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# Planetesimal Formation

## Microgravity Experiments Probing Collision Processes in the Solar Nebula

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Leiden Observatory

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Helen J. Fraser (Strathclyde University, UK)  
and Jürgen Blum (TU Braunschweig, GER)

# ESA Student Competition

A Chance to Fly in Zero-G



Novespace

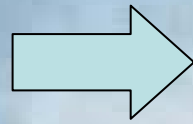
Annual competition since 2000

# Scientific Context

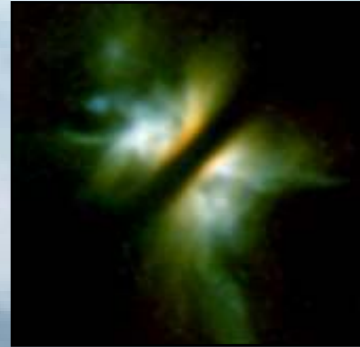
## Star Formation



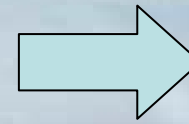
Gaseous Pillars in M16, HST (NASA)



## Proto-Planetary Disks



The Butterfly Star, HST-NICMOS (NASA)



## Initial Grain Growth

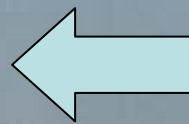


Blum et al. 1998. *Earth, Moon & Planets*: 80, 285.

## Planets



Image of Earth, Galileo Spacecraft (NASA/JPL)



