AdV mirror force requirements for calibration

L. Rolland

- Summary of calibration excitation on the mirrors
- Mirror actuation calibration
  - Asymmetric Michelson (see note VIR-0119A-13)
  - LN1/HP and LN(i)i/LN(i+1) calibration

Summary of mirror excitations for calibration

Dedicated ITF configurations

- Free swinging Michelson configurations (WE-NI, WI-NE, WI-NI)
  - Lines on BS, WI, WE, NI, NE mirror actuation in HP mode (5 Hz ➡ 2 kHz)
- Standalone coil driver measurements: LN1/HP, LN2/LN1 of mirror actuation
  - Lines/wide noise on BS, WE, NE (+WI, NI, PR, SR ?) (➡ 2 kHz) in all the modes

→ Calibration of BS and arm mirror actuation

- Locked cavity PR-BS-WI (HP or LN1)
  - Lines/wide noise on PR and BS (5 Hz ➡ 300 Hz)

→ Calibration of PR mirror actuation

- Locked cavity SR-BS-NI ? (HP or LN1)
  - Lines/wide noise on SR and BS (5 Hz ➡ 300 Hz)

→ Calibration of SR mirror actuation

- Locked arm cavities NI-NE / WI-WE (HP and LN1)
  - Lines/wide noise on NI and NE / WI and WE (5 Hz ➡ 2 kHz)

→ Cross-calibration/validation of arm mirror actuation

- Free swinging arm cavities
  - A line at few Hz on NE and WE (~1 Hz)

→ Arm cavity finesse estimation

- Free swinging Michelson configurations (WI-NI)
  - Lines on BS, WI, WE, NI, NE marionette actuation (5 Hz ➡ 50 Hz)
  - Lines on BS, WI, WE, NI, NE mirror actuation in LN1 mode (5 Hz ➡ 100 Hz)

→ Cross-check of mirror (LN1) and marionette calibration

Summary of mirror excitations for calibration

Dedicated injections in “step 12”

- Marionette calibration in “step 12”
  - Lines/wide noise on mirror and on marionette (5 Hz ➡ 300 Hz)

  → Calibration of marionetta actuation

- ITF transfer function measurement in “step 12”
  - White noise on NE and/or WE (5 Hz ➡ 2 kHz)

  → AdV sensitivity curve measurement + horizon

- Calibration lines in “step 12”, with signal-to-noise ratio >100
  - Few lines on BS, WE, NE, NI, NE, PR, SR mirrors (~15 Hz / 100 Hz / 500 Hz / 1 kHz)

- Check of h(t) in “step 12”
  - Lines/wide noise on WE and NE (9 Hz ➡ 2 kHz)

  → h(t) reconstruction and validation

- Hardware injections in “step 12”
  - Fake h(t) signals on WE and/or NE

  → Hardware/blind injections

- Mirror actuation calibration with photon calibration, in “step 12”
  - Lines on the mirrors (5 Hz ➡ few kHz)

  → Mirror actuation calibration (independent cross-check)

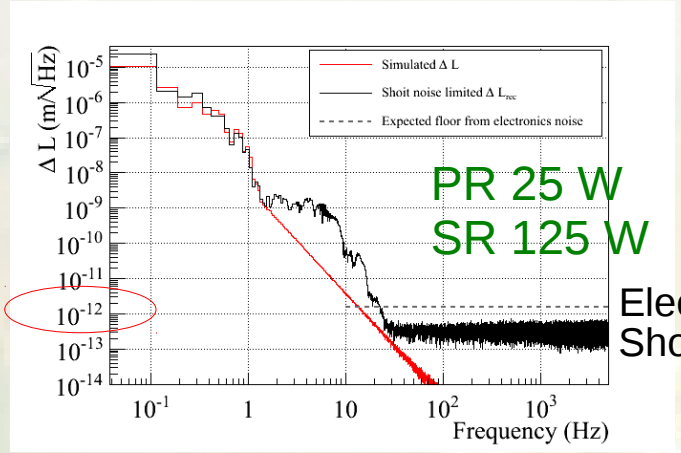
Summary of mirror excitations for calibration

- Injections in step 12 should not be critical regarding force applied on the mirrors.
  - Signal-to-noise ratio > 100 for the calibration lines
    (mainly the ones around ~100 Hz used to monitor gain/finesse for hrec)
  - Signal-to-noise ratio ~ 10 can be enough for the wide noise injections
- Injections for locked cavities should not be critical neither
  - To be confirmed by ISC
- The critical injections are for dedicated ITF configurations, in particular:
  - free swinging Michelson configurations in HP mode
  - LN/HP calibration with standalone coil driver measurements

