Observation of comets with the TNG telescope

Pamela Cambianica

INAF Astronomical observatory of Padova, Vicolo dell'Osservatorio 5, 35122 Padova, Italy
(email: **pamela.cambianica@inaf.it**)

Telescopio Nazionale Galileo: 25 years of Astronomy in La Palma
19-21 October 2021

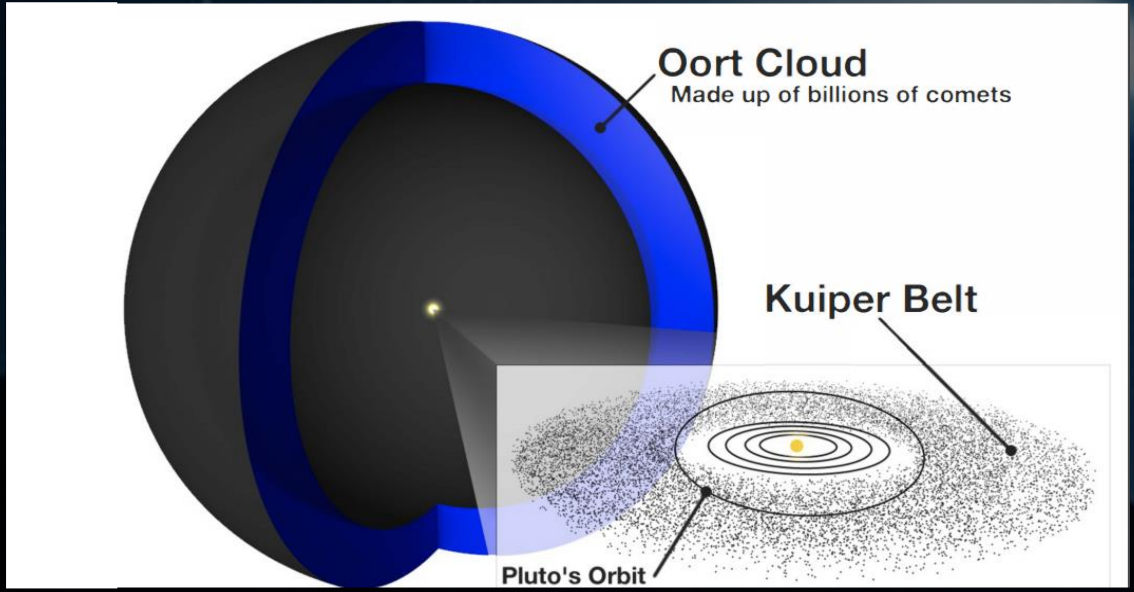
Outline

- The importance of studying comets
- The TNG telescope – DOLORES and HARPS-N instruments
- Dust environment model of the interstellar comet 2I/Borisov
- A high-spectral resolution catalog of emission lines in the visible spectrum of comet C/2020 F3 (NEOWISE)
- Conclusions

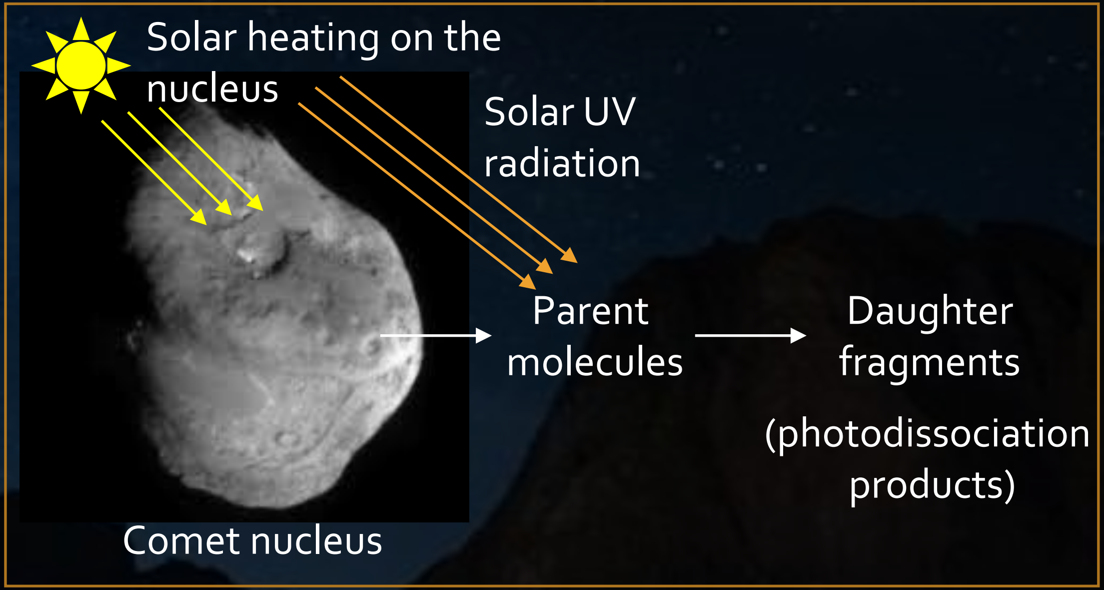
The importance of studying comets

Comets as tracers of Solar System formation and evolution

Comets formed at large distance from the Sun



Parent and daughter molecules



Ground observations are fundamental to understand the coma composition and the chemical and physical processes occurring in the nucleus.

The TNG telescope – DOLORES and HARPS-N instruments

*D*evice *O*ptimized for the *LO*w *RES*olution (**DOLORES**)

Low resolution spectrograph and camera installed at the Nasmyth B focus of the TNG

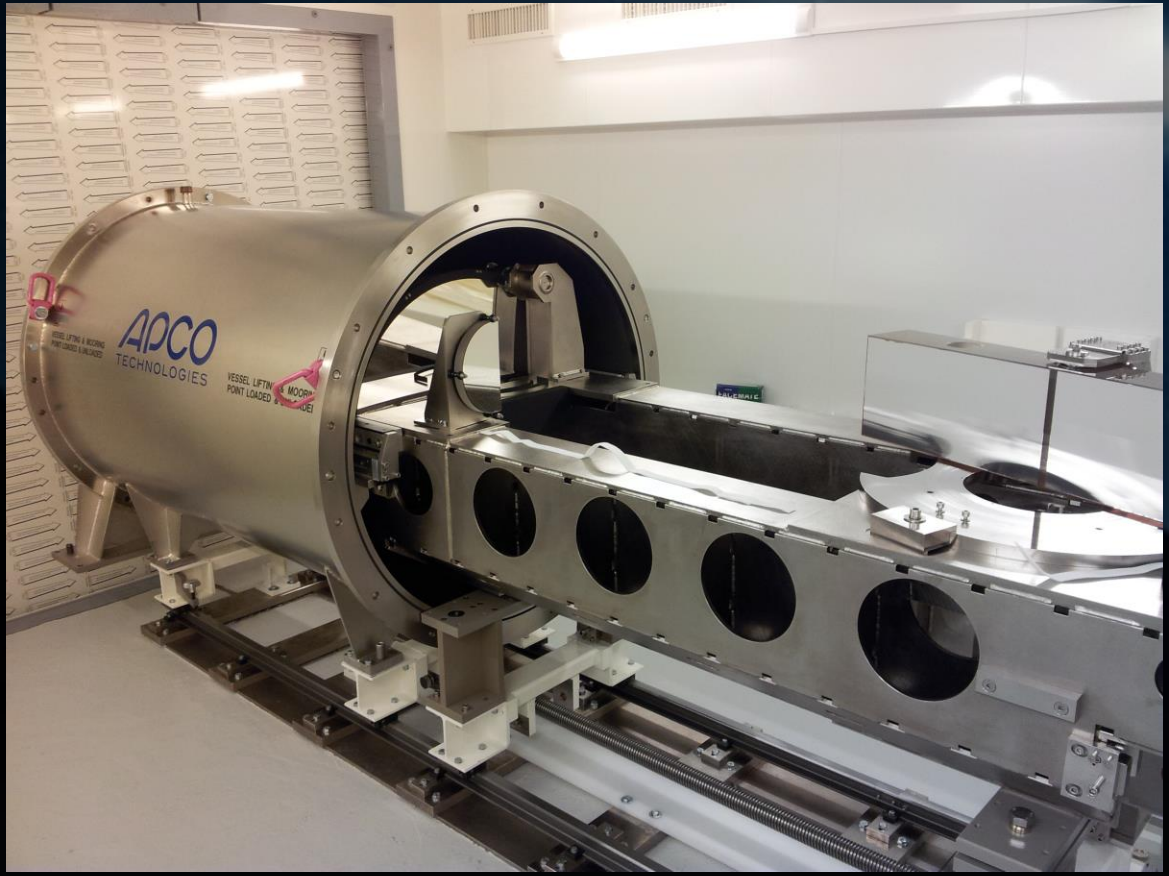
2048 X 2048 E2V-4240 CCD
Field of view: 8.6 X 8.6 arcmin with a 0.252 arcsec/pix scale