## Planetesimal Formation (The Subject of our Experiment)

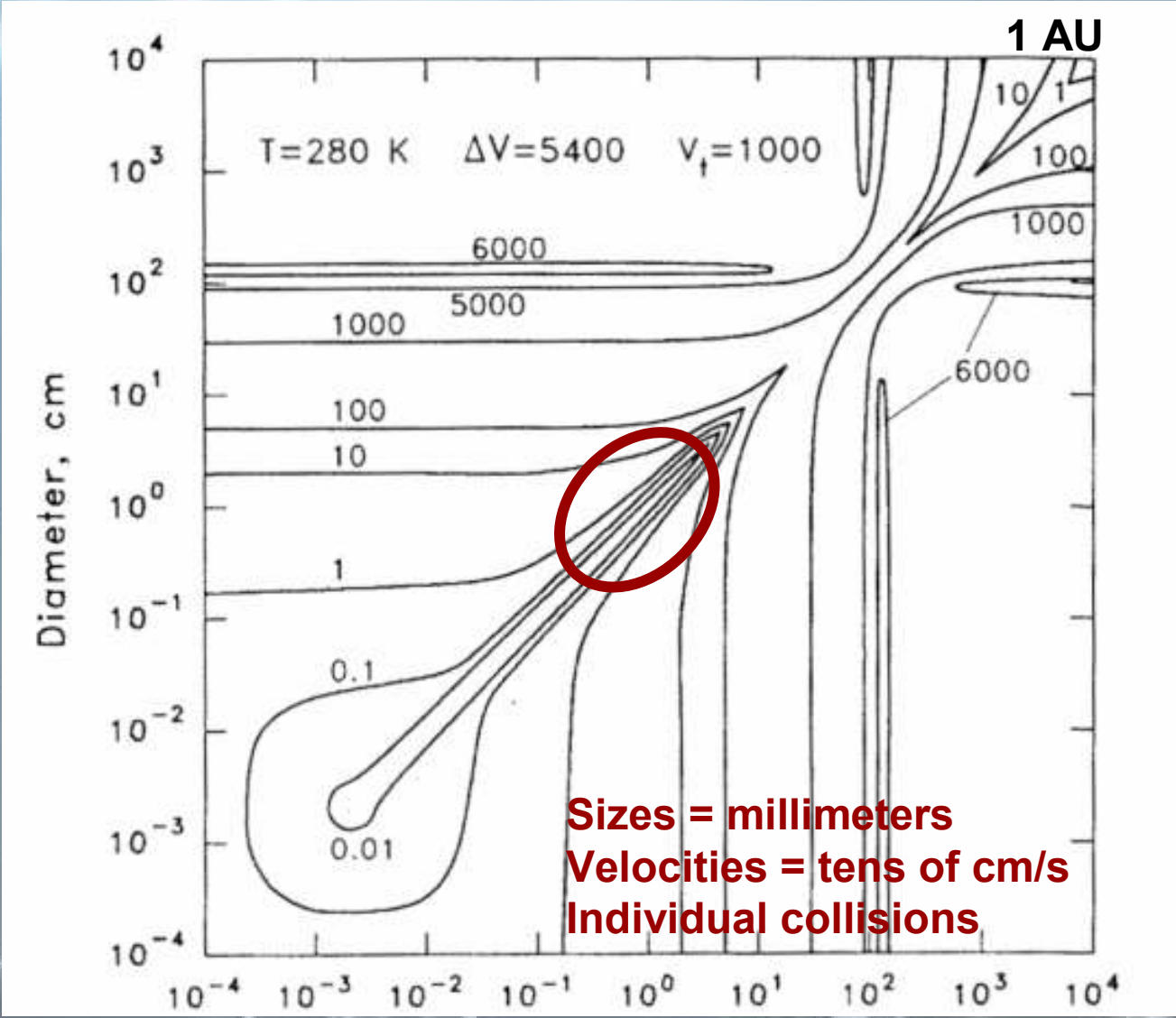


81P/Wild 2, Stardust Team (NASA/JPL)



Late Growth (Gravitational Attraction)

