Spectral survey of comets and Mars at near IR wavelengths with the TNG/GIANO spectrograph

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UNIVERSITÀ DEGLI STUDI FIRENZE

DOTTORATO DI RICERCA IN FISICA E ASTRONOMIA

XXIX CICLO

PhD Coordinator: Massimo Gurioli

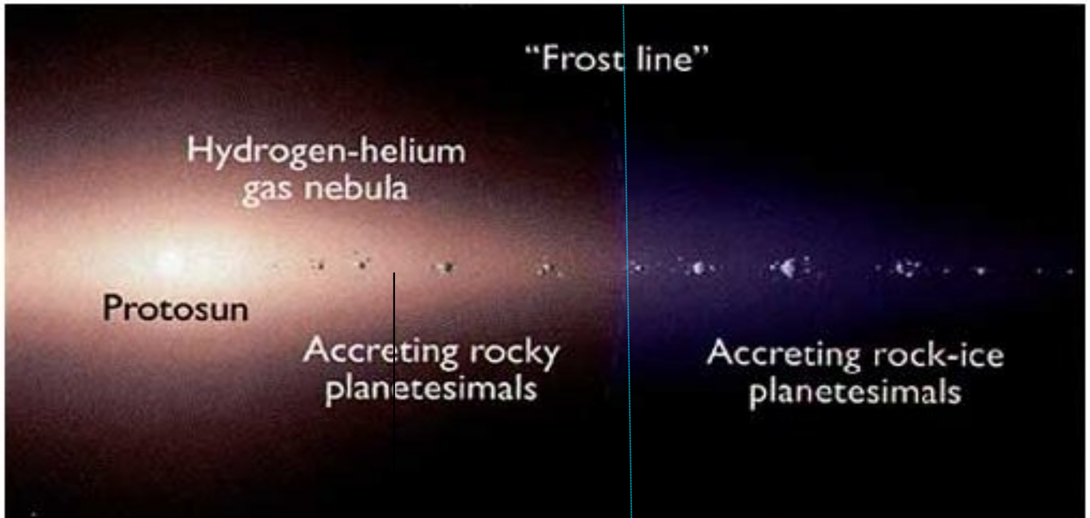
HIRES/E-ELT astrobiology science case.
Cosmogonic indicators in comets: Targeting a quantum leap using new-generation high-resolution echelle spectrometers.

PhD student: Sara Faggi

Tutors: John Robert Brucato and Gian Paolo Tozzi

in collaboration with: Michael J. Mumma and Geronimo L. Villanueva

The puzzling origin of Earth's oceans



Within frost line, rocks and metals condense, hydrogen compounds stay gaseous

Beyond frost line, hydrogen compounds, rocks,and metals condense.

~2.7 AU

30AU

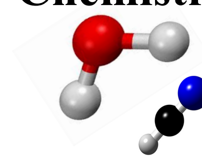
Who delivered water to Earth?
Were organics and water delivered to Earth by comets?