⇩

Imaging for comets

The TNG telescope – DOLORES and HARPS-N instruments

*H*igh *A*ccuracy *R*adial velocity *P*lanet *S*earcher for the *N*orthern hemisphere (HARPS-N)



Echelle high resolution spectrograph

Wavelength range: 383 – 693 nm
Spectral resolution: 115000

Two HARPS fibres (object + sky or Th-Ar)
Aperture on the sky of 1″

⇩

High-resolution spectroscopy for comets

Dust environment model of the interstellar comet 2I/Borisov

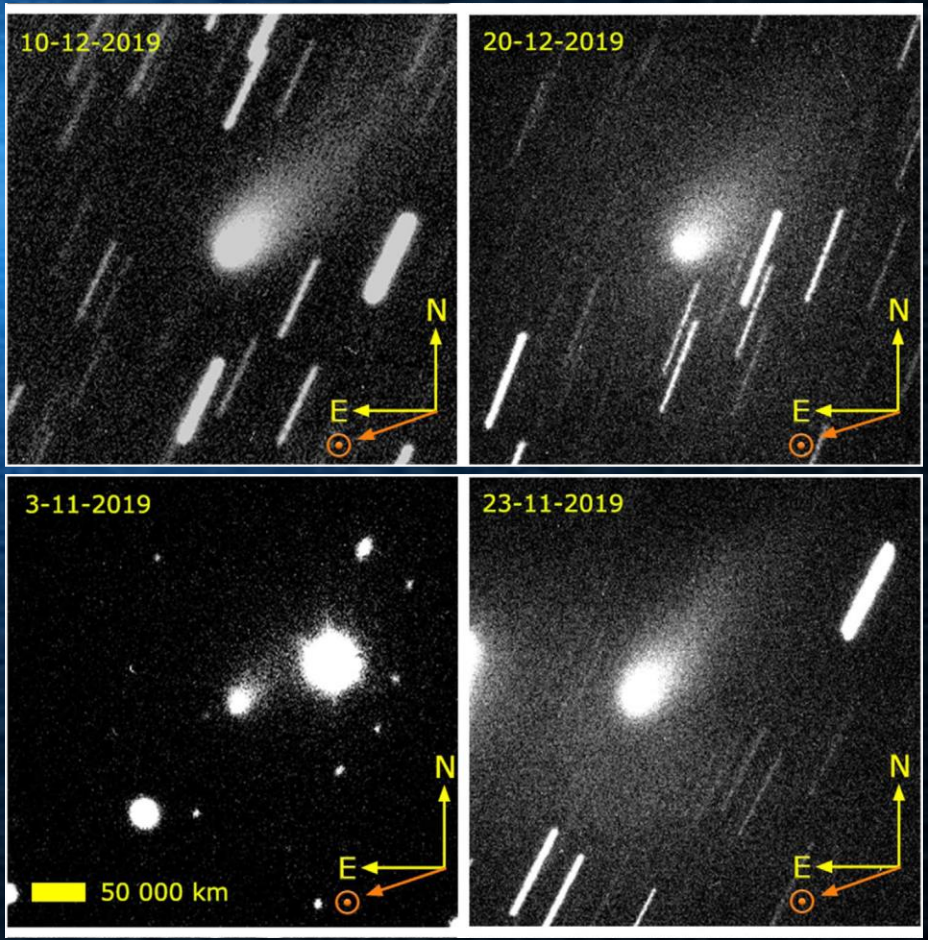
(Cremonese et al. 2020, ApJ)

The insterstellar comet 2I/2019 Q4 (Borisov) was detected in August 2019
The comet is an active icy object, showing a coma and a dust tail

Observations

- DOLORES instrument
- Images in the R band on 3 and 23 November 2019, and on 10 and 20 December 2019

Date (UT)	Exp.Time (sec)	Airmass	r_H (AU)	△ (AU)	Afρ (m)
2019-11-03T05:45:20.570	60	1,52	2.15	2.39	0.59
2019-11-23T04:57:33.391	1200	1.88	2.04	2.12	0.64
2019-12-10T06:25:22.720	1200	1.58	2.00	1.98	0.55
2019-12-20T06:03:08.806	1200	1.89	2.02	1.95	0.53



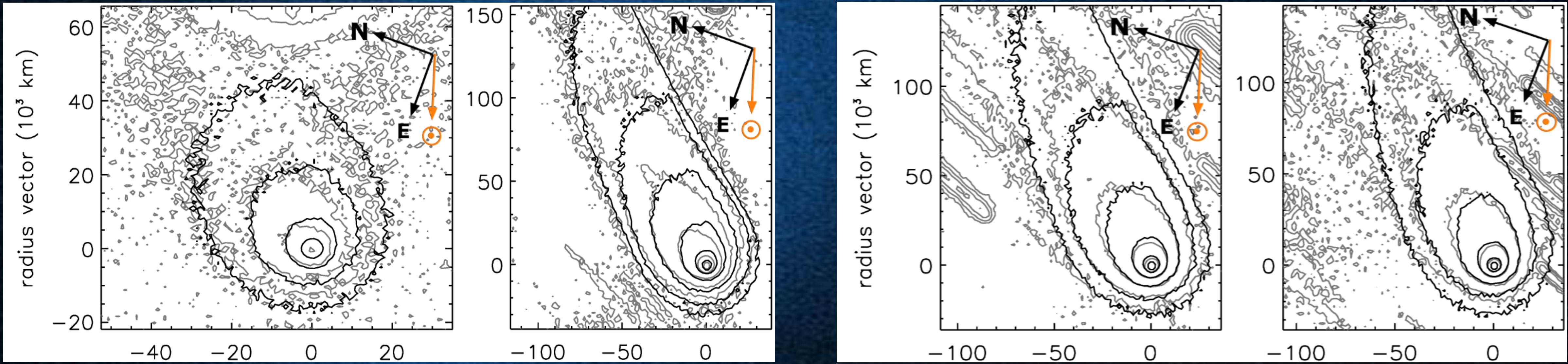
Dust environment model of the interstellar comet 2I/Borisov

(Cremonese et al. 2020, ApJ)

Probabilistic models of the dust tail and coma brightness

The motion of the dust in the coma and in the tail depends on the β parameter, i.e. the ratio between the solar radiation pressure and the gravity forces. The conversion of this parameter distribution allows to calculate the dust size distribution.

(for more details see Fulle et al. 2010)



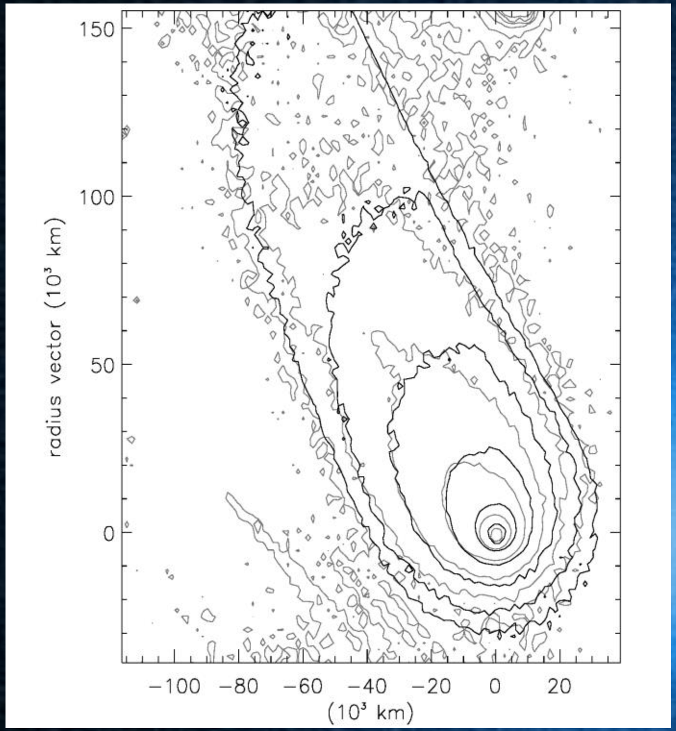
3 November 2019 23 November 2019 10 December 2019 20 December 2019

