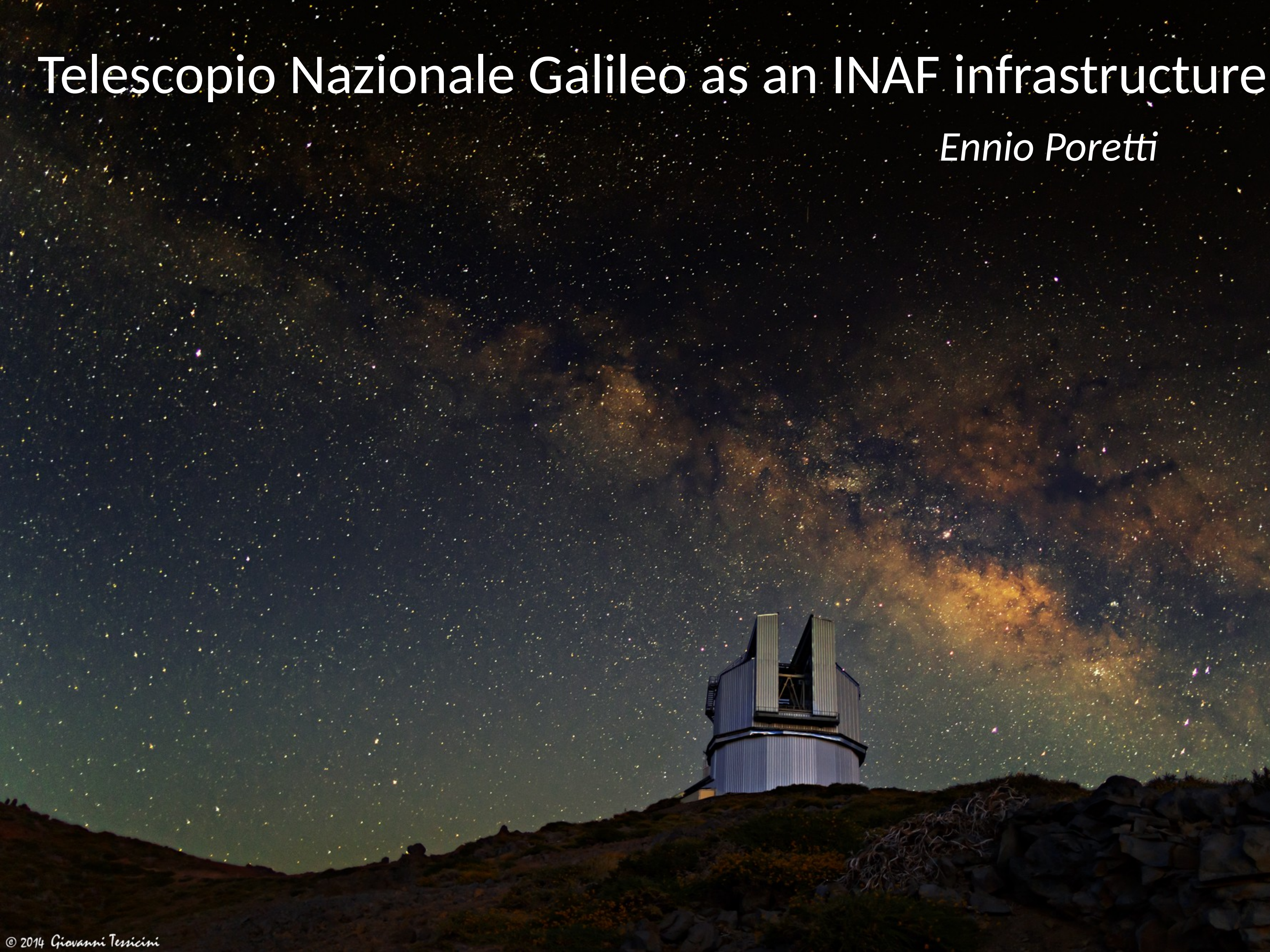
Telescopio Nazionale Galileo as an INAF infrastructure

Ennio Poretti



Instrument	Date
TNG	June, 9^{th} 1998
OIG	Dec, 10^{th} 1998
ARNICA	Dec, 18^{th} 1998
AdOpt	Dec, 18^{th} 1998
DOLORES	May, 20^{th} 2000
SARG	June, 9^{th} 2000
NICS	September, 17^{th} 2000
HARPS-N	March, 21^{st} 2012
GIANO	July, 27^{th} 2012
GIANO-B	Oct, 27^{th} 2016
GIARPS	March, 14^{th} 2017

M1 diameter	3.58 m
Focal length	38.5 m (f/11)
M2 diameter	0.875 m
M2 baffle diam.	1.165 m
Scale	5.36 arcsec/mm
Vignetting-free field	25 arcmin diameter

The Fundación Galileo Galilei-INAF (FGG-INAF) is a Spanish non-profit institution. The FGG's main aim is to promote astrophysical research by managing the Telescopio Nazionale Galileo (TNG), located at the Roque de Los Muchachos Observatory in La Palma, and developing INAF activities in the Canary Islands.

The financial support is ensured by the Italian Istituto Nazionale di Astrofisica (INAF). Decisional Board : ***PATRONATO,*** composed of 5 members: INAF President, INAF General Director, INAF Scientific Director, and two experts.

On the island: TNG Director. Also acting as *Gerente* FGG.
28 personnel units contracted by FGG.

4 INAF astronomers.

Administration (1+2), Technology (11), Informatics (4), Astronomy (8), Telescope Operators (5), Safety Manager (1).

FULL SERVICE MODE IN THE COVID-19 EMERGENCY.

INAF annual contribution	**2700 Keuro**	
Personnel Costs	1800 Keuro	2/3 full budget
San Antonio building purchase	150 Keuro	
General Expenses	350 Keuro	(electric power, CSC, ...)
External Enterprises	150 Keuro	(civil works, legal aspects,...)
Investments	100 Keuro	(new hardware, ...)
TNG operations	150 Keuro	(visitors, maintenance, ...)

OPTICON contribution (2017-20)	**370 Keuro**
Costs for upgrades (2019-20)	210 Keuro

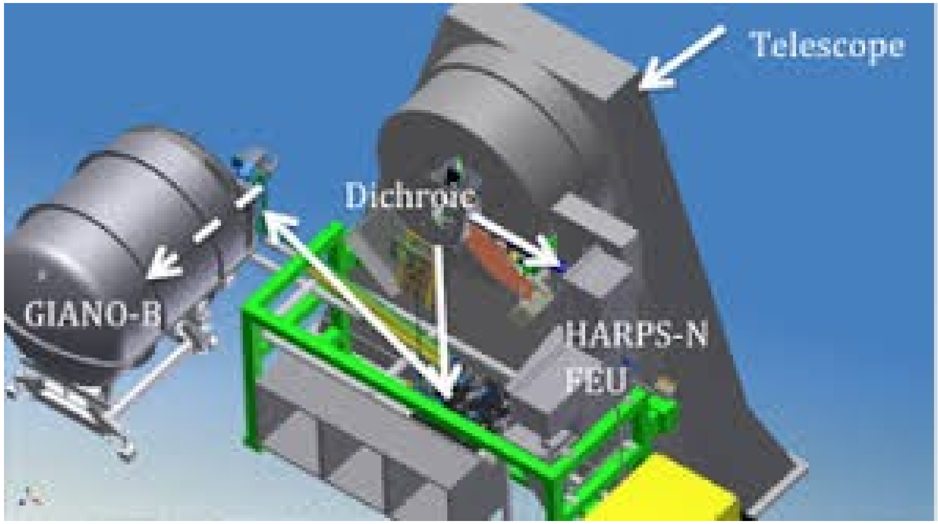
FGG full partner for the new OPTICON-RADIONET Pilot program
(funded and starting, 2021-2025).

Four interchangeable instruments

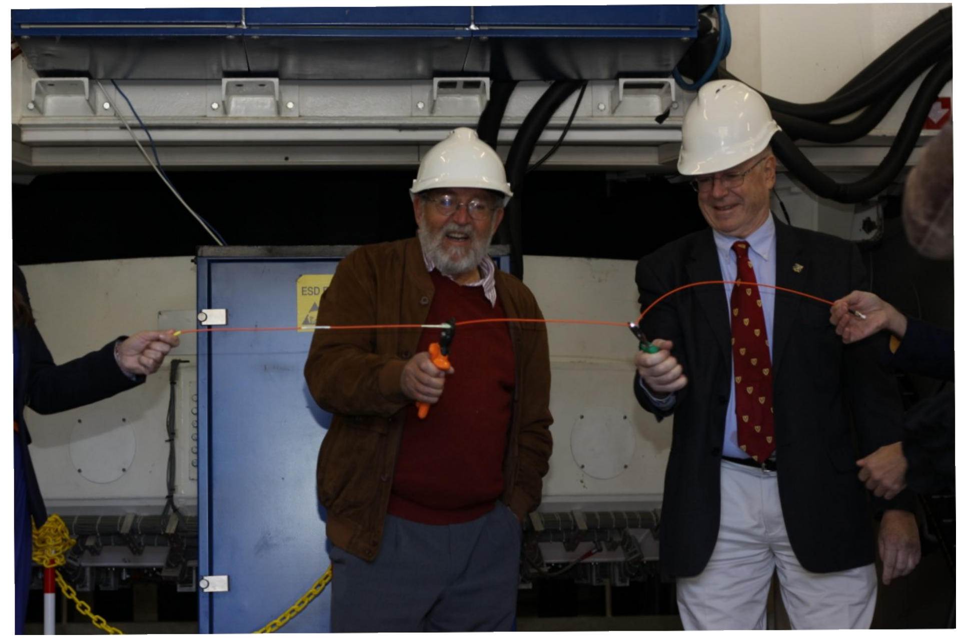
- **HARPS-N**, high-resolution spectrograph (R=115000) operating in the visible.
- **GIANO-B**, high-resolution spectrograph (R=50000) operating in the near infrared.
- **DOLORES**, low-resolution spectrograph (R<6000) and imaging.
- **NICS**, near-infrared instrument allowing low-resolution spectroscopy (R<2500),
  - imaging.
  - **and**

  - **SiFAP2,** ultrarapid photometer (time resolution 8 nanoseconds), offered as
  - PI instrument.

