Violin Modes

S2 violin team

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presented by S.Klimenko

- **Outline**
  - **Measurement of violin resonances.**
  - **Thermal noise**
  - **Plans**

S2 violin measurements

- **Measurement of PSD spectra with high resolution**
  - **UF (J.Castiglione, S.Klimenko) :**
    - **average of 10 one hour long stretches of lock data (Δf=0.28 mHz)**
    - **frequency and Q for L1, H1, H2 test masses (72 modes)**
  - **LHO (F.Raab,M.Landry,R.Berkowitz):**
    - **H1 PSD (5000sec X 10, Δf=0.2 mHz)**
    - **multi-parameter fit of H1 violin resonances (24 modes)**
- **Tracking of violin amplitudes with LineMonitor (UF)**
  - **Independent measurement of all 72 modes**
  - **Integration time 1 min**
  - **Separation of thermal and external excitations**

S2 violin frequencies

http://www.phys.ufl.edu/LIGO/LINE

H1

1		2		3	
	343.0683		686.1497		1029.4638
	343.4814		687.0558		1030.7791
	343.6558		687.3869		1031.2499
	344.4219		688.8757		1033.5375
	346.6499		693.4272		1040.3586
	346.9261		693.9294		1041.0495
	346.9752		693.9994		1041.1985
	347.0419		694.0944		1041.2845

L1

1		2		3	
	343.4152		686.9169		1030.5585
	344.0608		688.2850		1032.5874
	344.7156		689.5115		1034.4598
	344.8299		689.7416		1034.8027
	347.1790		694.2828		1041.6249
	347.2719		694.5960		1042.1226
	347.6847		695.4199		1043.3230
	347.7300		695.4811		1043.4469

H2

1		2		3	
	343.7501		687.4467		1031.3595
	343.8149		687.6720		1031.6298
	344.0508		688.1839		1032.4419
	344.1018		688.2552		1032.5908
	349.1996		698.4543		1047.8365
	349.2428		698.5652		1048.0275
	349.2817		698.6434		1048.1847
	349.6566		699.3785		1049.2395

S1

S1
343.754
343.814
344.051
344.110
349.201
349.245
349.282
349.659

measurement accuracy 0.5 mHz

Violin Frequencies and Q for H1

landry_m: LHO e-log 8/12/03

frequency, Hz

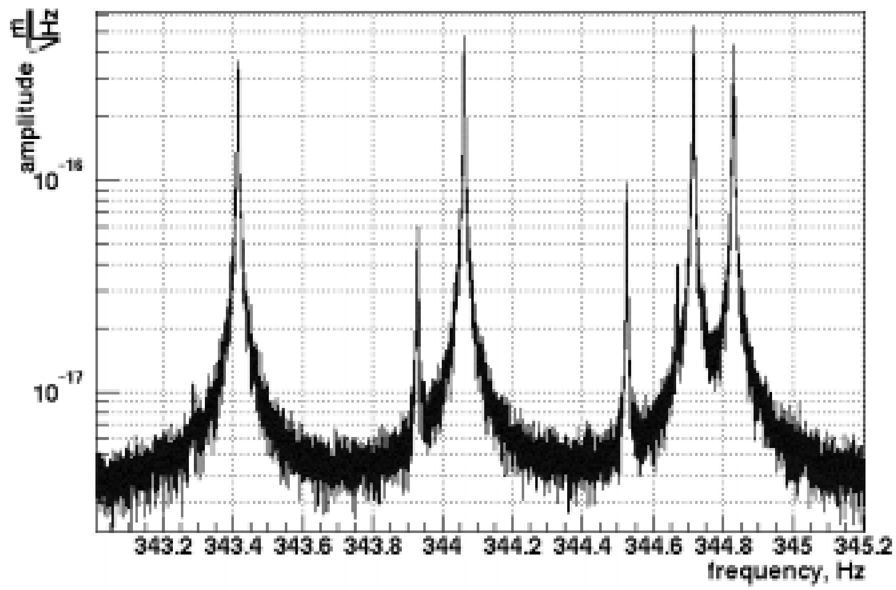
1	2	3
343.4156	686.9175	1030.5598
344.0609	688.2860	1032.5884
344.7162	689.5120	1034.4275
344.8302	689.7431	1034.8039
347.1798	694.2841	1041.6266
347.2723	694.5974	1042.1253
347.6809	695.4212	1043.3256
347.7333	695.4828	1043.4483

