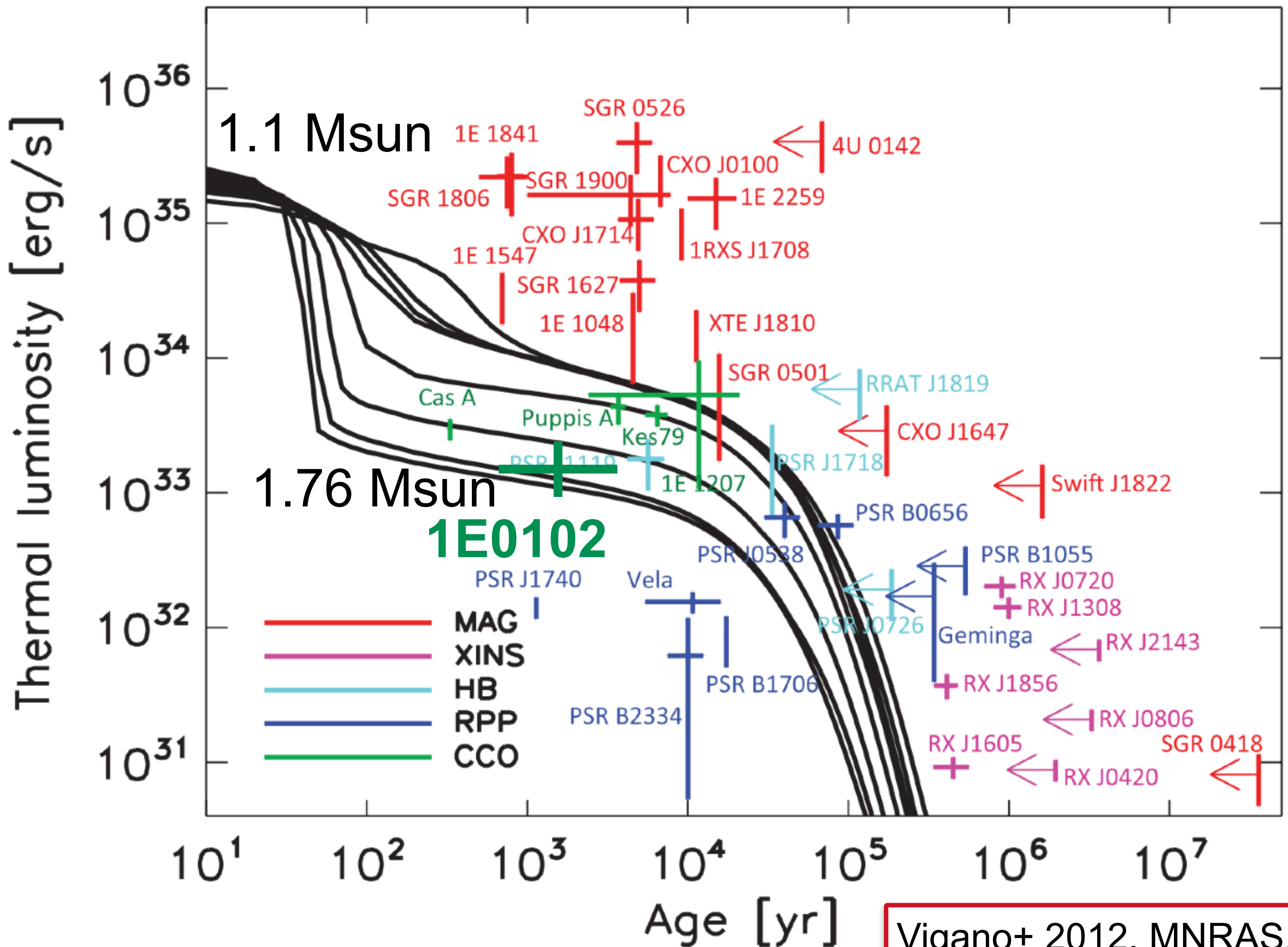
extragalactic NS in 1E0102.2-7219



Vigano+ 2012, MNRAS, 434, 123

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Mike's last first author paper

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Calibrating Interstellar Abundances Using Supernova Remnant Radiative Shocks

Michael A. Dopita[1,2], Ivo R. Seitenzahl[3,6], Ralph S. Sutherland[1,2], David C. Nicholls[1,2], Frédéric P. A. Vogt[4,7], Parviz Ghavamian[5], and Ashley J. Ruiter[3,6]
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Abstract

Using integral field data we extract the optical spectra of shocked interstellar clouds in *Kepler*'s supernova remnant located in the inner regions of our Galaxy, as well as in the Large Magellanic Cloud, the Small Magellanic Cloud, NGC 6822, and IC 1613. Using self-consistent shock modeling, we make a new determination of the chemical composition of the interstellar medium in N, O, Ne, S, Cl, and Ar in these galaxies and obtain accurate estimates of the fraction of refractory grains destroyed in the shock. By comparing our derived abundances with those obtained in recent works using observations of B-stars, F supergiant stars, and H II regions, we provide a new calibration for abundance scaling in the range of $7.9 \lesssim 12 + \log O/H \lesssim 9.1$.

