Interstellar minor bodies in the Solar System

Piotr Guzik

Jagiellonian University, Kraków, Poland

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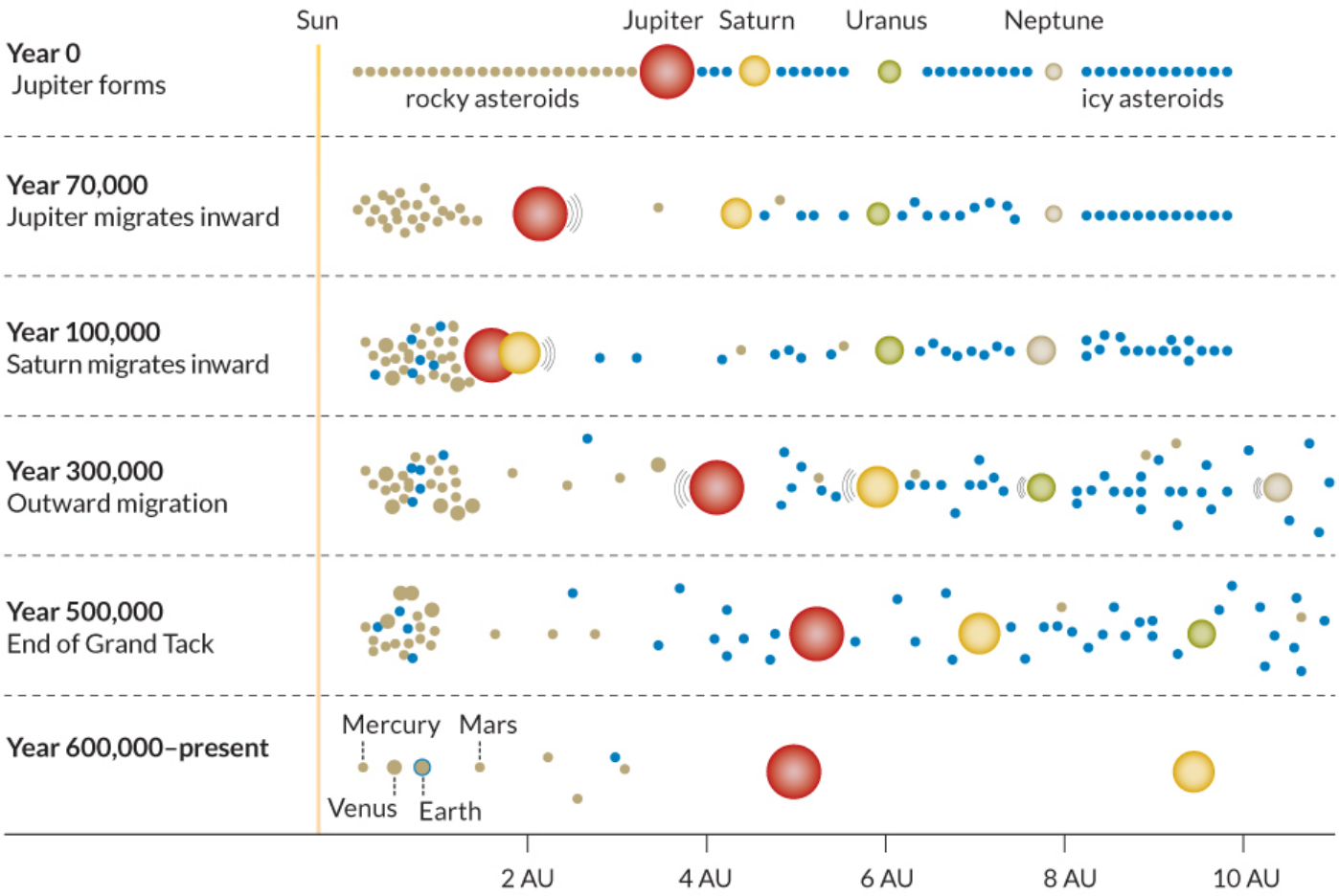
Interstellar minor bodies: early expectations

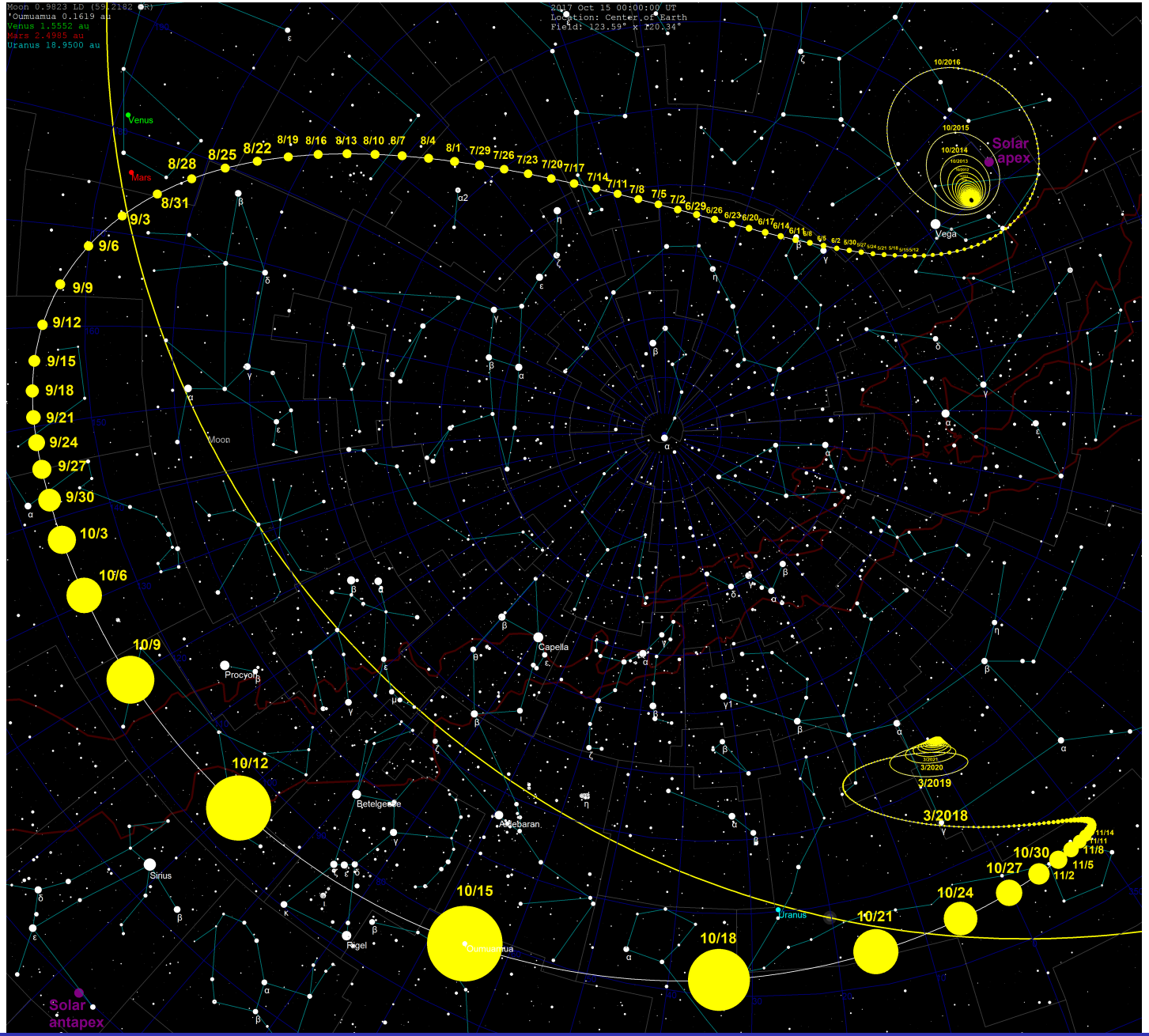


Giant planet formation and migration. *source: https://www-n.oca.eu/*

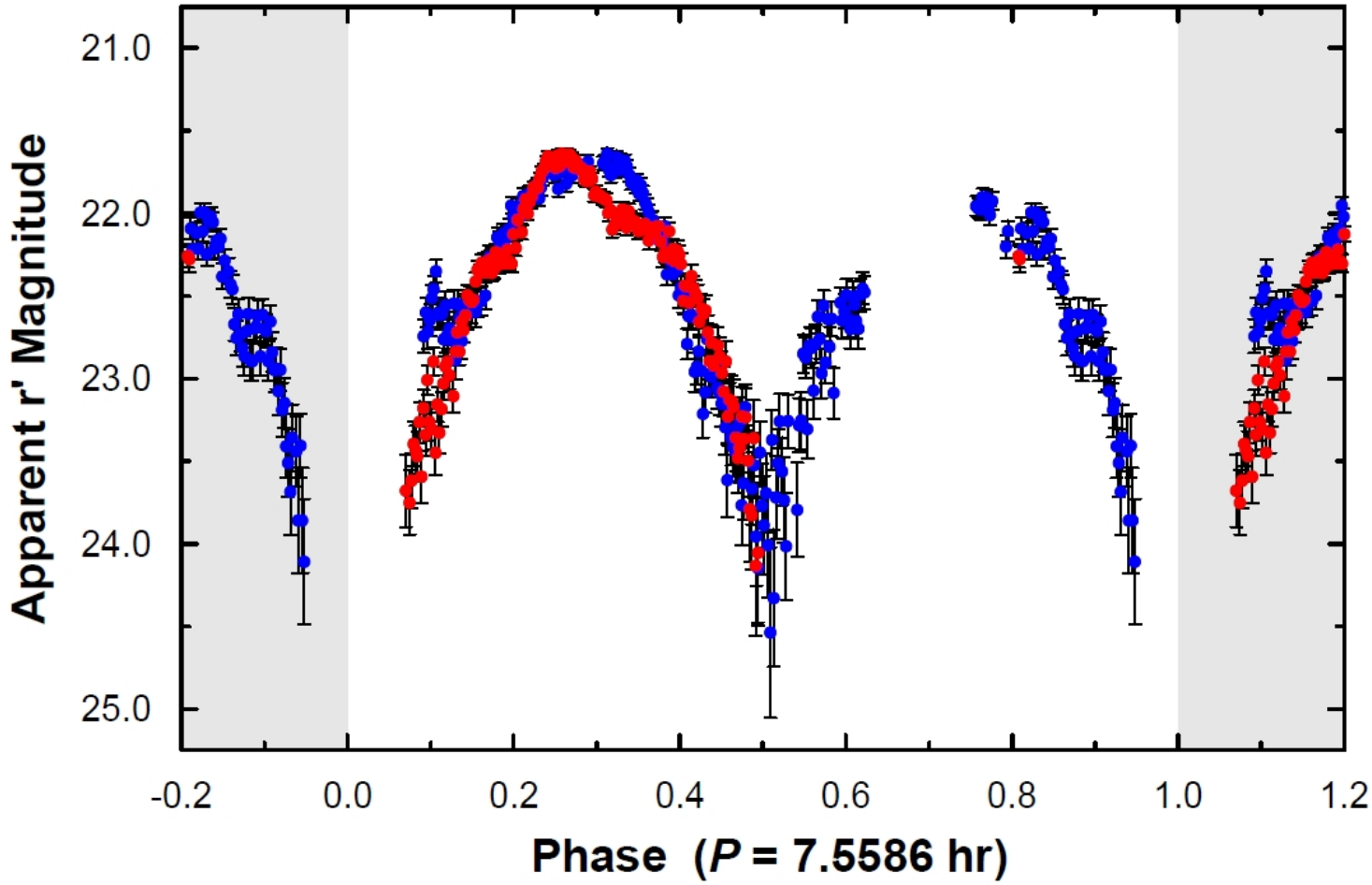
‘Oumuamua: discovery

- Found in mid-October 2017 by Pan-STARRS, about month after perihelion (at 0.25 AU)
- Faint ($\sim 20^{mag}$)), quickly receding from the Sun and Earth (closest approach at 0.16 AU, shortly before the discovery)
- High eccentricity: $e = 1.20$
- Excess speed at infinity ~ 26 km/s consistent with solar system motion
- Radiant very close to solar apex

