La gravimétrie dans le SI révisé

S. Merlet

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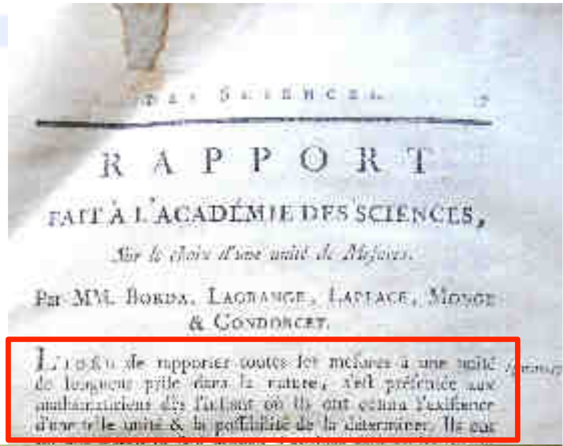
https://syrte.obspm.fr/spip/science/iaci/

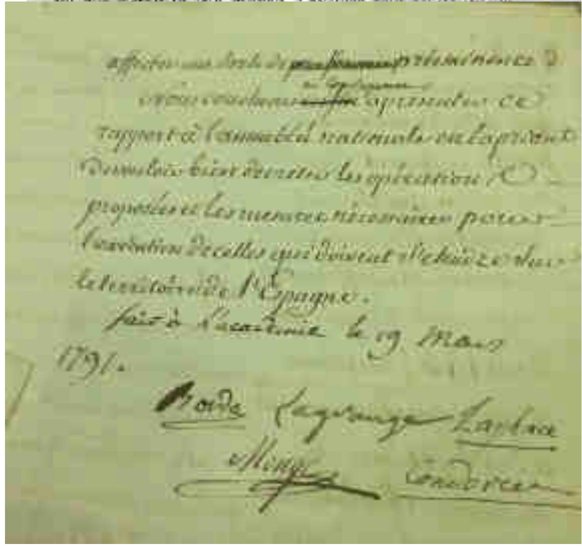
Système International d'Unités (SI)



DES SCIENCES. 3

RAPPORT
FAIT À L'ACADÉMIE DES SCIENCES,
Sur le choix d'une unité de Meſures.
Par MM. Borda, Lagrange, Laplace, Monge
& Condorcet.

L'idée de rapporter toutes les meſures à une unité de longueur priſe dans la nature, s'eſt préſentée aux mathématiciens dès l'inſtant où ils ont connu l'exiſtence d'une telle unité & la poſſibilité de la déterminer. Ils ont



[illegible] préliminaires
[illegible]
rapport à l'assemblée nationale [illegible]
[illegible] les opérations
proposées et les mesures nécessaires pour
l'exécution de celles qui doivent s'exécuter dans
le territoire de l'Espagne.
fait à l'académie le 19 Mars
1791.
Borda Lagrange Laplace
Monge Condorcet

19 mars 1791 kilogramme, mètre, (seconde)

16 novembre 2018

…. 20 mai 2019

$$h, \; c, \; \Delta\nu_{\mathrm{Cs}}$$

Histoire du kilogramme

?

XV

1791

1799

Convention du mètre

1875

1889

1901

h

2018

CGPM 2018

decides that, effective from 20 May 2019, the International System of Units, the SI, is the system of units in which:

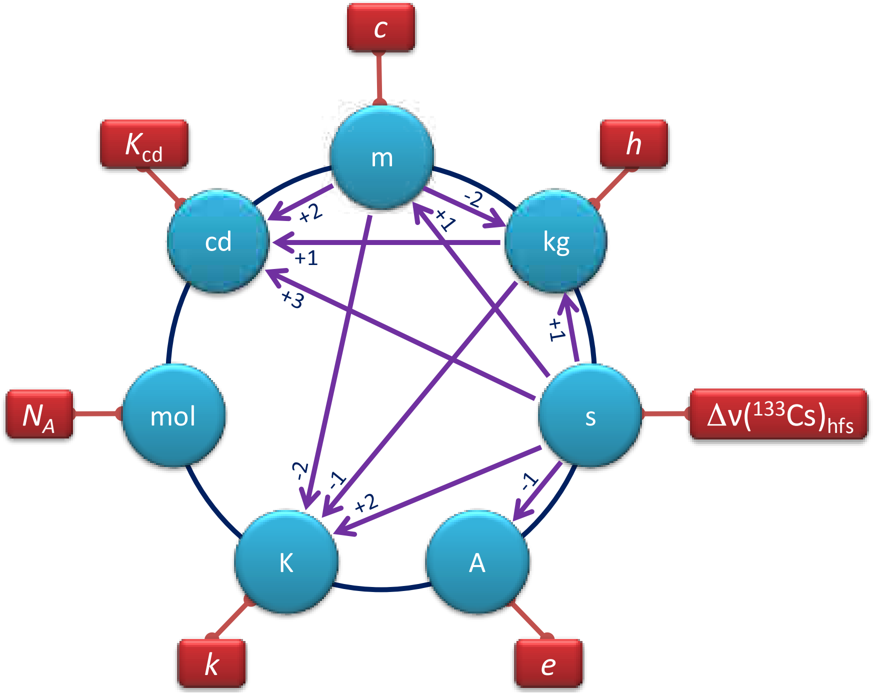
- the unperturbed ground state hyperfine transition frequency of the caesium 133 atom $\Delta\nu_{\mathrm{Cs}}$ is 9 192 631 770 Hz,
- the speed of light in vacuum *c* is 299 792 458 m/s,

→ Atomic clock

$c = 299\ 792\ 458$ metres per second

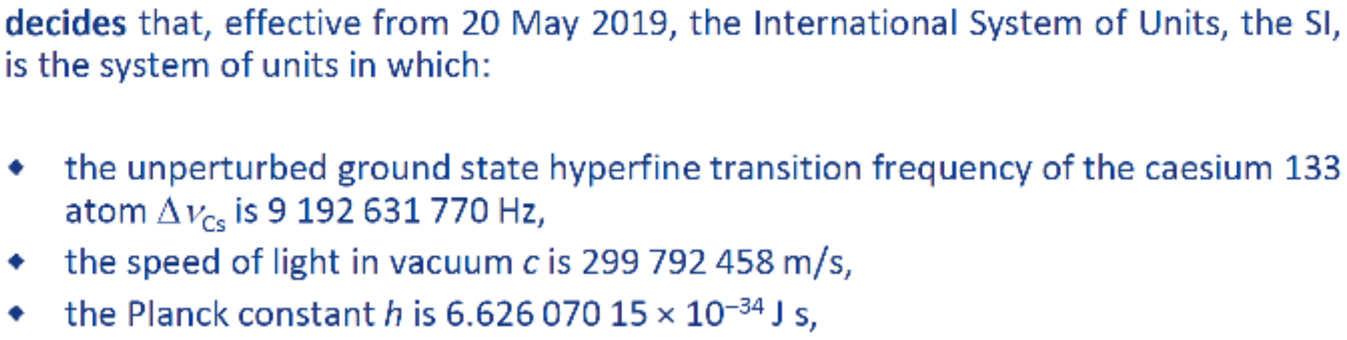
↑ Numerical value

↑ unit, with s already fixed



https://www.bipm.org/utils/common/pdf/CGPM-2018/26th-CGPM-Resolutions.pdf

CGPM 2018



decides that, effective from 20 May 2019, the International System of Units, the SI, is the system of units in which:

- the unperturbed ground state hyperfine transition frequency of the caesium 133 atom $\Delta\nu_{\mathrm{Cs}}$ is 9 192 631 770 Hz,
- the speed of light in vacuum c is 299 792 458 m/s,
- the Planck constant h is 6.626 070 15 × 10^{-34} J s,

→ Atomic clock

$c = 299\ 792\ 458$ metres per second

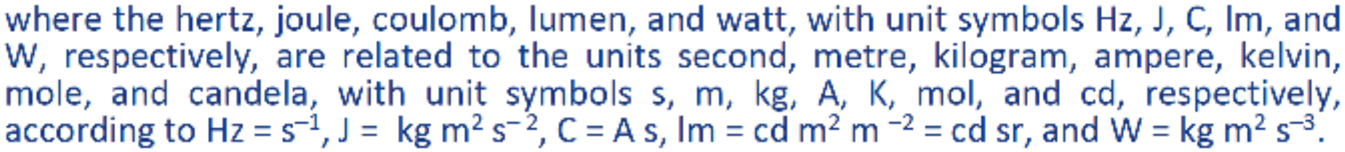
$h = 6.626\ 070\ 15 \times 10^{-34}\ \mathrm{kg}.m^2.s^{-1}$

Numerical value

$\mathrm{kg.m^2.s^{-1}}$

unit, with
$\mathrm{m^2.s^{-1}}$ already fixed

We fixed the size of mass.



where the hertz, joule, coulomb, lumen, and watt, with unit symbols Hz, J, C, lm, and W, respectively, are related to the units second, metre, kilogram, ampere, kelvin, mole, and candela, with unit symbols s, m, kg, A, K, mol, and cd, respectively, according to Hz = $\mathrm{s^{-1}}$, J = kg $\mathrm{m^2\,s^{-2}}$, C = A s, lm = cd $\mathrm{m^2\,m^{-2}}$ = cd sr, and W = kg $\mathrm{m^2\,s^{-3}}$.

https://www.bipm.org/utils/common/pdf/CGPM-2018/26th-CGPM-Resolutions.pdf

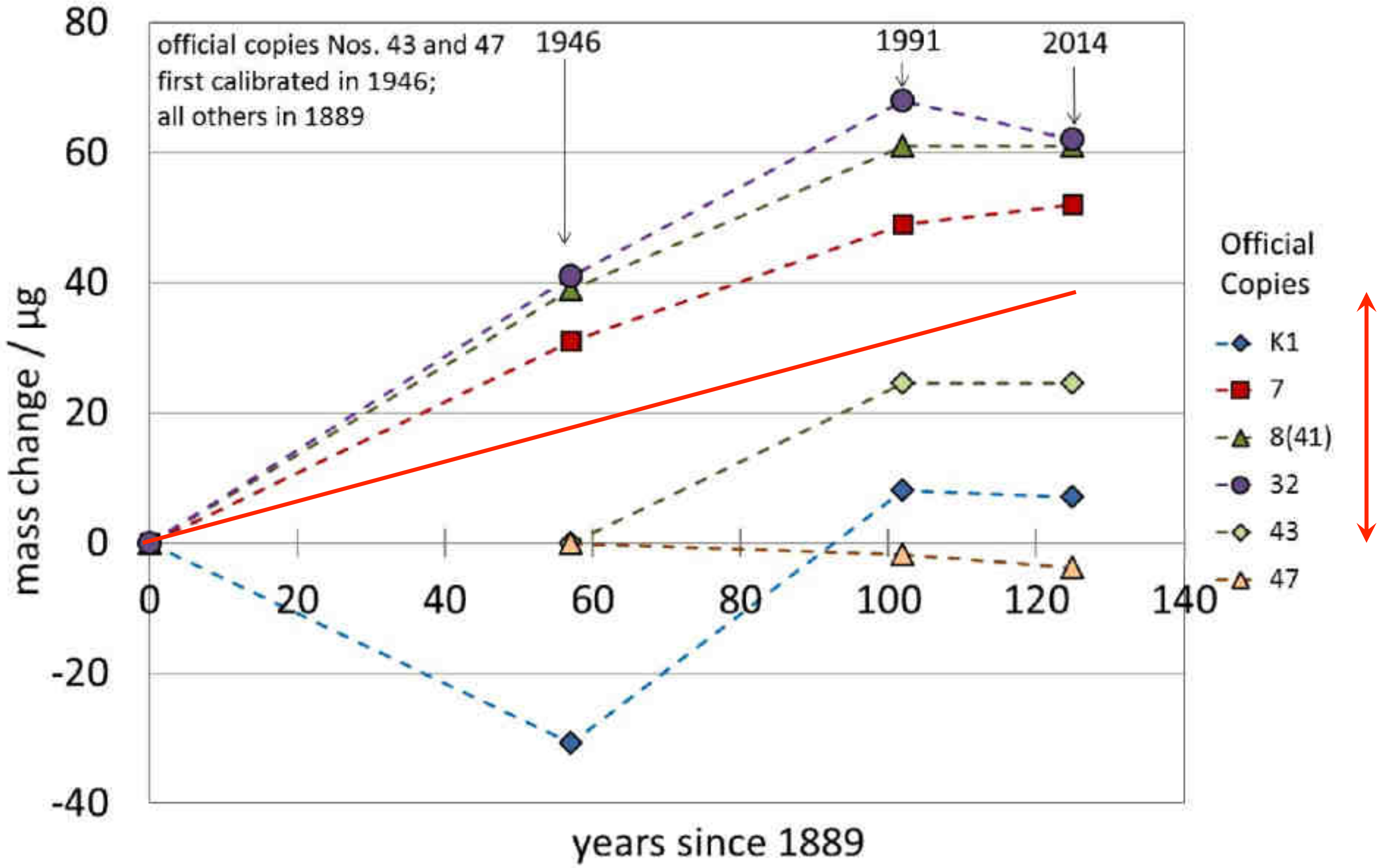
Sommaire

Notre participation dans ce changement

Le gravimètre atomique du LNE-SYRTE

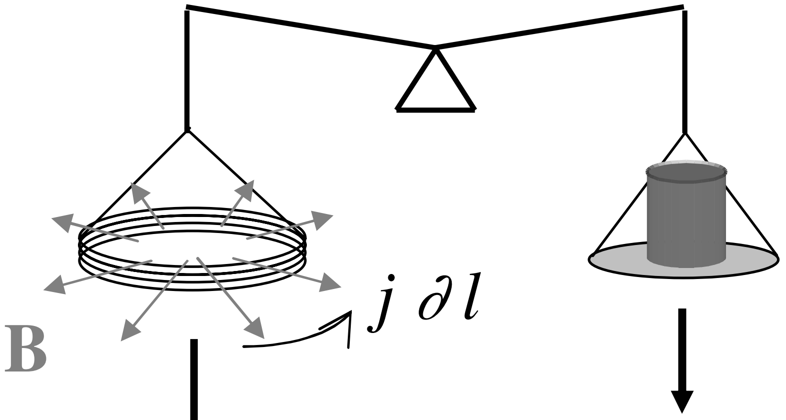
La gravi-gradio-métrie

IPK Stabilité



3×10^{-8}

Balance du watt



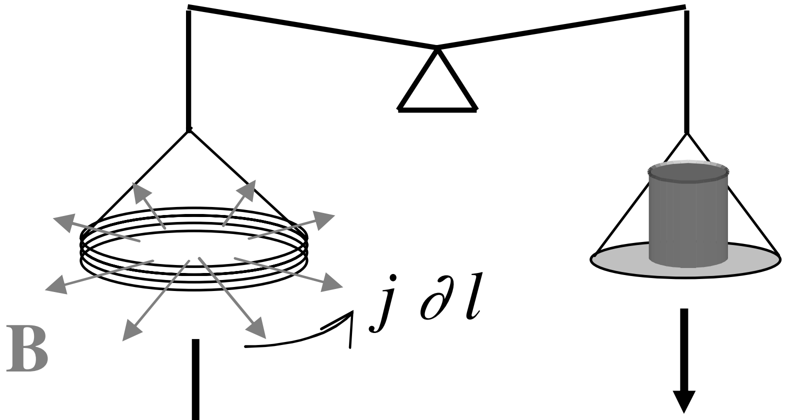
$\mathbf{F}_{\mathbf{Laplace}} = B \cdot l \cdot I$ $\mathbf{F}_{\mathbf{g}} = m \cdot g$

$$\boxed{F_z = mg = Bli}$$

Geometric factor

Balance du watt ou de Kibble

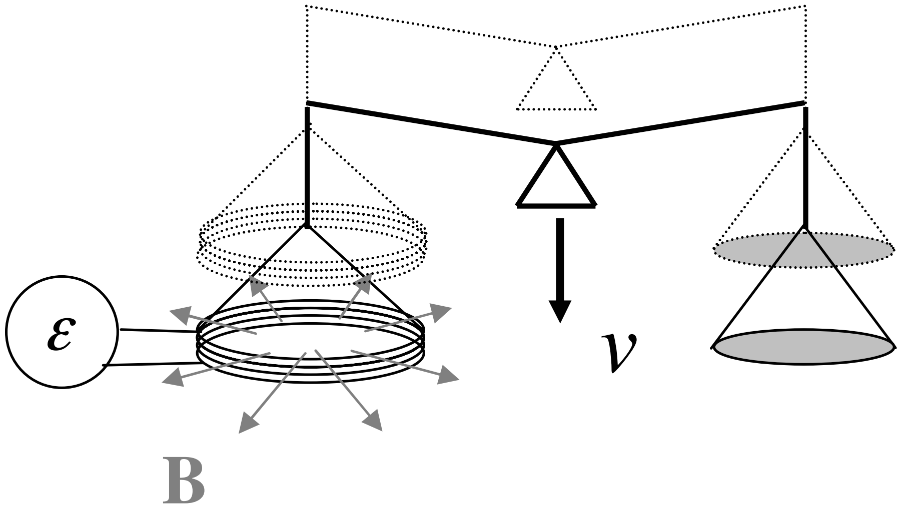
Etape statique



$\mathbf{F}_{\mathbf{Laplace}} = B \cdot l \cdot I$ $\mathbf{F}_{\mathbf{g}} = m \cdot g$

$$\boxed{F_z = mg = Bli}$$

Etape dynamique

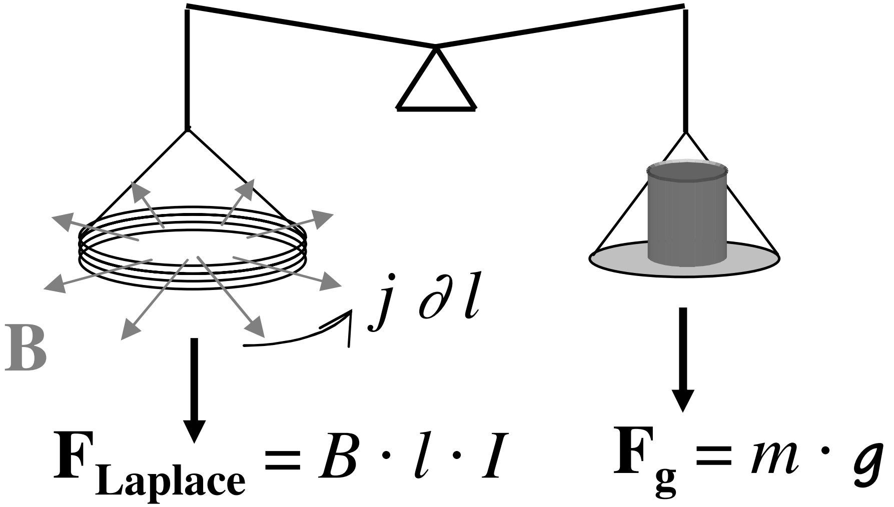


$$\boxed{\epsilon = -Blv}$$

$$mgv = \epsilon i = \epsilon V/R$$

Balance du watt ou de Kibble

Etape statique



$\mathbf{F}_{\mathbf{Laplace}} = B \cdot l \cdot I$ $\qquad$ $\mathbf{F}_{\mathbf{g}} = m \cdot g$

