

# The Telescopio Nazionale Galileo and its instruments after 20 years of operations

*Ennio Poretti*

Special thanks to  
Adriano Ghedina  
Gloria Andreuzzi

La Palma (Canary Islands, Spain)

Area: 2 kmq

Altitude: 2.396 meter (from 0 to 2400 m in 45 min by car)

TNG coordinates:

Longitude:  $17^{\circ} 53' 20.6''$  W

Latitude:  $28^{\circ} 45' 14.4''$  N















# The plan

1988 CRA : ESO+LBT+4m Italian telescope

CESARE BARBIERI : progetto GALILEO

Improved version of NTT

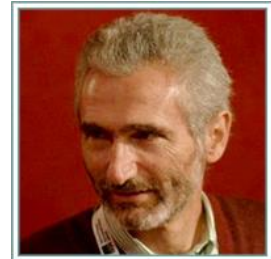
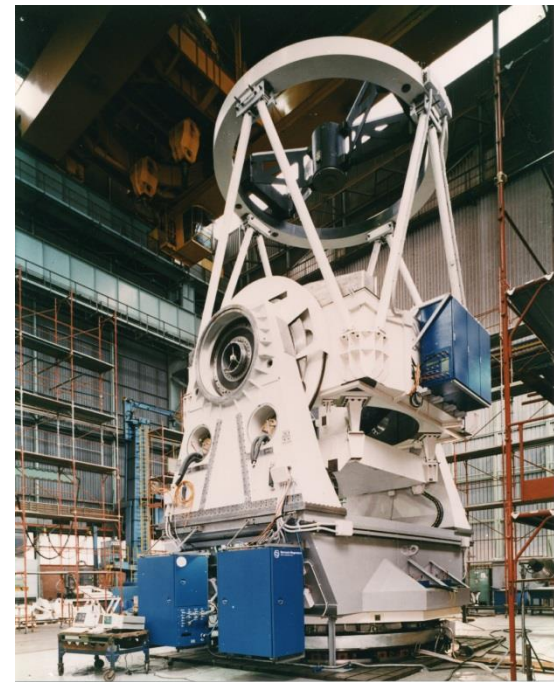


# The concept

- 1) 3.58 meniscus mirror with AO;
- 2) an exapod to support M2 and Tip/Tilt capabilities for M3;
- 3) Ritchey-Chretien optical configuration with two Nasmyth foci at F/11, with 80% of Encircled Energy within 0.3" in passive mode and 0.15" in active mode;
- 4) Possibility of a prime focus and of a trapped F/6 focus. To allow these options the configuration of the spiders was changed to 60deg separation for easier removal, the building raised and a new crane added;
- 5) new TCS and OCS, distributed VME, and HP;
- 6) location sites to be chosen between Mt.Graham, La Palma and Mauna Kea.



- 1991 – Site decision: La Palma
- 1992 – Optics ready (ZEISS): superb quality
- 1993 – Start of excavations at ORM
- 1994 – Telescope ready in Italy
- 1995 – Dome construction begins
- 1996 – June 29, Official inauguration
- 1996 – CNAA and CGG: Sperello di Serego









# Commissioning

- 1997 Favio Bortoletto: commissioning group
- Mount optics/define axes/AO
- TCS/Dome services/AC
- First light: June 9<sup>th</sup>, 1998
- Still to do: derotators/AG/GUI/archives/NI/instruments ...

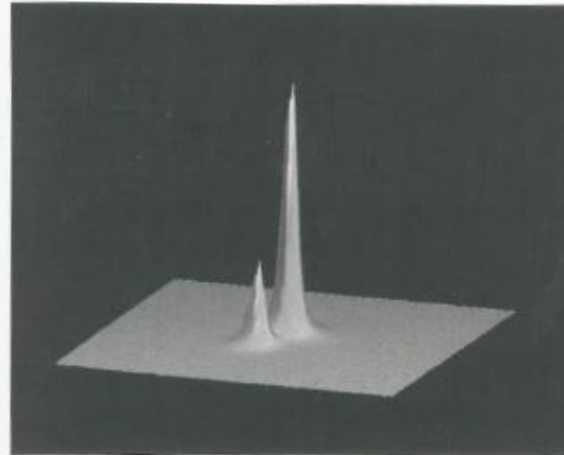
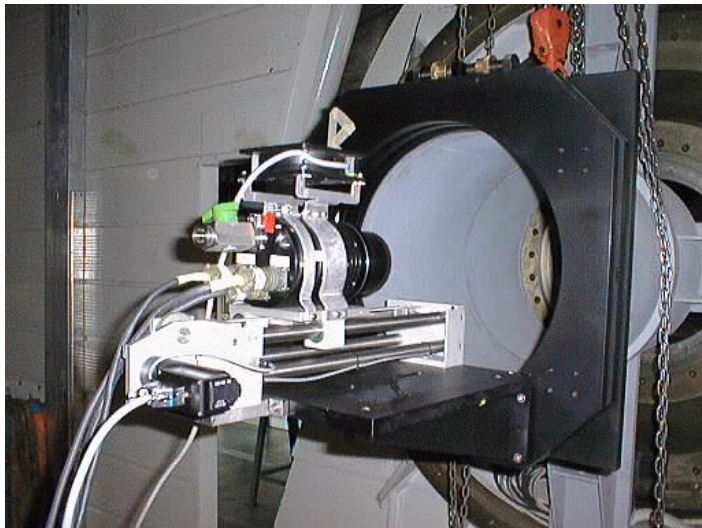


Fig. 7.2 - The first object observed: epsilon-lirae double-star system, separation: 2.6", profile FWHM: 0.8"



# Start of observations

During 1999 on best effort basis:  
Debugging and fine tuning of  
instrumentation and telescope

+Derotator B  
+LRS  
+SARG

preTAC – Fusi Pecci 1997  
1<sup>st</sup> TAC – Maccacaro 1999



AOT1 – Jan/Apr 2000

.....

AOT38 – Oct 2018/Mar19

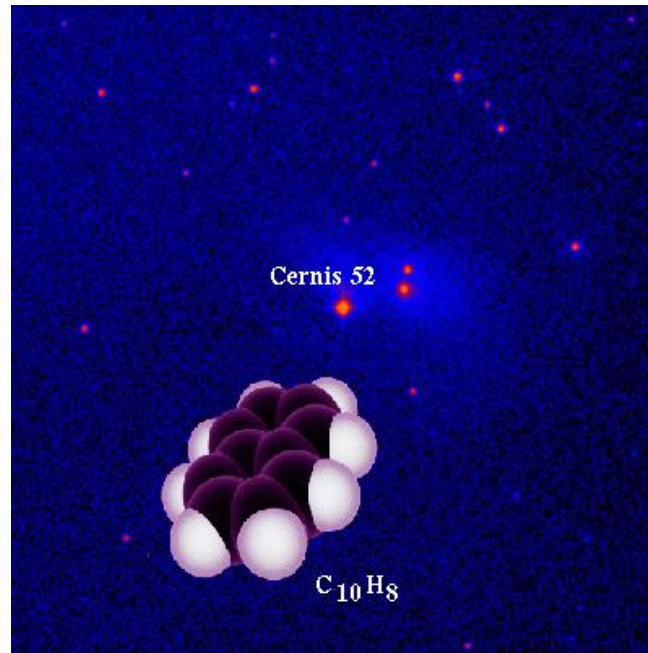


New Director E.Oliva in late 2000  
end of commissioning  
start of regular observations



