RU-D

The 2023 Highlights

&

The future = ORIGINS-2

Eric Emsellem

RU-D

From

Cosmic Large-scale structures

To

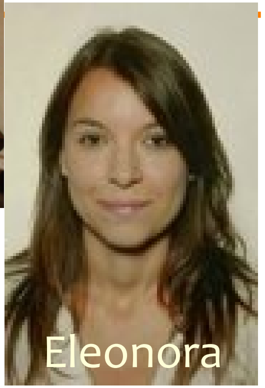
Galaxies, Stars, Planets

RU-D
Galaxies-Stars-Planets

Coordinators = Eleonora Bianchi, Eric Emsellem, Simon Vegetti

This year = 2023

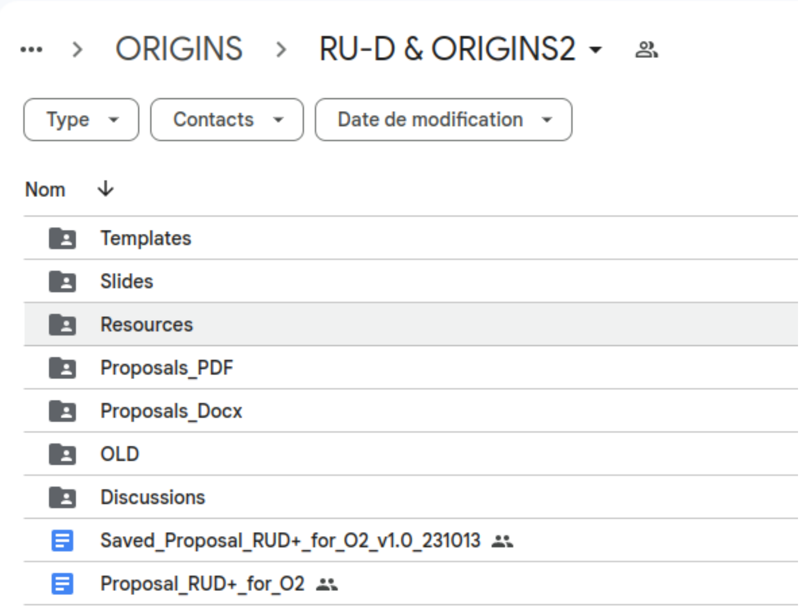
- ✓ **New coordinators =** *Eleonora Bianchi, Simona Vegetti*



- ✓ **Work and discussions within RU-D → ORIGINS-2**

- ✓ **RU-D Day:** April 19
- ✓ **Zoom:** May 19
- ✓ **Session 3** in June
- ✓ **Session 4:** Sept 14

- ✓ **Slack channel**
- ✓ **Google Drive**



RU-D
Galaxies-Stars-Planets

LMU

ORIGINS
Excellence Cluster

Pressure bumps and planet formation

Tommy Lau

Pressure bumps can form planets quickly

⇒ 1) small dust grains grow and accumulate : condition = pressure bump

2) streaming instability + concentration of large grains → planetesimals

3) planetesimals @ high-dust-density → efficient accretion

Follow-up study: **Lau, Birnstiel, Drazkowska, Sammler (Science, under review)**

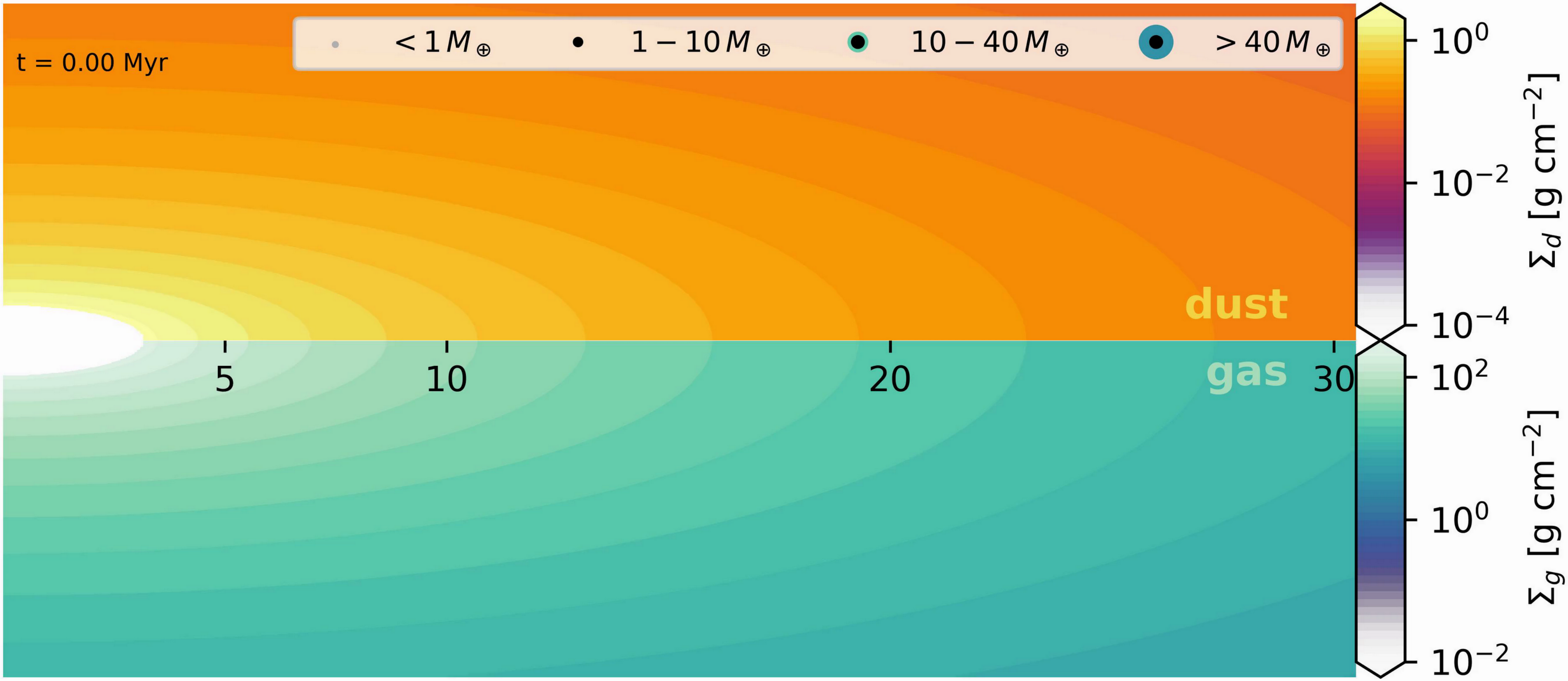
Artifical bump → 2 gas giants → big gap → new pressure bump !