Gyr

Appearance of Life — 3.6

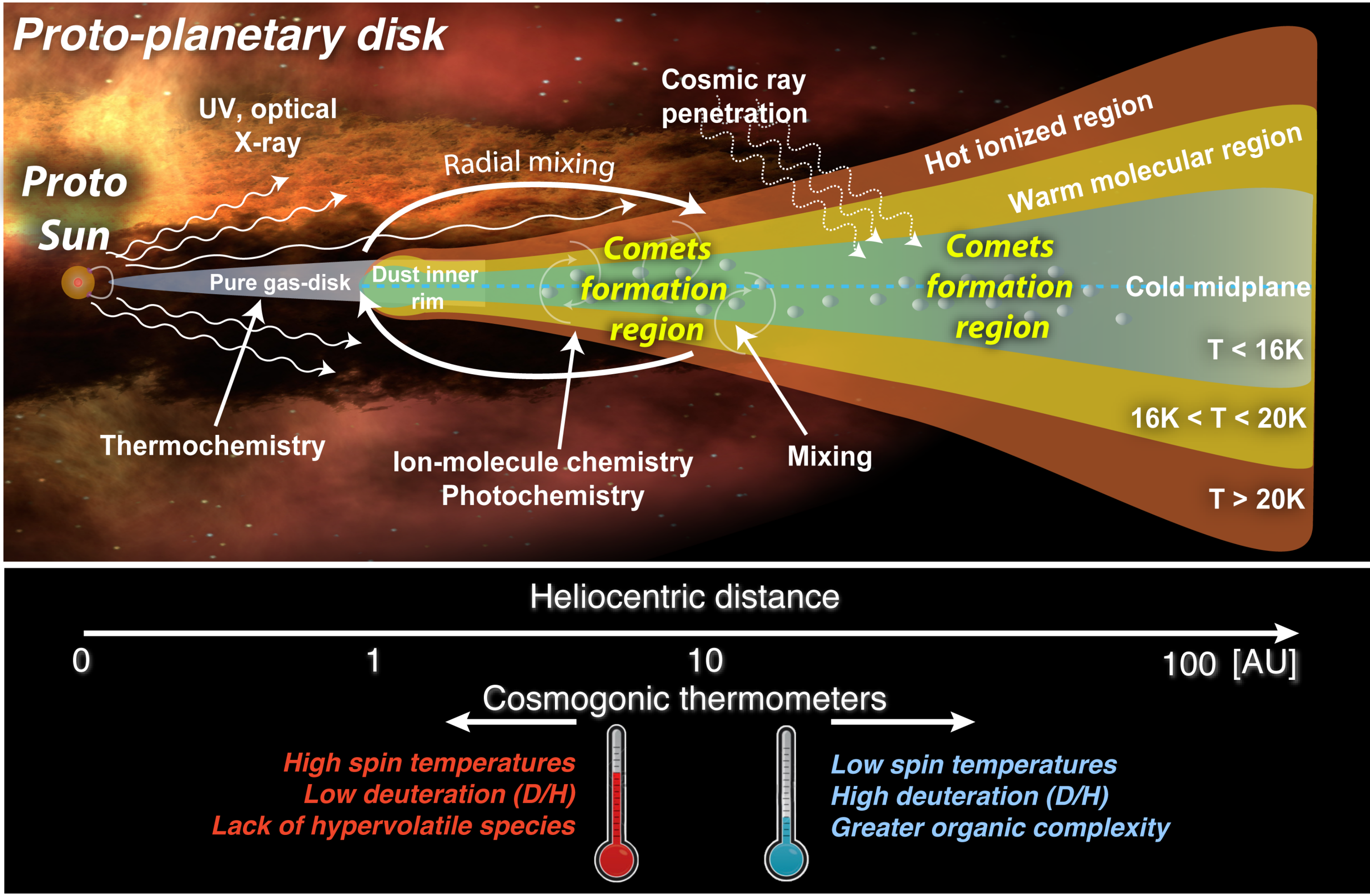
Late Cometary bombardment — 3.9

Prebiotic Chemistry — 4.0



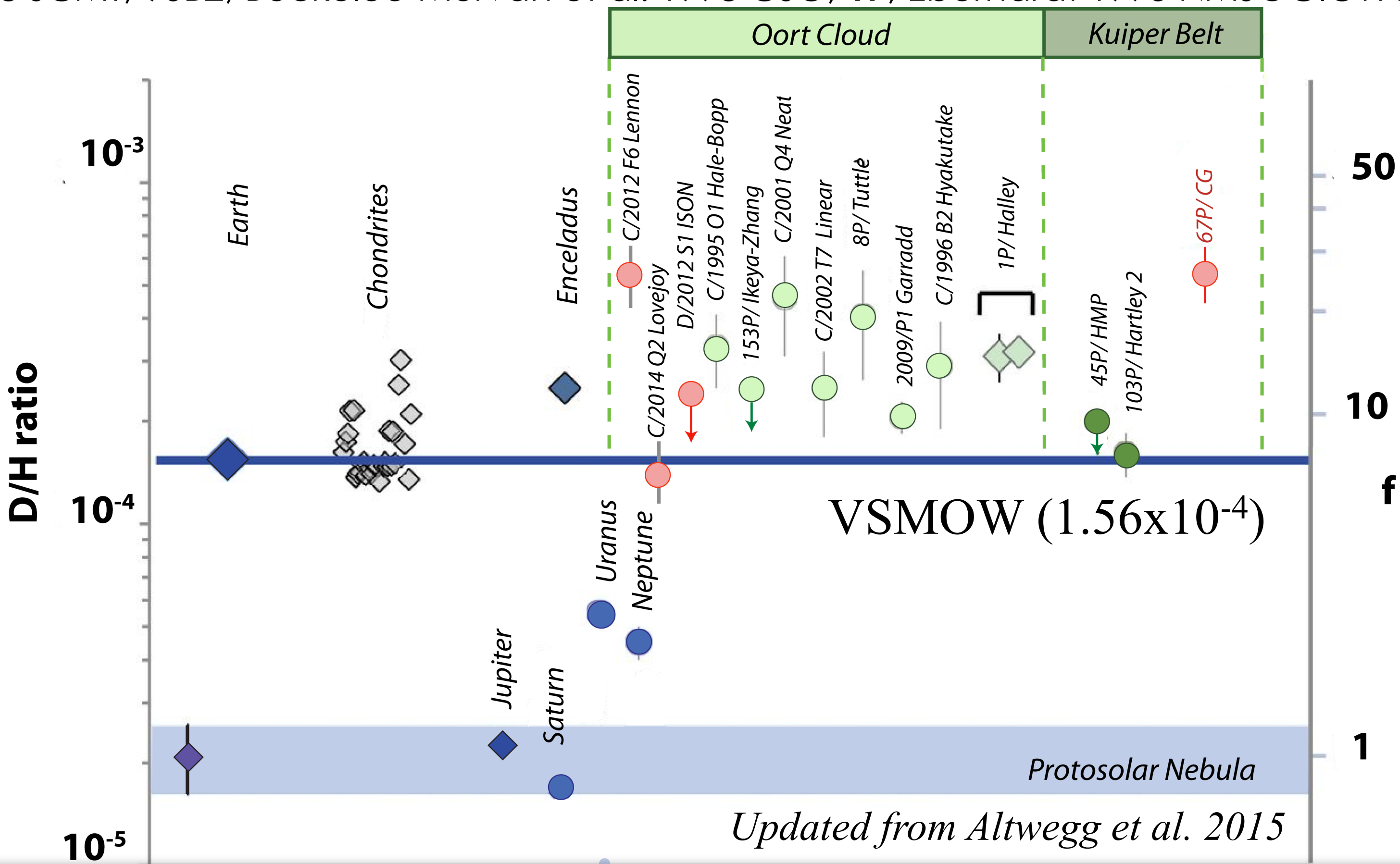
Earth Formation — 4.6

Solar System Evolution and Cosmogonic Indicators



Water D/H in the Solar System

12F6 and **14Q2**, Biver et al., 2016 IRAM&Odin; **12S1**, Gibb et al., 2016 CSHELL@NASA-IRTF; **67P**, Altwegg et al. 2015 ROSINA@ROSETTA; **09P1**, Bockelée-Morvan et al. 2012 HERSCHEL; **103P**, Hartogh et al. 2011 HERSCHEL; **45P**, Lis et al. 2008 HERSCHEL; **8P**, Villanueva et al.2008 CRIRES@VLT; **01Q4**, Weaver et al. 2004 STIS@HST; **02T7**, Weaver et al. 2003 STIS@HST; **95O1**, Meier et al. 1998 JCMT; **96B2**, Bockelée-Morvan et al. 1998 CSO; **1P**, Eberhardt 1995 NMS@GIOTTO.