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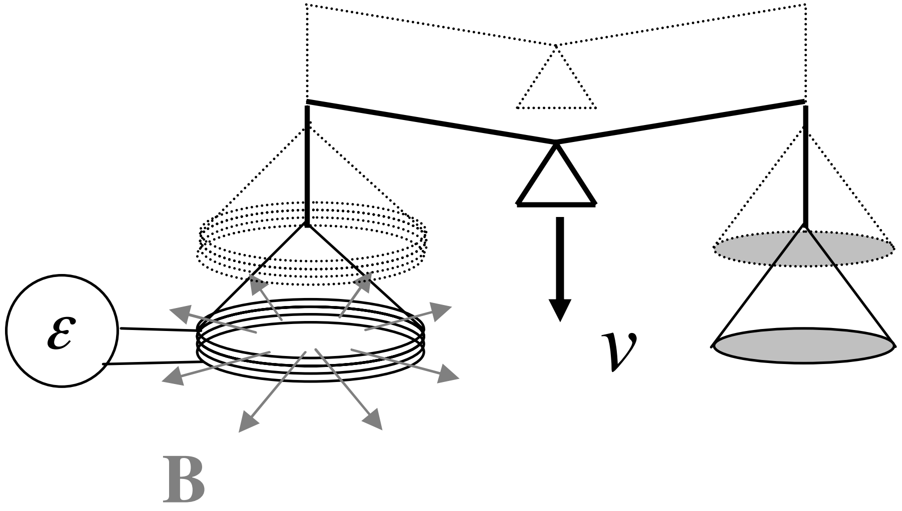
Etape dynamique



$$\boxed{\epsilon = -Blv}$$

$$mgv = \epsilon i = \epsilon V/R$$

$$mgv = \frac{A}{K_J^2 R_K}$$

$$A = \frac{n_1 f_1 n_2 f_2 i}{k}$$

$$\boxed{\frac{m}{h} = \frac{A}{4gv}}$$

1962: Josephson effect

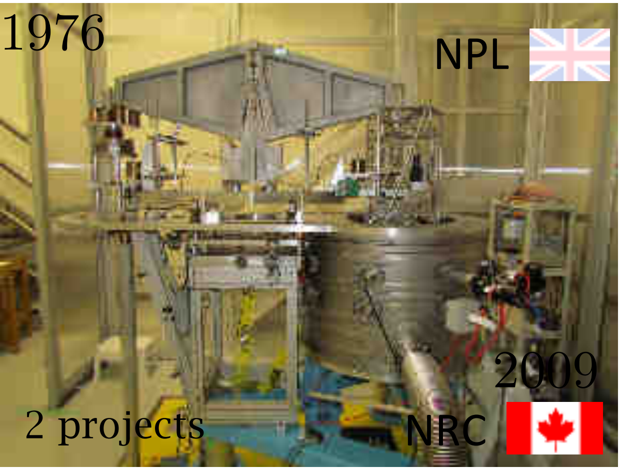
$V = nf/K_J \qquad K_J = 2e/h$

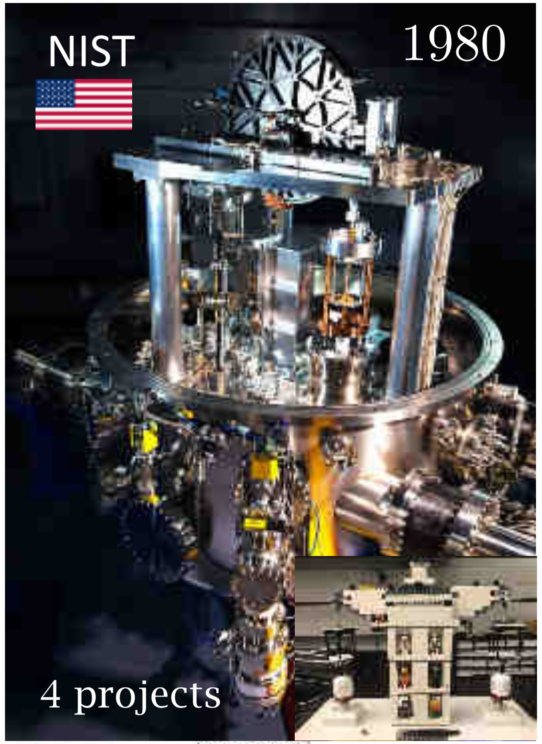
1980: Quantum Hall effect

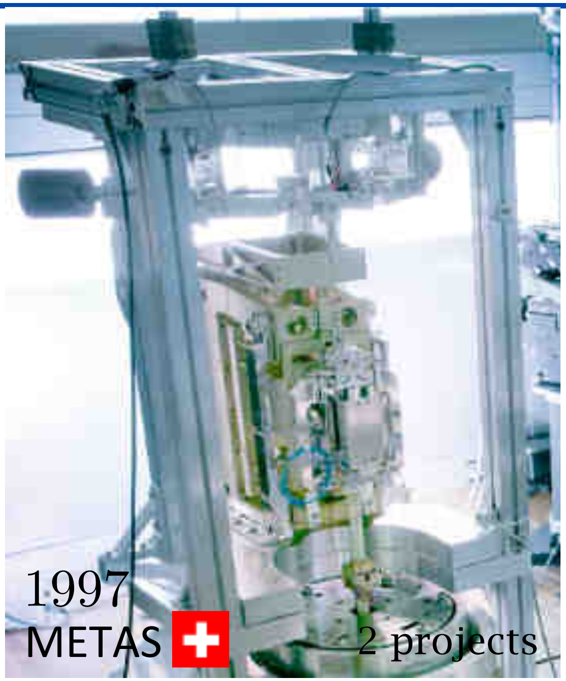
$R_H(i) = R_K/i \quad R_K = h/e^2$

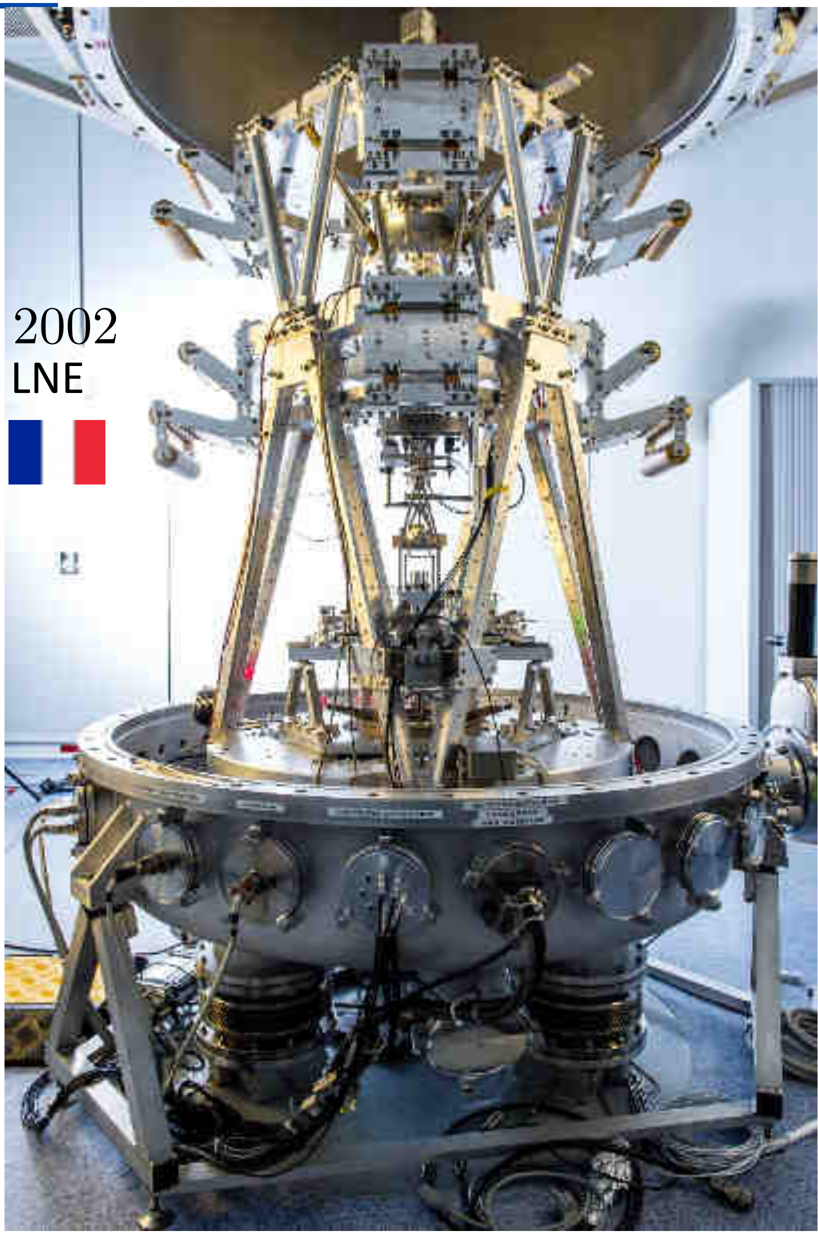
*Besoin d'une mesure de g, **exacte***

Projets de balance de Kibble









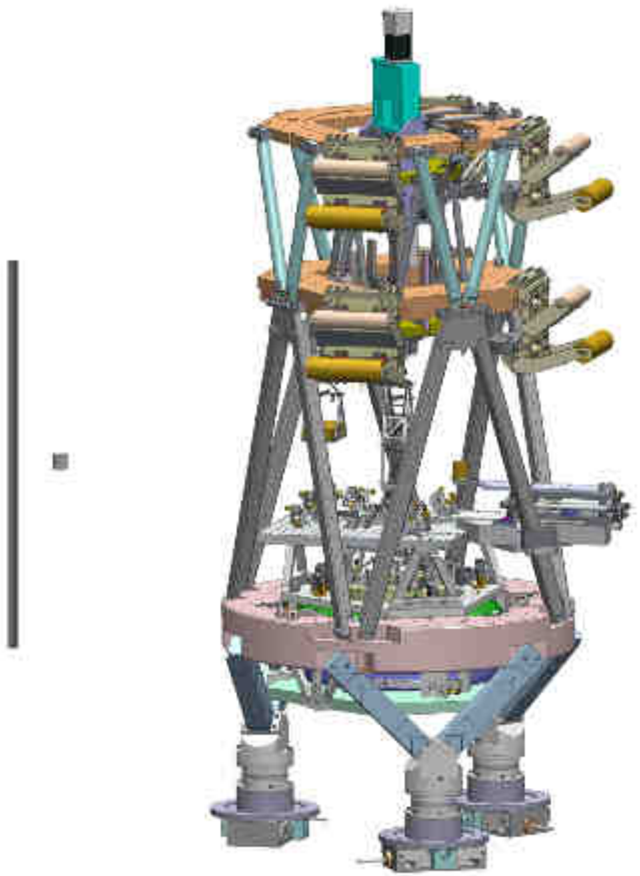
2006
NIM

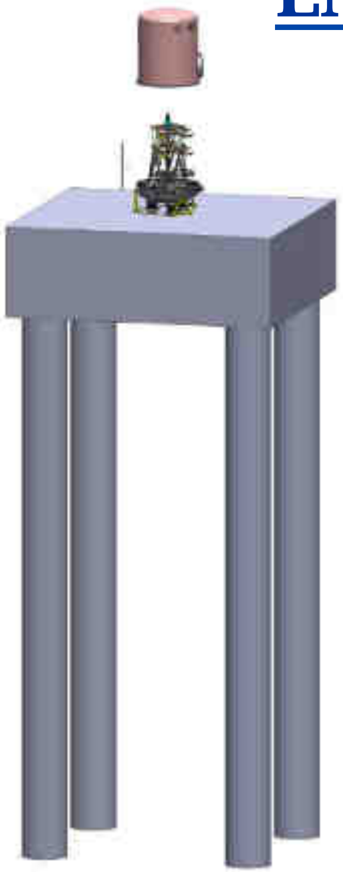
Beaucoup de différences (tailles, aimants, gravi…)

MSL, VNIIM…

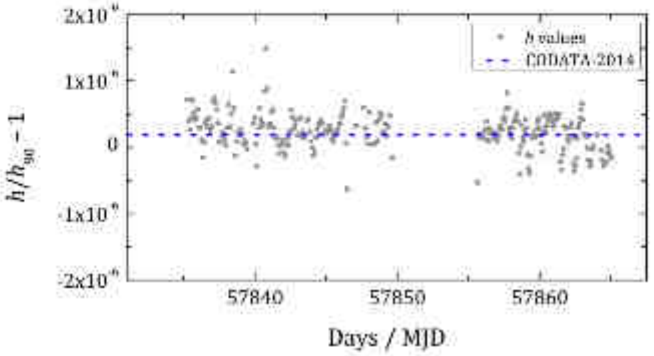
R. Steiner Rep. Prog. Phys. 76 (2013) 016101 (46pp)

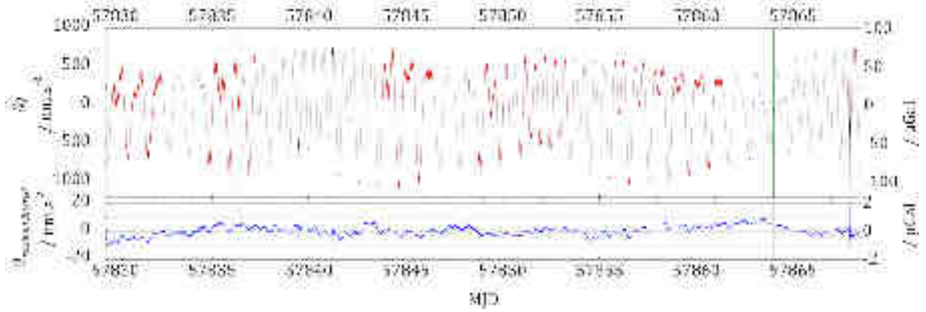
LNE KB 2017

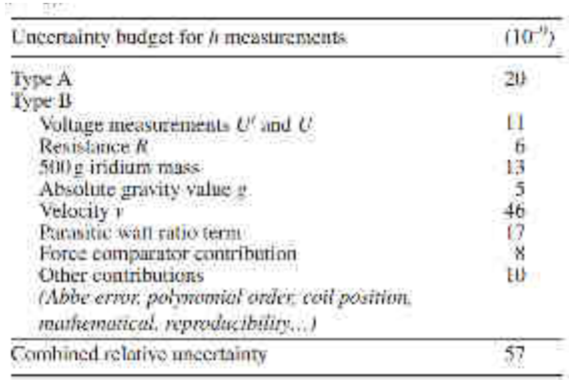




1T
Diamètre bobine: 266 mm
Mouvement bobine : 80 mm
Vitesse bobine: 2 mm/s
Masse : 500g