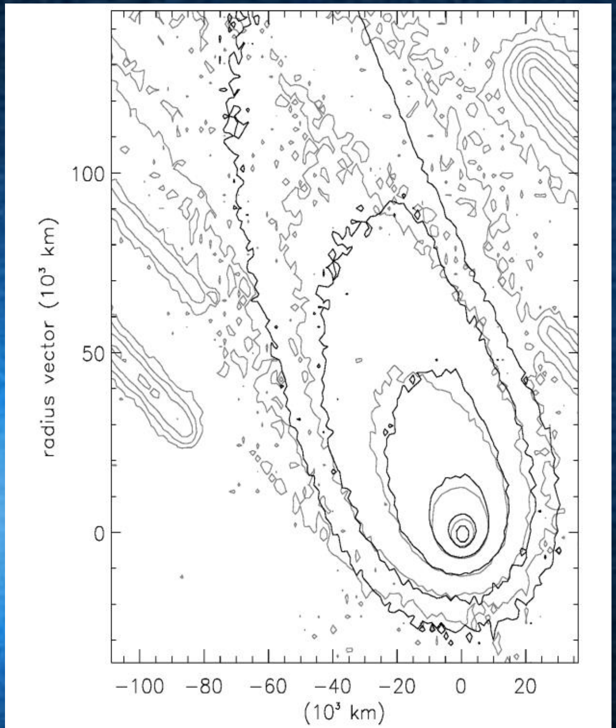
Computed (black isophotes) and observed (gray isophotes) dust tails

Dust environment model of the interstellar comet 2I/Borisov

(Cremonese et al. 2020, ApJ)

2I/Borisov is a twin of 67P





The best fit of the dust tail provides a velocity of the dust particle of 3 m/s, yielding a dust loss rate of 35 kg/s before perihelion (November 2019) and 30 kg/s after the perihelion (December 2019)

If the active area of 2.5 km^2 ejects dust there would be an erosion of 9 cm/day providing a dust ejection rate of 2000 kg/s, which implies a fallout of 98% taking into account the dust loss rate derived by our model.

A high-spectral resolution catalog of emission lines in the visible spectrum of comet C/2020 F3 (NEOWISE)

(Cambianica et al. 2021, A&A, Accepted)

Comet NEOWISE is considered as the brightest comet in the northern hemisphere since comet Hale-Bopp in 1997

Bright long period comet discovered on 27 March 2020

***Perihelion*: 3 July, 2020 at *heliocentric distance*: 0.29 AU**

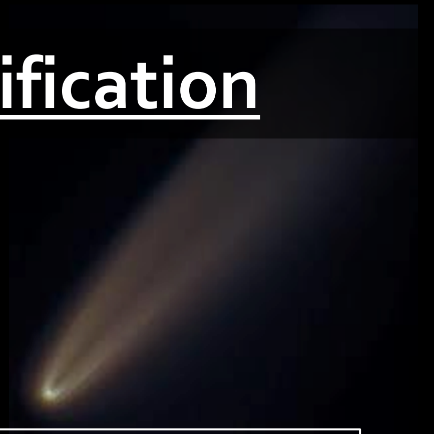
***Closest approach to Earth*: 0.70 AU (23 July 2020)**

***Dust and ion tails* (Knight and Battams, 2020)**

***Sodium tail*: 13 July, 2020 (Lin et al. 2020)**

***Visual Magnitude* of about 8 (June) to 0 (July)**

C/2020 F3 (NEOWISE) – Observations and emission lines identification



- 2 high resolution spectra: 26 July and 5 August, 2020
- HARPS-North Echelle spectrograph @ TNG (R=115000)
- Spectral range: 383-693 nm

The spectra have been used to generate a catalog of emission lines representing a useful tool for future studies of comets, since there are no catalogs in the literature with such a high spectral resolution

Laboratory molecular line lists

Molecule	Reference
C2	Phillips and Davis (2020)
	Chauville et al. (1977)
	Hunaerts (1967)
C3	Gausset et al. (1963)
CH	Masseron et al. (2014)
CN	Kurucz (1995)
	Davis and Phillips (1963)
NH_2	Dressler and Ramsay (1959)
	Ross et al. (1988)

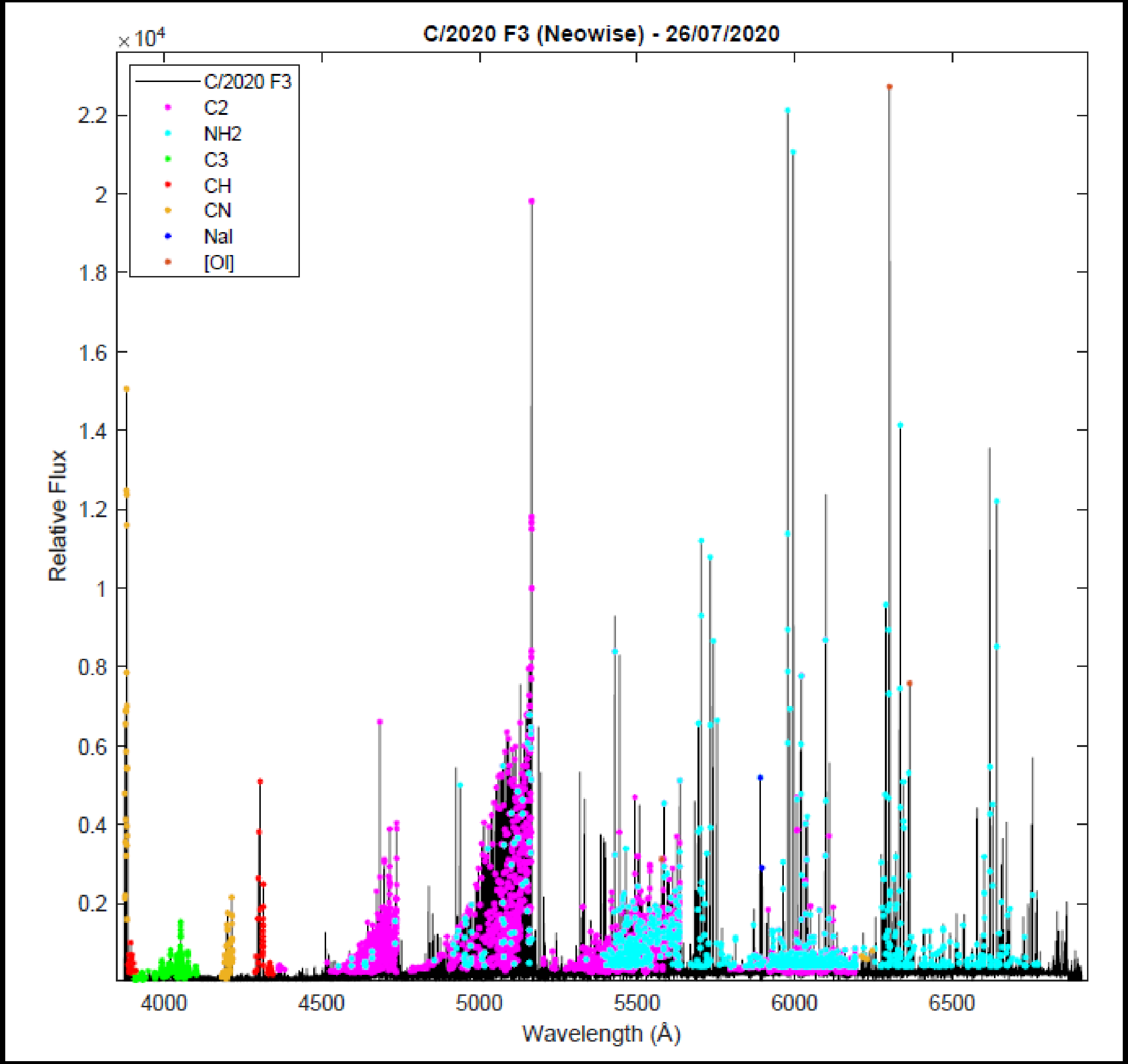
Table 2. Laboratory line lists used in this work.

