Elaboration et performances des signaux REFIMEVE

Benjamin Pointard, Rodolphe Le Targat

SYRTE

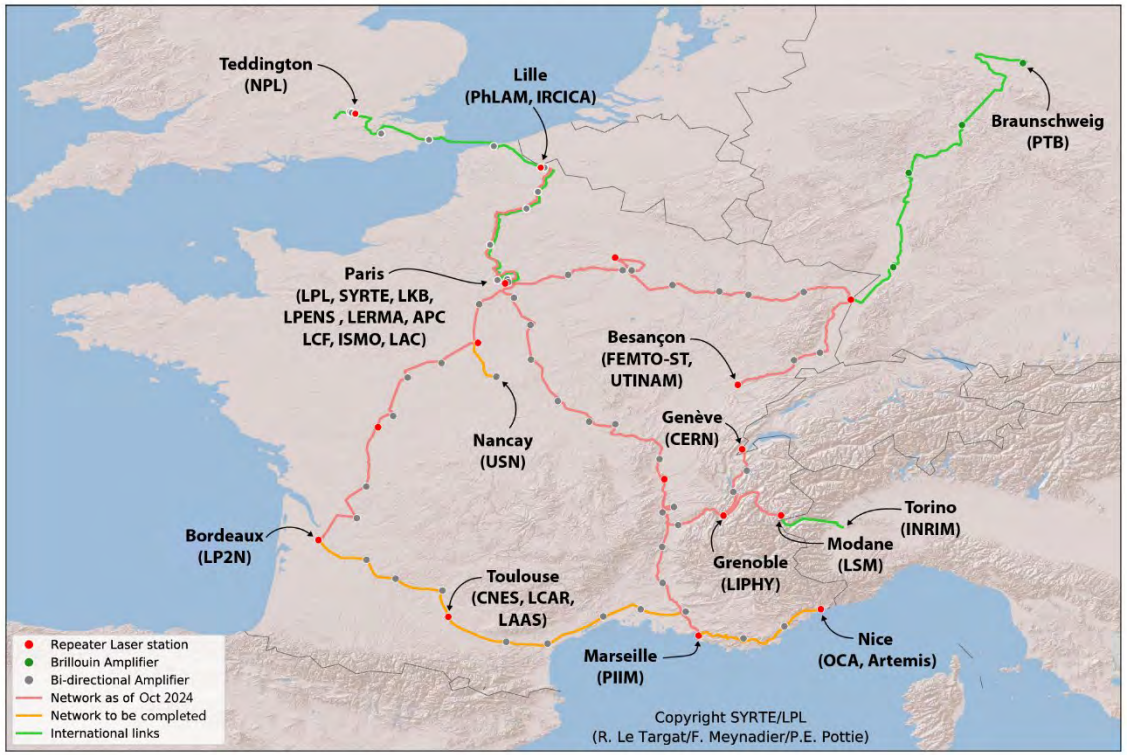
SYstèmes de Référence Temps et Espace (UMR8630)
Observatoire de Paris, 61, Avenue de l'Observatoire, 75014 Paris

REFIMEVE source: hybrid 1542 nm oscillator

MOTIVATION?

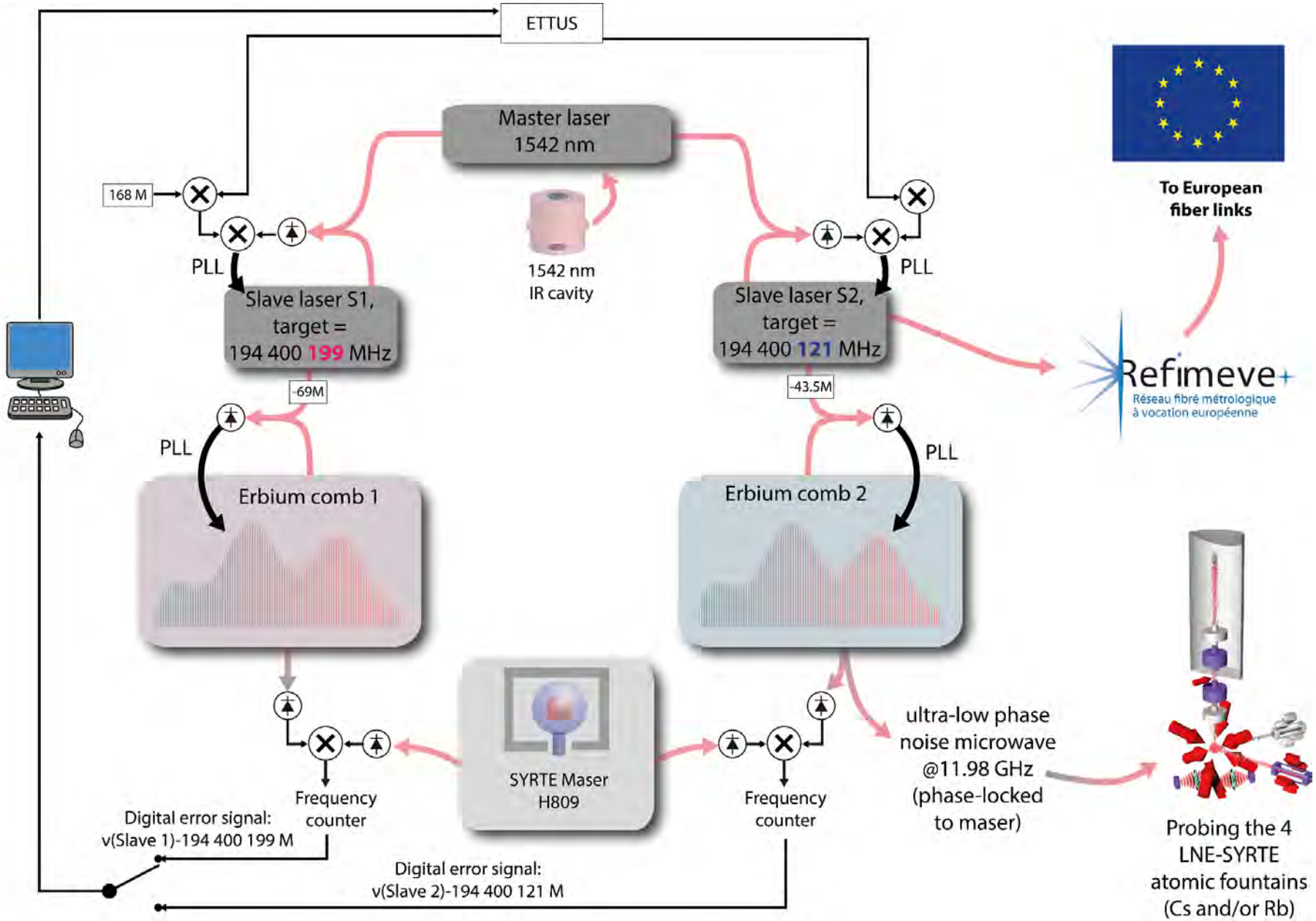
- ⇨ Distribute an ultrastable frequency signal to all the REFIMEVE users
- ⇨ Through the years, we transformed this signal into a frequency reference, at constant frequency (in average)
- ⇨ Consequence: users know exactly the frequency they receive