‘Oumuamua: origin

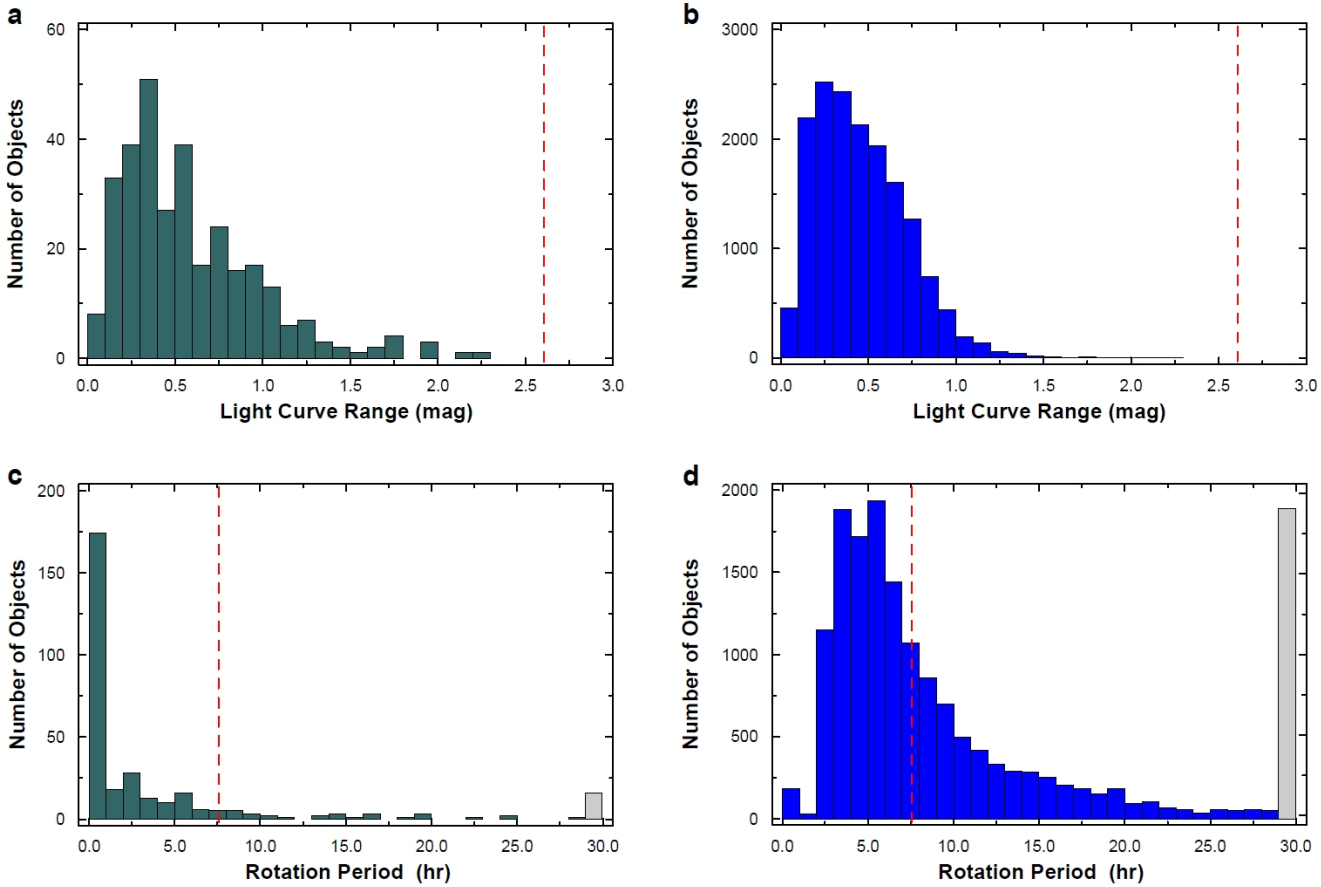


‘Oumuamua: lightcurve



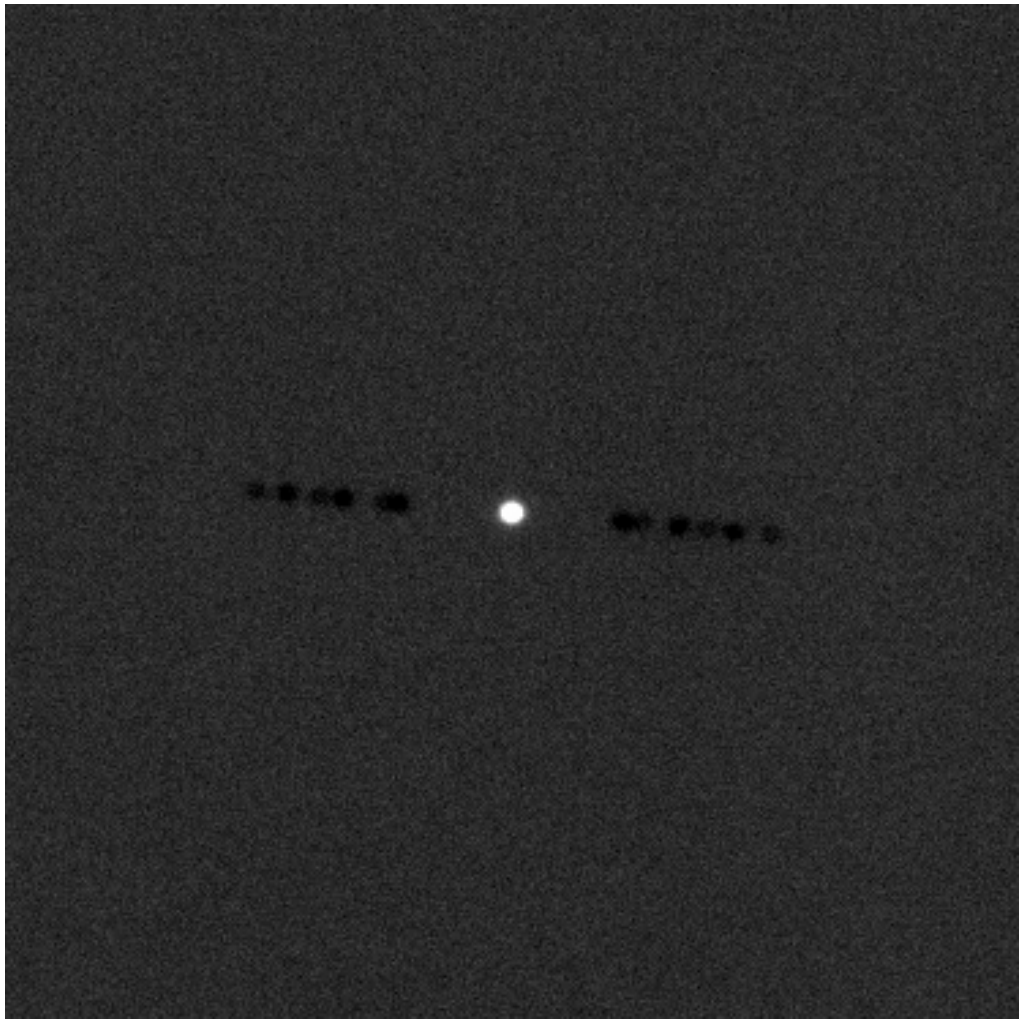
Rotational lightcurve of ‘Oumuamua.
(Drahus et al. 2018, Nature Astronomy 2, 407)

‘Oumuamua: comparison



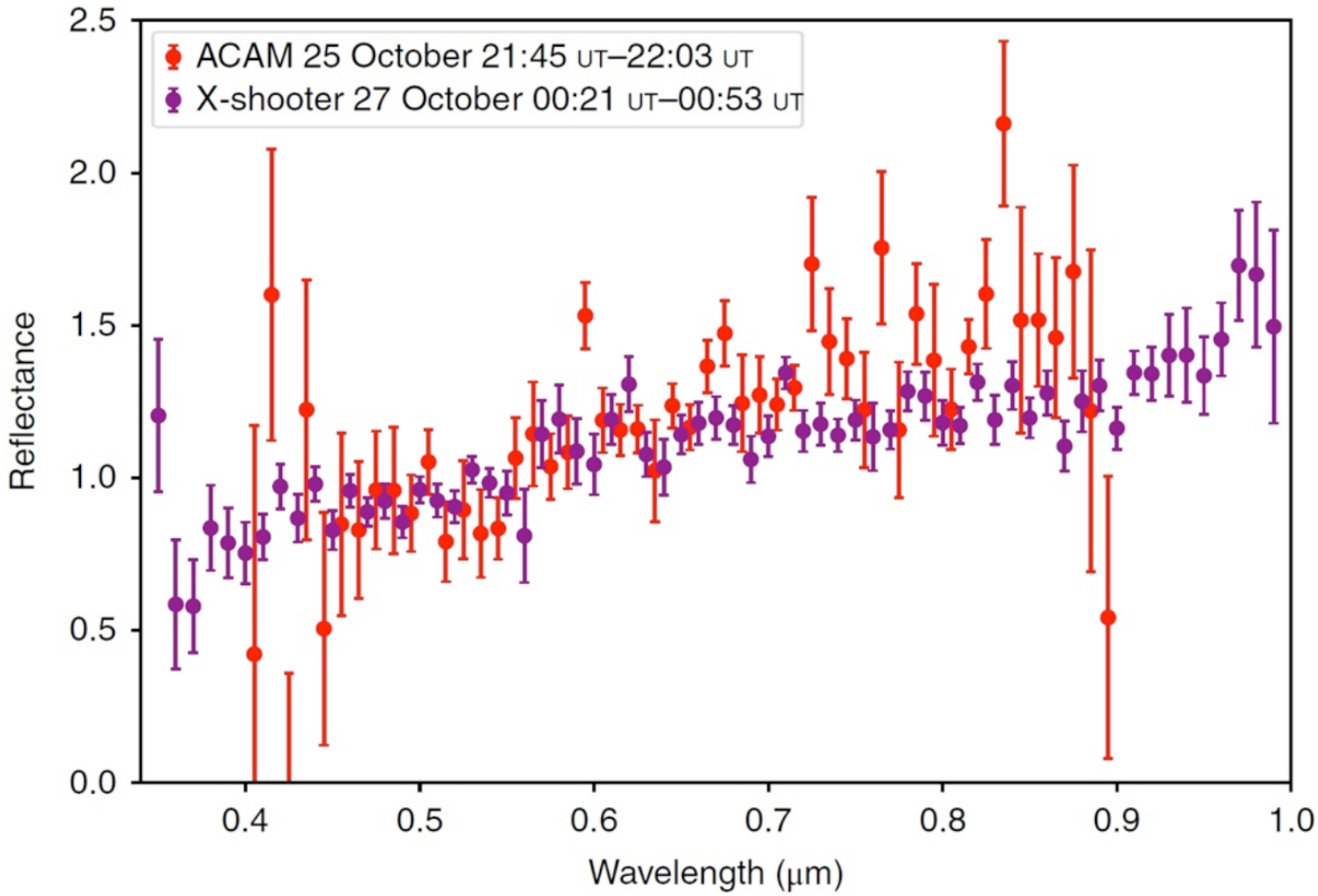
Properties of ‘Oumuamua compared with Solar System asteroids.
(Drahus et al. 2018, Nature Astronomy 2, 407)

‘Oumuamua: deep image



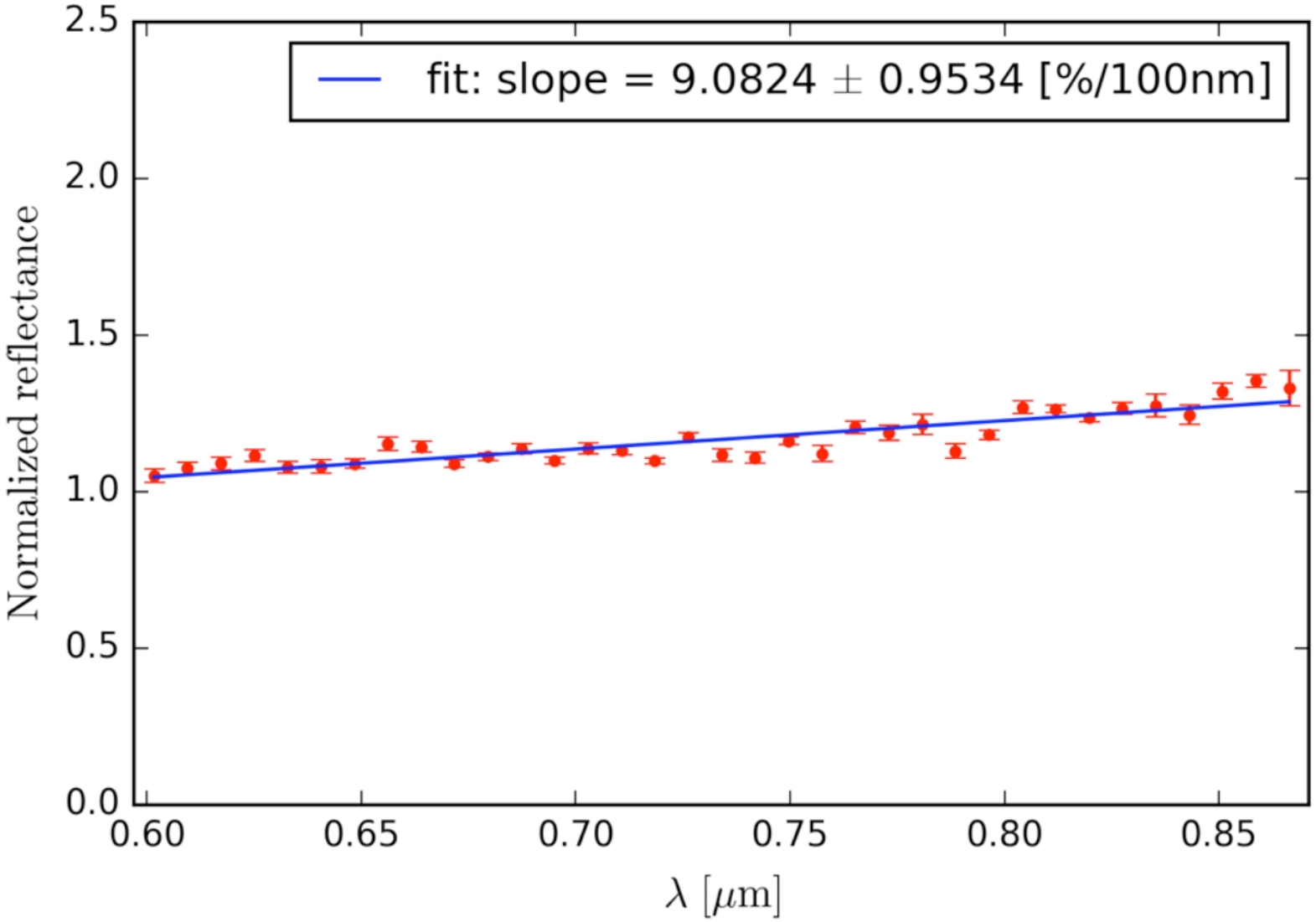
Deep image of ‘Oumuamua taken with Gemini North.
Drahus et al. 2018, Nature Astronomy 2, 407

