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VIRGO

Virgo Sensitivity Curve

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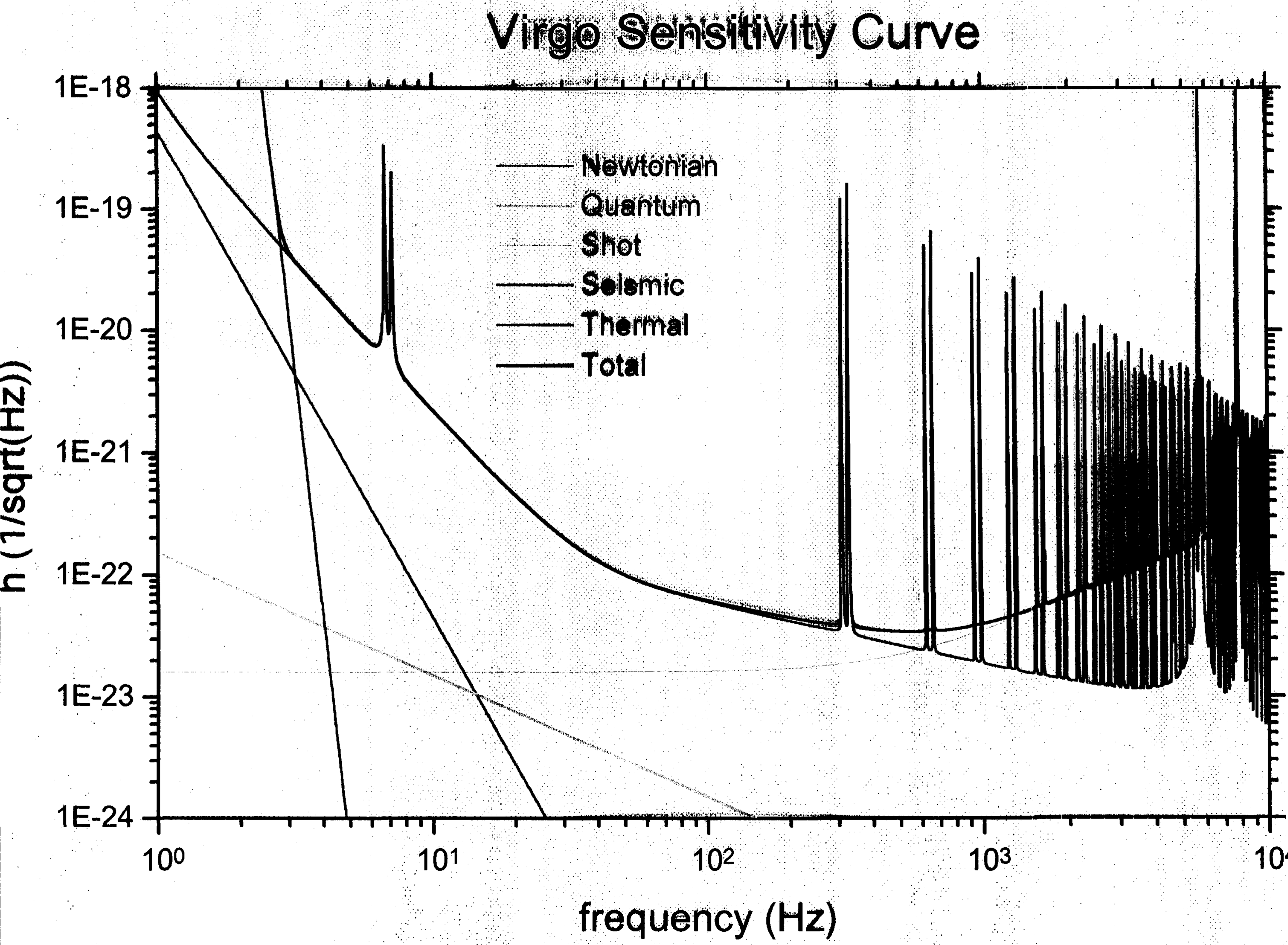
Virgo official Web site: http://www.pg.infn.it/virgo/



Virgo Sensitivity Curve
Newtonian
Quantum
Shot
Seismic
Thermal
Total
1E-18
1E-19
1E-20
1E-21
1E-22
1E-23
1E-24
h (1/sqrt(Hz))
10^0
10^1
10^2
10^3
10^4
frequency (Hz)

Shot Noise

power = 20W   fin. = 100   rec. = 50

$v0 := 500$ cut off freq.