REFIMEVE+ network and international links to NMIs



Labs	Received frequency
SYRTE	194 400 121 000 000 Hz
LPL	194 399 970 500 000 Hz
LP2N	194 400 008 500 000 Hz
PIIM	194 400 008 500 000 Hz
LKB Jussieu	194 400 008 500 000 Hz
PhLAM	194 400 084 500 000 Hz
LAC	194 400 008 500 000 Hz
LIPHY	194 400 008 500 000 Hz
ISMO	194 399 896 500 000 Hz
OCA Calern	194 399 970 500 000 Hz
LCAR	194 399 970 500 000 Hz
LAAS	194 399 970 500 000 Hz
CNES	194 400 008 500 000 Hz
CERN ALPHA	194 400 008 500 000 Hz
IJCLab	194 399 970 500 000 Hz

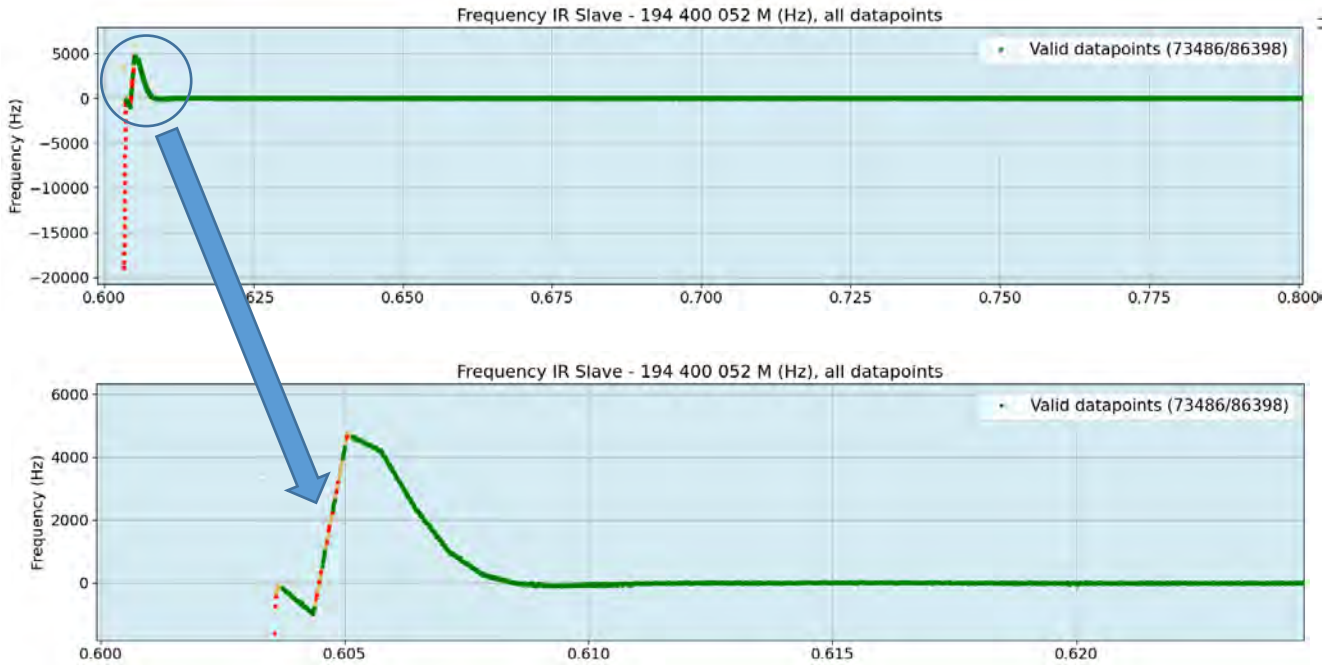
Generation of the signal



The feedback in practice

PRINCIPLE?