‘Oumuamua: spectrum

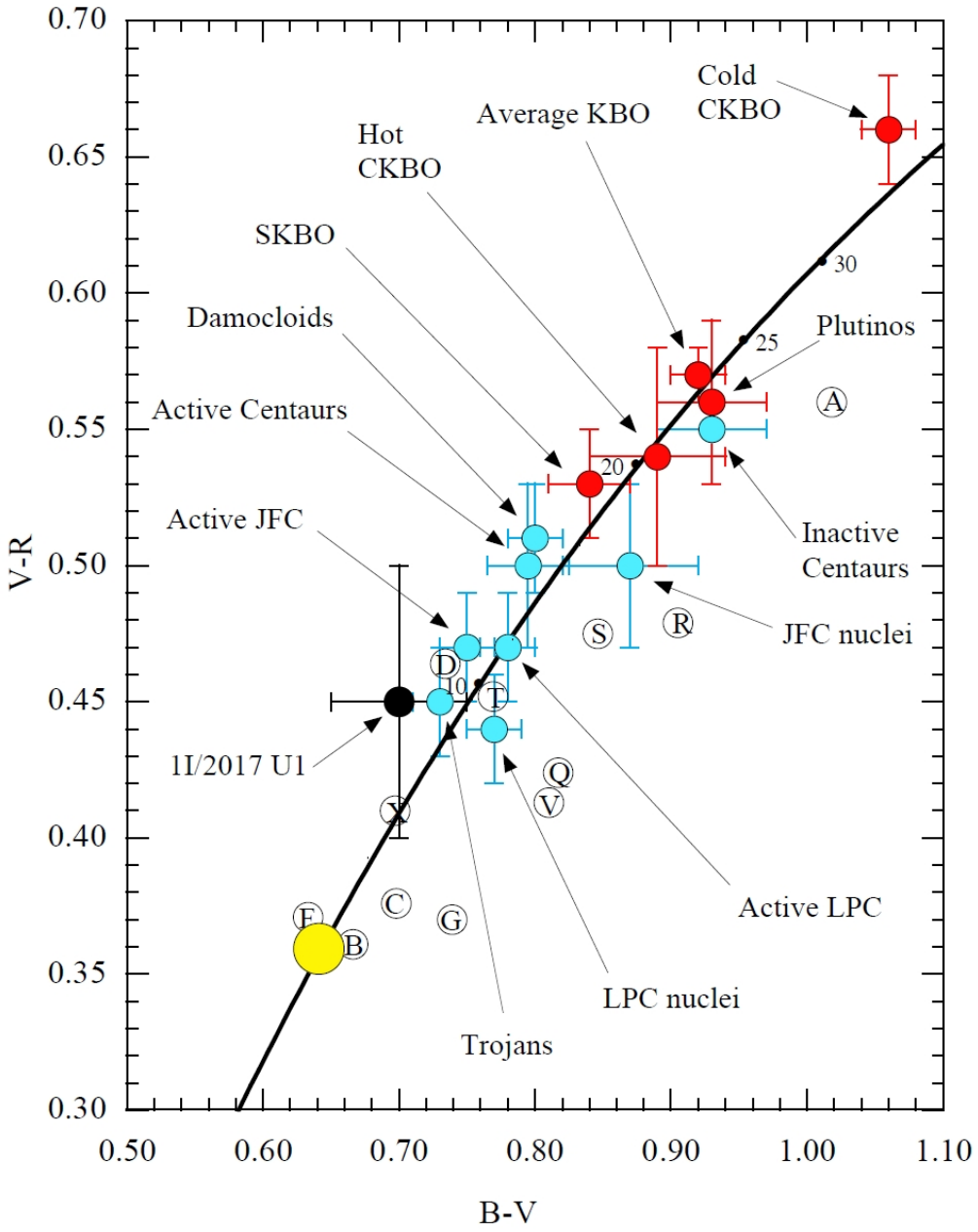


Reflectance spectrum of ‘Oumuamua.
Fitzsimmons et al. 2018, Nature Astronomy 2, 133

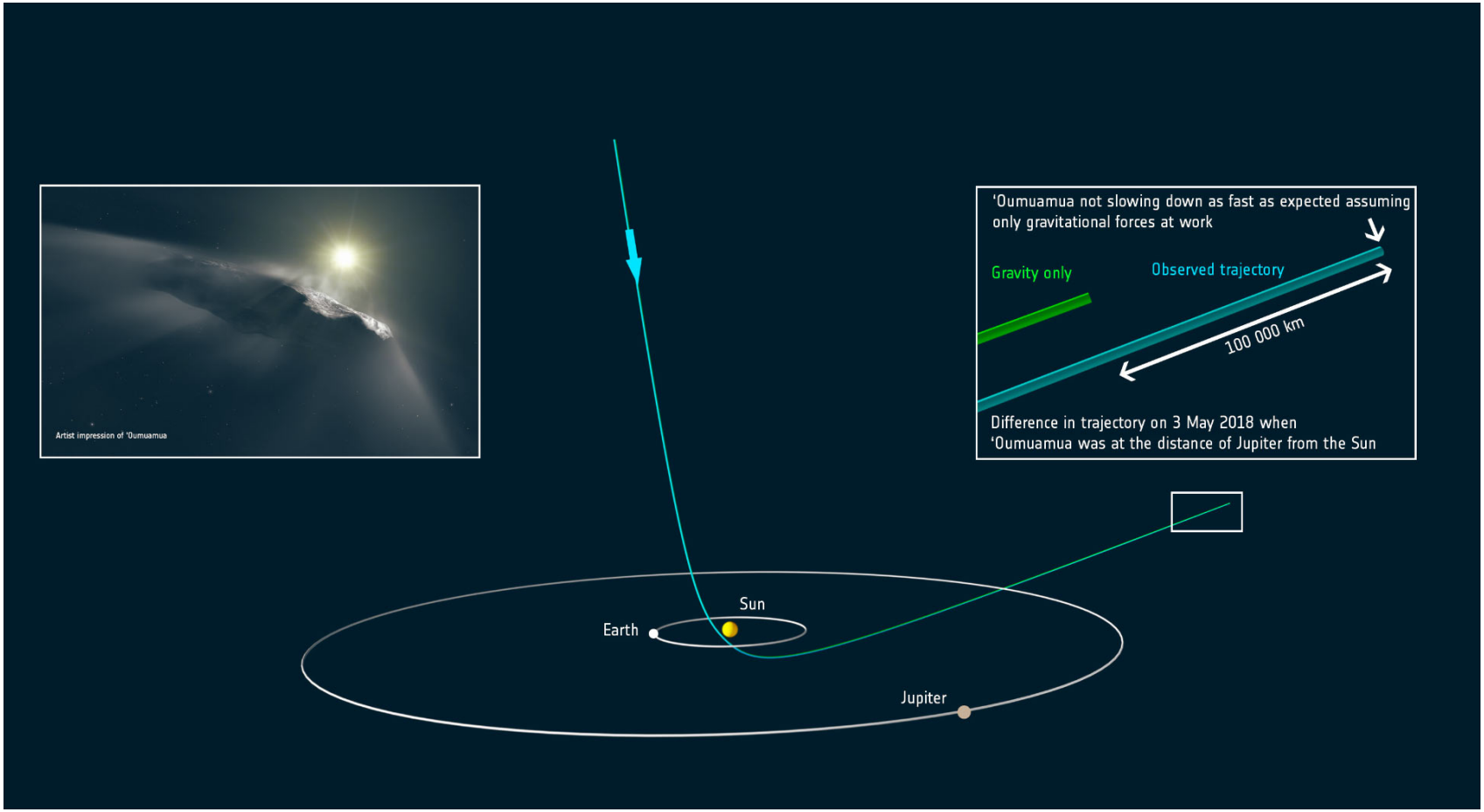
‘Oumuamua: spectrum



‘Oumuamua: color

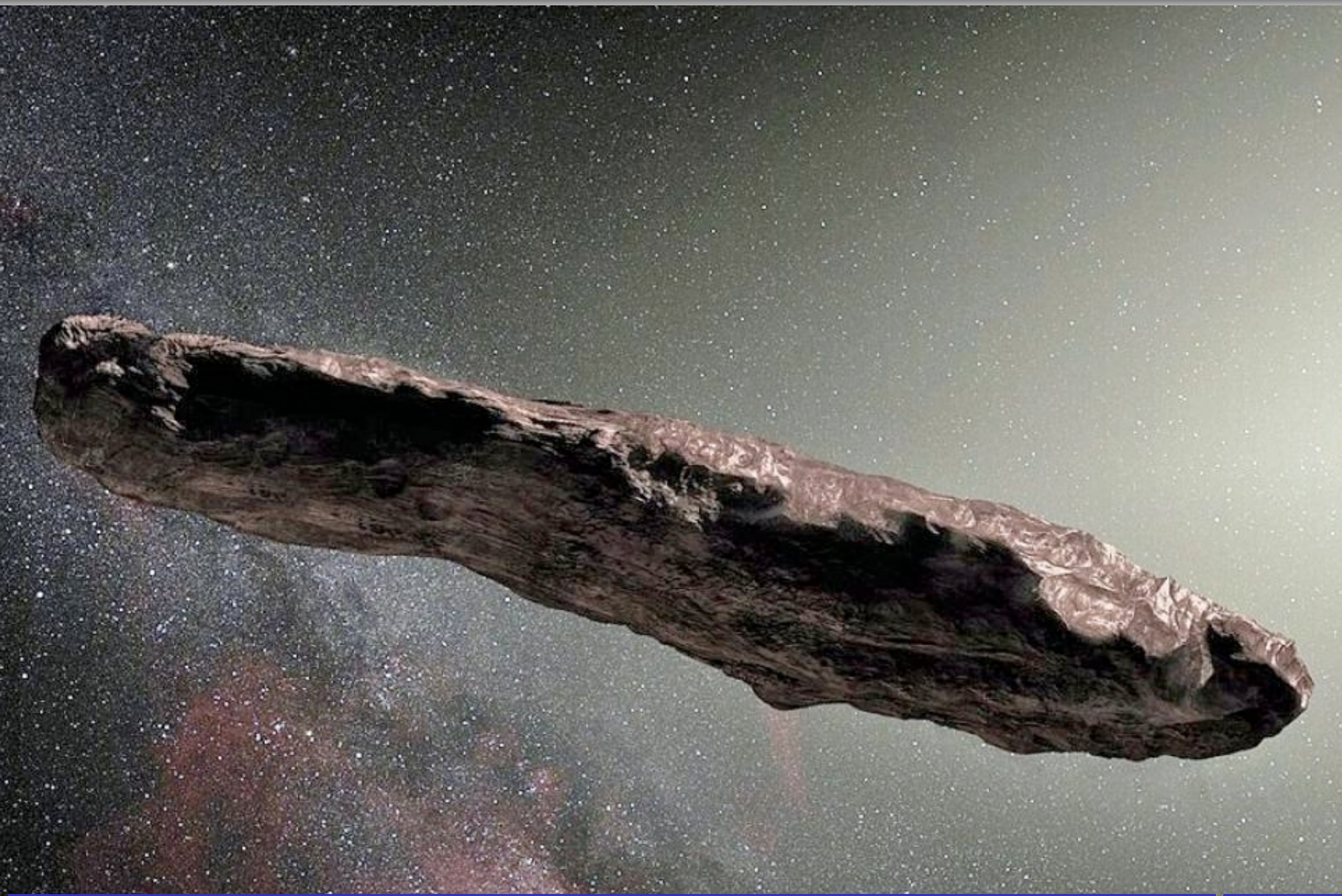


‘Oumuamua: the mystery

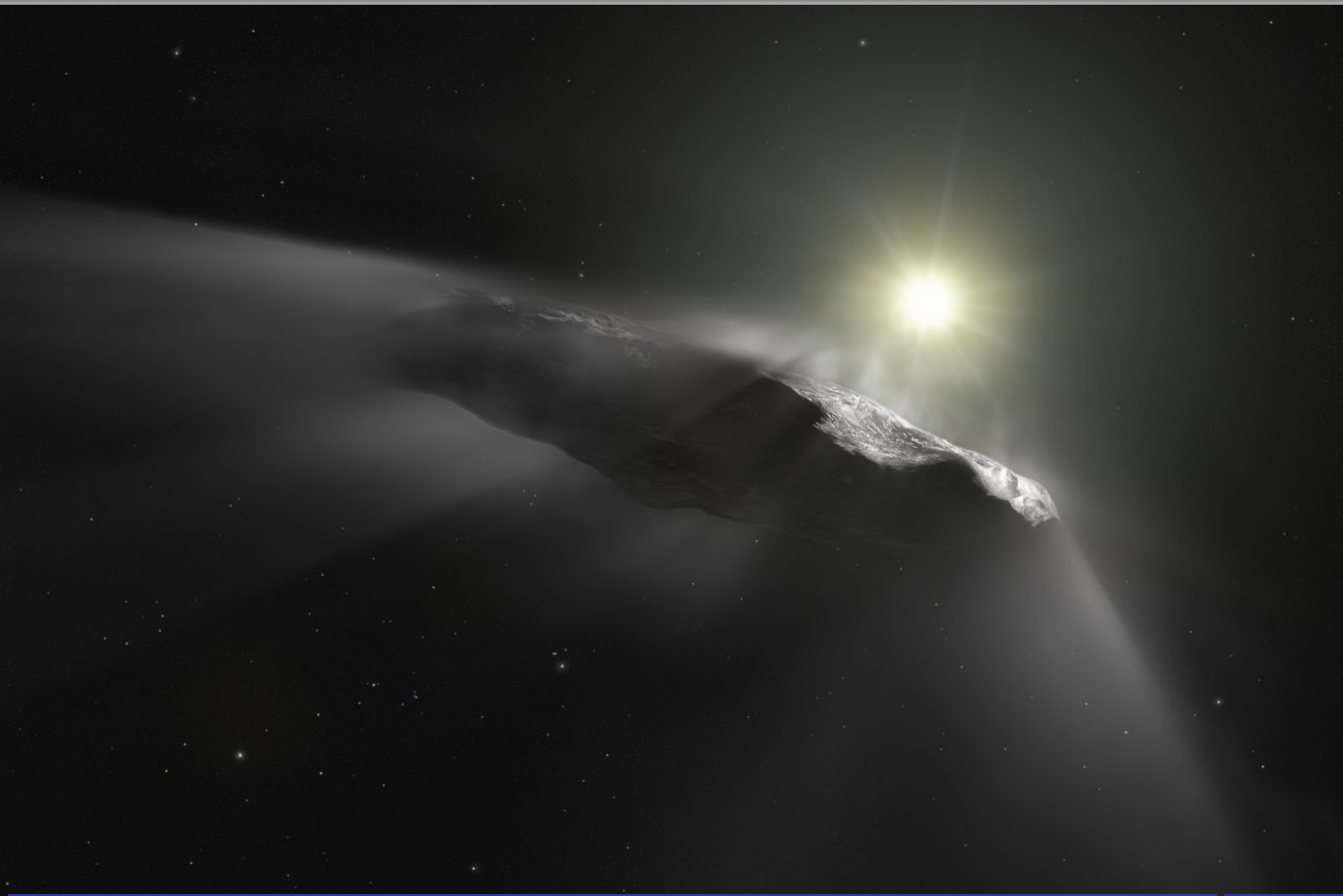


Non-gravitational acceleration of ‘Oumuamua
Micheli et al. 2018, Nature 559, 223

‘Oumuamua: What this thing really is?