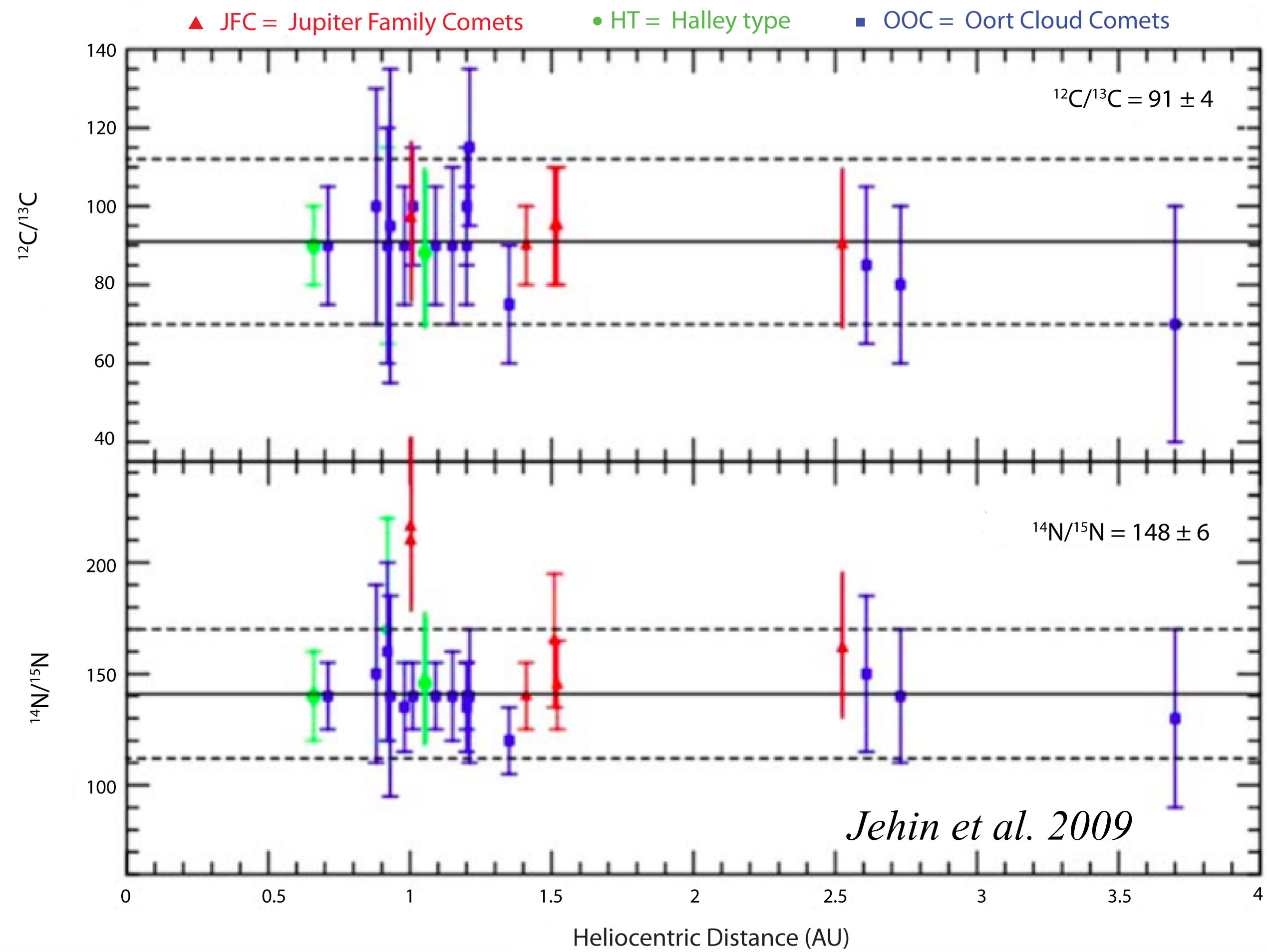


Carbon and Nitrogen fractionation in comets

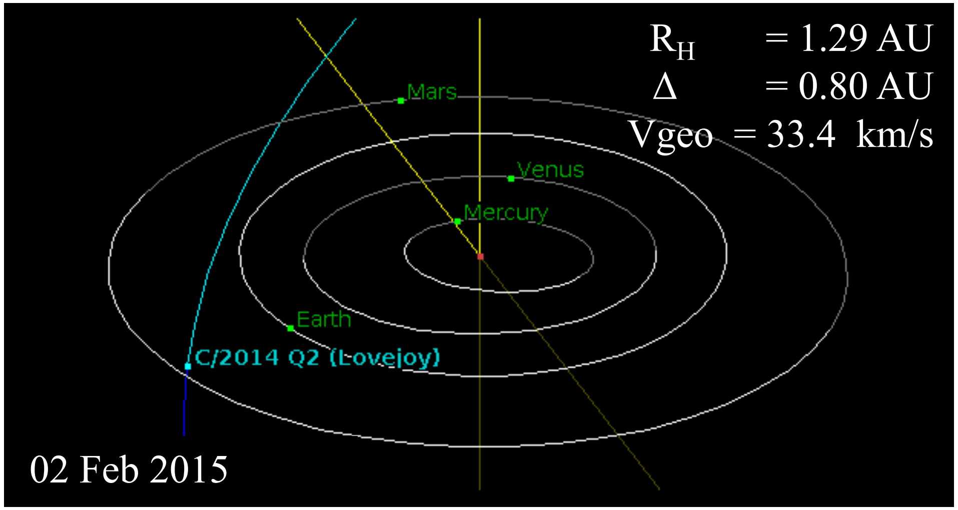
Terrestrial value:

$^{12}C/^{13}C = 89$

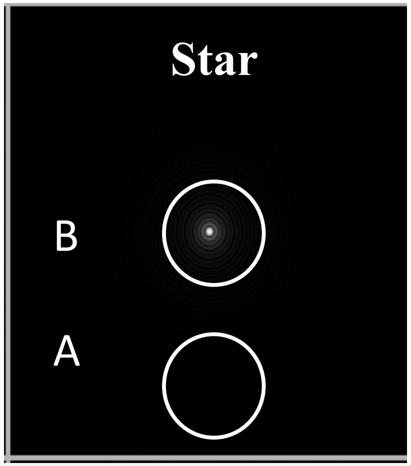
$^{14}N/^{15}N = 272$

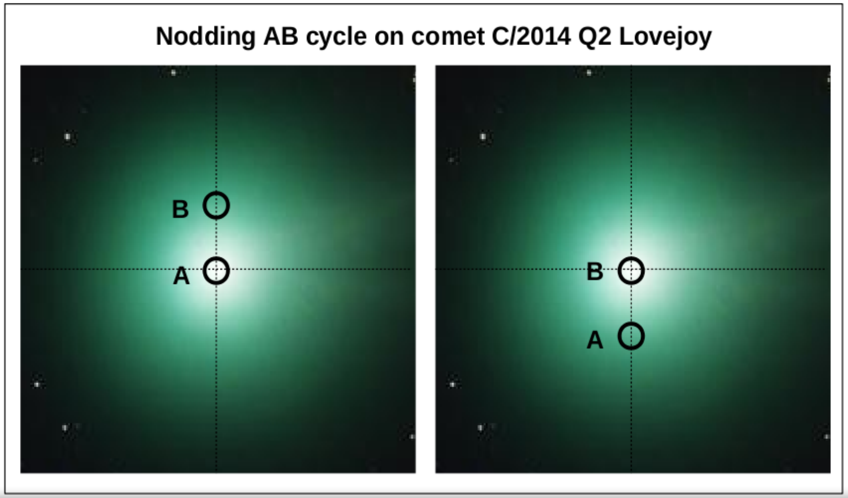


GIANO observations of comet C/2014 Q2 Lovejoy

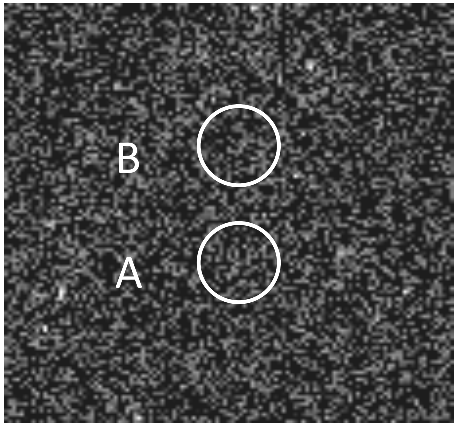


	UT time
31/Jan/2015	20:00 – 01:00
01/Feb/2015	19:00 – 00:40
02/Feb/2015	19:00 – 00:20