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



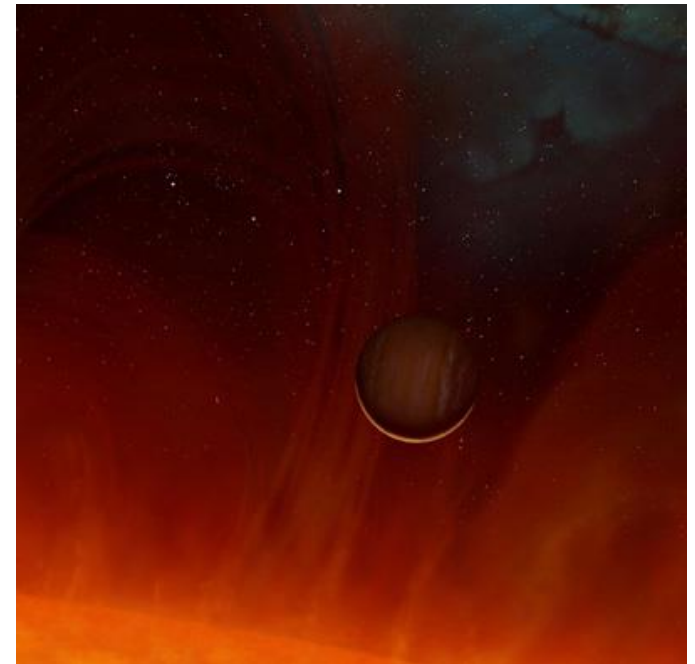


Napthalene in the interstellar space

*Iglesias Groth et al. 2008*

*A giant planet orbiting the 'extreme horizontal branch' star V 391 Pegasi*

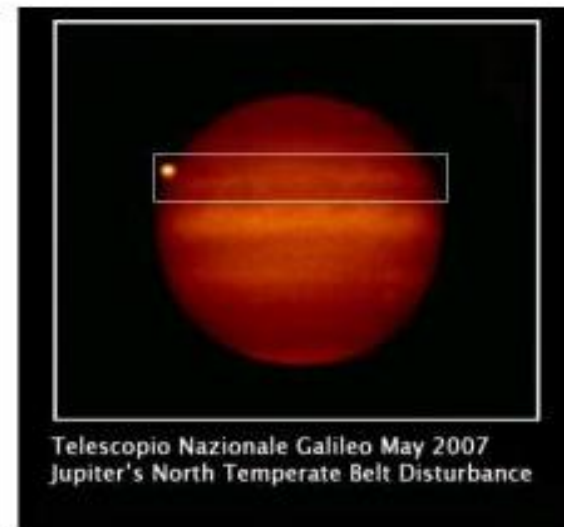
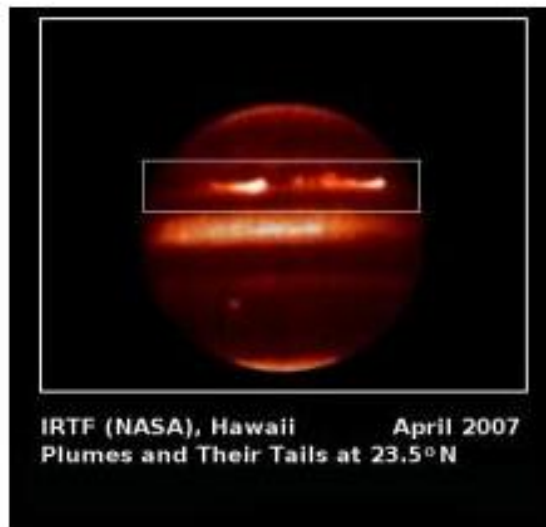
*Silvotti et al. 2007*





# Perturbations in the atmosphere of Jupiter. NICS image (right)

(A. Sanchez-Lavega, et al., 2008)



Dolores  
V and R  
images

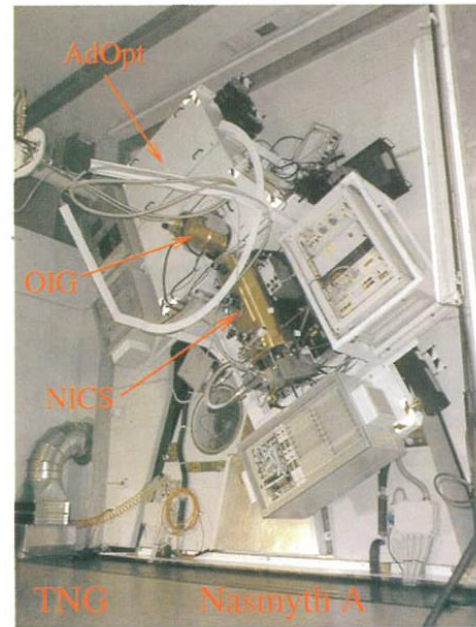
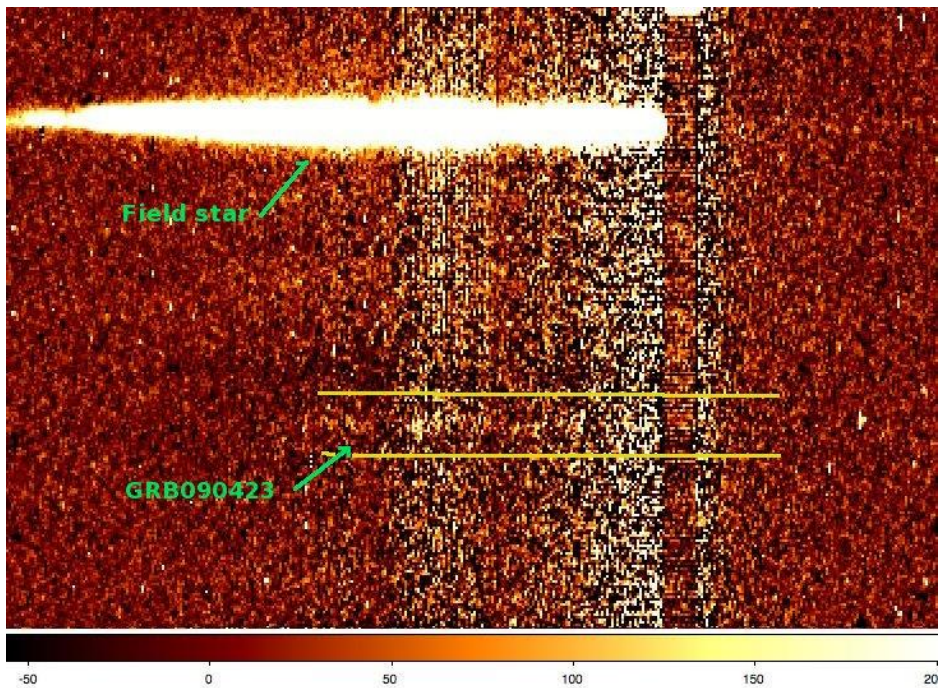
SN2008ha in UGC 16281  
no hydrogen lines!