GIANO-B and HARPS-N combined in the **GIARPS** observing mode. Simultaneous visible and infrared spectra of the same target.



Milestone	Date
Kick Off	September 1st, 2010
Start of integration	October 1st, 2011
Acceptance Geneva	January 1st, 2012
Commissioning	March/April 2012
Inauguration	April 23rd, 2012
Start of operations	May 1st, 2012
Open time	August 1st, 2012



Date : December 7, 2018

Collaboration Agreement

for the maintenance and operation of the HARPS-N spectrograph and its scientific use

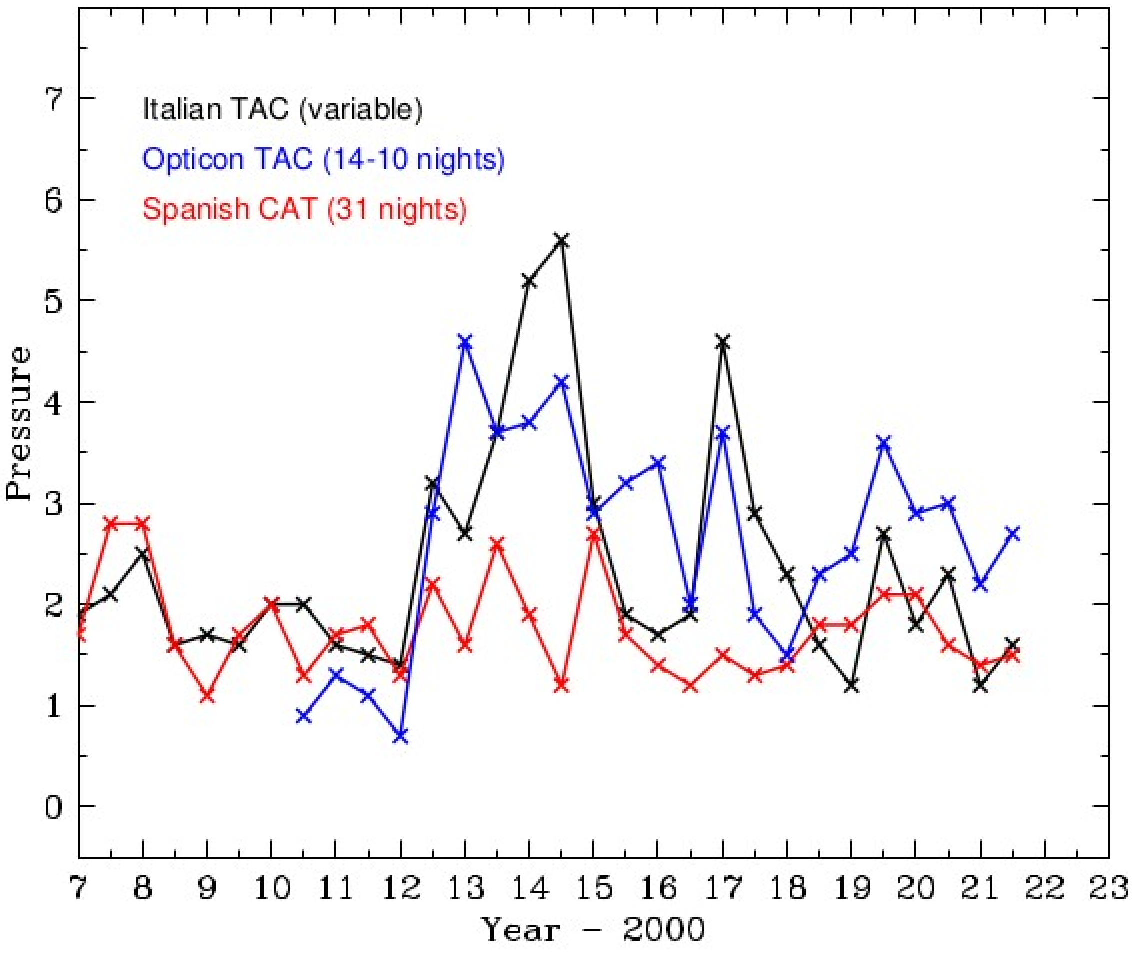
Renewed 5 years more: August 2017 – July 2022

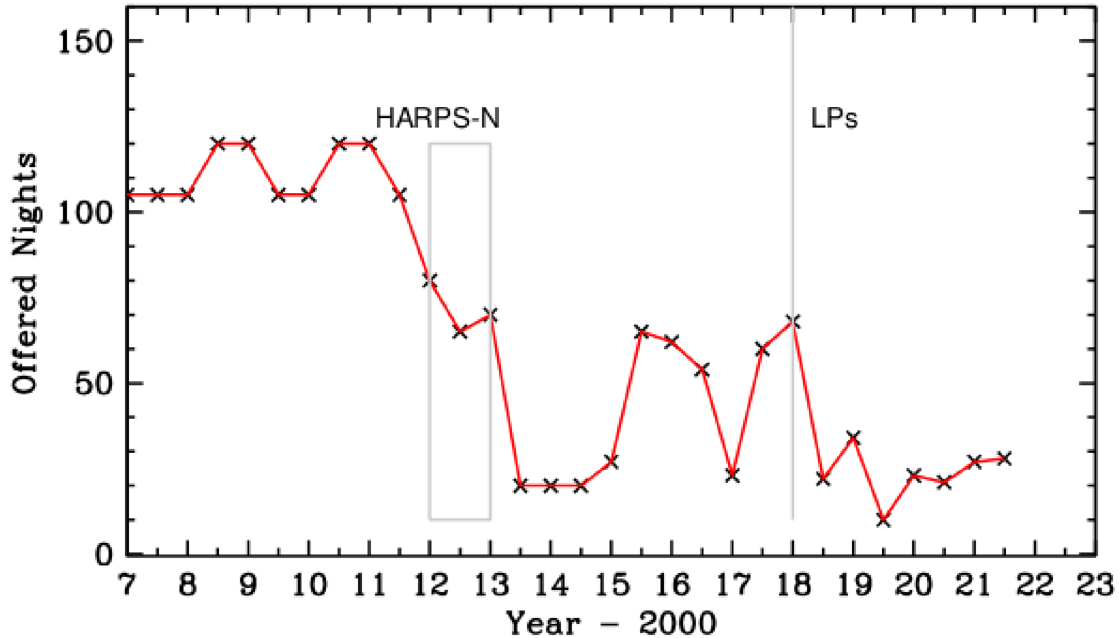
Night Statistics

	2020 [%]	2019 [%]	2018 [%]	2017 [%]	2016 [%]	2015 [%]
Down meteo	**26.5**	14.4	27.0	22.7	25.3	23.3
Technical failures	**2.7**	3.1	2.8	2.0	1.4	2.2
Engineering time	**2.2**	5.9	5.3	5.6	4.9	2.7
Idle time	**0.5**	0.6	0.5	0.6	1.0	0.4
Observed time	**68.1**	76.0	64.6	68.9	67.3	71.4
Open Shutter	**74.6**	71.9	76.2	72.8	74.1	72.7