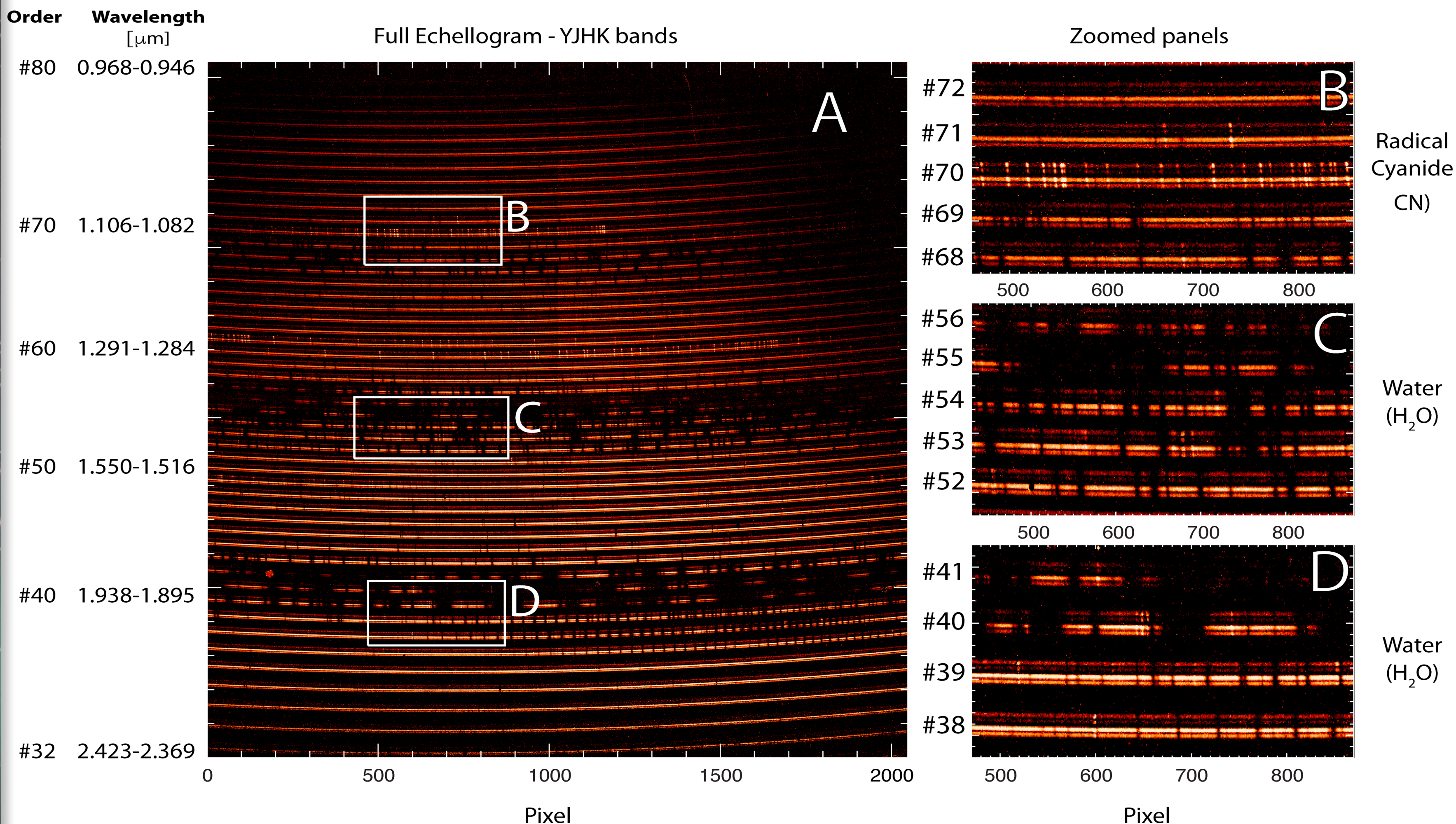




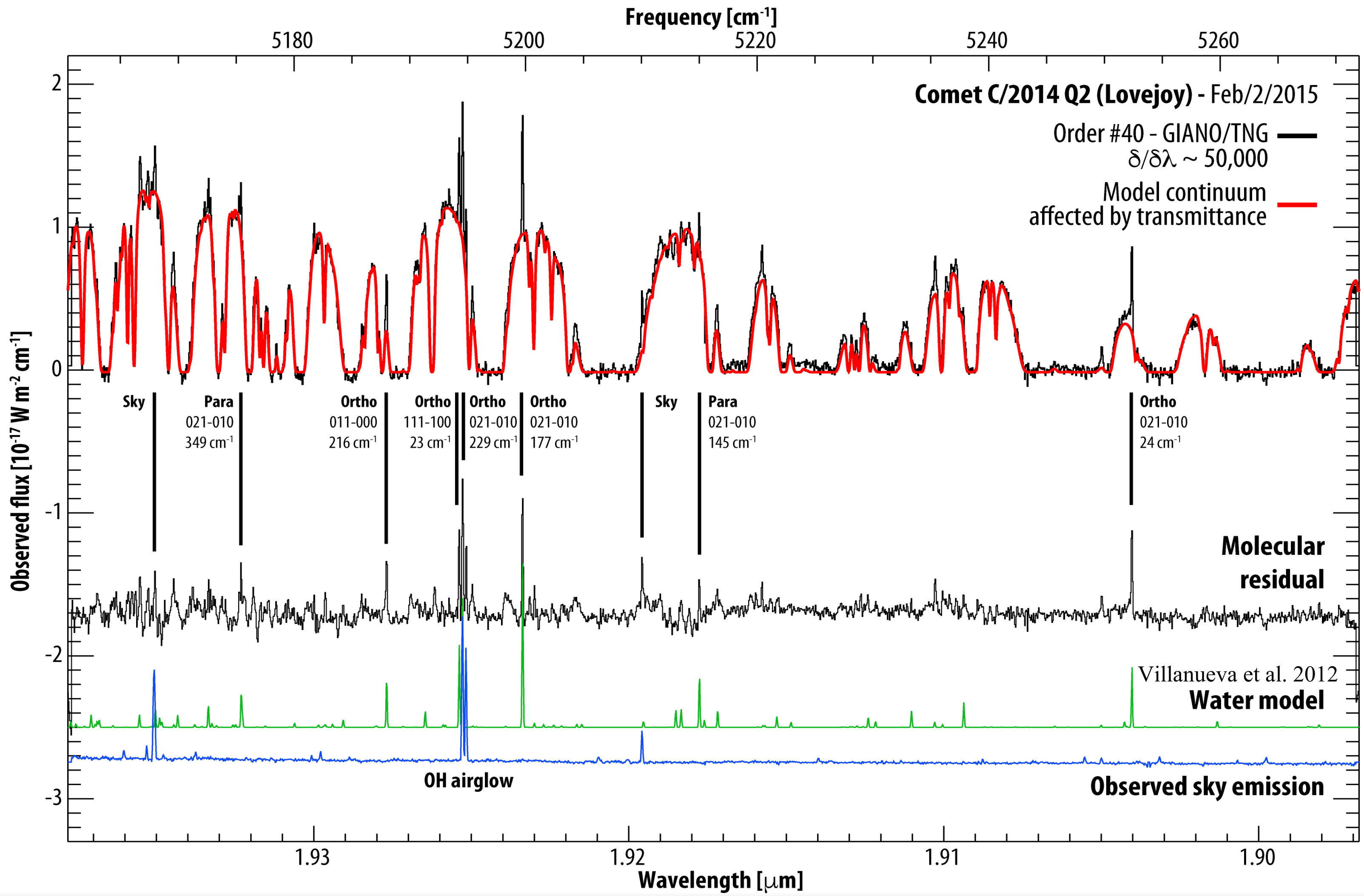
Sky shifted 800" in RA



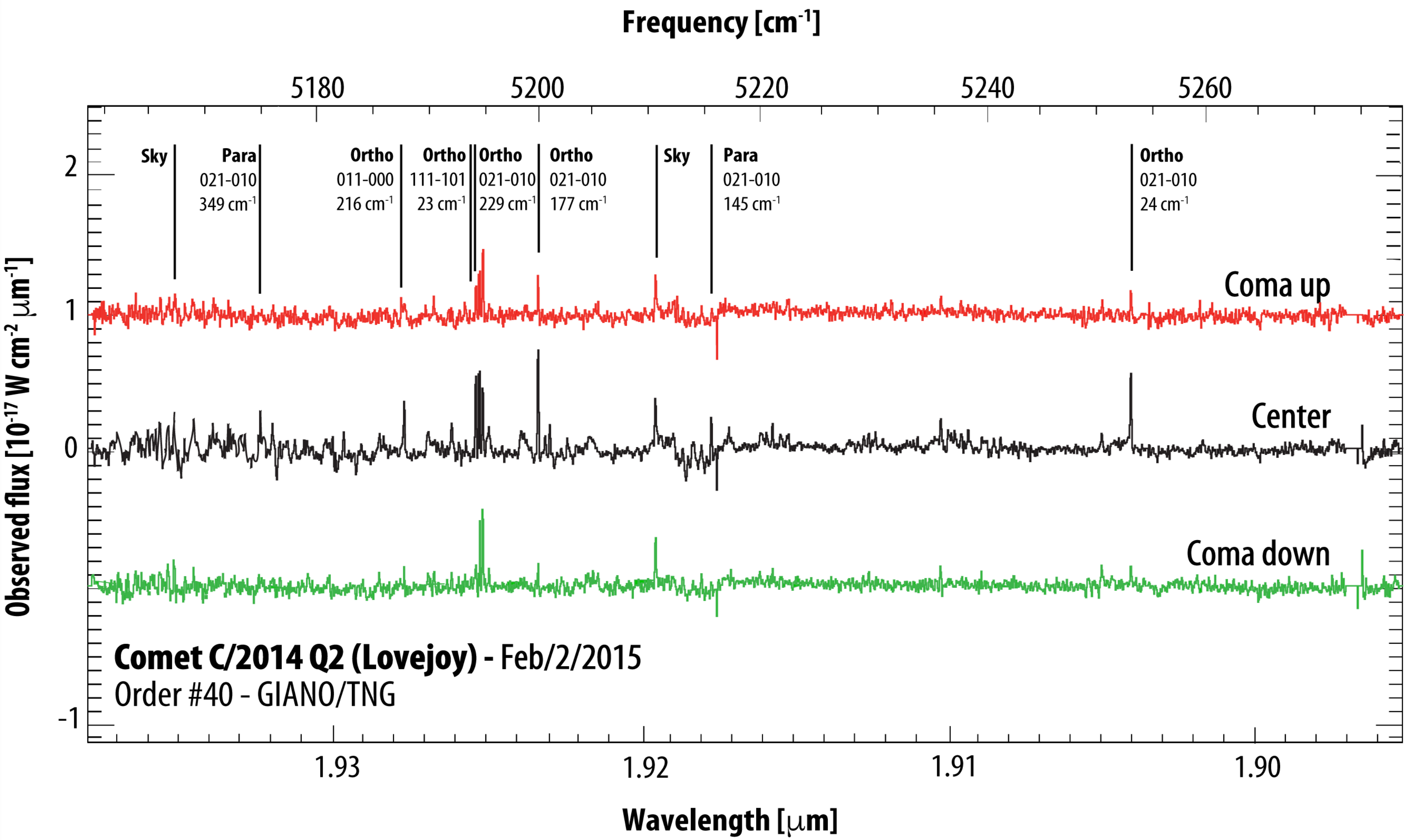
C/2014 Q2 Lovejoy comet GIANO/TNG Echellogram



