Cosmology, astronomy and exoplanets:

Galaxy structure and evolution (a.k.a. "Galaxies")

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The boundaries of this session/topic

- Everything in between the scale of stars and the cosmic web
- From high-redshift to the present-day

Will not discuss here in detail:

- Star formation
- Violent processes (high energy)
- The physics of the early universe / cosmology

Some related white papers (with presentations) not discussed in this session

- Barstow (Evans): Living Worlds and Cosmic Origins (LUVOIR)
- Jahnke: ESA-led HabEx multi-purpose camera
- Linz: High spatial resolution in FIR
- Wiedner: First light to life (Origins)
- Simionescu: Cosmic Web

• ...

• Koopmans: Dark ages with low frequency arrays

White papers in the "Galaxies" category

- All-Sky Visible and Near Infrared Space Astrometry (Hobbs)
- Faint objects in motion: the new frontier of high precision astrometry (Malbet)
- Precise Astrometry: Earth Analogs and Beyond (Horzempa)
- HAYDN: High-precision AsteroseismologY of DeNse stellar fields (Miglio)
- Chronos: Take the pulse of our Galactic neighbourhood (Michel)
- Massive Stars in Extremely Metal-Poor Galaxies: a Window into the Past (Garcia)
- Stellar Physics with High-Resolution UV Spectropolarimetry (Morin)
- Closing gaps to our origins (Gomez de Castro)
- A complete census of the gas phases in and around galaxies: far-UV spectropolarimetry (Lebouteiller)
- Unveiling the faint ultraviolet Universe (Zanella)
- A NIR Spectroscopic Galaxy Survey: From formation of galaxies to peak of activity (Ferreras)
- Space Project for Astrophysical and Cosmological Exploration (SPACE, Burgarella)
- The Far Infrared Spectroscopic Surveyor (Rigopoulou)
- Mapping Large-Scale-Structure Evolution over Cosmic Times (Silva)

NIR to FIR: Galaxies and surveys

Astrometry

Asteroseismology

UV: stars and gas impact on galaxies



allow us to reveal underlying forces... and much more (see e.g. Hobbs' talk)

Astrometry for galaxies' science

Faint objects in motion (Malbet)

• High-precision astrometry of faint objects: nature of dark matter via the kinematics of stars

subhalos via streams, disk; shape of halo with HVS; ultra-compact mini-halos with astrometric signatures; test of gravity in proxima centauri; dSph) (+ exoplanets)

• dedicated science program; 4 years duration, relative astrometry; M-class, builds up on Theia concept



StarWatch: Precise Astrometry: Earth Analogs and Beyond (Horzempa)

- builds up on SIM, interferometry for astrometry (with US)
- 5% parallax error at 16 kpc, PM for binary BHs (beyond MW) and potentially interesting for crowded fields



High-precision Asteroseismology of Dense stellar fields (Miglio)

→ A study of "simpler" populations (stellar clusters; bulge; nearby dwarf galaxies)

Chronos: Take the pulse of our Galactic neighbourhood (Michel)

- Variability of RGB stars: supplement *Gaia* + large spectroscopic surveys w/masses & ages Mv ~ 8- 11 (out to ~ 1.7 kpc); all-sky (5 years). Supplementing PLATO (1/2 sky and MS stars)
- Questions:
 - chemical evolution and star formation history (of the whole MW, using alpha-age as tracer beyond SN)
 - the early phases of the Galaxy (at early times, lots of action, but when and ordering/sorting);
 - kinematics of the disk (secular and external processes; formation)

Stars and their impact on galaxy evolution

Massive stars in extremely metal-poor galaxies: a window into the past (Garcia)

Science questions:

- Physics and evolution of XMP massive stars different from solar metallicity stars? What is impact of ionizing flux, yields and feedback?
- Insights on the physical properties of the First Stars: Does the distribution of stellar initial masses depend on metallicity? What kind of death-events XMP massive stars? Detection at very high redshifts?
- What evolutionary channels lead to binary stellar mass black holes and gravitational wave sources?



→ high quality optical and UV spectra of representative sample of massive stars with sub-SMC metallicity

LUVOIR: ESA to participate/lead MOS working at intermediate and high spectral resolution \rightarrow LUMOS

Stars and their impact on galaxy evolution Stellar physics with high resolution UV spectropolarimetry (Morin)

- The role of magnetic fields in stellar physics:
 - why only 10% massive stars with strong fields? how do magnetic fields affect stellar evolution (mass loss rate, angular momentum, convection, chemical abundances)? what is effect on circumstellar disk and planet formation?
- Impact on: environments (mass loss, winds, galaxy evolution) and exoplanets and habitability
- Options: on LUVOIR w/Pollux (to go beyond MW); ARAGO (in the MW); on board of CETUS (US); UV important because of diagnostic power; spectropolarimetry largely unexplored



Unveiling the faint ultraviolet Universe (Zanella)



<u>Goals</u>

- IGM in emission: unveil Cosmic Web and studies of exchange of baryons between galaxies and surroundings, unveiling how halo gas contributes to evolution of galaxies and link to galaxy angular momentum build-up
- Observations of neutral gas distribution (from Lyman-a emission) in galaxy clusters → importance of rampressure stripping at intermediate/high z
- Statistical samples of supernovae in UV to characterize the progenitor population of core-collapse SNe
- Accreting white dwarfs in globular clusters to constrain evolution and properties of most compact systems with shortest orbital periods (brightest low frequency GW sources or progenitors of SNIa)

 \rightarrow ~ 1m, 900- 3500; R ~ 1000, 1x1 arcmin²; low SB features (not LUVOIR because IFU), builds on MUSE (ESO)

Galaxy surveys

CHRONOS: NIR Spectroscopic Galaxy Survey: From the formation of galaxies to the peak of activity (Ferreras)

- Target a mass-limited sample of galaxies during two epochs
 - the formation of the first galaxies (at z > 6; cosmic dawn); UV Ly-alpha
 - at peak of galaxy formation activity (z: 1 3; cosmic noon); optical rest-frame
 - NIR spectra (I=0.8–2mm), to extract fundamental observables such as gas and stellar kinematics, chemical abundances, and ages
- Specific science questions
 - Connection between star formation history and mass assembly; Role AGN & SN feedback, with quantitative estimate of quenching timescales; formation of the first galaxies and sources of reionization; evolution of metallicity-mass relation, ...
- 10⁶ high quality spectra, high S/N in continuum. Space: faint sources and SNR; R ~ 1500 – 3000; Area: 3-6m
 - ELT/JSWT: ~ 1,000s galaxies;
 - Ideal complement to EUCLID or WFIRST







Galaxies and surveys

FIRSS (Rigopoulou)

 Goal: to probe multi-phase ISM from large-scale velocity resolved (3D) maps of dominant gas coolants in our Galaxy, nearby and distant galaxies

Mapping Large-Scale-Structure Evolution over Cosmic Times (Silva)

Line-Intensity-Mapping

- Cosmic SFR density: sources
- Galaxy properties:
- 1st galaxies ISM? Time evolution?

(talk by Delabrouille)





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Are we missing important topics or science questions?