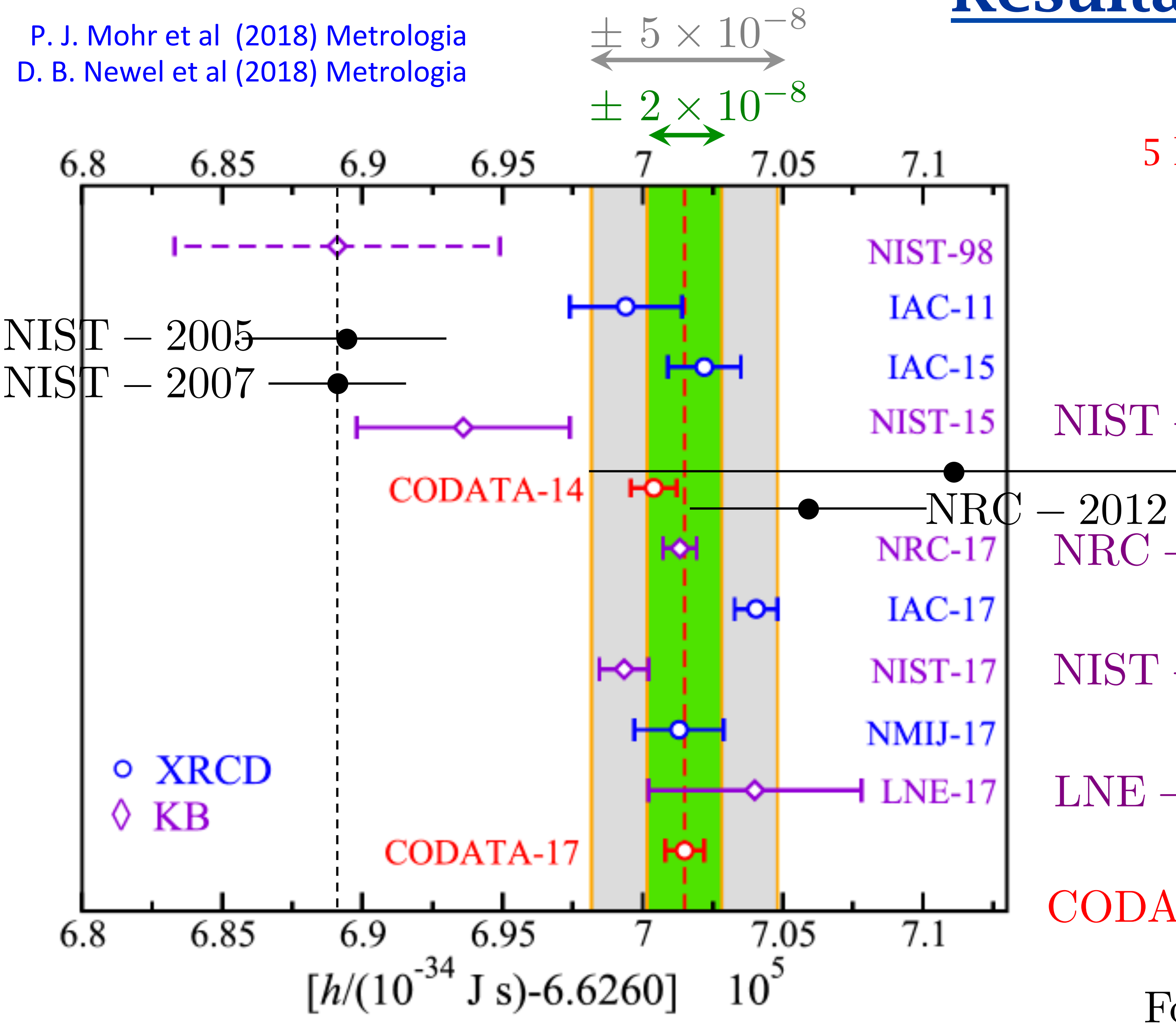




Uncertainty budget for *h* measurements	(10^{-9})
Type A	20
Type B	
Voltage measurements U' and U	11
Resistance R	6
500 g iridium mass	13
Absolute gravity value g	5
Velocity v	46
Parasitic wall ratio term	17
Force comparator contribution	8
Other contributions *(Abbe error, polynomial order, coil position, mathematical, reproducibility…)*	10
Combined relative uncertainty	57

Résultats

P. J. Mohr et al (2018) Metrologia
D. B. Newel et al (2018) Metrologia



5 labos/consortium publiés 8 valeurs mesurées de *h* qui ont été prises en compte

$\mathrm{IAC-11} \ \rightarrow\ 3.0 \times 10^{-8}$

$\mathrm{IAC-15} \ \rightarrow\ 2.0 \times 10^{-8}$

$\mathrm{NIST-15} \ \rightarrow\ 5.7 \times 10^{-8}$

$\mathrm{NRC-17} \ \rightarrow\ 0.9 \times 10^{-8}$

$\mathrm{IAC-17} \ \rightarrow\ 1.2 \times 10^{-8}$

$\mathrm{NIST-17} \ \rightarrow\ 1.3 \times 10^{-8}$

$\mathrm{NMIJ-17} \ \rightarrow\ 2.4 \times 10^{-8}$

$\mathrm{LNE-17} \ \rightarrow\ 5.7 \times 10^{-8}$

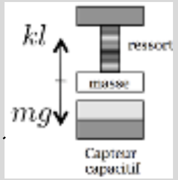
$\mathrm{CODATA-17} \ \rightarrow\ h = 6.626\ 070\ 150(69) \times 10^{-34} J.s$

$\mathrm{For\ SI\ rev} \ \rightarrow\ h = 6.626\ 070\ 15 \times 10^{-34} J.s$

Gravimétrie pour la balance de Kibble

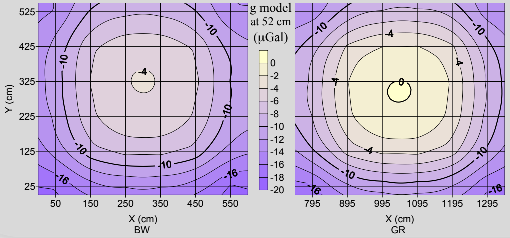
g transfert

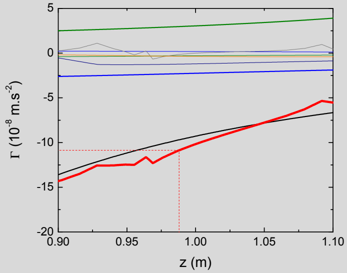
- Mesures relatives, cartographie 3D

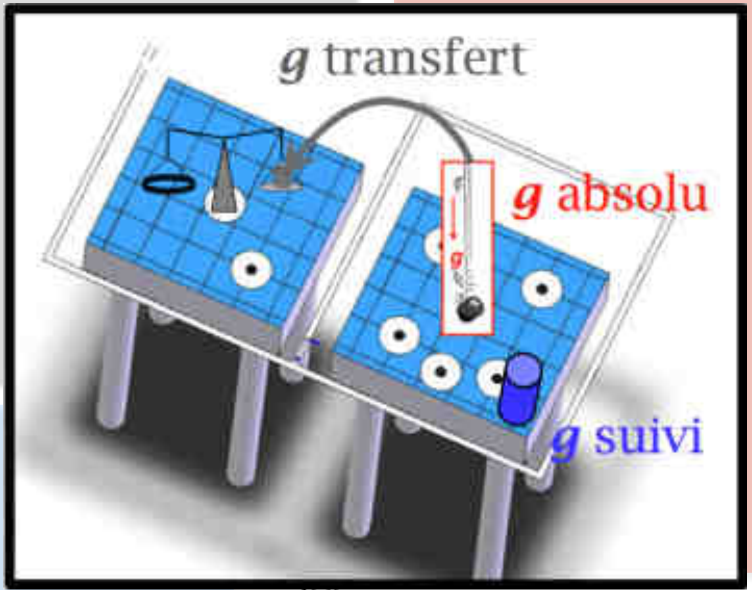


Gravimètre relatif
Scintrex CG5
Grosse dérive ($4\ 10^{-7} g$/jour) !
6Hz

- Modélisation 3D (labo et BK)

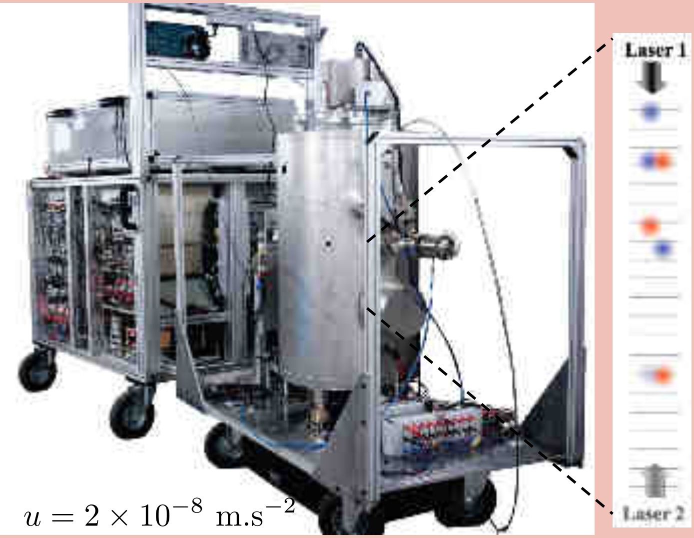






g absolu (et continu)

Observation de la chute libre d'un corps: des atomes froids de ^{87}Rb par Interférométrie Atomique.

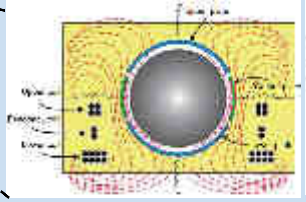


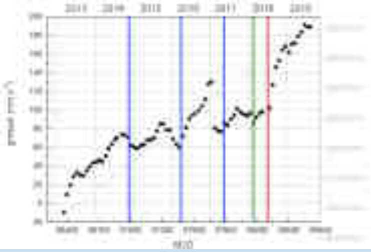
$u = 2 \times 10^{-8}$ m.s^{-2}

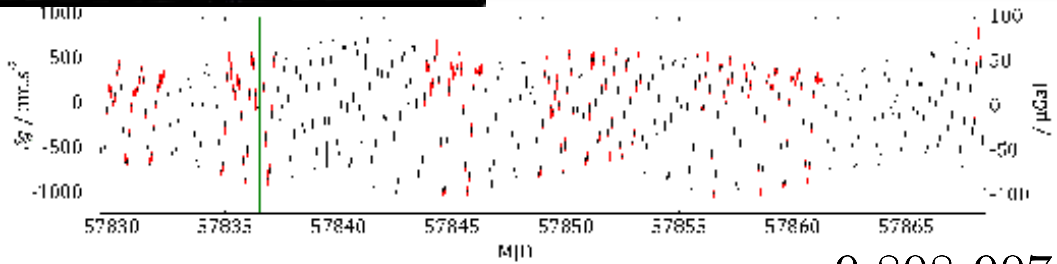
Développement d'une référence nationale, le **CAG**
Absolu, déplaçable, continu
3Hz
Participation aux comparaisons internationales (CIPM KC)
Transfert industriel, commercialisation

g suivi continu

Gravimètre supraconducteur relatif GWR iGrav
Faible dérive ($4\ 10^{-9} g$/an)
12Hz
Non déplaçable







$$g = 9.808\ 907\ 45(2)\ \text{m.s}^{-2}$$

Sommaire

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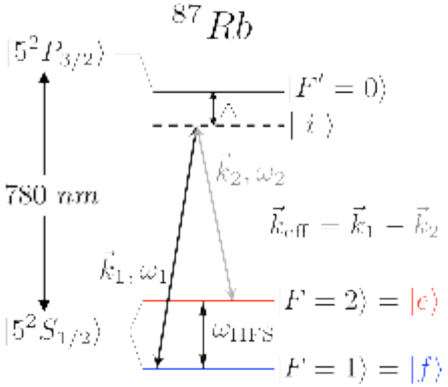
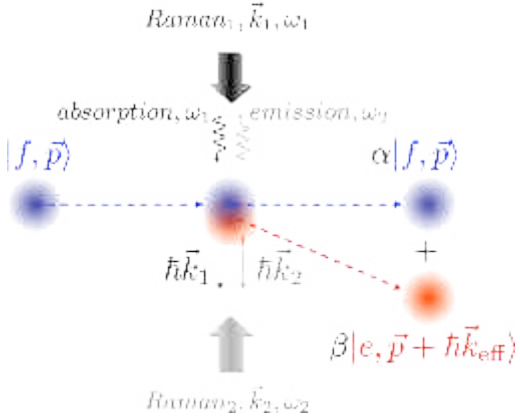
La gravi-gradio-métrie

Atom interferometer

Stimulated Raman transitions

3 level atom





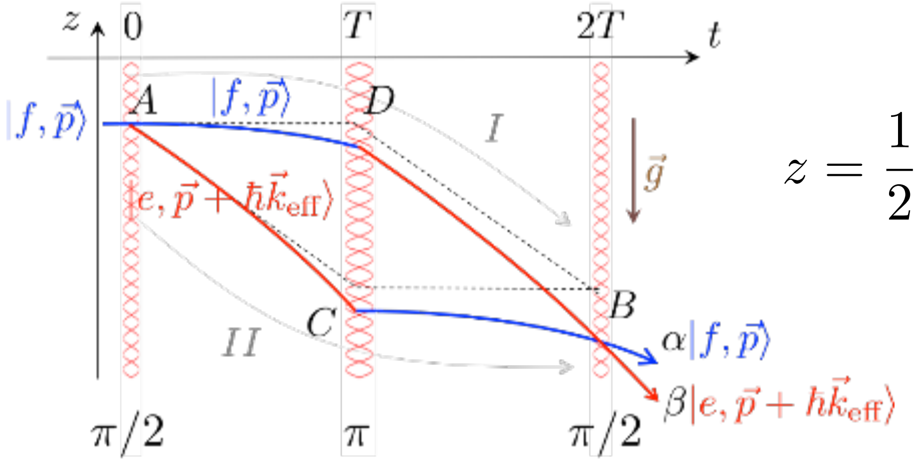
Two photon transition coupling $|f\rangle$ and $|e\rangle$

$$\phi(t) = \omega_{\text{eff}}t - \vec{k}_{\text{eff}}\vec{z}(t) + \varphi_{\text{eff}}(t)$$

Interest of Raman transitions:
Bijection internal – external state

Consequence : detection on internal state

Sampling of the positions at the 3 pulses



$$z = \frac{1}{2}gt^2$$

$$P_{|\vec{p}\rangle \to |\vec{p}+\hbar\vec{k}_{\text{eff}}\rangle} = \frac{1}{2}(1 - C\cos\Delta\Phi)$$

$$\begin{aligned} \Delta\Phi &= \Phi_{II} - \Phi_I \\ &= (\phi_A - \phi_C)\text{-}(\phi_D - \phi_B) \\ &= \phi(0) - 2\phi(T) + \phi(2T) \end{aligned}$$

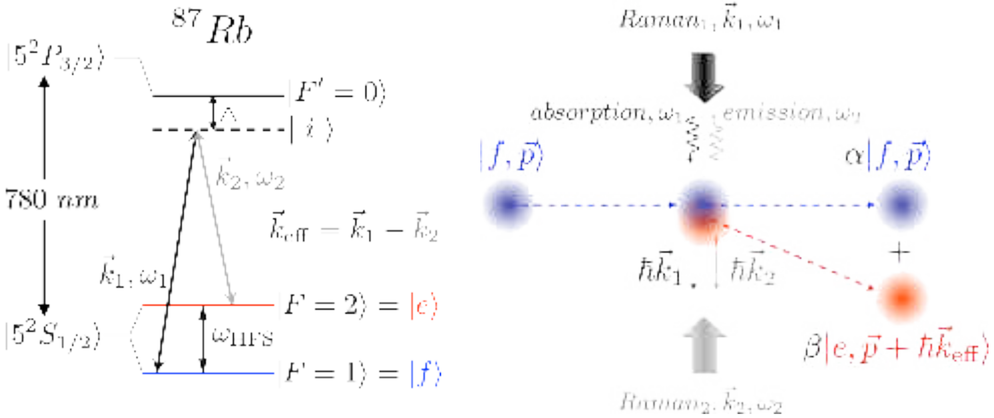
$$\boxed{\Delta\Phi = -\vec{k}_{\text{eff}}\vec{g}T^2}$$

Scales as T^2, benefits of cold atoms

Atom interferometer

Stimulated Raman transitions

3 level atom



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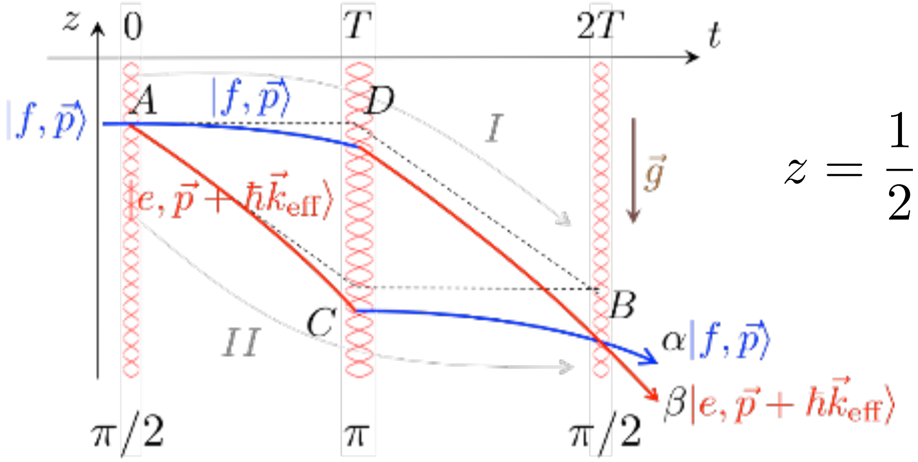

$$z=\frac{1}{2}gt^2$$

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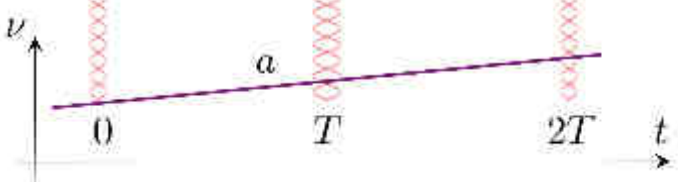
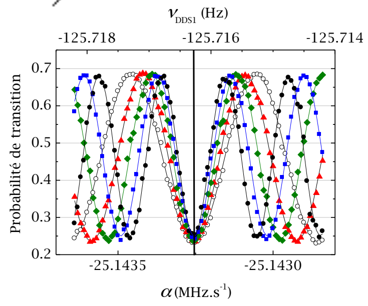