- Hybrid optical oscillator at 1542 nm:
  - Locked to an ultrastable fabry-Perot cavity on short timescales
  - slowly locked to a maser, with a timescale of a few 10 s
- The resulting hybrid oscillator benefits from the short term stability of the optical cavity and from the long term stability of the maser



IN PRACTICE

- External actuator (ETTUS) correcting the frequency of the laser locked to the free running cavity:

$$\nu_{\text{Slave}} = \nu_{\text{Master}} + f_{\text{OFFSET}}$$

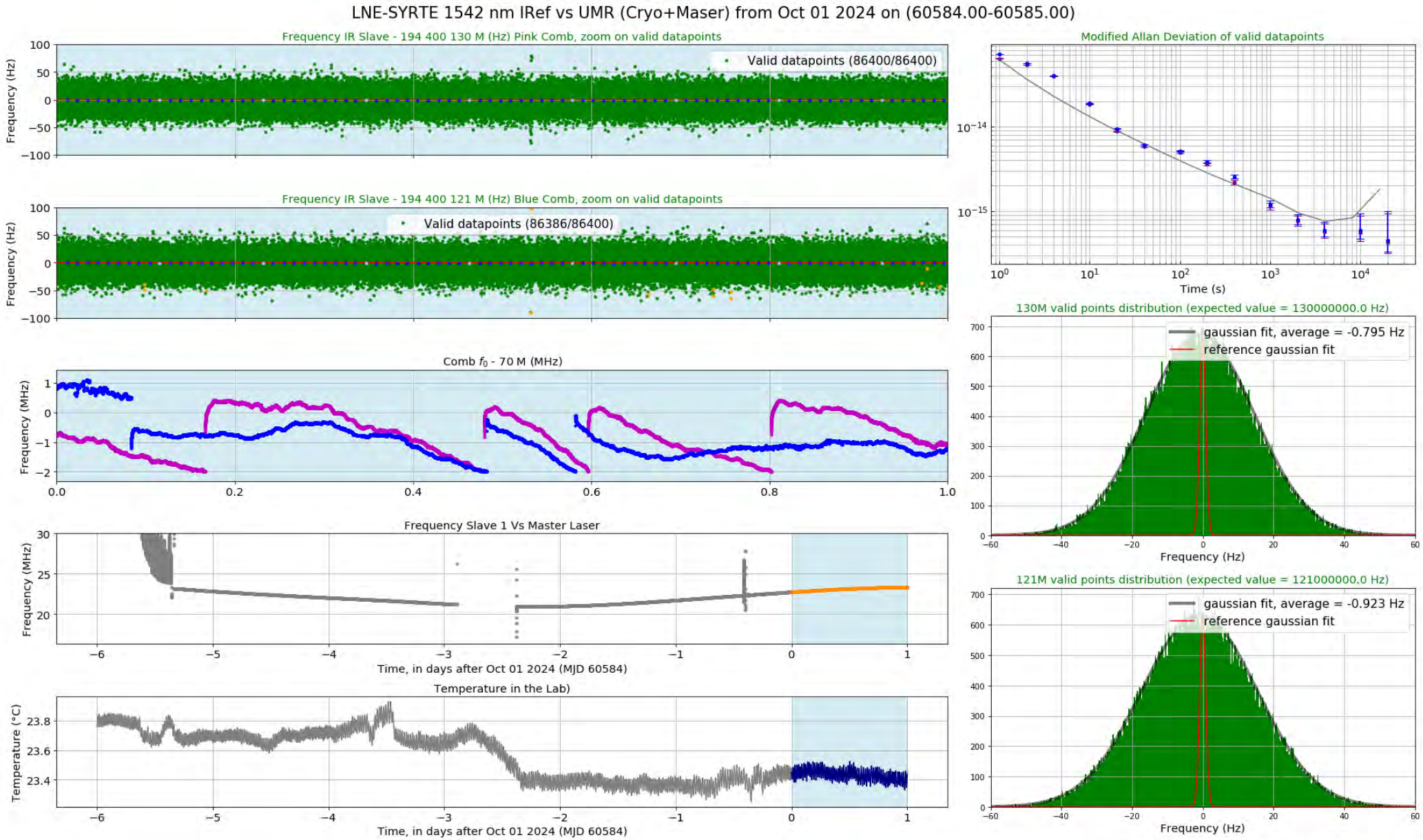
- A frequency comb locked to the slave laser allows reading ν_{Slave}

- Frequency behavior over segment N is fit by $\alpha_N(t - t_{N+1}) + \beta_N$
- Frequency of the ETTUS over segment $N+1$ is corrected such as:

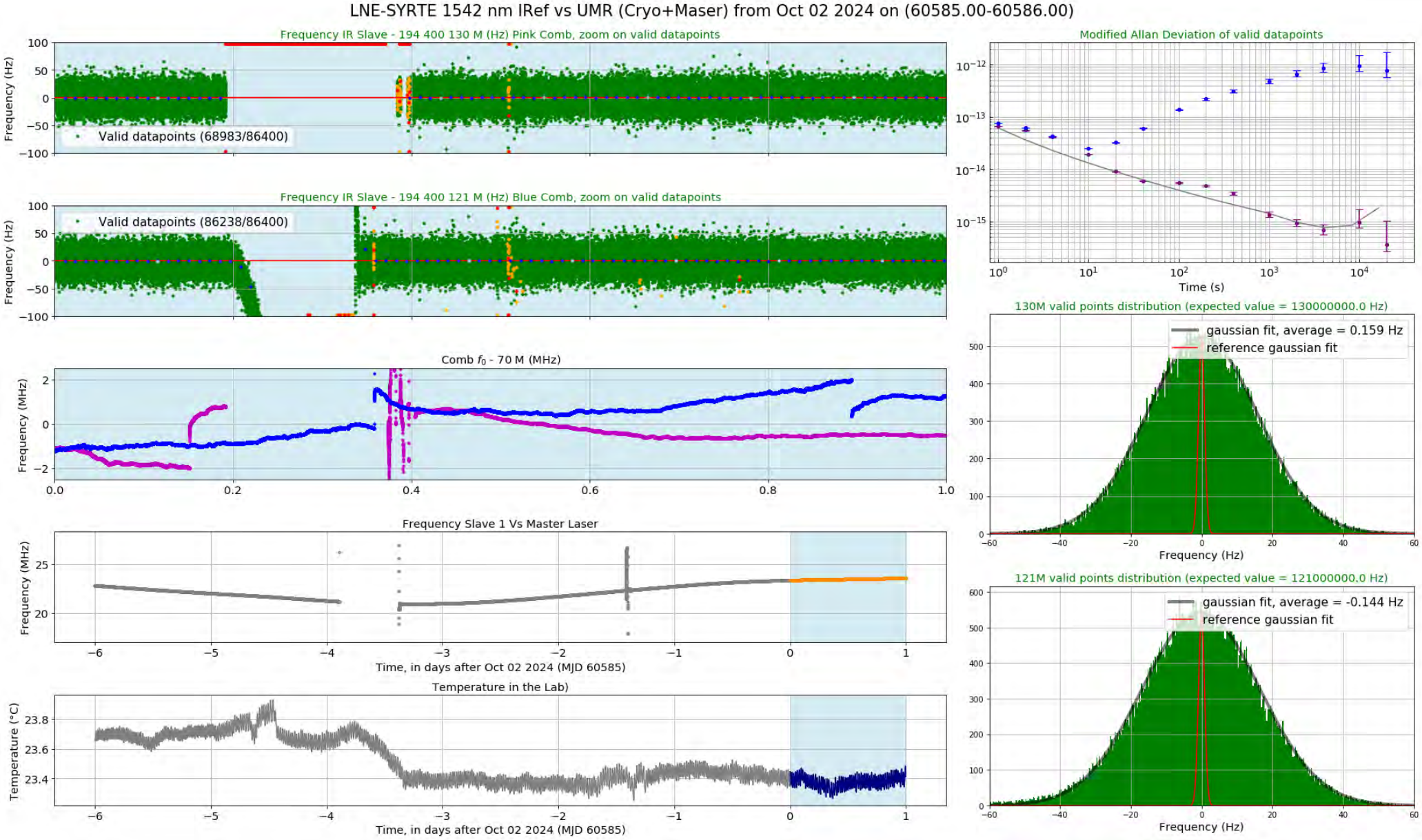
$$\left(\frac{df_{\text{OFFSET}}}{dt}\right)_{N+1} = \left(\frac{df_{\text{OFFSET}}}{dt}\right)_N - \alpha_N - \frac{\beta_N}{T}$$

