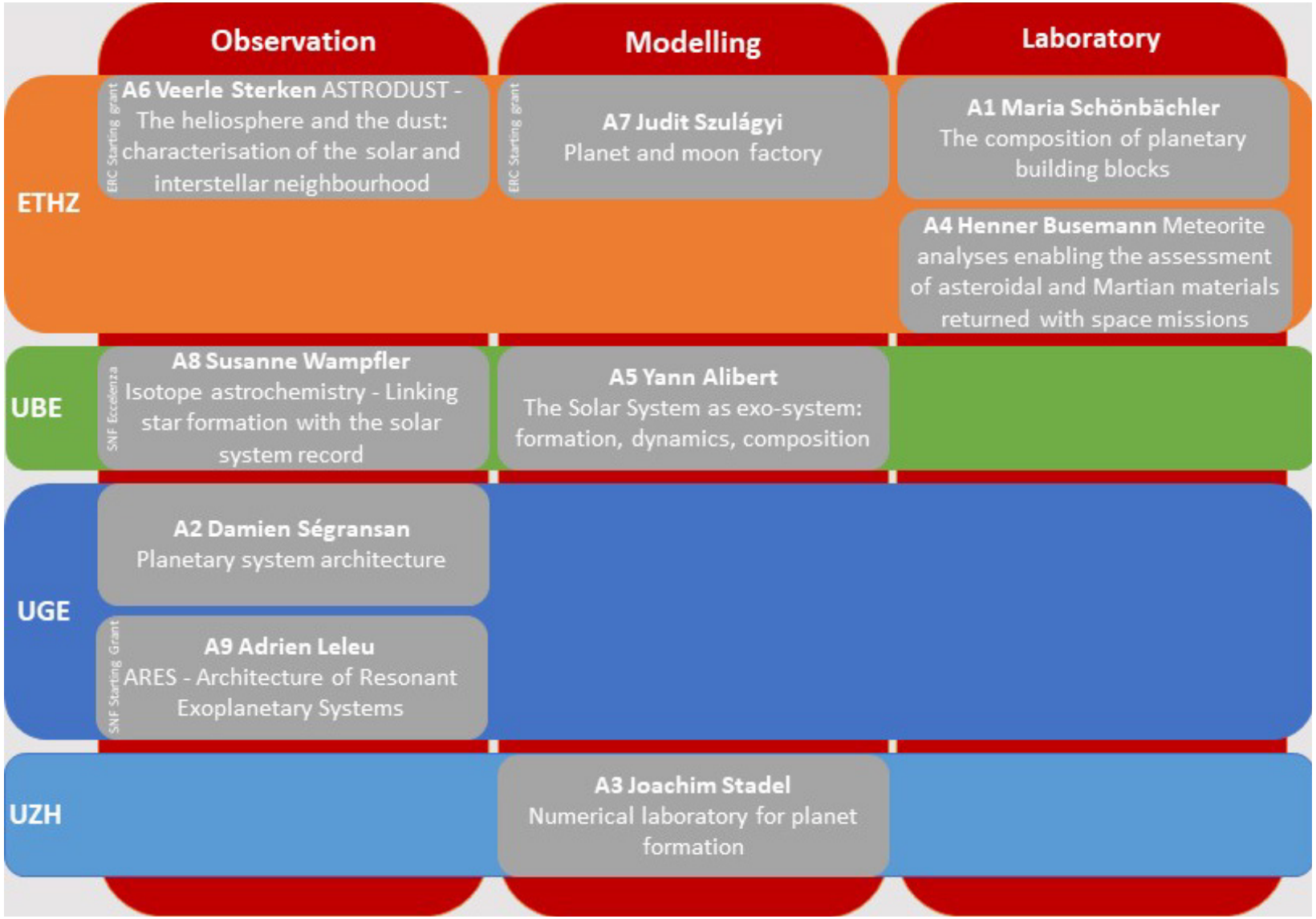
Domain A – Formation and Architecture of Planetary Systems



Domain A

5 NCCR projects

4 additional

+ many “embedded” associated projects

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Science Speed Dating

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Katarzyna Liszewska (A1): Iron isotope heterogeneity in the protoplanetary disk

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Jean-Baptiste Delisle (A2): A comparative study of the architecture of planetary systems with and without a Giant planet beyond the ice line

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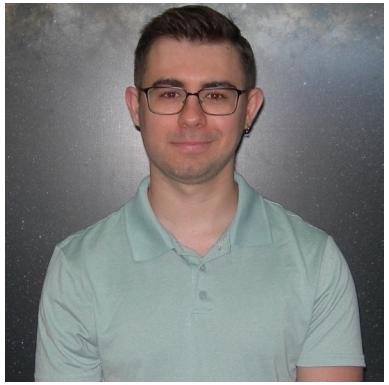
William Ceva (A2): Finding directly imageable substellar companions using legacy RV survey data with Hipparcos-Gaia proper motion anomalies



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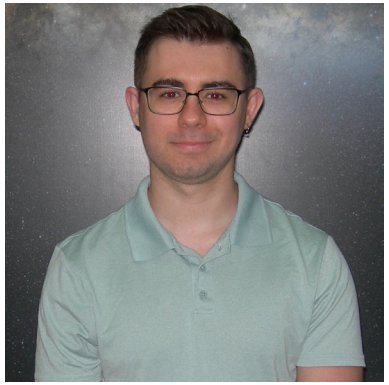

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Domain A – Formation and Architecture of Planetary Systems

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Noble gases in CLs and ungrouped carbonaceous chondrites

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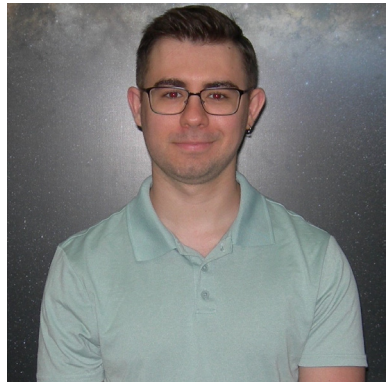

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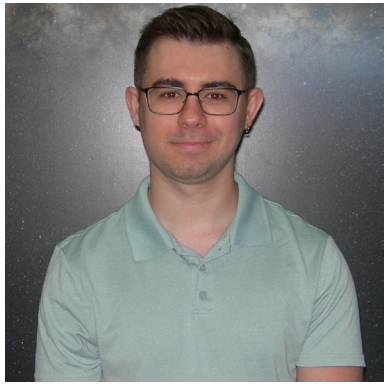

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Domain A – Formation and Architecture of Planetary Systems

National Centre of Competence in Research

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Veerle Sterken (A6): In-situ cosmic dust measurements crossing astro-physics, planetary science and heliophysics

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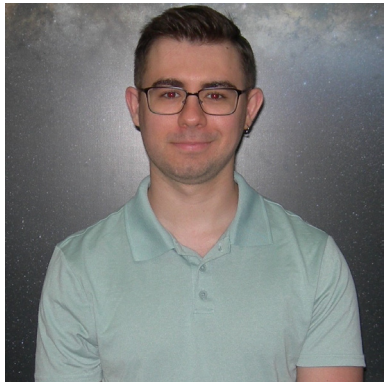

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National Centre of Competence in Research

Project A1 The composition of planetary building blocks

Maria Schönbächler, ETHZ

Swiss National Science Foundation

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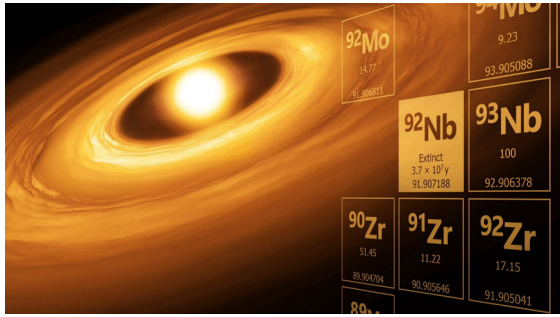
A1 The composition of planetary building blocks

National Centre of Competence in Research



Builds on previous project 1.4 with the aim to constrain:

- physico-chemical processes acting on the way **from dust to planetesimals**
- the **local distribution** of dust in the disk and its **modification through transport, mixing & thermal processing:** relationship between building materials and planetary objects

➔Approach: obtain new high-precision **isotope data of meteorites and combine with models**

- Nucleosynthetic **Fe** & **Ti isotope variations** in planets, meteorites and their components
- combined with **accretion models** of Earth
- **Late addition** of material from outer solar system (carbonaceous chondrites) during main accretion?

→ **PhD students K. Liszewska/M. Rüfenacht**

- Models of disk evolution including dust transport
- Incorporation of **nucleosynthetic anomalies into "Bern model"**
  (in collaboration with L. Mayer, Uni Zürich & Y. Alibert, Uni Bern)

→ **Postdoc JD Bodénan (4 months only)**

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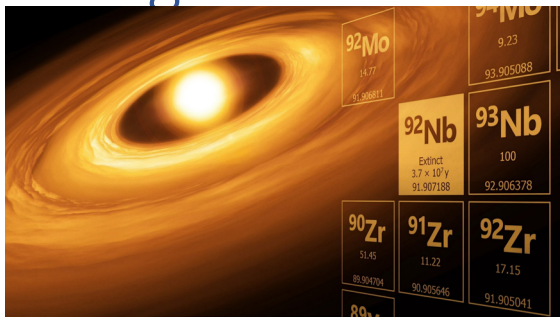
A1 The composition of planetary building blocks - Progress



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- Nucleosynthetic **Fe** & **Ti isotope variations – disk heterogeneities**

PhD student K. Liszewska
→ paper on Fe isotopes in bulk meteorites in preparation

M. Rüfenacht now postdoc
(back from maternity leave)
→ Ti isotope paper under revision in GCA

- Models of disk evolution including dust transport
- Incorporation of **nucleosynthetic anomalies into "Bern model"**
  (in collaboration with L. Mayer, Uni Zürich & Y. Alibert, Uni Bern)

Postdoc JD Bodénan left in October 2022
→ "TEMPus VoLA" paper in preparation

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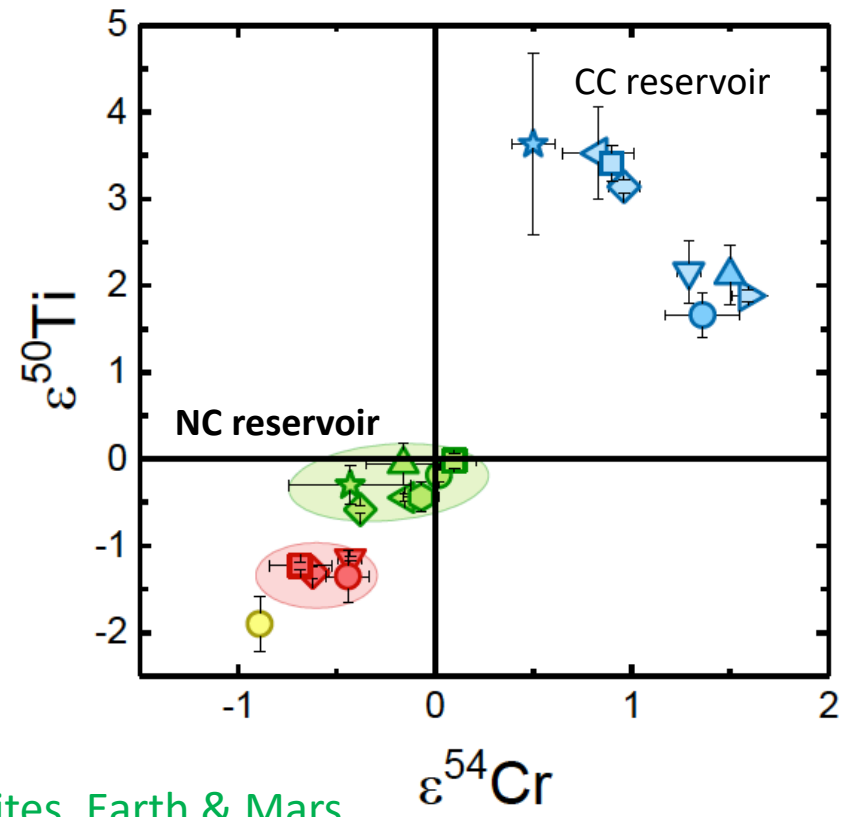
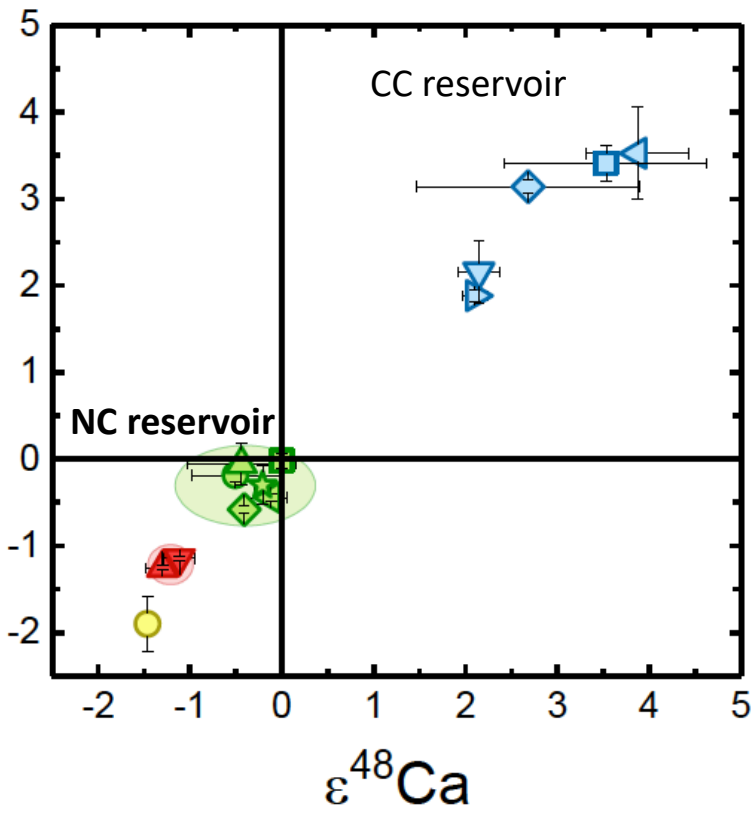
Results: Sub-reservoirs in the inner disk/NC reservoir