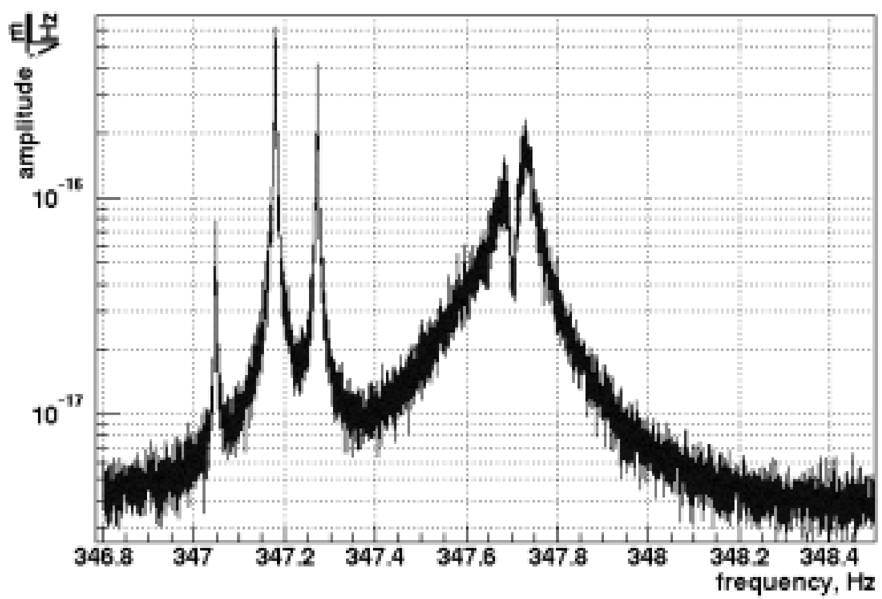
good agreement with UF measurements

Q

114141	131305	100041
102178	168904	100023
124191	84445	100100
143743	47284	100049
155091	177715	177690
116995	106881	134832
16074	144035	189356
20372	150336	200870

