Manipulation of Gravity using the Random Positioning Machine: RPM

(Space starts on Ground !)

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Manipulating Gravity

Gravity = Force

Magnitude

Direction

ISS

LDC

2D clinostat

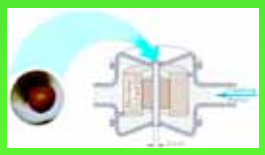
RPM

Magnetic Levitation

Inorganic

Plant

Animal



magnetic field — magnetic permeability of vacuum

Levitation: $$F_z = F_{magnetic} + F_{gravity} = 0 \Rightarrow B_z B_z' = \frac{\rho}{\chi}\mu_0 g$$

magnetic field gradient — magnetic susceptibility

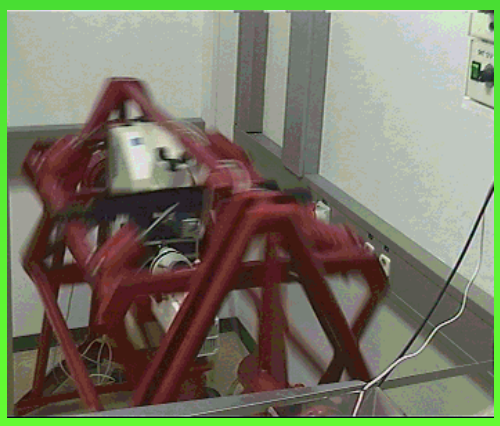
Berry & Geim, Eur. J. Phys. 1997

Slow & Fast Rotating Clinostats

Principle (Sachs, 1879)
The 'classic' clinostat is a machine for microweight simulation through a constant change, in 2D, of the direction of the gravity vector @ ~ 1-5 rpm
• ***Plants (cells)***

'Punjab' clinostat

Principle (Briebleb, 1965)
The 'classic' clinostat is a machine for microweight simulation through a constant change, in 2D, of the direction of the gravity vector @ ~ 50-80 rpm
• ***Single cells / tissues***



Clinostat – microscope, DLR, Germany

Also Great for Education

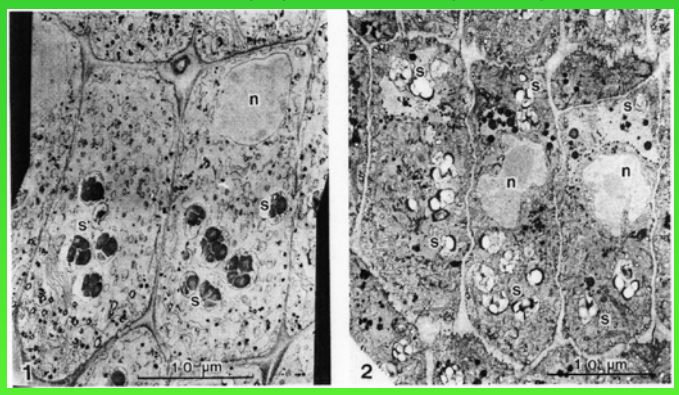
History of the RPM (1)

- Probably one of the first users of a cardanic frames for gravity research (Magnus University of Utrecht, 1924)
- In Italy a 3D clinostat experiments were performed (Scano 1963)
- Japanese researchers developed a 3D clinostat (Murakami and Yamada 1988)

from: Van Loon, J, Adv. Space Res. 2007

One of first sophisticated 3D rotating systems

Garden cress (Lepidium sativum) statocytes



1g control 3D-clinostat

built in 1986

ISAS, Japan
(courtesy: dr. Yamashita)

- First results of this '3D clinostat': Murakami *et al*. Jap. Soc. Biol. Sci. Space, 1988.
- System later better described by Hoson *et al.* 1992.

Random Positioning Machine (RPM) in NL

Principle

The RPM is a machine for microweight simulation through a random change, in 3D, of the direction of the gravity vector.