Then → two smaller mass (ice) giants → the young outer Solar System !

Pressure bumps and planet formation

Tommy Lau

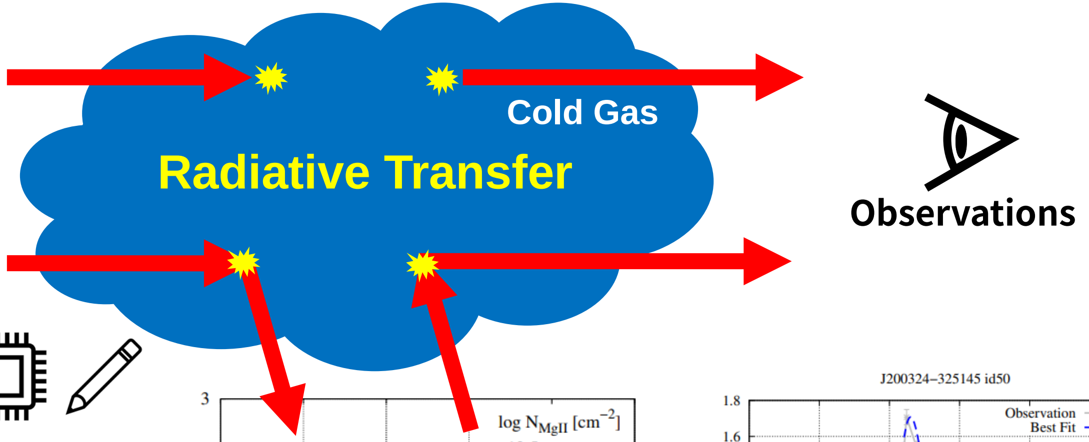
Follow-up study: Lau, Birnstiel, Drazkowska, Sammler (Science under review)

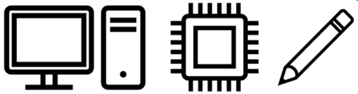


Probing Cold Gas with Mg II Radiative Transfer

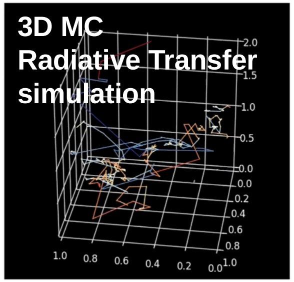
Seok-Jun Chang

Mg II resonance doublet

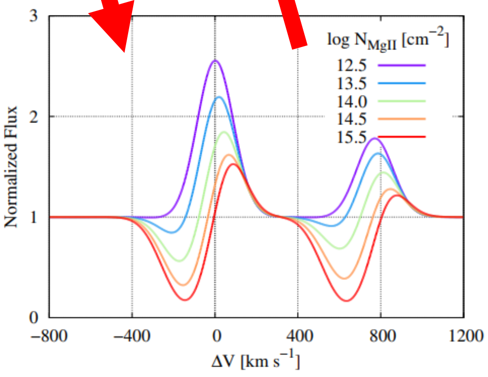




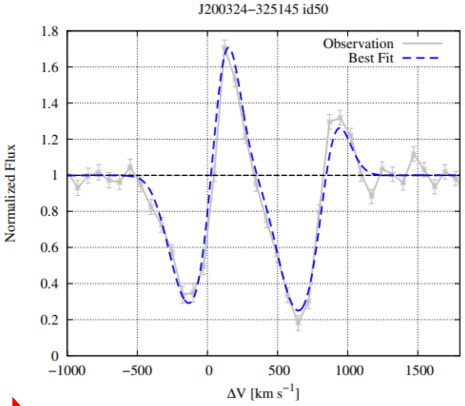
Theory MPA



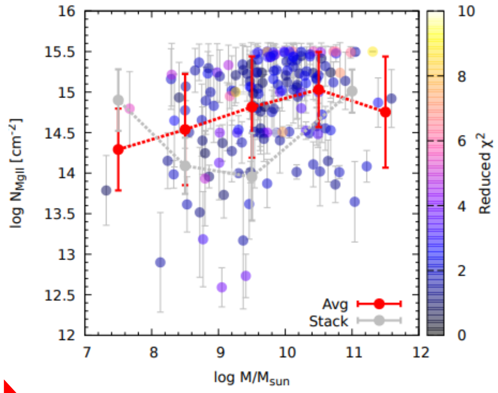
Gronke et al. 2014
Chang et al. 2023



Generating Mg II spectra from the radiative transfer simulation
(Chang & Gronke 2023, submitted)