Table 1
Log of WiFeS Observations of SNR

Position	R.A. (J2000)	Decl. (J2000)	Date	Exp. Time (s)
IC 1613-S8	01:05:02.1	+02:08:43	2017 Nov 20	2 × 1000
IC 1613-S8	01:05:02.1	+02:08:43	2017 Nov 22	2 × 1200
SMC-0104-72.3	01:06:25.2	−72:05:29	2016 Nov 28	2 × 1200
LMC-N103B	05:08:58.6	−68:43:33	2014 Dec 18	2 × 1800
LMC-N103B	05:08:58.6	−68:43:33	2014 Dec 19	2 × 1800
NGC 6822-Ho12	19:44:56.5	−14:48:30	2016 Aug 7	2 × 1800
NGC 6822-Ho12	19:44:56.5	−14:48:30	2016 Aug 7	1 × 1800
Kepler SNR	17:30:36.2	−21:28:49	2018 May 13	3 × 500
Kepler SNR	17:30:36.2	−21:28:49	2018 May 13	2 × 1500

Position	…p. Time (s)
IC 1613	× 1000
IC 1613	× 1200
SMC-01	× 1200
LMC-N	× 1800
LMC-N	× 1800
NGC 68	× 1800
NGC 68	× 1800
Kepler S	× 500
Kepler S	× 1500