RPM at DESC

Use for

- ***Cells / tissues***
- ***Plants***
- ***Small animals (e.g. drosophila, fish, rodents)***
- ***Technology (H/W tests)***

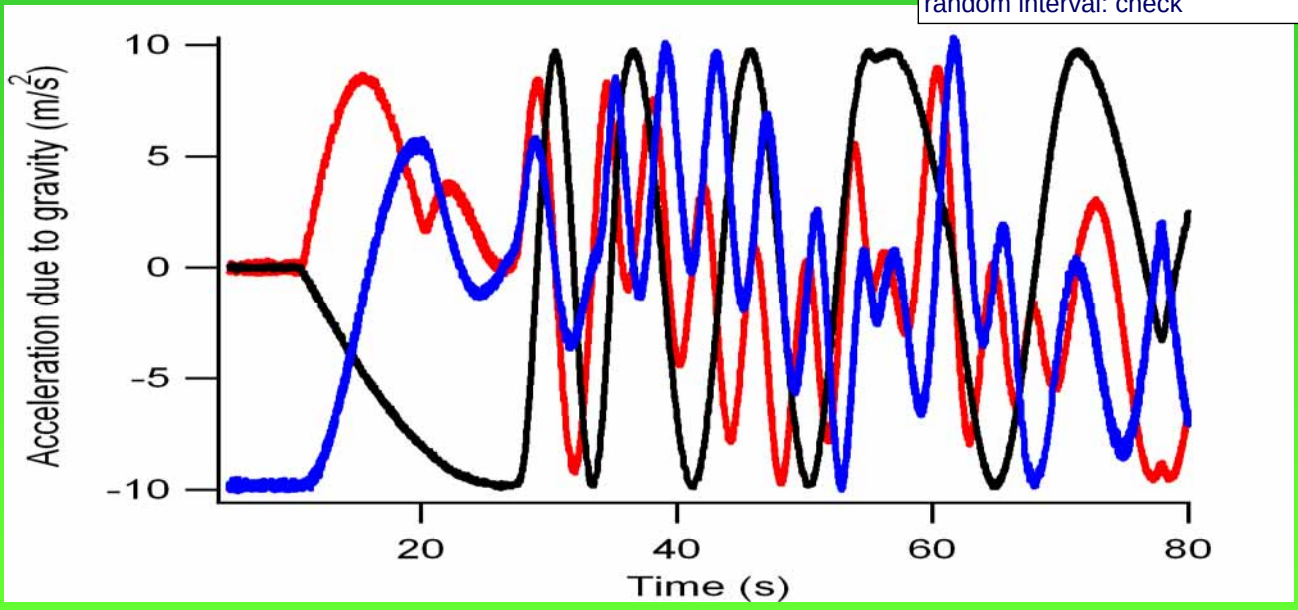
Main Features

- **Temp. 4-40°C**
- **Operational modes: random (0.1-6 rad/sec), centrifuge (0.1-60 rpm) and clinostat (0.1-60 rpm) and freely programmable mode**
- **Experiment interfaces: 12/15 volt power line, RS-232 (422) data bus (optical), Fiber optic video connection and camera**
- **Maximum experiment mass to be accommodated ~10 kg.**
- **Functional experiment accommodation volume 450 × 450 × 300 mm**
- **Possibility for microscopy, life support**

g-vector components during 3-D rotation

g_x (red); g_y (black); g_z (blue)

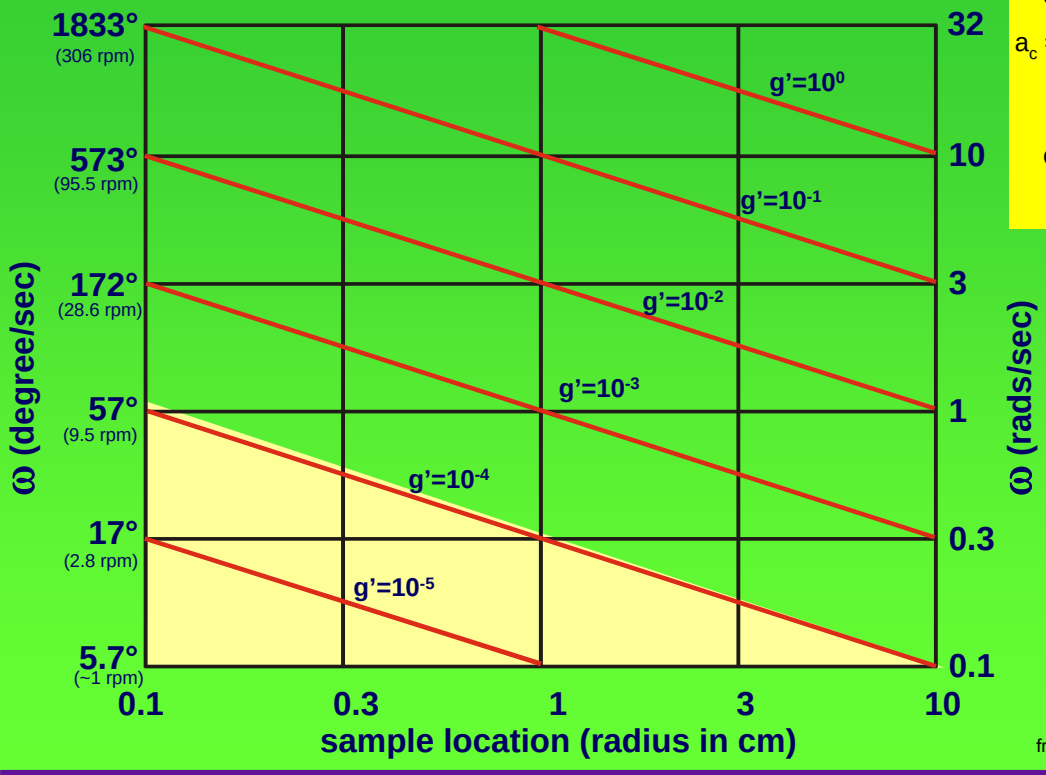
Regime:
Real random: random speed: 0 - 60
random direction: check
random interval: check