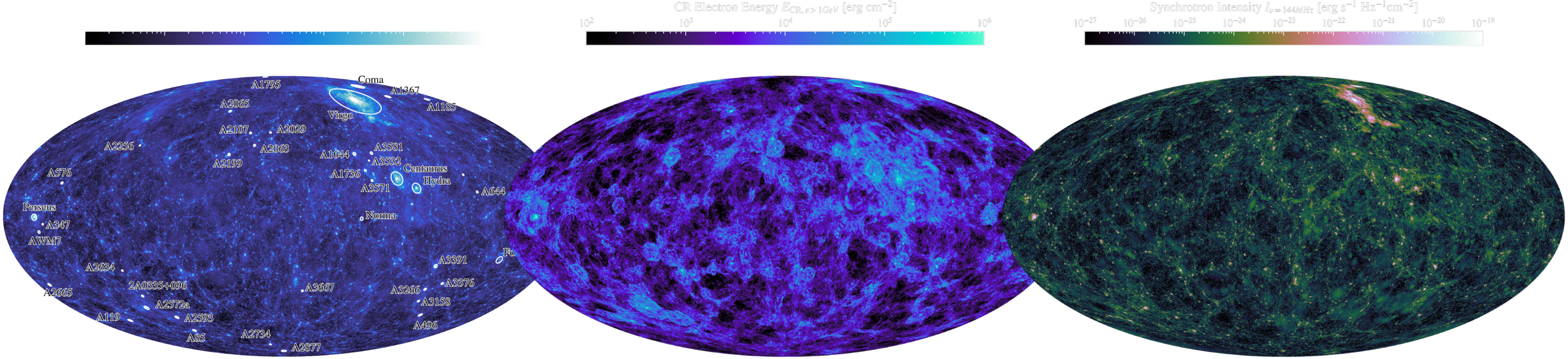
Fitting Mg II spectra obtained by VLT MUSE
(Dutta et al. 2023, Chang et al. in prep)



Studying the properties of cold gas and galaxies

Cosmic rays as tracers of the cosmic web

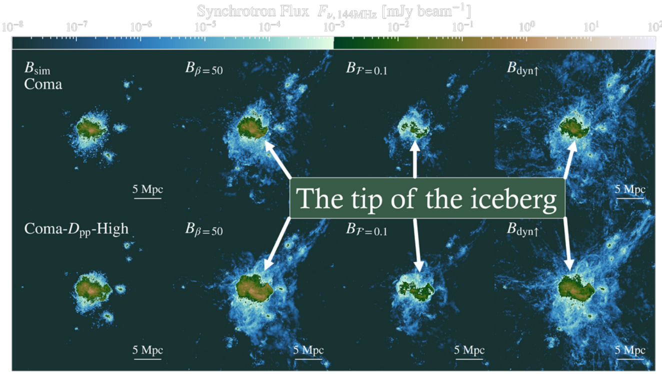
Ludwig Böss



Long-lived CR electrons
⇒ diffuse synchrotron

Acceleration
@ accretion shocks
⇒ synchrotron bright filaments and clusters

B-Diffuse synchrotron emission
@ accretion shocks
⇒ synchrotron bright filaments and clusters

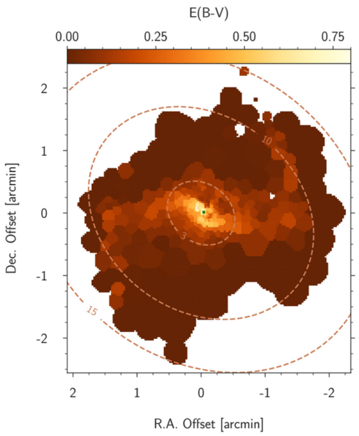


Zoom-in :
Turbulent re-acceleration **boost** the emission ⇒ still requires stacking

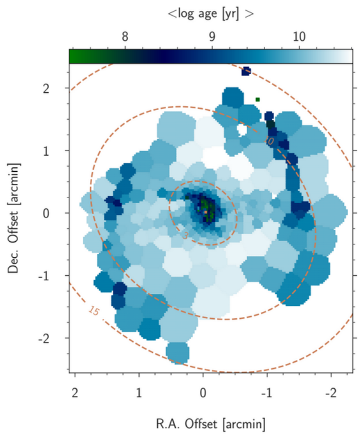
Böss, Dolag, Steinwandel et al., sub. to A&A

Resolved spectroscopy of stellar pops

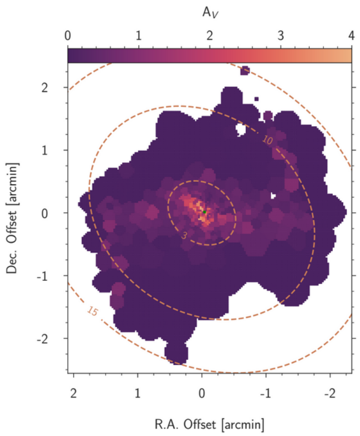
Eva Sextl



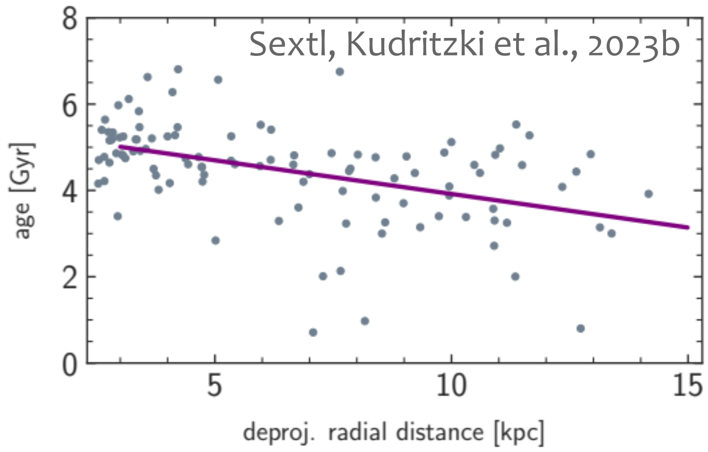
reddening



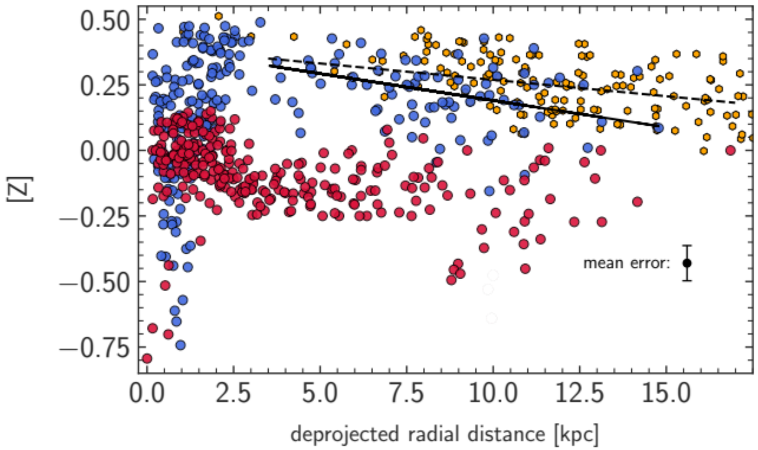
extinction



age



Inside-out growth of stellar disk



- young population <age> < 1 Gyr
- old ~ 10 Gyr
- HII regions ~ 0.005 Gyr

Time evolution :