Valenti et al. 2009

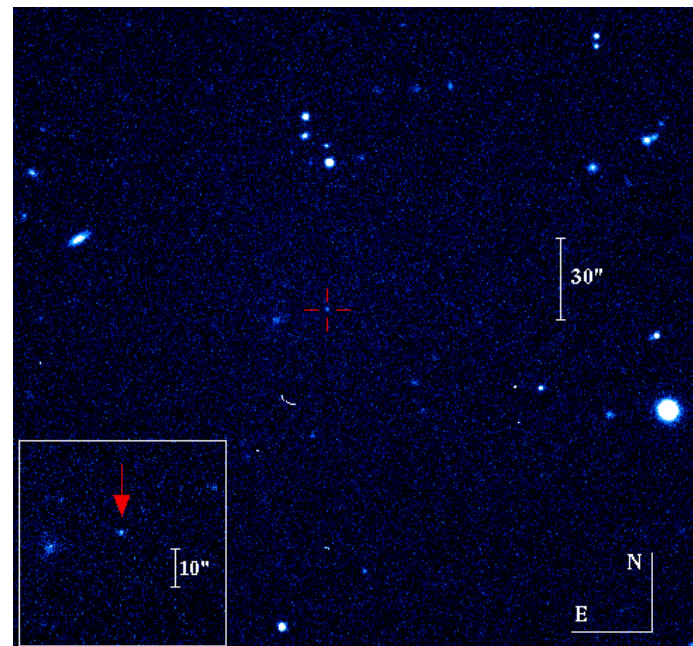




# The TNG caught the farthest GRB (090423) ever observed : $z=8.1$ (Salvaterra et al. 2009)

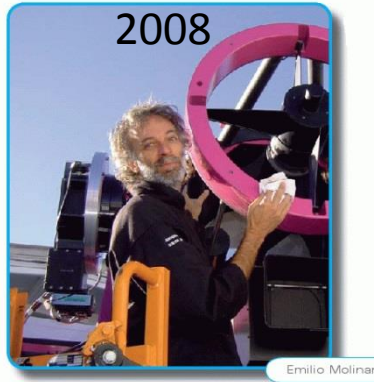


# The farthest ( $z=2.6$ ) **short** GRB (090426) ever observed (Antonelli et al. 2009)

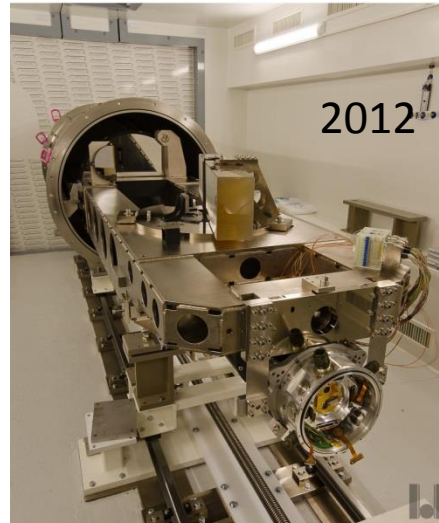




Emilio  
Molinari



TNG &  
HARPS-N





## Characterization of the planetary system Kepler-101 with HARPS-N<sup>★,★★</sup>

### A hot super-Neptune with an Earth-sized low-mass companion

A. S. Bonomo<sup>1</sup>, A. Sozzetti<sup>1</sup>, C. Lovis<sup>2</sup>, L. Malavolta<sup>3,4</sup>, K. Rice<sup>5</sup>, L. A. Buchhave<sup>6,7</sup>, D. Sasselov<sup>6</sup>, A. C. Cameron<sup>8</sup>,  
D. W. Latham<sup>6</sup>, E. Molinari<sup>9,10</sup>, F. Pepe<sup>2</sup>, S. Udry<sup>2</sup>, L. Affer<sup>11</sup>, D. Charbonneau<sup>6</sup>, R. Cosentino<sup>9</sup>, C. D. Dressing<sup>6</sup>,  
X. Dumusque<sup>6</sup>, P. Figueira<sup>12</sup>, A. F. M. Fiorenzano<sup>9</sup>, S. Gettel<sup>6</sup>, A. Harutyunyan<sup>9</sup>, R. D. Haywood<sup>8</sup>, K. Horne<sup>8</sup>,  
M. Lopez-Morales<sup>6</sup>, M. Mayor<sup>2</sup>, G. Micela<sup>11</sup>, F. Motalebi<sup>2</sup>, V. Nascimbeni<sup>4</sup>, D. F. Phillips<sup>6</sup>, G. Piotto<sup>3,4</sup>, D. Pollacco<sup>13</sup>,  
D. Queloz<sup>2,14</sup>, D. Ségransan<sup>2</sup>, A. Szentgyorgyi<sup>6</sup>, and C. Watson<sup>15</sup>

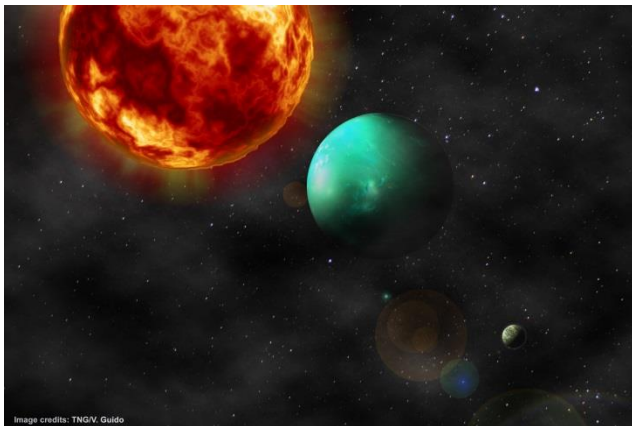
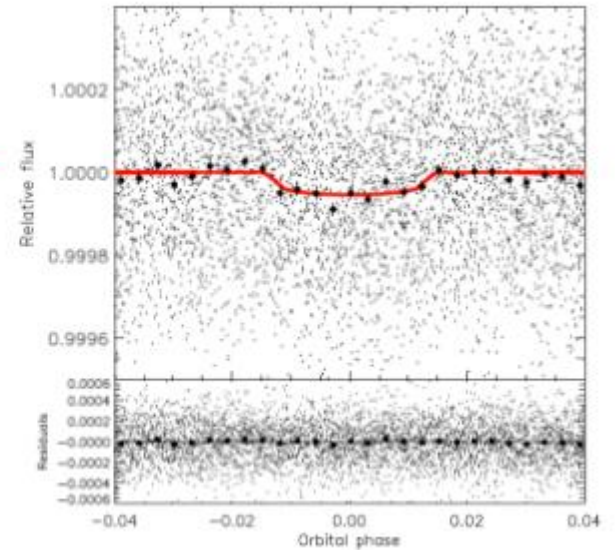
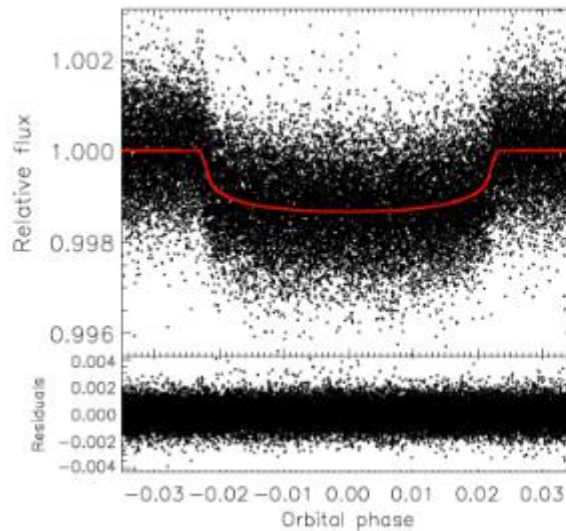
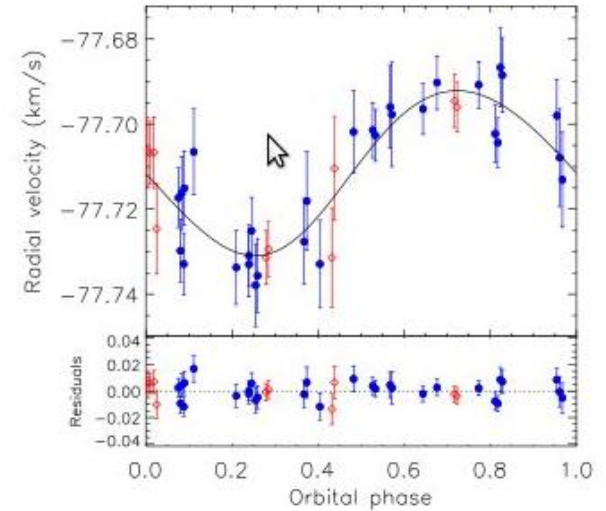


Image credits: TNG/V. Guido

LETTER TO THE EDITOR

## The GAPS programme with HARPS-N at TNG

### IV. A planetary system around XO-2S<sup>\*,\*\*</sup>

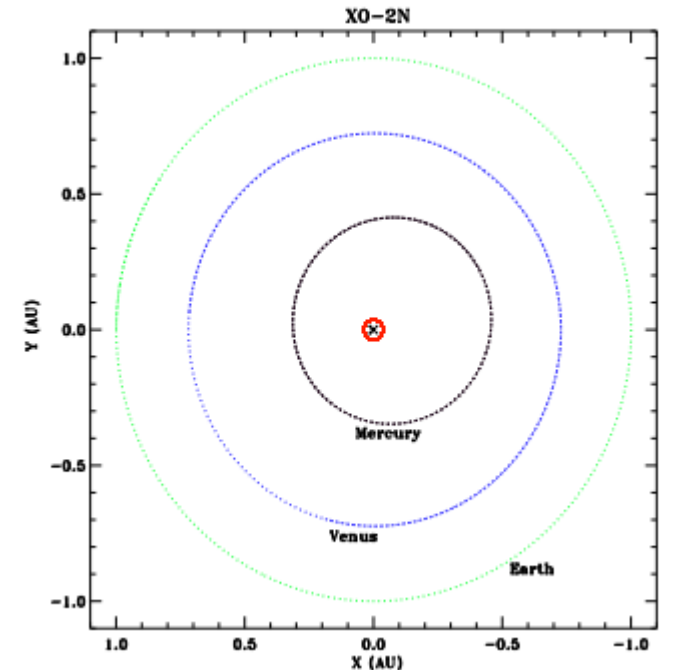
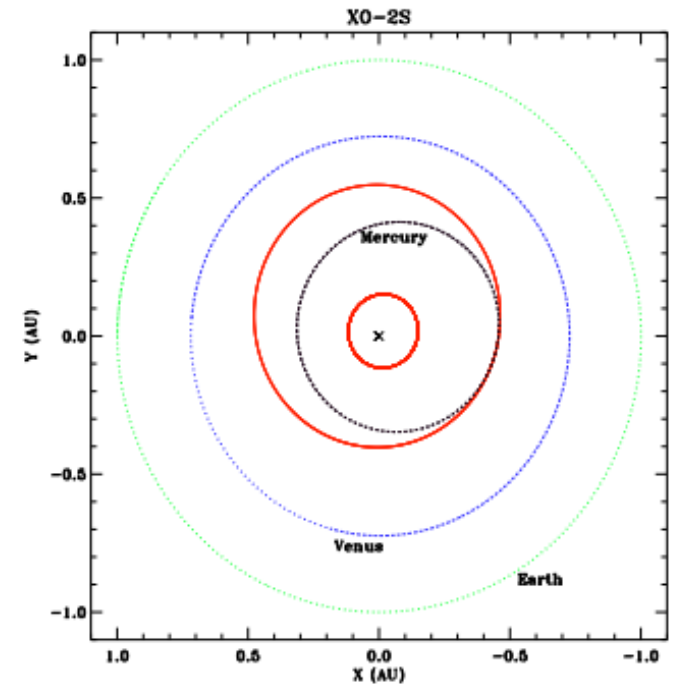
S. Desidera<sup>1</sup>, A. S. Bonomo<sup>2</sup>, R. U. Claudi<sup>1</sup>, M. Damasso<sup>2,3</sup>, K. Biazzo<sup>4</sup>, A. Sozzetti<sup>2</sup>, F. Marzari<sup>5,1</sup>, S. Benatti<sup>1</sup>, D. Gandolfi<sup>4,6</sup>, R. Gratton<sup>1</sup>, A. F. Lanza<sup>4</sup>, V. Nascimbeni<sup>7,1</sup>, G. Andreuzzi<sup>8</sup>, L. Affer<sup>9</sup>, M. Barbieri<sup>7</sup>, L. R. Bedin<sup>1</sup>,