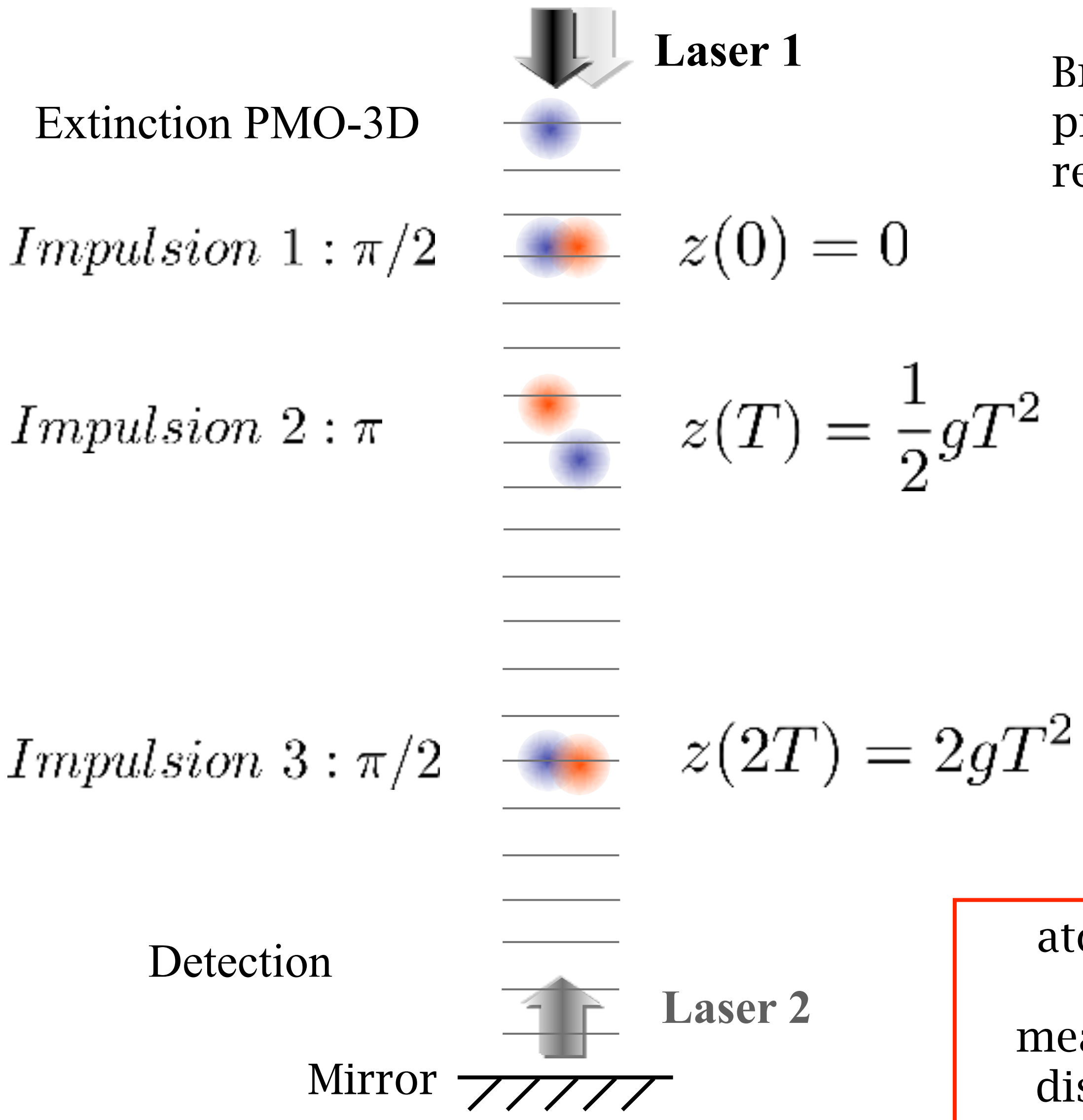


$$\Delta\Phi=-\vec{k}_{\rm eff}\vec{g}T^2+aT^2$$

$$g=a/k_{\rm eff}$$

Scales as T^2, benefits of cold atoms

Cold Atom Gravimeter (CAG) sequence



Laser 1

Extinction PMO-3D

$Impulsion\ 1 : \pi/2$ $\quad z(0) = 0$

$Impulsion\ 2 : \pi$ $\quad z(T) = \frac{1}{2}gT^2$

$Impulsion\ 3 : \pi/2$ $\quad z(2T) = 2gT^2$

Detection

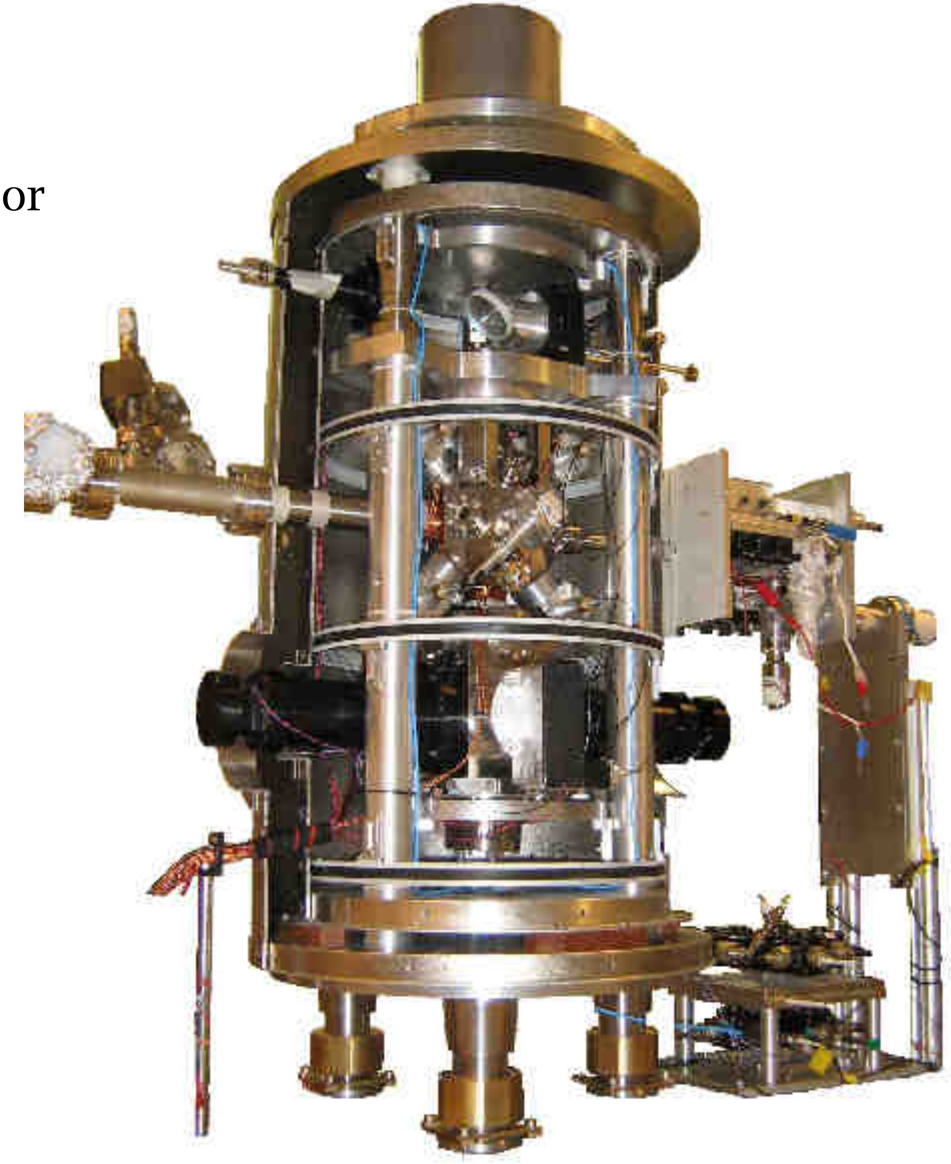
Laser 2

Mirror

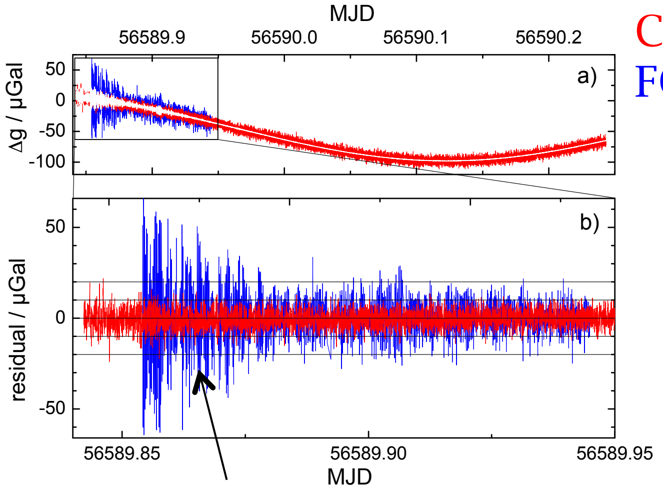
Bring two lasers in a co-propagating way and retroreflect them on a mirror

Position of the equiphases defined by the mirror position

atomic measurement
=
measure of the relative displacement atoms/ mirror

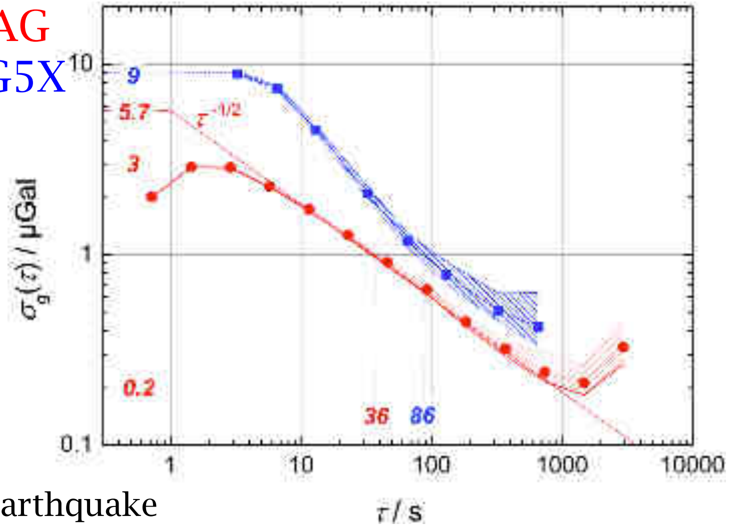


CAG performances & capabilities



CAG

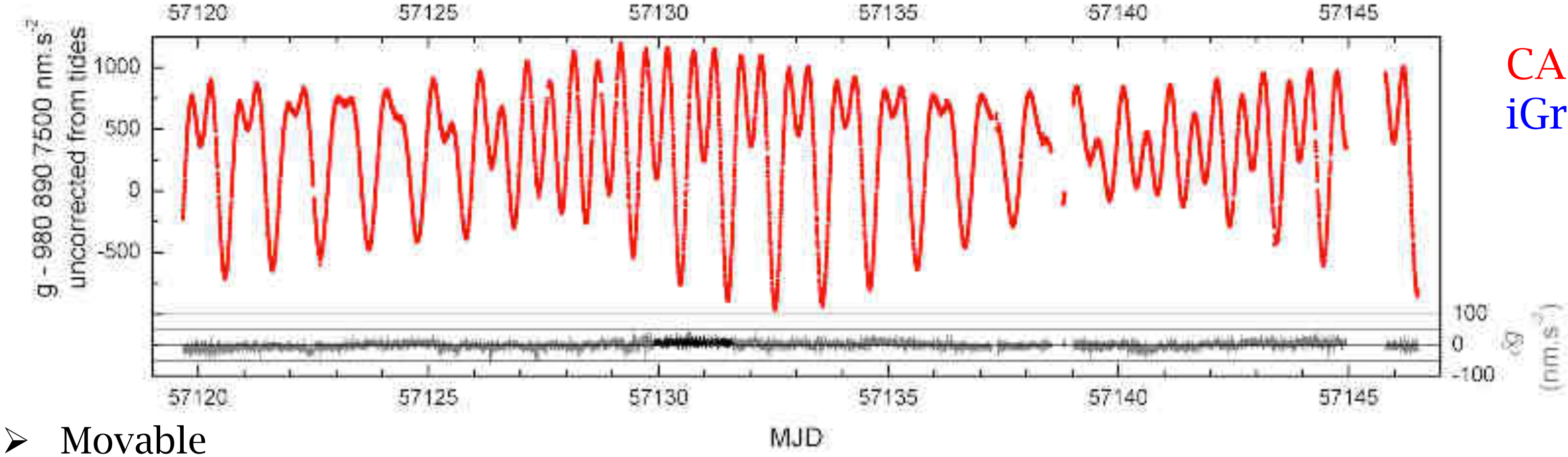
FG5X



Excess noise due (end of an) earthquake

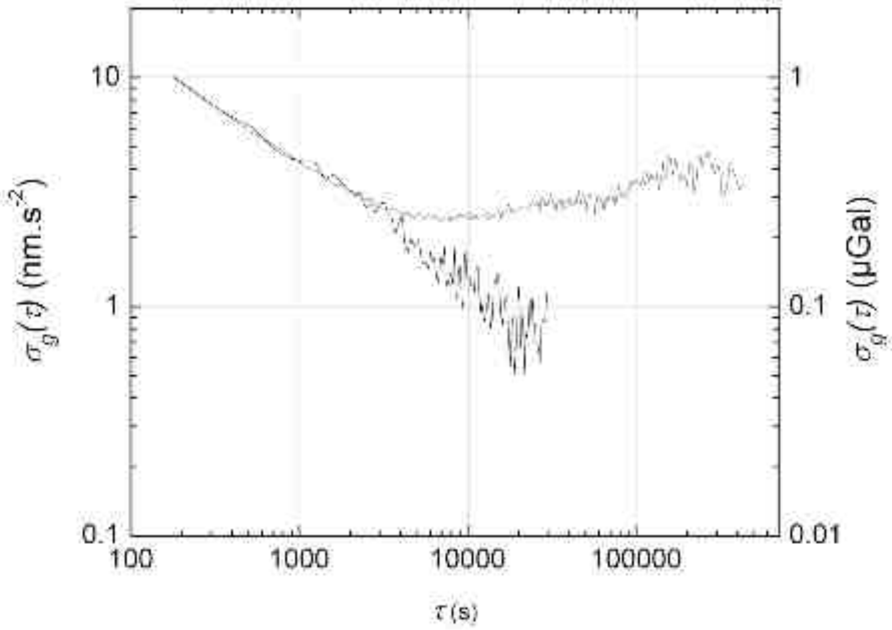
Better immunity of the CAG

*P. Gillot et al., Metrologia **51** (2014)*



CAG

iGrav



- Movable
- Comparison with other technologies
- Participation to international Key Comparisons
- Continuous accurate measurement
- Industrial transfer