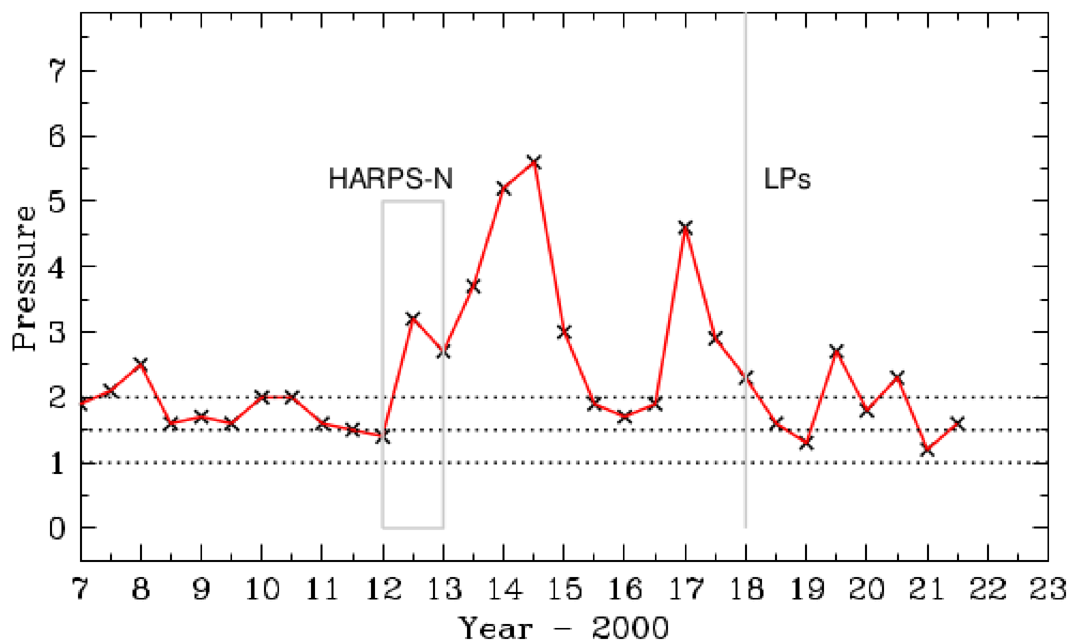
	AOT 38	AOT 39	AOT 40	AOT 41	AOT 42	AOT 43	AOT 44	Typical Semester
INAF OPEN TIME	12	12	10	18	16	26	28	20
INAF Large Prog.	47	47	39	43	43	34	36	40
INAF Long Term	-	4	3	-	6	6	-	3
GTO (INAF-GTO agr.)	40	40	33	40	40	40	40	40
Spanish CAT (Intl. protocol)	31	31	26	31	31	31	31	31
CCI ITP (Intl. protocol)	8	7	7	8	7	7	8	8
OPTICON	10	10	10	10	10	10	10	10
TNG-NOT (Agreement)	10	10	8	5	5	5	5	5
Technical nights (DDT, payback,...)	24	22	42 Alum.	28 PAO	24	24	24	24

PRESSURE ON OFFERED OBSERVING TIME





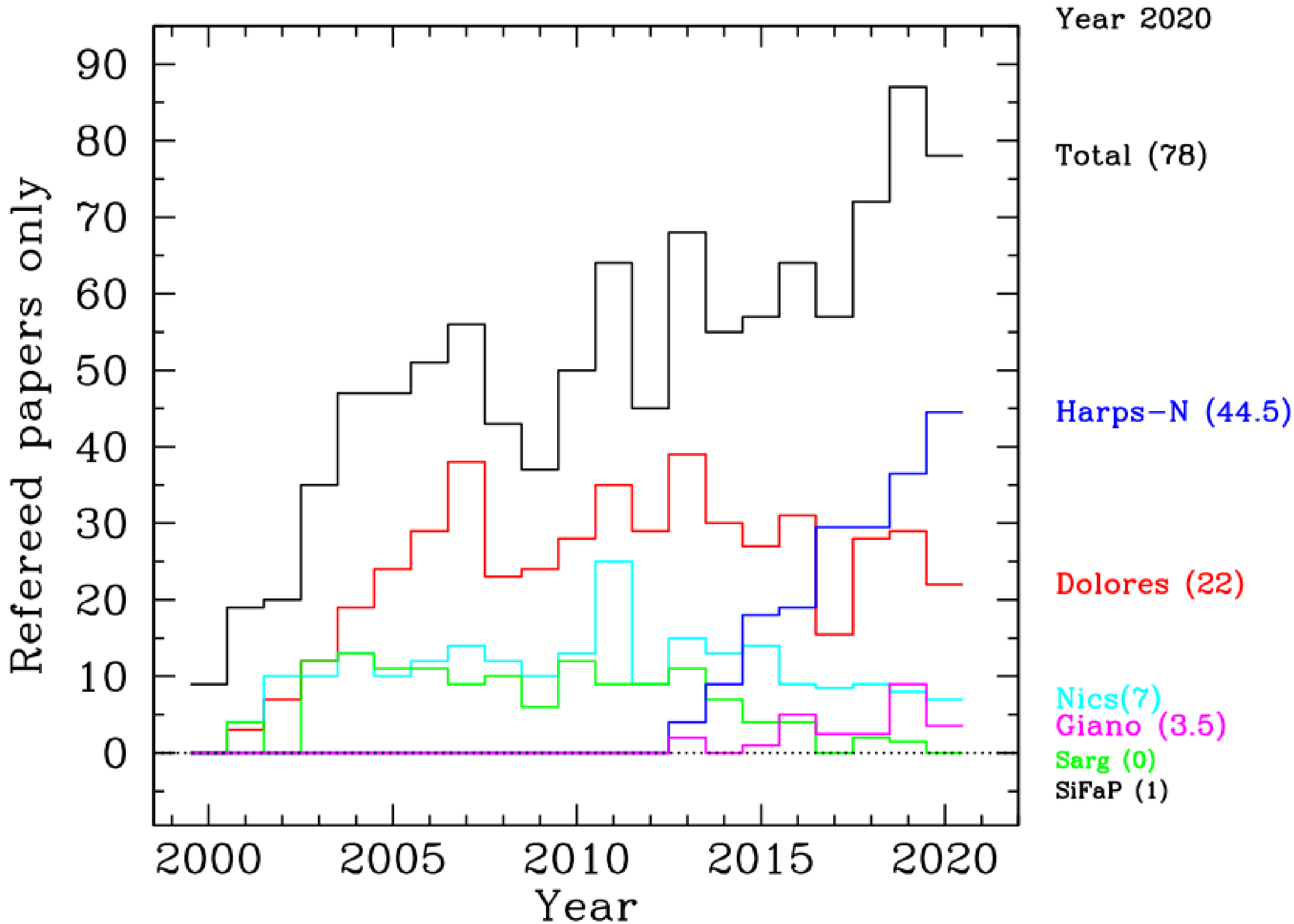
150
100
50
0
Offered Nights
HARPS-N
LPs
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Year – 2000



7
6
5
4
3
2
1
0
Pressure
HARPS-N
LPs
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Year – 2000

Publication record *(source TNG webpage)*

Peer-review journals only



The birth of the Italian Exoplanetary Science: the GAPS collaboration
30-40 nights on each semester (TAC dependent) since AOT26 (2012B)

GAPS

GLOBAL ARCHITECTURE OF PLANETARY SYSTEMS

Harps-N

A&A 649, A29 (2021)
https://doi.org/10.1051/0004-6361/202039247

Astronomy & Astrophysics

The GAPS programme at TNG

XXX. Atmospheric Rossiter-McLaughlin effect and atmospheric dynamics of KELT-20b★

M. Rainer[1], F. Borsa[2], L. Pino[1,3], G. Frustagli[2,4], M. Brogi[5,6,7], K. Biazzo[8], A. S. Bonomo[6], I. Carleo[9,10], R. Claudi[10], R. Gratton[10], A. F. Lanza[11], A. Maggio[12], J. Maldonado[12], L. Mancini[13,14,6], G. Micela[12], G. Scandariato[11], A. Sozzetti[6], N. Buchschacher[15], R. Cosentino[17], E. Covino[16], A. Ghedina[17], M. Gonzalez[17], G. Leto[11], M. Lodi[17], A. F. Martinez Fiorenzano[17], E. Molinari[18], M. Molinaro[19], D. Nardiello[20,10], E. Oliva[1], I. Pagano[11], M. Pedani[17], G. Piotto[21], and E. Poretti[17]

(Affiliations can be found after the references)

Received 24 August 2020 / Accepted 16 March 2021

BY COMBINING PHOTOMETRY AND SPECTROSCOPY

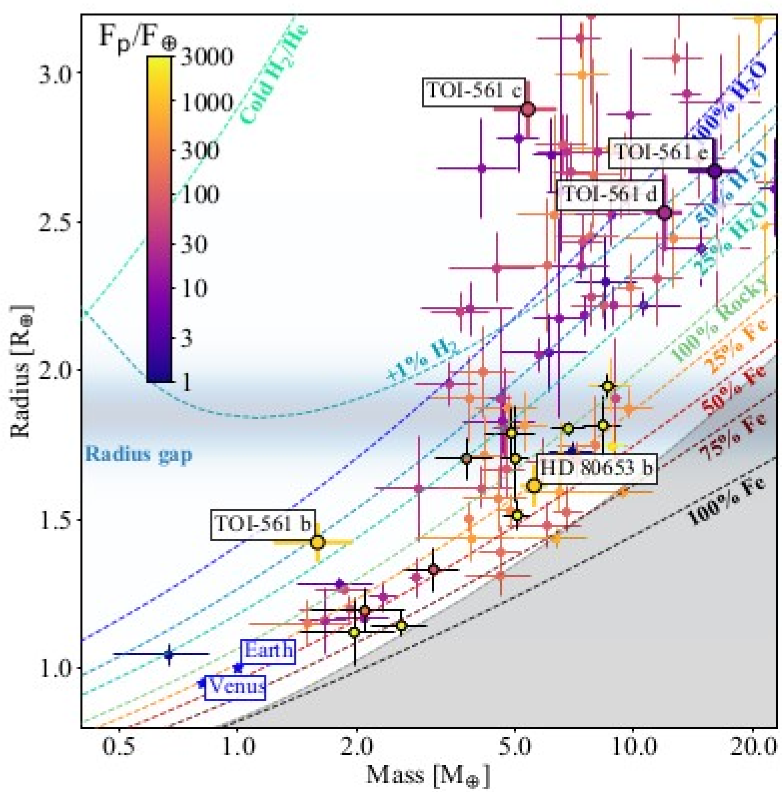


Figure 4: HIGHLIGHT #1. The state-of-art of our knowledge on planets smaller than 2.8 Earth radii is depicted in the radius-mass diagram. From this conceptually simple plot we can infer the composition of the planetary interiors, indicated by the dashed lines. It is noteworthy how many planets having similar sizes as our Earth actually have such completely different structures. In particular, the origin of the so-called radius valley at R 1.70 R_E (light-blue shaded) is likely due to a transition between rocky and non-rocky planets with extended H-He envelopes. **The densities of the systems TOI-561 and HD 80653 have been obtained with HARPS-N;** first authors are two PhD students, Gaia Lacedelli (Padova University) and Giuseppe Frustagli (Milano-Bicocca University), respectively.