Metallicity gradient

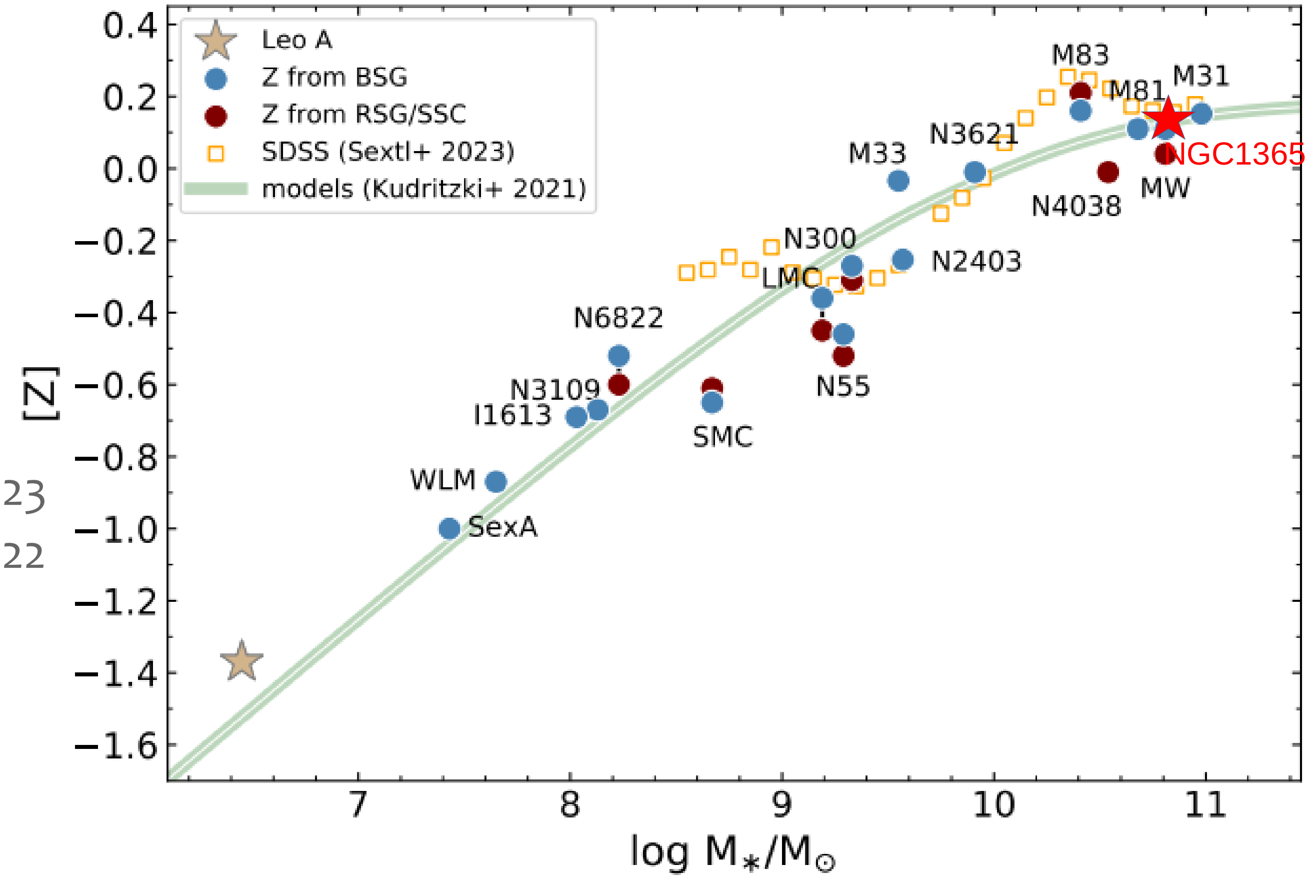
Central anomaly (AGN-driven?)