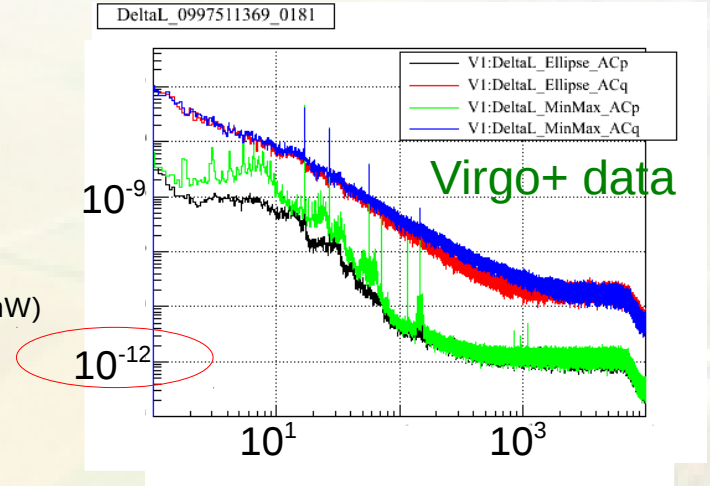
These are the two main measurements for mirror actuator calibration

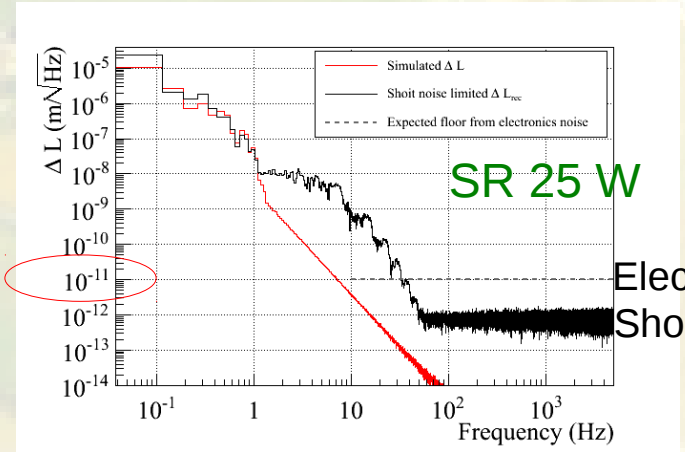
Free swinging Michelson data

- Simulations of free swinging Michelson data and reconstruction of ΔL using Siesta software
  - Simulation of B1p DC and AC signals
  - Apply the ΔL reconstruction on the simulated signal --> calibration data sensitivity curve
  - *See results in note VIR-0119A-13 (+ Virgo week slides VIR-0150A-13)*