$hstn(f) := 1.6 \cdot 10^{-23} \cdot \sqrt{1 + \left(\frac{f}{v0}\right)^2}$ $hst_{i1} := hstn(f_{i1})$

Newtonian Noise

grav. constant $G := 6.67 \cdot 10^{-11}$

Earth density $\rho e := 2000$

seismic noise (in Cascina) $PSDsys(f) := \left(\frac{10^{-7}}{f^2}\right)^2$

Plane wave param. $Dd := 200$

sound velocity $Vs := 5000$

$DxNt(f) := \sqrt{2 \cdot 12 \cdot 7.48 \cdot G^2 \cdot \rho e^2 \cdot \frac{PSDsys(f)}{(2 \cdot \pi \cdot f)^4} \cdot \sqrt{2}}$ by Saulson

$DxNt(f) := \sqrt{2} \cdot \sqrt{2} \cdot G \cdot \frac{\rho e \cdot \sqrt{PSDsys(f)}}{2 \cdot \pi \cdot f \cdot Vs} \cdot Dd \cdot e^{-\left(\frac{2 \cdot \pi \cdot f \cdot Dd}{Vs}\right)}$ by Geppo

$hNt(f) := \sqrt{2} \cdot \frac{2.7 \cdot G \cdot \rho e}{(2 \cdot \pi \cdot f)^2} \cdot \frac{\sqrt{PSDsys(f)}}{3000}$ by Thorne (ΔL)

$hN_{i1} := hNt(f_{i1}) + 10^{-100} \cdot 0$ $hNt(4) = 1.680017 \cdot 10^{-21}$

Seismic Noise (through the superattenuator)

$f0 := 0.759$ $Dsnt(f) := \sqrt{PSDsys(f)} \cdot \left(\frac{f0}{f}\right)^{18} \cdot \frac{2}{3000}$ $\left(\frac{0.759}{4}\right)^{18} = 1.016886 \cdot 10^{-13}$

$hS_{i1} := Dsnt(f_{i1})$ $Dsnt(4) = 4.237024 \cdot 10^{-25}$

Quantum limit

$Qsnt(f) := 1.5 \cdot \frac{10^{-22}}{f}$ $hQ_{i1} := Qsnt(f_{i1})$

Virgo Sensitivity Curve

General constants

Temperature		$T = 300$
Boltzman constant		$kb = 1.380658 \cdot 10^{-23}$
grav. acc.		$g = 9.8$

material properties

C85 steel (wires):	densità acciaio	$\rho w = 7.9 \cdot 10^{3}$
	cal. spec. acciaio (J/(K Kg))	$cstg = 502$
	cal.spec.per unit.vol.(J/(K m3))	$cst = cstg \cdot \rho w$
	cond. therm. acciaio (W/(m K))	$kthst = 16.3$
	coef. dil. therm. acciaio	$\alpha st = 17 \cdot 10^{-6}$
	yeld strength (Pa)	$BB = 2.6 \cdot 10^{9}$
	Young modulus (Pa)	$E = 2.1 \cdot 10^{11}$
	ϕ loss angle	$\phi s = 1 \cdot 10^{-3}$
fused quartz (mirror):	densità quarzo	$\rho m = 2.2 \cdot 10^{3}$
	ϕ "misurato ad Orsay"	$\phi q = 1 \cdot 10^{-6}$

Geometrical parameters

mirrors:

near mirror (c): mirror height $hc := .10$ $\quad lc := \frac{hc}{2}$

mirror radius $Rc := .175$

half wires separation $b1c := 0.025$

$Bc(b) := \sqrt{b^2 + Rc^2}$ $\quad Bc(b1c) = 0.176777$

mirror mass $mc := \pi \cdot Rc^2 \cdot hc \cdot \rho m$ $\quad mc = 21.166481$

mirror momentum of inertia $Ic := mc \cdot \left(\frac{hc^2}{12} + \frac{Rc^2}{4} \right)$ $\quad Ic = 0.179695$

far mirror (f): mirror height $hf := .20$ $\quad lf := \frac{hf}{2}$

mirror radius $Rf := .175$

half wires separation $b1f := 0.025$

$Bf(b) := \sqrt{b^2 + Rf^2}$ $\quad Bf(b1f) = 0.176777$

mirror mass $mf := \pi \cdot Rf^2 \cdot hf \cdot \rho m$ $\quad mf = 42.332961$

mirror momentum of inertia $If := mf \cdot \left(\frac{hf^2}{12} + \frac{Rf^2}{4} \right)$ $\quad If = 0.465222$

wires: length $L := 0.7$

to determine the radius we assume a safety factor of $kk := .65$

$rc := \sqrt{\frac{mc \cdot g}{4 \cdot \pi \cdot kk \cdot BB}}$ $rc = 9.883006 \cdot 10^{-5}$ $2 \cdot rc \cdot 10^{6} = 197.660129$ we assume $rc := 100 \cdot 10^{-6}$