Carbonaceous chondrites
CI CM CO CV
CR CH CB CK
Earth-Mars-like
OC Mars EC Win
Aub Earth R
Vesta-like
HED Ang Aca Bra
Meso
Ureilite-like
Ureilites

New high precision Ti & Cr isotope data



Ca isotope data from literature



From Rüfenacht et al., GCA, in revision

blue: carbonaceous chondrites
green: ordinary, enstatite and R-chondrites, Earth & Mars
red: HED, mesosiderites, angrites, acapulcoites
yellow: ureilites

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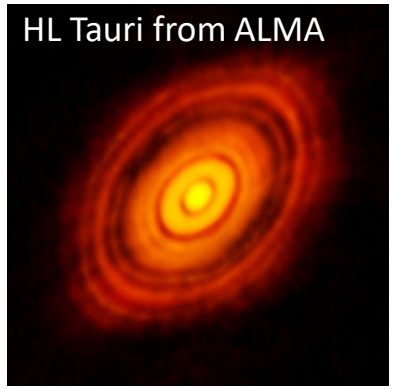
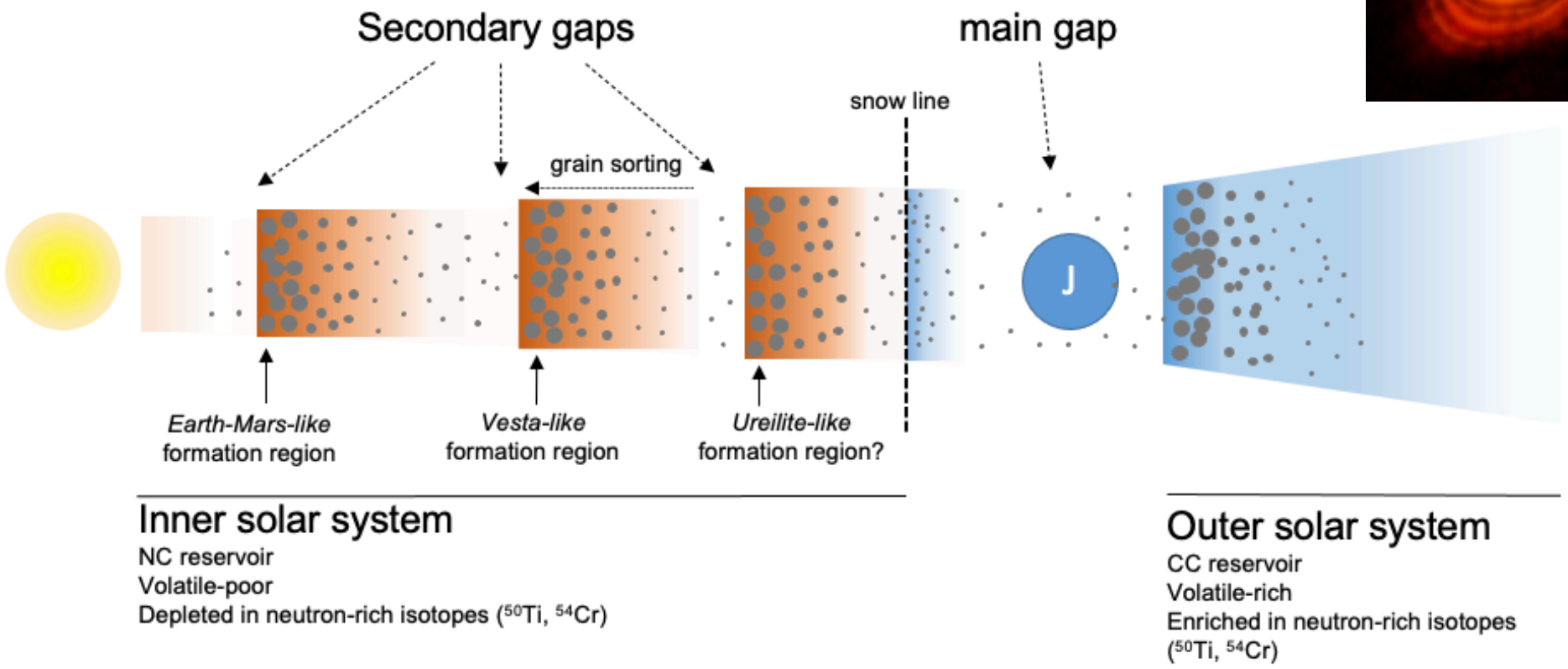
Results: Sub-reservoirs in the disk



Grain sorting, see Hutchison et al. 2022



→ **Isotopic sub-reservoirs mirror rings in the disk**

From Rüfenacht et al., GCA, in revision

Open questions:

When did rings/planetesimals form? Rings before or due to Jupiter?

Role of pebble/CI accretion? Isotopic evolution over time?

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PlanetS
National Centre of Competence in Research

Project A2 Planetary system architecture

Damien Ségransan, UGE

Swiss National Science Foundation

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A2 Planetary Systems Architecture

WP1 Giant planets and brown dwarfs in the GAIA era (N. Unger, JB Delisle, Berry Holl, S. Udry)
WP2 Massive giant planets and ultra-cool brown dwarf characterisation (W. Ceva, S. Udry)
WP3 Formation and evolution of multi-planetary systems (S. Udry, A. Leleu , JB Delisle, N. Unger)

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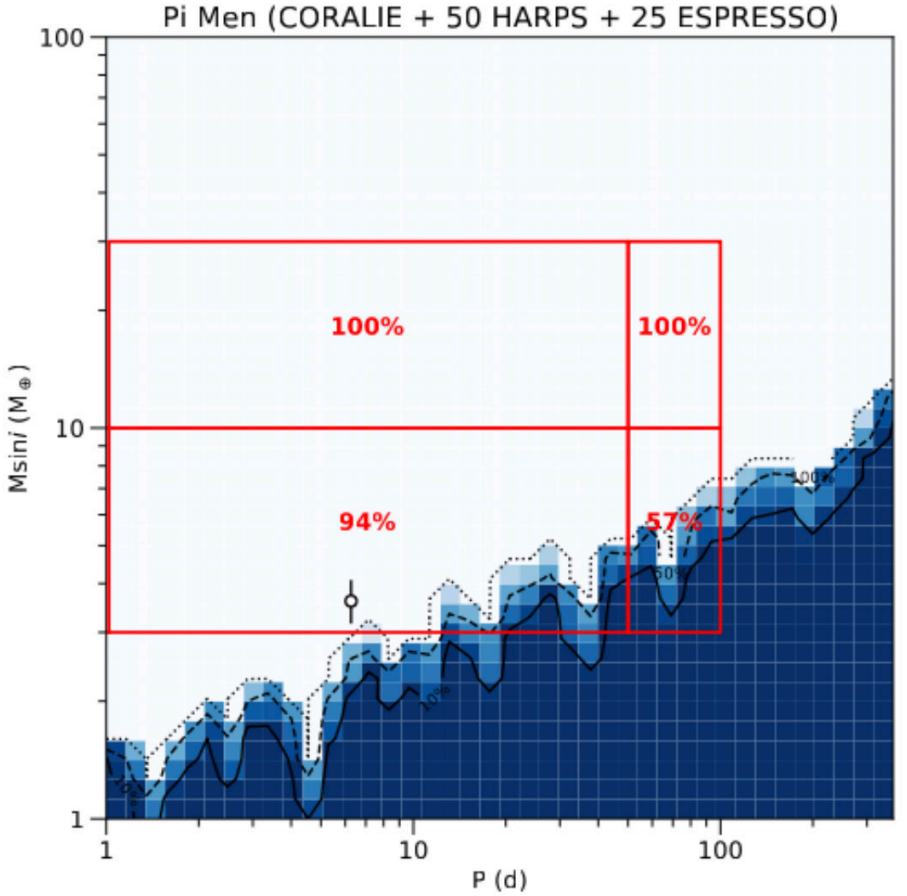
Delisle, Ségransan, Udry, Ceva, Leleu



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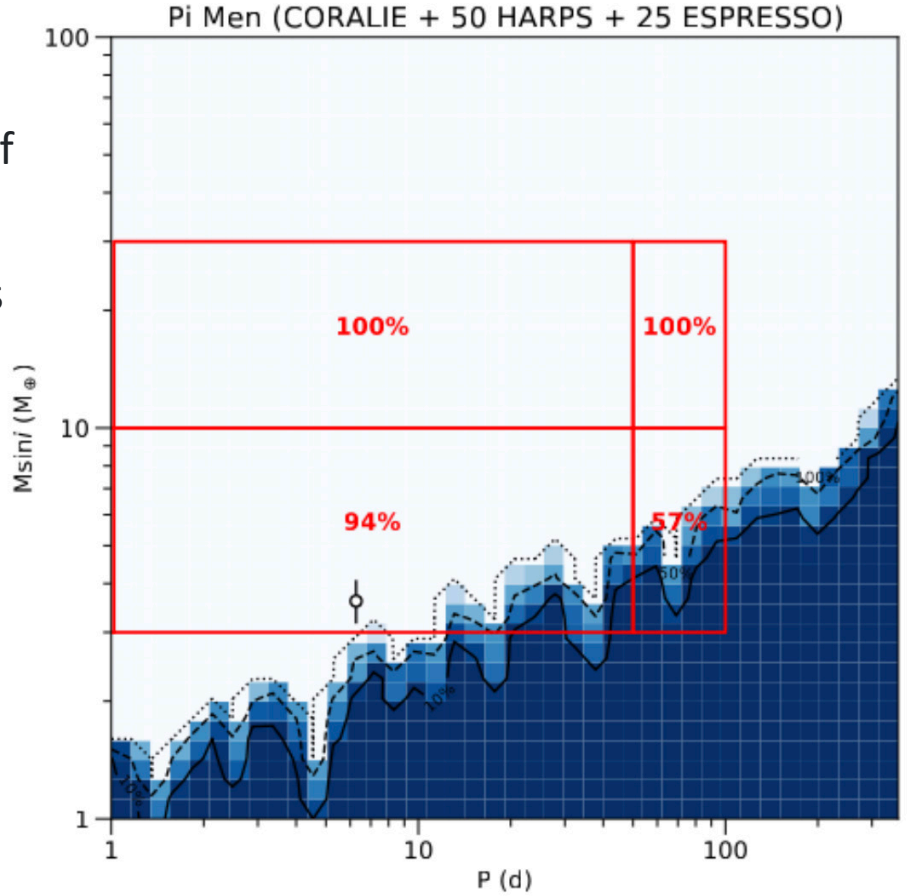
Delisle, Ségransan, Udry, Ceva, Leleu

- In-situ formation and inward-migration, predict radically different occurrences of close-in super-Earths and Neptune-type planets in the **presence of a cold giant**
- We are working on the determination of the occurrence of close-in super-Earths and Neptunes in systems with or without a cold giant