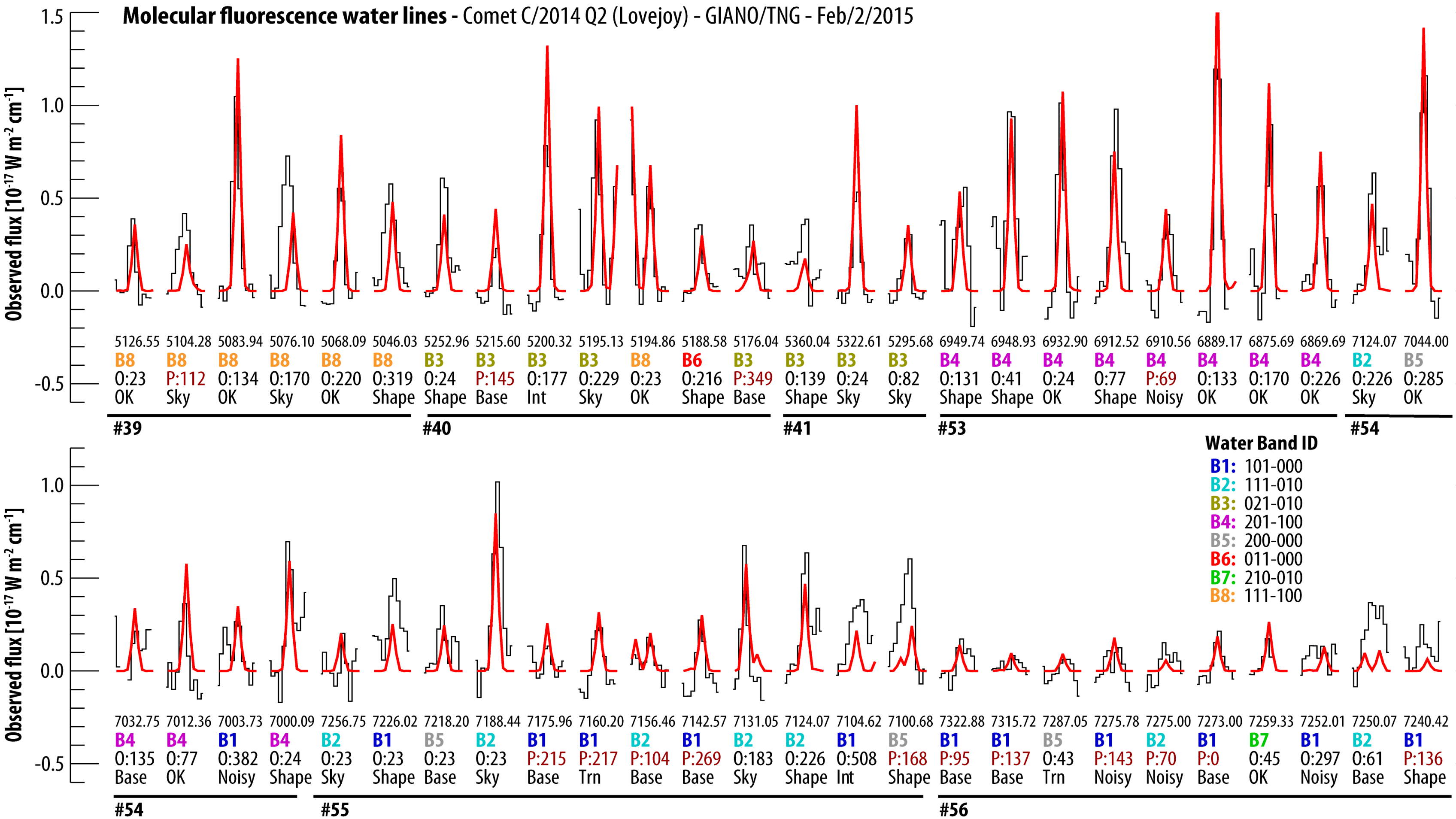
Identification of cometary water emissions



Identification of cometary water emissions



Data analysis: 52 detected lines across 8 water bands



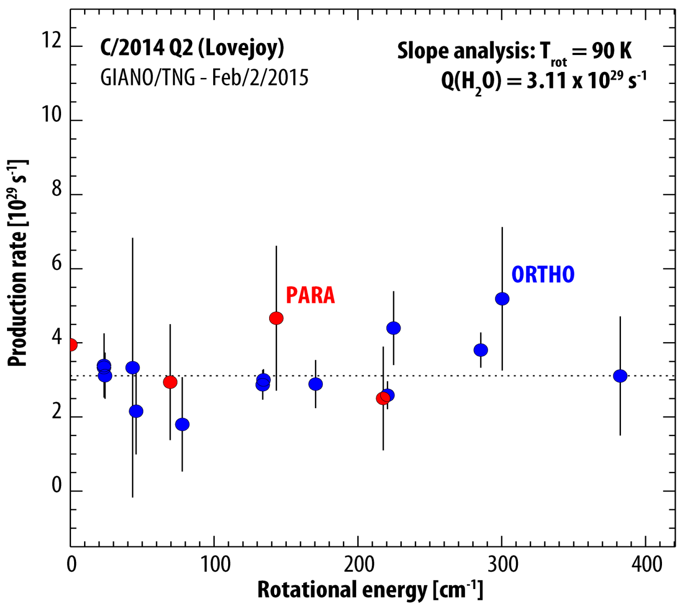
Faggi et al. 2016, ApJ

What we have achieved with GIANO

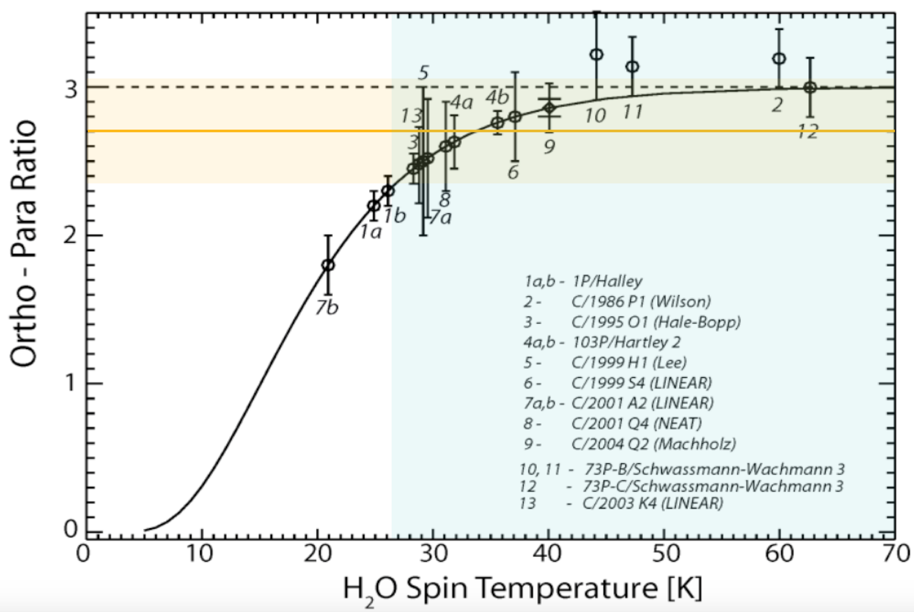
-Rotational temperature: Trot = (90 ± 20) K