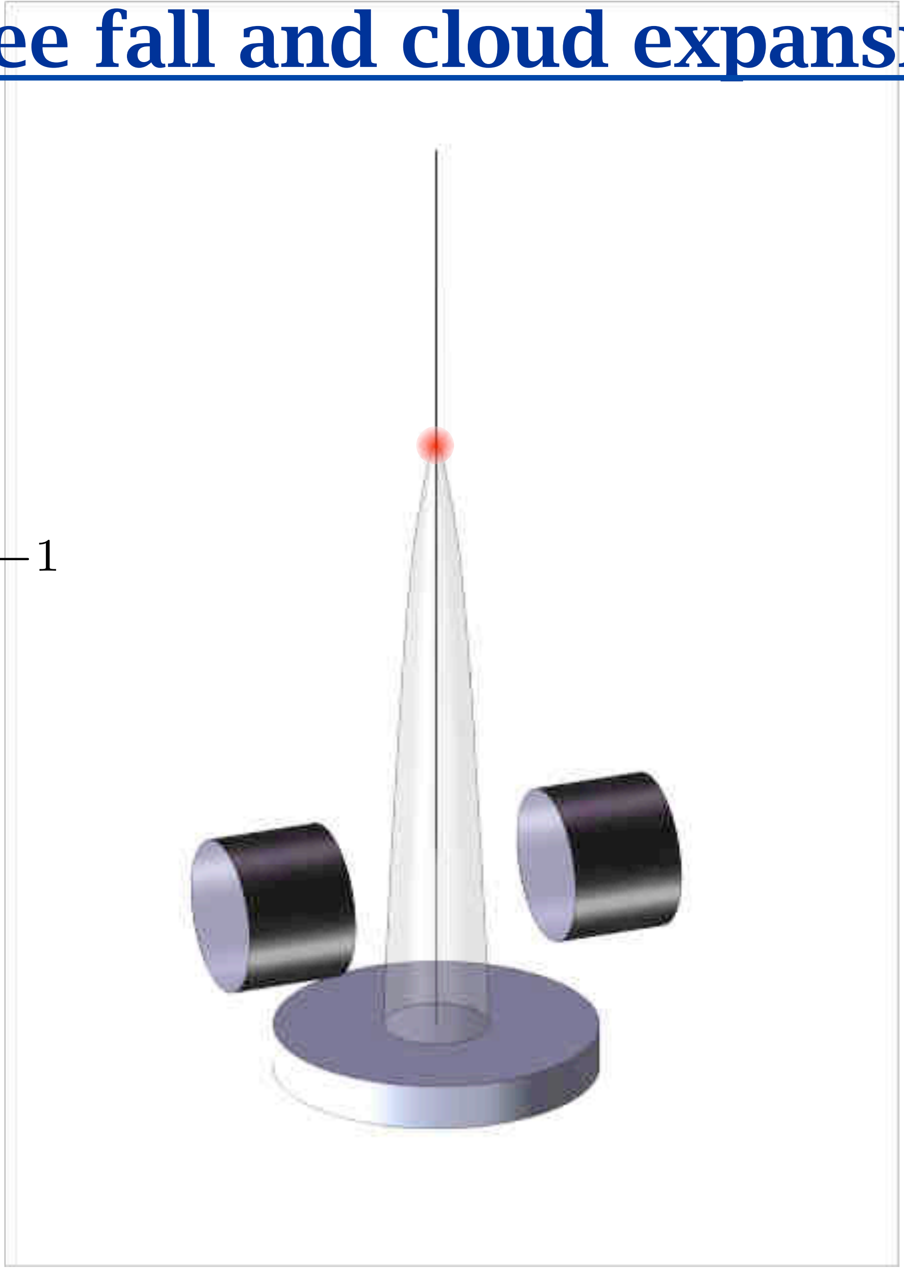
Accuracy : 4.3 µGal

Free fall and cloud expansion

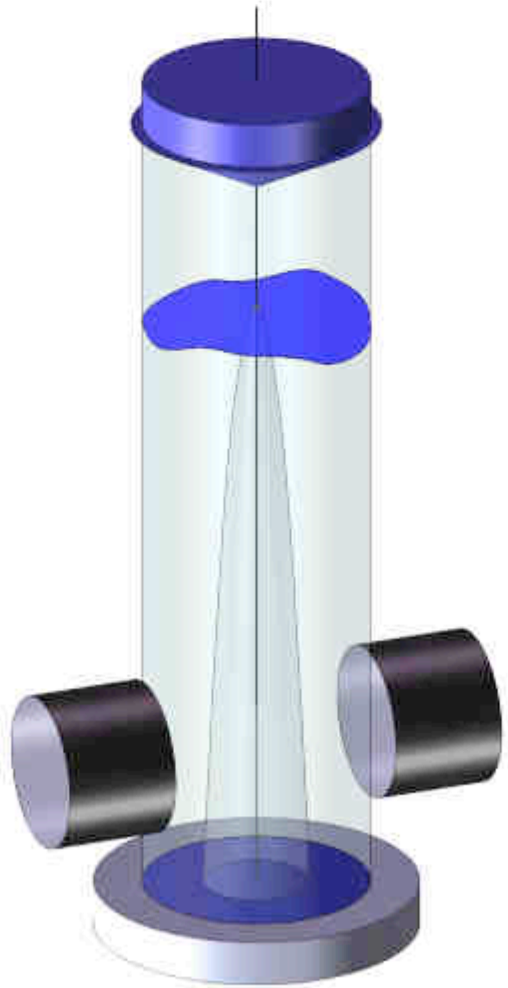
Cold Atoms

$T_{emp} \sim 2\mu K$

$\sigma_v \sim 14\ mm.s^{-1}$



1st Raman



Laser beam

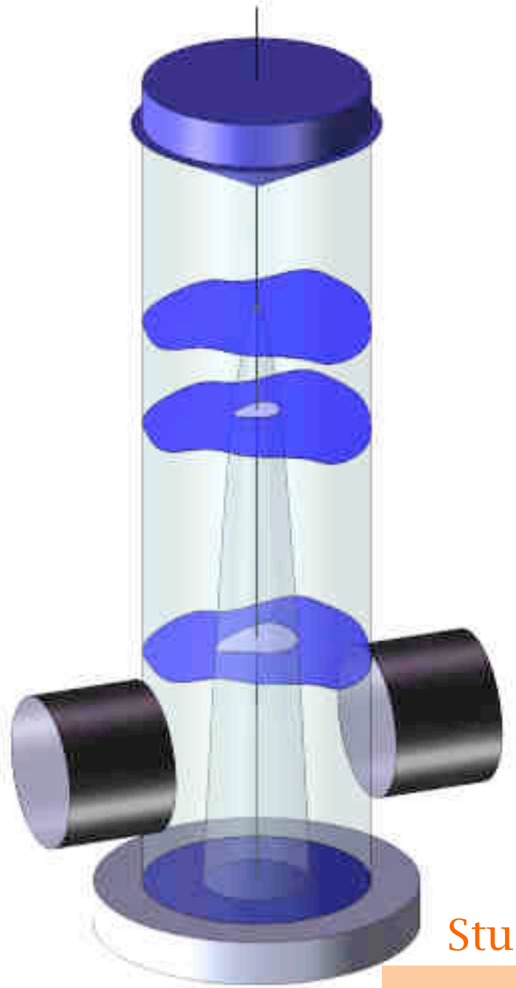
Reflexion
system

Wavefront distortion and cloud expansion

Cold Atoms

$T_{emp} \sim 2\mu K$

$\sigma_v \sim 14\ mm.s^{-1}$



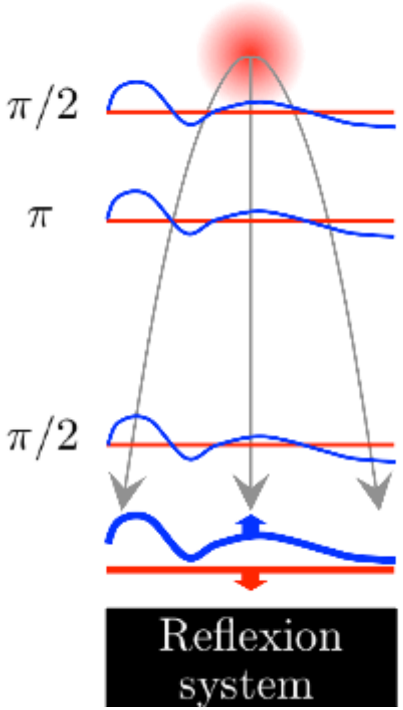
$r\ \ (2\sigma_v,\ \ \text{for}\ T = 80ms)$

$0\ mm$

T

T

$5\ mm$



Following an atomic trajectory the total phase coming from wavefront imprinted at each pulse is non zero due to the ballistic expansion of the atomic cloud.

Study case: curvature

$$\phi\ \sim\ Kr^2 \qquad \Delta\Phi = 2K\sigma_v^2T^2 = \frac{k_{\text{eff}}}{R}\frac{k_{\text{B}}T_{emp}}{m_{\text{Rb}}}T^2$$

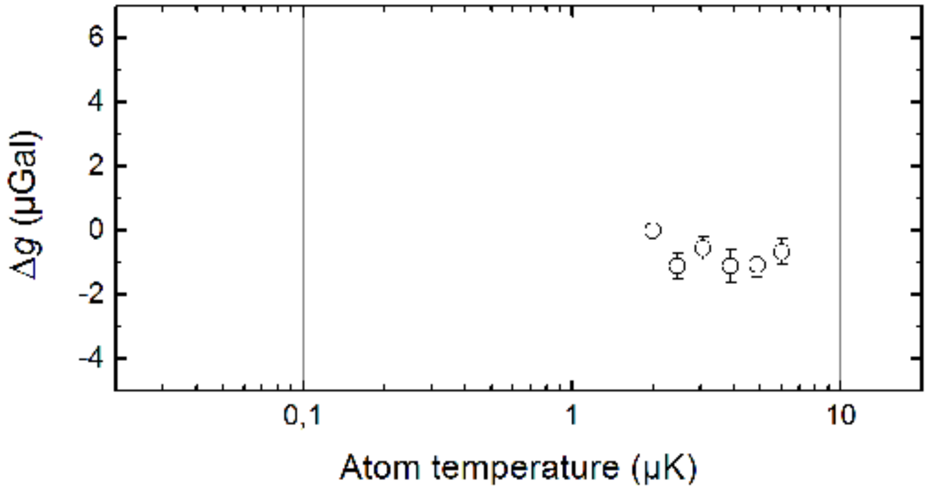
$$\text{for}\ \Delta g = 10^{-9}g,\ \ R = 20km,\ \ \lambda/300\ PV\ \ (2r = 1cm)$$

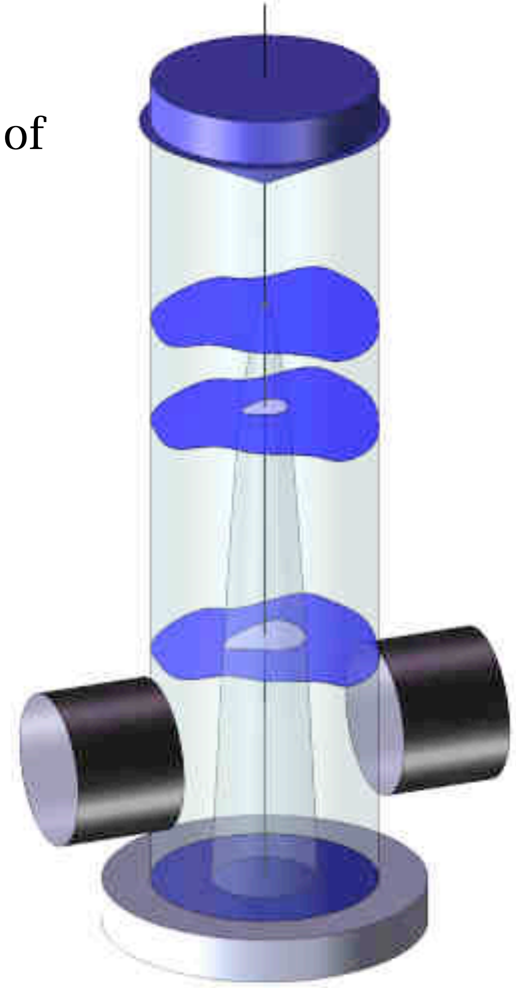
Wavefront Bias determination

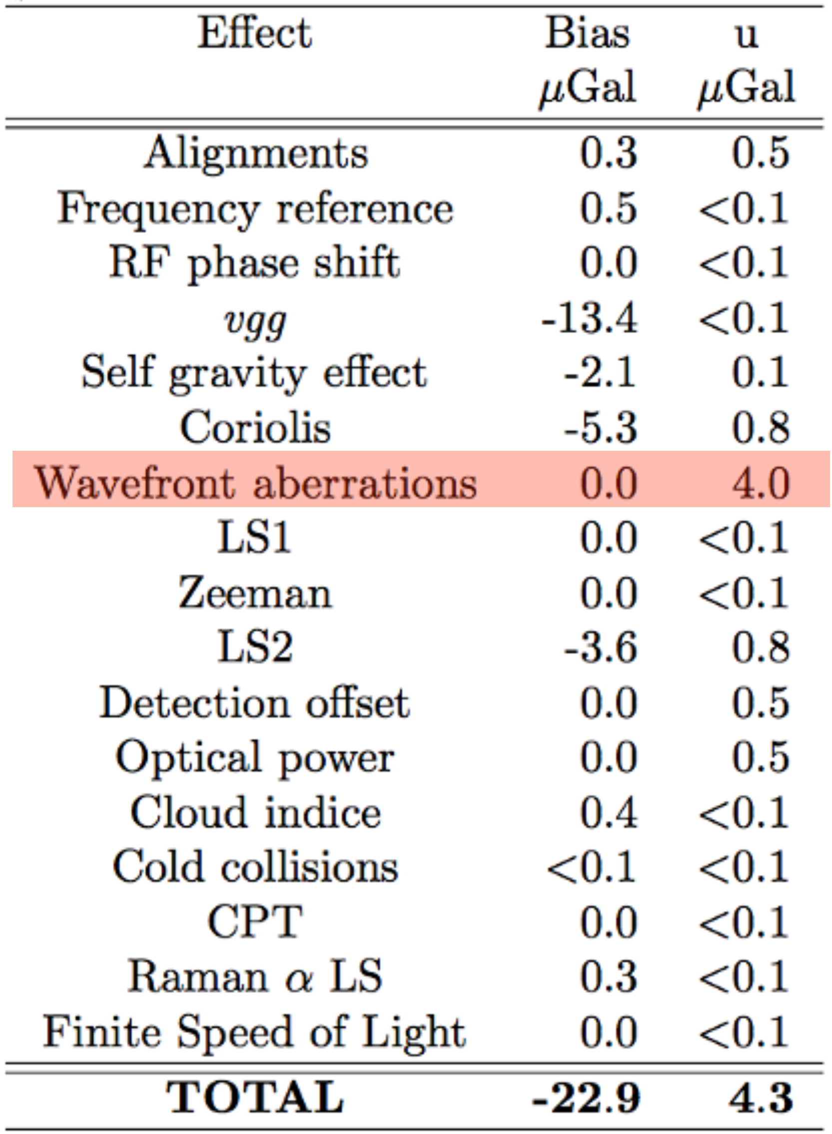
Previous determination:

Increase the temperature to modify the effect of **wavefront aberrations**

A.Louchet-Chauvet et al New J. Phys. ***13****, 065025 (2011)*



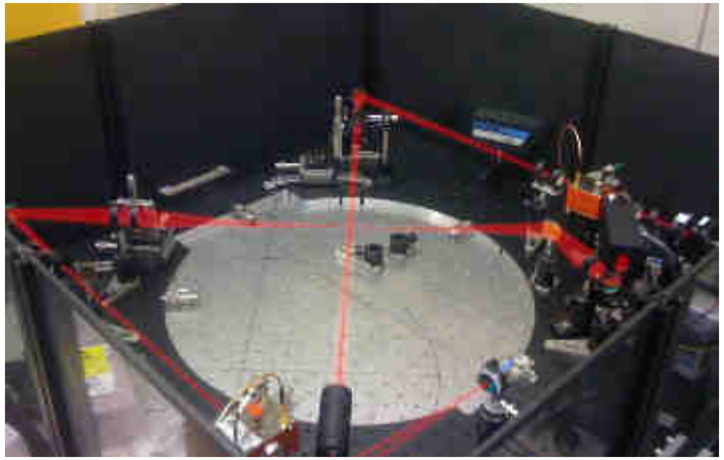


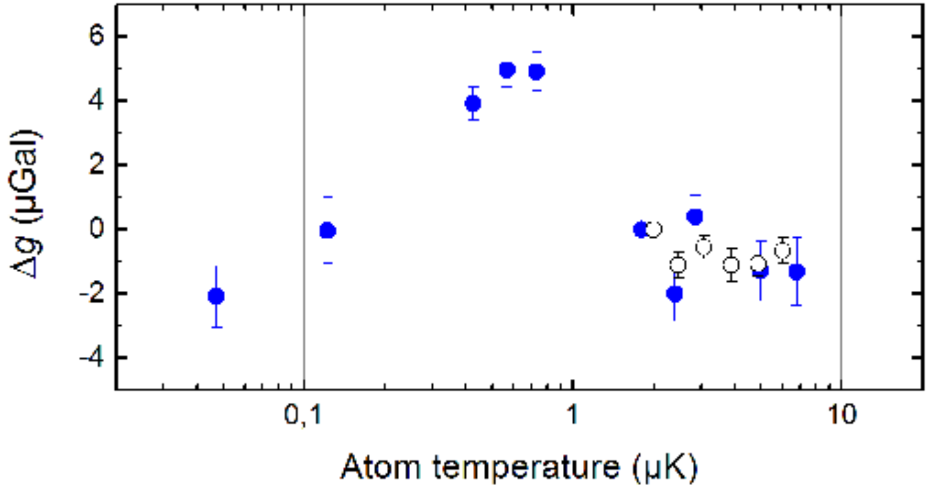


Effect	Bias μGal	u μGal
Alignments	0.3	0.5
Frequency reference	0.5	<0.1
RF phase shift	0.0	<0.1
vgg	-13.4	<0.1
Self gravity effect	-2.1	0.1
Coriolis	-5.3	0.8
Wavefront aberrations	0.0	4.0
LS1	0.0	<0.1
Zeeman	0.0	<0.1
LS2	-3.6	0.8
Detection offset	0.0	0.5
Optical power	0.0	0.5
Cloud indice	0.4	<0.1
Cold collisions	<0.1	<0.1
CPT	0.0	<0.1
Raman α LS	0.3	<0.1
Finite Speed of Light	0.0	<0.1
TOTAL	**-22.9**	**4.3**

$$\Delta g \;=\; (0 \;\pm\; 4)\;\mu Gal$$

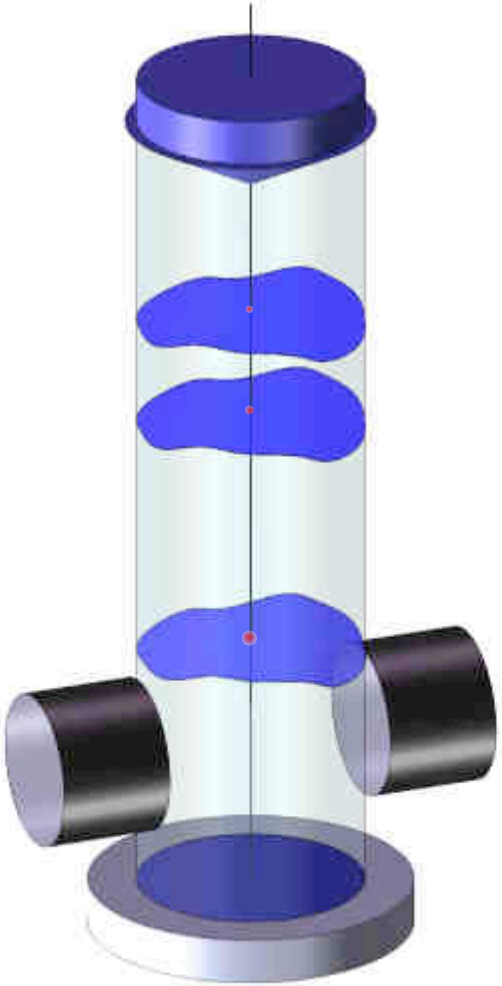
Implement Ultracold Source on CAG





Differential gravity measurements as a function of the atomic temperature from 50nK to 7µK