Taken from Random Positioning Machine, Amsterdam

Data: Mel Bacabac

Residual force



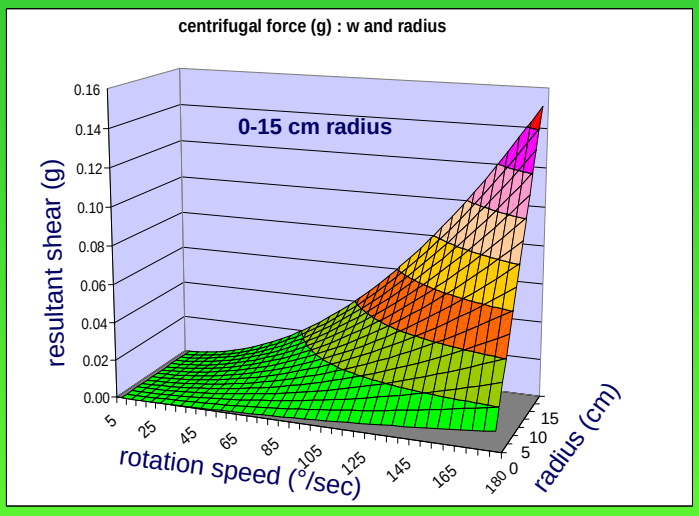
shear (g')= $a_c = \omega^2 r$

a_c = centripetal acceleration (m/s²)
ω = angular velocity (rad/s)
r = radius (m)

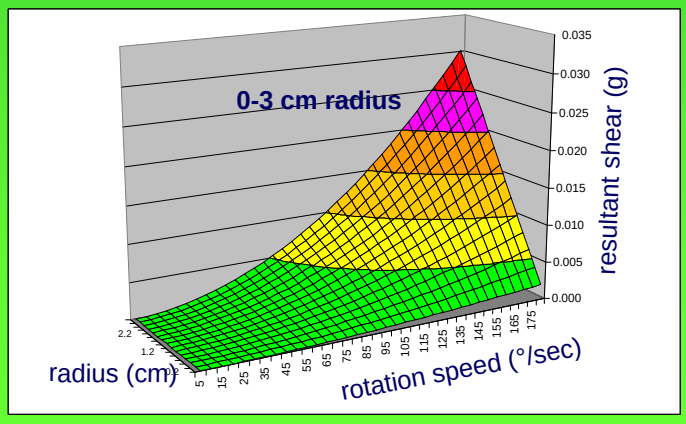
experienced centripetal force:
$F_c = ma_c = m\omega^2 r$