-Water production rate:

$Q(H_2O) = (3.11 \pm 0.14) \times 10^{29}\ s^{-1}$
agrees with NIRSPEC nucleocentric Measurement [Paganini+2015]



Faggi et al. 2016, ApJ



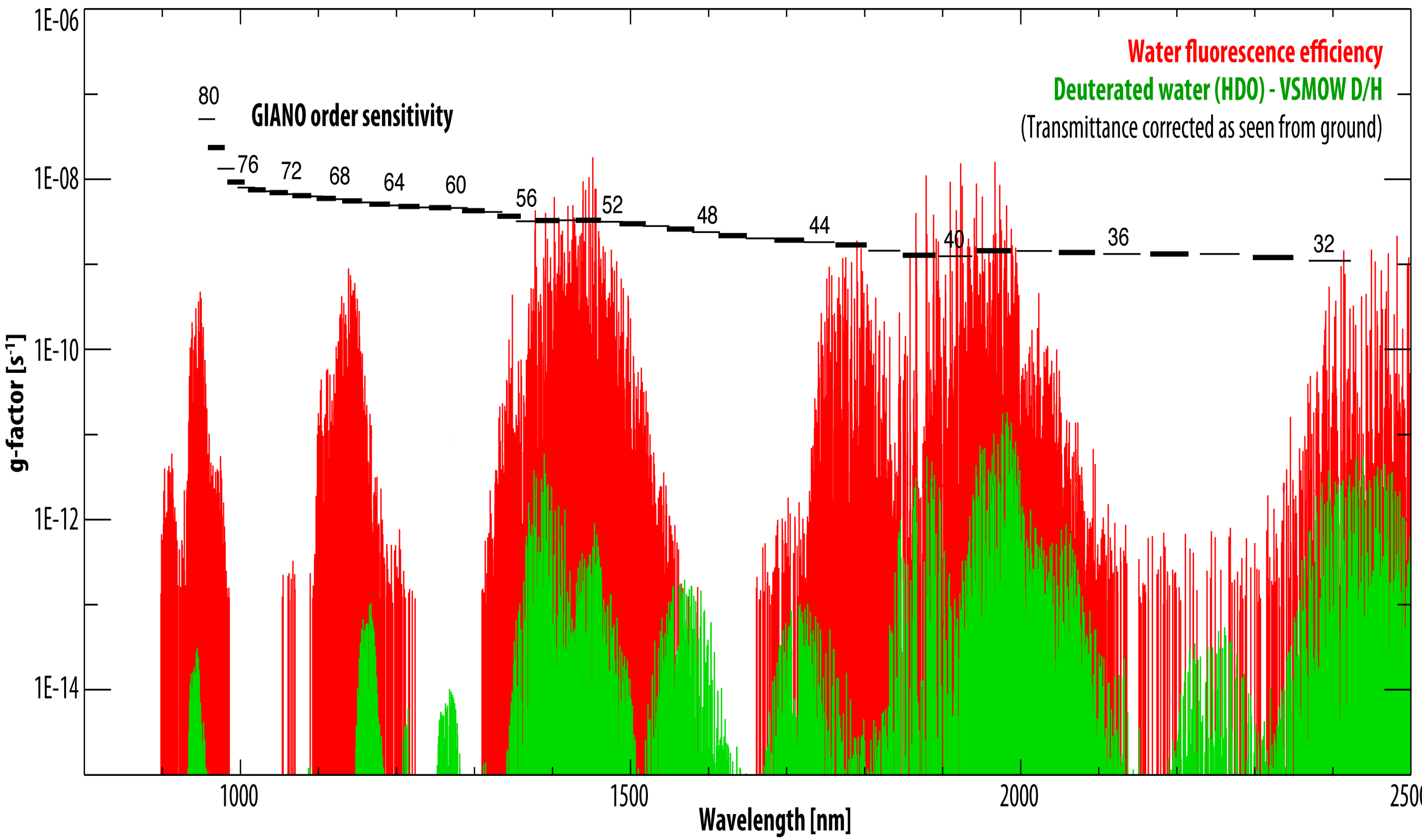
$Q(H_2O)^{ORTHO} = (2.54 \pm 0.17) \times 10^{29}\ s^{-1}$

$Q(H_2O)^{PARA} = (0.83 \pm 0.18) \times 10^{29}\ s^{-1}$

OPR = (2.7 ± 0.7)

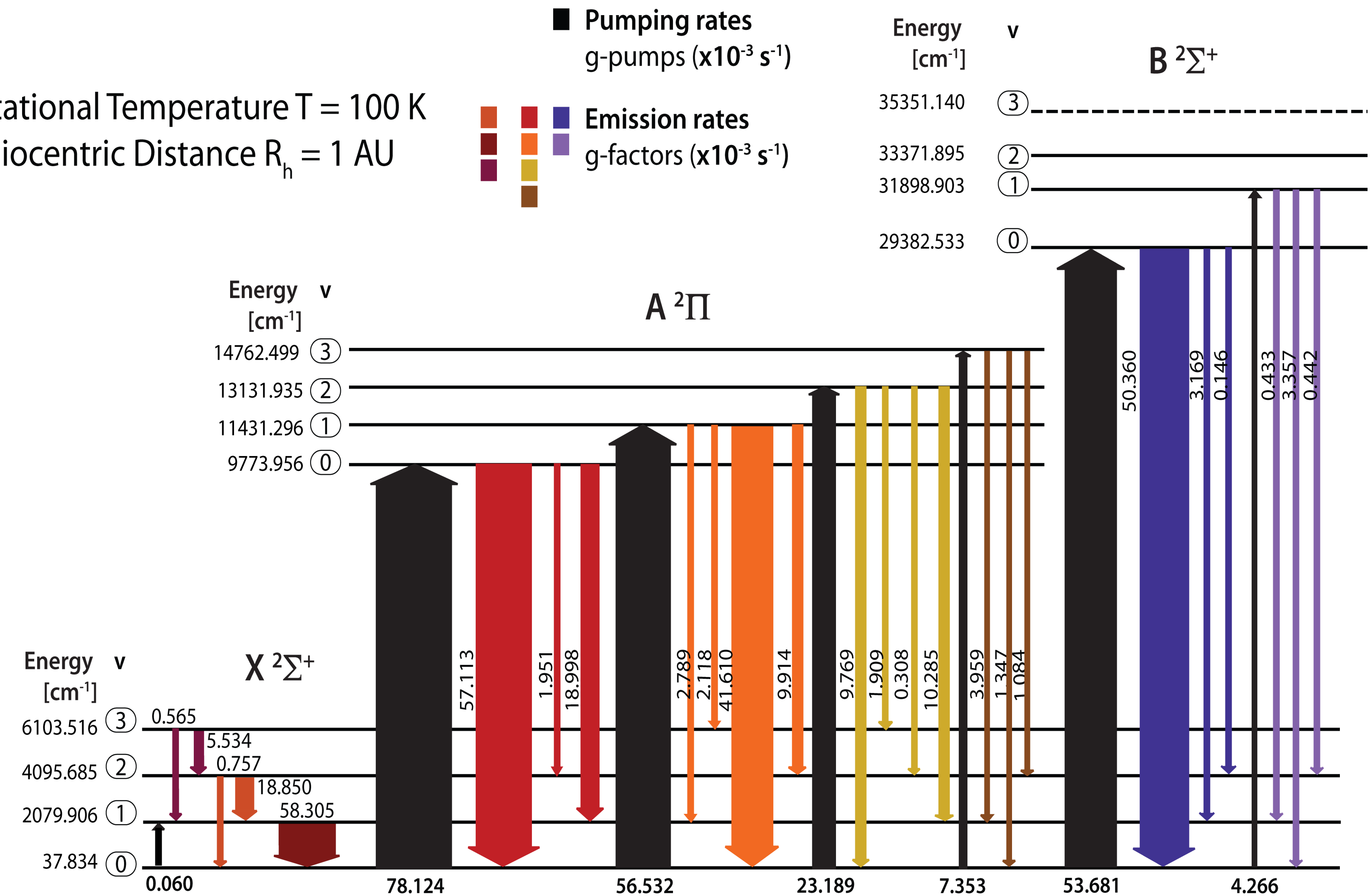
Could we detect HDO with GIANO?