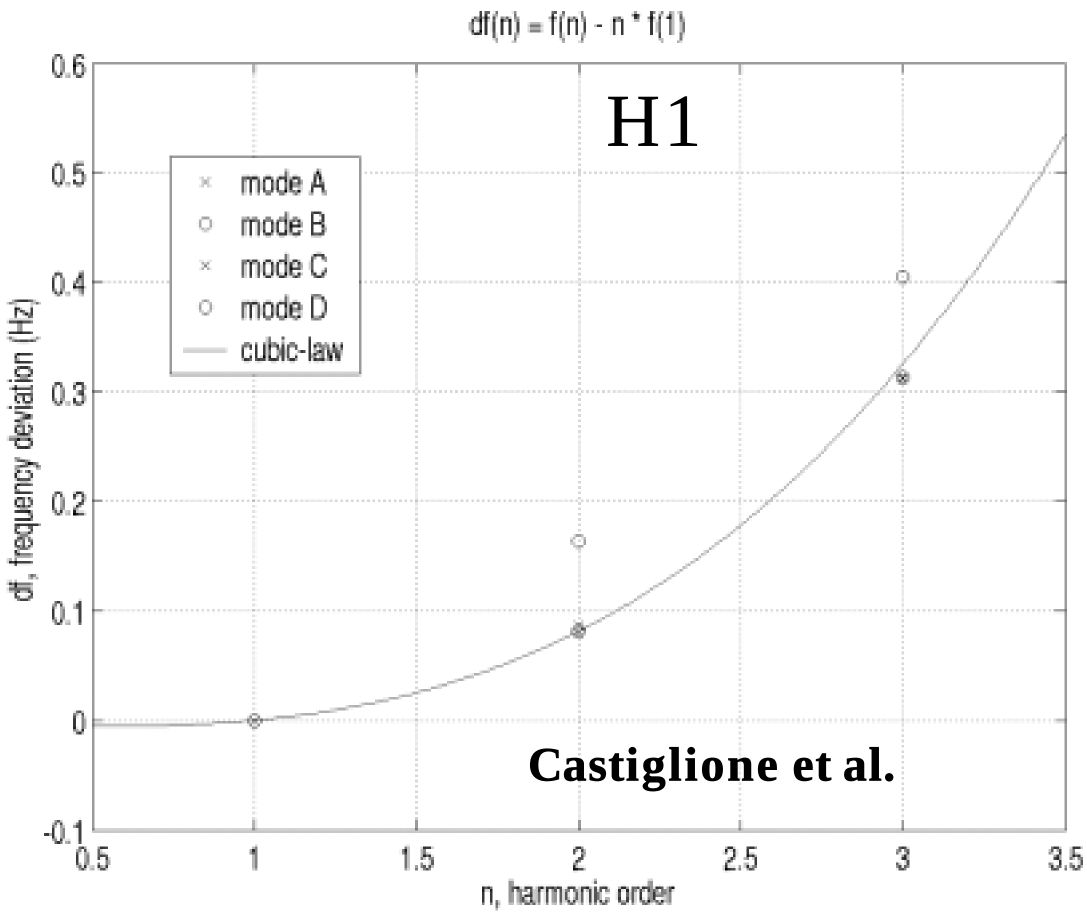
H1 first modes





Anharmonicity

$$f_n = \sqrt{\frac{T}{\rho}}\,\frac{n}{2L}\left[1 + 2\left(\frac{EI}{TL^2}\right)^{1/2} + \frac{1}{2}\pi^2 n^2\left(\frac{EI}{TL^2}\right)\right]$$ ***Gonzalez,Saulson***