$rf := \sqrt{\frac{mf \cdot g}{4 \cdot \pi \cdot kk \cdot BB}}$ $rf = 1.397668 \cdot 10^{-4}$ $2 \cdot rf \cdot 10^{6} = 279.533635$ we assume $rf := 150 \cdot 10^{-6}$

moment of inertia of the wire cross section $I2c := rc^{4} \cdot \frac{\pi}{4}$ $I2f := rf^{4} \cdot \frac{\pi}{4}$

------------------------------ Thermal Noise ------------------------------

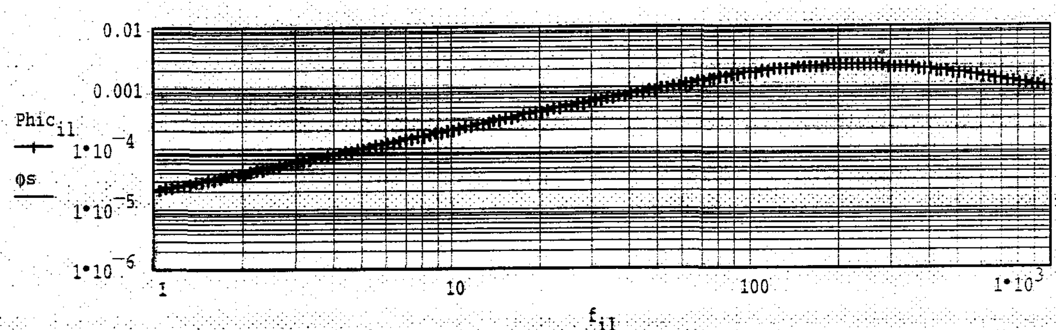
Thermoelastic damping in steel wires ----- near mirror--------------

$\Delta := \frac{E \cdot \alpha st^{2} \cdot T}{cst}$ $\tau := \frac{cst \cdot (2 \cdot rc)^{2}}{2 \cdot \pi \cdot 2.16 \cdot kthst}$ $\frac{1}{2 \cdot \pi \cdot \tau} = 221.947652$ $\phi thc(w) := \frac{\Delta \cdot w \cdot \tau}{1 + w^{2} \cdot \tau^{2}}$ $\Delta = 0.004591$

$\phi thc(2 \cdot \pi \cdot 1) = 2.068465 \cdot 10^{-5}$ $\phi penc(w) := \frac{1}{2 \cdot L} \cdot \sqrt{\frac{E \cdot I2c}{mc \cdot g}} \cdot \phi thc(w)$ $\phi penc(2 \cdot \pi \cdot 1) = 4.166174 \cdot 10^{-9}$

$\phi thc(2 \cdot \pi \cdot 10) = 2.064317 \cdot 10^{-4}$ $\phi penc(2 \cdot \pi \cdot 10) = 4.157818 \cdot 10^{-8}$

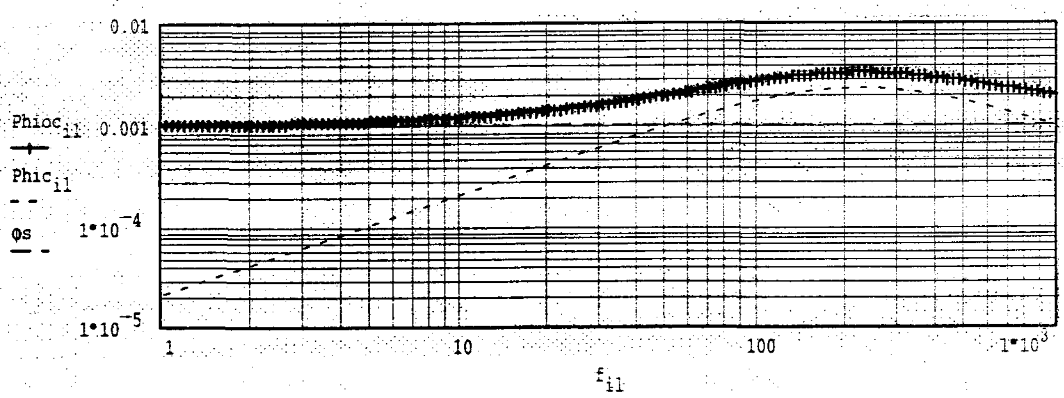
$il := 1 .. 200$ $f_{il} := 10^{\frac{il}{50} - 1}$ $\max(f) = 1 \cdot 10^{3}$ $f_{1} = 0.104713$ $Phic_{il} := \phi thc(2 \cdot \pi \cdot f_{il})$