Emission lines identification

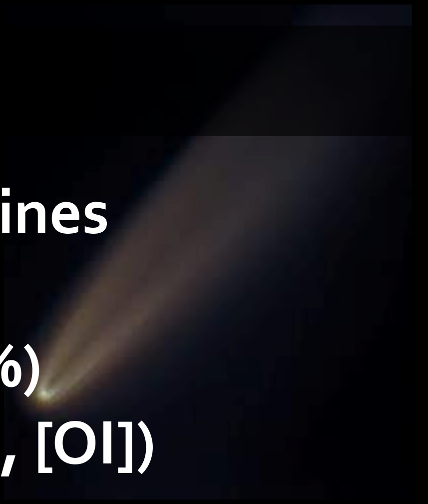
Atlas of other comets

Cremonese +2007 TNG data
Horne 1986
McKemmish +2020
Sneden +2014
Rousselot +2000
Picazzio +2002
Brown +1996b
Cochran and Cochran +2002

C/2020 F3 (NEOWISE) – Results



(Cambianica et al. 2021, A&A, Accepted)



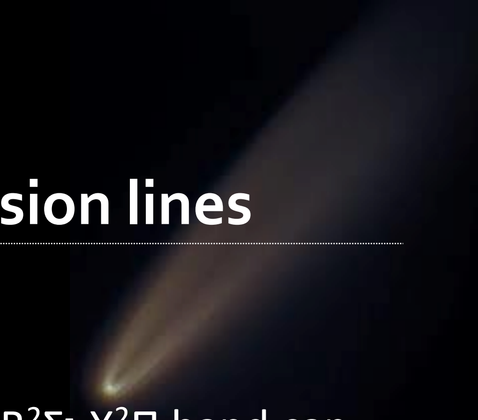
5193 Cometary emission lines

4488 Identified lines (87 %)
(C_2, NH_2, C_3, CH, CN, NaI, [OI])

705 Unidentified lines (13 %)

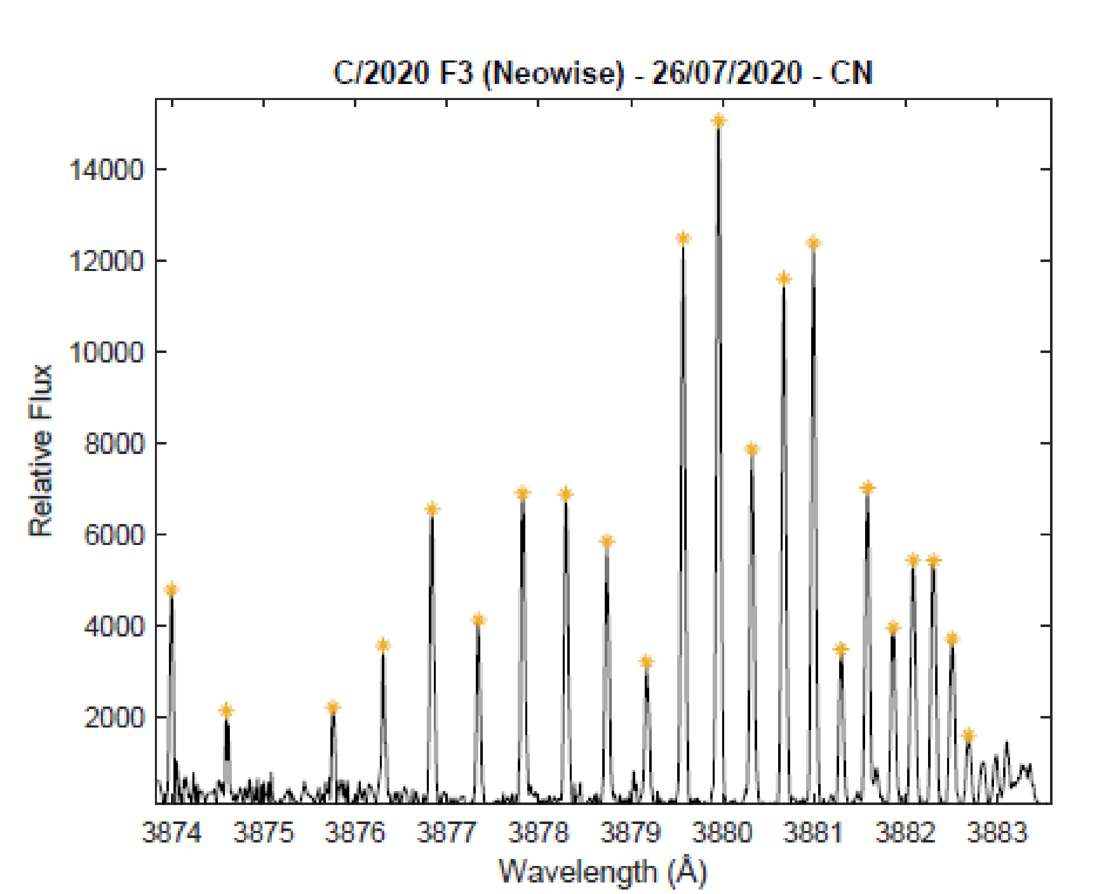
λ	I_{rel}	Molecule	Transition
3881.29	3473.89	CN	(0-0) P(14)
3881.58	7010.15	CN	(0-0) P(15)
3881.86	3956.06	CN	(0-0) P(16)
3882.08	5434.31	CN	(0-0) P(17)
3882.30	5420.32	CN	(0-0) P(18)
3882.50	3714.71	CN	(0-0) P(19)
3882.68	1596.70	CN	(0-0) P(20)
3882.83	994.43	Unidentified	
3882.85	1000.31	Unidentified	
3882.98	1163.69	Unidentified	
3883.10	1455.86	Unidentified	
3883.16	545.78	Unidentified	
3883.18	560.45	Unidentified	
3883.20	554.76	Unidentified	
3883.23	677.91	Unidentified	
3883.26	950.52	Unidentified	
3883.28	919.84	Unidentified	
3883.31	847.39	Unidentified	
3883.35	965.12	Unidentified	
3883.39	522.09	Unidentified	
3886.41	445.48	CH	B X R
3888.91	259.90	CH	B X R