from: Van Loon, J, Adv. Space Res. 2007

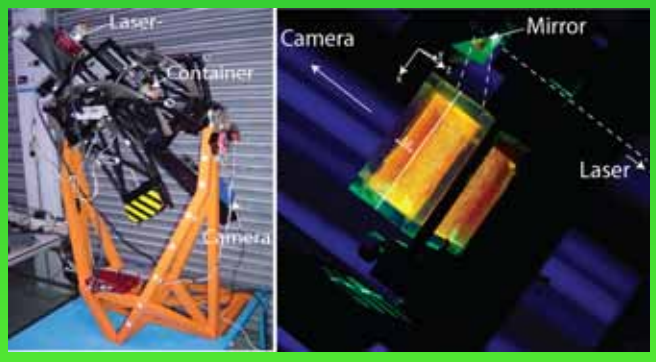
Residual inertial shear gravity



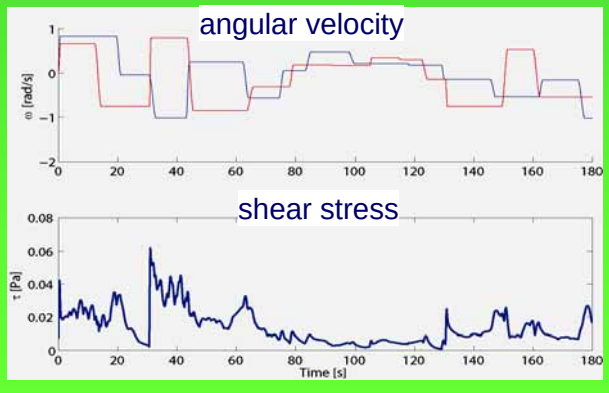
15° = 0.2617993 reds
60° = 1.047197 rads
120° = 2.094394 rads
180° = 1π rads (3.141592)

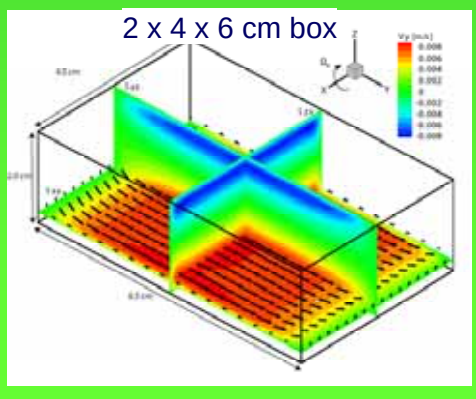


Fluid shear force in 'standard box'



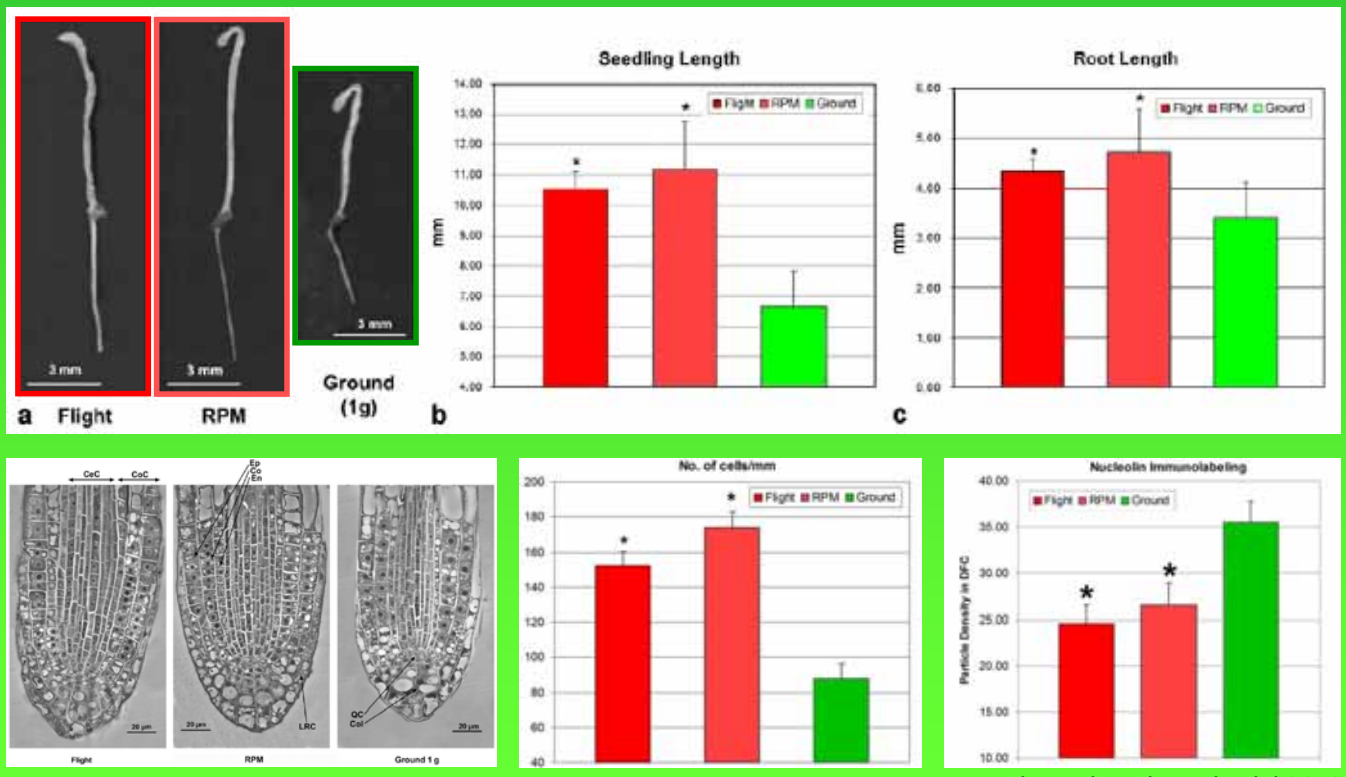
PIV measurements
(Particle Image Velocimetry)