Elect noise (DC ~ 1 mW)
Shot noise





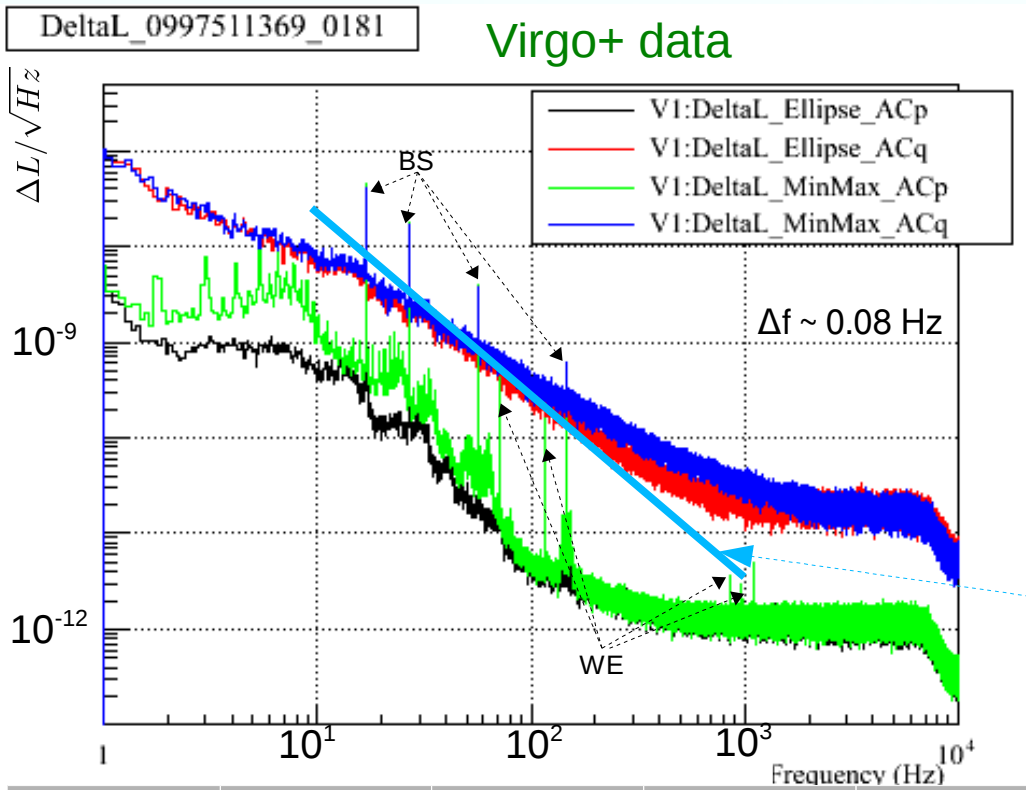
Elect noise (DC ~0. 1 mW)
Shot noise

- Sensitivity in ΔL not better than for Virgo+

With mirrors of 42 kg, and coupling of 0.7 mN/A, 1 V would induce a force of 0.1 mN:

➜ Actuator calibration precision decreasing from ~100 Hz and ~300 Hz for sensitivity floors at 10^{-11} m and 10^{-12} m

Free swinging Michelson data: case of Virgo+



Mirror mass ~ 20 kg

Coil driver conversion ~ 1 A/V
Actuator conversion ~ 1 mN/A
} ~ 1 mN/V/coil

$$\Delta z = \frac{1}{(2\pi f)^2\, m} \times F$$

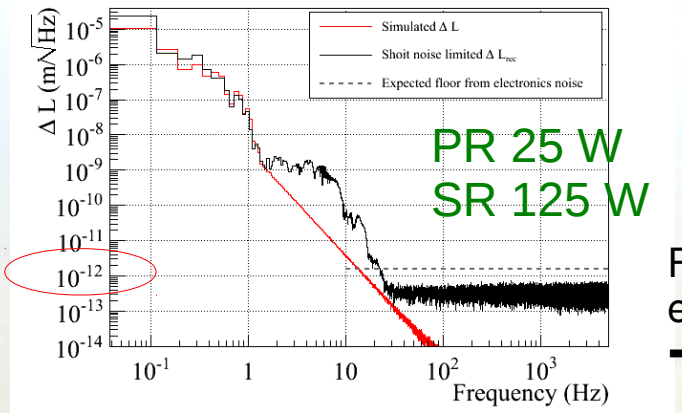
Typical injections, during 3 minutes
- NE, WE: 2 to 5 lines with amplitudes 0.1 to 0.3 V
- BS: few lines with amplitudes 1 to 3 V

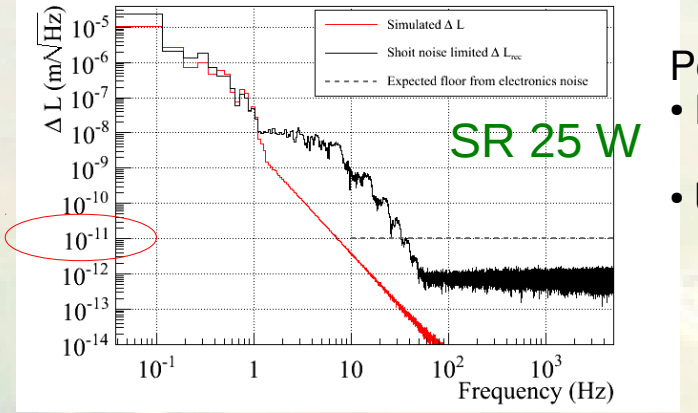
0.3 V line excitation, 2 coils (WE, U-D or L-R)
- 10 Hz ➡ 7e-9 m
- 100 Hz ➡ 7e-11 m
- 1 kHz ➡ 7e-13 m