C/2020 F3 (NEOWISE) – Results

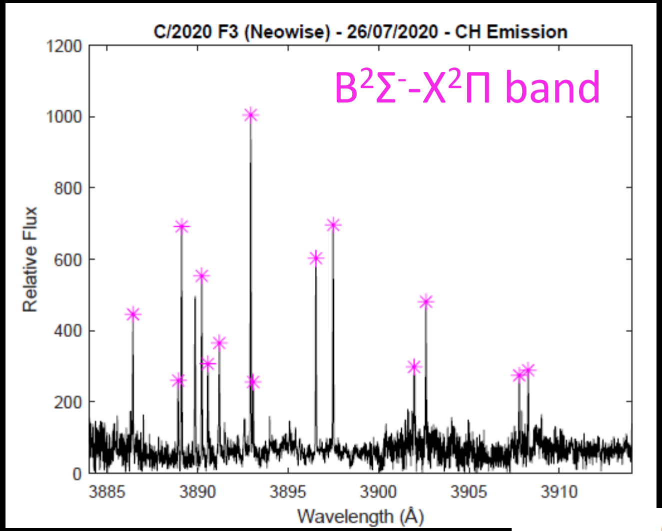


CN - 82 identified emission lines

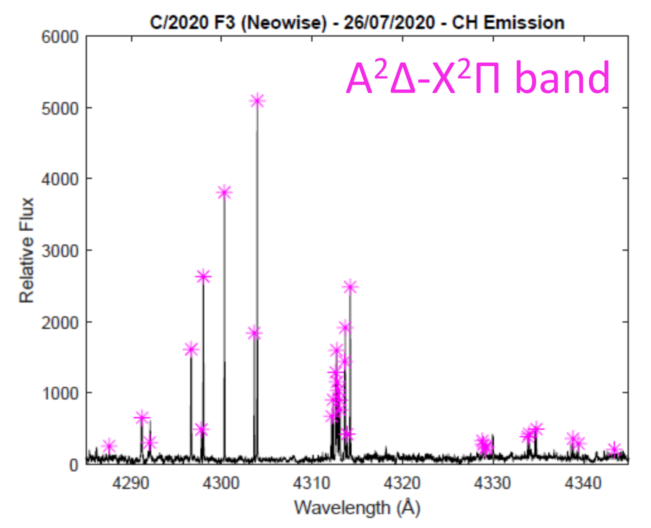
Violet system 3883 Å, P-Branch



CH - 45 identified emission lines



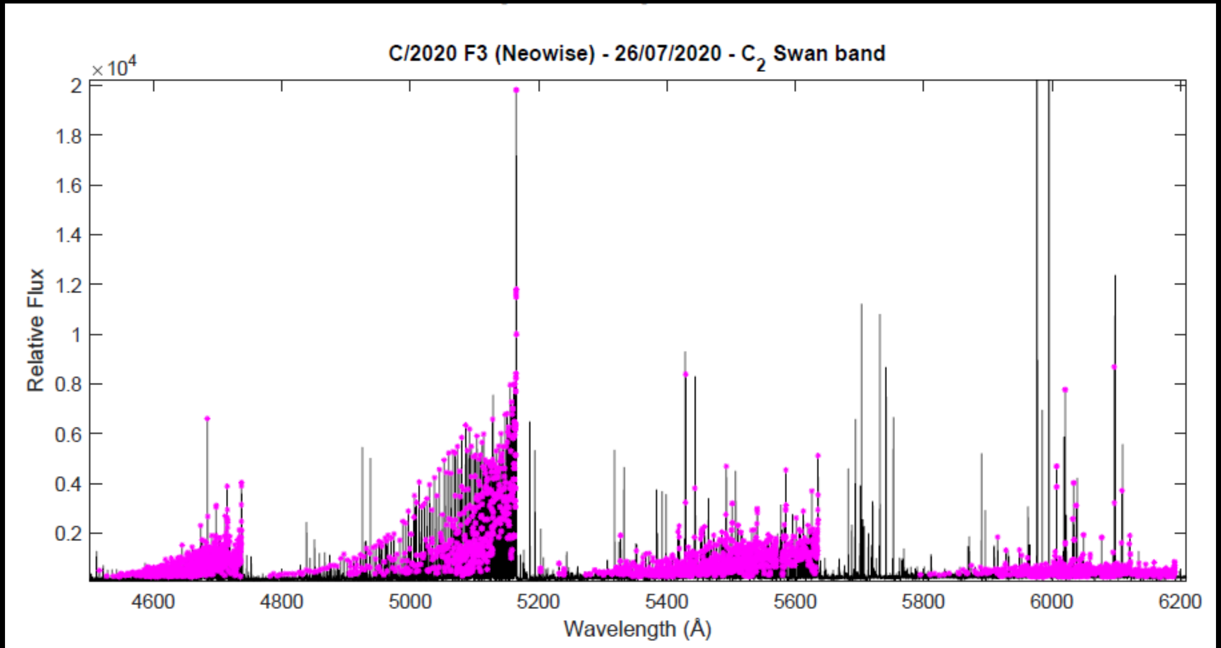
The $B^2\Sigma^- - X^2\Pi$ band can be resolved from CN only at high resolution.