# Size and Velocity Realms in Disks



Weidenschilling & Cuzzi, 1993



# Instrument Design



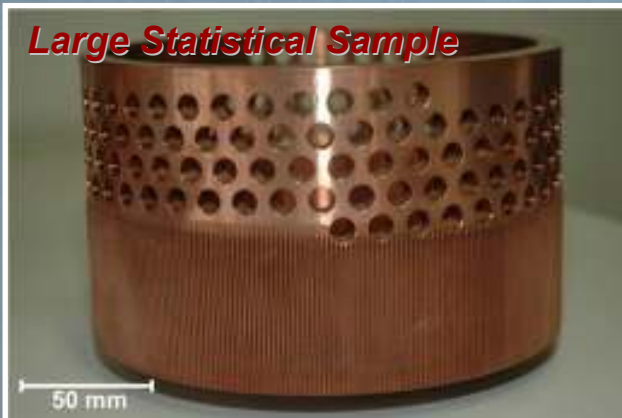
Dust Cake



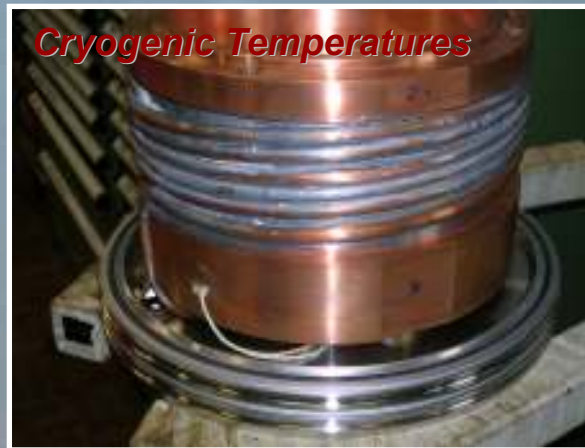
Firing Pistons



Vacuum Chamber



Particle Storage Device



Thermal Reservoir

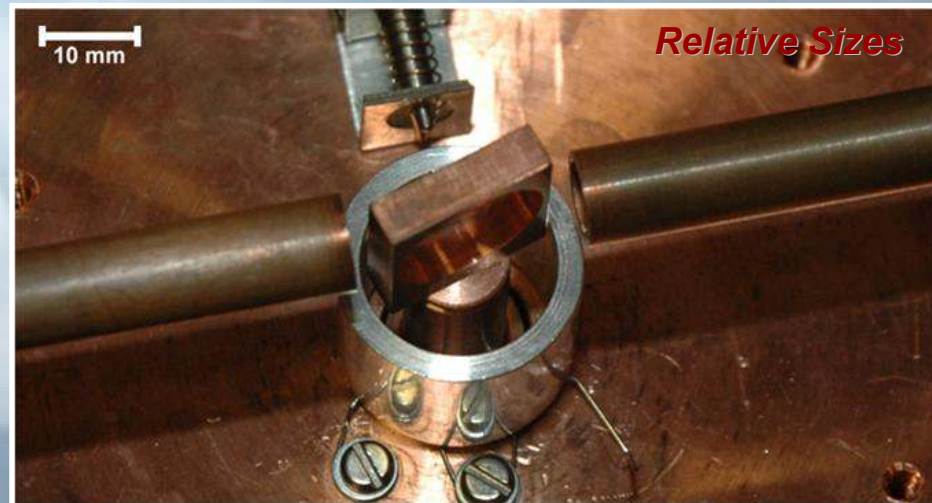


Experiment in Rack

# Instrument Design



Collision Space



Collision Alignment



Visual Alignment

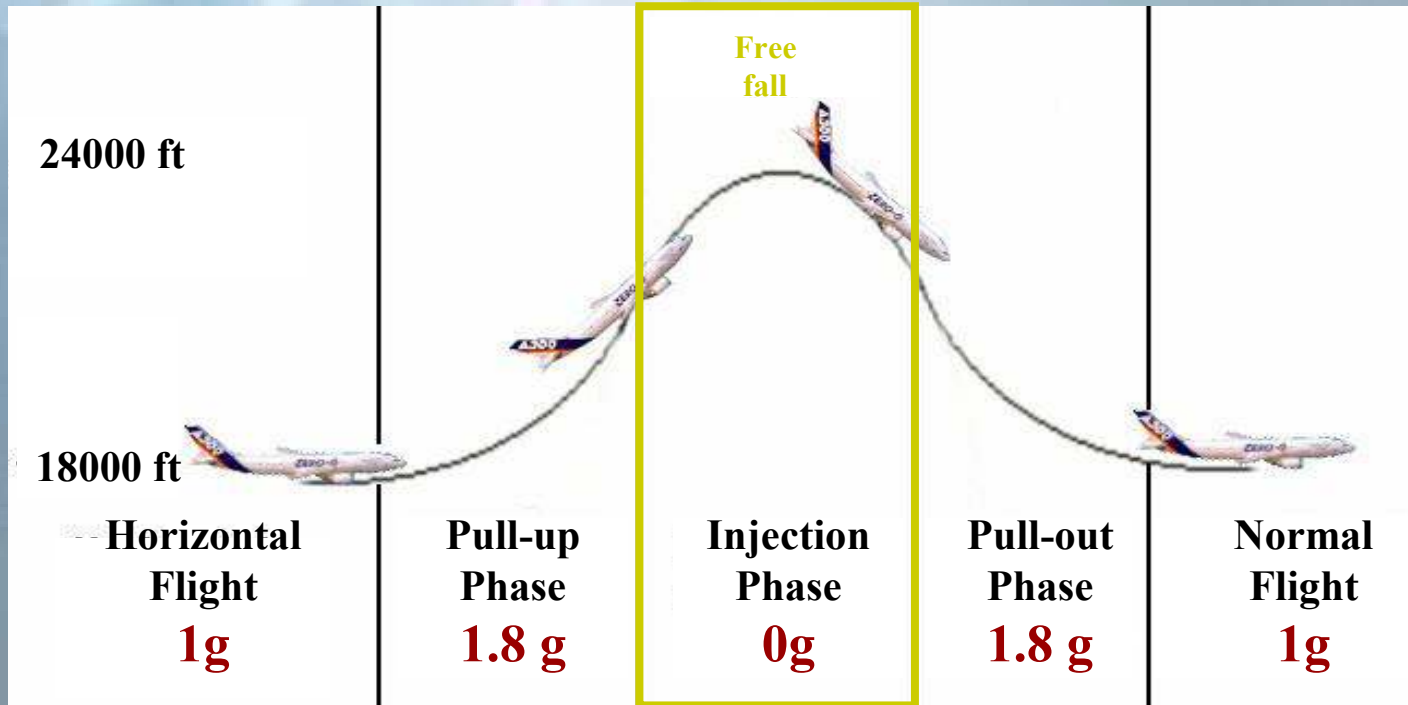


Data Acquisition

*Long  
Duration  
Microgravity!!!*

# Parabolic Flight Maneuver

## One Parabola



1 Flight = 31 Parabolas

Each parabola provides up to 22 seconds of reduced gravity or weightlessness





# Sample Data from the Experiment

## Particle and Large Target Collisions



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Demerese Salter – Leiden Observatory – VLTI Summer School in Porto – 1 June 2007



# Sample Data from the Experiment

## Particle - Particle Collisions



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# Results

## Collision Statistics

- ✓ Semi-elastic Collisions: majority, roughly 80-90% of all collisions
- ✓ Fragmentation: 10% of all particle-particle collisions
- ✓ Sticking: Only when mass ratio was high
- ✓ Only 15% of the translational energy is conserved during most events

## Conclusions

- ✓ Relative sizes important for constructive versus destructive growth.
- ✓ Small aggregates with  $v_{\text{rel}} \lesssim 16\text{-}22$  cm/s can stick to larger aggregates.
- ✓ Similarly sized aggregates with  $v_{\text{rel}} \gtrsim 36\text{-}40$  cm/s could mark the onset of fragmentation.
- ✓ The majority of fragmentation and sticking events for particle-target events occurred at small impact angles.