Fit over 60 seconds of data, updated every 5 seconds, constant T=100 s

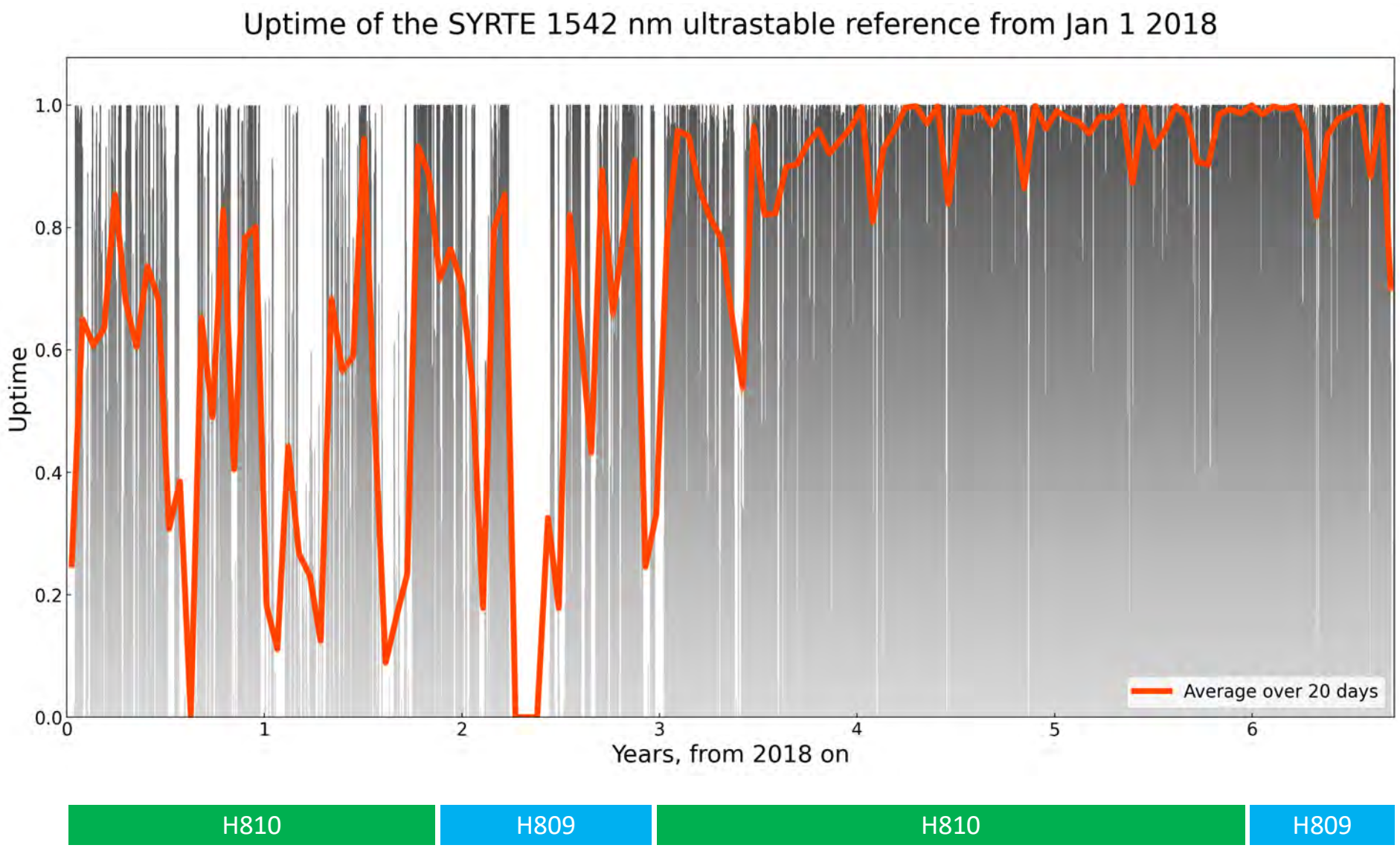
Daily reports



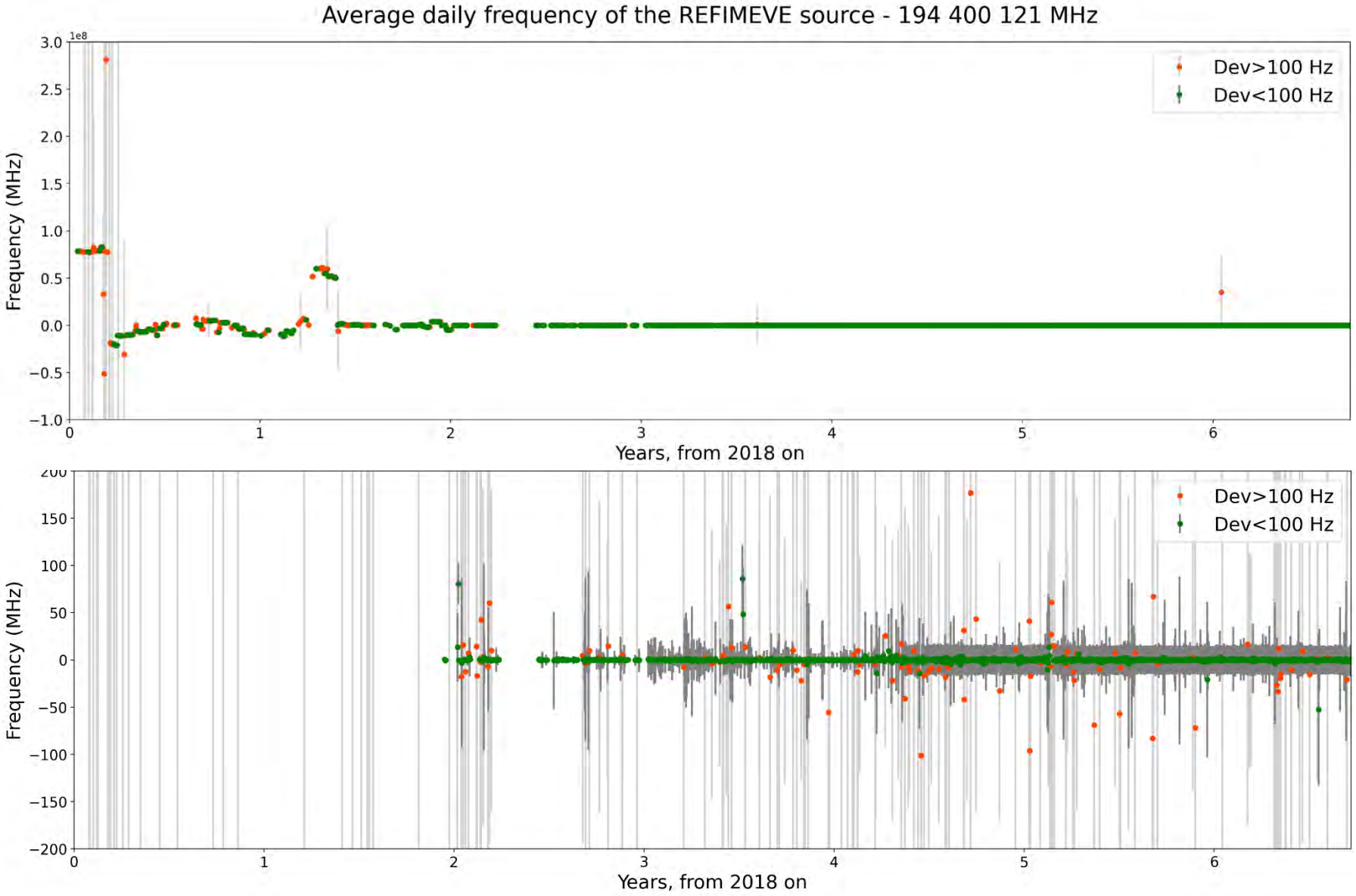
Daily reports



Uptime of the 1542 nm frequency reference