Article

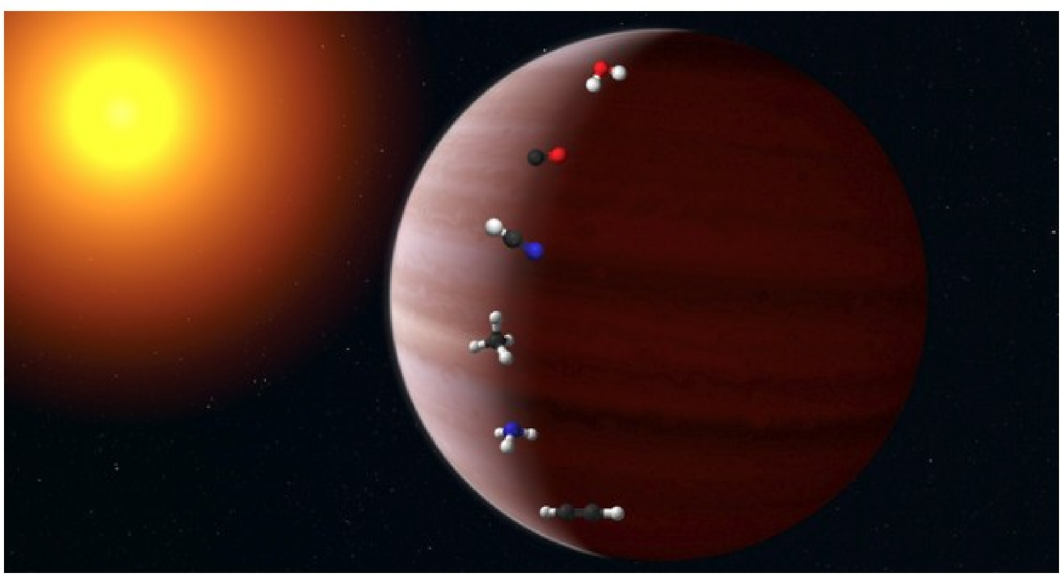
nature

Five carbon- and nitrogen-bearing species in a hot giant planet's atmosphere

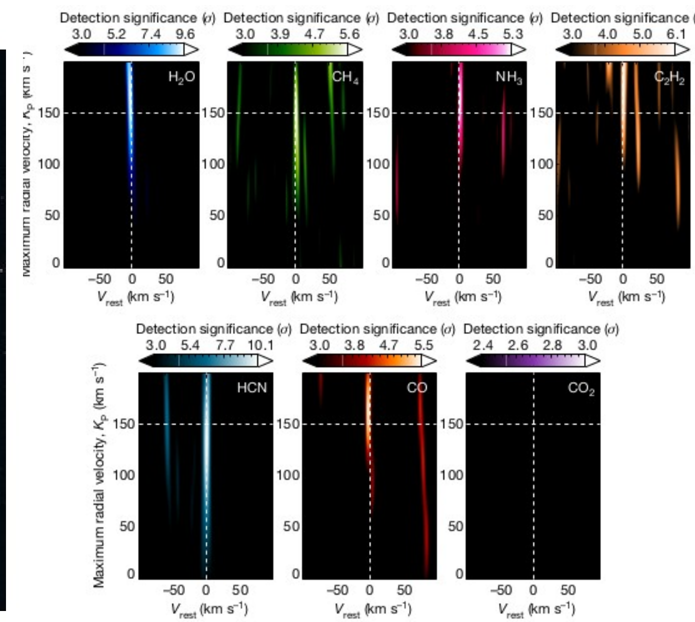
HD209458b has a density lower than Jupiter's and orbits its star at a distance of just over 7 million kilometers - twenty times smaller than Earth's distance from the Sun. This results in a high planet temperature, around 1200ºC, and a very short orbital period of 3.5 days. Moreover, we see it passing in front of the parent star.

The research team led by Paolo Giacobbe has gathered data over four planetary transits of HD209458b, observing in the near-infrared portion of the electromagnetic spectrum with GIANO-B. The observations were performed as part of the INAF Global Architecture of Planetary Systems (GAPS) large programme. While the planet transits in front of the star, starlight is filtered by the planet's atmosphere, thus marking the characteristic "fingerprints" of the molecules it contains. Such a transmission spectroscopy allowed astronomers to study the planet's atmosphere at the terminator - the region that separates the planet's dayside, illuminated by the star, from its nightside. The spectra obtained with GIANO-B enabled the researchers to identify, for the first time simultaneously, the six molecular species in the atmosphere of HD209458b thanks to their thousands of resolved spectral lines. This discovery opens new horizons to be explored.

According to current theoretical models of exoplanetary atmospheres, discovering so many molecules in the atmosphere of HD209458b, many of them carbon-bearing, would indicate an atmospheric chemistry that is richer in carbon rather than in oxygen. This feature suggests that the planet formed beyond the water snowline, several astronomical units away from its parent star, where the gas in the protoplanetary disk was expected to be richer in carbon. In Solar System terms, HD209458b would have formed beyond the orbit of Mars, most likely between the orbits of Jupiter and Saturn, and would have later migrated towards its star at the distance we observe it today, one tenth of the Mercury-Sun distance. This validates the theories that hot Jupiters formed much farther away from their current position.



Credits to Marco Galliani, MediaInaf

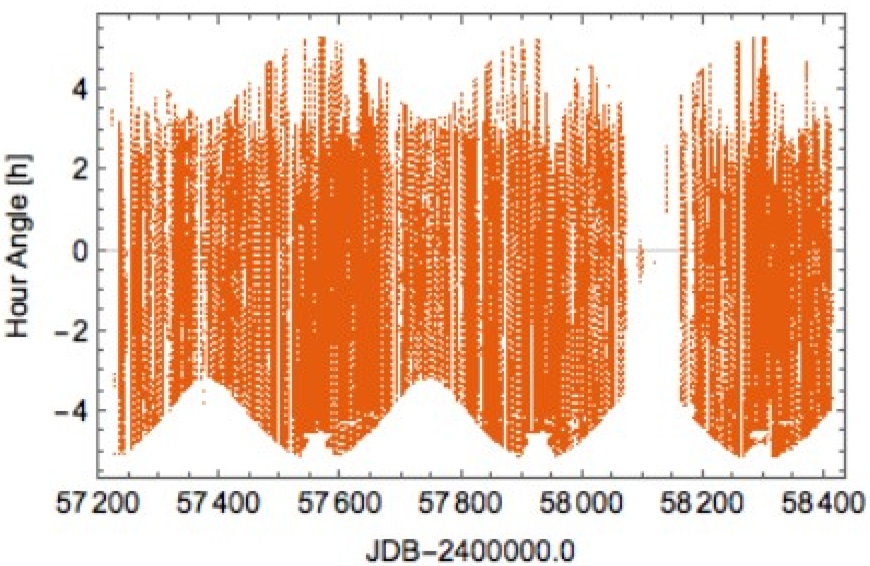


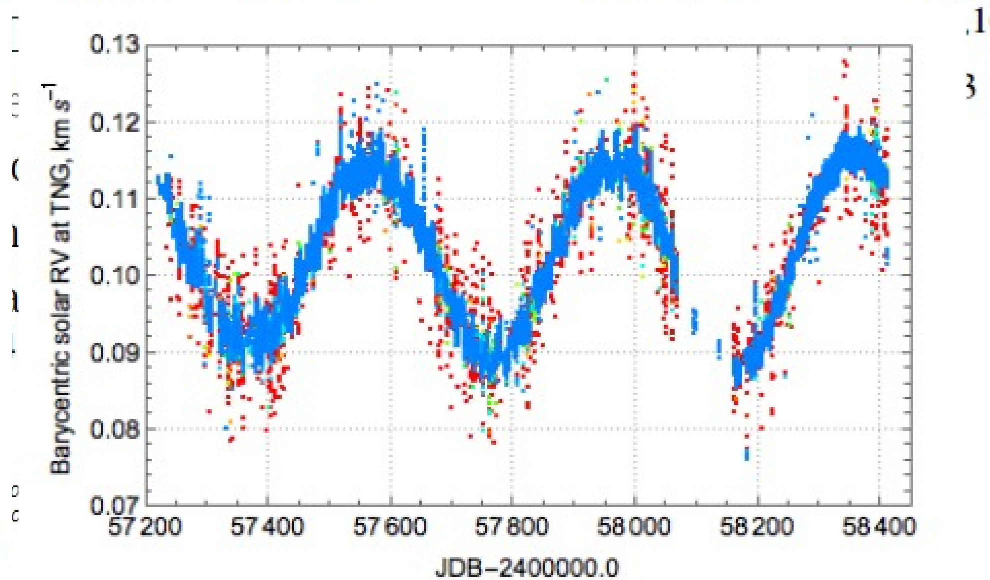
The Sun as a star

David Phillips, Xavier Dumusque, TNG staff, et al.