Sextl, Kudritzki et al., 2023b

Stellar spectroscopy of galaxies

Sextl, Kudritzki

- **Individual supergiants**
- **Population synthesis**



Urbaneja, Bresolin, Kudritzki, 2023

Bresolin, Kudritzki, Urbaneja, 2022

Sextl, Kudritzki et al. 2023a

Sextl, Kudritzki et al. 2023b

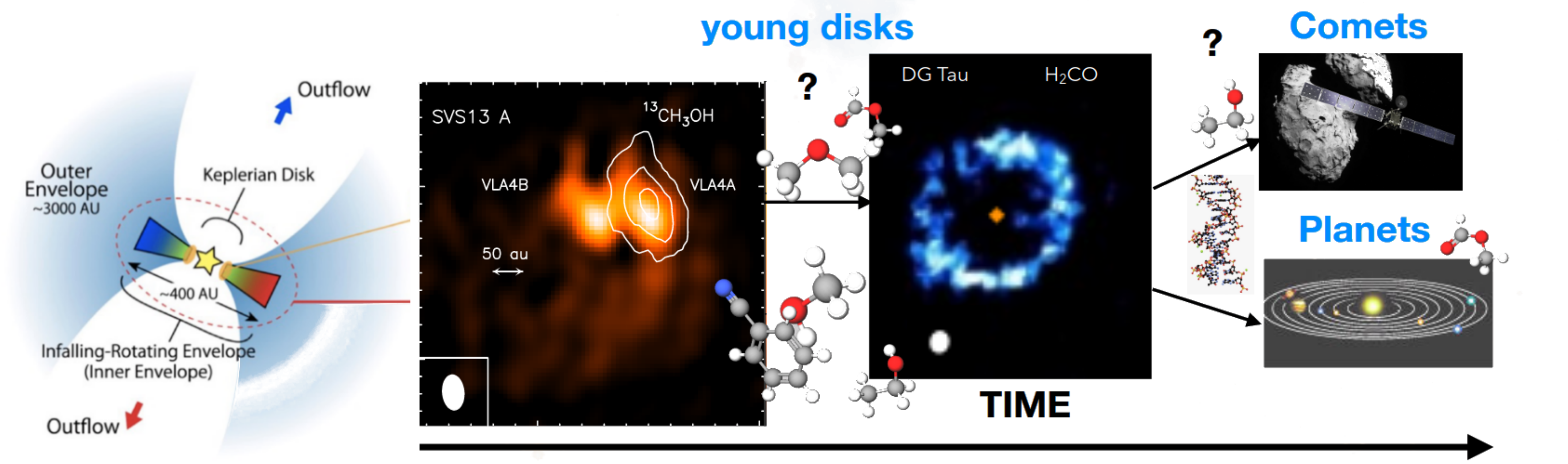
Kudritzki, Teklu et al. 2021

⇒ mass-metallicity relation of star-forming galaxies

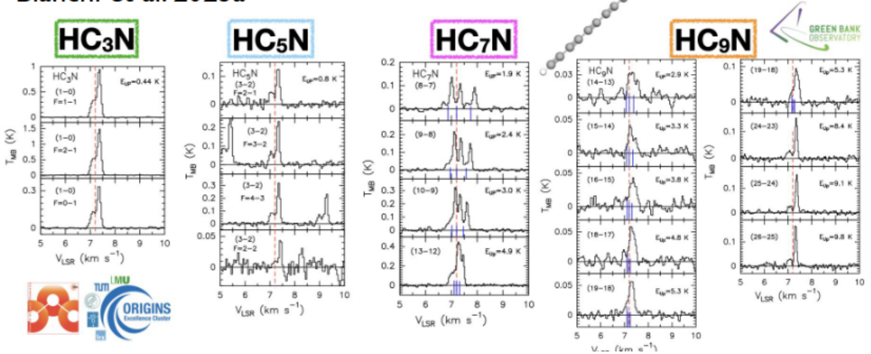
Astrochemistry of Solar Systems

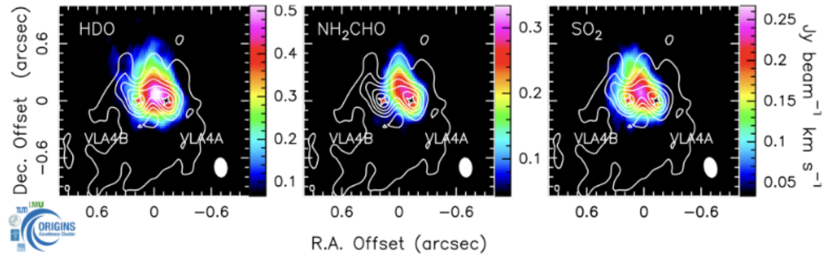
Eleonora Bianchi

Physics & chemistry of Solar System precursors:
chemical connection: *protostellar – protoplanetary disk – Solar System bodies*



Bianchi et al. 2023a





Bianchi et al. 2023b

RU-D

Galaxies-Stars-Planets

LMU

TUM

ORIGINS

Excellence Cluster

ESO

lrz

RU-D : towards ORIGINS-2

Many discussions :
- RUD-Day
- Telecons and Dedicated meetings
- Exchanges via Slack, emails, private 1:1's
- Feedback from Steering Committee via Barbara

⇒ led to a ***drafted guideline over the Summer***
⇒ then to a **summary proposal with all projects**

Special thanks to
Til Birnstiel
Klaus Dolag
Barbara Ercolano
Max Gronke
Thorsten Naab
Paola Popesso
Volker Springel
& many behind the scene

Still lacking a coherent picture

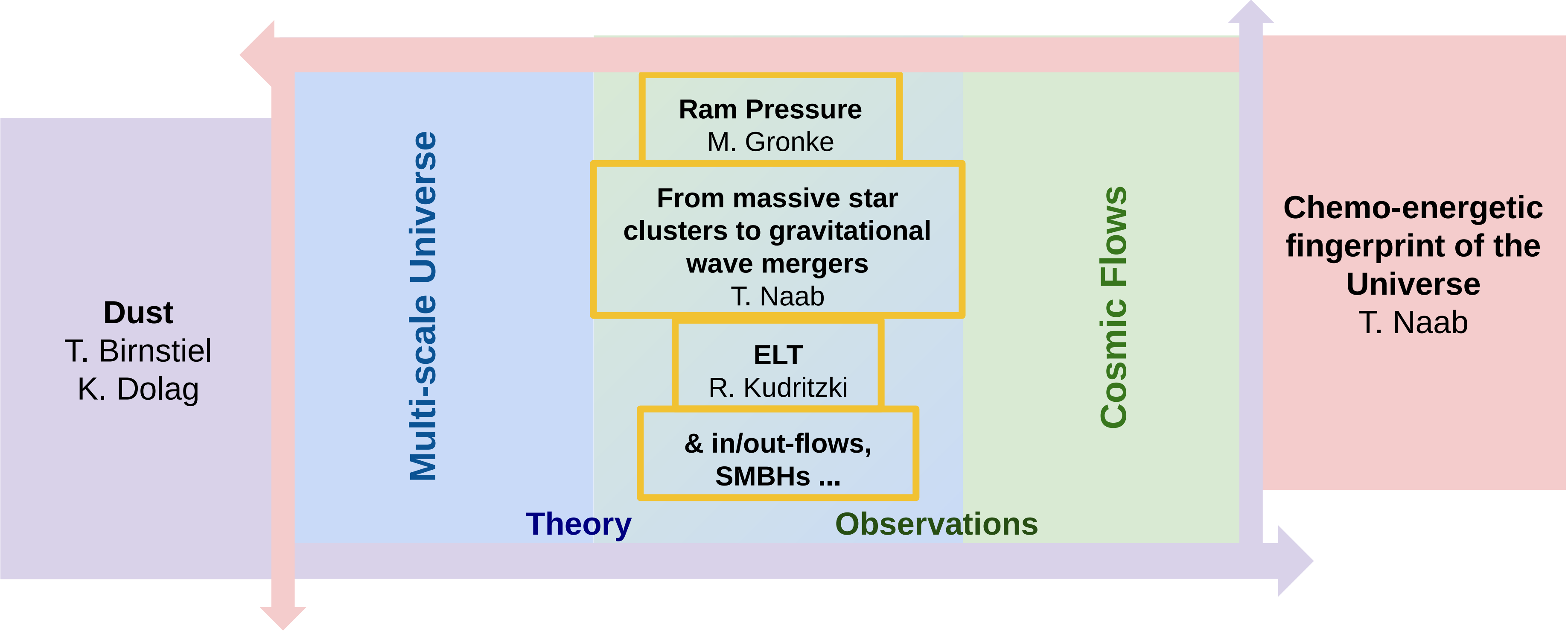
⇒ most importantly : an ambitious and coherent set of projects
[« things we would not do without ORIGINS-2 »]