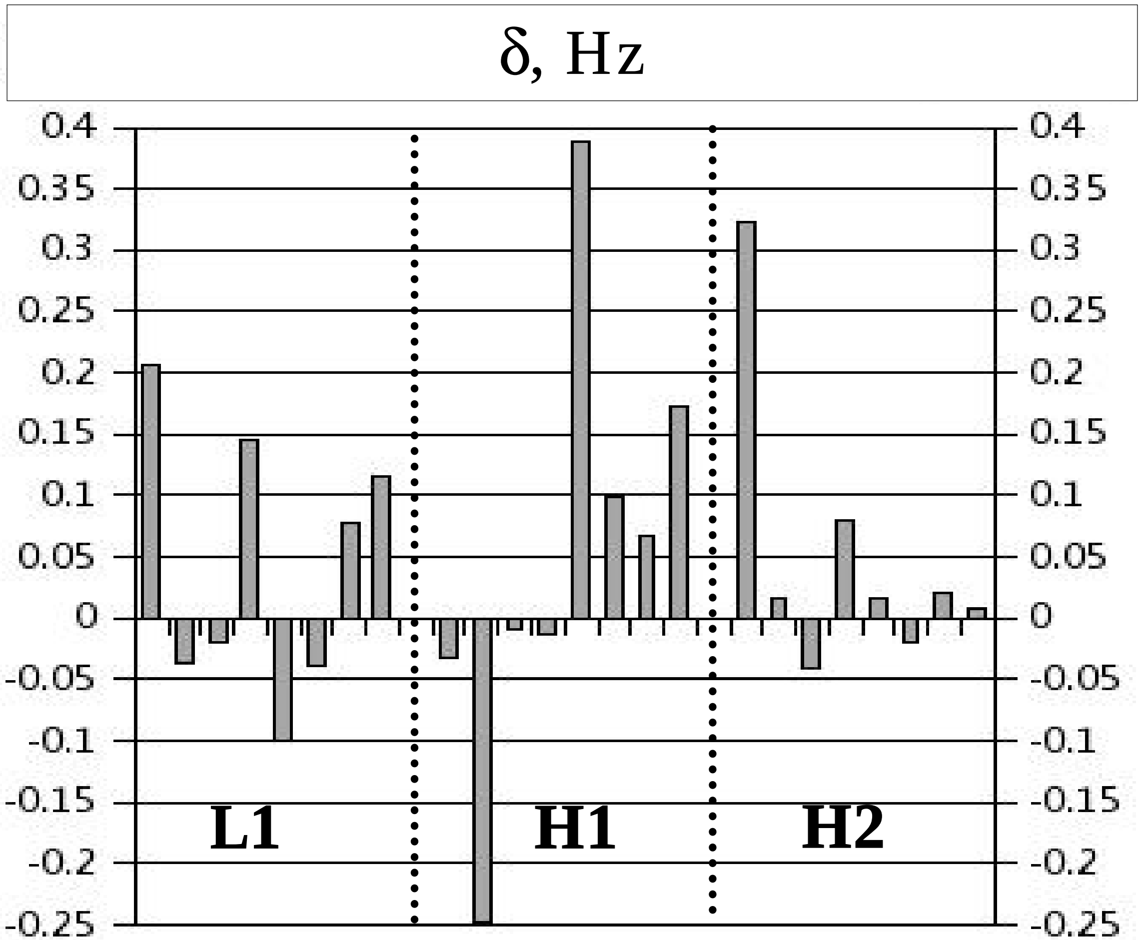
Deviation from n^3

Jason's law: $\delta = f_3 - 4f_2 + 5f_1$

$\delta \equiv 0,$

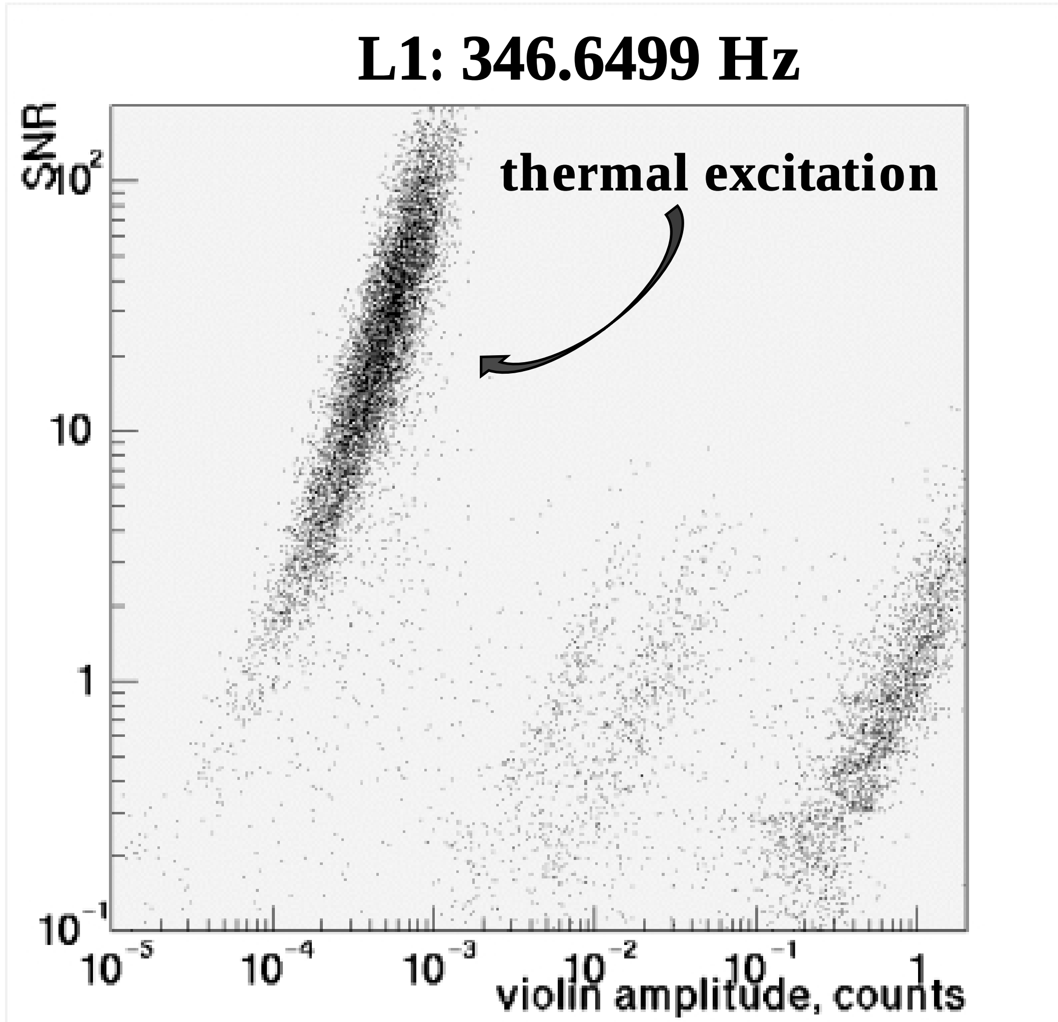
if $f_n = an + bn^3$

δ error ~5 mHz



violin amplitudes