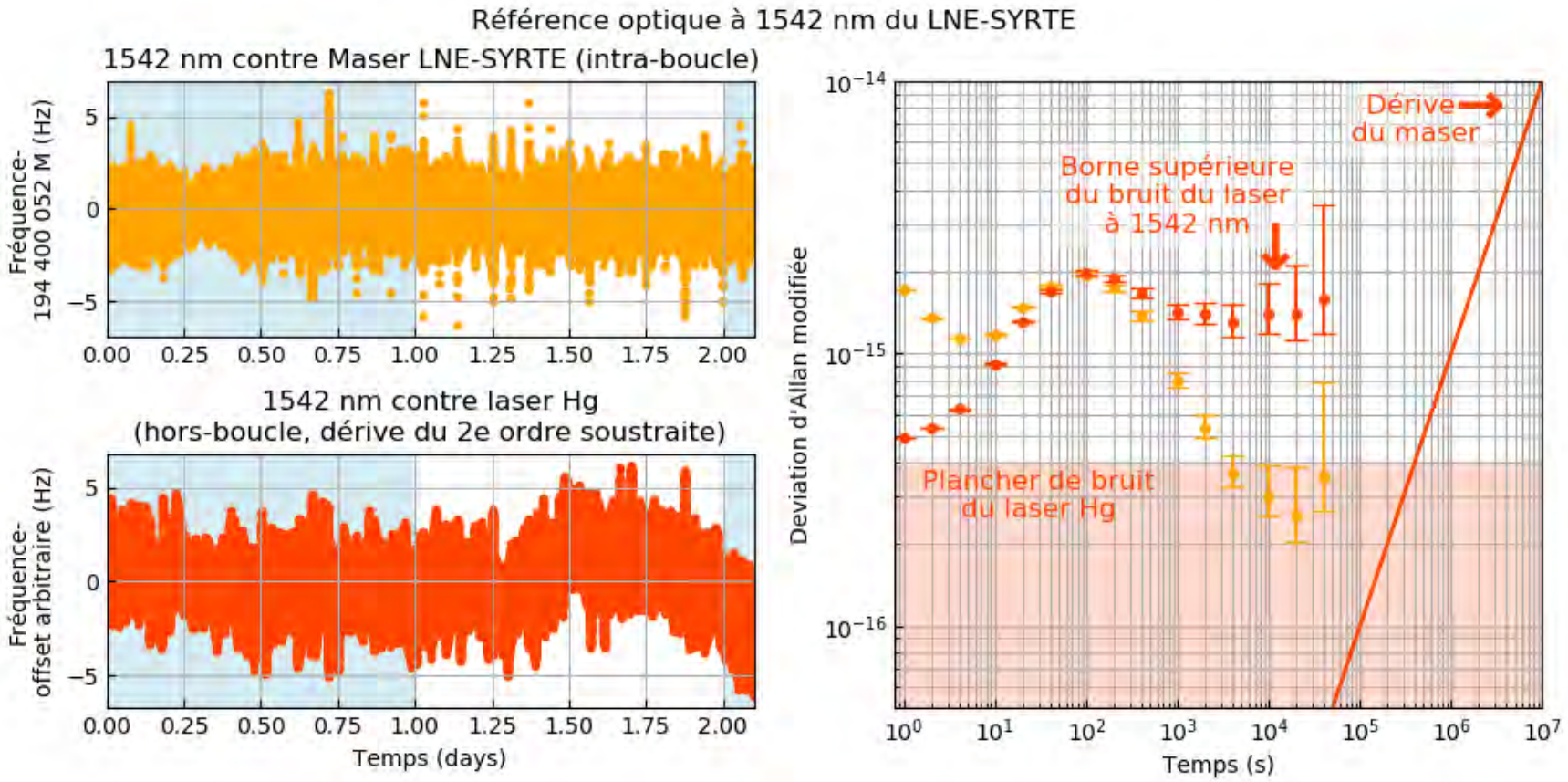


Frequency of the reference @SYRTE



Performance of the source

- Locally, the 1542 nm carrier is measured against the maser and against ultrastable lasers at 1160 nm, 1062 nm and 698 nm