R. Karcher et al., New J. Phys. ***20*** *(2018) 113041*



Effect	Bias µGal	u µGal
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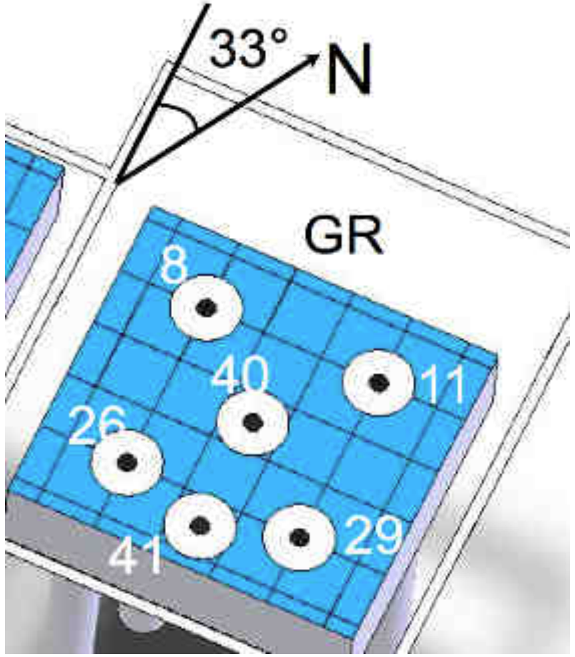
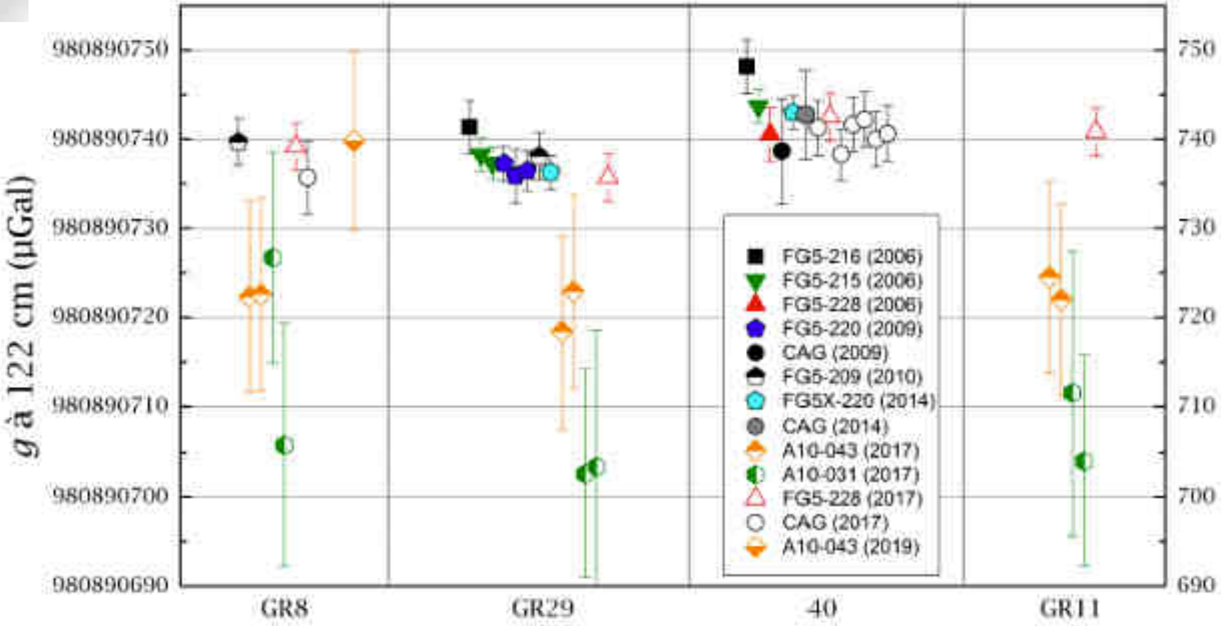
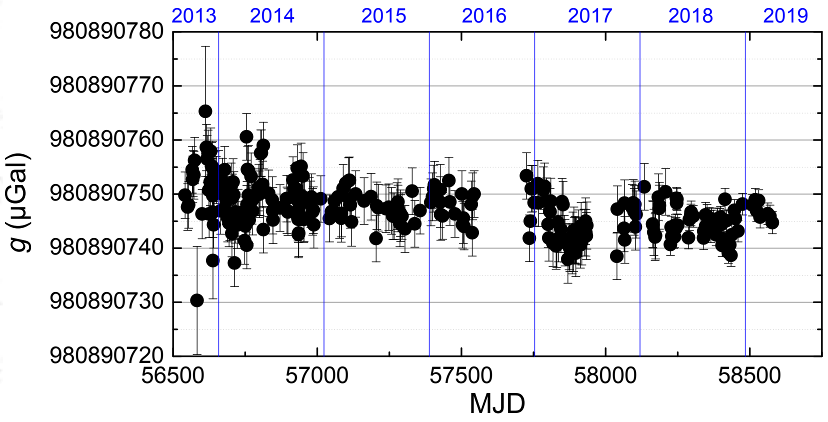
Wavefront aberrations	-5.6	1.3
LS1	0.0	<0.1
Zeeman	0.0	<0.1
LS2	-3.6	0.8
Detection offset	0.0	0.5
Optical power	0.0	0.5
Cloud indice	0.4	<0.1
Cold collisions	<0.1	<0.1
CPT	0.0	<0.1
Raman α LS	0.3	<0.1
Finite Speed of Light	0.0	<0.1
TOTAL	**-28.5**	**2.0**

$$\Delta g = (-5.3 \pm 1.3)\ \mu Gal$$

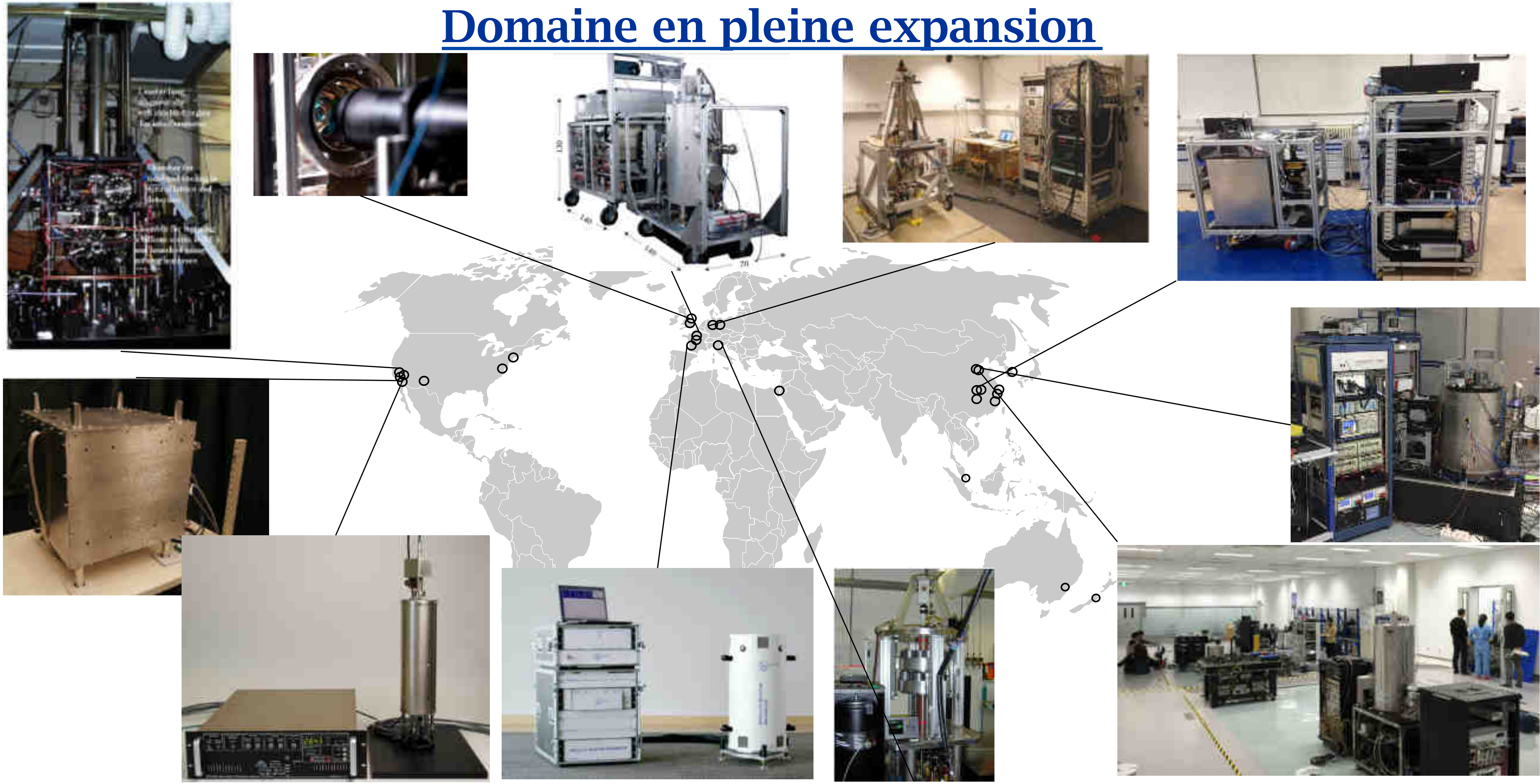
National comparison



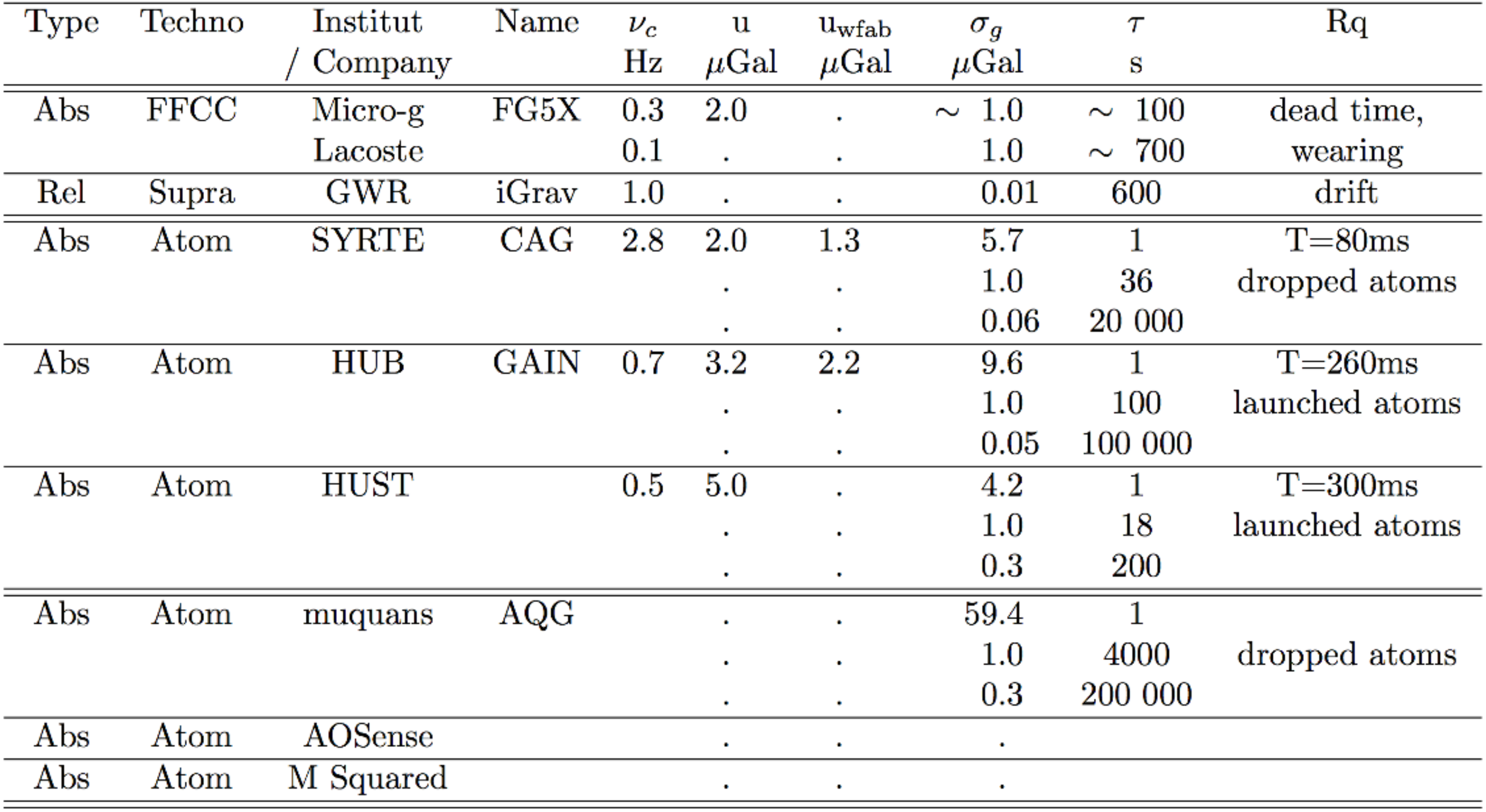




Domaine en pleine expansion



Comparison with other gravimeters



Type	Techno	Institut / Company	Name	ν_c Hz	u μGal	u_{wfab} μGal	σ_g μGal	τ s	Rq
Abs	FFCC	Micro-g	FG5X	0.3	2.0	.	∼ 1.0	∼ 100	dead time,
		Lacoste		0.1	.	.	1.0	∼ 700	wearing
Rel	Supra	GWR	iGrav	1.0	.	.	0.01	600	drift
Abs	Atom	SYRTE	CAG	2.8	2.0	1.3	5.7	1	T=80ms
					.	.	1.0	36	dropped atoms
					.	.	0.06	20 000	
Abs	Atom	HUB	GAIN	0.7	3.2	2.2	9.6	1	T=260ms
					.	.	1.0	100	launched atoms
					.	.	0.05	100 000	
Abs	Atom	HUST		0.5	5.0	.	4.2	1	T=300ms
					.	.	1.0	18	launched atoms
					.	.	0.3	200	
Abs	Atom	muquans	AQG		.	.	59.4	1	
					.	.	1.0	4000	dropped atoms
					.	.	0.3	200 000	
Abs	Atom	AOSense			.	.	.		
Abs	Atom	M Squared			.	.	.		