C/2020 F3 (NEOWISE) – Results

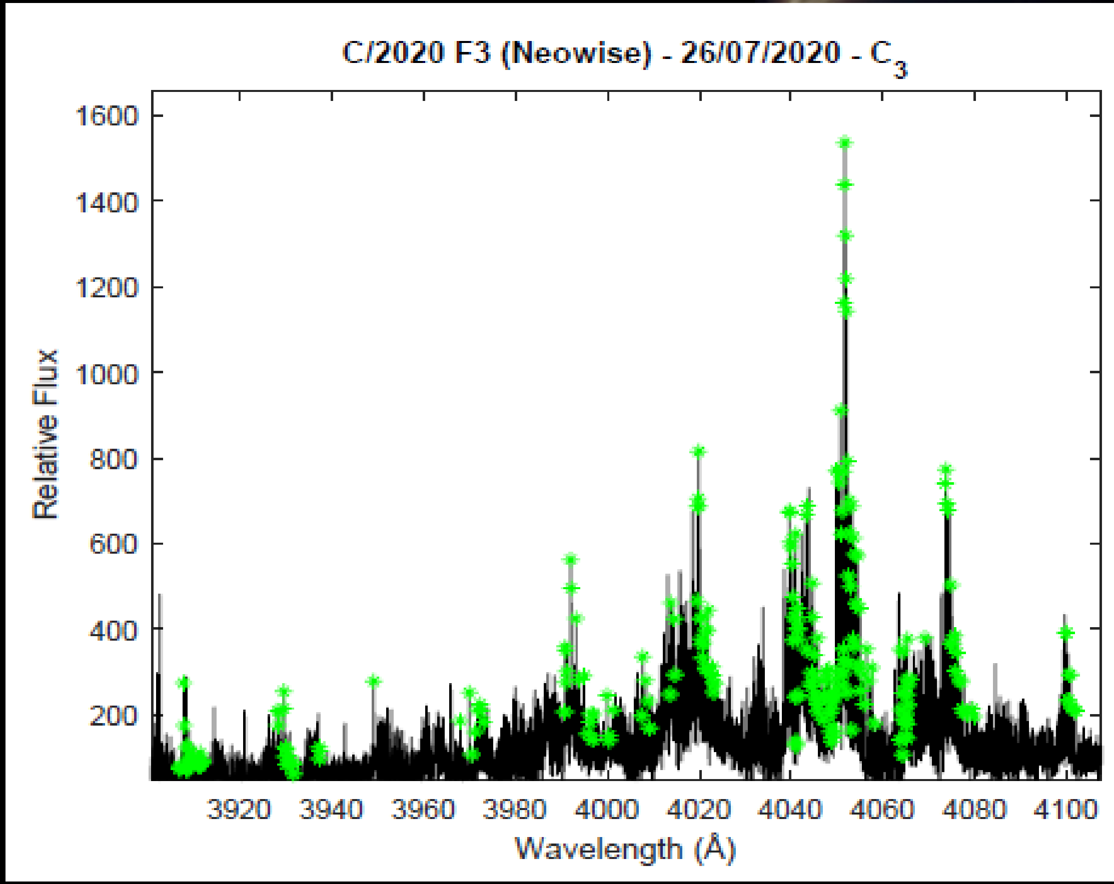
C_2 - 3161 identified emission lines

Swan-System



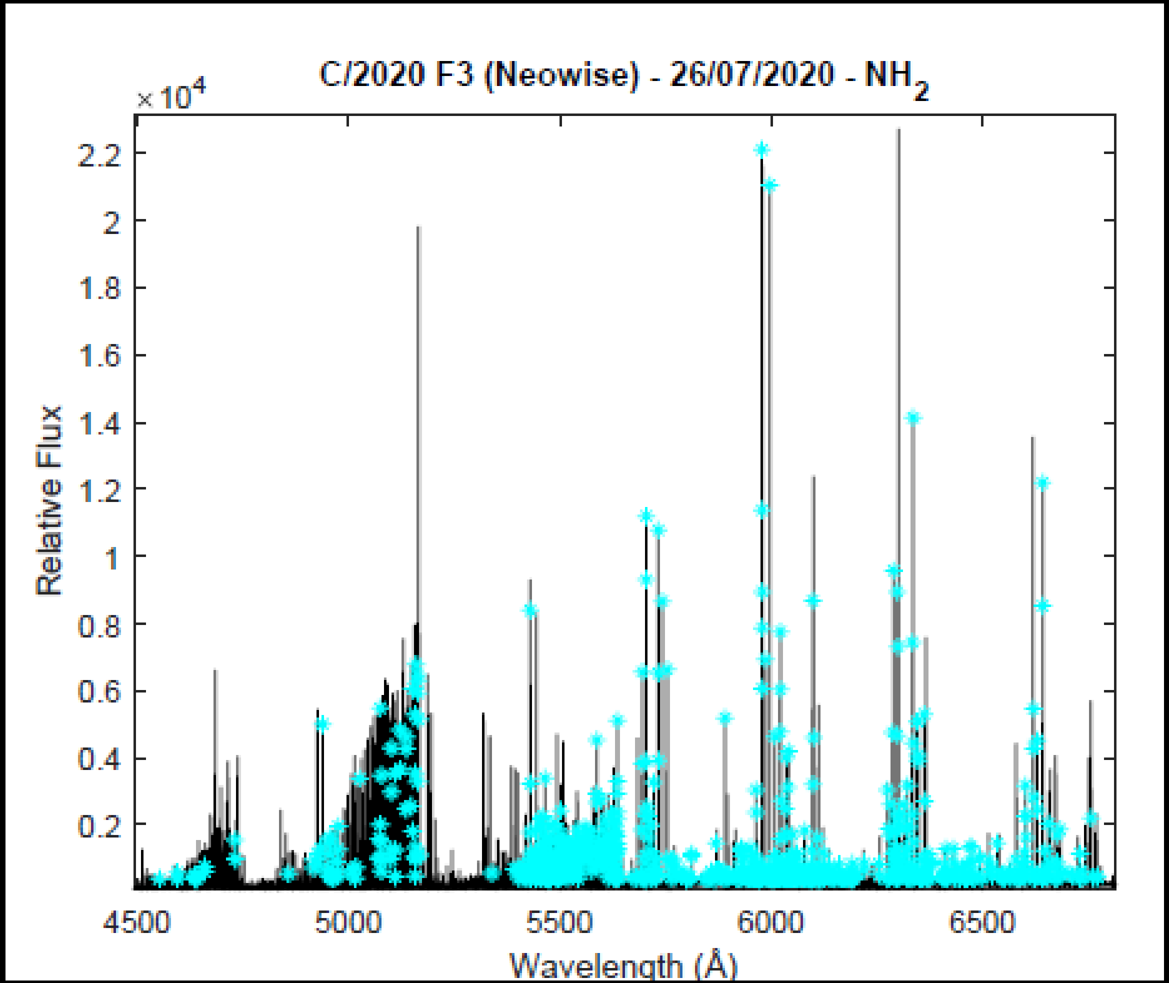
C_3 - 246 identified emission lines

4050 Å Group