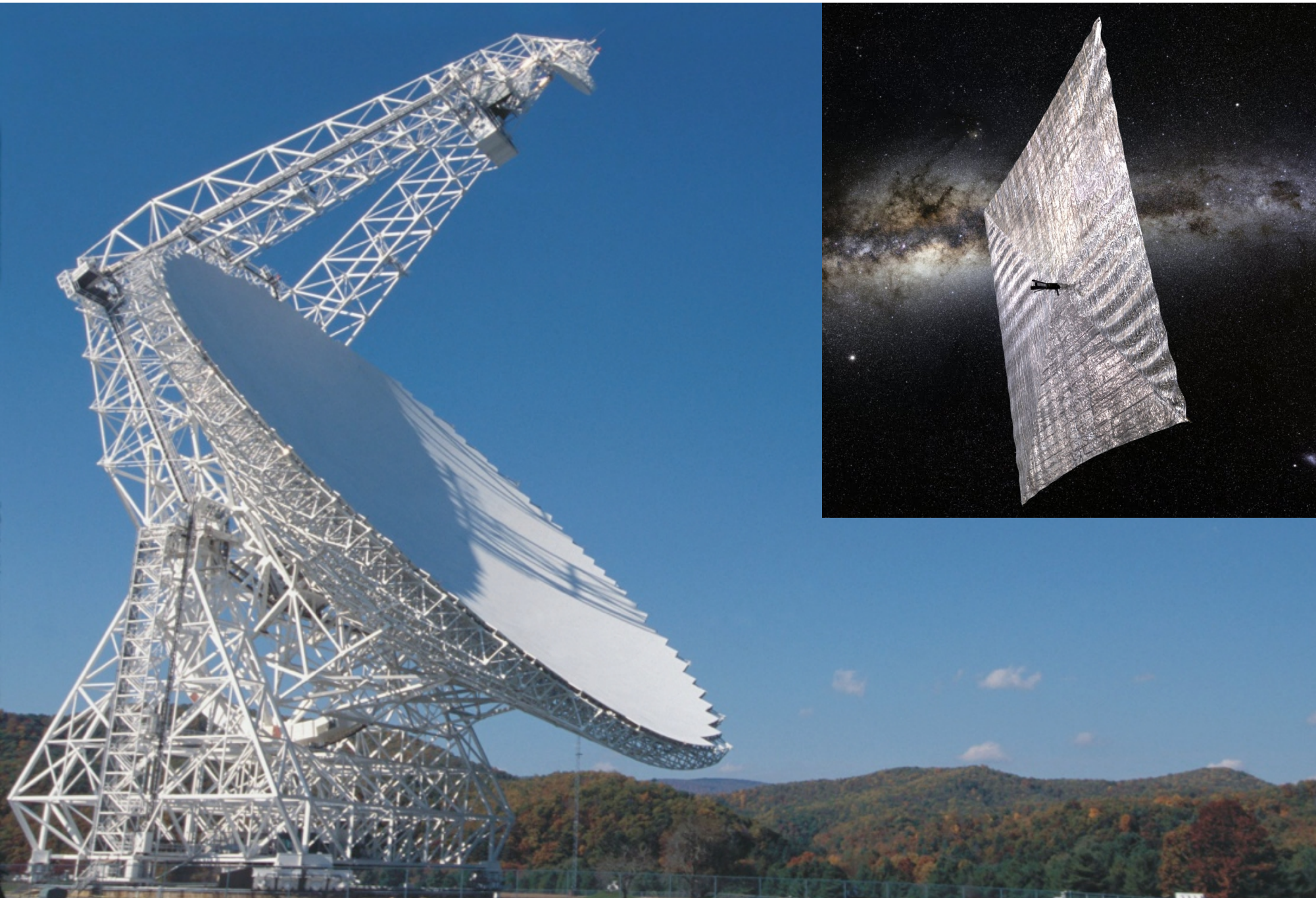


‘Oumuamua: What this thing really is?



‘Oumuamua: What this thing really is?

‘Oumuamua: non-natural hypotheses



“Extraordinary claims require extraordinary evidence.”

– Carl Sagan

Interstellar crusher

- Idea shortly after ‘Oumuamua, developed several month later
- Search through online astrometric databases (PCCP, NEOCP)
- Orbit computation (Bill Gray’s FindOrb)
- Check for significantly hyperbolic orbits
- Alert if potential interstellar object found

Interstellar crusher: the first alert

Object Astronomia/InterstellarAlert ×

interstellaralert@gmail.com

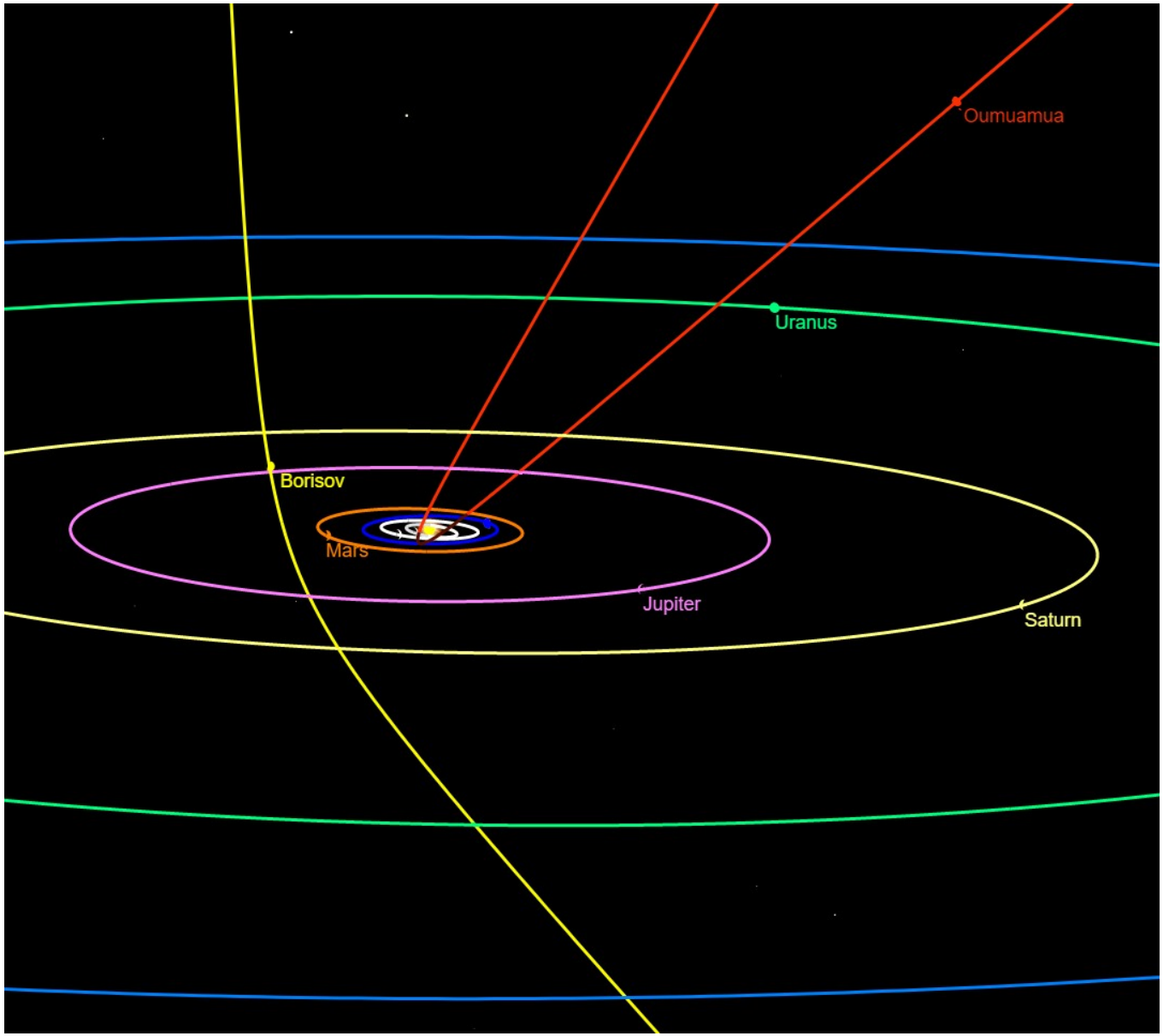
do mnie, m.drahus

angielski > polski Przetłumacz wiadomość

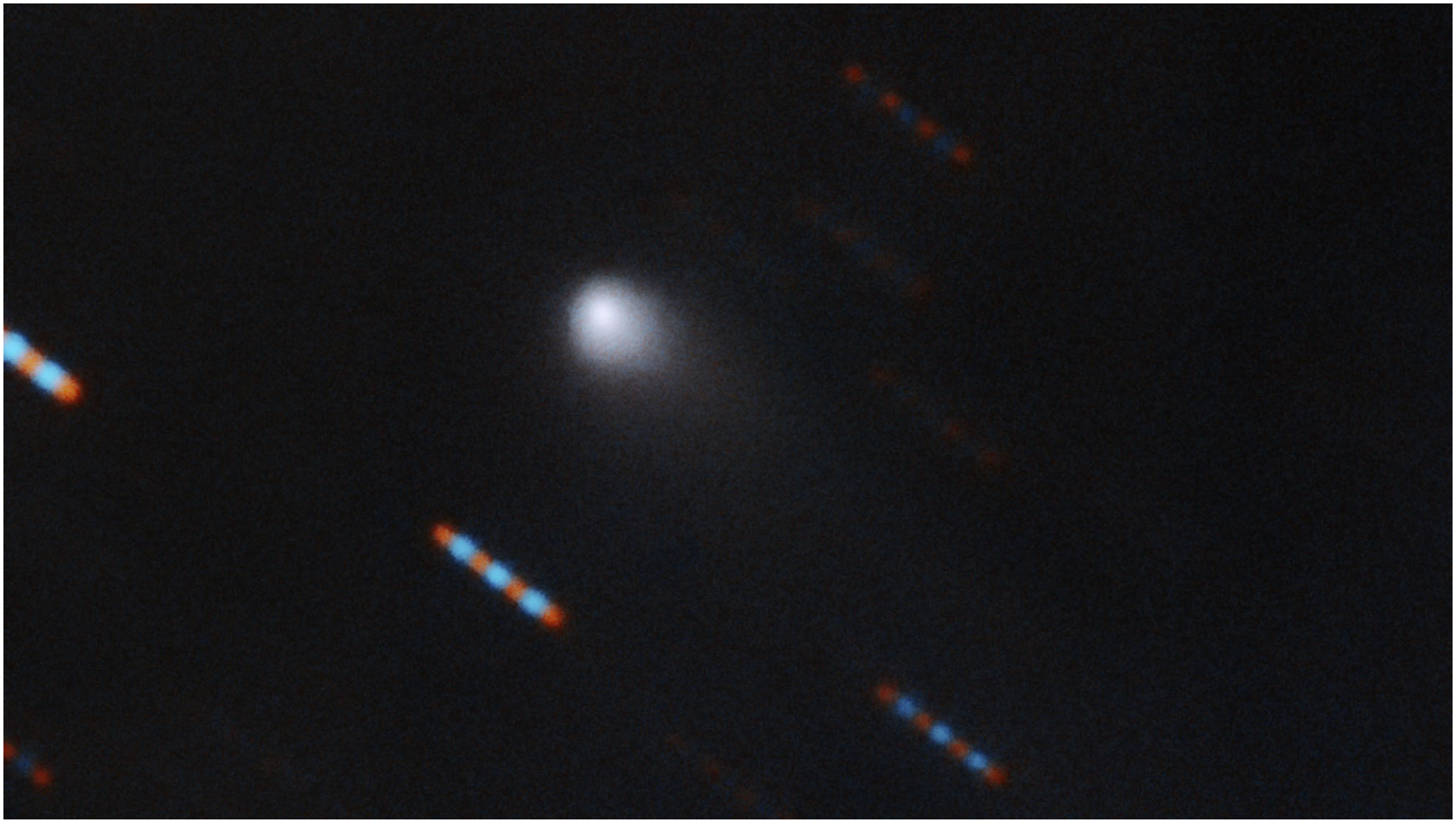
gb00239: 0.814+/- 0.096
gb00234: 2.699+/- 0.478
P10R3vi: 1.005+/- 0.000
C0V3RQ2: 0.998+/- 0.063
A10fGxk: 0.982+/- 0.005

First alert (8 Sep 2019, 05:15 UT)