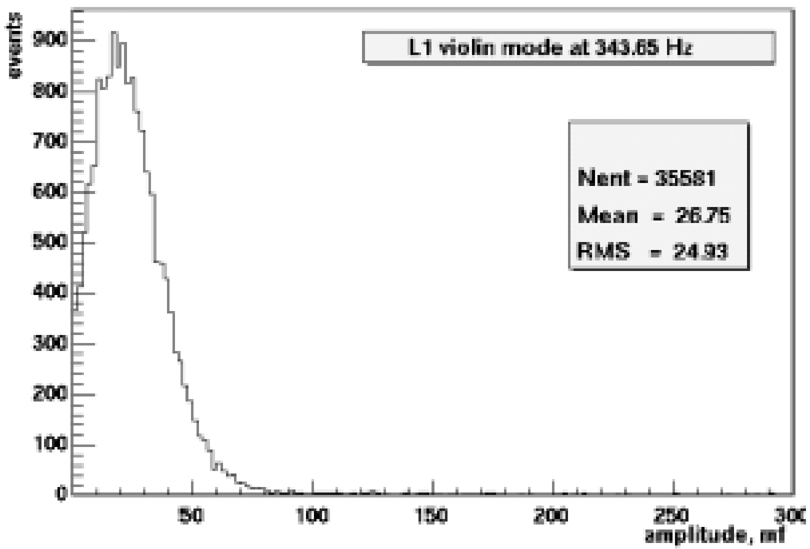
- **Measured with the LineMonitor**

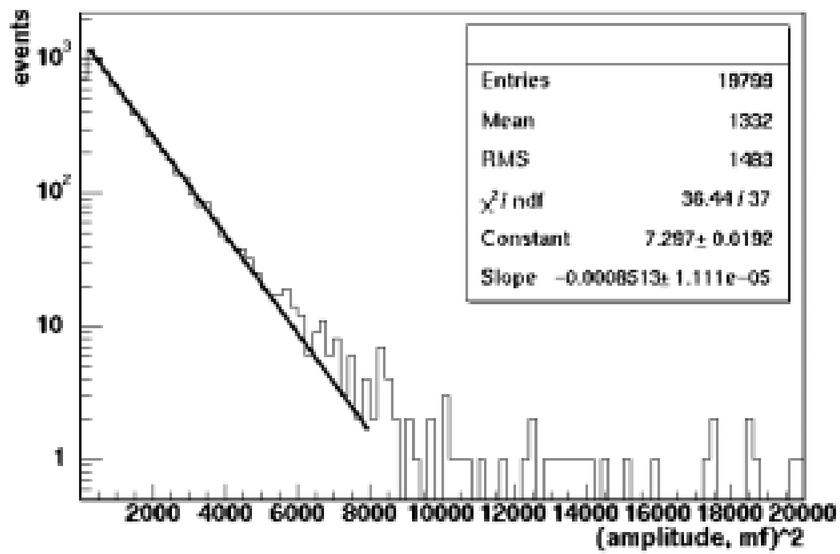


Average square amplitude

- *P(a)* – Rayleigh distribution
- *P(a²)* – exponential
  - slope *s* gives <a²>