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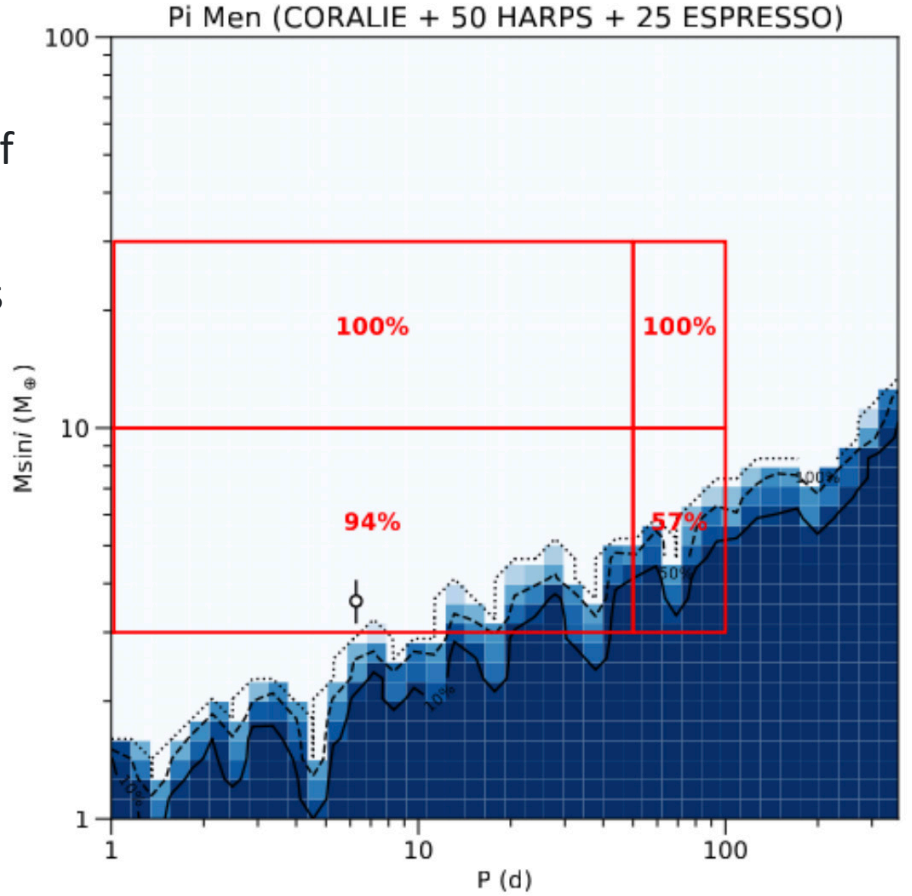

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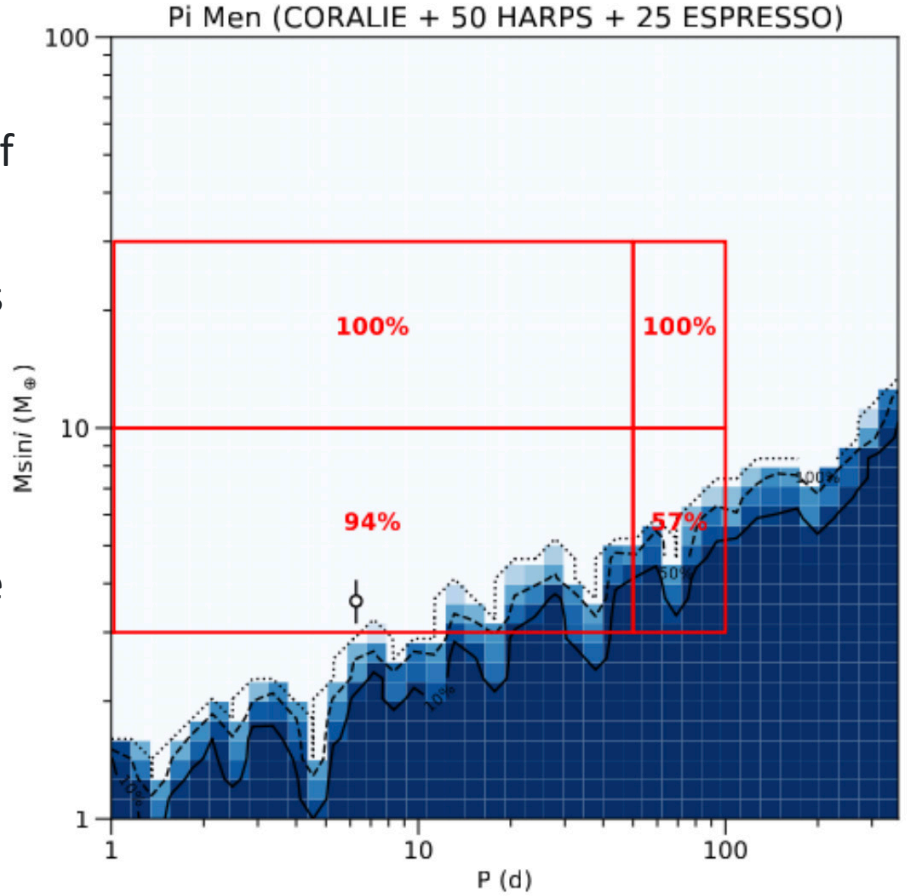
- We obtained, since 2021, 75 HARPS observing nights to probe the mini-Neptune domain
- We submitted for 2023-2025 a 90 nights HARPS+ESPRESSO proposal to reach the Super-Earth regime



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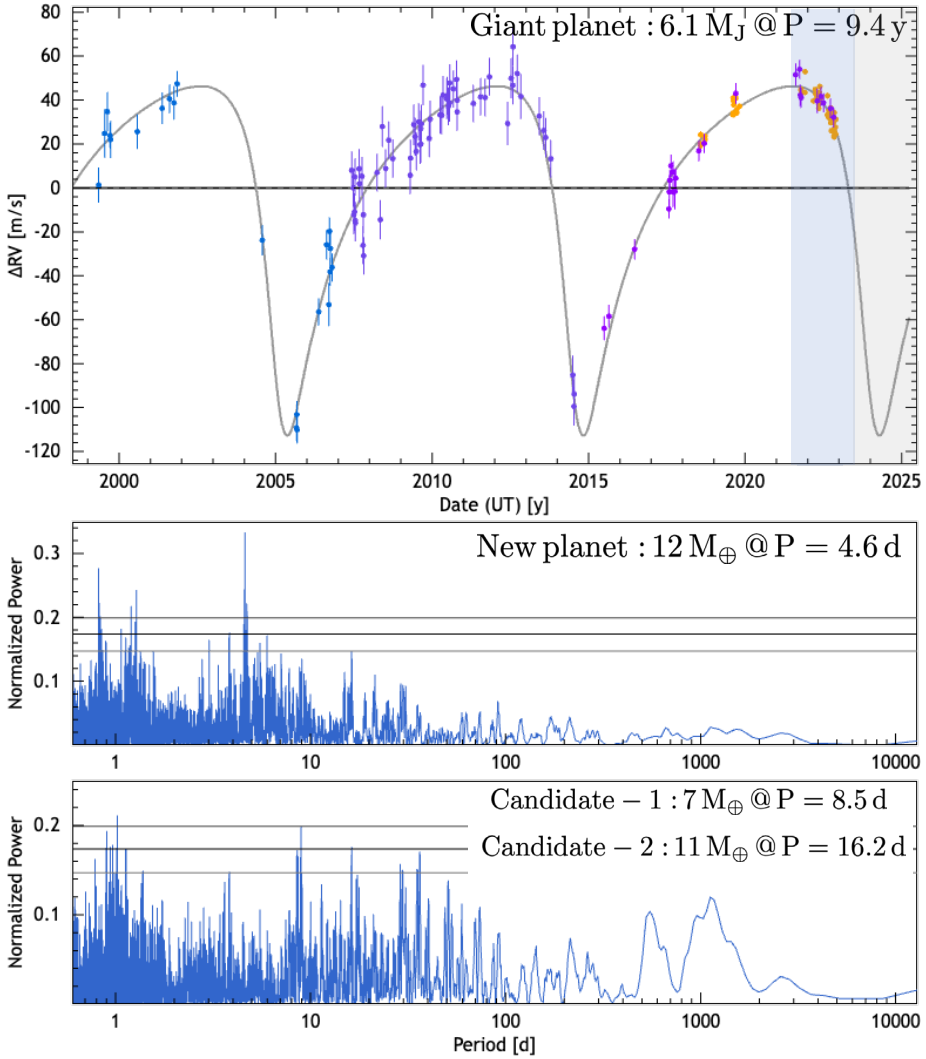
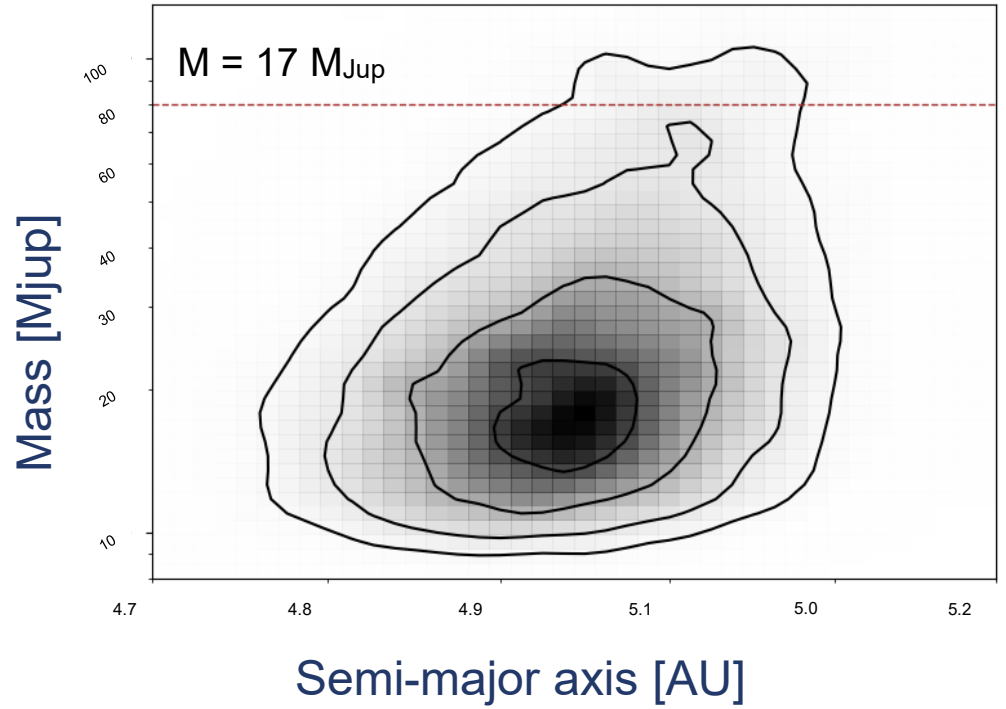
Preliminary results from the HARPS pilot programme

"Probing the inner region of planetary systems with giant planets beyond the ice line"





True mass determination using the combined fit of the RVs and of the Hipparcos-Gaia Proper-Motion anomaly

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National Centre of Competence in Research

Project A3 Numerical laboratory for planet formation

Joachim Stadel, UZH

Swiss National Science Foundation

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National Centre of Competence in Research

A3 Numerical Laboratory for Planet Formation

Joachim Stadel, Lucio Mayer, Simon Grimm

*How we get **from protoplanetary dust to planets** is tied to a complex interplay of physical processes which require the **very best numerical simulations** and the development of new numerical approaches in order to make significant advances in the field of planet formation theory*

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  lead: Lucio Mayer (UZH) + Alessia Franchini (PDRA UZH) + Noah Kubli (PhD UZH)

Multi-physics simulation of protoplanetary disk

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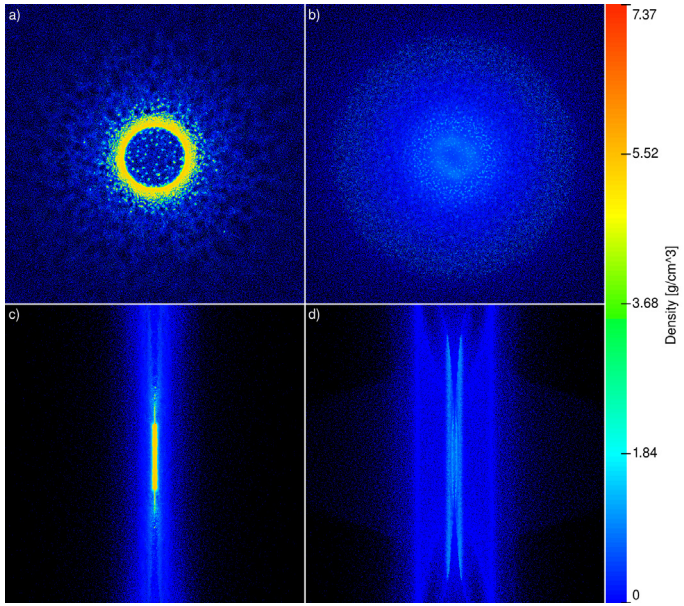
Multi-physics simulation of protoplanetary disk

Iron Ring formed from a head-on Giant Impact



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- **WP3:** *Higher Capability N-body Simulations*

  lead: Simon Grimm (ETHZ/UZH) + Joachim Stadel (UZH)

Collaborations: Cosmochemistry (Schönbächler), dust & ices in disks (Pommerol), TempusVola (H. Capelo)