This week : good opportunity to reach convergence on the main core

1st step : restructuring around 2 main umbrellas

Open Questions from ORIGINS-1

How did galaxy structure evolve & how is the visible Universe connected to the dark?
Is our Milky Way special?
How do stars form and how were galaxies enriched with heavy elements?
Which conditions lead to the formation of our Solar System or habitable systems ?



2nd step : find a common drive

RU-D Galaxies-Stars-Planets

Habitability

Towards a self-consistent understanding of the physics associated with habitability

How / When does the Universe process the cosmic material to form the building blocks of life ?
How does the Universe create differences, and which flows derive from there ?
Multi-scale and Time / Timescales ?
How do the different astrophysical ecosystems transport and process cosmic material across the various scales ?
Supply chain → to form a hospitable/habitable Universe

Dust
T. Birnstiel
K. Dolag

Multi-scale Universe

Ram Pressure
M. Gronke

From massive star clusters to gravitational wave mergers
T. Naab

ELT
R. Kudritzki

& in/out-flows, SMBHs ...

Cosmic Flows

Chemo-energetic fingerprint of the Universe
T. Naab

Theory **Observations**

Proposals ⇒ the core of the new RU-D

RU-D Galaxies-Stars-Planets

Cosmic Flows [CosFlow]

Project 1 Early structure formation in the web
Project 2 The halo assembly bias
Project 3 Baryons and dark matter at the nodes
Project 4 Baryons and dark matter along filaments
Project 5 The eROSITA Universe
Project 6 The flow of baryons on the web
Project 7 Gas around galaxies
Project 8 An isolated or interacting multiphase CGM?
Project 9 Precipitation or Chaotic cold accretion
Project 10 At the heart of massive halos
Project 11 The many ways of quenching a galaxy
Project 12 Connecting the nearby Groups

Multi-Scale Universe [MScU]

Project 1: The baryon cycle in disks
Project 2: Formation of the first galaxies
Project 3: From clouds to planets
Project 4: From black holes to galaxy clusters
Project 5:Galactic winds
Project 6: The escape of ionising radiation

Ram-Pressure Stripping [RPS]

Project 1: Resolving Ram Pressure Stripping
Project 2: Jellyfish, how long is thy tail ?
Project 3: RPS in a cosmological context
Project 4: The multifrequency view on RPS

Planet formation in context [PF]

Project 1: Characterising the atmospheres of planets
Project 2: The birth environment of planets
Project 3: The effect of the host star on planetary atmospheres
Project 4: The extended environment of exoplanets

Stellar & Massive BHs [BH]

Project 1: Gws and the generation of elements
Project 2: Central SMBHs and the nature of DM