$$\left\langle a^2 \right\rangle = s^{-1}\frac{4-\pi}{4} \sim kT$$





work in progress at UF:
run LM on 72 modes
do the amplitude analysis

Modeling of Thermal Noise

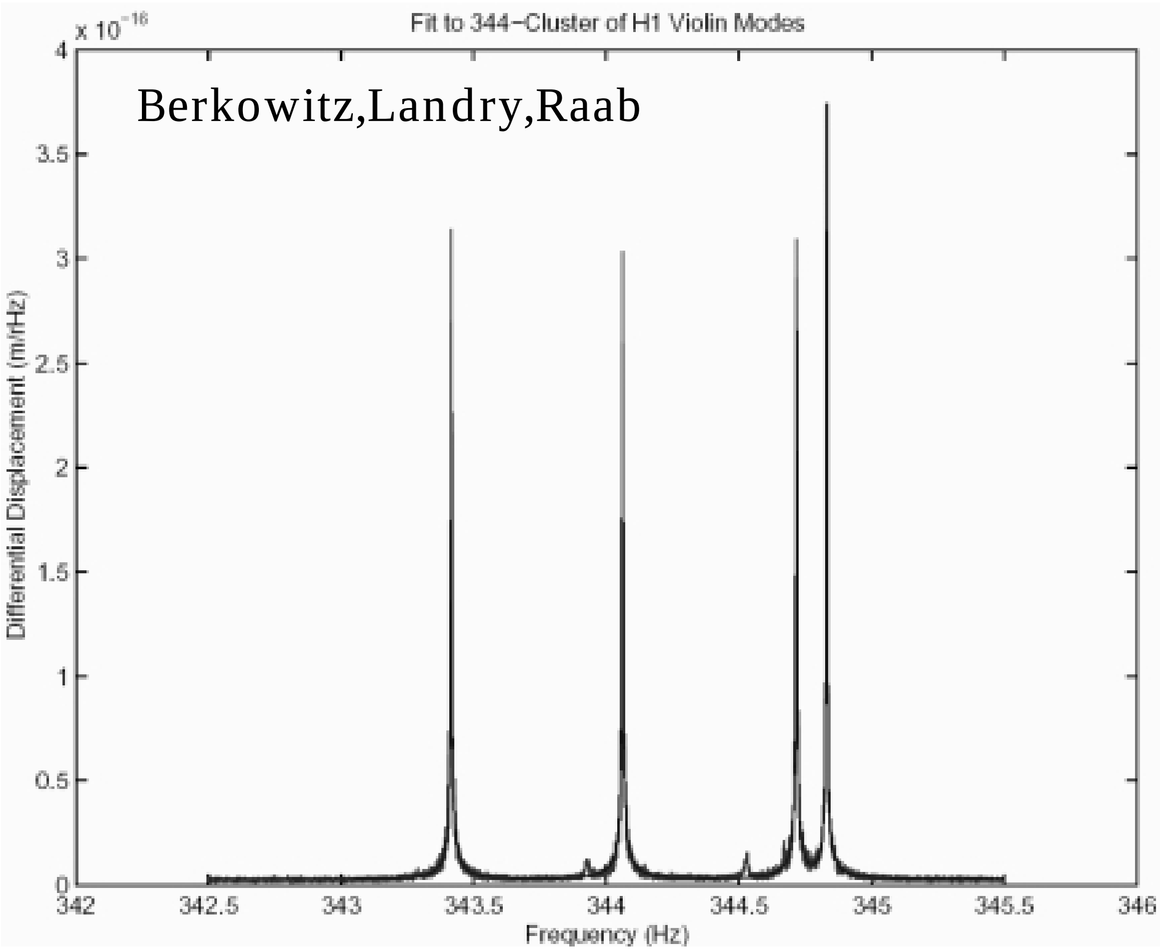
- **A.Gillespie and F.Raab, Phys.Lett. A 178 (1993) 357, Gillespie's PHD**
  phenomenological model based on anelastic oscillator.
- **G.Gonzalez and P.Saulson, J.Acoust.Soc.Am.96(1994) 207.**
  4th order beam equation for suspension wire. Predicts anharmonicity and thermal noise.
- **M.Barton** (model for LIGO LOS);
- **V.Sannibale and G.Cella**
  time-domain model of the LIGO (Advanced) suspension
- **G.Cella and A.Vicere (Urbino Summer School, 1999).**
  Mechanical Simulation Environment - allows modeling of arbitrarily complex mechanical suspensions.
- **S.Mohanty, LIGO T990014-E**
  model of LIGO Suspension based on Green functions
- **G.Cagnoli and N.Robertson, Class. Quant. Grav. 19 (2002) 4043**
  model for advanced LIGO suspension (modified by M.Rakhmanov for LIGO-I)

H1 violin thermal noise

model:

A.Gillespie, F.Raab

$$X^2(\omega) = \frac{4kT}{\mu\omega} \cdot \frac{\omega_0^2 \Phi(\omega)}{\left(\omega_0^2 - \omega^2\right)^2 + \omega_0^4 \Phi^2(\omega)}$$