# Future of the Instrument

Three separate experiments in the short-term:

- **Warm Dust Agglomerates (October 2006)**
  - **Cold Dust Agglomerates (July 2007?)**
  - **Ice and Icy Dust Samples (October 2007?)**
    - **Ongoing ground-based Studies**

*Salter et al. (2007, in prep) – Instrumentation*

*Heielmann et al. (2007, in prep) – Scientific Data Analysis*

## And Me?

### My PhD Research

**The Evolution of Dust and Gas in Proto-Planetary Disks**  
The Observational Approach



# THE END





# Pre-Flight Procedures (ICES Team)

**06.15 – Departure from accommodation in Bordeaux**

**07.00 – Arrival at Bordeaux Airport**

**08.15 – Flyers confirmed to Novespace personnel**

**08.30 – Distribution of motion sickness preventative medication**

**08.55 – Last restroom run**

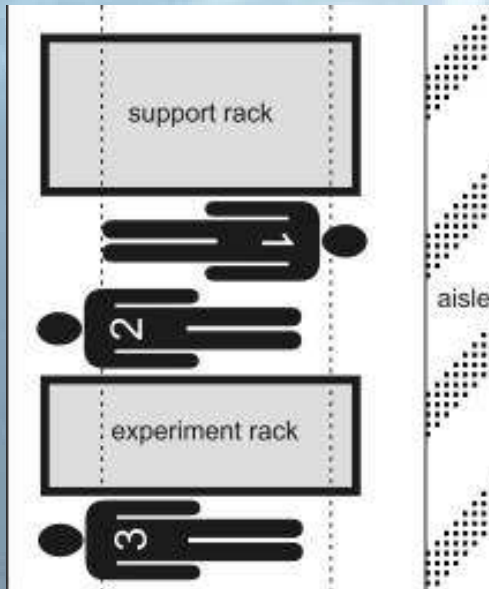
**09.00 – Closing of the plane doors**

**09.30 – Scheduled departure from Bordeaux airport**

**09.45 – Experimenters to their experiments**

**10.00 – First Parabola**

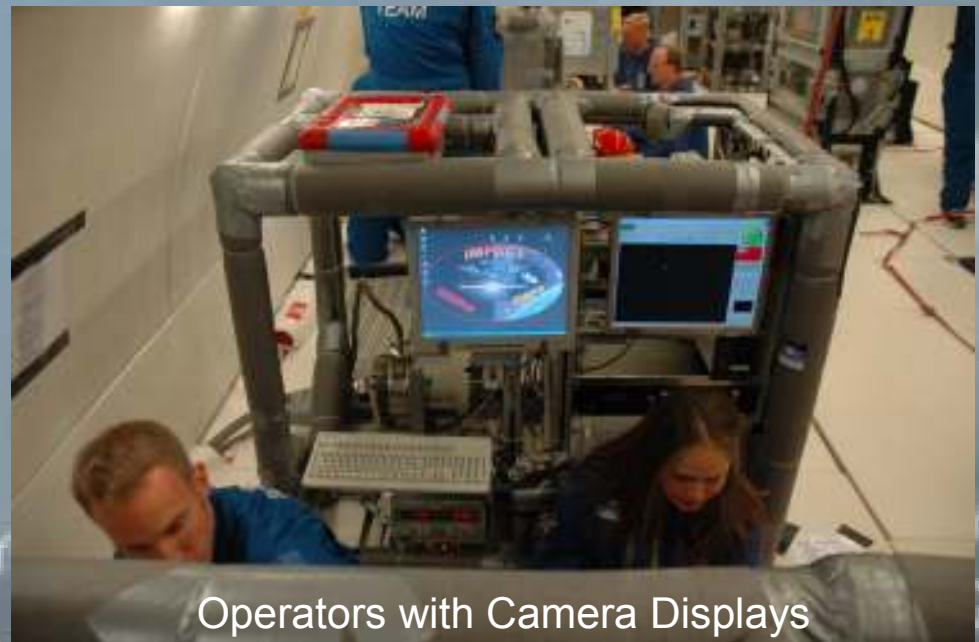
# On Board the Zero-G Plane



Experiment Setup



Support Rack first in Zero-G plane



Operators with Camera Displays