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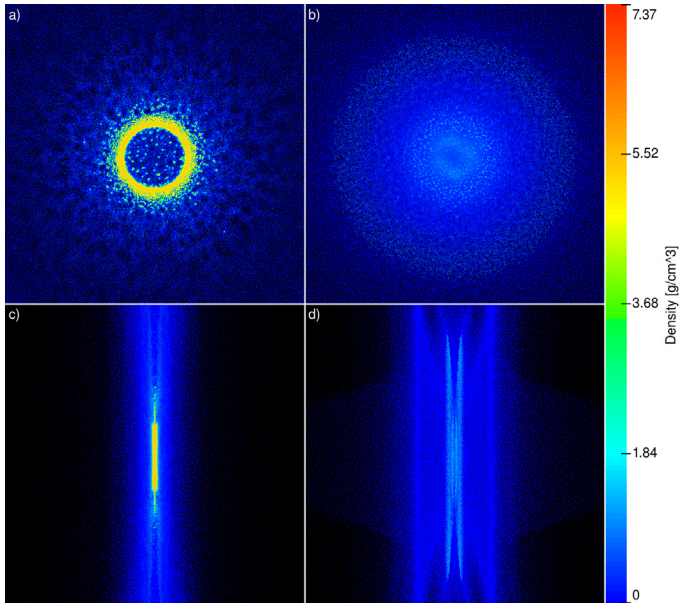

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Joachim Stadel, Lucio Mayer, Simon Grimm

WP1 Alessia Franchini (PDRA UZH) hired (starting Fall 2023)

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Joachim Stadel, Lucio Mayer, Simon Grimm

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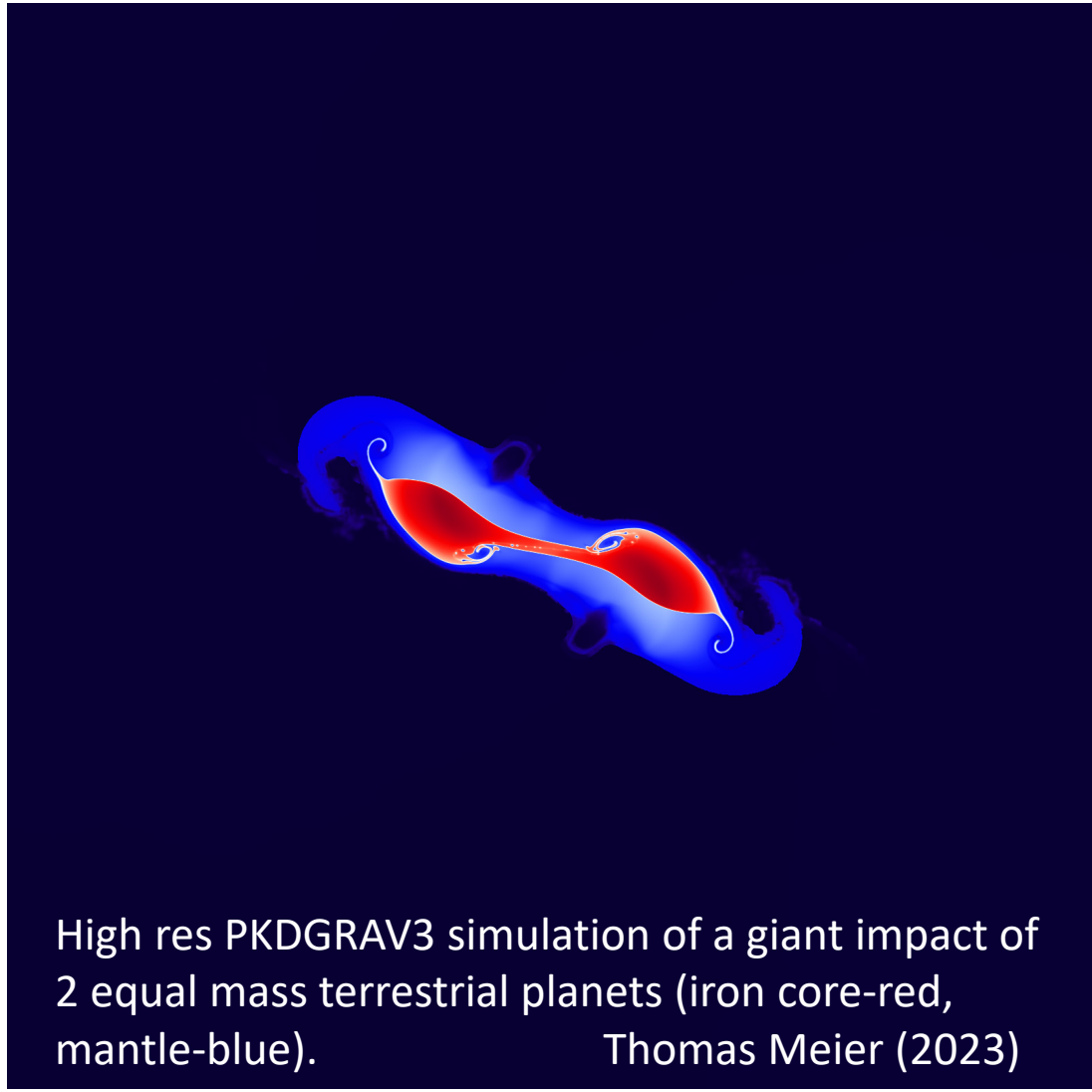
WP2 *PKDGRAV3 SPH code development*

- Forming **iron-rich** planets with giant impacts (Reinhardt+2022,MNRAS)
- Isentropic SPH and new interfaces correction implemented
- Up to billion particle SPH runs of planet collisions now possible



High res PKDGRAV3 simulation of a giant impact of 2 equal mass terrestrial planets (iron core-red, mantle-blue). Thomas Meier (2023)

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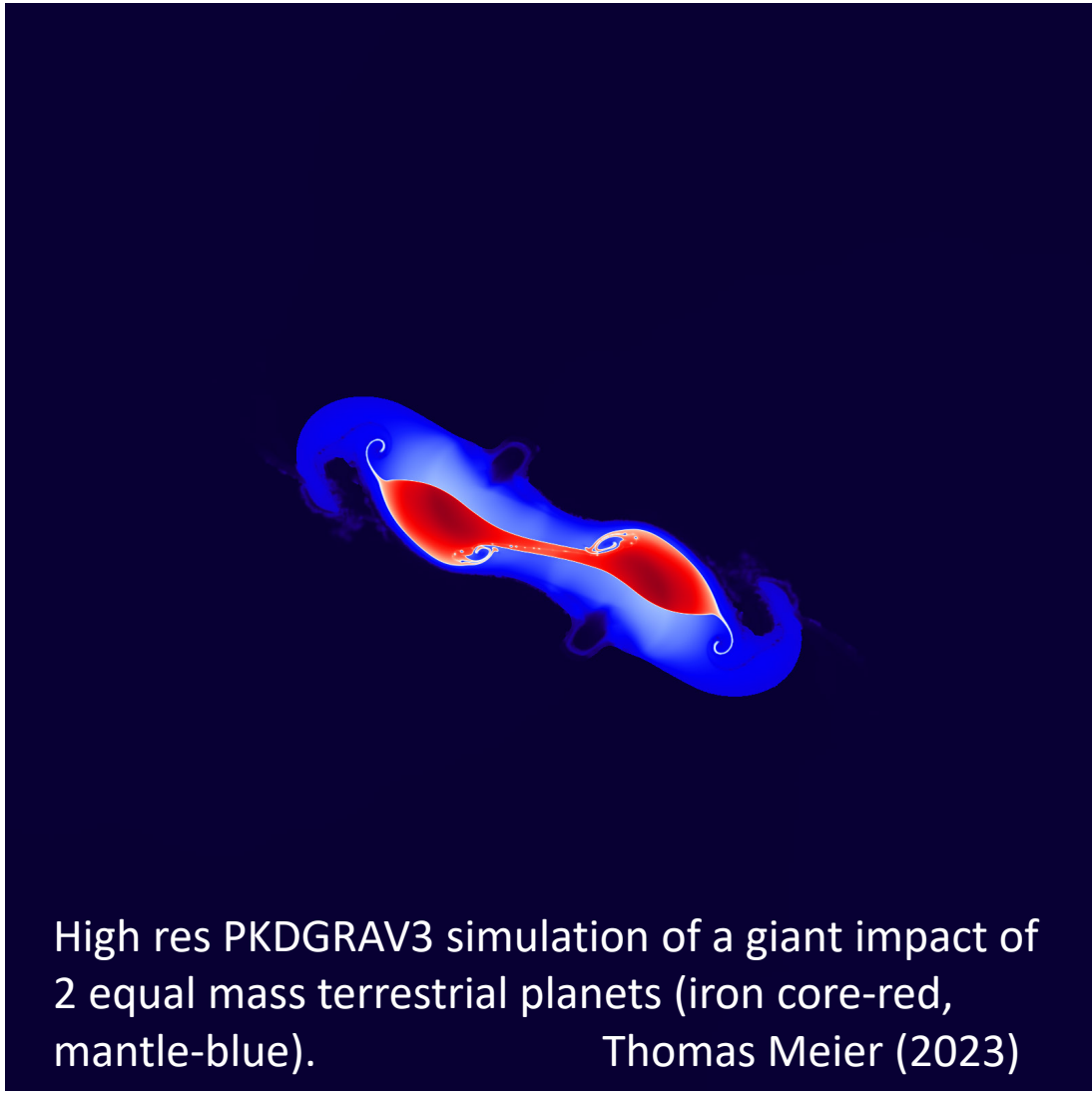
- Finalizing **Moon Paper I** (soon to be submitted, work of Miles Timpe)
- H/He EOS (“SCvH”) integrated and investigating GI gas clump collisions and mergers (with Ravit Helled, Christian Reinhardt – ongoing)



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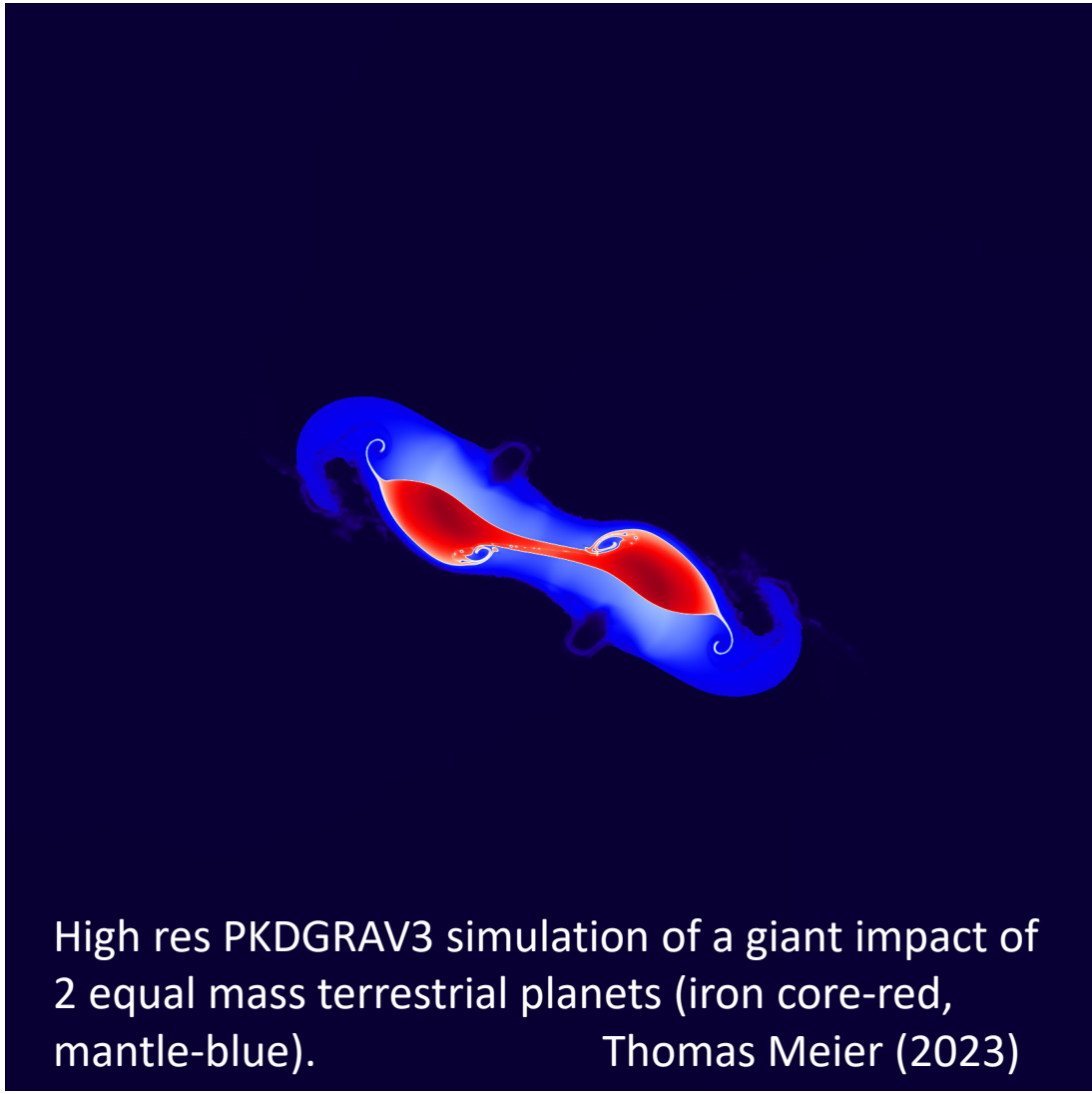
WP3 *GENGA2 paper published, and new code released*

One key milestone is to incorporate material strength treatment into PKDGRAV3 to handle surface features and smaller bodies



High res PKDGRAV3 simulation of a giant impact of 2 equal mass terrestrial planets (iron core-red, mantle-blue). Thomas Meier (2023)

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National Centre of Competence in Research

Project A4 Meteorite analyses enabling the assessment of asteroidal and Martian materials returned with space missions

Henner Busemann, ETHZ

Swiss National Science Foundation

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A4 Meteorite analyses enabling the assessment of asteroidal and Martian materials returned with space missions

Doctoral student Romain Alosius

WP1 Noble gases in CL & ungrouped carbonaceous chondrites (CCs)

- parent body processing? links to other asteroids from “outer” CC reservoir?
- similarities to asteroids Ryugu or, particularly, Bennu?