## The GAPS Programme with HARPS-N@TNG

### V. A comprehensive analysis of the XO-2 stellar and planetary systems <sup>\*</sup>

M. Damasso<sup>1,2</sup>, K. Biazzo<sup>3</sup>, A.S. Bonomo<sup>1</sup>, S. Desidera<sup>4</sup>, A.F. Lanza<sup>3</sup>, V. Nascimbeni<sup>4,5</sup>, M. Esposito<sup>6,7</sup>, G. Scandariato<sup>3</sup>, A. Sozzetti<sup>1</sup>, R. Cosentino<sup>3,8</sup>, R. Gratton<sup>4</sup>, L. Malavolta<sup>5,9</sup>, M. Rainer<sup>10</sup>, D. Gandolfi<sup>3,11</sup>, E. Poretti<sup>10</sup>, R. Zanmar Sanchez<sup>3</sup>, I. Ribas<sup>12</sup>, N. Santos<sup>13,14,15</sup>, L. Affer<sup>16</sup>, G. Andreuzzi<sup>8</sup>, M. Barbieri<sup>4</sup>, L. R. Bedin<sup>4</sup>, S. Benatti<sup>4</sup>, A. Bernagozzi<sup>2</sup>, E. Bertolini<sup>2</sup>, M. Bonavita<sup>4</sup>, F. Borsa<sup>10</sup>, L. Borsato<sup>5</sup>, W. Boschin<sup>8</sup>, P. Calcidese<sup>2</sup>, A. Carbognani<sup>2</sup>, D. Cenadelli<sup>2</sup>, J.M. Christille<sup>2,17</sup>, R.U. Claudi<sup>4</sup>, E. Covino<sup>18</sup>, A. Cunial<sup>5</sup>, P. Giacobbe<sup>1</sup>, V. Granata<sup>5</sup>, A. Harutyunyan<sup>8</sup>, M. G. Lattanzi<sup>1</sup>, G. Leto<sup>3</sup>, M. Libralato<sup>4,5</sup>, G. Lodato<sup>19</sup>, V. Lorenzi<sup>8</sup>, L. Mancini<sup>20</sup>, A.F. Martinez Fiorenzano<sup>8</sup>, F. Marzari<sup>4,5</sup>, S. Masiero<sup>4,5</sup>, G. Micela<sup>16</sup>, E. Molinari<sup>8,21</sup>, M. Molinaro<sup>22</sup>, U. Munari<sup>4</sup>, S. Murabito<sup>6,7</sup>, I. Pagano<sup>3</sup>, M. Pedani<sup>8</sup>, G. Piotto<sup>4,5</sup>, A. Rosenberg<sup>6,7</sup>, R. Silvotti<sup>1</sup>, J. Southworth<sup>23</sup>

Parameter	XO-2N	XO-2S
$T_{eff}$ [K]	5332±57	5395±54
$\log g$ [cgs]	4.44±0.08	4.43±0.08
[Fe/H] [dex]	0.43±0.05	0.39±0.05
Microturb. $\xi$ [km s <sup>-1</sup> ]	0.88±0.11	0.90±0.10
$V \sin I_*$ [km s <sup>-1</sup> ]	1.07±0.09	1.5±0.3
Mass [ $M_{\odot}$ ]	0.97±0.05	0.98±0.05
Radius [ $R_{\odot}$ ]	1.01 <sup>+0.1</sup> <sub>-0.07</sub>	1.02 <sup>+0.09</sup> <sub>-0.06</sub>
Age [Gyr]	0.998 <sup>+0.033</sup> <sub>-0.032</sub>	-
	7.9 <sup>+2.3</sup> <sub>-3.0</sub>	7.1 <sup>+2.5</sup> <sub>-2.9</sub>
	7.8 <sup>+1.2</sup> <sub>-1.3</sub>	-
Luminosity [ $L_{\odot}$ ]	0.70±0.04	0.79±0.14