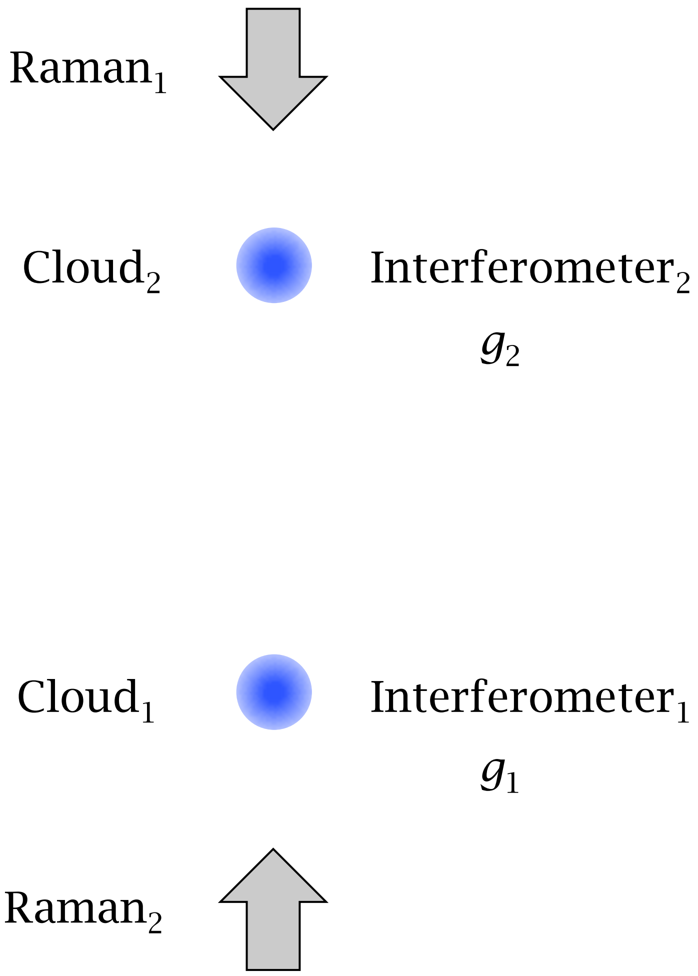
Sommaire

Notre participation dans ce changement

Le gravimètre atomique du LNE-SYRTE

La gravi-gradio-métrie

Quantum dual gravi-gradio meter



Raman$_1$

Cloud$_2$ Interferometer$_2$ g_2

Cloud$_1$ Interferometer$_1$ g_1

Raman$_2$

$g_1, \; g_2, \; g_1 - g_2$

- Simultaneous interferometers on two cold atom clouds with common Raman lasers
- Differential measurement allows for extracting the acceleration difference (and thus the Earth gravity gradient)
- **Suppression of common mode noise**, and in particular of the vibration noise
- Adapted for onboard measurements
- g and Δg: resolve ambiguities in determination of mass and position

How to increase the sensitivity ?

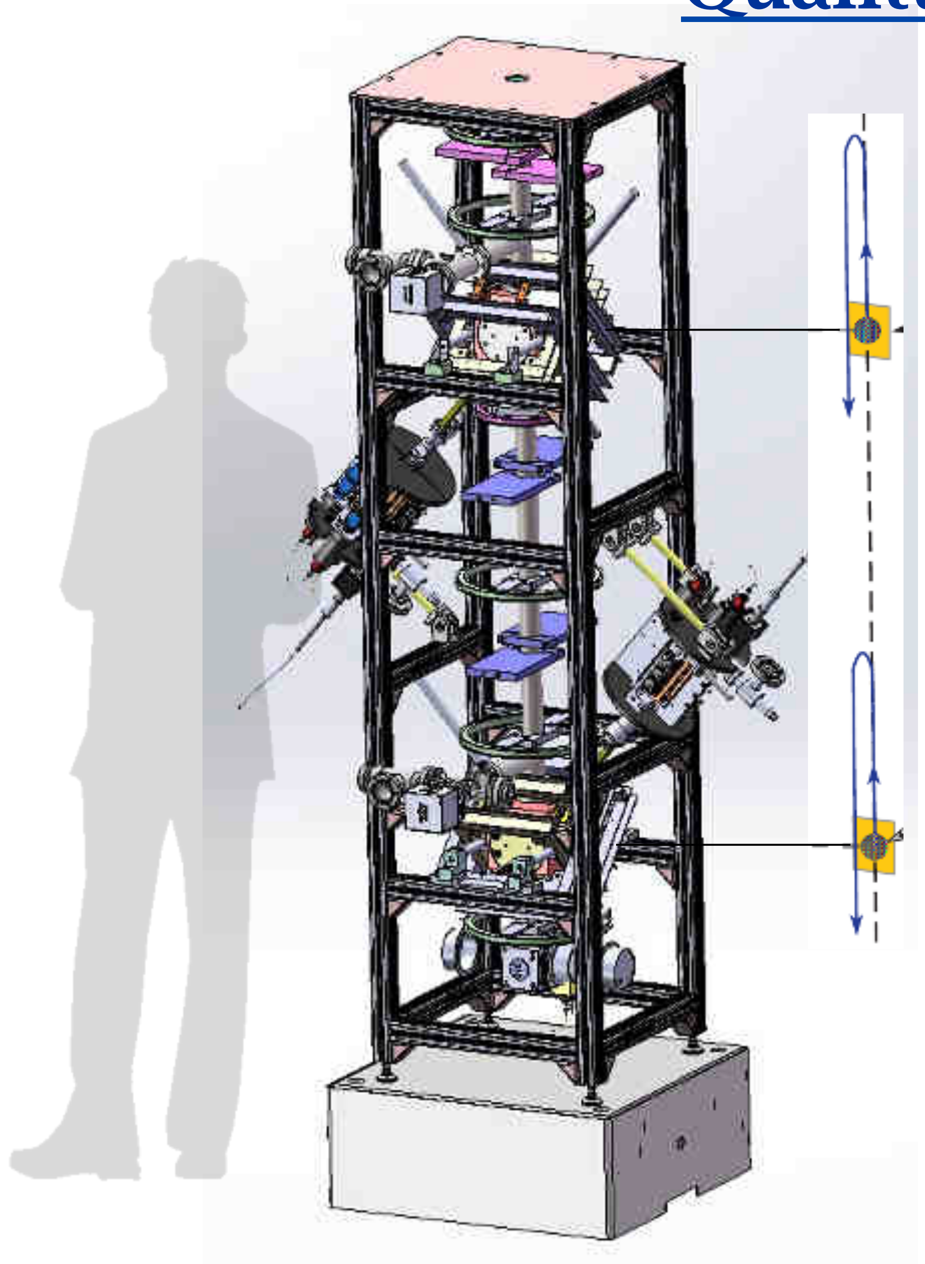
$$\triangle\Phi = \vec{k}_{\mathrm{eff}}\vec{g}T^2$$

Increase the scale factor

New tools

- High order Bragg diffraction
  LMBS with up to N photons
- Ultracold atoms
  Fast generation on atom chip

Quantum dual gravi-gradio meter



→ 2 ultracold Rb clouds obtained on 2 chips

→ 2 clouds launched with elevator

→ 2 Interferometers drived by LMTB

Targeted parameters

$$T_c = 2s \quad N_{\text{atoms}} = 5.10^5$$
$$T_{emp} = 10 - 100nK$$
$$p = 100\hbar k \quad 2T = 0.5s$$

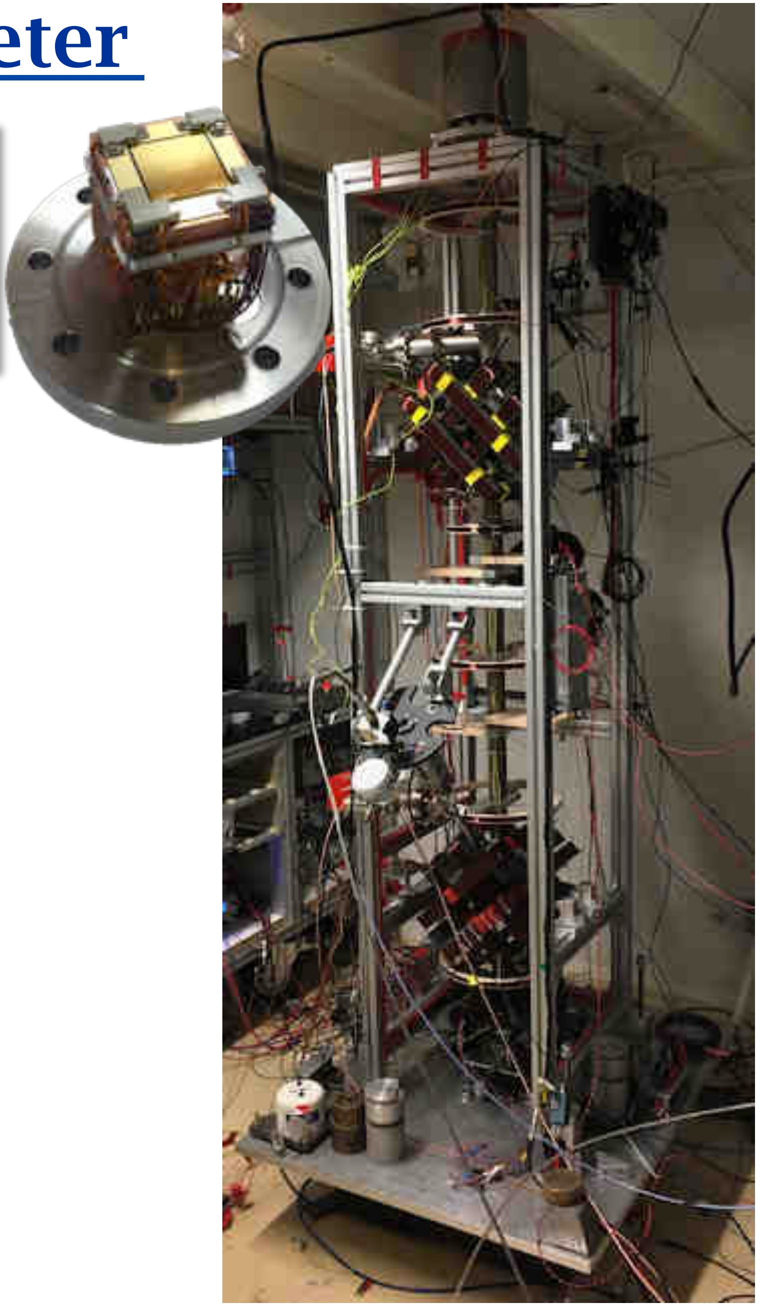
$$\sigma_{\text{g}}^1 = 9 \times 10^{-11} m.s^{-2}.Hz^{-1/2}$$

If limitated by QNP

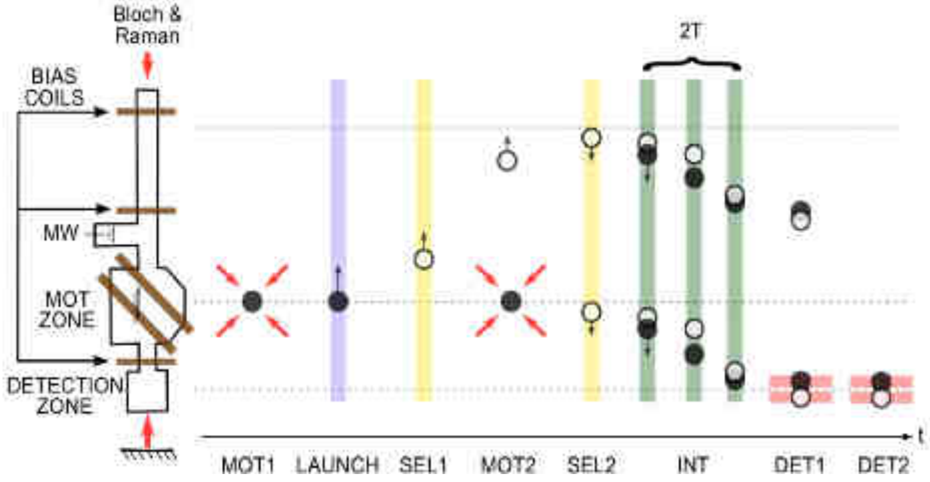
$$\Delta z = 1m$$

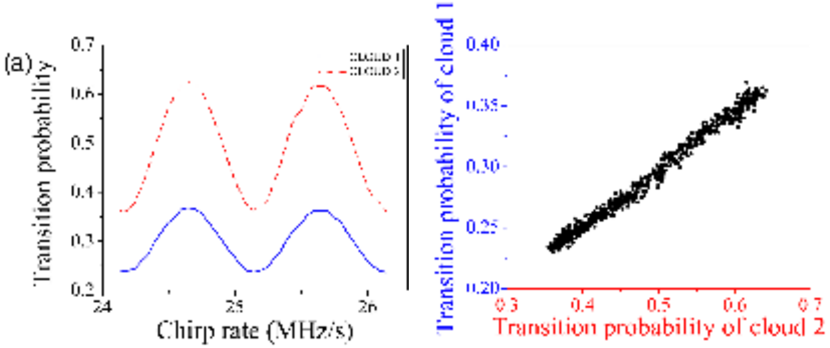
$$\boxed{\sigma_{\text{grad}g} = 126\ mE\ @1s}$$

More than one order of
magnitude better than
state of the art

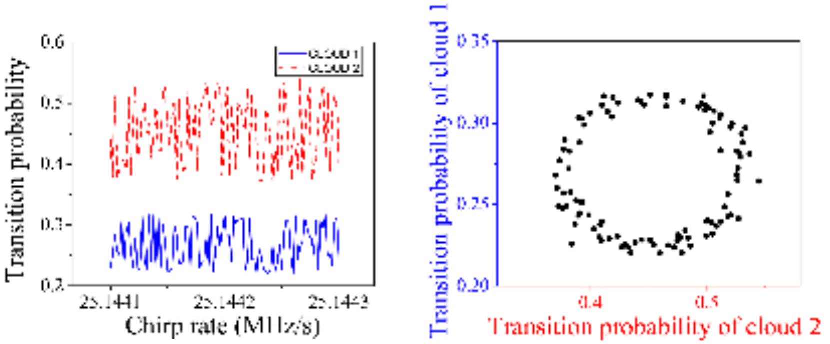


Quantum dual gravi-gradio meter, first results





T=1ms



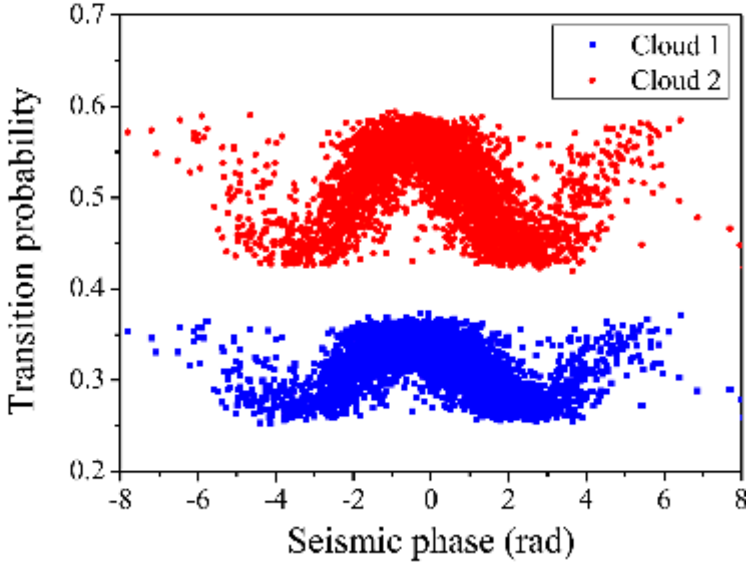
T=35ms

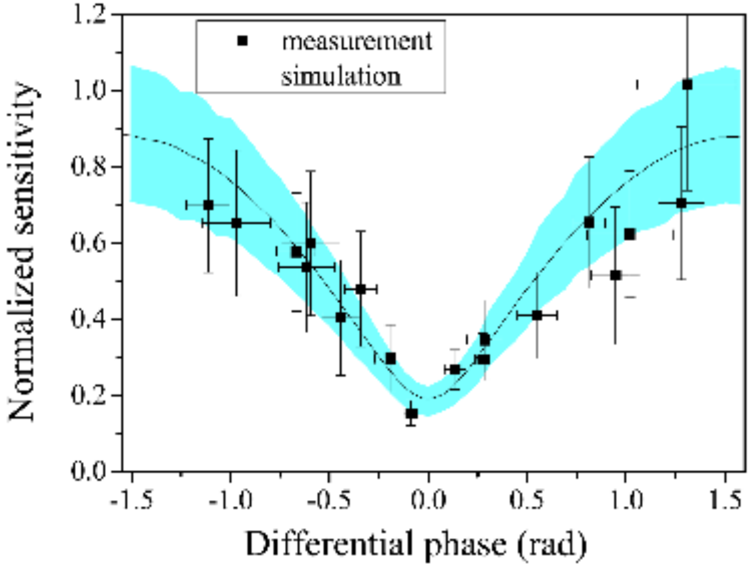
Use of a seismometer

$$P_i = A_i + \frac{C_i}{2}\cos(D_i\Phi_{\text{vib},s} + \Phi_i)$$

M. Langlois et al., Phys. Rev. A ***96*** *053624 (2017)*

T=60ms





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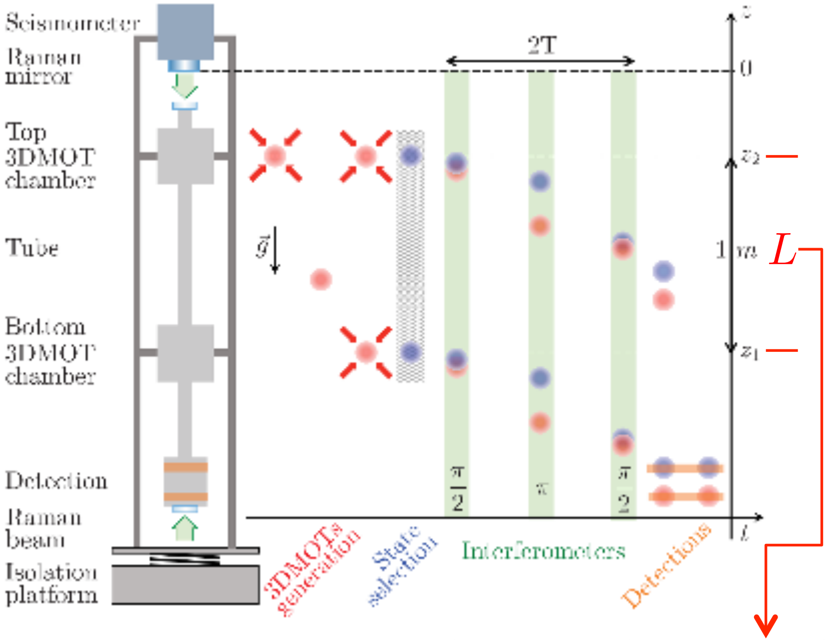
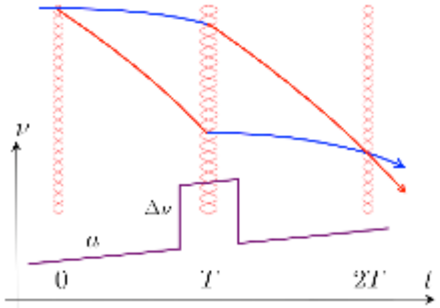