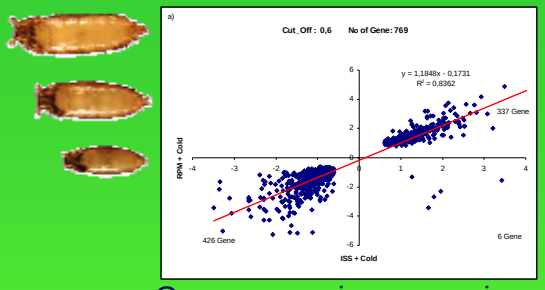
Leguy et al. Grav & Space Biol. 25(1). 2011

RPM examples-1: Arabidopsis Growth



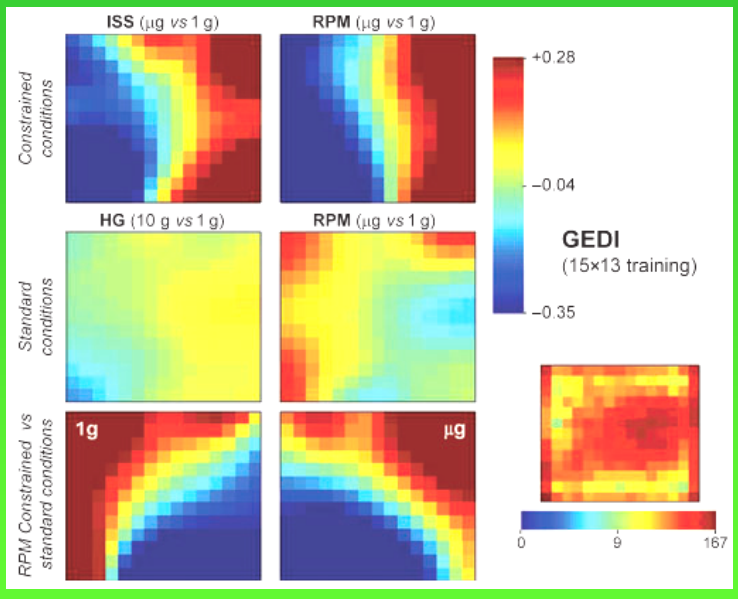
Matia et al. J Plant Physiol 2010

RPM examples-1: Drosophila Development



Gene expression comparison

Adults @ 2g



Gene expression dynamics inspector 15x13 clustering analysis

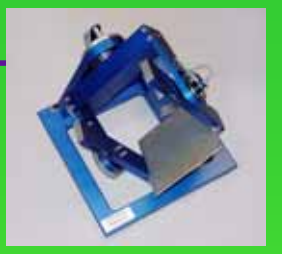
Herranz et al. Molecular Ecology 2010

Use of 3D rotating devices remarks :

In general:

- Experiments using ‘Eastern’ systems use lower accelerations (1-5 rpm) as compared to ‘Western’ systems (>50 rpm)
- Comparison of different paradigms needed
- Fluid motion / dynamics in 3D systems needs further clarification
- Same end-result (in µg and e.g. RPM) do not necessarily mean the same response-pathway

Use of a Random Positioning Machine :



In Conclusion:

- RPM can very well be used to familiarize users with gravity related research (as well as centrifuges !!)
- Not all experiments will be suited for RPM
- Already flown experiments can be verified for RPM and further developed on ground for later re-flight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Questions
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