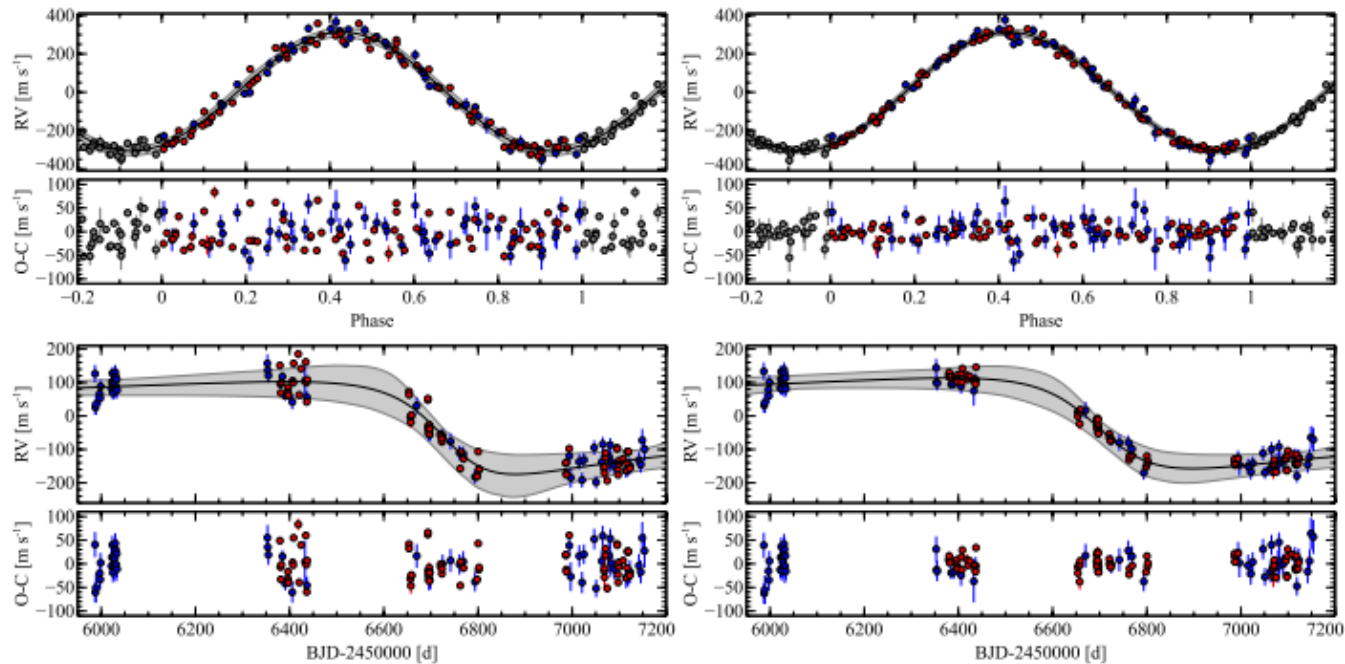




## The GAPS programme with HARPS-N at TNG

### XI. Pr 0211 in M 44: the first multi-planet system in an open cluster<sup>★,★★</sup>

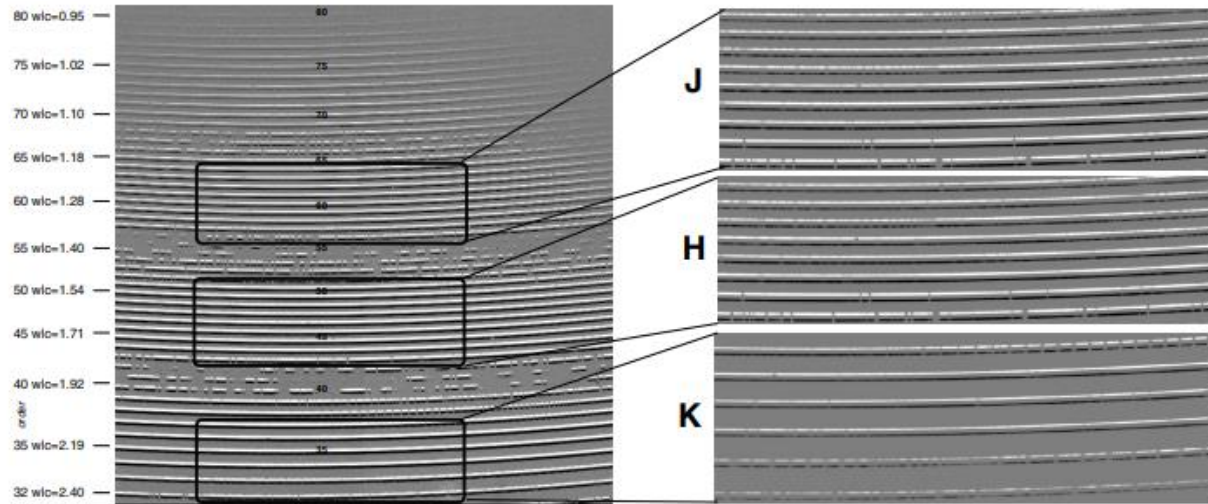
L. Malavolta<sup>1,2</sup>, V. Nascimbeni<sup>2</sup>, G. Piotto<sup>1,2</sup>, S. N. Quinn<sup>3</sup>, L. Borsato<sup>1,2</sup>, V. Granata<sup>1,2</sup>, A. S. Bonomo<sup>6</sup>, F. Marzari<sup>1</sup>,  
L. R. Bedin<sup>1,2</sup>, M. Rainer<sup>5</sup>, S. Desidera<sup>2</sup>, A. F. Lanza<sup>4</sup>, E. Poretti<sup>5</sup>, A. Sozzetti<sup>6</sup>, R. J. White<sup>3</sup>, D. W. Latham<sup>7</sup>,  
A. Cunial<sup>1,2</sup>, M. Libralato<sup>1,2</sup>, D. Nardiello<sup>1,2</sup>, C. Boccato<sup>2</sup>, R. U. Claudi<sup>2</sup>, R. Cosentino<sup>7,8</sup>, E. Covino<sup>9</sup>, R. Gratton<sup>2</sup>,  
A. Maggio<sup>10</sup>, G. Micela<sup>10</sup>, E. Molinari<sup>9,11</sup>, I. Pagano<sup>4</sup>, R. Smareglia<sup>12</sup>, L. Affer<sup>10</sup>, G. Andreuzzi<sup>8,13</sup>, A. Aparicio<sup>14,15</sup>,  
S. Benatti<sup>2</sup>, A. Bignamini<sup>12</sup>, F. Borsa<sup>5</sup>, M. Damasso<sup>6</sup>, L. Di Fabrizio<sup>8</sup>, A. Harutyunyan<sup>8</sup>, M. Esposito<sup>9</sup>,  
A. F. M. Fiorenzano<sup>8</sup>, D. Gandolfi<sup>16,17</sup>, P. Giacobbe<sup>6</sup>, J. I. González Hernández<sup>14,15</sup>, J. Maldonado<sup>10</sup>, S. Masiero<sup>2</sup>,  
M. Molinaro<sup>12</sup>, M. Pedani<sup>8</sup>, and G. Scandariato<sup>4</sup>



**Fig. 7.** Orbital solution and RV residuals before (left panels) and after (right panels) the inclusion of activity in the global fit. The two upper panels show the RV fit and its residuals for the inner planet, phased on its period, after removing the solution of the second planet. The two lower panels show the RV fit as a function of time for the outer planet, after removing the solution of the inner one. Red and blue dots represent HARPS-N and TRES data, respectively. The gray shaded areas represent the  $3\sigma$  confidence regions

# GIANO spectroscopy of red supergiants in the young open cluster RSGC2

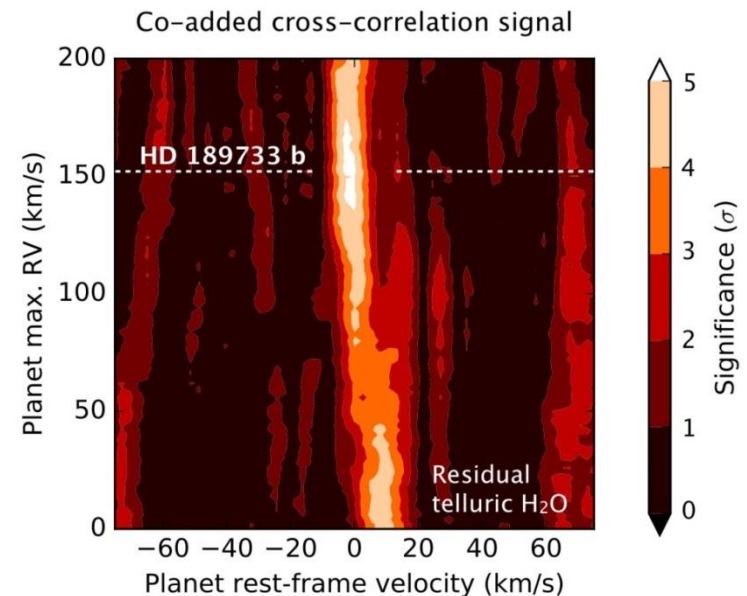
*Origlia et al. 2013*



**Fig. 1.** GIANO 2D (sky-subtracted) spectra of one of the observed RSG stars. Sky subtraction has been performed by nodding on fiber, resulting in one positive and one negative spectrum.



**Detection of the water in the atmosphere of HD189733b**  
*(Brogi et al., A&A 2018)*

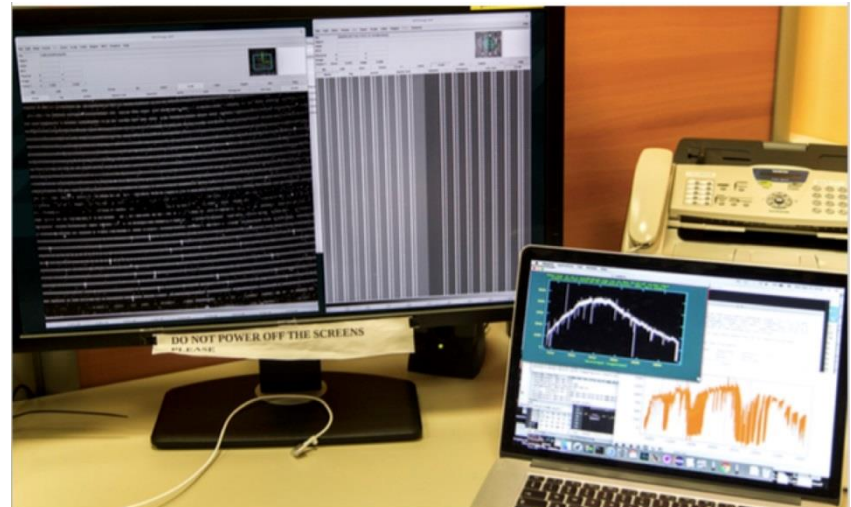
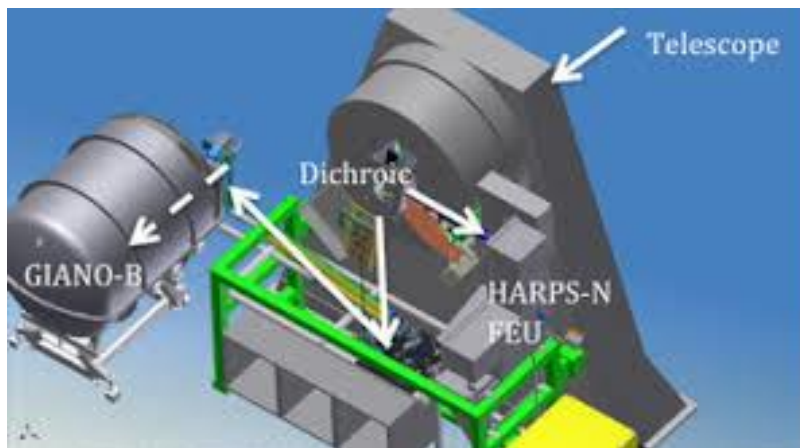