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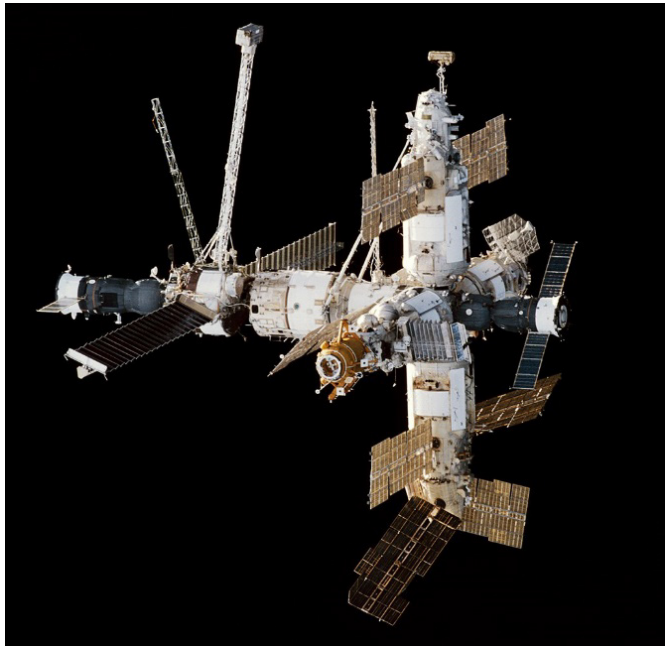
WP4 Neon in the local interstellar medium – not started yet

- completion of “COLLISA” experiment
  (interstellar neutrals trapped onboard MIR space station)



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A4 Meteorite analyses enabling the assessment of asteroidal and Martian materials returned with space missions - Progress

Doctoral student Romain Alosius

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- parent body processes recorded in CCs
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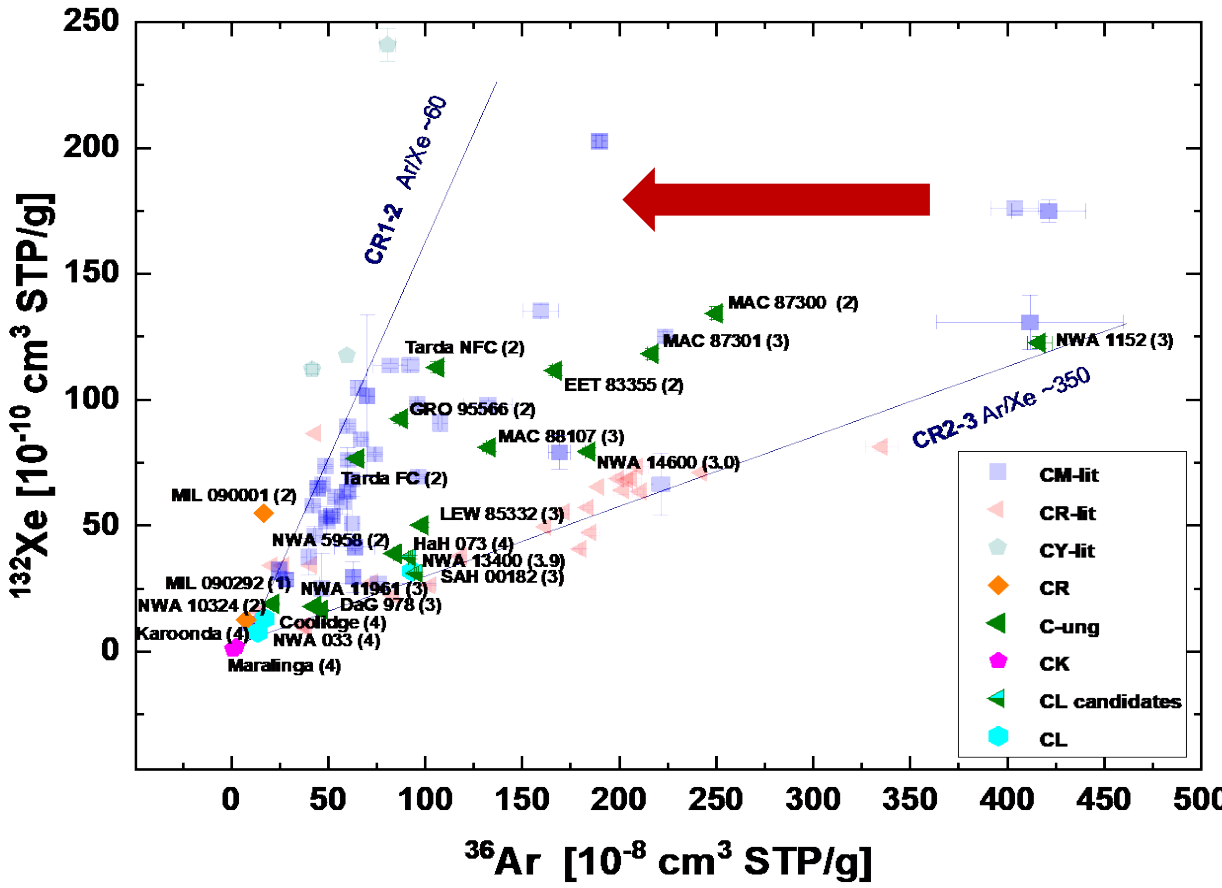
  noble gas loss upon aqueous alteration
- new class of CL chondrites:

  noble gas loss likely due to mild thermal alteration



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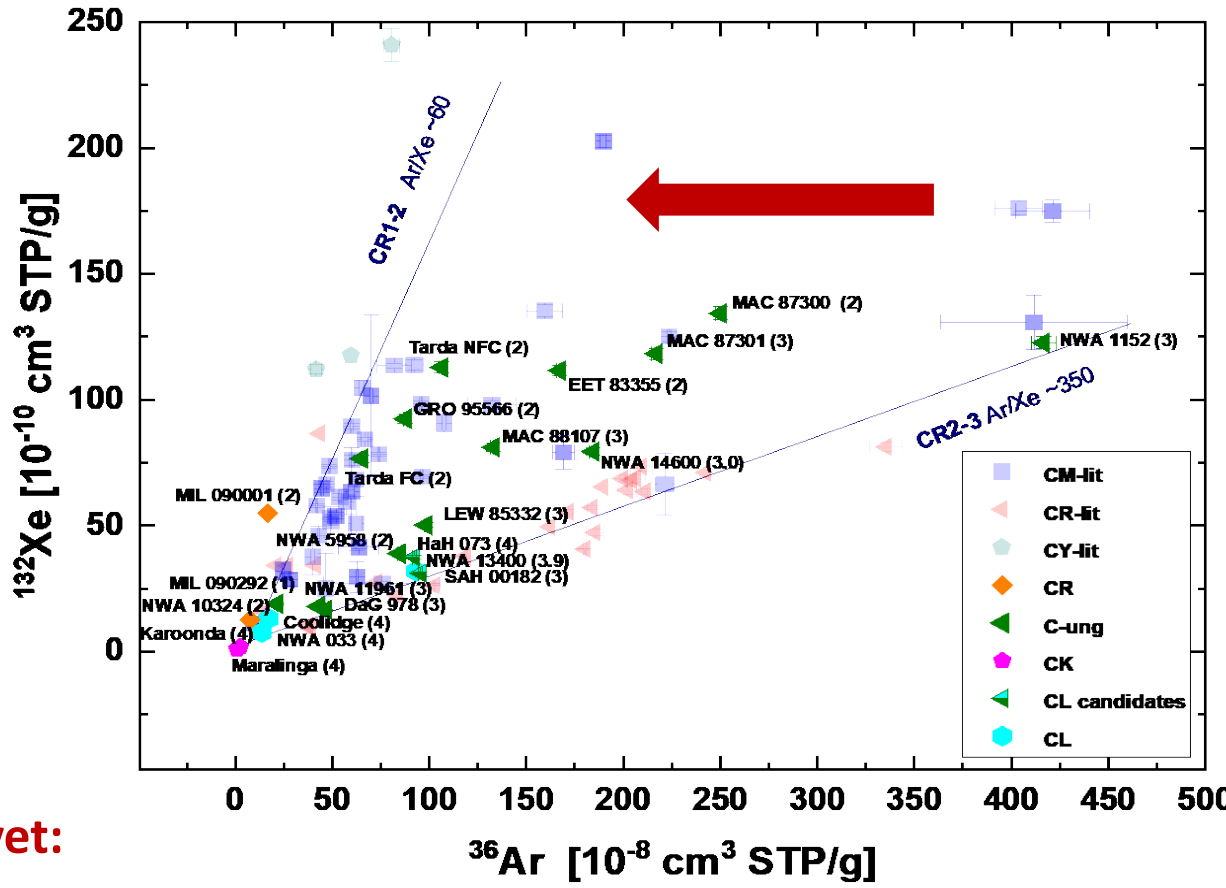

collaboration with UBE (C5), A. Pommerol – not started yet:

WP5 The study of Martian meteorites and carbonaceous chondrites by nano-CT

- using state-of-the-art equipment, tests to find sub-mm-sized noble gas carriers

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A4 M. Riebe+N. Allen: Unlocking the origin of Earth's volatiles (SNF Ambizione fellowship)

A new thermometer for hydrothermal alteration on asteroids

Nicola M. Allen, My E. I. Riebe, Dionysis I. Foustoukos, **Henner Busemann**, Conel M. O'D. Alexander, George D. Cody, Colin Maden

1. Acid resistant residues of meteorites contain noble gas-rich phases
2. Hydrothermal alteration of residues in lab
   - 250 - 400 °C, 50 MPa, 27, 68 or 163 days in water solutions
3. Analyzed the noble gas composition of altered IOM
4. **The composition of noble gases changes during hydrothermal alteration**
   - The Ne/Ar ratio can be used as a thermometer (Fig. 1)
   - Calculated temperatures similar to other thermometers (Fig. 2)