Could we detect HDO with GIANO (fiber-fed)?

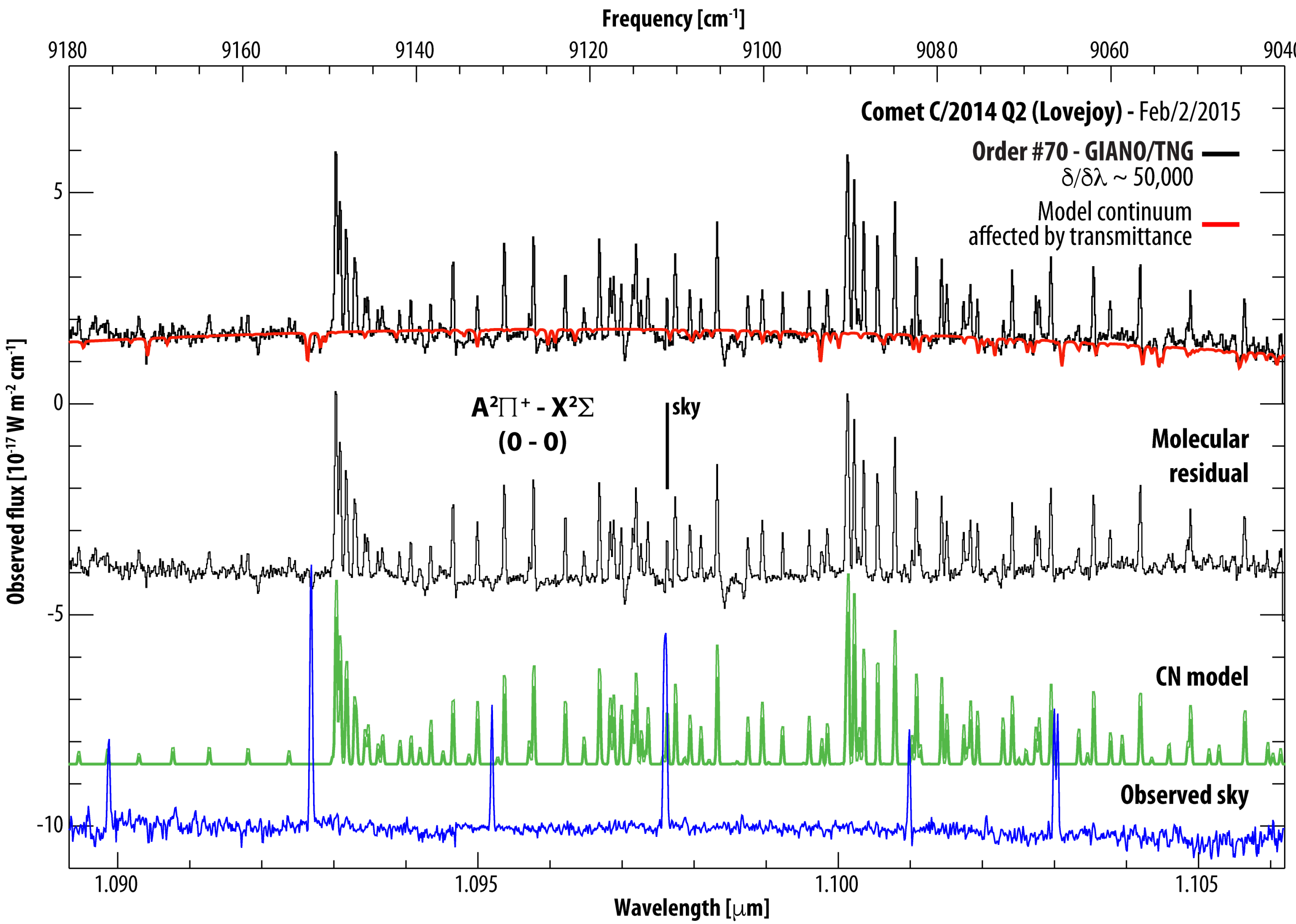


Quantum Mechanic Fluorescence model of CN radical

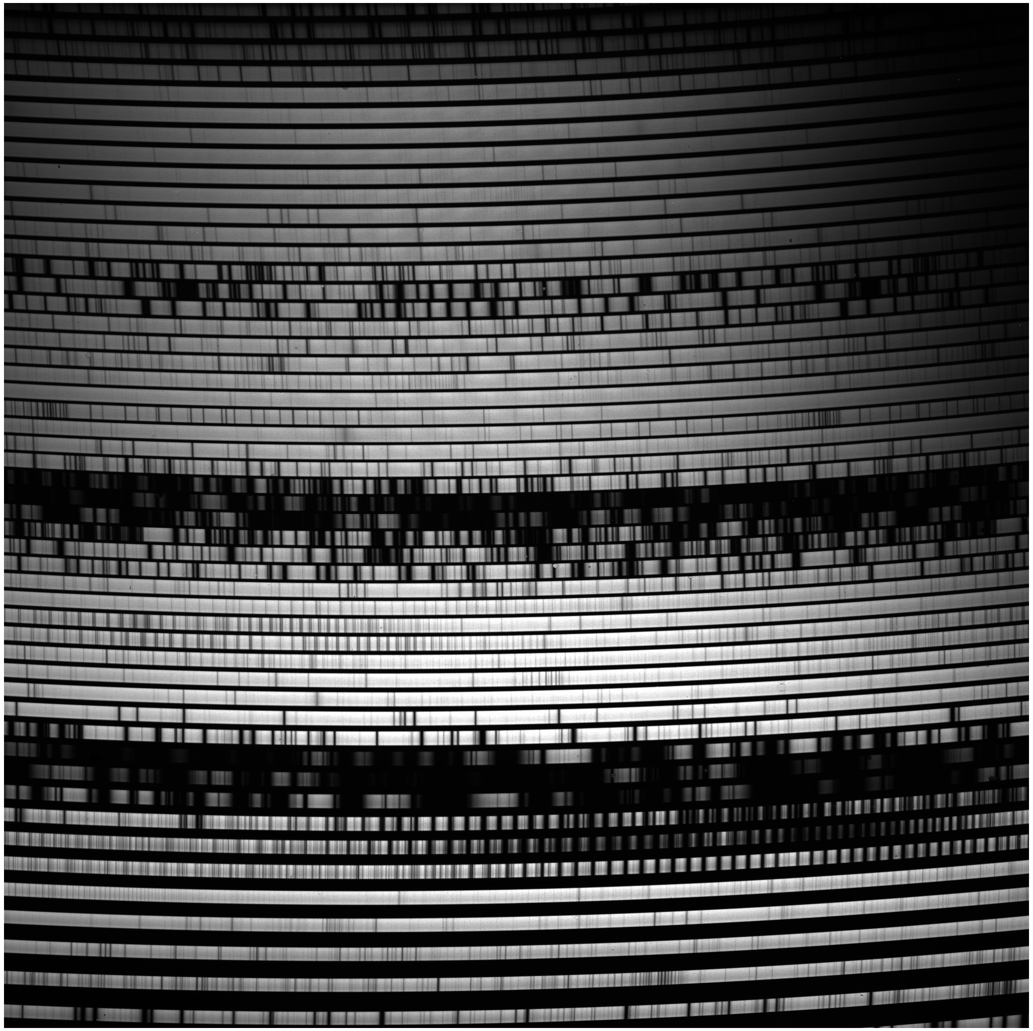
Rotational Temperature T = 100 K
Heliocentric Distance R_h = 1 AU