$$\Delta\Phi = \Phi_2 - \Phi_1 = kg_2T^2 - kg_1T^2 = k\gamma\boxed{L}T^2$$

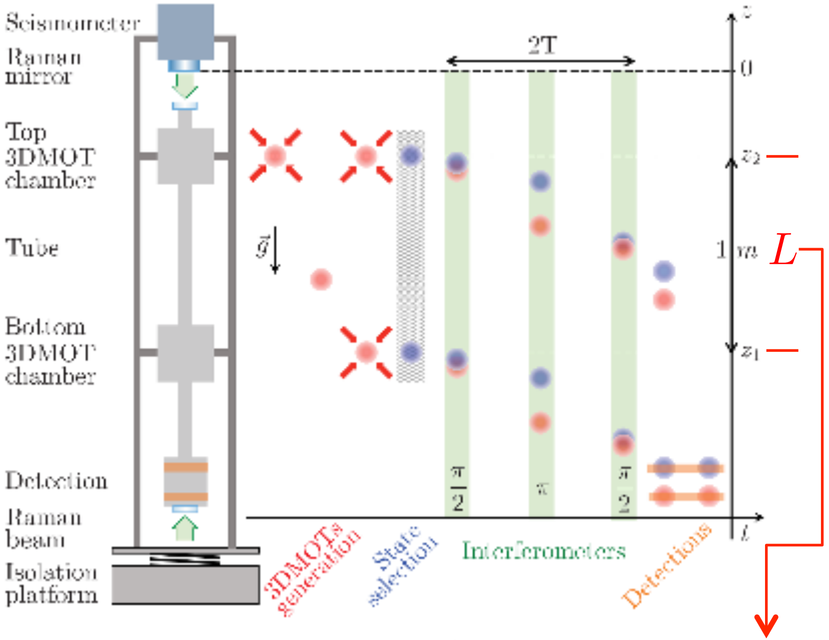
$$\Phi_i = kg_iT^2 + aT^2 + K_i\Delta\nu \begin{cases} \Delta\Phi_i^{\mathrm{FC}} = aT^2 \\ \Delta\Phi_i^{\mathrm{FJ}} = K_i\Delta\nu \end{cases}$$



$$\begin{cases} \Delta\nu = \dfrac{k(g_1 - g_2)T^2}{K_2 - K_1} \\ a_s = -k\left(\dfrac{K_2g_1 - K_1g_2}{K_2 - K_1}\right) = -kg_s \end{cases} \xrightarrow[g_i = g_0 + \gamma z_i]{K_i = 8\pi z_i/c} \begin{cases} \Delta\nu_\gamma = -\gamma\dfrac{kT^2c}{8\pi} \\ g_s = g_0 \end{cases}$$

Accurate determinations of **both** the gravity acceleration (at the mirror position) and the gravity gradient, **independent from the baseline**

Quantum dual gravi-gradio meter, first results



$$\Delta\Phi = \Phi_2 - \Phi_1 = k g_2 T^2 - k g_1 T^2 = k\gamma \boxed{L} T^2$$

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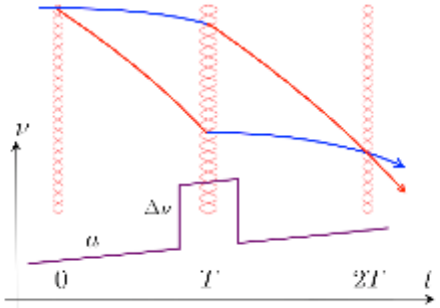

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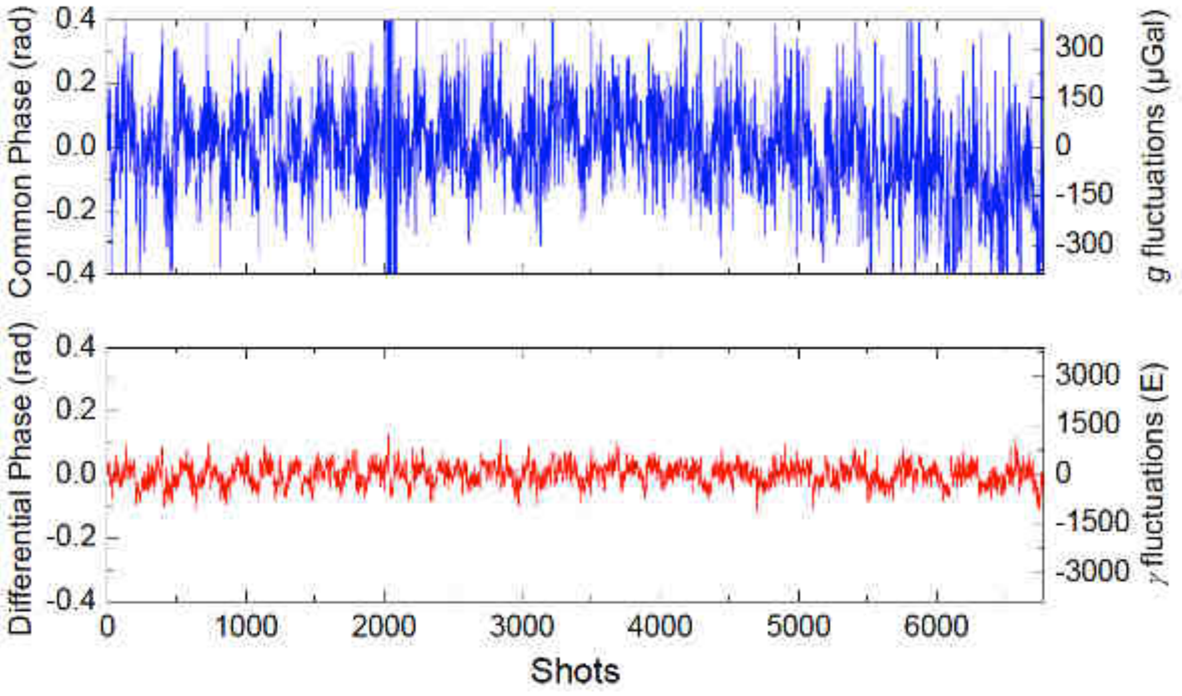


*R. Caldani et al., Phys. Rev. A **99** 033601 (2019)*

Conclusion

Le **CAG** a démontré sa capacité à mesurer, de manière absolue, *g* en continu.

g dans $h_{LNE\text{-}2017}$, prise en compte par le CODATA dans l'ajustement h_{2018} pour la nouvelle définition du kg

→ *Nouvelle mise en pratique*

Participe à des comparaisons internationales et nationales.

Les gravimètres atomique sont adaptés pour des applications jusqu'alors réalisées par des gravimètres supraconducteurs et/ou à coins de cube en chute libre.

Technologie transférée à l'industrie. Support aux utilisateurs.

Performances encore améliorables avec les atomes ultra-froids, *ouvrir la « sea of problems » et de nouvelles applications*. → **objectif sub-µGal**

$$9.808\ 907\ 45(2)\ m/s^2$$

Double capteur **Gravi-Gradio** en cours de développement. *La mesure des deux grandeurs, qui dépendent différemment des masses et de leurs positions, permettra de résoudre les ambiguïtés entre les masses et les positions des sources d'anomalies de gravité.*

→ *Soutenance de thèse Romain Caldani vendredi 10h*

La cartographie gravimétrique embarquée sera bientôt possible avec des gradiomètres à atomes UF pilotés avec des LMBS.

- Aller dans l'espace ?
- Atomes sont en chute libre comme le satellite, T=10s ?; (2T=5s 2mE@1s)

https://syrte.obspm.fr/spip/science/iaci/
https://syrte.obspm.fr/spip/science/iaci/publications/

PNTG

EMN European Metrology Network

PNTG : Positioning Navigation Timing and Geodesy

Sea level monitoring, future georeferenced services like autonomous driving, classical construction surveying, or time-synchronization in telecommunication networks – they are all examples for economic and scientific applications of internationally highly-coordinated positioning, navigation, timing, and geodesy (PNTG) infrastructure. Advance in these classically separated fields leads to similar metrological challenges and requires interdisciplinary approaches combining gravimetry, time and frequency, and length metrology. A European Metrology Network (EMN) in PNTG seems an ideal vehicle to organize such collaboration efficiently in Europe. This project will lay the groundworks for this EMN.

In summary, the project will reorganize the metrology competence in PNTG, spread today over different locations and metrology disciplines to a joint, focussed, and effective network. The target of the project and all its outcomes is to address the explicit needs in industry and scientific geodesy from the end-user point of view. This will support most critical services for modern economy, as well as for hazard monitoring.

JNP w-02 PNTG

Support for an EMN on Positioning, Navigation, Timing and Geodesy

Need

Georeferenced services
Autonomous driving, ...

Network synchronization
Finance, telecom, energy

Sea level monitoring
Δheight ~ 3.5 mm/yr

Critical site monitoring
Δposition ~ 0.1 mm/yr

Kibble balance
U(g) ~ O(10^{-8})

UN General Assembly 2015:
„...invites member states to enhance the global geodetic reference frame"

Metrology Competence

Chronometric levelling
Towards a unified height system

Atom gravimeter

Time synchronization
GNSS- & fibre-based

Dimensional traceability

Space geodesy
Reference frame traceability

GALILEO & EGNOS
Time service provision

Efficient EMN preparation
— Liaison development —
— Web PNTG platform —
— SRA for PNTG metrology —
— Knowledge-sharing programme —
— European PNTG metrology research infrastructure plan —

WP4 Impact
Stakeholder committee · standardisation · workshops partially co-organized with FIG or IAG · white paper · SRA publication · conference representation · EURAMET feedback
6 PM

WP3 An SRA for European PNTG metrology
— SRA draft development —
Document review · tripartite stakeholder consultation track
— SRA implementation roadmap —
— Strategy evaluation —
18 PM

WP2 European PNTG metrology research infrastructure: development and dissemination
— Metrology research infrastructure plan —
Existing infrastructure review · NMI and stakeholder priorities and needs · smart specialization strategy · other Initiatives European- and worldwide
— Knowledge sharing programme development —
Research result collation · presentation material · PNTG training workshop · NMI empowerment programme
16 PM

WP1 Towards systematic liaison and interaction with the PTNG stakeholder community
— Stakeholder mapping, prioritization, and activation —
designated contacts · stakeholder workshops · committee memberships · advisory board
— Communications plan —
responsibilities · communication channels · workshop requirements · interaction EMN and JNP
— PNTG web portal —
service database · best practice and research results compilation · designated contacts · stakeholder and capacity database · workshops material · secondment market
14 PM

JNP Impact

Successful EMN PNTG launch

Strategic Research Agenda (SRA): coordinated, stakeholder-oriented metrology research in the field

Infrastructure plan for efficient PNTG metrology

New structures and tools, e.g.:
- **Capacity database:** European metrology experts for IAG, ISO, ITU-T, European Commission
- **Service database:** PNTG services European-wide more easily accessible

Wider Impact through the EMN

Advancing metrology for key security infrastructure
Environmental and civil hazard monitoring
Reliability and robustness for „real-time economy"

„Such an **international partner to tackle metrology problems** would reflect the successful international organization and working structure of surveying in FIG ..." R. Staiger, FIG President

„Although this is a European endeavor, we have joined the program, because **we recognize the global impact** ... " M. Pearlman, ILRS Central Bureau

„The network would be particularly interesting for the **European GNSS Agency (GSA) and the European GNSS programmes**..." F. Diani, GSA

„... **information on available facilities, methods and services** for development and testing of GNSS receivers and distance measuring" A. Cerman, Skoda

JNP Consortium

Established collaboration with PNTG community
Coordinator: F. Pollinger
Budget 493 k€ / 58 PM

Metrology Support

EMN PNTG
FTE ≳ 80

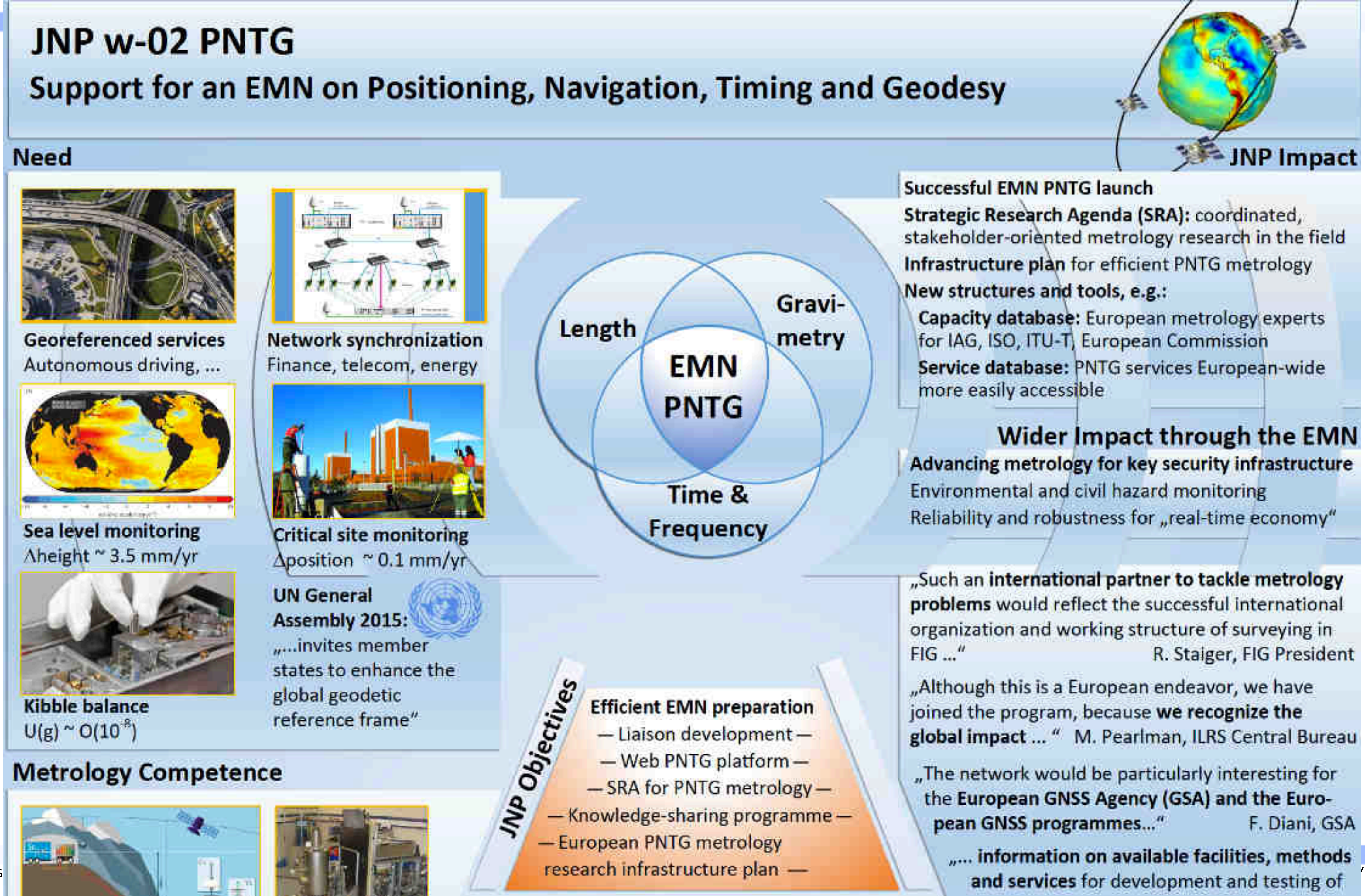
External Support

Geodesy

Agencies

Industry

Academia



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Metrology Competence

JNP Objectives

Efficient EMN preparation
— Liaison development —
— Web PNTG platform —
— SRA for PNTG metrology —
— Knowledge-sharing programme —
— European PNTG metrology research infrastructure plan —

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Merci

https://syrte.obspm.fr/spip/science/iaci/
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