# Four instruments fully operational

- **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, imaging polarimetry, spectropolarimetry

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



## 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\*

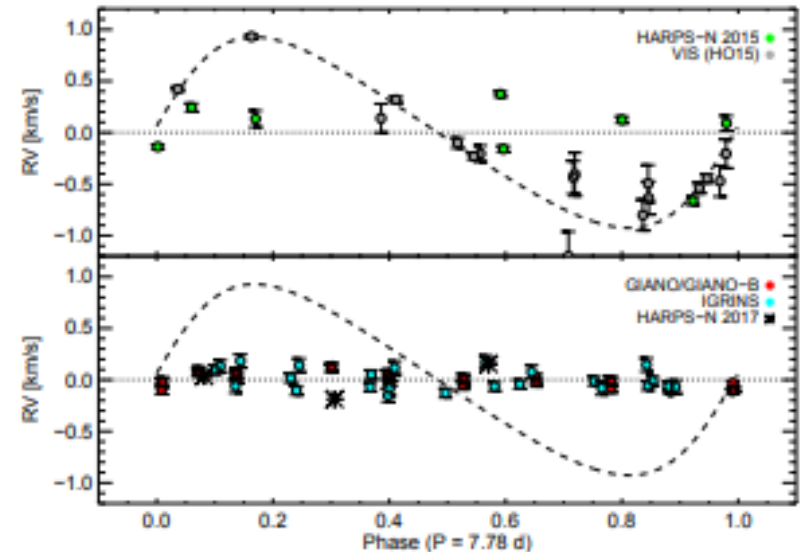
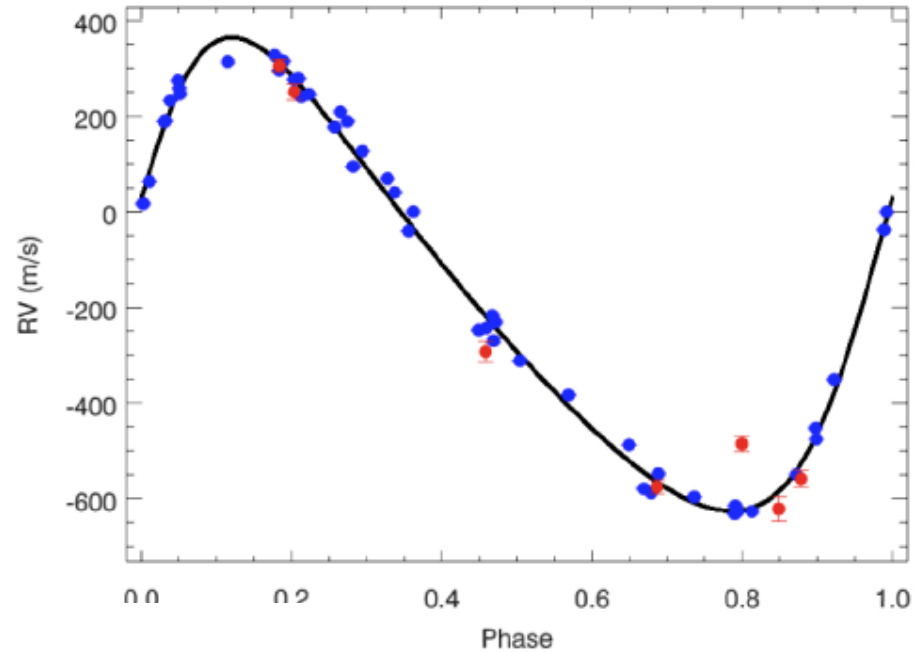
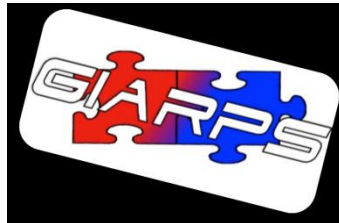
E. González-Álvarez<sup>1,2</sup>, L. Affer<sup>1</sup>, G. Micela<sup>1</sup>, J. Maldonado<sup>1</sup>, I. Carleo<sup>3,4</sup>, M. Damasso<sup>4,5</sup>, V. D'Orazi<sup>3</sup>, A. F. Lanza<sup>6</sup>, K. Biazzo<sup>6</sup>, E. Poretti<sup>7</sup>, R. Gratton<sup>3</sup>, A. Sozzetti<sup>5</sup>,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

GIANO + HARPS-N

A&A 613, A50 (2018)

## Multi-band high resolution spectroscopy rules out the hot Jupiter BD+20 1790b First data from the GIARPS Commissioning

**id** I. Carleo<sup>1,2</sup>, S. Benatti<sup>2</sup>, A. F. Lanza<sup>3</sup>, R. Gratton<sup>2</sup>, R. Claudi<sup>2</sup>, S. Desidera<sup>2</sup>, G. N. M Sissa<sup>2</sup>, A. Ghedina<sup>6</sup>, F. Ghinassi<sup>6</sup>, J. Guerra<sup>6</sup>, A. Harutyunyan<sup>6</sup>, G. Micela<sup>7</sup>, E. Moli Baffa<sup>5</sup>, A. Baruffolo<sup>2</sup>, A. Bignamini<sup>8</sup>, N. Buchschacher<sup>9</sup>, M. Cecconi<sup>6</sup>, R. Cosentino<sup>6</sup>, M. L. Fini<sup>5</sup>, D. Fugazza<sup>10</sup>, A. Galli<sup>6</sup>, E. Giani<sup>5</sup>, C. González<sup>6</sup>, E. González-Álvarez<sup>7,11</sup>, M. Hernandez Diaz<sup>6</sup>, M. Iuzzolino<sup>5,12</sup>, K. F. Kaplan<sup>4</sup>, B. T. Kidder<sup>4</sup>, M. Lodi<sup>6</sup>, L. Malavolta<sup>1</sup>, Perez Ventura<sup>6</sup>, A. Puglisi<sup>5</sup>, M. Rainer<sup>10</sup>, L. Riverol<sup>6</sup>, C. Riverol<sup>6</sup>, J. San Juan<sup>6</sup>, S. Scuderi<sup>5</sup>, A. Sozzetti<sup>15</sup> and M. Sozzi<sup>5</sup>





## Optical pulsations from a transitional millisecond pulsar

Ambrosino, F.; Papitto, A.; Stella, L.; et al.

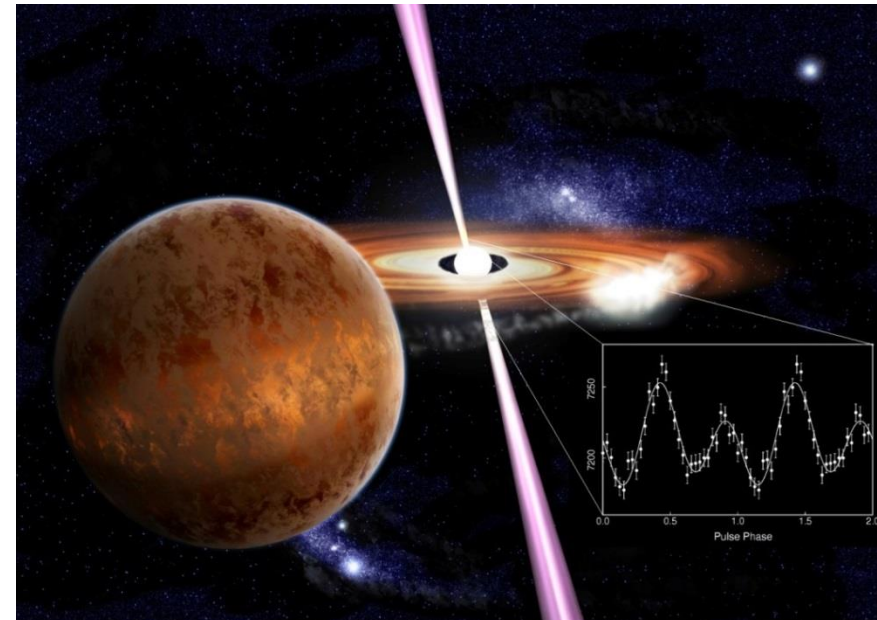
Nature Astronomy, 1, 854 (based on observations made with SiFAP@TNG); Category: D