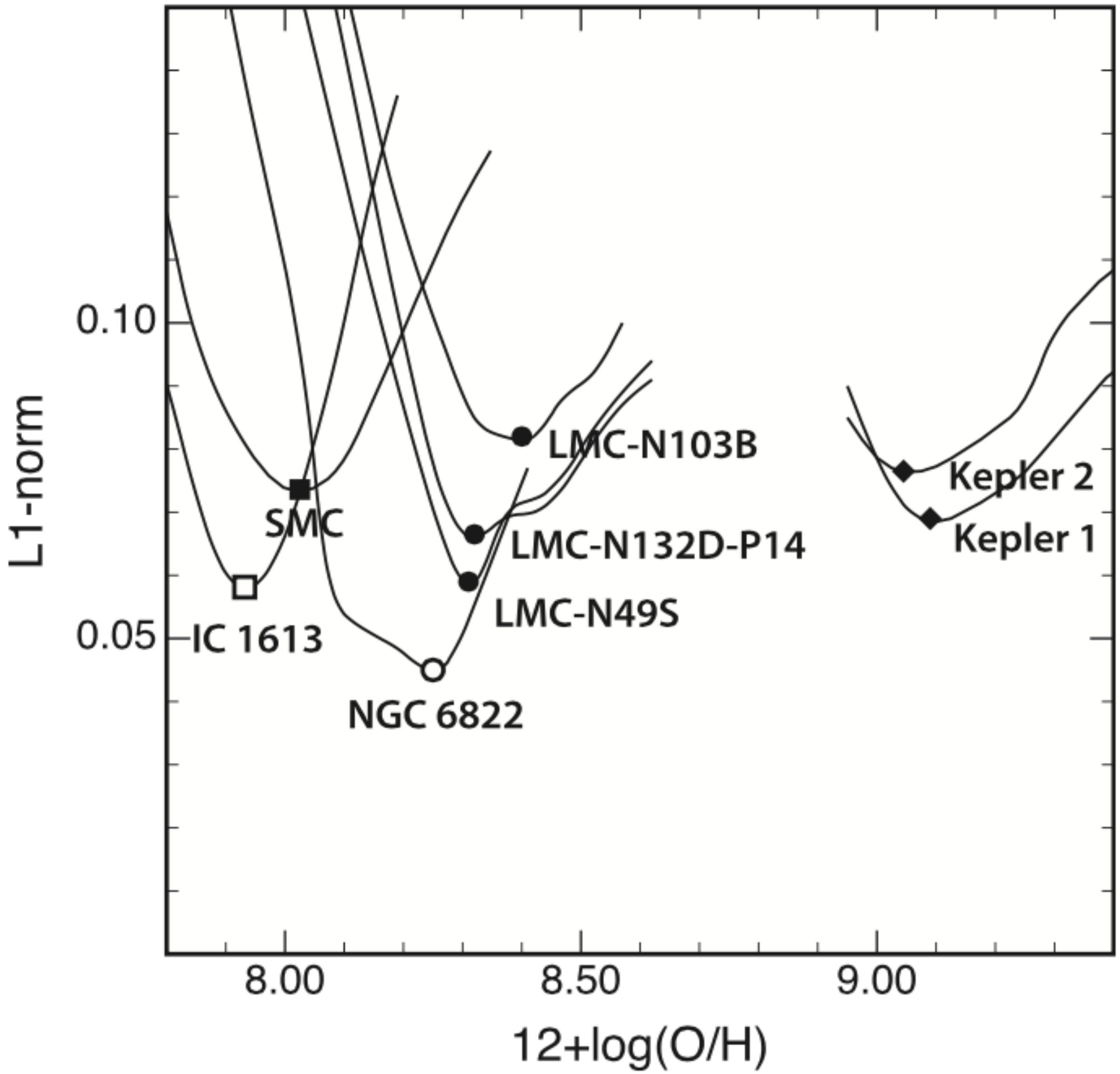

Figure 8. Behavior of the L1-norm as a function of the scaled O abundance for the observed SNRs. The shock velocities, ram pressures, and mixing ratio of the fast and slow shock components are kept fixed in these models. The best-fit abundances of each galaxy are marked.

Abundances with precision comparable to those from B-type stars or H II regions.

Abundances for

He, C, N, O,

Ne, Mg, Si, S, Cl

Ca, Ar, Fe, Ni

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ISM abundances for local dwarfs and the MW

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Table 3

Derived Shock Parameters, Abundances (12 + log X/H), and Inferred Ionic Depletion Factors

	Galaxy *Kepler* 1	Galaxy *Kepler* 2	LMC N49	LMC N103B	LMC N132D	SMC 0104-72.3	NGC 6822 Ho 12	IC 1613 S8
Shock Parameters:								
P_{ram} (dynes cm^{-2})	1.81E–07	1.80E–07	2.67E–07	1.33E–06	3.52E–07	1.82E–09	6.19E–08	3.70E–08
V_s (km s^{-1})	220	220	210	220	200	230	200	230
Fast Shock Fraction *F*	1.00	1.00	0.82	0.79	0.88	0.37	0.53	0.60
Shock Age (yr)	50	40						
Elemental Abundance:								
He	11.02 ± 0.03	11.06 ± 0.03	10.96 ± 0.03	10.92 ± 0.03	10.96 ± 0.03	10.91 ± 0.03	10.95 ± 0.03	10.94 ± 0.03
C	9.06 ± 0.32	8.99 ± 0.32	8.09 ± 0.32	(8.09)	8.09 ± 0.32	7.50 ± 0.32	(7.45)	7.20 ± 0.32
N	8.44 ± 0.08	8.27 ± 0.08	7.17 ± 0.05	7.17 ± 0.05	7.32 ± 0.05	6.82 ± 0.06	6.99 ± 0.07	6.67 ± 0.05
O	9.09 ± 0.06	9.04 ± 0.06	8.32 ± 0.04	8.37 ± 0.04	8.32 ± 0.04	8.02 ± 0.06	8.25 ± 0.06	7.92 ± 0.04
Ne	8.49 ± 0.10	8.32 ± 0.10	7.66 ± 0.05	7.57 ± 0.05	7.62 ± 0.04	7.04 ± 0.10	7.52 ± 0.06	7.01 ± 0.05
Mg	(7.70)	(7.65)	(7.19)	(7.19)	(7.19)	(6.64)	(6.95)	(6.52)
Si	(7.64)	(7.59)	(7.11)	(7.11)	(7.11)	(6.77)	(6.89)	(6.66)
S	7.84 ± 0.07	7.79 ± 0.07	7.03 ± 0.09	6.88 ± 0.09	7.10 ± 0.07	6.79 ± 0.13	6.84 ± 0.07	6.69 ± 0.06
Cl	5.68 ± 0.12	5.58 ± 0.12	(4.96)	(4.96)	4.96 ± 0.10	4.37 ± 0.15	(4.49)	(4.04)
Ar	6.43 ± 0.14	6.23 ± 0.14	(5.79)	(5.79)	5.79 ± 0.10	(5.49)	5.65 ± 0.14	5.33 ± 0.14
Ca	(6.46)	(6.46)	(6.02)	(6.02)	(6.02)	(5.67)	(5.91)	(5.28)
Fe	(7.66)	(7.66)	(7.33)	(7.33)	(7.33)	(6.76)	(7.13)	(6.75)
Ni	(6.34)	(6.34)	(5.91)	(5.91)	(5.91)	(5.55)	(5.79)	(5.36)