Proposals – Resources

RU-D
Galaxies-Stars-Planets
ORIGINS Excellence Cluster

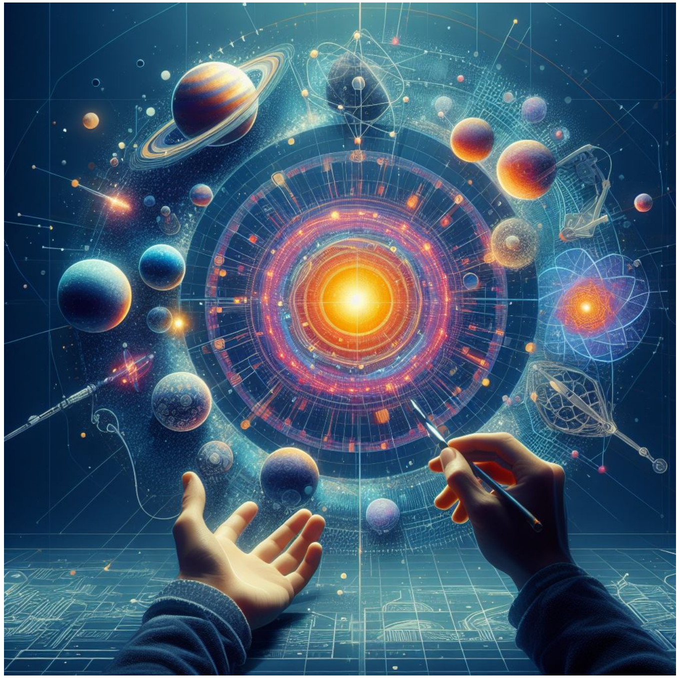
PROJECTS					REQUESTS [FTE yr]						
Connector / Proposal	#	Project Title	PI	cols	1st Half		2nd Half		REQUESTS [FTE yr]		
			2 names are in order per project. In that case funding will be shared.		PhD	PostDoc	PhD	PostDoc	Total PhD	Total PostDoc	grand Total
			FILL IN ONLY THE BLUE REGION		FILL IN ONLY THE BLUE REGION				89.5	98	187.5
Cosmic Flows	1	The early structure formation in the web.	Mroczkowski (3), Dolag (3.5)	Mroczkowski, Dolag	3.5	0	0	3	3.5	3	6.5
	2	The halo assembly bias. How the web defines the dark matter distribution in	Popesso (3), Dolag(3.5)	Popesso, Dolag, Bulbul	3.5	3	0	0	3.5	3	6.5
	3	Baryons and dark matter at the nodes. The high redshift clusters case.	Dolag (3), Mroczkowski (3.5)	Bulbul, Comparat, Mroczkowski, Dolag, Sanders	3.5	0	3.5	0	7	0	7
	4	Baryons and dark matter along filaments. The mysterious Universe looked u	Popesso (3.5), Merloni (3.5)	Popesso, Bulbul, Merloni, Dolag	3.5	0	3.5	0	7	0	7
	5	The eROSITA Universe. From cosmology to the ICM physics at the nodes o	Bulbul (3)	Bulbul, Sanders	0	3	0	0	0	3	3
	6	The flow of baryons on the web. From the intergalactic to the circumgalactic	Péroux (3) & De Cia (3.5))	Péroux, Mroczkowski, Merloni, De Cia	0	3	3.5	0	3.5	3	6.5
	7	Gas around galaxies. The hot CGM component.	Comparat (3) Merloni (3.5)	Comparat, Merloni, Popesso, Péroux	0	3	0	3	0	6	6
	8	An isolated or a shared and interacting multiphase CGM?	Popesso (3) Comparat (3.5)	Popesso, Comparat, Merloni, Dolag, De Cia, Péroux	0	3	3.5	0	3.5	3	6.5
	9	Precipitation or Chaotic cold accretion: mechanisms of the baryonic exchang	Popesso (3), Merloni (3.5)	Popesso, Merloni, Dolag	0	3	3.5	0	3.5	3	6.5
	10	At the heart of massive halos: at the core of the triggering mechanism.	Merloni (3), Dolag (3)	Merloni, Popesso, Dolag	0	3	0	3	0	6	6
	11	The many ways of quenching a galaxy: from filament quenching to AGN fee	Cirasuolo (3), Popesso (3.5)	Cirasuolo, Popesso	0	3	3.5	0	3.5	3	6.5
	12	Connecting the Local Group and other nearby groups in the Local Volume. T	Rejkuba (3), Hilker (3)	Rejkuba, Hilker	0	3	0	3	0	6	6
Multi-Scale Universe	1	Accretion-driven self-regulation and the energy budget in star-forming disks	Emsellem (3), Burkert (3.5)	Emsellem, Burkert, Naab, Genzel, Tacconi		3	3.5		3.5	3	6.5
	2	Formation of the first galaxies seen by JWST with high-resolution cosmologi	Springel (3), Burkert (3)	Springel, Burkert		3	3		3	3	6
	3	From clouds to planets: how the initial conditions of discs formed in filament	Burkert(3), Pineda(3)	Burkert, Birnstiel, Ercolano, Heigl, Küffmeier, Pineda		3		3	0	6	6
	4	From black holes to galaxy clusters: how the AGN feedback heats the interc	Dolag/Churazov(3),Emsellem/Dolag(3.5)	Dolag, Emsellem, Churazov, Khalibullin		3	3.5		3.5	3	6.5
	5	The multiphase, multiscale and multiphysics nature of galactic winds	Mainieri	Mainieri, Gronke, Arrigoni-Battaia, Vegetti		3	3.5		3.5	3	6.5
	6	The escape of ionising radiation from stars to the IGM	Ciardi (1.5), Gronke (1.5)	Gronke, Ciardi, Burkert		3			0	3	3
Planet formation in context	1	Characterising the atmospheres of planets	Ercolano	Ercolano, Heng, Rifesser, Preibisch, Birnstiel	0	3	0	2	0	5	5
	2	The birth environment of planets	Ercolano, Grassi	Ercolano, Grassi, Caselli, Preibisch , Birnstiel, Rifesser, Heng	0	3	0	2	0	5	5
	3	The effect of the host star on the evolution of planetary atmospheres	Ercolano	Ercolano, Preibisch, Heng, Rifesser, Birnstiel	0	0	3	0	3	0	3
	4	The extended environment of exoplanets including the concept of galactic ha	Ercolano, Preibisch	Ercolano, Preibisch, Rifesser , Birnstiel , Heng	0	0	3	0		0	0
The physics of Ram-Pressure	1	Everything you wanted to know about Ram Pressure and its impact on galax	Gronke	Arrigoni-Battaia, Churazov, Dolag, Gronke		2		2	0	4	4
CONNECTORS					REQUESTS [FTE yr]				TOTAL		
Dust	1	Numerical treatment of dust in astrophysical simulations and its application t	Dolag/Birnstiel(3), Kudriski(1.5)	Dolag, Birnstiel, Kudritzki		4.5			0	4.5	4.5
	2	Compositional tracking of evolving dust in planet-forming disks and disk win	Birnstiel/Ercolano(3), Ercolano/Grassi(3.5)	Birnstiel, Ercolano, Grassi		3	3.5		3.5	3	6.5
	3	Profiling primitive organic material from meteorites and return mission sampl	Schmitt-Kopplin(3.5)	Birnstiel, Caselli, Grassi, Giuliano	3.5				3.5	0	3.5
	4	Multi-wavelength observations of dust/PAHs in planet-forming disks.	Macias/Siebenmorgen(3)	Birnstiel, Enßlin, Ercolano, Macias, Miotello, Siebenmorgen		3			0	3	3
	5	Laboratory inestigations of dust/ice optical properties	Ivlev/Giuliano (lab equipment)	Birnstiel, Caselli, Giuliano, Ivlev, Macias, Siebenmorgen							
	6	3D-Analysis of multi-wavelength observations of dust/PAHs.	Ensslin/Birnsiel(3.5), Birnstiel/Ensslin(3)	Birnstiel, Ensslin		3	3.5		3.5	3	6.5
Supermassive black holes	1	Gravitational waves and the generation of elements at extreme stellar densi	Hilker/Naab (3,5)	Hilker, Naab, Janka, Thomas	3.5				3.5	0	3.5
	2	Central supermassive black holes in massive galaxies and the nature of dar	Naab/Thomas (3,5)	Naab, Thomas			3.5		3.5	0	3.5
Chemo-Fingerprint	1	From mass-losing progenitors to supernovae: stellar evolution across all me	deMink/Kudritzki (3), Janka (3,5)	de Mink, Janka, Kudritzki, Burkert, Suyu		3	3.5		3.5	3	6.5
	2	From turbulent supernovae to the turbulent ISM and outflows	Janka (3), Burkert/Emsellem (3,5)	Janka, de Mink, Naab, Burkert, Emsellem		3	3.5		3.5	3	6.5
	3	from ISM to IGM: Multiphase mixing in (magnetised) turbulent media	Kudritzki(1,5),Gronke/Dolag(3,5),Dolag/Pakmor(3)	Gronke, Dolag, Kudritzki	3.5	1.5	3		6.5	1.5	8
	4	From ISM to protoplanetary disks: Condensation within the enriched, magne	Caselli/Naab(3.5)	Caselli, Naab			3.5		3.5	0	3.5
	5	From driven turbulence to galaxy clusters: The role of viscosity	Springel/Dolag(3.5)	Springel, Dolag	3.5				3.5	0	3.5
	6	From X-ray observations: metals as tracer of past stellar evolution, outflows	Churazov/Dolag(3)	Churazov, Khabibullin, Dolag		3			0	3	3
					REQUESTS [FTE yr]						