## Pulses of visible light from a millisecond pulsar

*(Ambrosino et al. 2017, Nature Astronomy)*

*Silicon Fast optical Astronomical Photometer (SiFAP) visitor instrument*

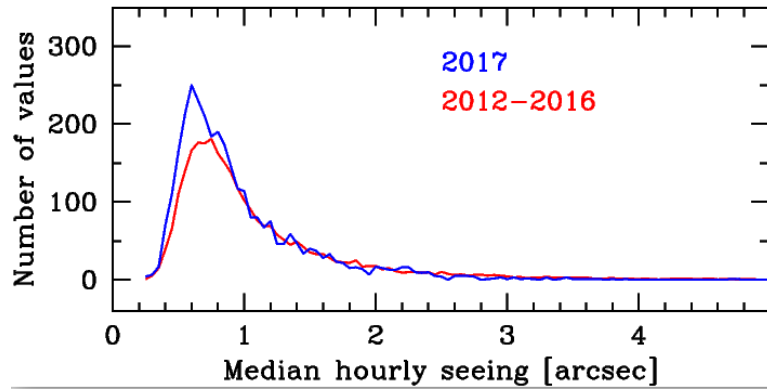
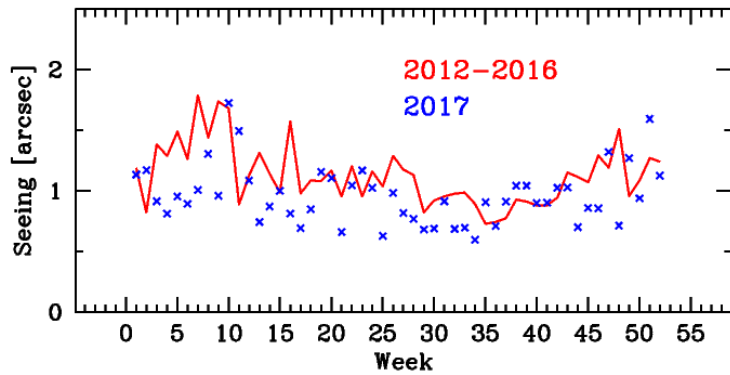
*Optical polarimeters available: PAOLO, HANPO*



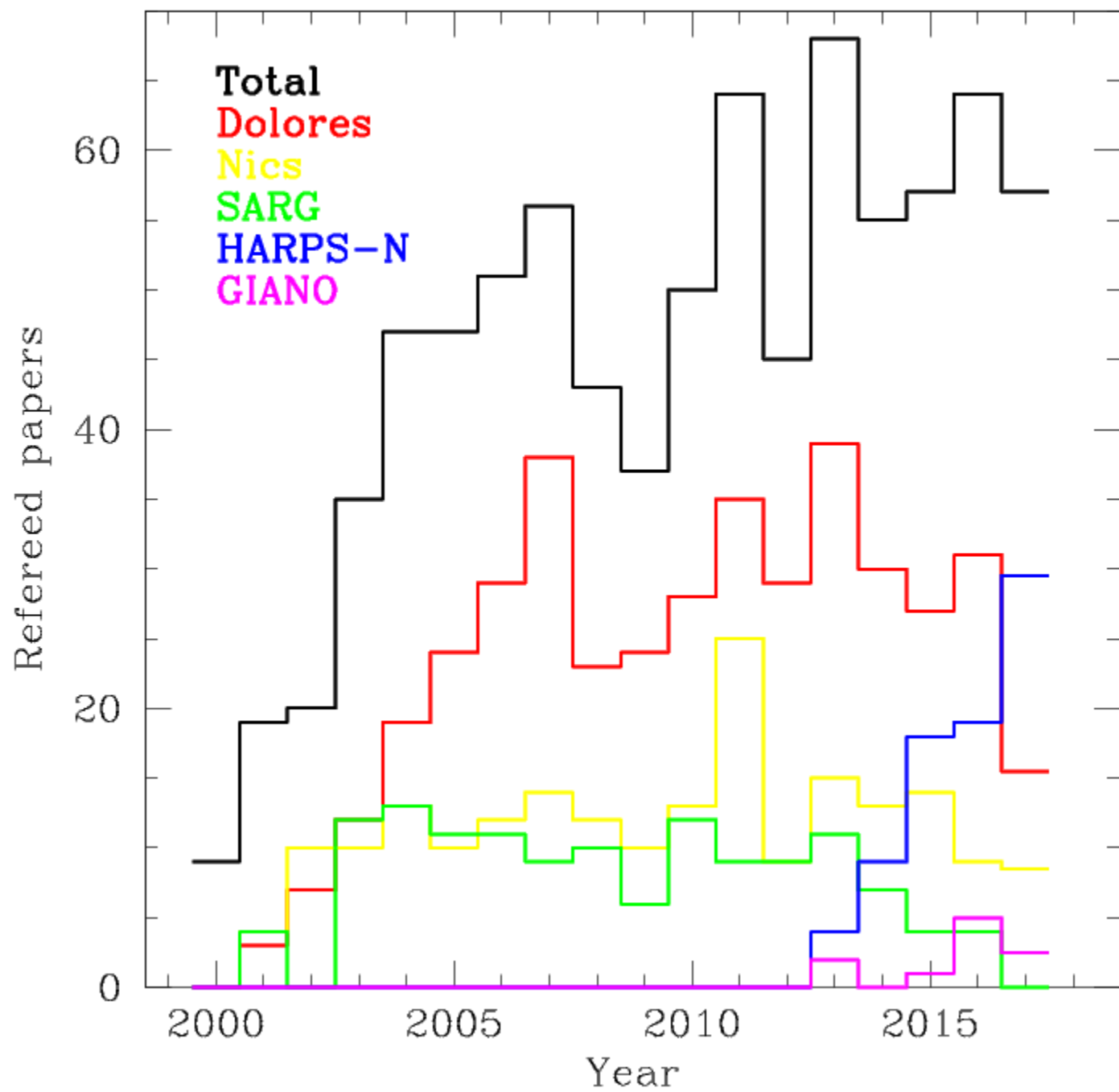
- Twenty years of TNG operations (1998-2018)
- Agreement with the HARPS-N Consortium renewed for 5 years (2017-2022).
- Five years of the HARPS-N Consortium celebrated with a meeting in Santa Cruz on February 9, 2018
- HARPS-N solar telescope operating daytime
- GIANO-B solar telescope operating soon, next to HARPS-N one







	2017	2016	2015
Average down meteo	22.7%	24.0%	22.6%
Average technical failures	2.0%	1.5%	2.1%
Total engineering time	5.6%	4.7%	2.6%
Average shutter open ratio	76.8%	73.8%	73%