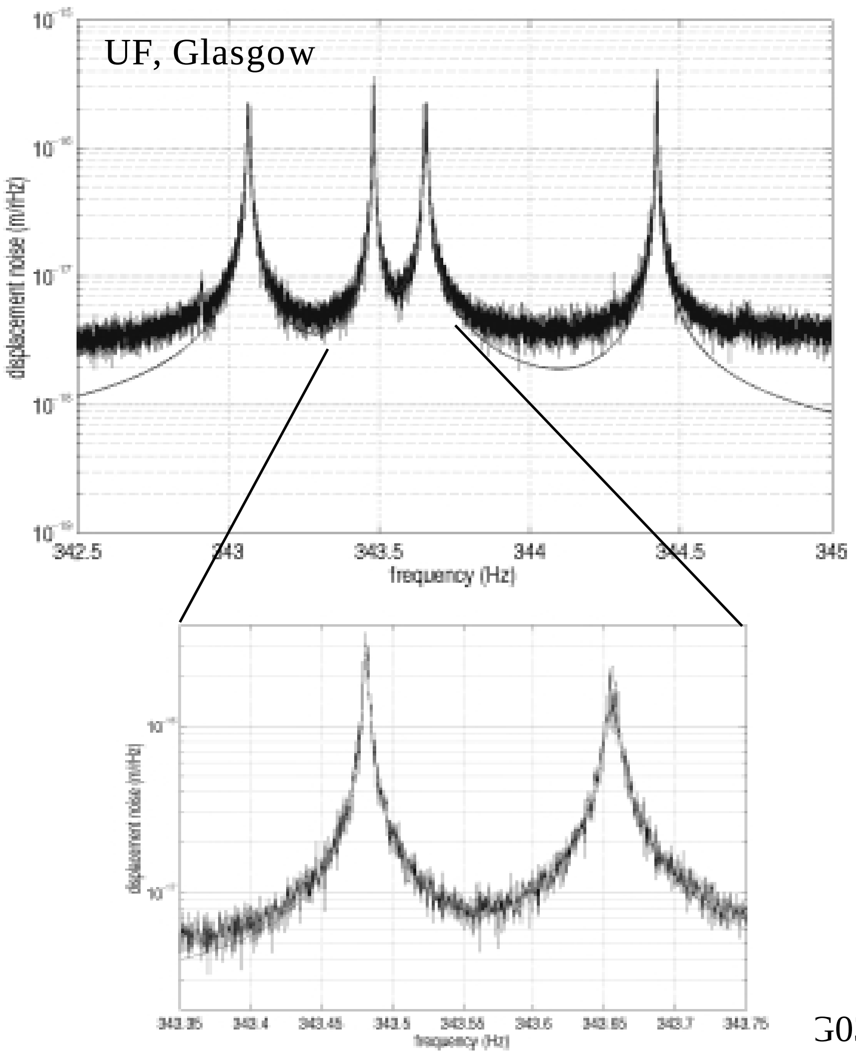


LIGO-G030457-00-Z

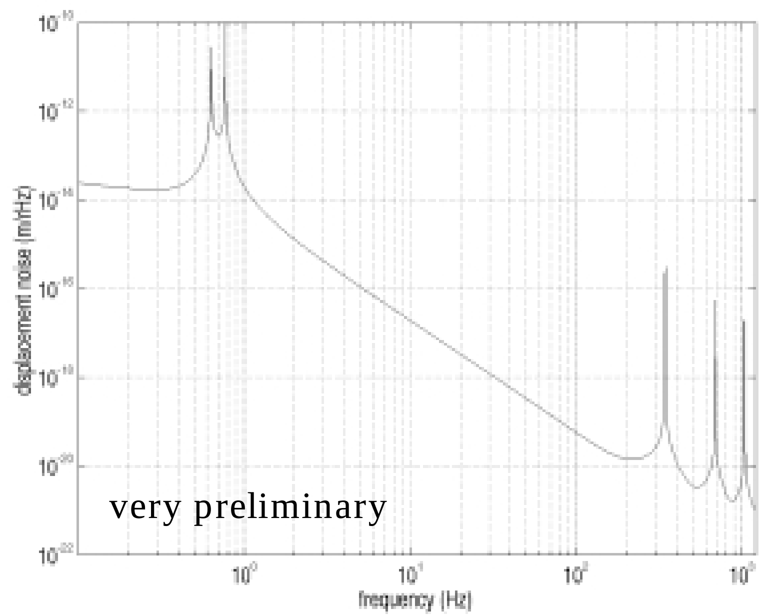
L1 violin thermal noise

Fluctuation dissipation theorem: $X^2(\omega) = 4kT \cdot \mathrm{Im}\{-H(\omega)/\omega\}$

H(ω) obtained from Glasgow model: **G.Cagnoli, M.Rakhmanov**



thermal noise for L1 first four modes



Plans

- **Complete data analysis for all three interferometers**
- **Interpretation of the experimental results & comparison with theory**
  - **deviation from n3**
  - **mode splitting**
  - **effects of calibration and servo**
  - **distribution of violin amplitudes (LineMonitor)**
  - **……..**
- **Estimation of LIGO thermal noise**
- **Look at large outliers detected by LineMonitor.**