DO NOT TOUCH THE REGION to the RIGHT PLEASE

DO NOT TOUCH THE REGION to the LEFT PLEASE

⇒ ~ 188 FTE-yr (=90 for PhDs, 98 for Post-Docs)

RU-D, towards ORIGINS-2 – Overarching Questions



What are the conditions that made such a corner of the Universe so conducive to life ?

RU-D, towards ORIGINS-2 – Overarching Questions

Cosmic habitability: the (many) ways to create a hospitable universe

- How do physical processes **set the cascade of scales** ⇒ galaxy, star and planet formation?
- How do the different astrophysical ecosystems **transport and process** cosmic material across the various scales ?
- How does feedback and its chemo-energetic imprint **set and enrich the turbulent media at all scales** (ICM, IGM, CGM, ISM)
- How to **observationally** constrain the physical processes at play on different scales?
- Can we produce a synthetic Universe to provide observers a theoretical tool to **test predictions** versus observations?

RU-D, towards ORIGINS-2 – Overarching Questions

Cosmic habitability:
the (many) ways to create a hospitable universe

1- Cosmic Web structuring and how it shapes galaxies

- Pinning down the first galaxies [**Large surveys, JWST, theory, simulations**]
- From filaments and nodes to groups [**4MOST, MOONS, DESI, SZ, simulations**]

2- Large-scale baryonic flows

- Dissecting the CGM and its connection with the IGM and the central galaxy [**AtLAST, eROSITA, CMB surveys, simulations**]

3- Galactic processes and its impact on environment

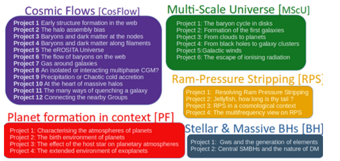
- Galactic flows and the baryon cycle [**VLT, JWST, ELT, ALMA, high-res simulations**]
- Multi-scale dynamical coupling [**Multi-lambda data, zoom-in simulations, SF sim**]

4- Galactic habitability

- Establishing & testing the concept of galactic habitability [**Extra Solary systems obs, numerical modelling, simulations**]

RU-D, towards ORIGINS-2 – Overarching Questions

Cosmic habitability:
the (many) ways to create a hospitable universe



CosFlow-P12 ?

1- Cosmic Web structuring and how it shapes galaxies

- Pinning down the first galaxies **MScU-P2**
- From filaments and nodes to groups **CosFlow-P1+P2+P3+P4+P5**

2- Large-scale baryonic flows

- Dissecting the CGM and its connection with the IGM and the central galaxy **CosFlow-P6+P7+P8**, **RPS-P1+P2+P3+P4**

3- Galactic processes and its impact on environment

- Galactic flows and the baryon cycle **MScU-P4+P5+P6**, **CosFlow-P10+P11**
- Multi-scale dynamical coupling **MScU-P1**, **BH-P1+P2**

4- Galactic habitability

- Establishing & testing the concept of galactic habitability **PF-P1+P2+P3+P4**, **MScU-P3**

RU-D, towards ORIGINS-2 – Next Steps

Cosmic habitability:
the (many) ways to create a hospitable universe

Need for a **coherent set of exciting & ambitious projects**
→ fueling the core driver

⇒ **Reshuffle, merge, rephrase** existing set of projects

⇒ Derive the required **resources**

⇒ Emphasise the need and usage of **infrastructures**

⇒ Support from the **2 connectors** : « Dust » & « Chemo-fingerprint »

Good time to help with the convergence

Cosmic habitability

the (many) ways to create a hospitable universe

RUD

SCALES

How do physical processes **set the cascade of scales**
⇒ galaxy, star and planet formation?

FLOWS

How do the different astrophysical ecosystems
transport and process cosmic material across the various scales ?

ENRICH

How does feedback and its chemo-energetic imprint
set and enrich the turbulent media at all scales (ICM, IGM, CGM, ISM)

CONSTRAIN

How to **observationally constrain**
the physical processes at play on different scales?

& PREDICT

Can we produce a **synthetic Universe** to provide observers
a theoretical tool to **test predictions** versus observations?