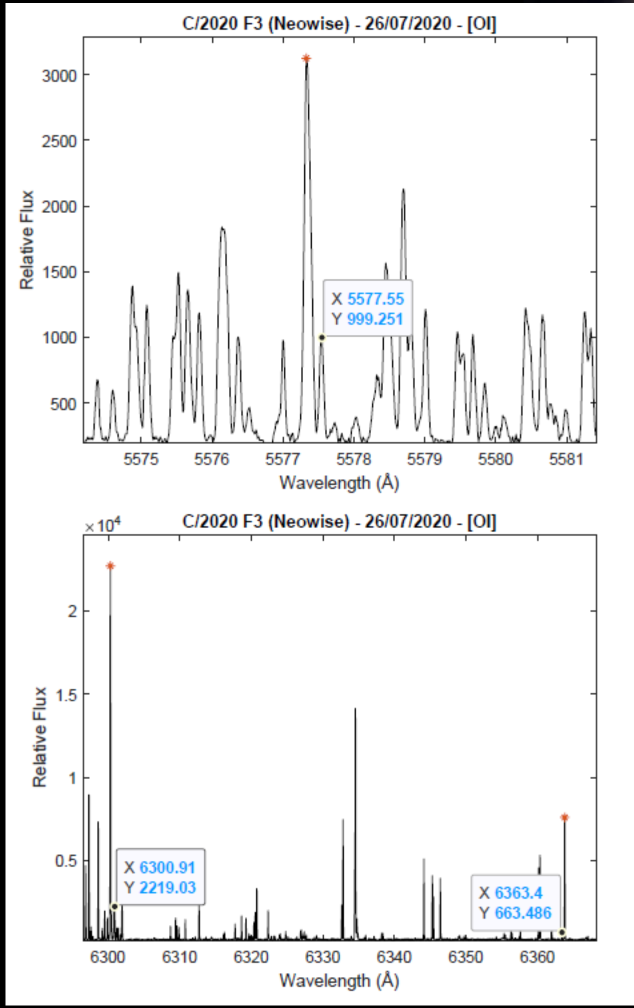


C/2020 F3 (NEOWISE) – Results

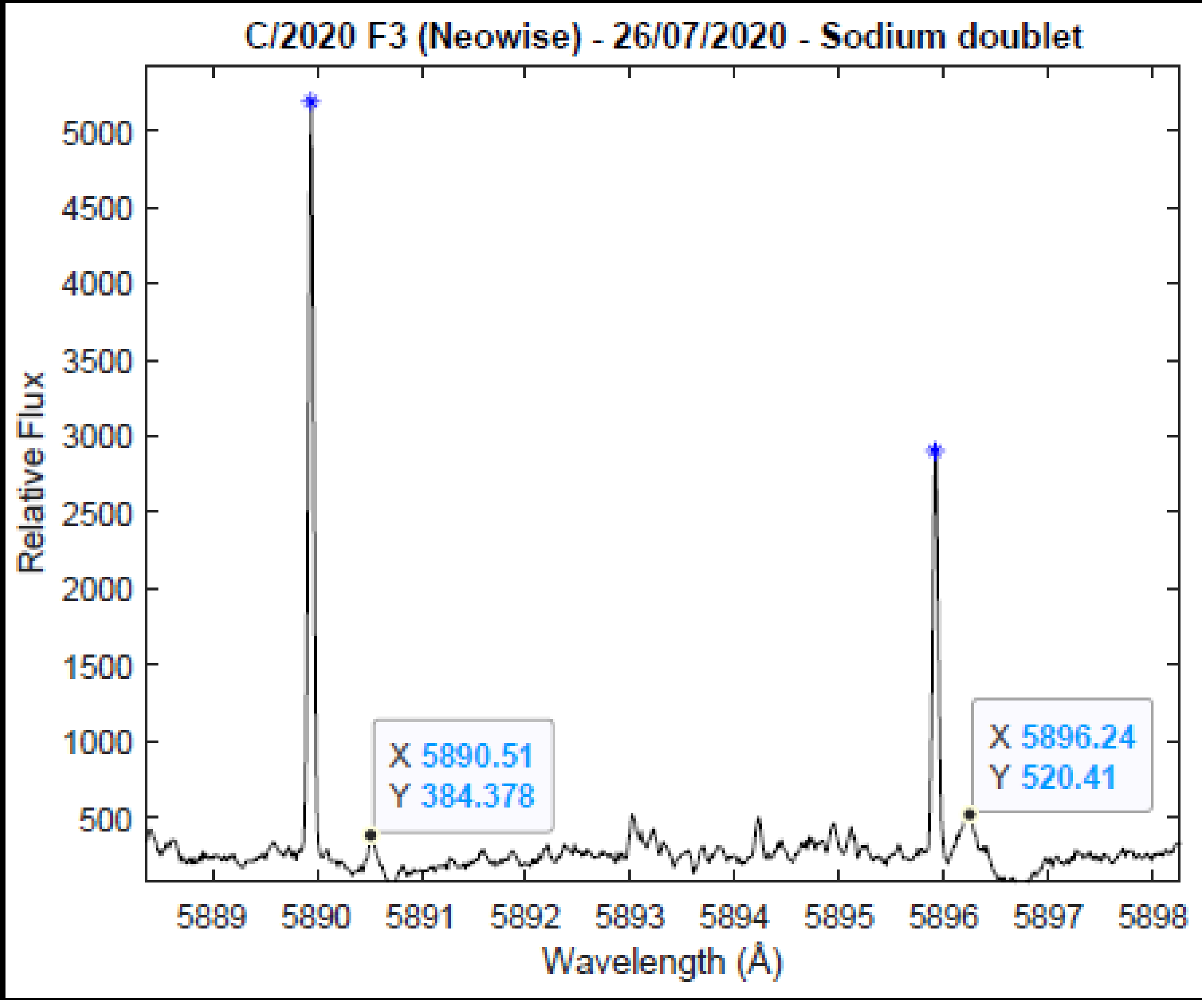
NH2 - 950 identified emission lines

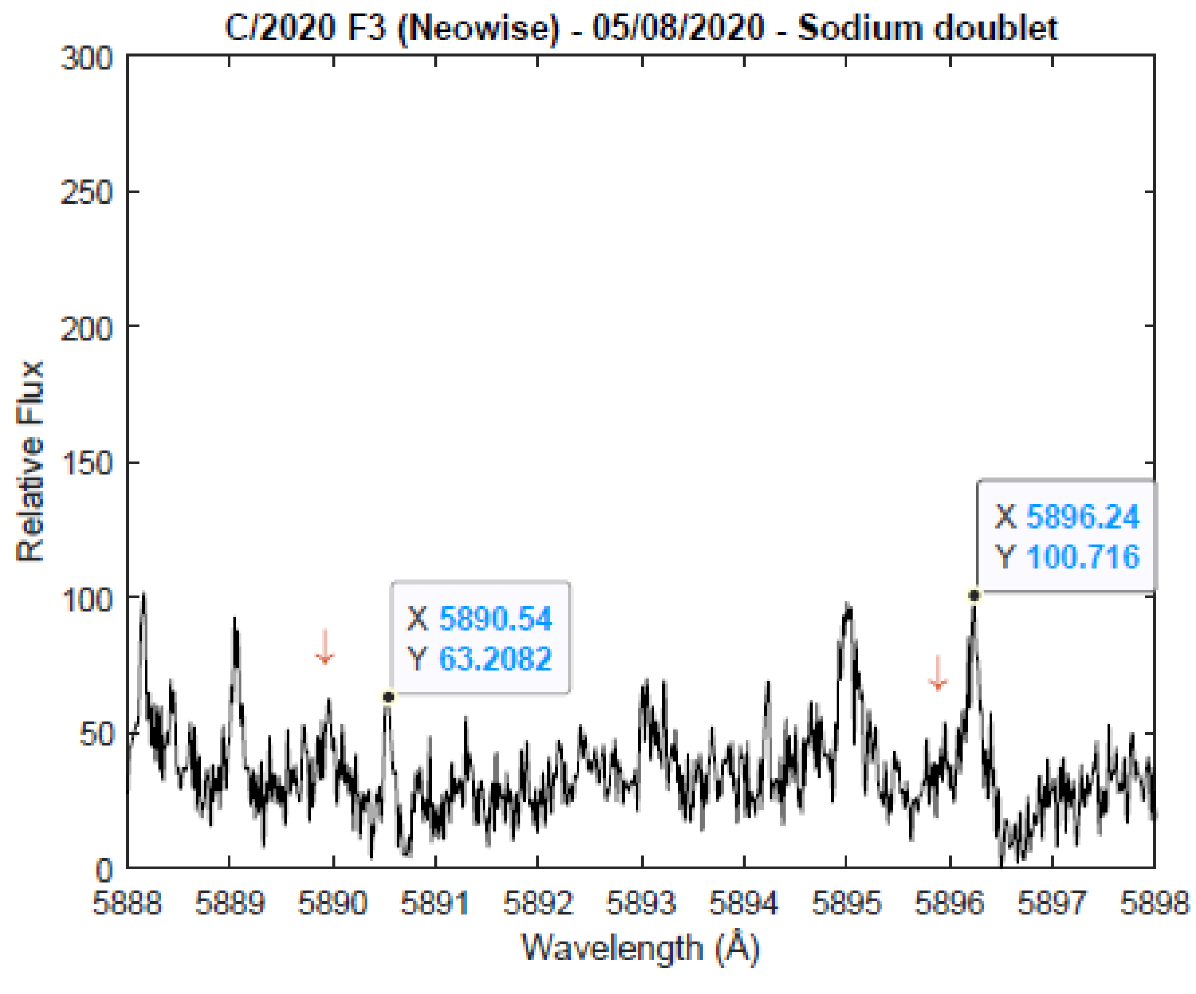


[OI]



C/2020 F3 (NEOWISE) – Results - Sodium doublet (1/2)