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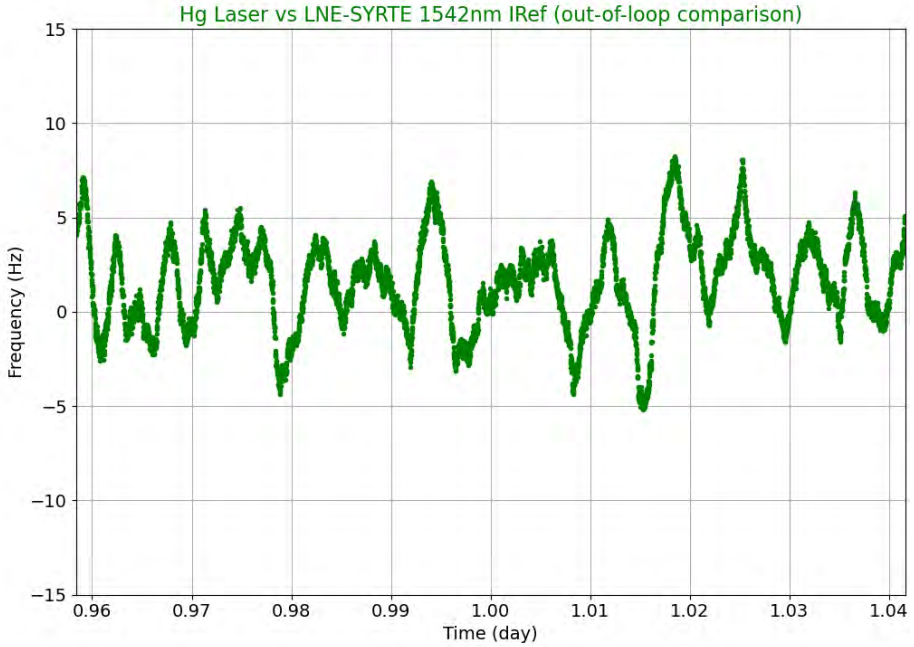
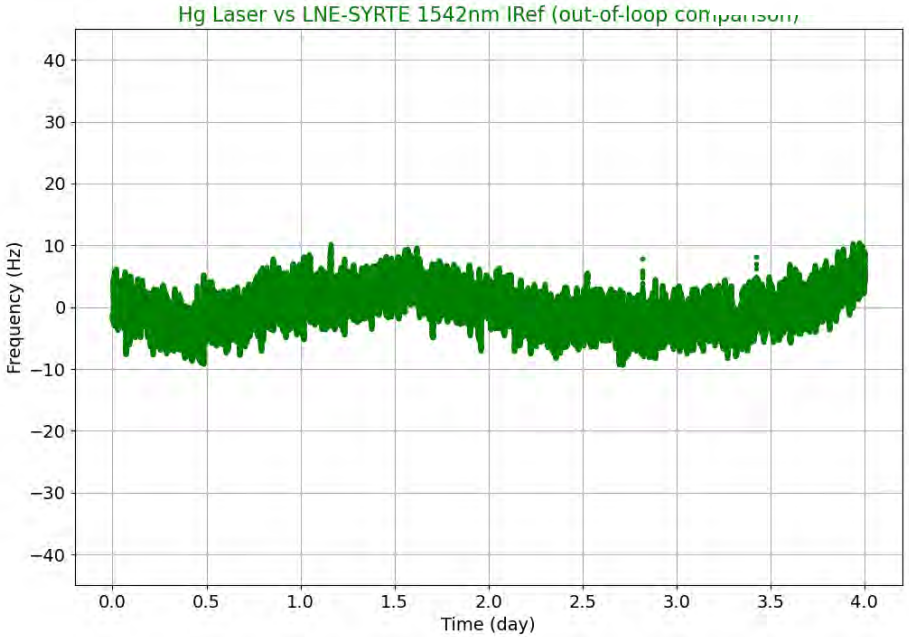
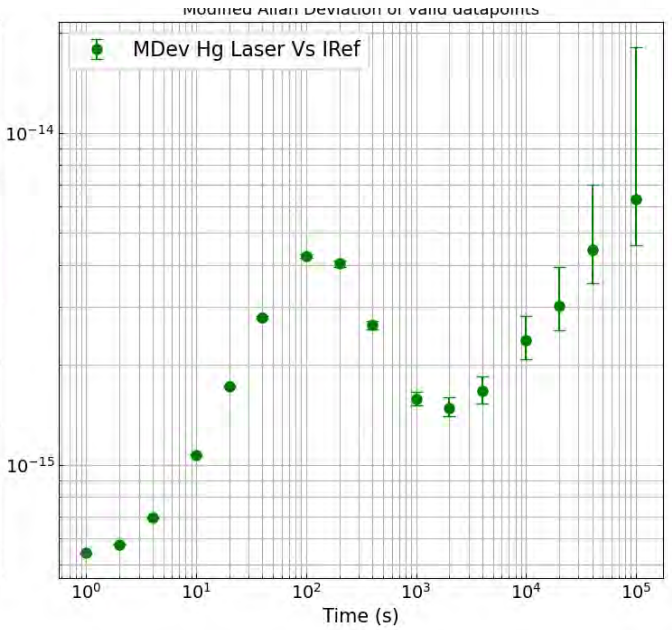
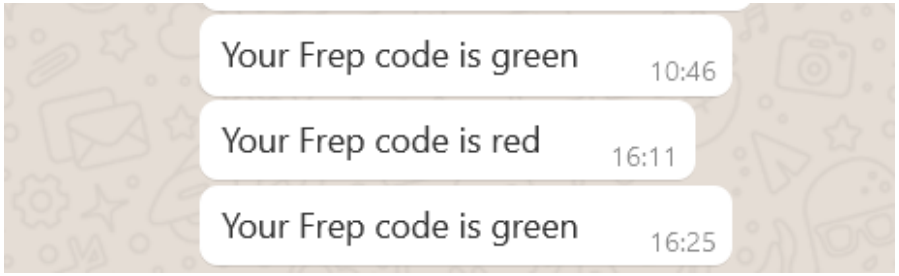


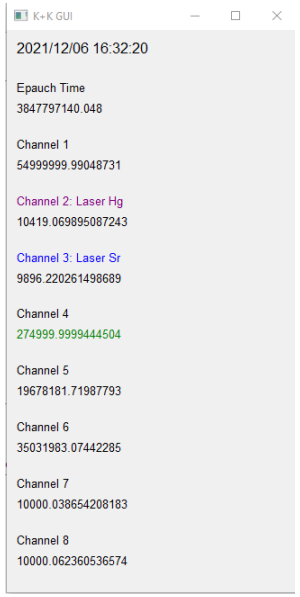




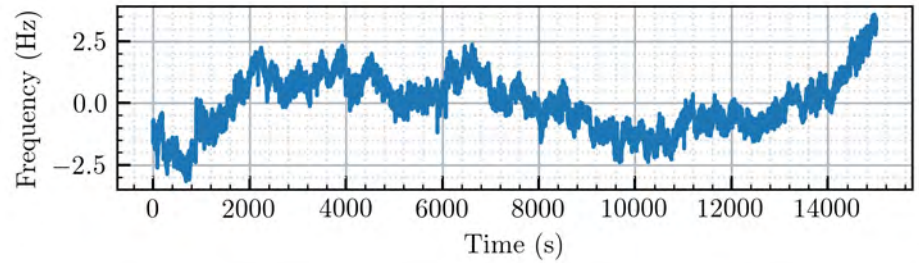
Why doesn’t it work all the time ?