Si definisce un phi operativo, per i processi dissipativi nei fili, dato dalla somma del phi costante + phi termoelastico

$$\phi wc(w) := \phi s + \phi thc(w)$$

$Phioc_{il} := \phi wc(2 \cdot \pi \cdot f_{il})$



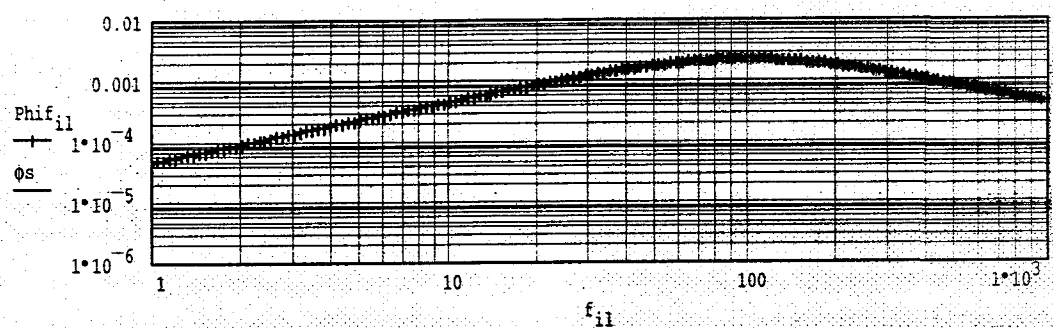
Thermoelastic damping in steel wires ----- far mirror--------------

$$\Delta := \frac{E\cdot \alpha st^2 \cdot T}{cst} \qquad \tau := \frac{cst\cdot(2\cdot rf)^2}{2\cdot\pi\cdot 2.16\cdot kthst} \qquad \frac{1}{2\cdot\pi\cdot\tau} = 98.643401 \qquad \phi thf(w) := \frac{\Delta\cdot w\cdot\tau}{1+w^2\cdot\tau^2} \qquad \Delta = 0.004591$$

$$\phi thf(2\cdot\pi\cdot 1) = 4.653663\cdot 10^{-5} \qquad \phi penf(w) := \frac{1}{2\cdot L}\cdot\sqrt{\frac{E\cdot I2f}{mf\cdot g}}\cdot\phi thf(w) \qquad \phi penf(2\cdot\pi\cdot 1) = 1.491254\cdot 10^{-8}$$

$$\phi thf(2\cdot\pi\cdot 10) = 4.606797\cdot 10^{-4} \qquad \phi penf(2\cdot\pi\cdot 10) = 1.476236\cdot 10^{-7}$$