F (Hz)	17	27	57	71.5	116.5	147	851.5	951.5
Exc (V)	1.7	1.7	1.7	0.3	0.3	1.7	0.3	0.3
ΔL (10^{-12} m)	11000	5100	1000	110	40	150	1	0.8
Mirror	BS	BS	BS	WE-UD	WE-LR	BS	WE-UD	WE-LR
Noise (10^{-12} m/rHz)	800	110	20	10	4	2	1.	1.
"SNR" (rHz)	14	45	50	11	**10**	75	**1**	0.8
Coherence	1	1	1	0.999	**0.999**	1	**0.845**	0.775
Gain stat. error	0.06%	0.1%	0.07%	0.6%	**0.5%**	0.1%	**7%**	10%
Phase stat. error (degrees)	0.037	0.065	0.039	0.34	**0.31**	0.058	**4.3**	5.9

$$SNR = \frac{\Delta L}{Noise}(\sqrt{Hz})$$

Free swinging Michelson data: case of AdV





Mirror mass ~ 42 kg

Coil driver and current to force conversion TBD

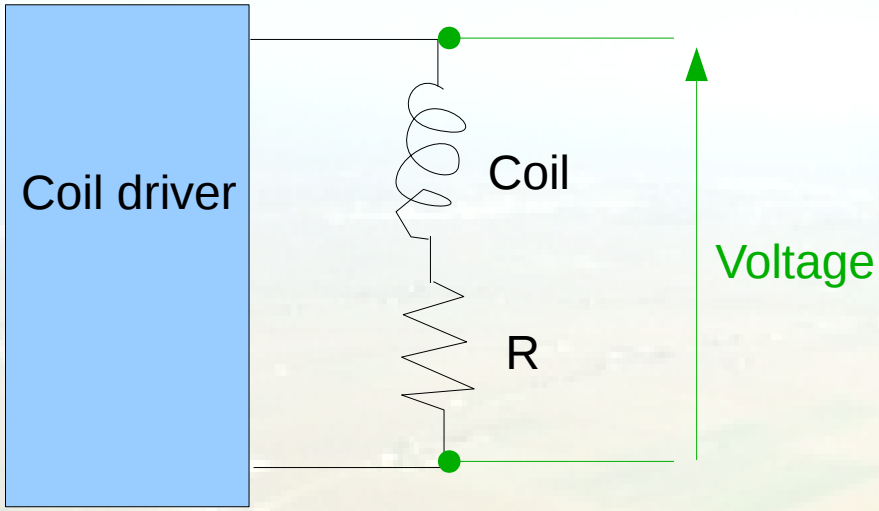
Free Michelson sensitivity similar to Virgo ones,
even worse in the case of SR 25 W configuration
➡ similar mirror motions required in HP mode for calibration

What will be the maximum current allowed the coils for few minutes ?

Possible ways to improve the measurements:

- Increase injection duration
  - Improve measurement in sqrt(duration) -> not very efficient (minutes -> hours)
- Use another beam instead of B1p (to have more power)
  - Use B2 beam
    - Need to check in Virgo+ data
    - Need to check the expected power on AdV B2 photodiodes
  - Use B1
    - Big challenge: need to lock the two OMCs with swinging mirrors
    - Effect of sideband attenuation ?
    - Effect on higher-order modes ?
- Pick-off more power on B1p
  - Constant pick-off cannot be increased (too high losses towards B1)
  - Would need a flip mount mirror on SDB1, quite complicated
  -
- Improvement to be done:
  - Try to reduce non-linear noise in ΔL reconstruction (but only below 100 Hz)

HP/LN measurements



What is the sensitivity of this sensing channel in term of current flowing in the coil, in the different modes, HP, LN1, LN2, ... ?

Aim: have this single sensing channel sensitive to:
- high currents sent in HP mode during free swinging Michelson (5 Hz to >1 kHz)
- medium currents sent in LNi modes during calibration injections (5 Hz to >1 kHz)
- if possible, low currents sent in LN1 or LN2 mode during Science Mode (5 Hz to few 100s Hz)

Conclusions

Most critical calibration measurements wrt force on the mirror are injections in free swinging Michelson configurations

- Needs are similar to what was done in Virgo+

  - 10 Hz ➡ ~5 10^{-9} m
  - 100 Hz ➡ ~5 10^{-11} m
  - 1 kHz ➡ ~5 10^{-13} m

~1 mN/mirror per line in HP mode,
i.e. ~5 mN/mirror

Needed force must be higher in SR, 25 W configuration, by a factor between 1 and 10.