2I/Borisov: orbital diagram

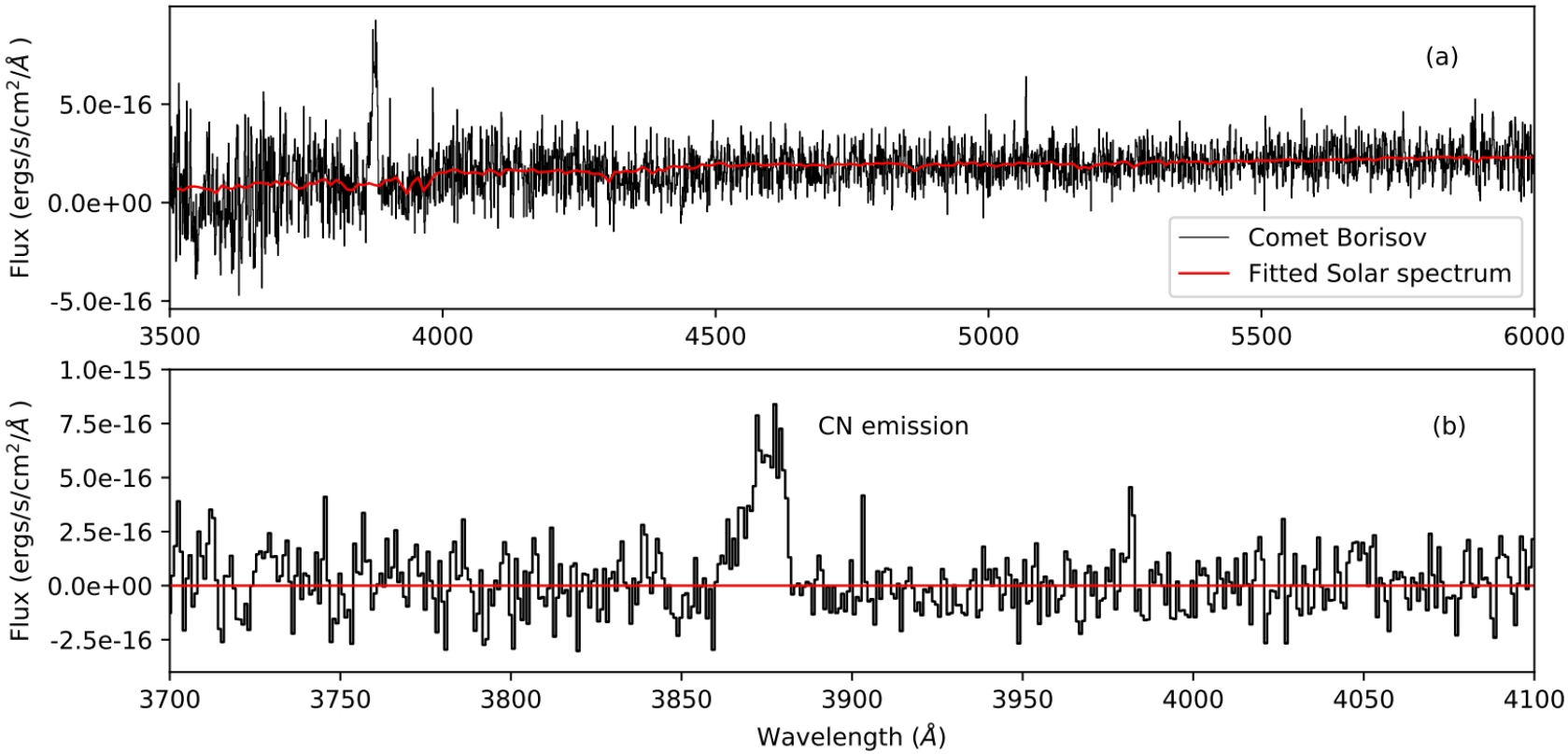


2I/Borisov: our first results



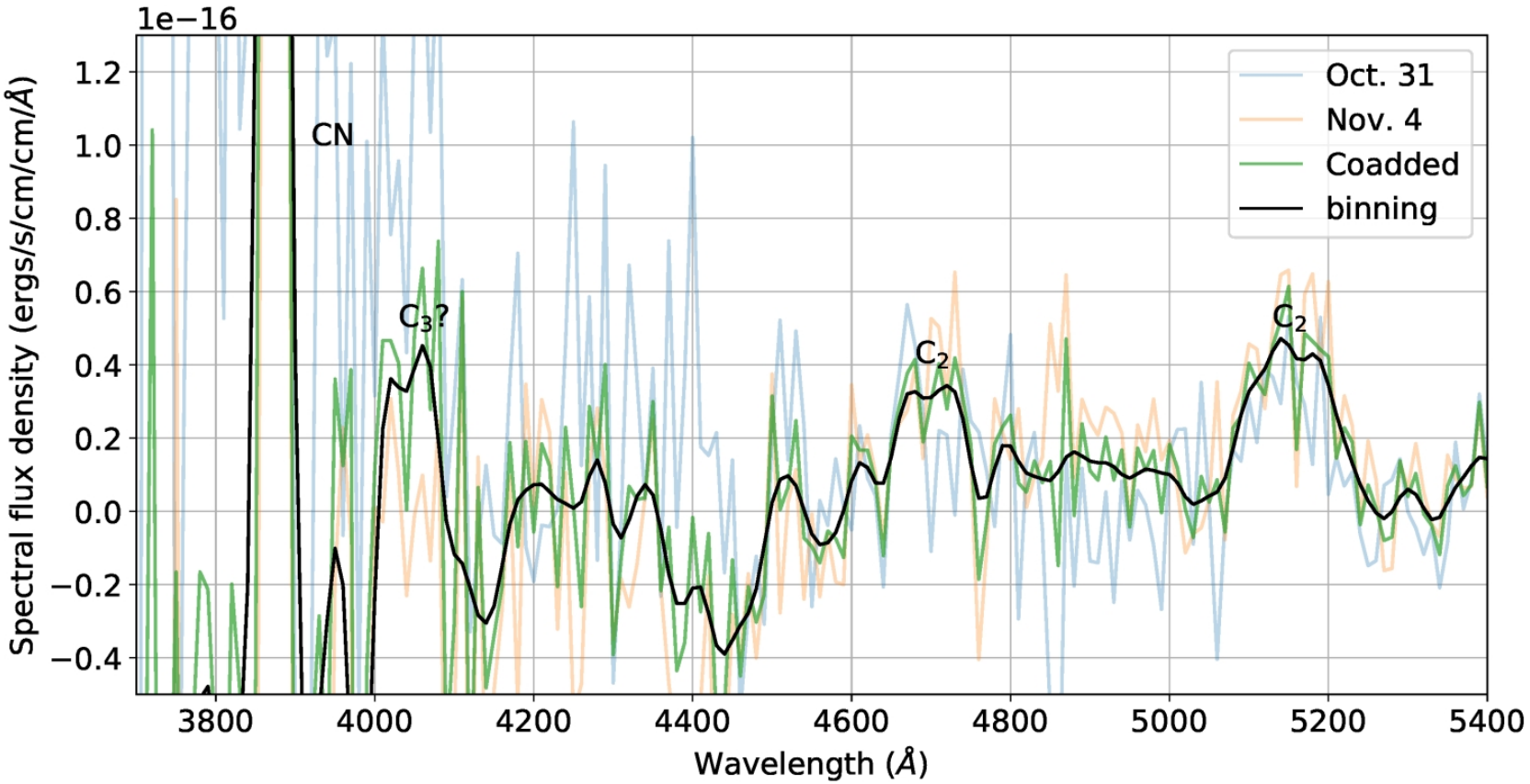
Interstellar comet 2I/Borisov as seen by Gemini North telescope.
source: https://www.gemini.edu/

2I/Borisov: CN



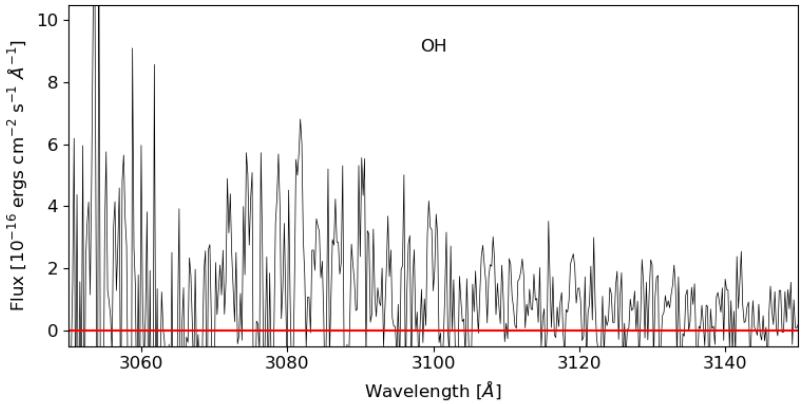
Spectrum of comet 2I/Borisov obtained with WHT telescope.
Fitzsimmons et al. 2019, ApJL 885, L9

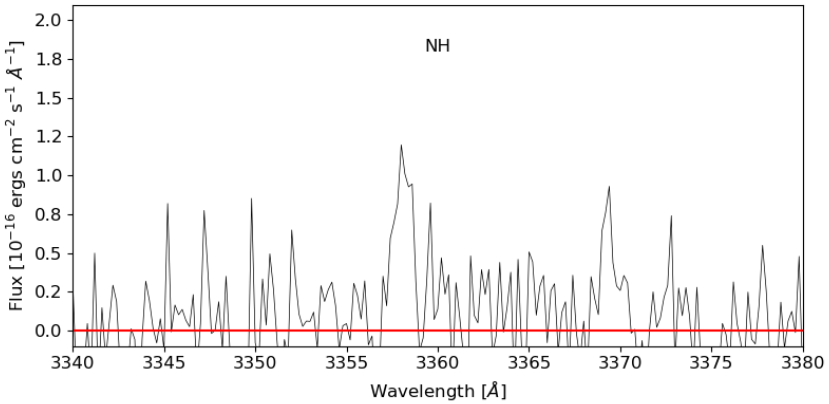
2I/Borisov: C2

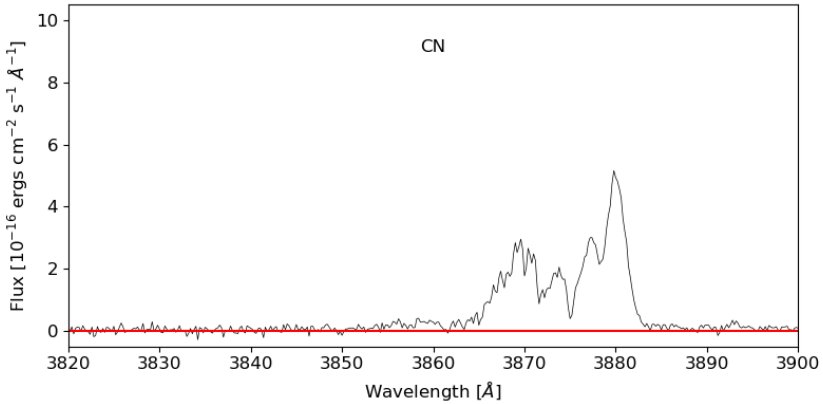


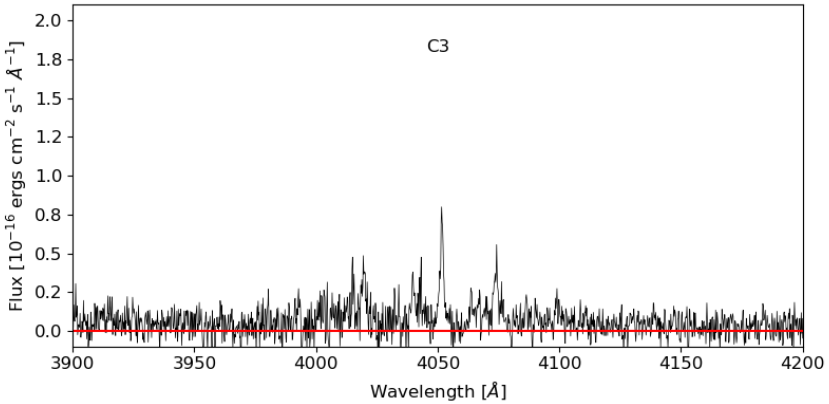
Spectrum of comet 2I/Borisov obtained by the MDM Observatory Hiltner 2.4 m telescope. *Lin et al. 2020, ApJL 889, L30*