$$Phif_{i1} := \phi thf(2\cdot\pi\cdot f_{i1})$$



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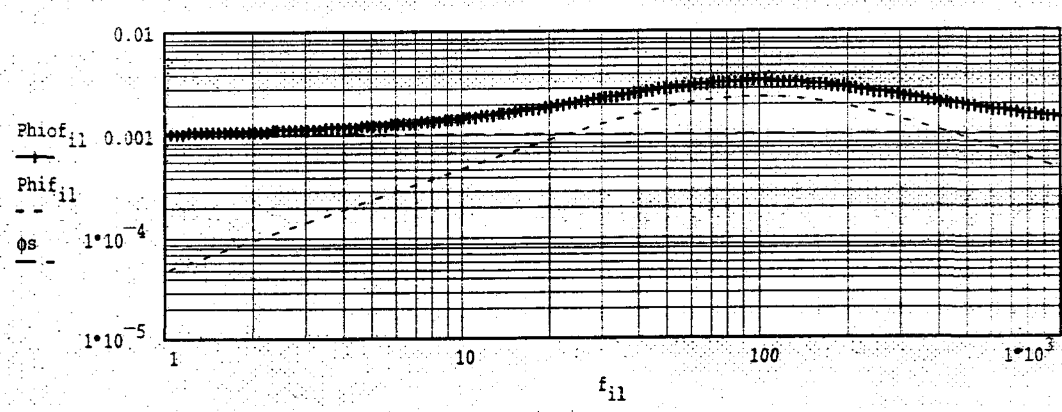
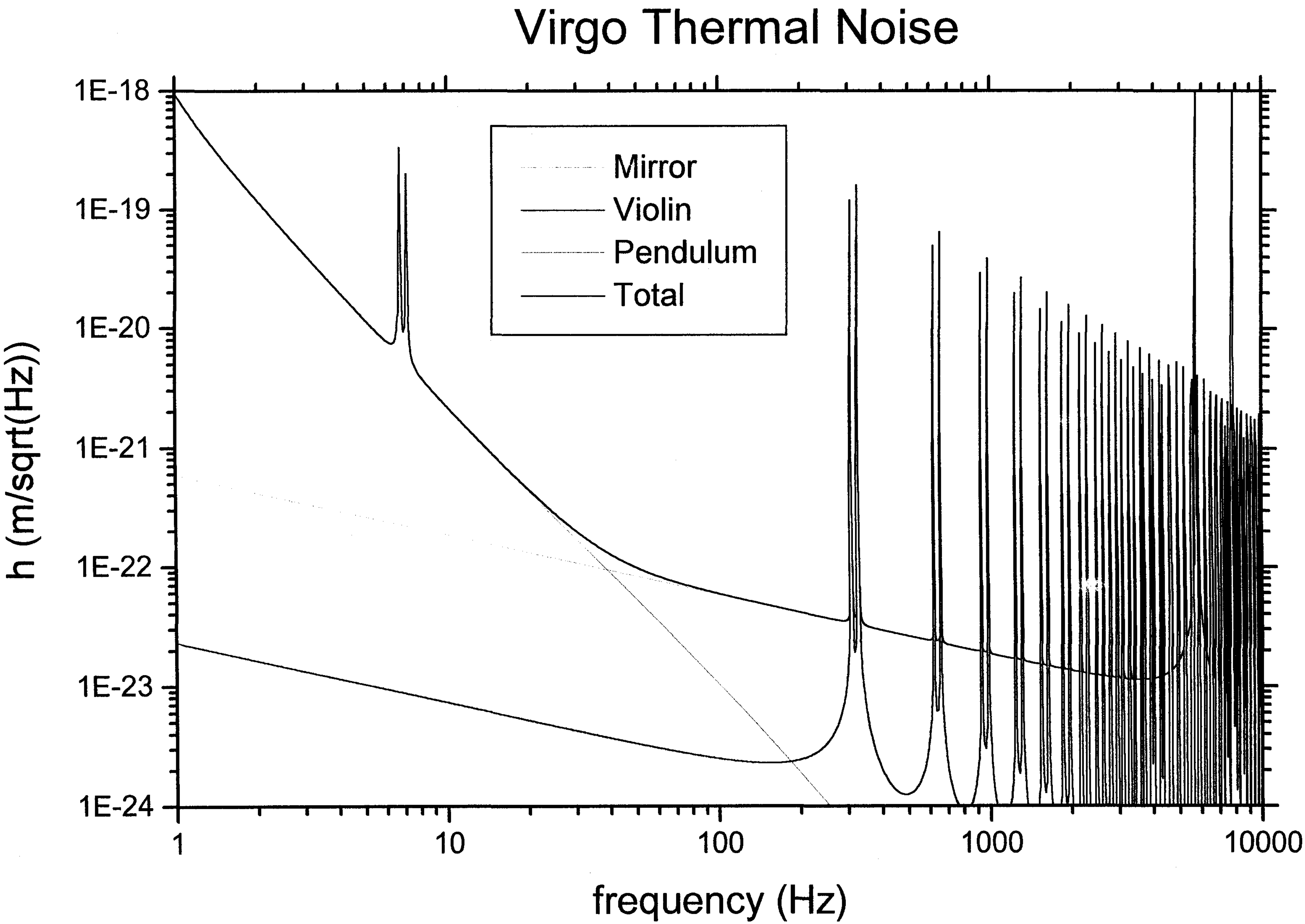
$$Phiof_{i1} := \phi wf(2\cdot\pi\cdot f_{i1})$$




Virgo Thermal Noise
Mirror
Violin
Pendulum
Total
1E-18
1E-19
1E-20
1E-21
1E-22
1E-23
1E-24
h (m/sqrt(Hz))
1
10
100
1000
10000
frequency (Hz)