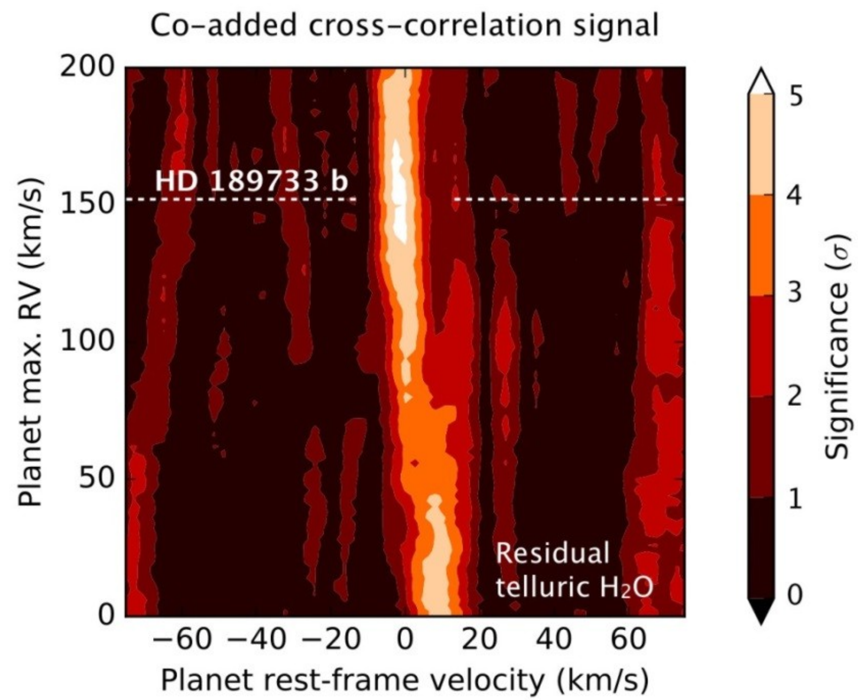
LCST (Low Cost Solar Telescope) operating daytime.
It feeds HARPS-N spectrograph.

Three years of Sun-as-a-star radial-velocity observations on the approach to solar minimum.





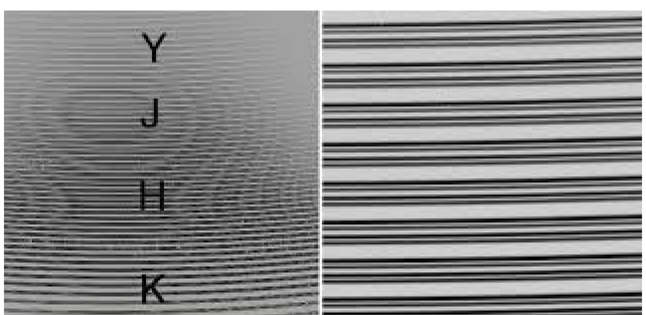
GIANO



(Cold) Slit Echelle spectrograph.

R = 50000.

0.9-2.45 micron in a single exposure



Detection of the water in the atmosphere of HD189733b

(Brogi et al., A&A 2018)

GIANO + HARPS-N

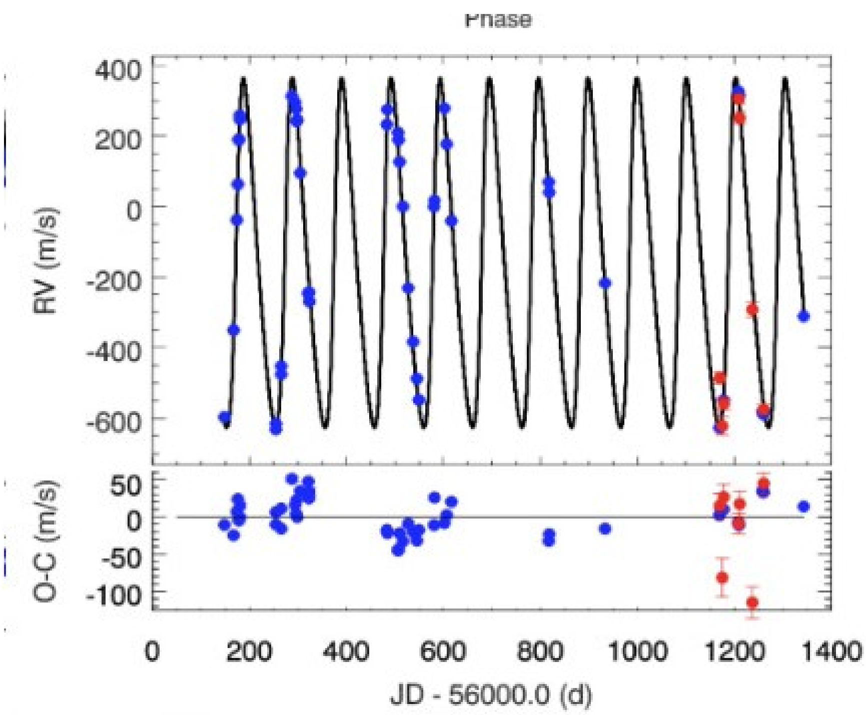
A&A 606, A51 (2017)
DOI: 10.1051/0004-6361/201731124

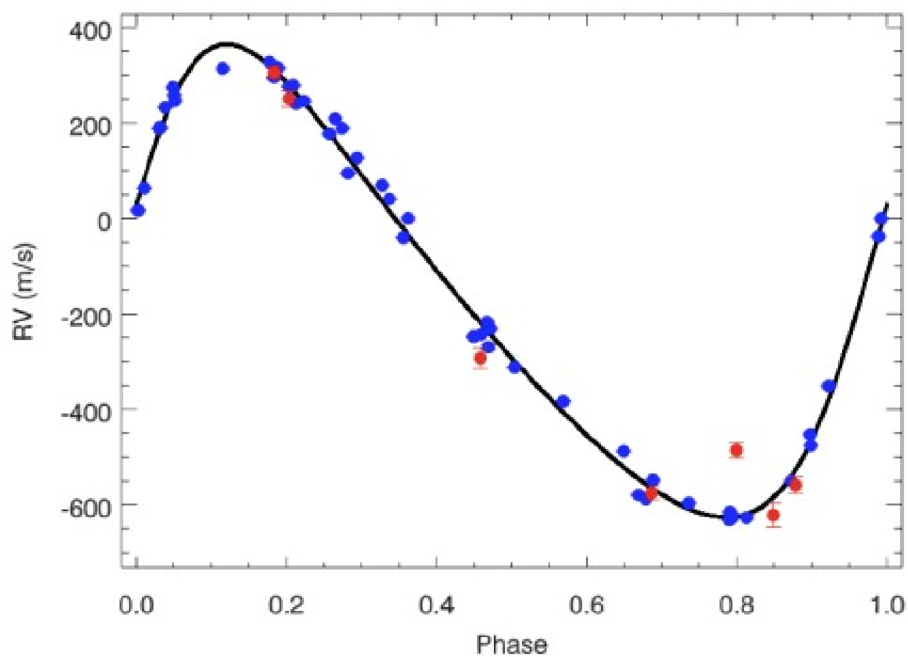
Astronomy & Astrophysics

The GAPS Programme with HARPS-N at TNG

XV. A substellar companion around a K giant star identified with quasi-simultaneous HARPS-N and GIANO measurements*

E. González-Álvarez[1,2], L. Affer[1], G. Micela[1], J. Maldonado[1], I. Carleo[3,4], M. Damasso[4,5], V. D'Orazi[3], A. F. Lanza[6], K. Biazzo[6], E. Poretti[7], R. Gratton[3], A. Sozzetti[5], S. Desidera[3], N. Sanna[8], A. Harutyunyan[9], F. Massi[8], E. Oliva[8], R. Claudi[3], R. Cosentino[9], E. Covino[10], A. Maggio[1], S. Masiero[1], E. Molinari[9,11], I. Pagano[6], G. Piotto[3,4], R. Smareglia[12], S. Benatti[3], A. S. Bonomo[5], F. Borsa[7], M. Esposito[10], P. Giacobbe[5], L. Malavolta[3,4], A. Martinez-Fiorenzano[9], V. Nascimbeni[3,4], M. Pedani[9], M. Rainer[7], and G. Scandariato[6]