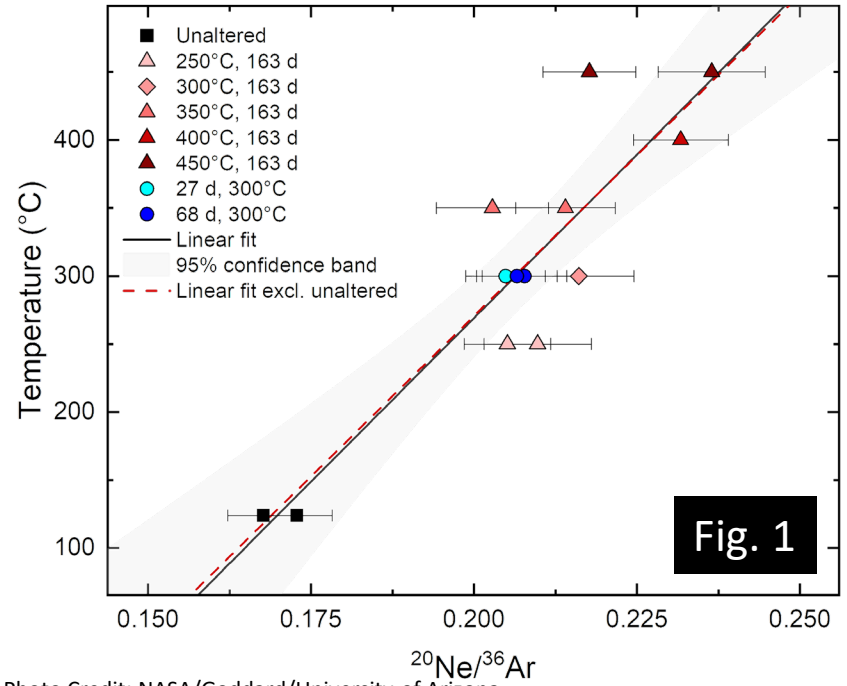

Fig. 1

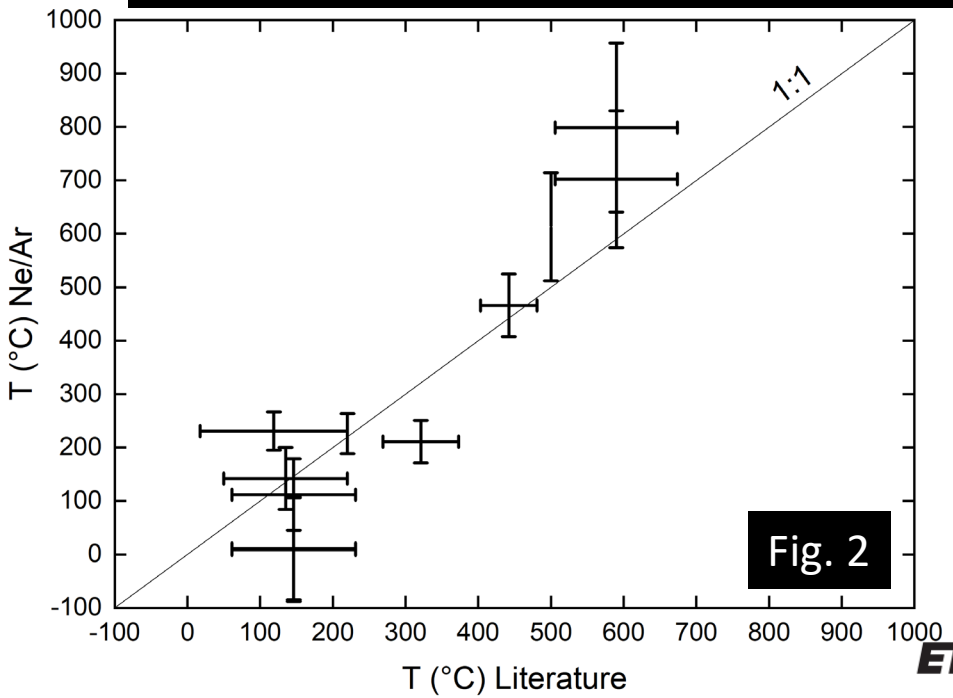

Fig. 2

Noble gases can be used to estimate alteration temperature of carbonaceous chondrites

Photo Credit: NASA/Goddard/University of Arizona

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Project A5 The Solar System as exo-system: formation, dynamics, composition

Yann Alibert, UBE

Swiss National Science Foundation

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A5: The Solar System as exo-system: formation, dynamics, composition

WP1: Mass & orbital elements: Use population synthesis to produce SoSy-like systems - **Not started yet**

WP2: Planetary building blocks & the bulk composition of planets - Planetesimal formation (Yuhito Shibaike) & volatile detection (Stefano Spadaccia)

WP3: Chemical and isotopical trends - the case of Uranus (Jeanne Davoult & Andrin Kessler)

WP4: Minor bodies - preparing for Comet Interceptor (Nico Haslebacher) and using Hayabusa2 & DART data (Sabina Raducan & Martin Jutzi)

WP5: Solar system planets as exoplanets (with C2/3) - **Not started yet**

- **Mars dichotomy explained by impact processes**
- **Preparing the EnVision mission to Venus**
- Close-in planet's interior heat budget is modified by star/planet interactions (ohmic dissipation)

Grayver, Bower et al. (2022), ApJL

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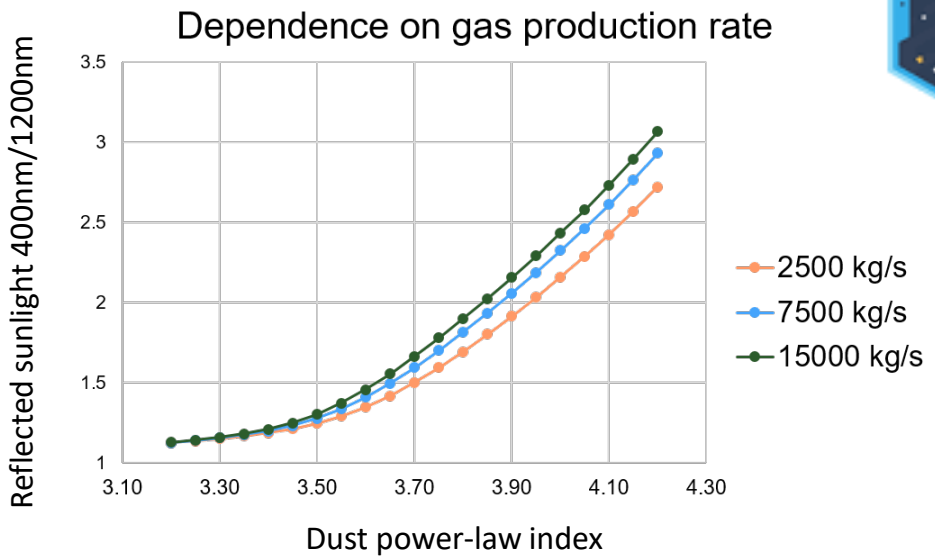
Jeanne Davoult & Andrin Kessler

=> Uranus Orbiter and Probe (future Flagships) talk Tuesday morning

Nico Haslebacher

First version of the **Cometary Model of Dust Environments** (ComMoDE) to consortium



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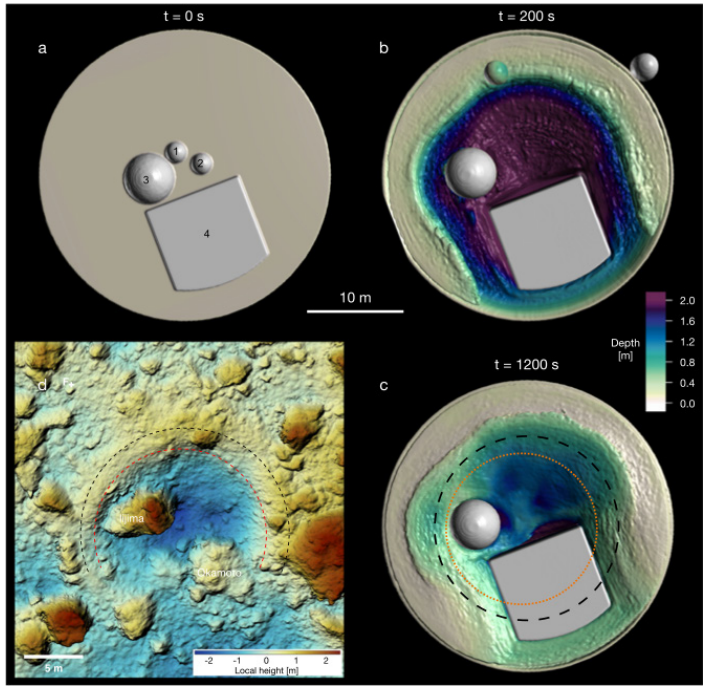
Sabina Raducan and Martin Jutzi

Constraining the properties of rubble pile asteroids from numerical simulations of Hayabusa2 and DART mission impact experiments

Main results

- Surfaces must be **very young** (of the order of ~1–10 Myr)
- **"Collisional strength"** of small bodies (asteroids, comets, planetesimals) might be **much lower** than previously thought



BernSPH simulation of Hayabusa2 SCI impact on asteroid Ryugu reproduces the crater formation and boulder displacement

- Jutzi, Raducan et al. 2022 Nature Comm.
- Raducan, Jutzi et al. 2023 Science submitted

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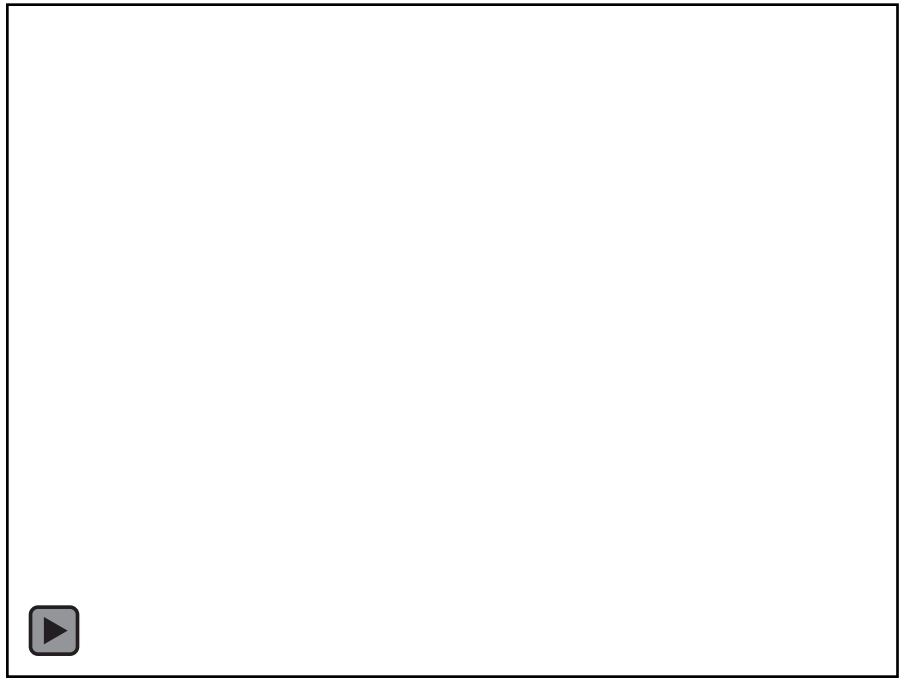

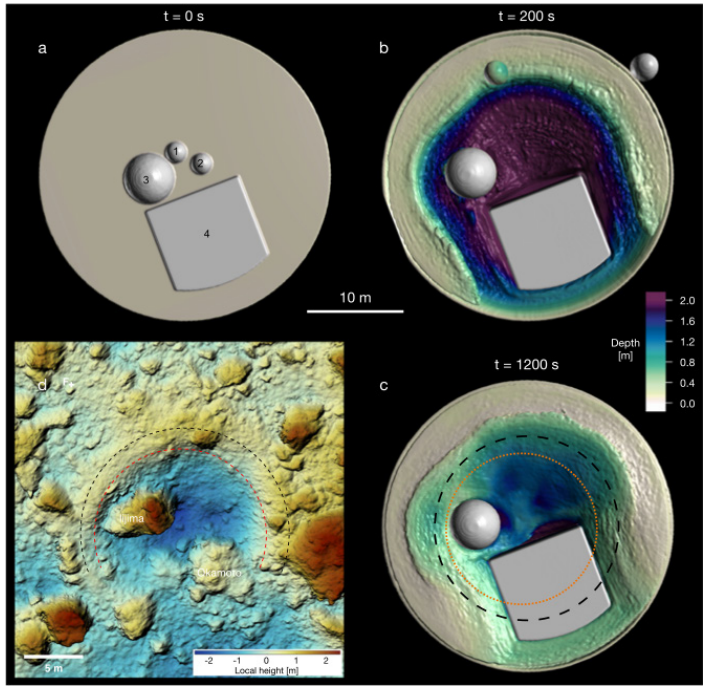

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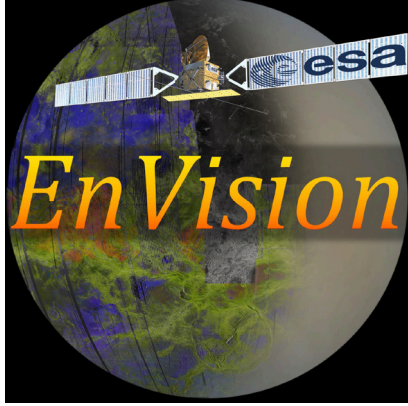
Paul Tackley's group