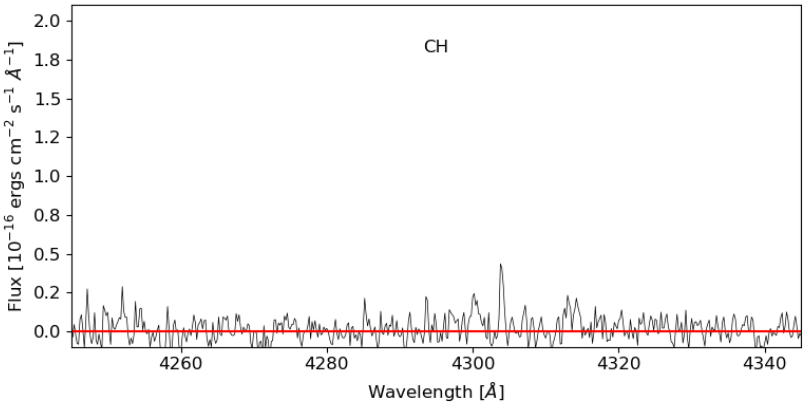
2I/Borisov: our spectra

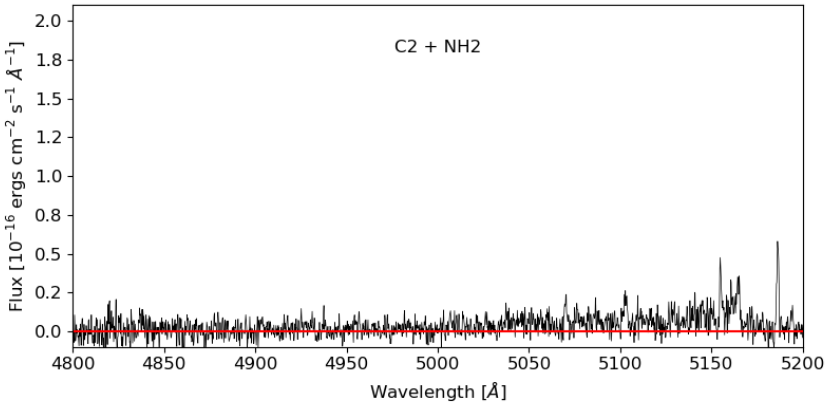




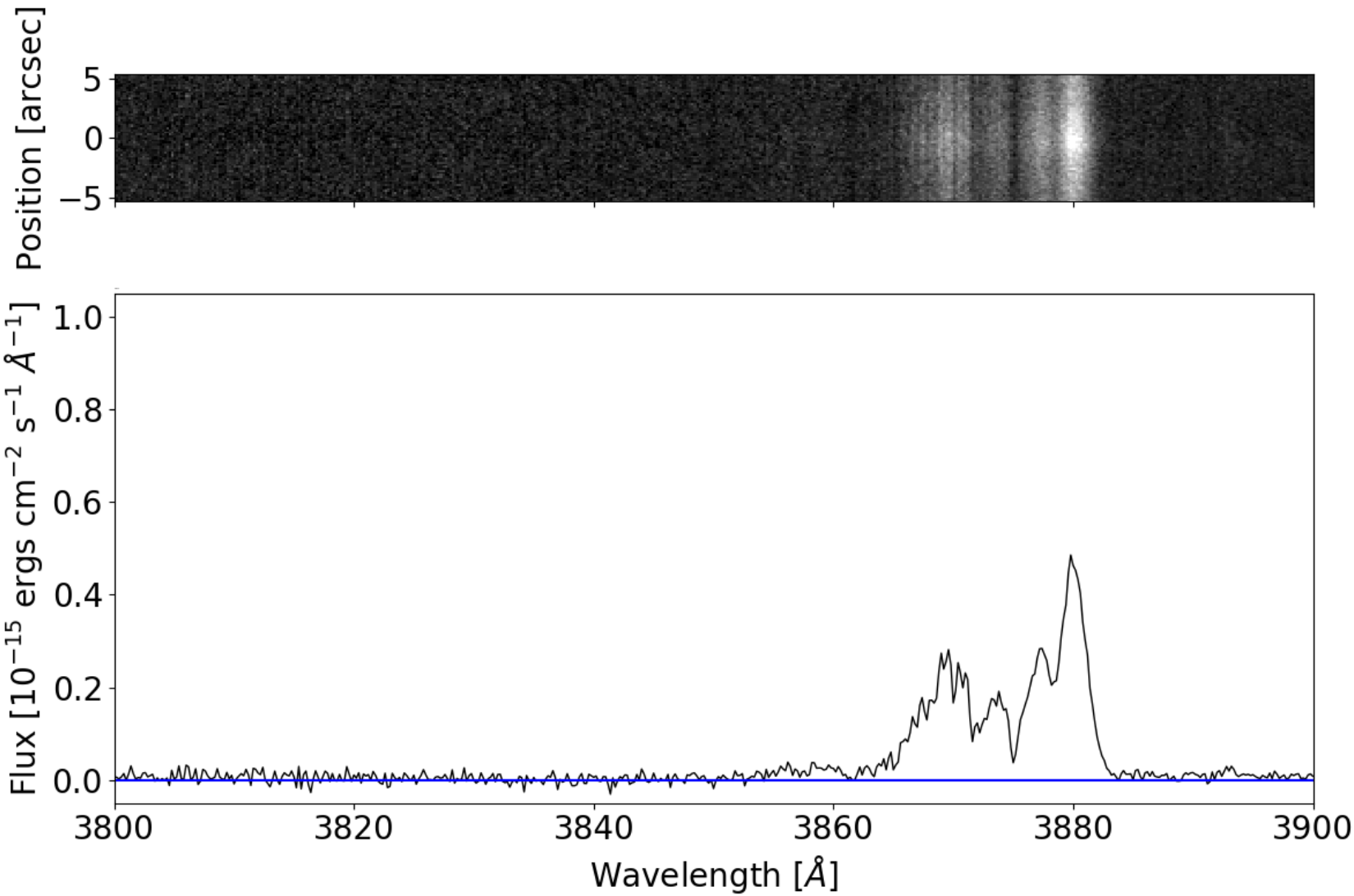




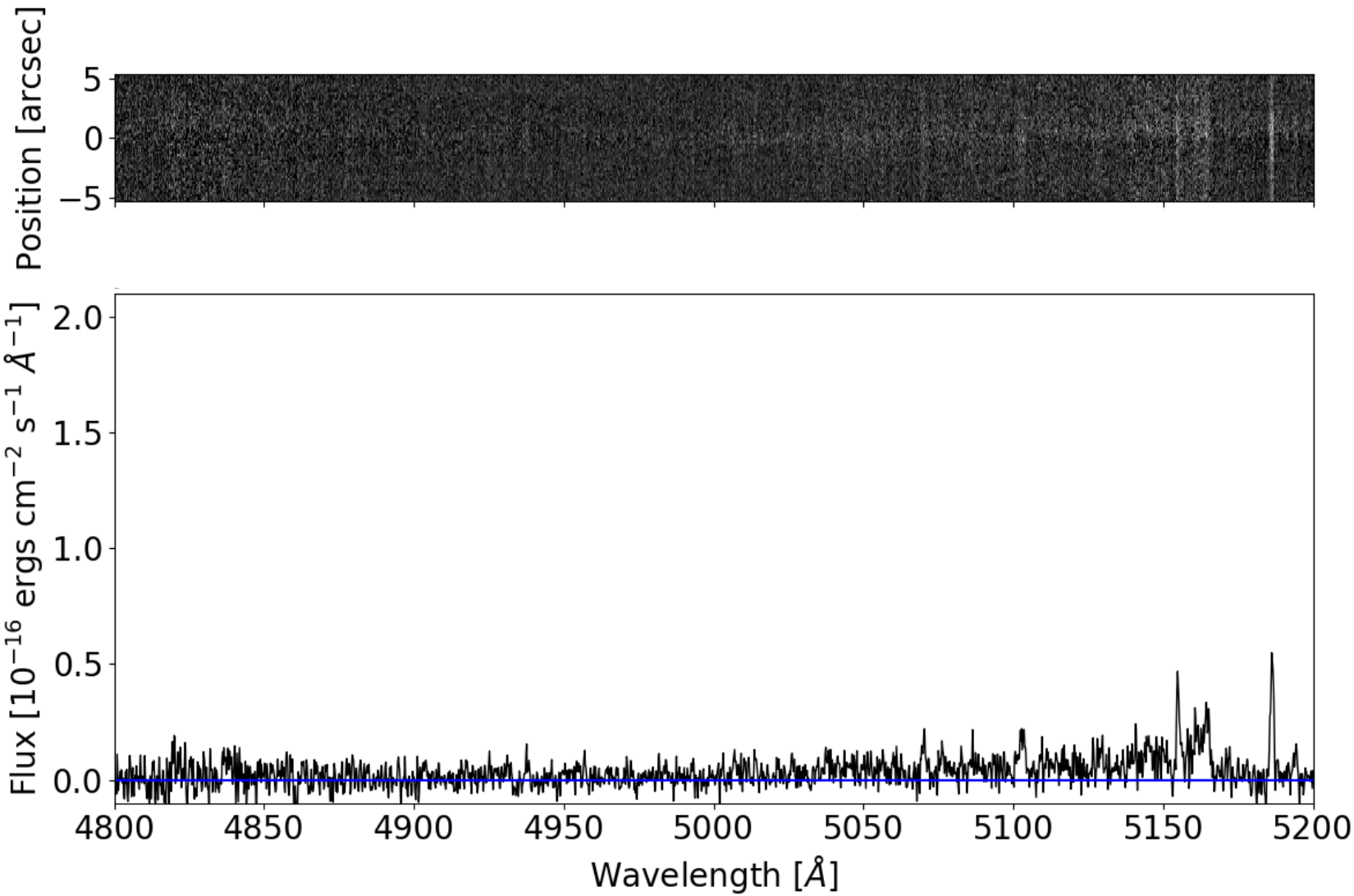




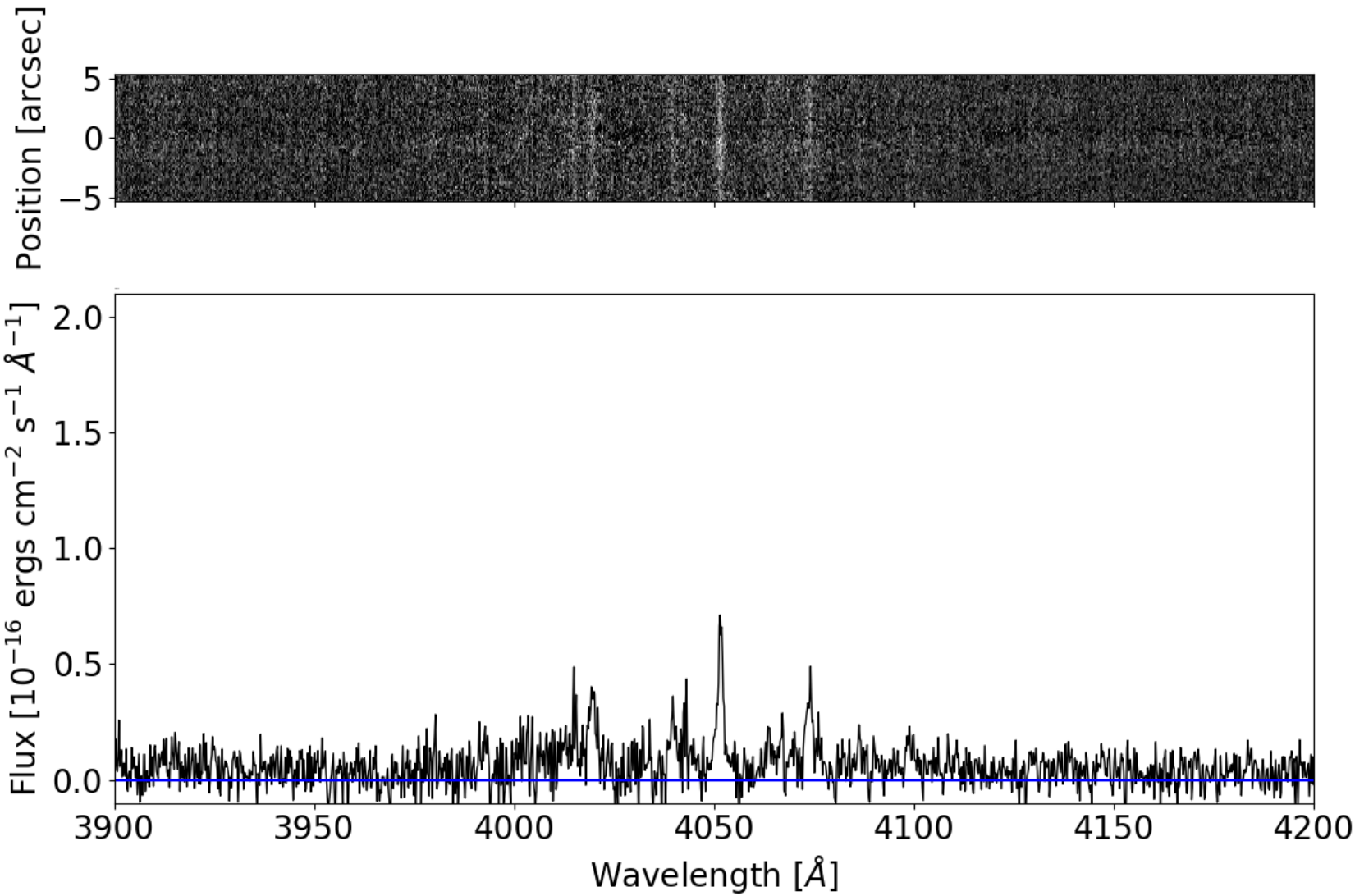
2I/Borisov: CN



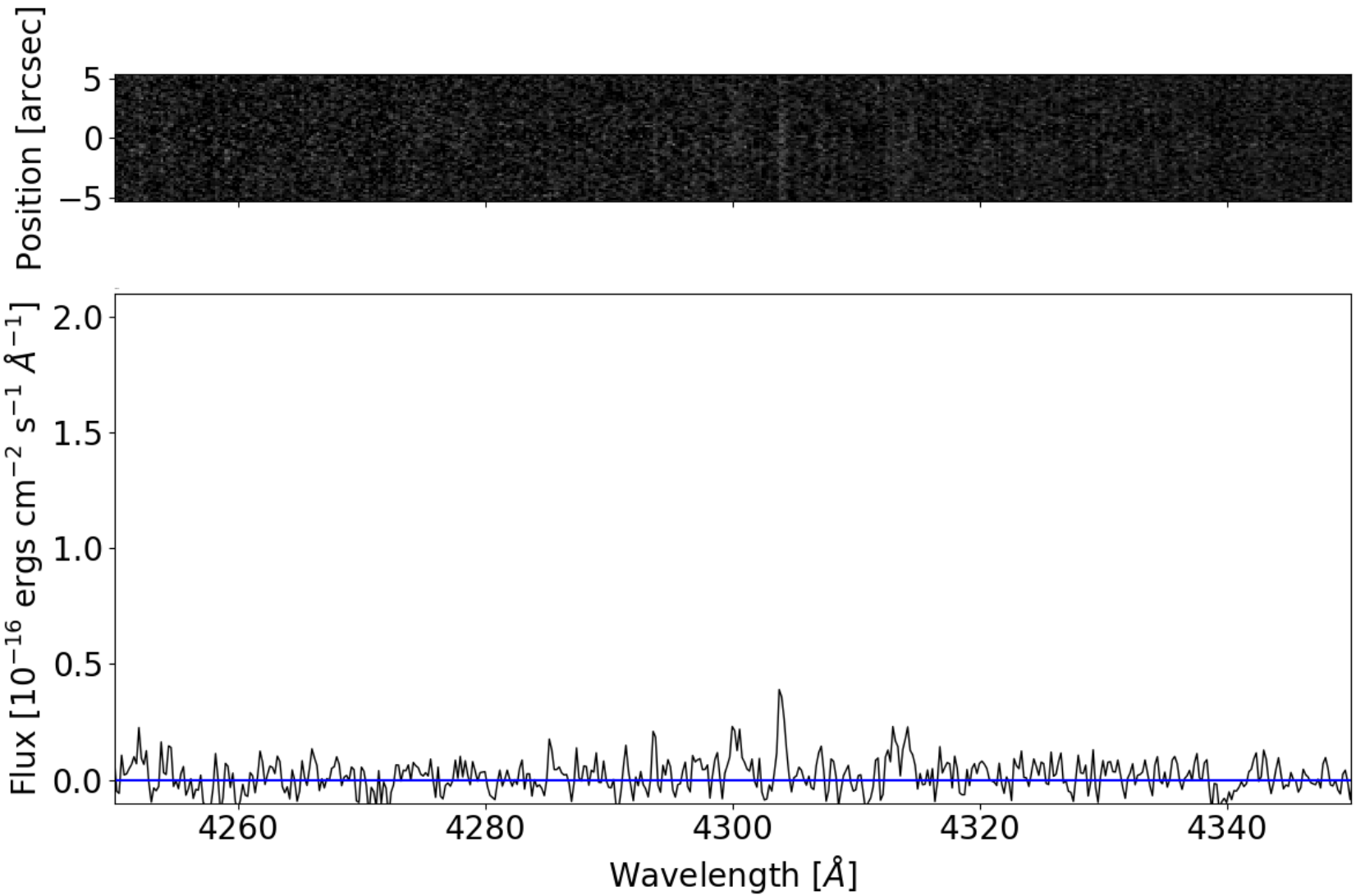
2I/Borisov: C2 + NH2