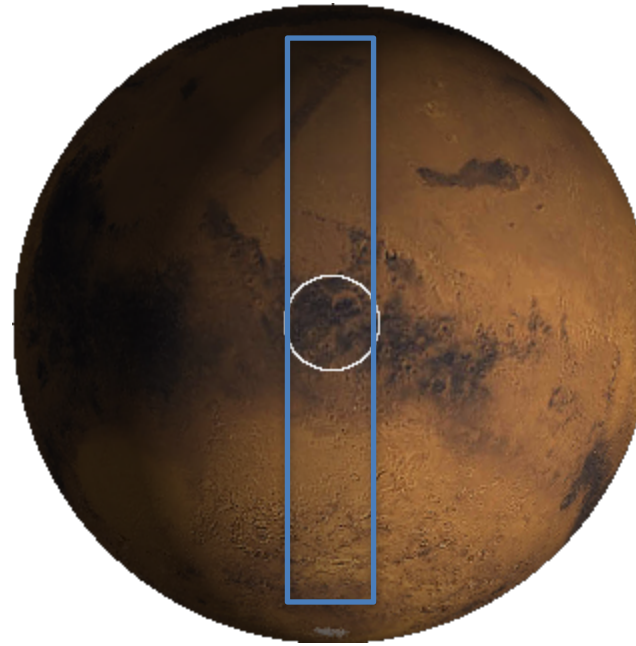


Identification of cometary CN emissions



Commissioning:
Mars GIANO-B/TNG echellogram

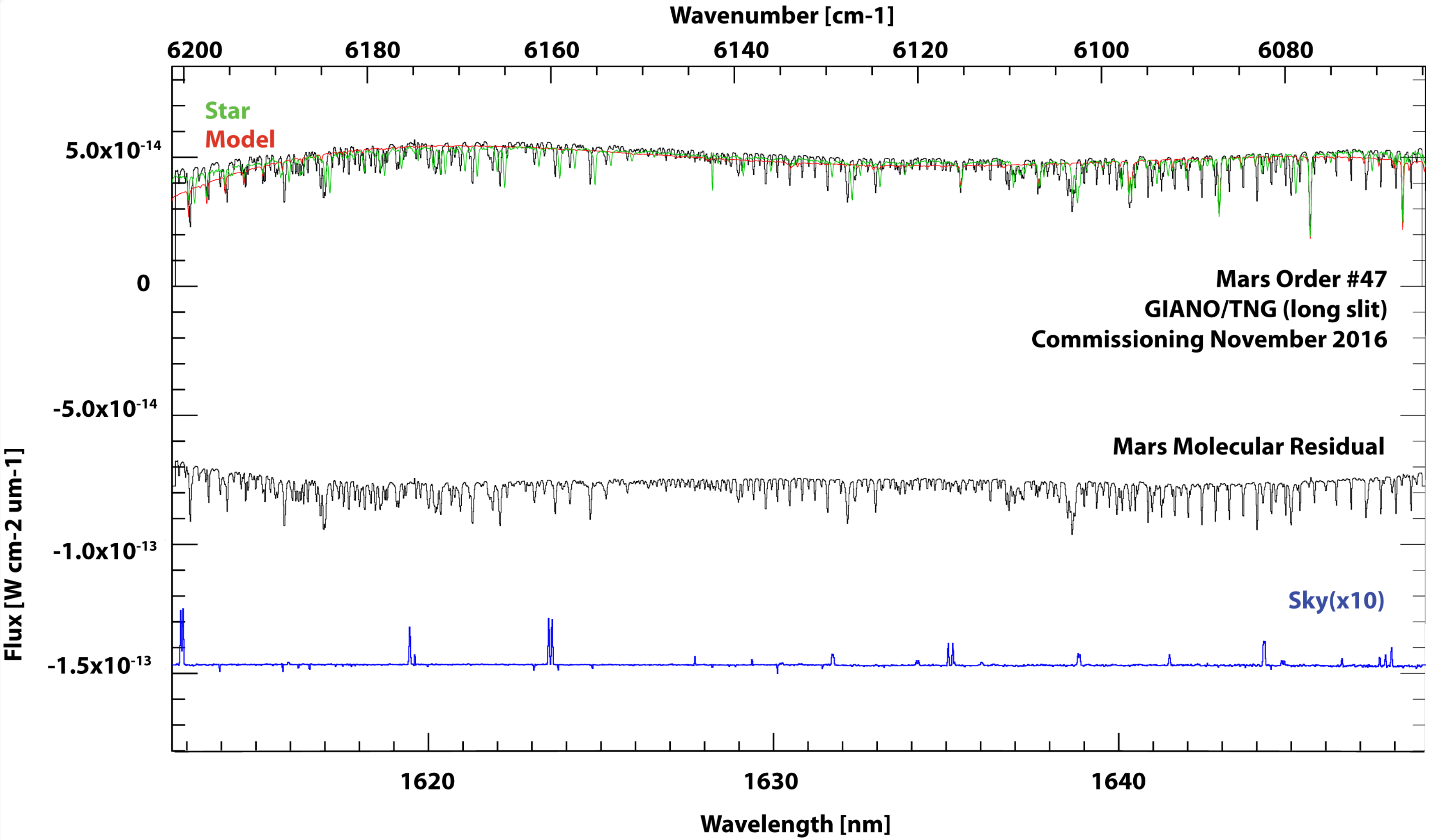




-Long slit ~(1”x6 “)
-Stare mode + sky far
-Extended object (mapping with new pipeline)

Thanks to GIARPS team for the data

Mars GIANO/TNG preliminary extracted spectra



Thanks to Massi F. for the collaboration in the data reduction.

Conclusions

1. Le osservazioni HR sono complementari e **NON IN CONCORRENZA** con quelle di bassa e media risoluzione o di imaging. Anzi spesso le osservazioni con DOLORES o NICS possono essere di aiuto a quelle HR;
2. La regione 1-2.5 micron in HR è stata fino ad ora poco studiata per mancanza di spettrografi HR e perché considerata meno interessante di quella attorno a 3.5 micron;
3. Con HR si possono rivelare elementi presenti anche nell'atmosfera terrestre. Basta scegliere il momento per cui la velocità radiale della sorgente è alta.
4. Nelle comete abbiamo studiato "solo" l'acqua e il CN, ma ci sono molte righe ancora non identificate, che potrebbero essere O_2 (vedi Rosetta) e altre molto importanti da punto di vista astrobiologico. Per studiarle occorre fare dei modelli di fluorescenza degli elementi sospetti e fare il confronto con le righe osservate.
5. GIANO-B senza fibre ottiche sarà molto più sensibile del vecchio GIANO, per cui se arriva una cometa brillante potrebbe essere possibile misurare HDO/H_2O e OPR con buon SNR.
6. L'estensione nel visibile (GIARPS) permette di misurare abbondanze isotopiche di vari elementi allo stesso tempo (C, N, H..) e in vari range spettrali e OPR.