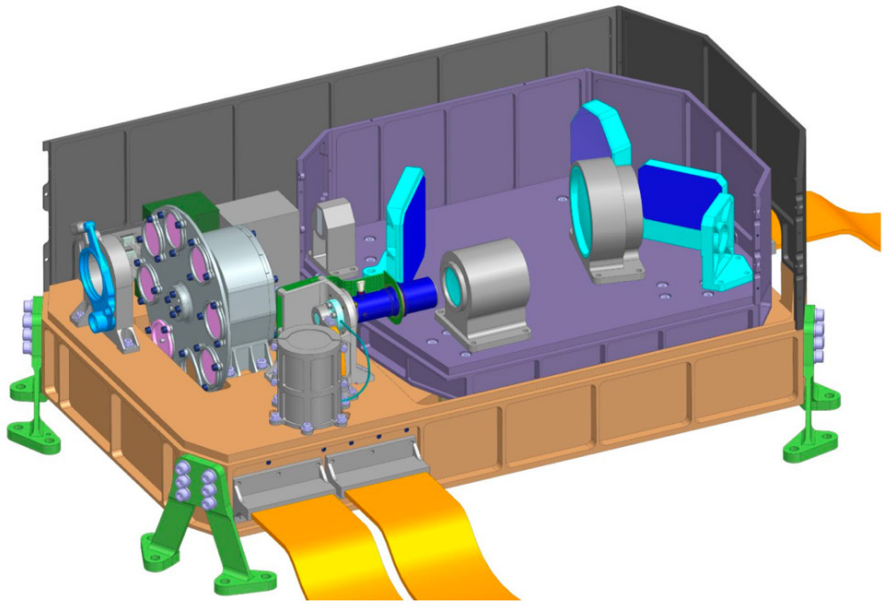
ETH zürich | n|w Fachhochschule Nordwestschweiz | Hochschule Luzern | Space Acoustics | Koegl Space

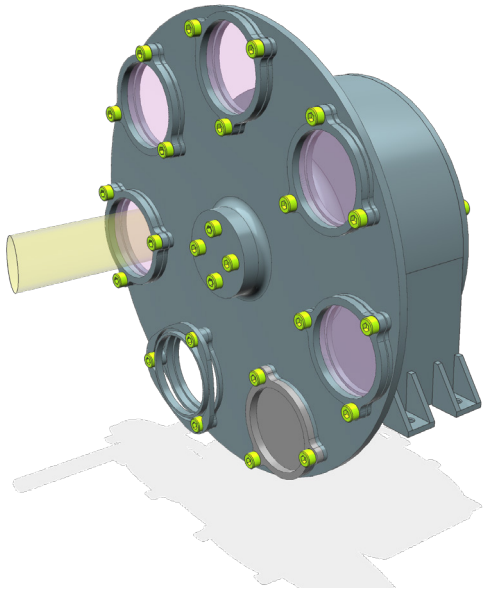


Venus: preparing for EnVIsion

EnVision / VenSpec-H Instrument

- high-resolution IR spectrometer
- **detection of SO2, H2O and HDO** in atmosphere





Filter Wheel Mechanism

- The Swiss consortium partners ETHZ, HSLU, FHNW, Space Acoustics & KOEGL Space hold a key role in the EnVision / VenSpec-H instrument development:
  - Mechanical and thermal engineering of the VenSpec-H Instrument
  - Filter Wheel Mechanism (FWM)

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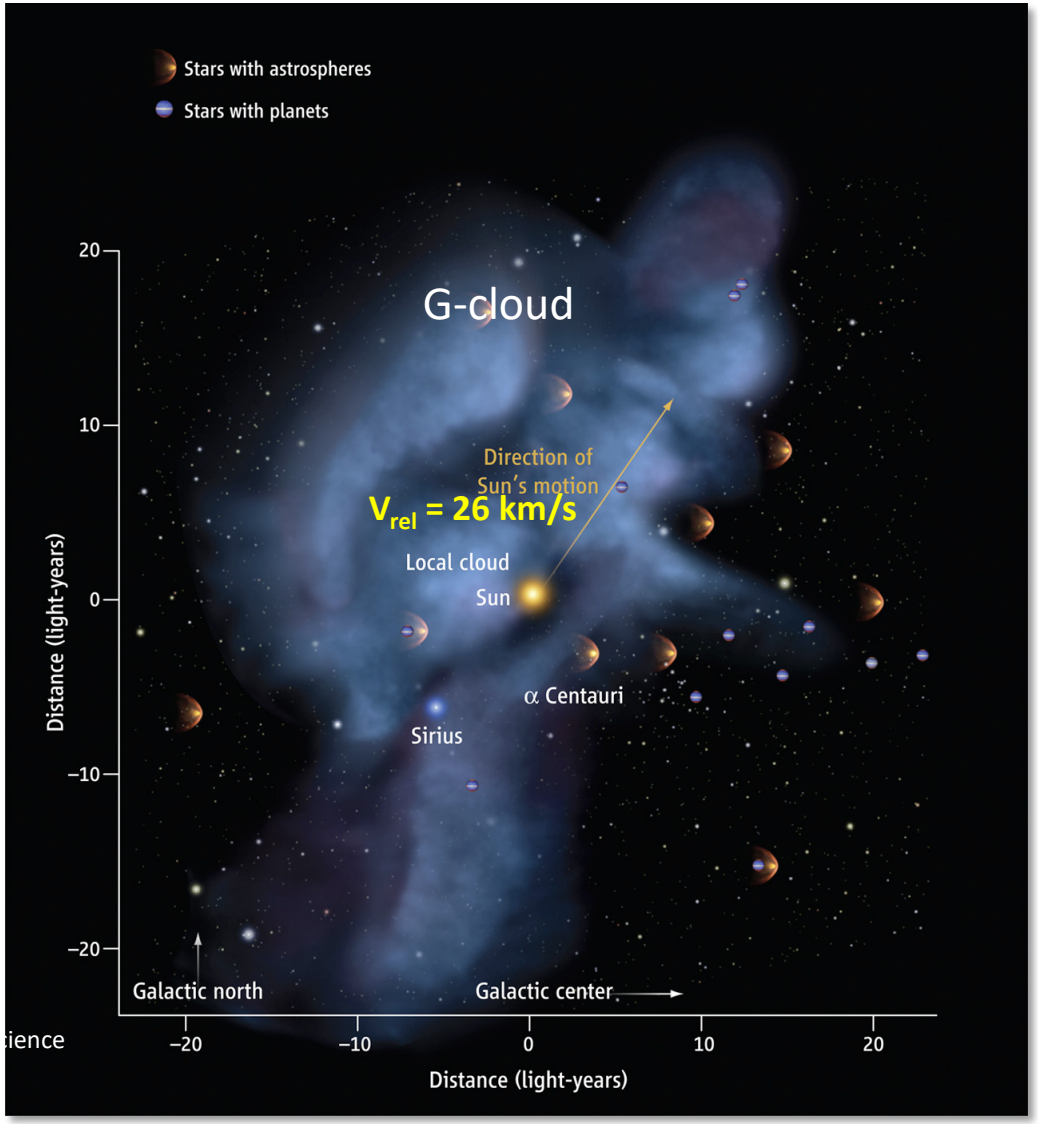
Project A6 ASTRODUST - The heliosphere and the dust: characterisation of the solar and interstellar neighbourhood

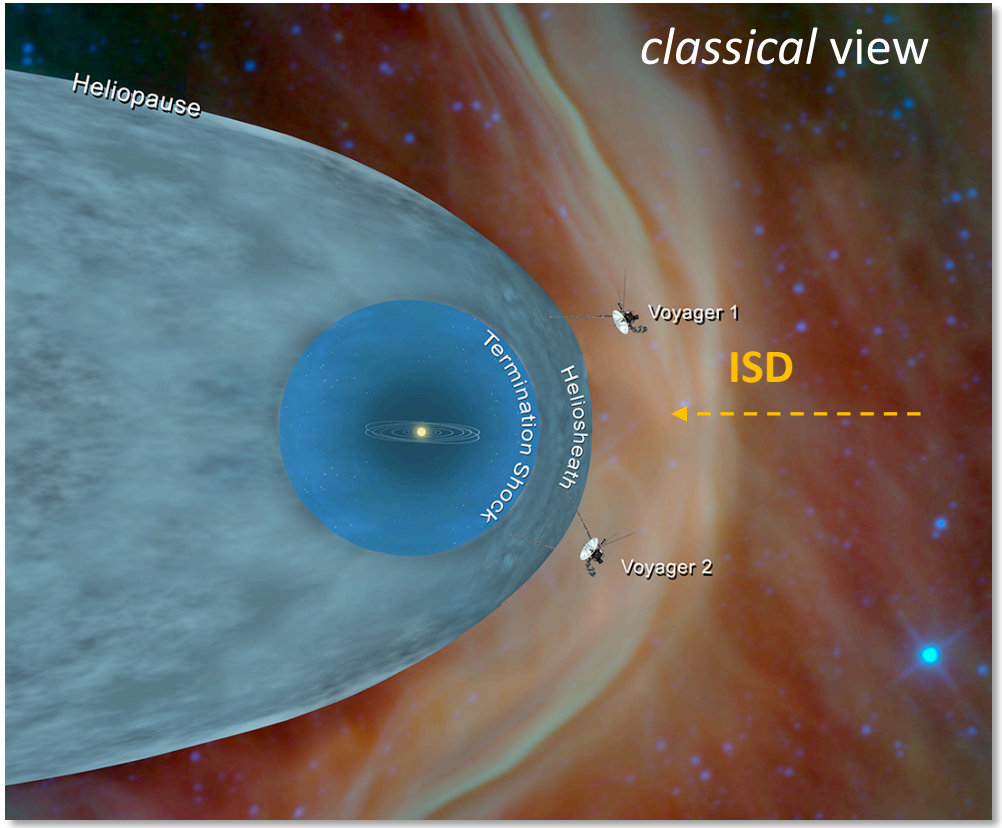
Veerle Sterken, ETHZ

Swiss National
Science Foundation

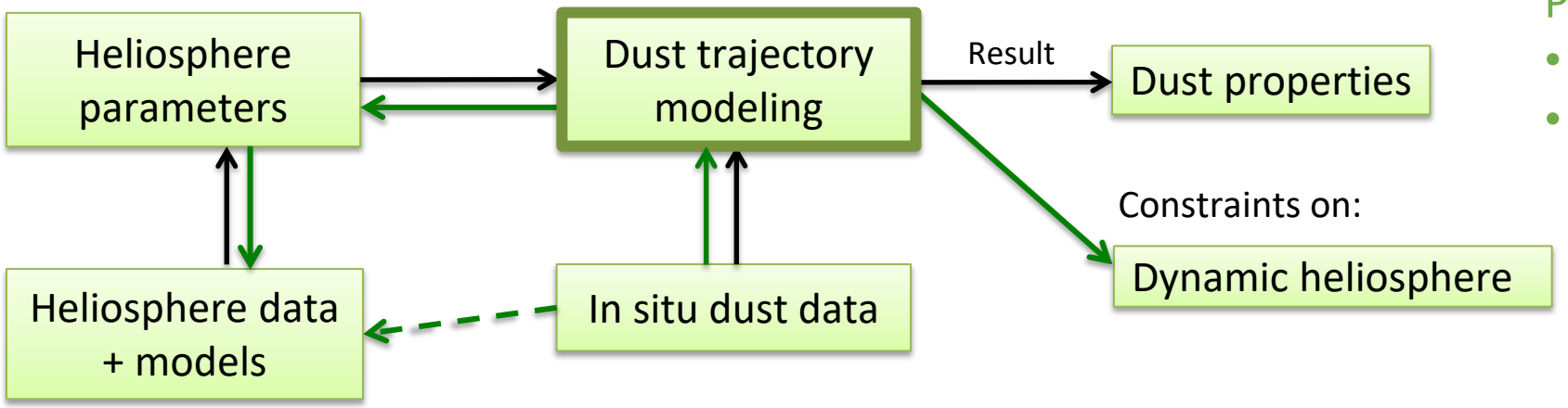
The Local Interstellar Cloud



The Heliosphere

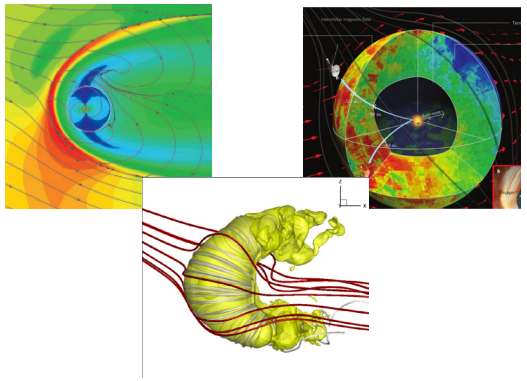


The Heliosphere and the Dust: Characterization of the Solar and Interstellar Neighbourhood



Personnel changes:

- S. Hunziker until Nov. 2022
- A. Péronne from June/July 2023



WP1. Basic simulator & preliminary s/c predictions

WP2. Data (re-)analysis

WP3. Heliosphere toy model → dust trajectories → sim. + data

WP4. MHD model output → dust trajectories → sim. + data

WP5. Application to other astrospheres / past of solar system

SYNERGY: Using in situ data to help constrain heliosphere

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Progress

WP2 Data (re-)analysis *(Baalmann, Sterken)*

- WIND/STEREO antenna data (in progress)
- **Ulysses data (publ. in prep.)**

Instrument Calibration *(Hunziker, Sterken)*

- "*Fluffy dust data analysis*" **published**
  - Micron-sized ISD measured by Ulysses is likely *real*
  - Porosity matters (for signal interpretation of dust instrumentation)

- **New "fluffy dust" synthesis successful** (collaboration in ETHZ, interdisciplinary student)

WP1 Predictions *(Hunziker, Sterken)*

- Interstellar Probe, Destiny+ (publ. in prep.), New Horizons, Voyager, etc.