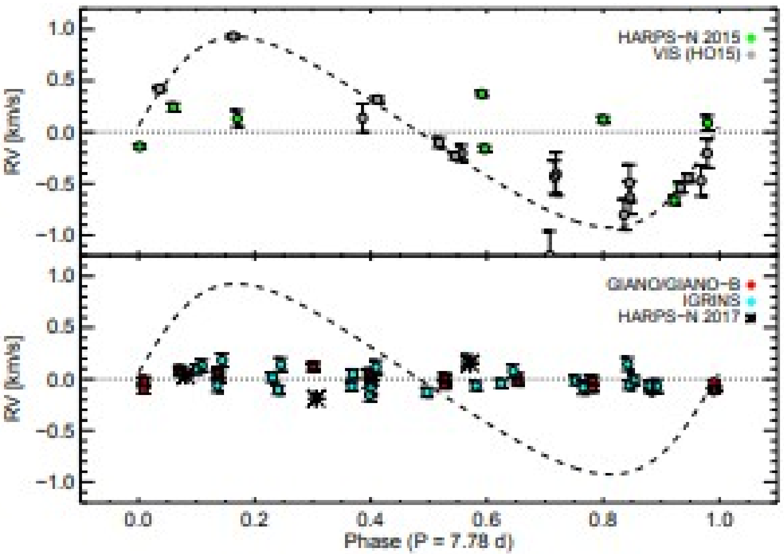


A&A 613, A50 (2018)

Multi-band high resolution spectroscopy rules out the hot Jupiter BD+20 1790b

First data from the GIARPS Commissioning

I. Carleo[1,2], S. Benatti[2], A. F. Lanza[3], R. Gratton[2], R. Claudi[2], S. Desidera[2], G. N. Mace[4], S. Messina[3], N. Sanna[5], E. Sissa[2], A. Ghedina[6], F. Ghinassi[6], J. Guerra[6], A. Harutyunyan[6], G. Micela[7], E. Molinari[6,16], E. Oliva[5], A. Tozzi[5], C. Baffa[5], A. Baruffolo[2], A. Bignamini[8], N. Buchschacher[9], M. Cecconi[6], R. Cosentino[6], M. Endl[4], G. Falcini[5], D. Fantinel[2], L. Fini[5], D. Fugazza[10], A. Galli[6], E. Giani[5], C. González[6], E. González-Álvarez[7,11], M. González[6], N. Hernandez[6], M. Hernandez Diaz[6], M. Iuzzolino[5,12], K. F. Kaplan[4], B. T. Kidder[4], M. Lodi[6], L. Malavolta[1], J. Maldonado[7], L. Origlia[13], H. Perez Ventura[6], A. Puglisi[5], M. Rainer[10], L. Riverol[6], C. Riverol[6], J. San Juan[6], S. Scuderi[3], U. Seemann[14], K. R. Sokal[4], A. Sozzetti[15] and M. Sozzi[5]



Previous data interpreted as a signal induced by stellar activity (P_{rot}=2. 80 d) found by photometry

New GIARPS data do not support the previous Keplerian solution (P=7.78 d)

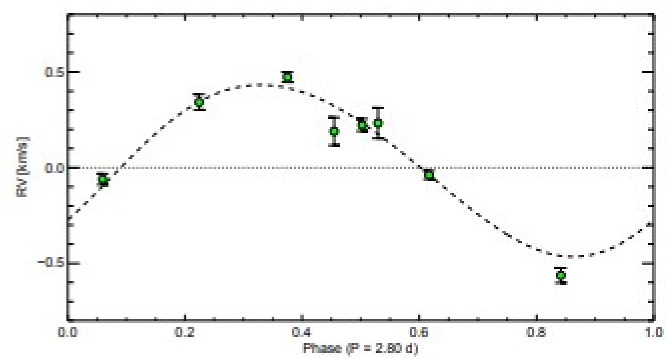


Fig. 3. Phase-folded HARPS – N RVs (2015, reprocessed from HO15 dataset) at stellar rotational period.

GIARPS MODE TO REMOVE SIGNAL AMBIGUITIES

(stellar activity vs keplerian motion)

SPA – Stellar Population Astrophysics

The detailed age-resolved chemistry of the MW disk

SPA was granted 80 nights of observing time over 3 years (Program ID A37TAC13)

SPA uses HARPS-N and GIANO-B spectrographs of the TNG to obtain high resolution and high quality spectra of about 500 luminous stars in the Milky Way disk and associated clusters to constrain its formation and chemical enrichment history.

TEAM

PRINCIPAL INVESTIGATOR : LIVIA ORIGLIA (INAF-OAS BOLOGNA)

G. Bono (Universita' di Roma Tor Vergata): WP1 coordinator - **Variable stars**

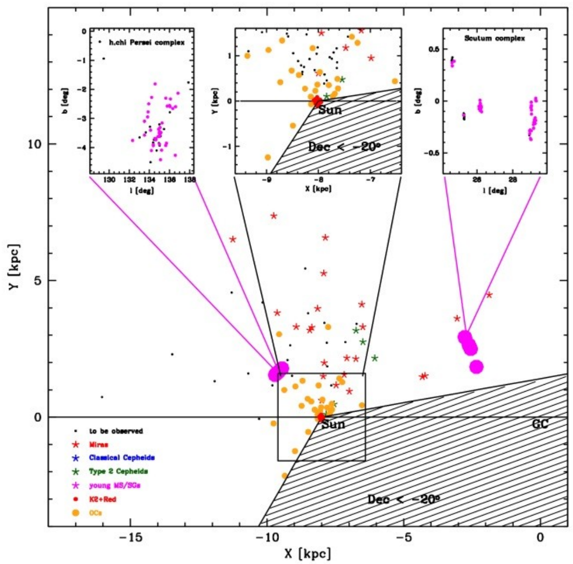
E. Dalessandro (INAF - OAS Bologna): WP2 coordinator - **Young massive clusters**

A. Bragaglia (INAF - OAS Bologna): WP3 coordinator - **Open clusters**

Co-Is: G. Andreuzzi (INAF - OA Roma/TNG), **G. Casali** (INAF - OA Arcetri), **E. Carretta** (INAF - OAS Bologna), **S. Cassisi** (INAF - OA Teramo), **G. Catanzaro** (INAF - OA Catania), **G. Cescutti** (INAF - OA Trieste), **R. da Silva** (Uni Tor Vergata), **V. D' Orazi** (INAF - OA Padova), **C. Fanelli** (Uni-BO), **G. Fiorentino** (INAF - OA Roma), **A. Frasca** (INAF - OA Catania), **L. Inno** (INAF - OA Arcetri), **A. Lanzafame** (Uni CT), **S. Lucatello** (INAF - OA Padova), **L. Magrini** (INAF - OA Arcetri), **M. Marconi** (INAF - OA Capodimonte), **M. Monelli** (IAC - Spain), **A. Mucciarelli** (UniBO), **E. Oliva**(INAF - OA Arcetri), **M. Rainer** (INAF_ OA Arcetri), **D. Romano** (INAF - OAS Bologna), **N. Sanna** (INAF - OA Arcetri), **O. Straniero** (INAF - OA Teramo), **M. Tosi** (INAF - OAS Bologna), **A. Vallenari** (INAF - OA Padova)

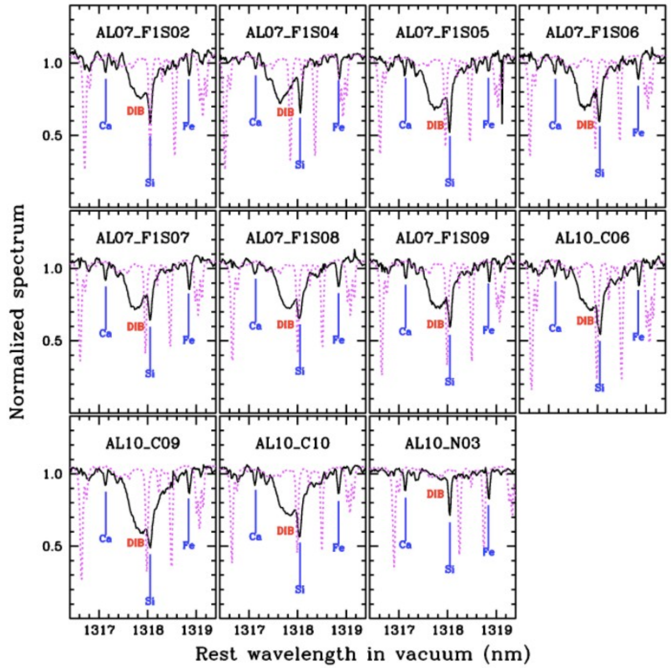
SPA – Stellar Population Astrophysics: first results

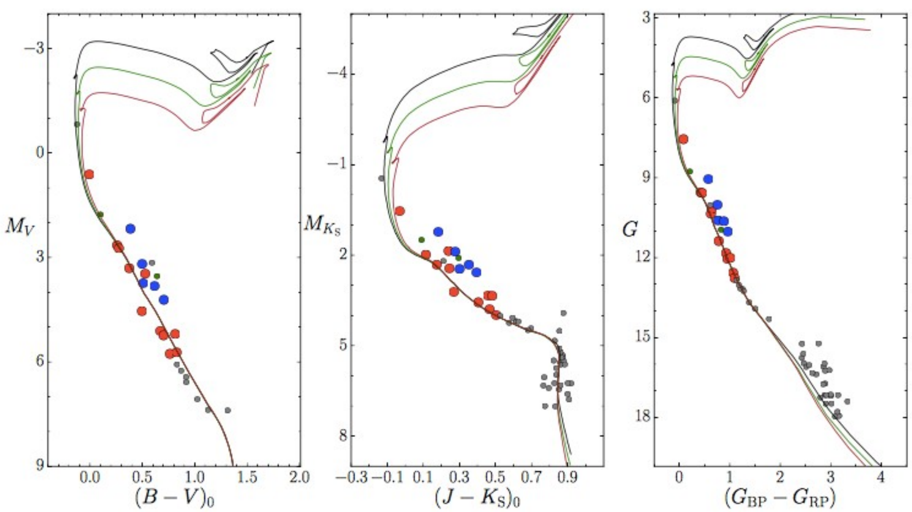
The detailed age-resolved chemistry of the MW disk



chemical abundances of RSGs in the Perseus complex

Origlia et al. (2019)





Open clusters and disk metallicity gradient

Frasca et al. (2019)

2. Status of observations

A total of 80 nights or equivalently 720 hours of observing time over six semesters has been requested to fulfil the science goals of the *SPA Large Programme*.
The TAC (A37_TAC13) granted 117+117=234 hrs in Periods 37 and 38, 117+117=234 hrs in Periods 39 and 40 (only 99 out of the 117 hrs actually scheduled in Period 40 due to telescope maintenance in October 2019) and 81+81=162hr in Periods 41 and 42 of observing time.
A grand-total of 612 hrs of observing time have been nominally scheduled during the six semesters from Period 37 to 42, implying a cut of 108 hrs (i.e. 15%) with respect to our request.