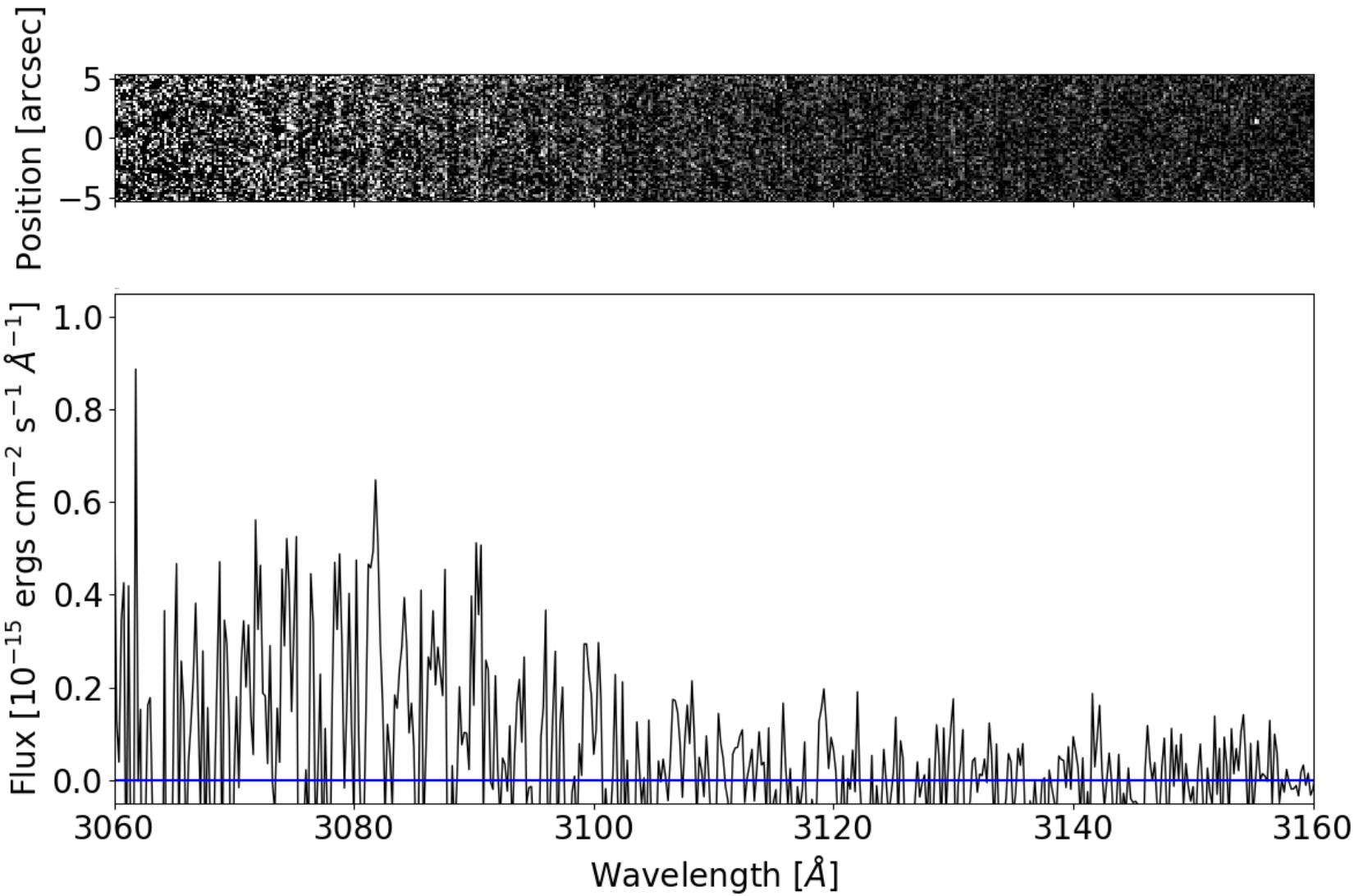
2I/Borisov: C3



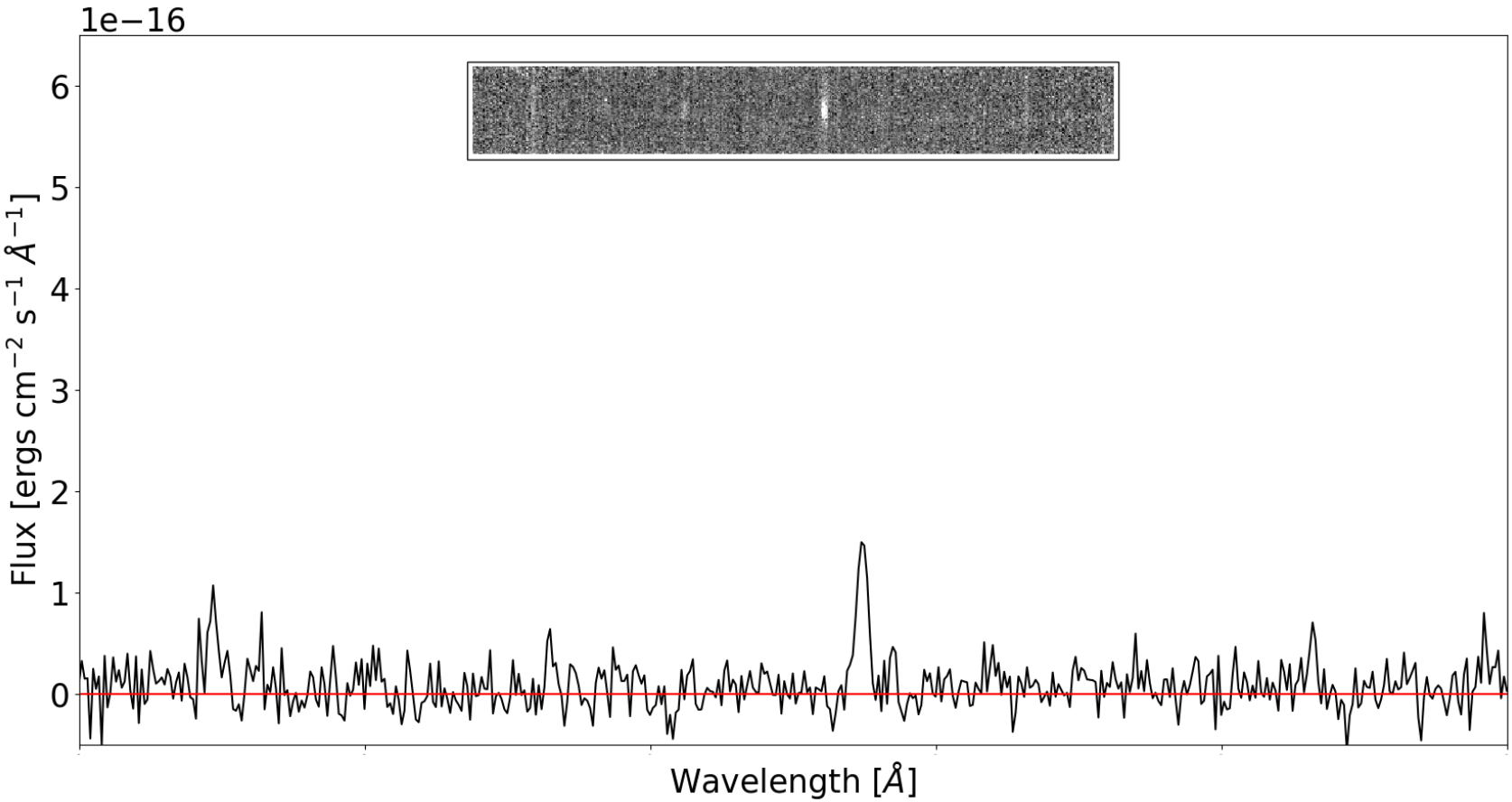
2I/Borisov: CH



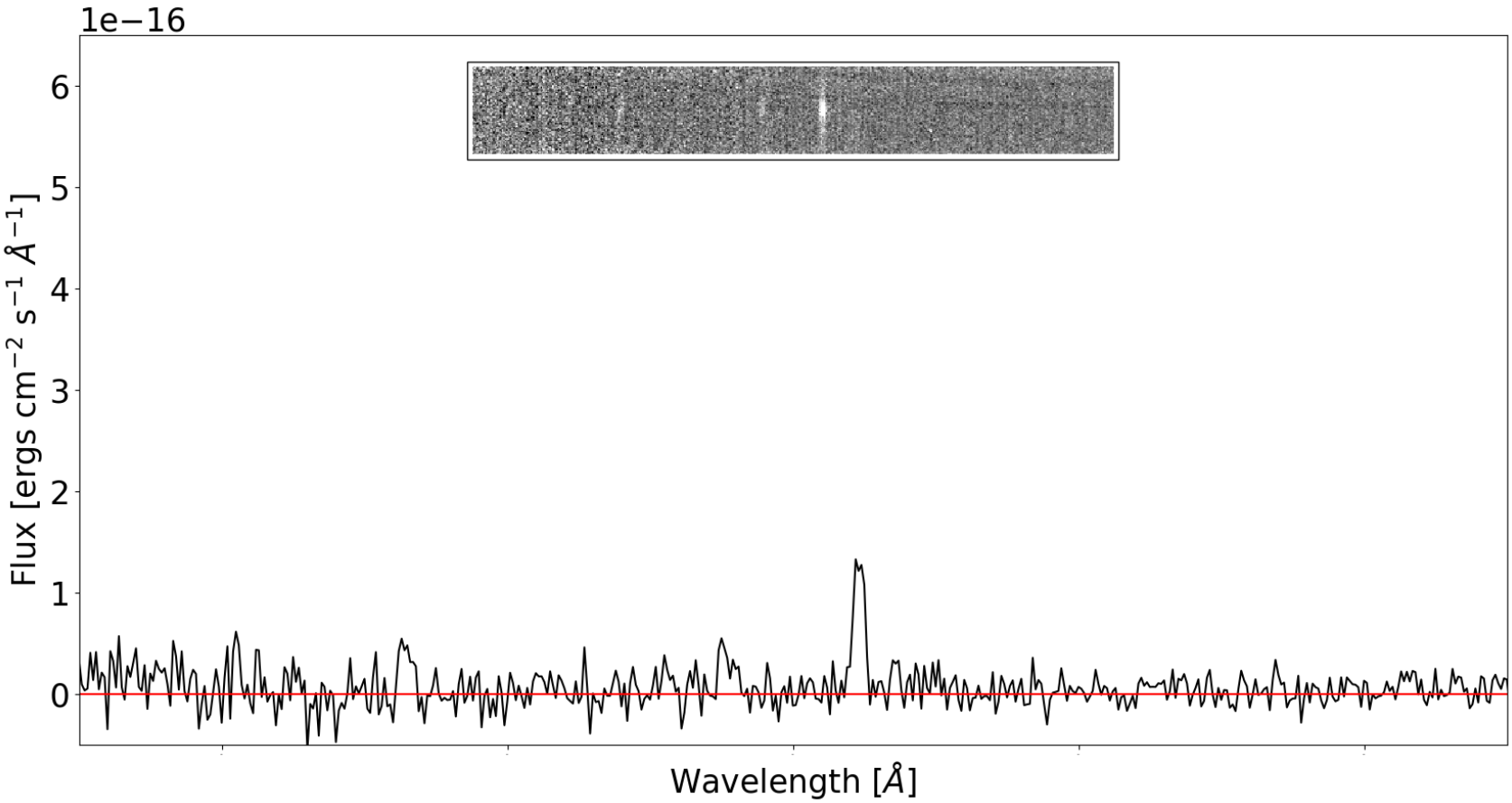
2I/Borisov: OH (water!)



2I/Borisov: unidentified lines



2I/Borisov: unidentified lines

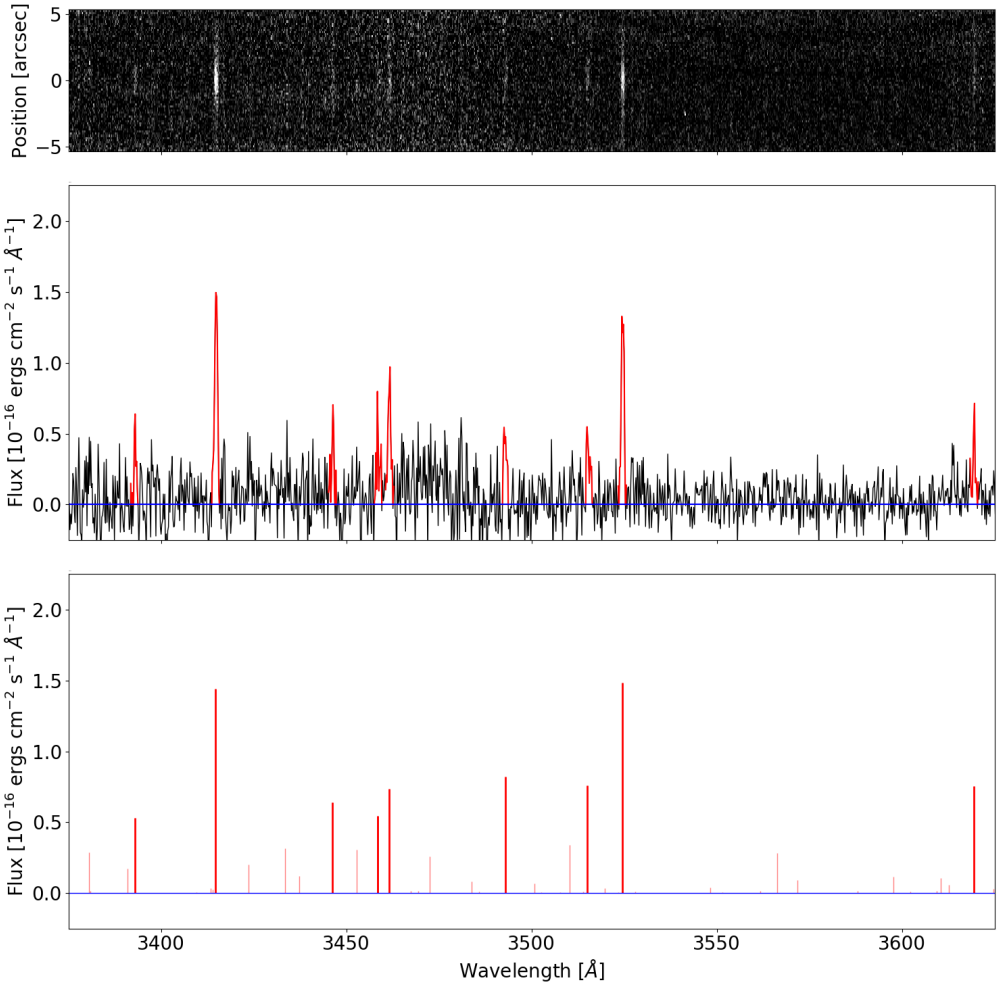


2I/Borisov: unidentified lines

TABLE II (*continued*)