Potential NCCR PlanetS collaborations

Future missions *(Sterken, Baalmann, Hunziker)*

- **Lunar Gateway cosmic dust package – interest by ESA**
  - Feasibility study in 2023/2024
- DOLPHIN mission (collaboration ISAE-ETHZ)
- Decadal survey: Interstellar Probe, SunCHASER

Science

- Complex dust: dust analogs for instrument calibration
- Heliosphere/Astrosphere: effects on exoplanet systems

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Project A8 Isotope astrochemistry - Linking star formation with the solar system record

Susanne Wampfler, UBE

Swiss National Science Foundation

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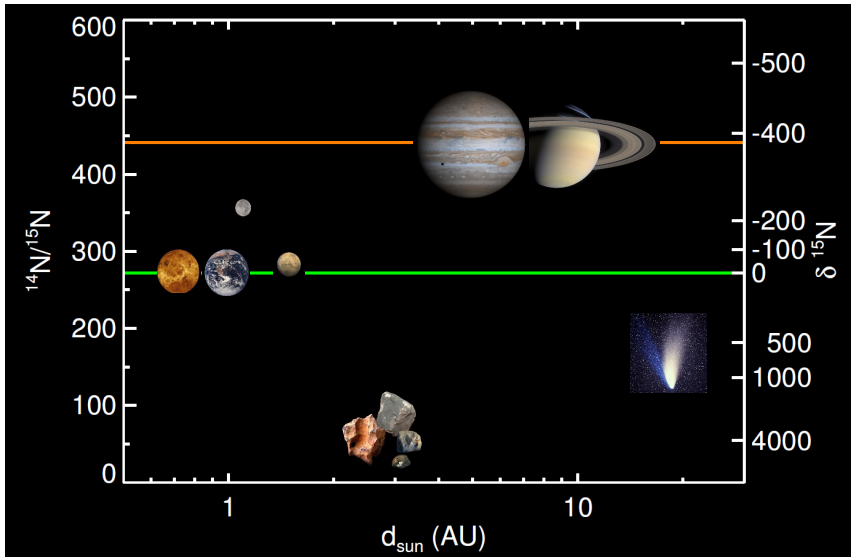
A8 Isotope astrochemistry: linking star formation with the solar system record

Goal: Understanding the **origin of the stable isotope anomalies** of the solar system, and isotopic fractionation during star formation



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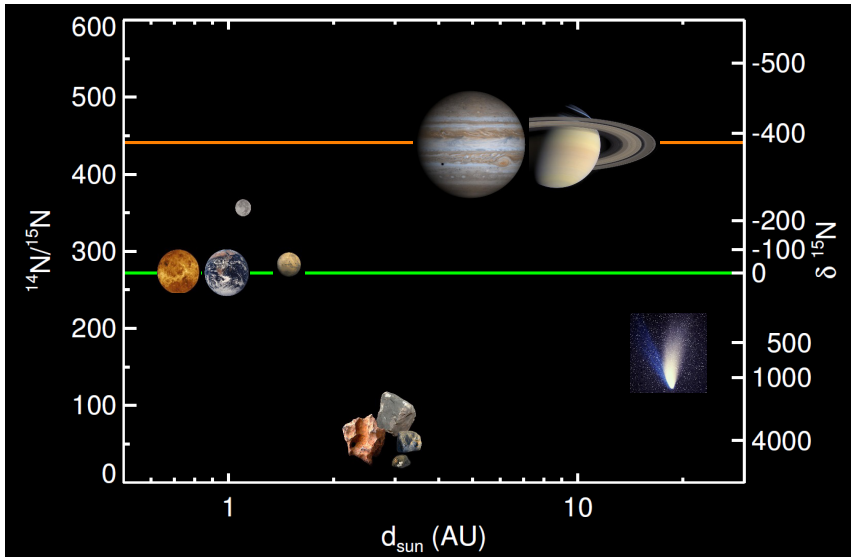
Observational projects focus on resolving the **puzzling results obtained from N_2H^+ and NH_3 around protostars** that are at odds with solar system (e.g. comet 67P)



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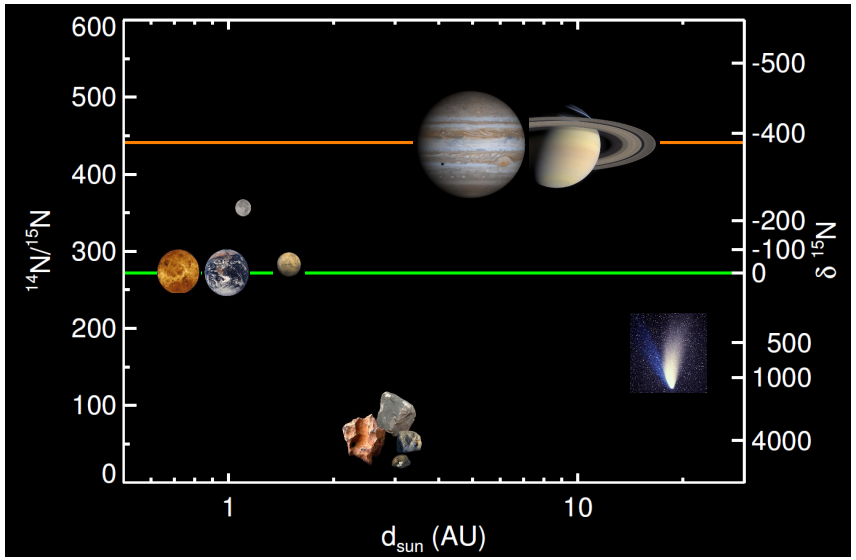
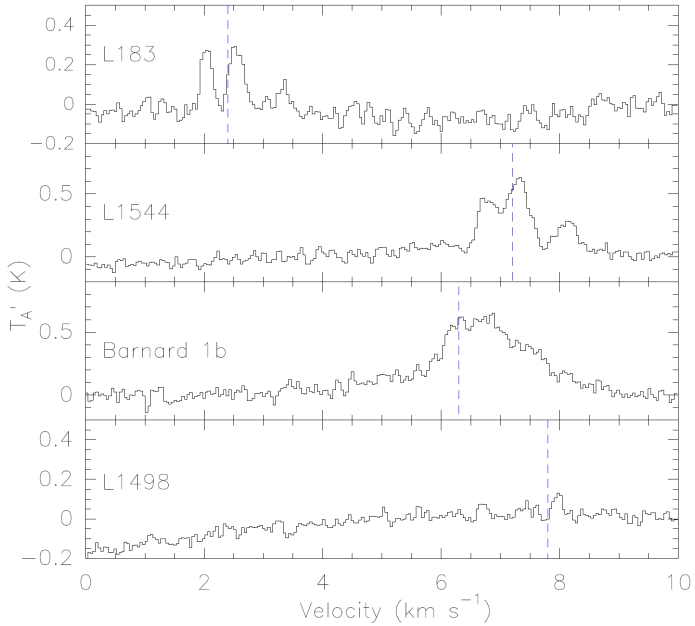


Several successful observing campaigns:
NH_2 detections with the APEX telescope. Follow-up proposal searching for the ^{15}N-isotopologue with ALMA almost completed.

NH_2D with the IRAM 30m telescope almost complete ⟶ line assignment of $^{15}NH_2D$ cannot be confirmed.

Ammonium salts as semi-volatile nitrogen-carriers may help in resolving the discrepant pictures from solar system and astrochemistry. Search for **ammonium salts** of HCN with the Greenbank telescope: non-detection ⟶ better spectroscopy needed



NH_2D observations with IRAM 30m telescope

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Project A9 ARES - Architecture of Resonant Exoplanetary Systems Adrien Leleu, UGE

Adrien Leleu obtained a SNF Starting Grant on
The *Architecture of resonant exoplanetary systems - RIVERS* => dedicated talk follows

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Domain A – Formation and Architecture of Planetary Systems

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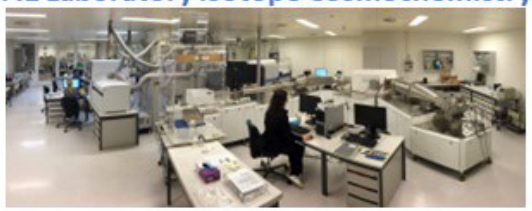
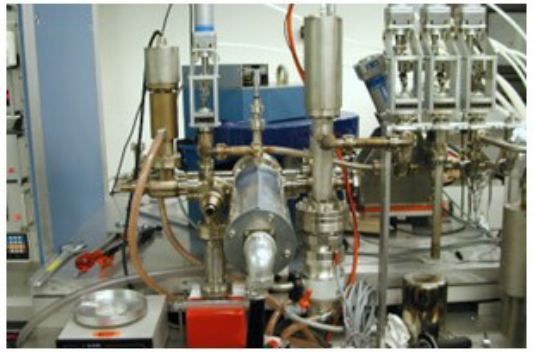
Domain A
collaborations
initial discussions
common interests…

A1 Laboratory Isotope Cosmochemistry

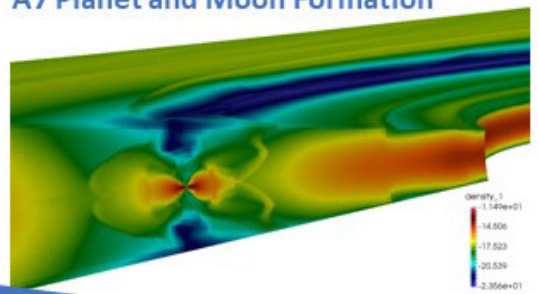


C5

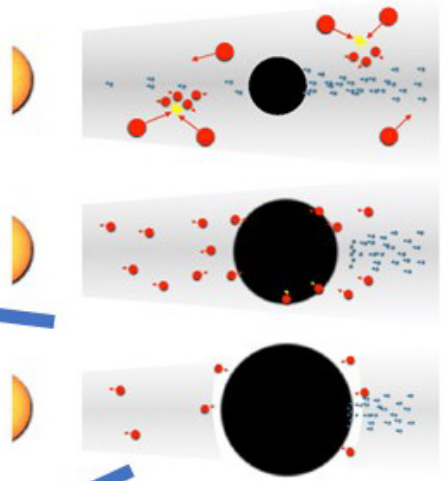


A4 Meteorite Studies & Sample Return

A7 Planet and Moon Formation



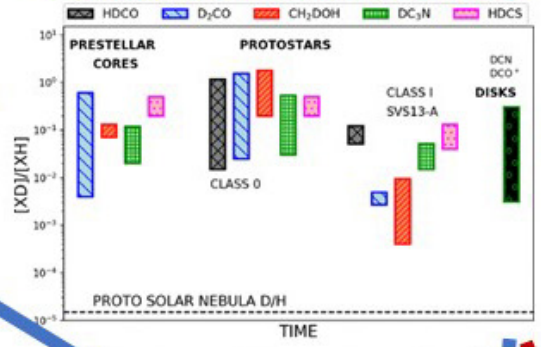
A5 Modelling Planet Formation



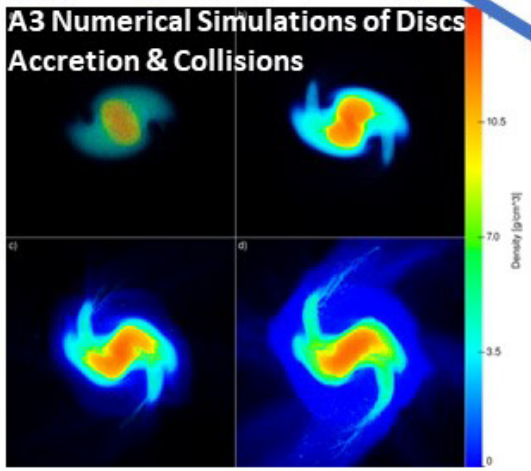
C3

C5

A8 Observational Astrochemistry

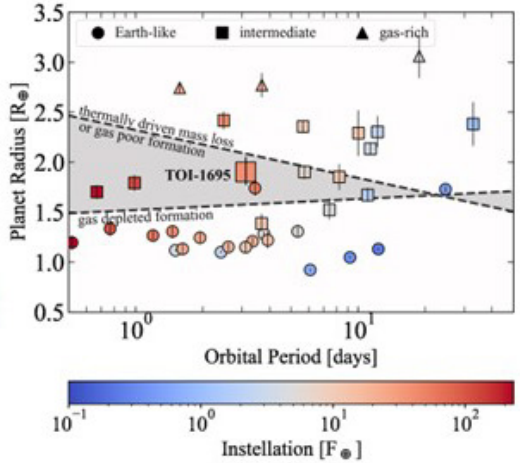


A3 Numerical Simulations of Discs Accretion & Collisions



B4

A6 Interstellar Dust



A2 Observing Exoplanetary System

Nanoparticles in Medicine

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