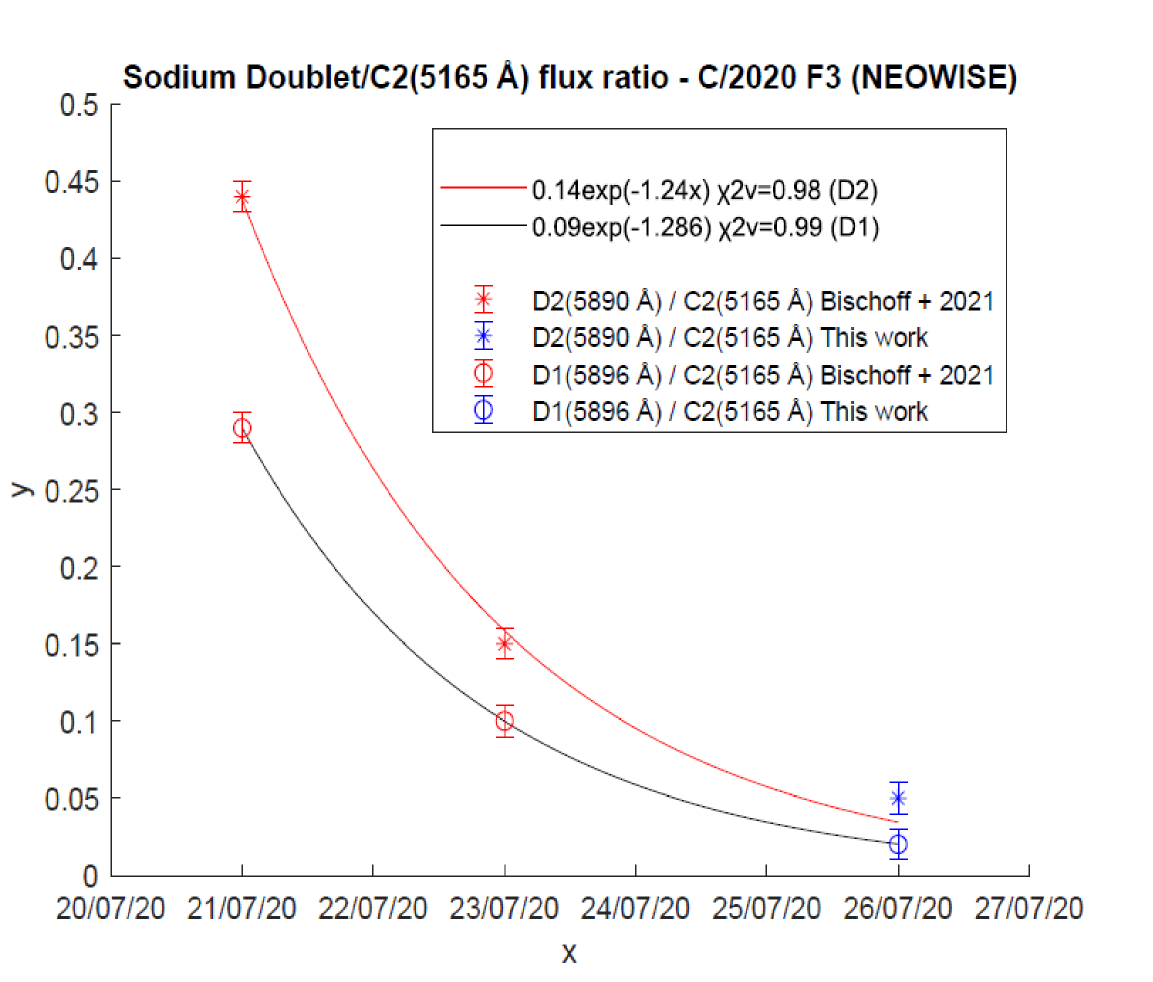




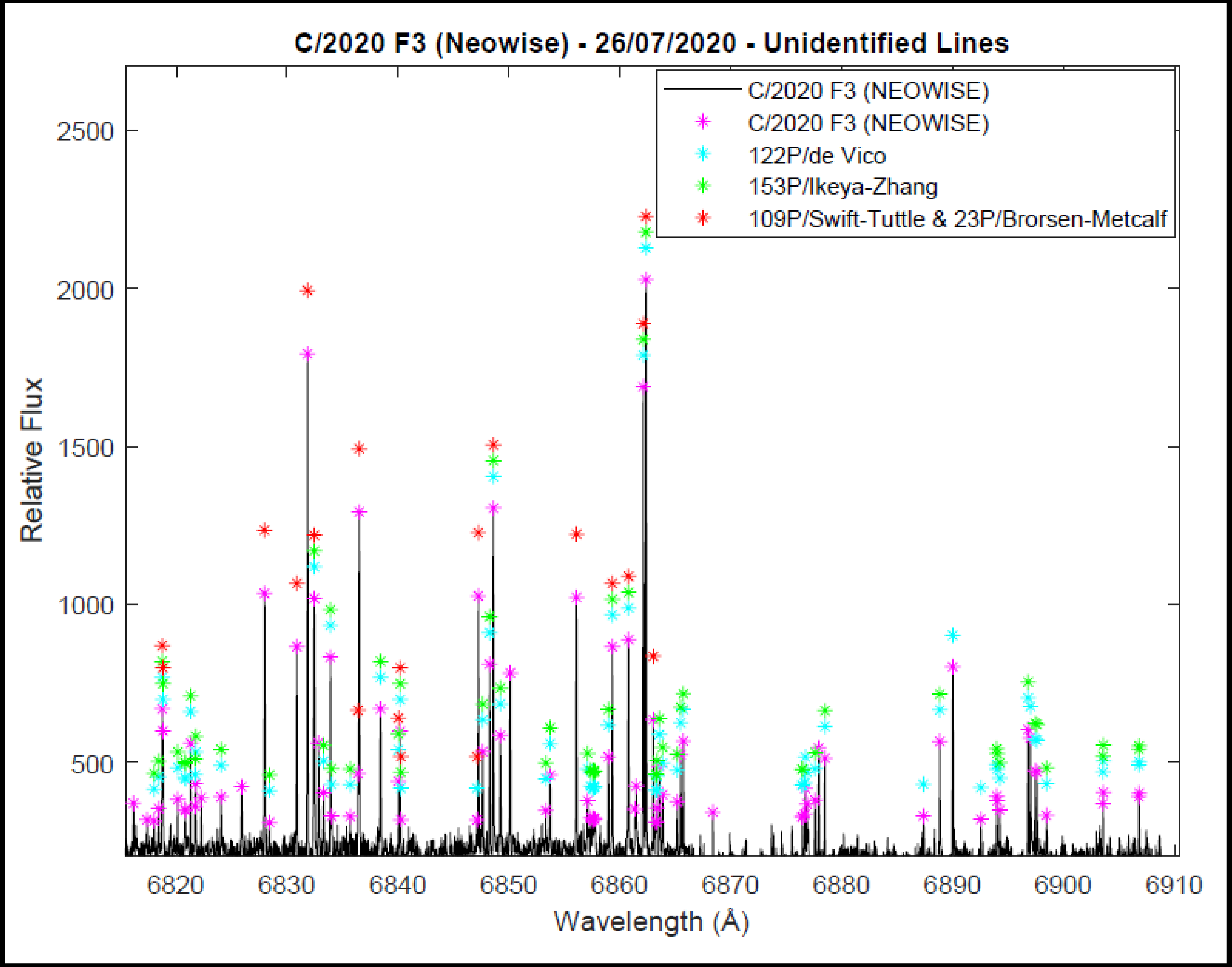
C/2020 F3 (NEOWISE) – Results - Sodium doublet (2/2)

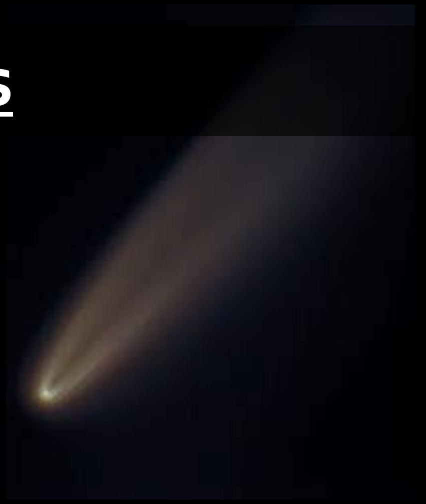
Emission Line	Date	Heliocentric Distance [AU]	$\frac{Flux[EmissionLine]}{Flux[C_2(5165Å)]}$	Instrument	References
NaI_{D2} 5890Å	21 July 2020	0.61	0.44±0.01	FLECHAS	1
NaI_{D2} 5890Å	23 July 2020	0.65	0.15±0.01	FLECHAS	1
NaI_{D2} 5890Å	26 July 2020	0.72	0.05±0.01	HARPS-N	this work
NaI_{D1} 5896Å	21 July 2020	0.61	0.29±0.01	FLECHAS	1
NaI_{D1} 5896Å	23 July 2020	0.65	0.10±0.01	FLECHAS	1
NaI_{D1} 5896Å	26 July 2020	0.72	0.02±0.01	HARPS-N	this work

Reference 1) Bischoff & Mugrauer (2021)



C/2020 F3 (NEOWISE) – Results – 705 unidentified lines





Conclusions

Ground observations are fundamental to understand the coma composition and the chemical and physical processes occurring in the nucleus.

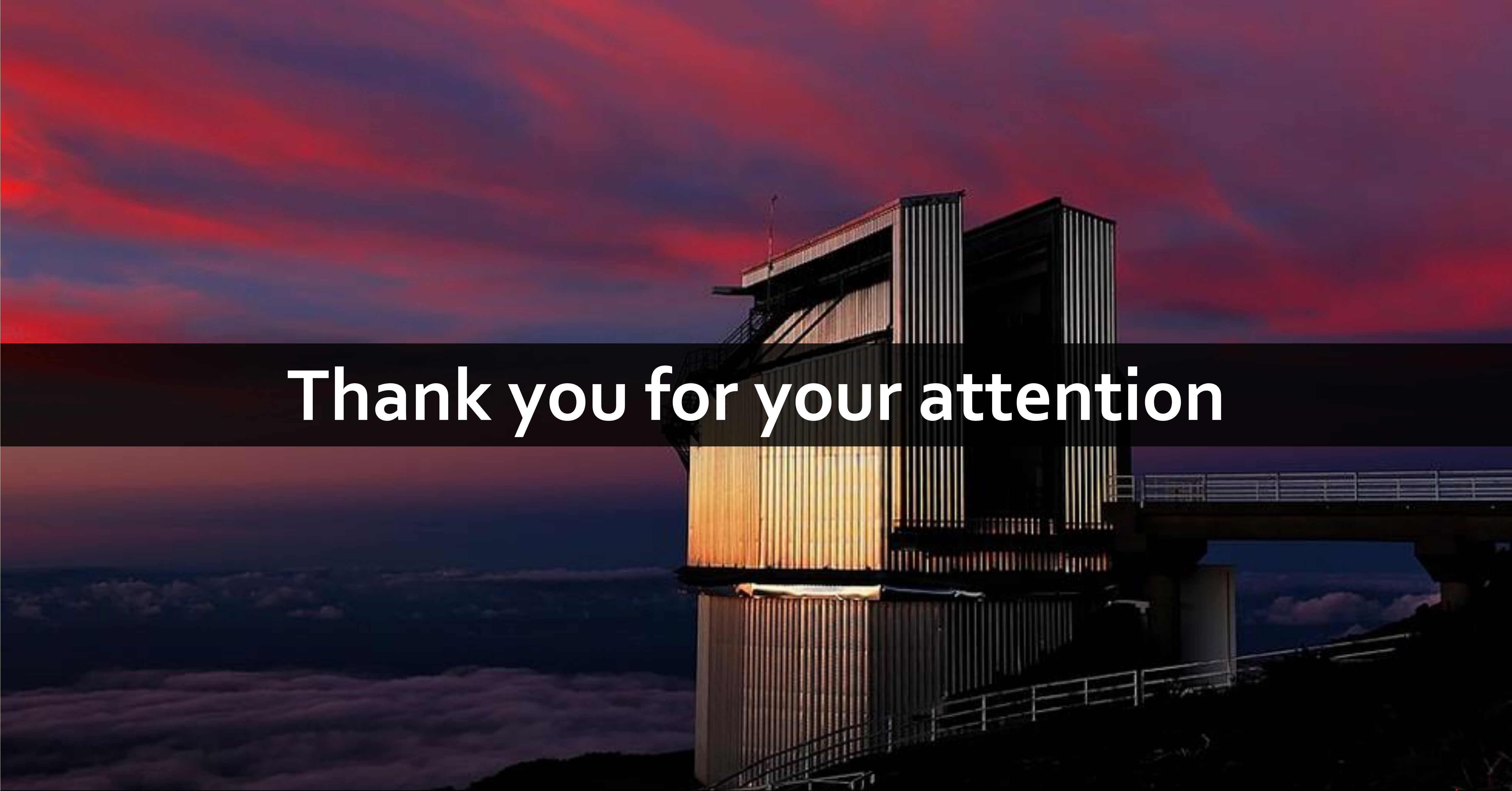
HARPS-N
High – resolution spectroscopy

DOLORES
Imaging

Future works

Production rates of the molecules in the coma of comet NEOWISE

Comparison with other comets (67P/Churyumov-Gerasimenko)


Thank you for your attention