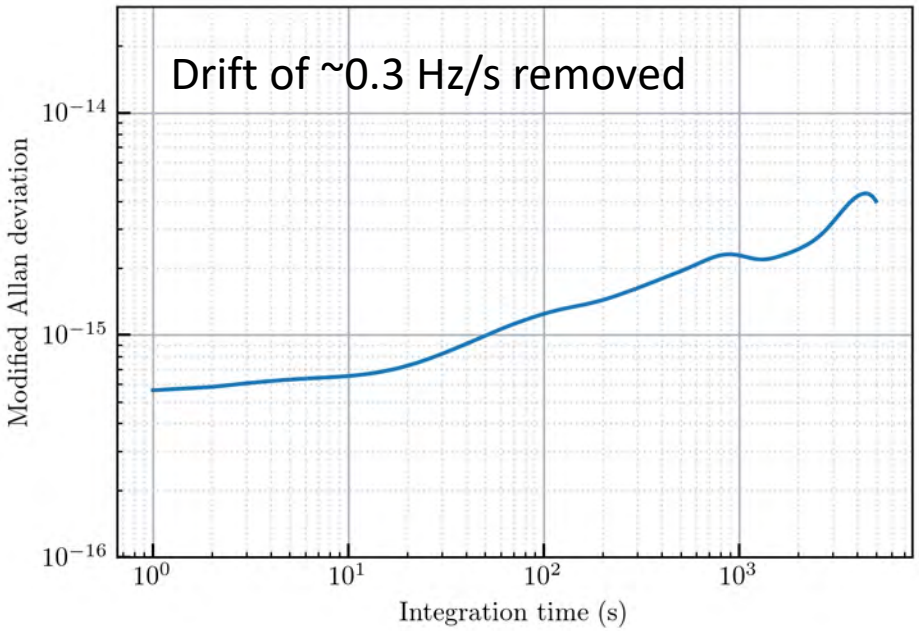
- Highly operational but still …
  - We don’t have auto-relocks everywhere
  - Room shared between several projects





- New source under development





Local RF reference for onboard instruments, aka how to use REFIMEVE in the RF domain

- REFIMEVE delivers an **accurate** IR Reference (ultrastable laser steered to stick to the maser), eg at LP2N:

194 400 008 500 000 Hz in average, with excursions <+/- 20 Hz

- How do we fabricate a 10 MHz signal out of that? With a frequency comb, we phase lock a beatnote between REFIMEVE and a freqency comb to a DDS itself referenced to an harmonic of f_{rep}:

$$\nu_{\mathrm{REFIMEVE}} - \mathrm{N} f_{rep} = n f_{rep}$$

- This way, we build an accurate 250 MHz (and subsequently 1 GHz, 10 MHz and 100 MHz) by dividing the optical frequency by an float number controlled over > 20 digits:

$$\frac{\nu_{\mathrm{REFIMEVE}}}{N + n}$$

adjusted to be as close as possible to 250M

Comb N number

Fraction <1 added with DDS

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- Exemple:
  - N=777600,
  - And DDS clocked by $4f_{rep}$, (~1 GHz), with a tuning word of 2 392 537 302 040 leads to $n = 0.033999994397163911113281 25$
  - In the end:

$$f_{rep} = \frac{\nu_{\mathrm{REFIMEVE}}}{N+n} = 250\ \mathrm{MHz} + 2.63\ \mathrm{pHz}$$

Error of $\sim 10^{-20}$, that will be reported in the 10 MHz signal once rescaled! (+maser error: continuously measured at SYRTE against Cs and Rb in microwave fountains),

Conclusion

- Infrared carrier with a stability of 5×10^{-16} at 1 s
- Average frequence disciplined to the SYRTE Master maser (drift $\sim 5 \times 10^{-16}$ at 1 day, a few 10^{-14} per year)
- Instantaneous fluctuations estimated to be +/- 5 Hz
- Uptime usually good (>99% in 2023) until recently … we'll recover!

Whad'U need?

- **13** digits? No need to do anything
- **14** digits? Quick email will suffice
- **15 or 16** digits?

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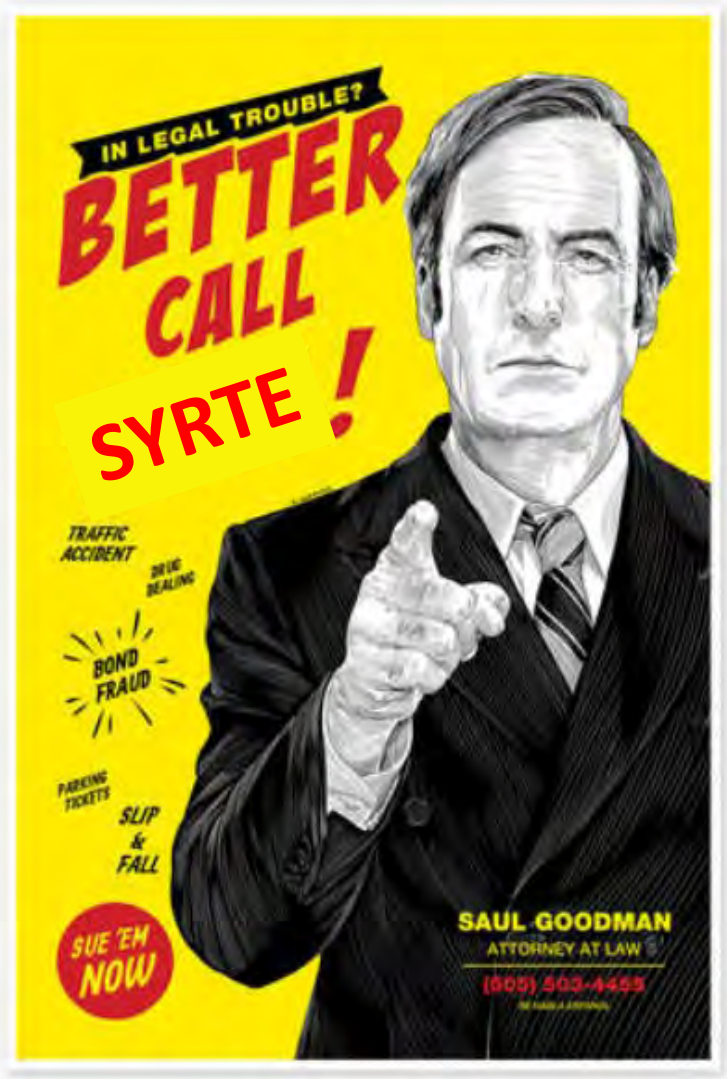

Benjamin POINTARD
(Post-doc, IR CNRS from Dec 1 2024)

Rodolphe LE TARGAT