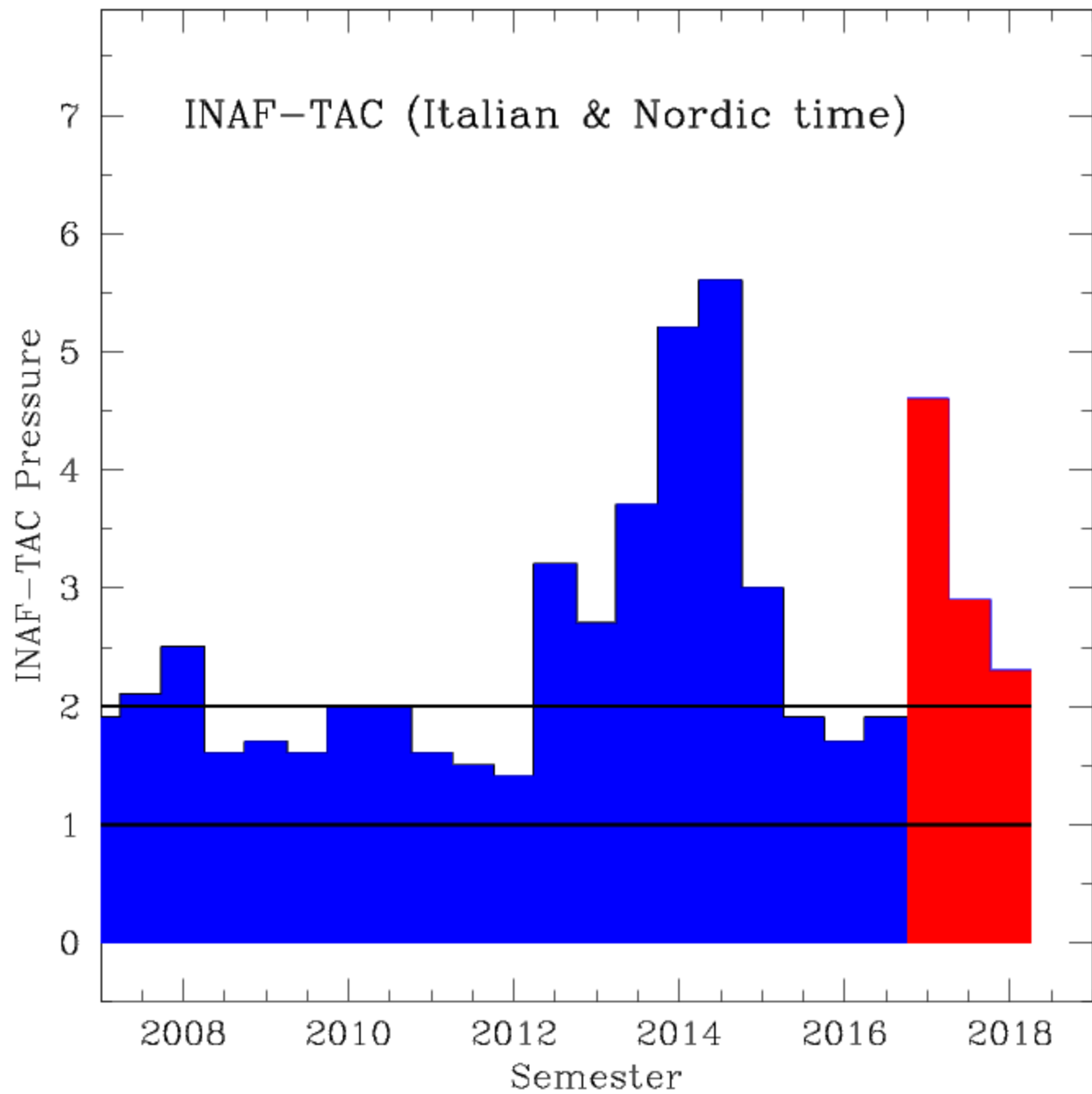
In the era of mature 8m-class telescopes, and with 40m-class telescopes approaching the event horizon, it is mandatory to define compelling scientific programs that justify the investments that the Italian astronomical community is making to maintain TNG operative and competitive. TNG is offering competitive instrumentation, especially in the case of HARPS-N and GIANO, which can be jointly used in the GIARPS instrumental combination. Therefore, INAF opens observing time to major scientific programs, extending over several semesters and/or exploiting a significant fraction of the INAF nights.

## **LARGE PROGRAMS IN AOT37**

Nine Large Programs submitted, two approved.

Very high scientific content

121 nights requested in AOT 37, 49 available for LP





In this call TNG opens observing time to less time-demanding programs, but still having the need to extend over a few consecutive semesters to be completed and/or to ensure the necessary follow-up.

The "Long Term" programs must be able to strictly address major open problems in modern astrophysics, characterizing the TNG role in the next 1-2 years.

## **LONG TERM PROGRAMS IN AOT38**

Six Long Term Programs submitted, TBD approved.

Fifteen normal proposals submitted.

Pressure on Italian Time: 2.3

# AOT 38 (2018B) TIME BREAKDOWN

- 47 nights ongoing INAF-Large Programs
- 40 nights Harps-N Consortium GTO
- 31 nights Spanish CAT
- 8 nights CCI International Time Program
- 10 nights OPTICON H2020 TNA Program
- 10 nights joint NOT-INAF call
- 12 nights for the INAF-TAC

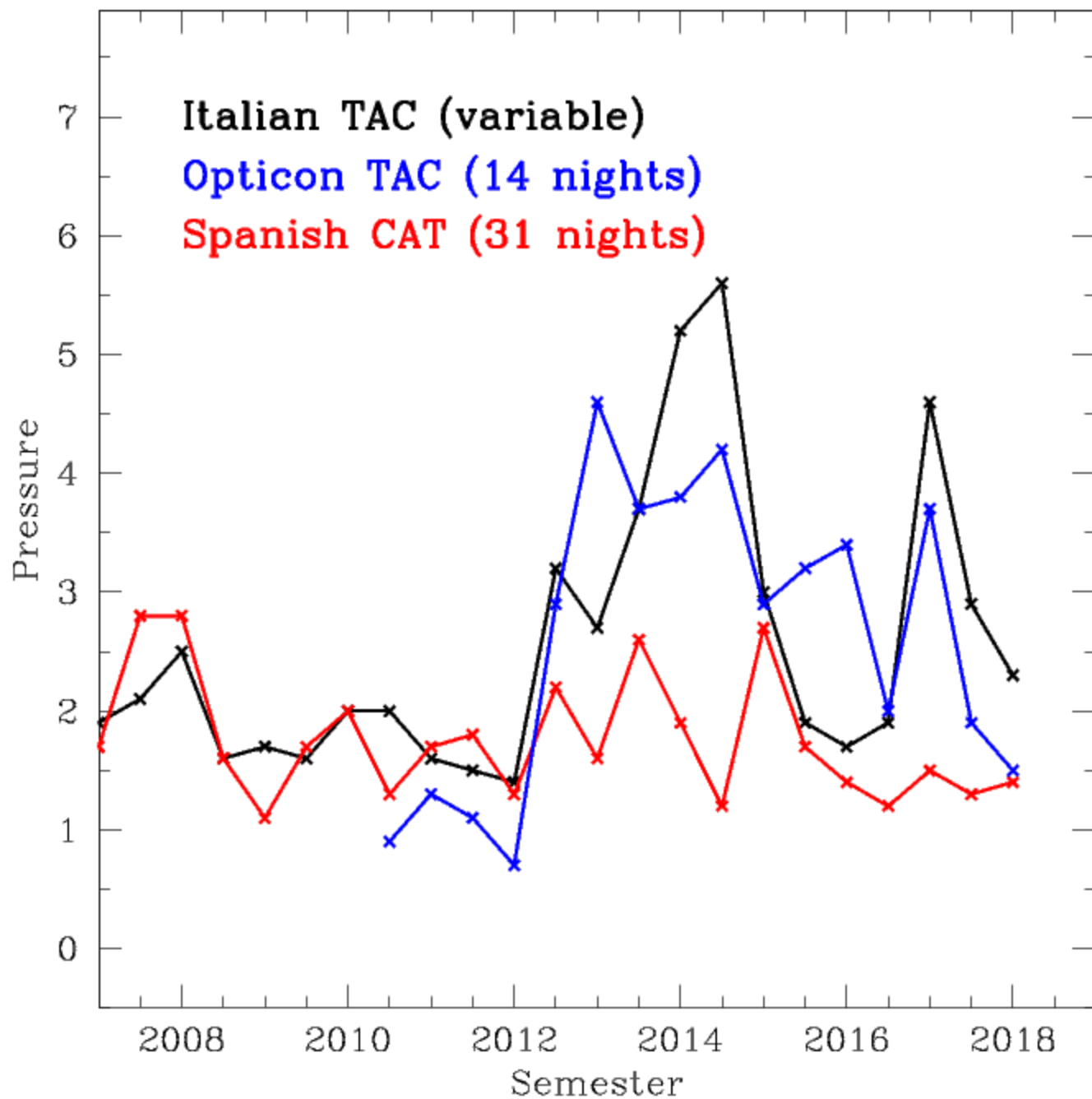
The schedule is dominated by large blocks of nights allocated to GTO and INAF-LPs.

Service observations requiring regular monitoring are very difficult to allocate.

Some constraints apply. E.g., the 15 CCI ITP nights cannot be allocated in a single semester, OPTICON nights reduced to 10 this call.

Don't forget DDT (see policy on TNG webpages).





# CONCLUSIONS AND PERSPECTIVES

Twenty years of TNG, an important piece of history of the Italian astronomy has passed through here.

Currently, two highly requested instruments, GIANO-B and HARPS-N. The strategic decision to join them appears well justified.

Strong National and International competition on the use of both HARPS-N (K2 OPTICON programmes, GAIA DR2 ITP follow-up programme) and GIARPS (transmission spectroscopy, circumstellar discs).

Italian community well represented. *PIs: Micela (LP Inaf), Origlia (LP Inaf), Caratti o Garatti (ITP).*

GIARPS ready for TESS, CHEOPS, PLATO, ARIEL,...

DOLORES and NICS available for Gravitational Waves follow-up programs

New ideas welcome. Working group of instrumentation at ORM appointed.