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Alexei Khokhlov
1954 - 4 May 2019

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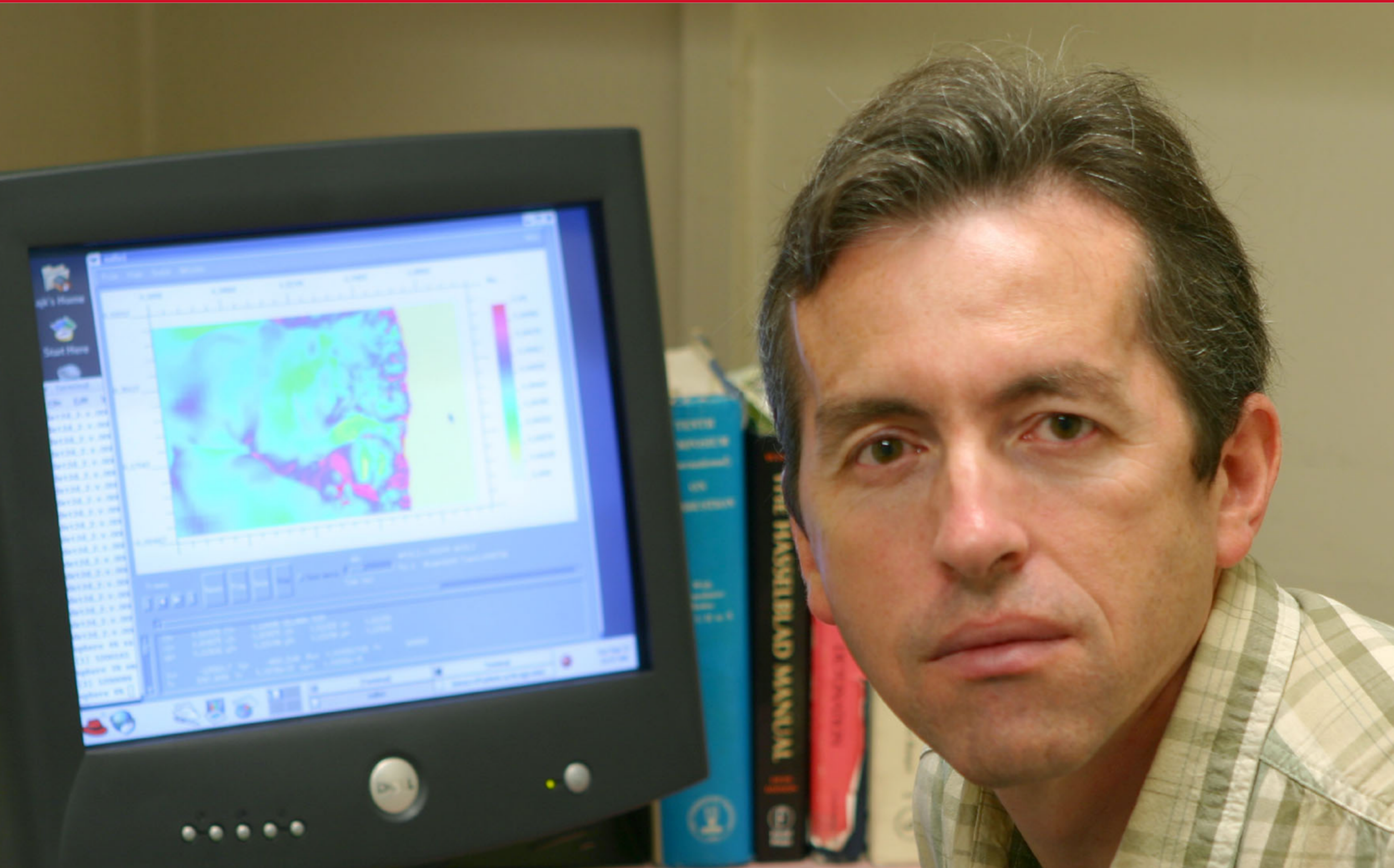

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It has been an honor.
Vale, Mike!

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