Such a 15% cut applied by the TAC had an impact on the SPA science. Indeed, we have been forced to modify our strategy and significantly cut the observations of especially interesting but faint targets (about 80 stars), like old and/or reddened variables and MS stars in some older and/or more distant open clusters. These targets were also critical to properly sample specific regions of the age/Galactocentric distance parameter space. We could only partially mitigate that problem with observations of more luminous field stars with known distances from Gaia.

In 2018 and 2019 observations have been mostly executed in visitor mode. In 2019 we appreciated the possibility to have a second observer paid by the TNG in two relatively long runs.
We are especially grateful to the TNG personnel for executing service observations during the entire 2020, due to Covid-19 restrictions.

According to the official table with the status of SPA observations made available to us by the TNG Director, 596 hrs of open telescope was recorded out to the 612 hrs nominally scheduled.

During the 596 hrs of observations in the six semesters from Period 37 to Period 42, we secured spectra for 520 stars in the disk field and associated star clusters, spreading a wide range of Galactocentric distances and divided in three main age groups, as shown in Figure 1 and detailed below .

GHOsT

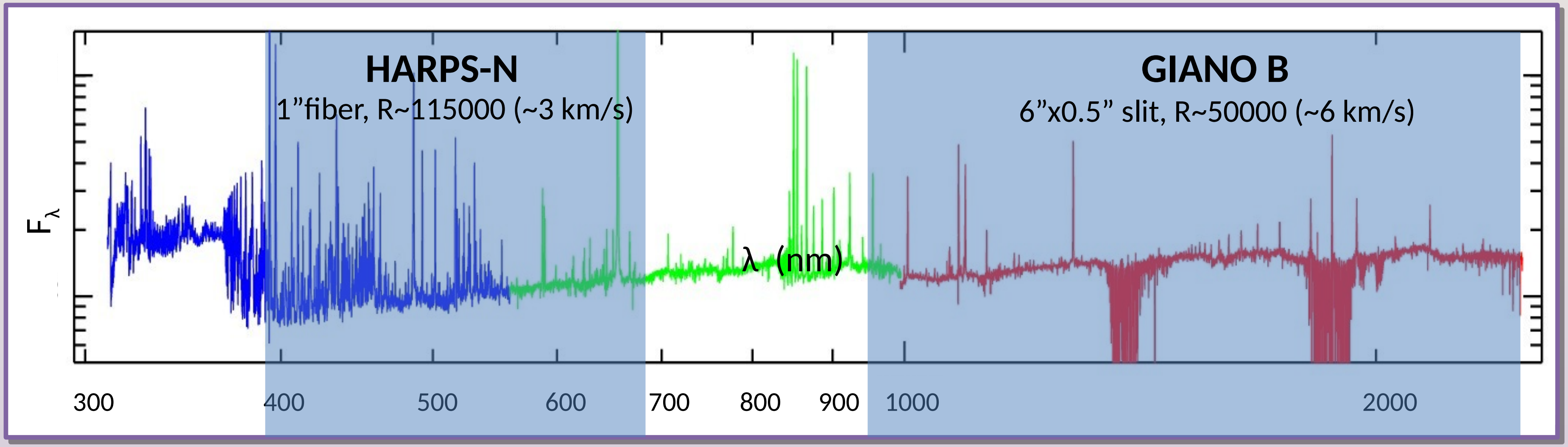
GIARPS High-resolution Observations of T Tauri Stars

PI: *S. Antoniucci (**OAR**)*

Co-Is: *B. Nisini, T. Giannini, F. Vitali, A. Di Paola, A. Giunta (**OAR**), K. Biazzo, A. Frasca (**OACt**), J. M. Alcalà (**OACn**), D. Fedele, L. Podio, F. Bacciotti, N. Sanna (**OAA**), E. Rigliaco (**OAPd**), U. Munari (**OAPd-Asiago**), C. F. Manara (**ESO**), A. Harutyunyan (**TNG-FGG**), G. Herczeg (**KIAA**)*

GHOsT Project

GIARPS is the only instrument now available with simultaneous (avoid systematics!) optical-NIR coverage at high spectral resolution



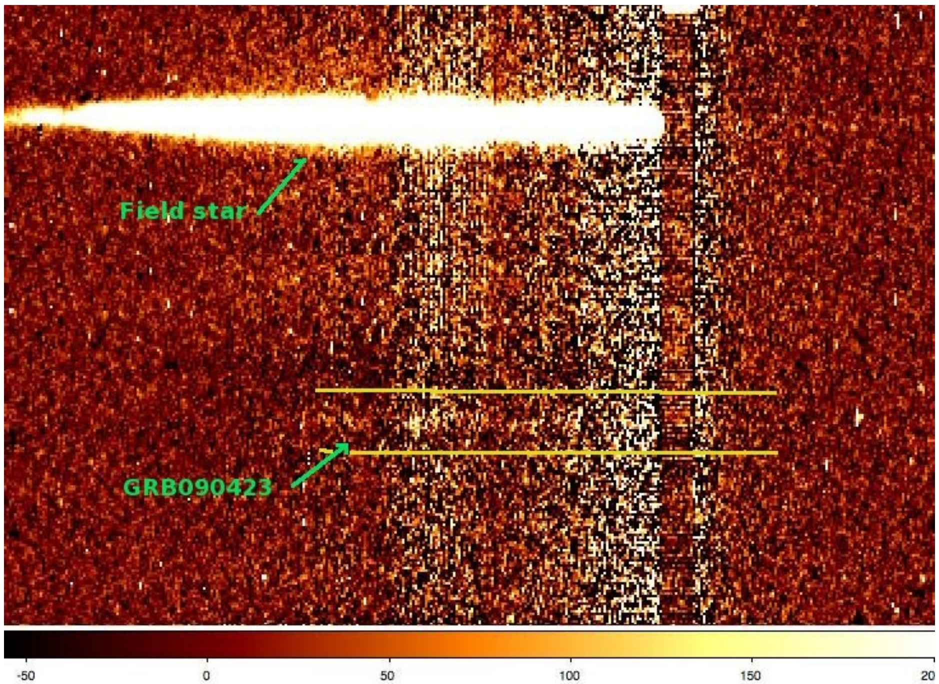
Aims: → derive stellar and accretion/ejection parameters simultaneously and homogeneously
→ characterize the components of the system on a statistically significant sample of T Tauri stars

Sample: → ~ 80 objects in the Taurus-Auriga star-forming region

Method: → analysis of line fluxes, profiles, and absorption features at optical and NIR wavelengths

DOLORES and NICS

The TNG caught the farthest GRB (090423) ever observed : z=8.2 *(Salvaterra et al. 2009)*