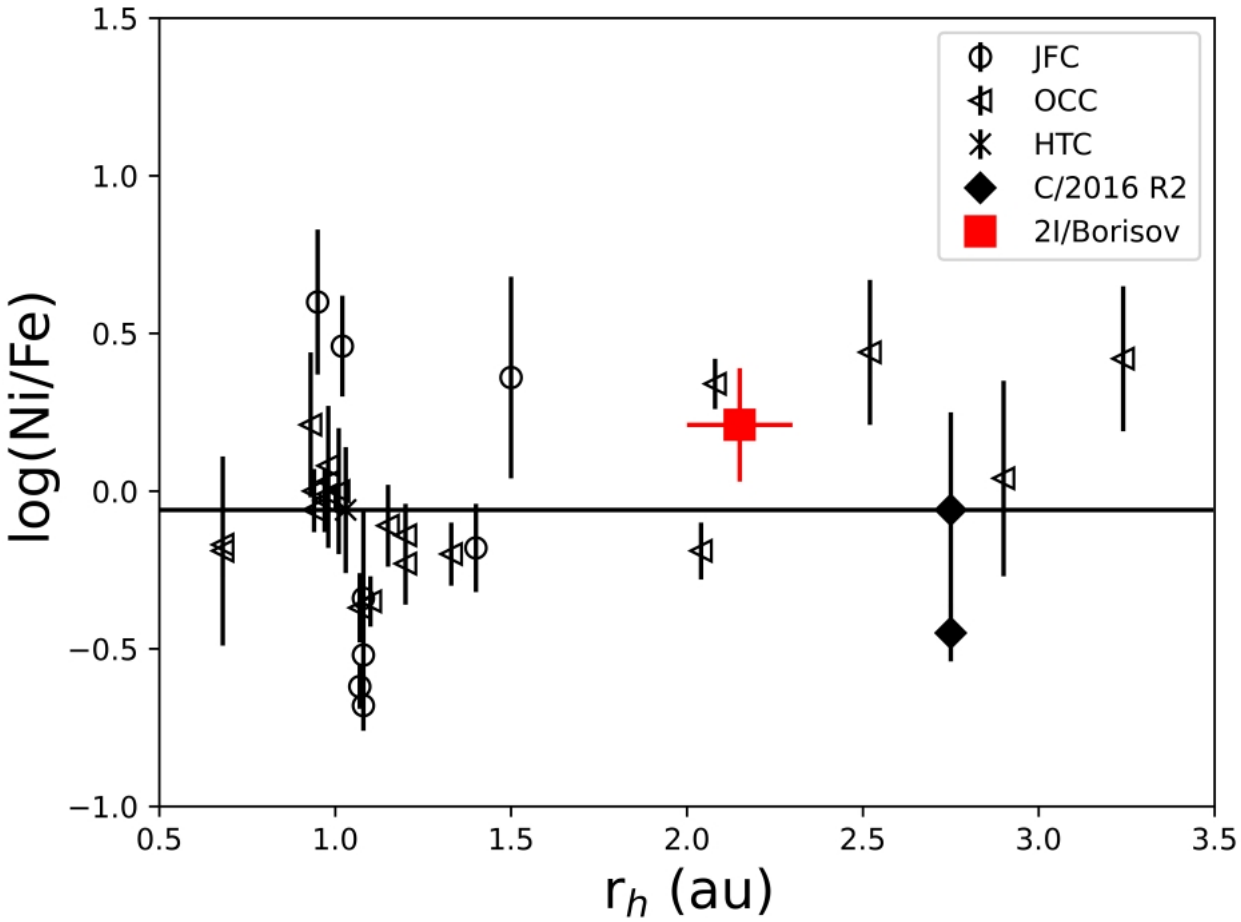
Observed wavelength	Solar wavelength	Identification	RMT No.	Int.	Observed intensity Head 0.0	Tail 1.0	Head 1.3	Tail 2.0
3413.946	3413.947	NI I	17	112	21	10	3	1
3414.775	3414.779	NI I	19	816	248	169	145	75
3417.190	3417.169	CO I	23	121	17	22	11	4
3417.879	3417.870	FE I	81	139	19	17	7	0
3418.520	3418.522	FE I	81	111	14	15	7	0
3420.740	3420.748	NI I	9	84	5	0	0	0
3422.675	3422.661	FE I	85	65	22	13	10	5
3423.725	3423.715	NI I	20	366	134	89	59	33
3424.304	3424.299	FE I	81	128	21	21	18	5
3426.421					14	8	0	0
3426.624	3426.635	FE I	82	121	8	4	0	0
3427.134	3427.129	FE I	81	218	84	55	30	13
3431.605					5	6	0	0
3433.076	3433.048	CO I	23	111	3	0	0	0
3433.579	3433.579	NI I	19	492	100	63	51	22
3437.303	3437.291	NI I	3	184	72	43	26	7
3440.627	3440.626	FE I	6	1243	135	89	79	46
3441.011	3441.019	FE I	6	634	164	108	98	54
3443.685	3443.655	CO I	22	141	9	5	0	0
3443.899	3443.884	FE I	6	655	68	43	34	16
3445.140	3445.125	FE I	81	137	30	16	12	1
3446.285	3446.271	NI I	20	470	152	101	82	42
3447.285	3447.285	FE I	82	100	8	8	5	0
3449.181	3449.175	CO I	22	115	9	6	0	0
3449.444	3449.448	CO I	22	138	12	9	2	0
3450.330	3450.334	FE I	82	97	13	6	0	0
3452.287	3452.284	FE I	25	151	15	11	6	2
3452.906	3452.905	NI I	17	247	147	105	53	37
3453.516	3453.512	CO I	22	310	91	49	31	7
3458.463	3458.467	NI I	19	656	199	138	95	59
3461.663	3461.667	NI I	17	758	180	121	86	54
3462.813	3462.816	CO I	23	126	19	16	6	4

2I/Borisov: its nickel vapour!



Emission lines from gaseous atomic nickel in the near-UV spectrum of 2I/Borisov. *(Guzik et al. 2021, Nature 593, 375)*

2I/Borisov: nickel and iron

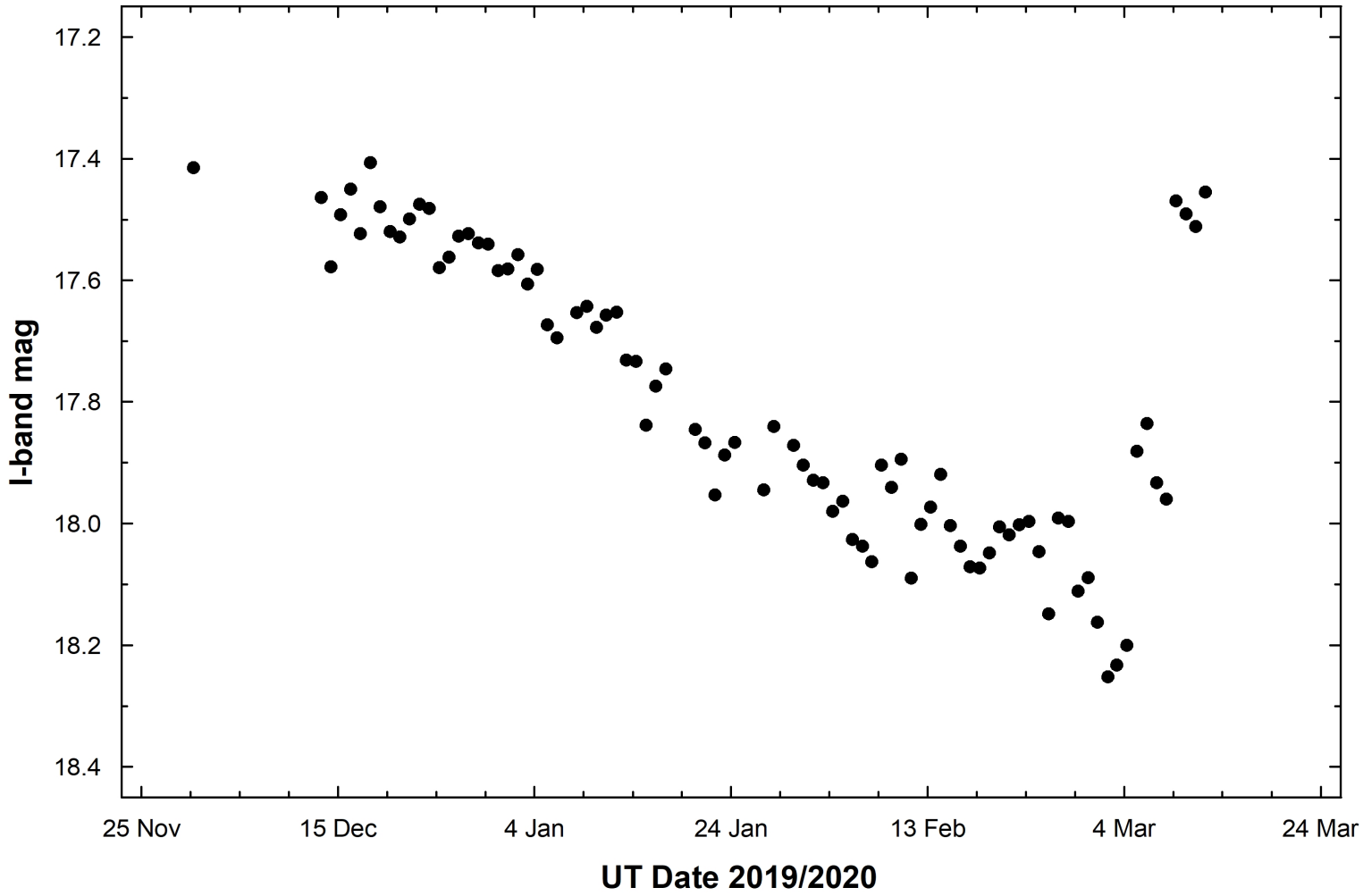


Comparison between the log(Ni/Fe) ratio of 2I and the values measured by *Manfroid et al., 2021, Nature, 593, 372*. Adapted from: *Opitom et al. 2021 A&A 650, L19*

2I/Borisov - photometric monitoring with OGLE telescope

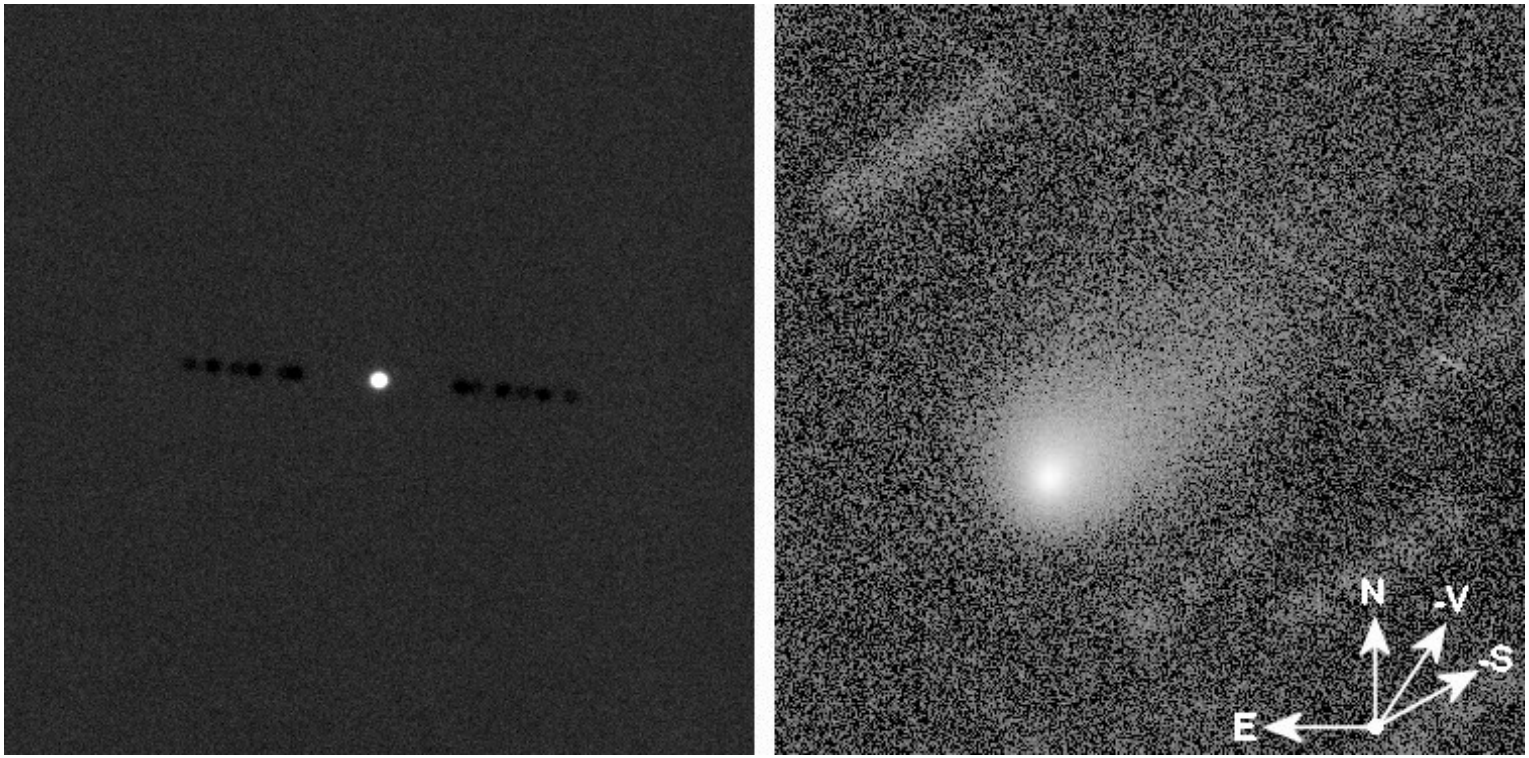
- OGLE - 1.3 m telescope at Las Campanas (Chile)
- Regular observations: start - December 13th 2019, end - March 15th 2020
- Every clear night 15 exposures in V and 15 exp in I, each 40s long
- February - March, comet in Milky Way - dense starfields $\rightarrow$ challenging photometry

2I/Borisov: outburst



Lightcurve of comet 2I/Borisov obtained with 1.3-m OGLE telescope.

1I/'Oumuamua, 2I/Borisov: comparison



1I/'Oumuamua (left) and 2I/Borisov (right) observed with the Gemini North telescope. From Drahus et al. (2018, Nat. Astron. 2, 407) and Guzik et al. (2020, Nat. Astron. 4, 53), respectively.

What's next...

Vera C. Rubin Observatory.

Interstellar minor bodies: the bridge