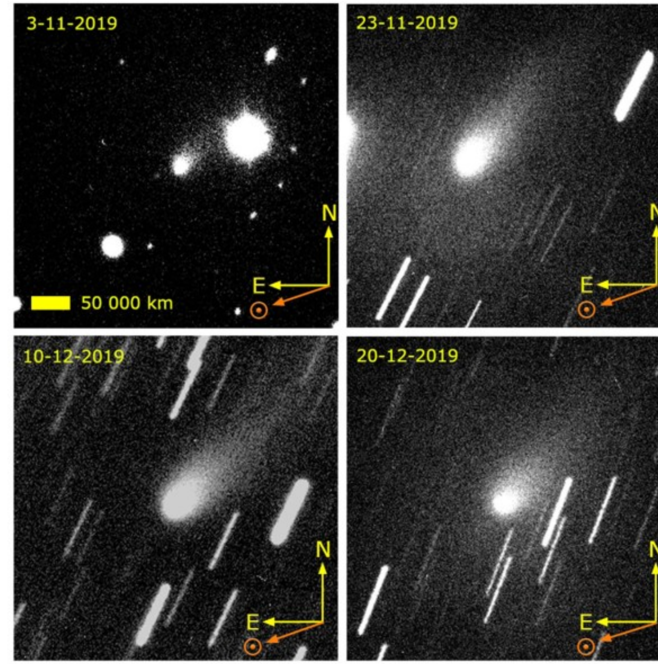
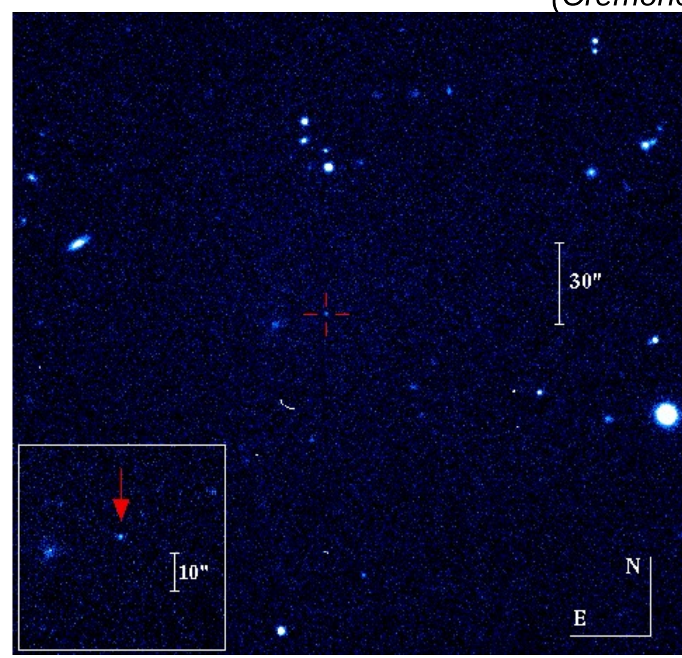


Figure 1. The four images of the comet 2I/Borisov obtained at the TNG telescope on 2019 November 3 and 23 and on 2019 December

(Cremonese et al. 2020)



The farthest (z=2.6) short GRB (090426) ever observed *(Antonelli et al. 2009)*

SCIENCE AND OUTREACH

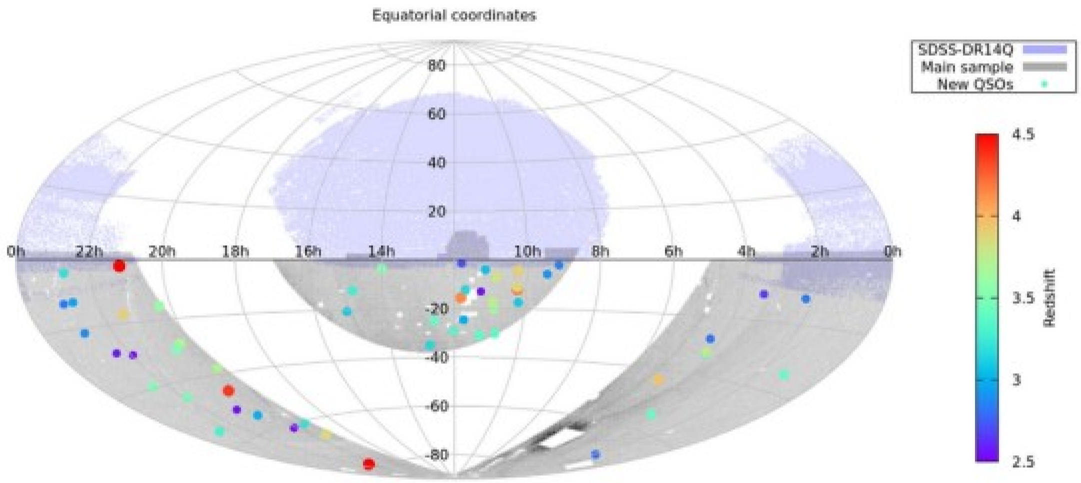
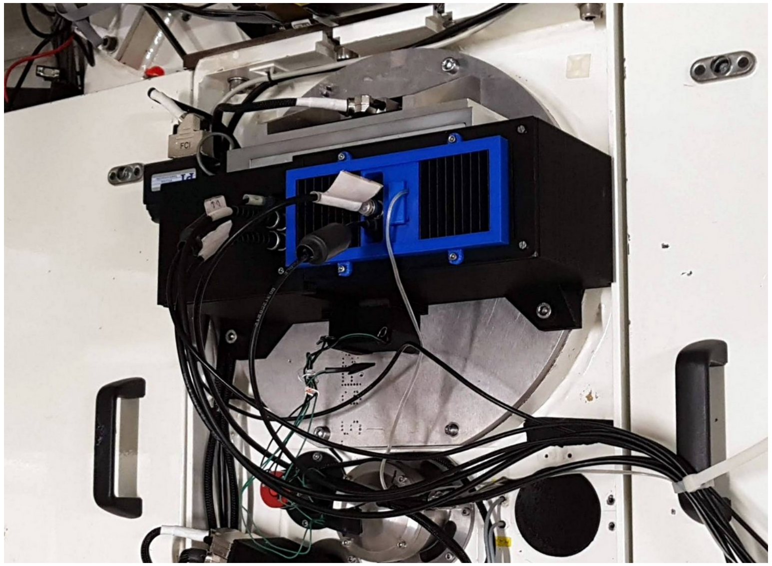


Figure 6: HIGHLIGHT #3. Figure shows the location of the formerly known QSOs in the North (in blue), the location of the sources screened by the selection algorithm (gray) and the 54 newly identified QSOs (colored circles). The success rate in identifying new QSOs has been $\sim$ 80%. **A preliminary test of the reliability of the predictions of the QUBRICS algorithm took place at TNG where 3 new QSOs were discovered (over a total of 4 QSO candidates) using Dolores. The observations have been carried out by Vittoria Altomonte and Andrea Cama, winners of the 2019 Italian edition of** ***Olimpiadi di Astronomia*****.** The young winners spent some hours as astronomers at TNG where they carried out the observations under the supervision of G. Calderone (INAF-OA Trieste), G. Andreuzzi (TNG) and M. Pedani (TNG).

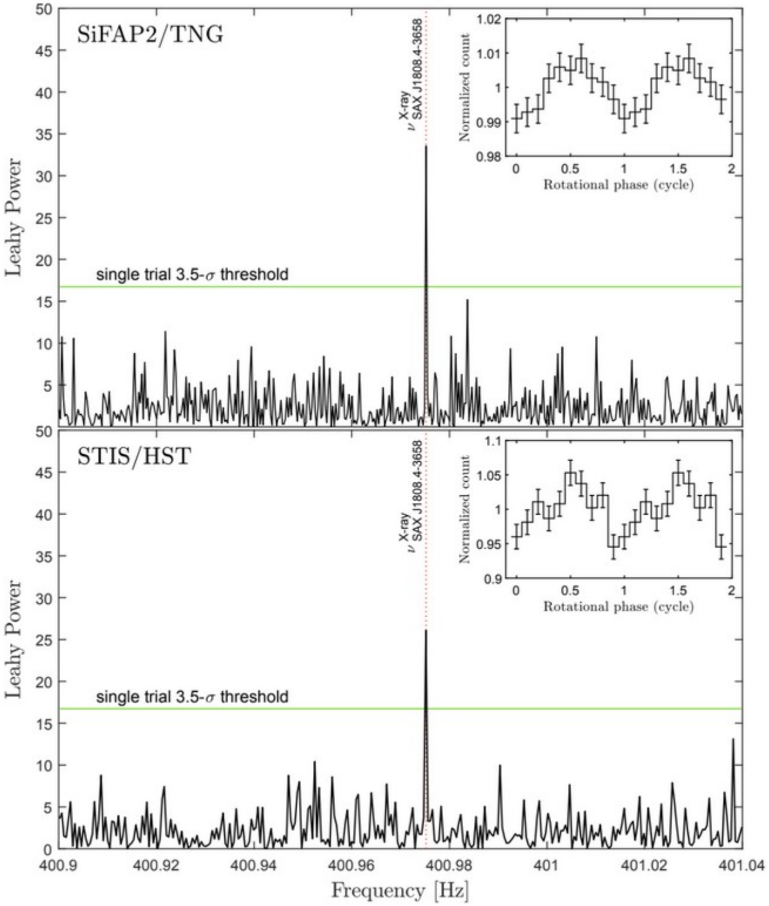
Silicon Fast optical Astronomical Photometer (SiFAP2) visitor instrument

Fast photometry based on
Multi Pixel Photon Counters (MPPC)

Pulses of visible light from a millisecond pulsar
(Ambrosino et al. 2017, Nature Astronomy)



First light of SiFAP2 on November 14, 2018



Ambrosino et al. 2020, Nature Astronomy

CRITICALITIES AND FUTURE ACTIVITIES

Current manpower tailored on managing TNG only. Few development perspectives

Confirmation of a stable budget from INAF (2.7 Meuro).

OPTICON participation is a key activity (need for a well-performing Infrastructure).

Other projects to develop INAF activities in Canary Islands need extra-money and new personnel.

HARPS-N: excellence in the exoplanet science in the Northern Hemisphere

Space missions on exoplanets (TESS, CHEOPS, ARIEL, PLATO,…) ensure a bright future.

GIANO-B: infrared spectrograph to characterize stars and exoplanets.

DOLORES and NICS are playing the game of the elusive chase to the optical counterpart of a gravitational wave event.

New instruments: SiFAP2, LOCNES, waiting for a third generation?