Swiss Science Priorities

Jean-Paul Kneib (EPFL) , Mark Sargent (ISSI Bern)
Miroslava Dessauges-Zavadsky (Geneva University)

Science (Astrophysics)	Data Science and Simulations	Computing Platforms	Infrastructure	Communications & Outreach
SKAO Working Groups • Extragalactic • Cosmology • Solar, Heliospheric and Ionospheric • Our Galaxy **Science Interests** • Intensity Mapping • Cosmic Dawn & Reionization • Extragalactic & Nearby Galaxies • And more...	**M** • Advances in computational imaging, • Bayesian inference, • Generative models and deep learning **Tools in Development** • SPHEXA • Bluebuild • Karabo • SEAMS • And more...	**CSCS Provides** • Expert Engineering Support • Storage Computing • One cluster for sandbox environment • Support for SKAO Data Science Challenges **Switzerland has also begun planning for a SRCNET node**	**Development of the Mid-band 6 proof of Concept** • Extend the observation frequency range to 15-25 + GHz • Realization of the Elegant Bread Board (EBB)	**Communications Supports** • 4-Year Report • Fantasy Basel • Open Days • Cosmos Archeology • Press • Community Interest Articles • Proposal Support • Social Media
Chair: (UniGe) **Co-Chair:** D. Crichton (ETHZ)	**Cha** Emma Tolley (EPFL) **Co-Chair:** Simon Felix (FHNW)	**Chair:** Victor Holanda (CSCS) **Co-Chair:** Darren Reed (UZH)	**Chair:** Dominique Bovey (HES-SO) **Co-Chair:** Gilles Feusier (EPFL)	**Chair:** Tanya Petersen (EPFL) **Co-Chair:** Hamsa Padmanabhan (UniGe)

Emma Tolley

Elena Gavagnin

Florina Ciorba+Lucio Mayer

Emma Tolley

Pablo Lopez

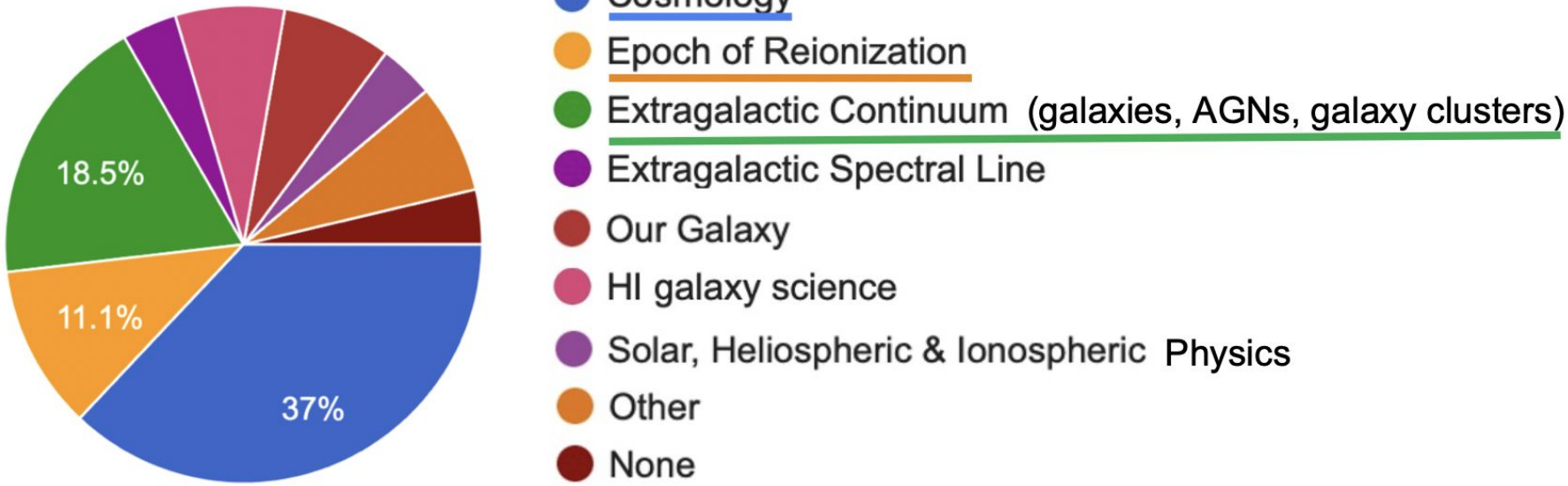
Rohini Joshi

Dominique Bovey

This Talk + Alexandre Refregier

Swiss SKA SWG membership/participation

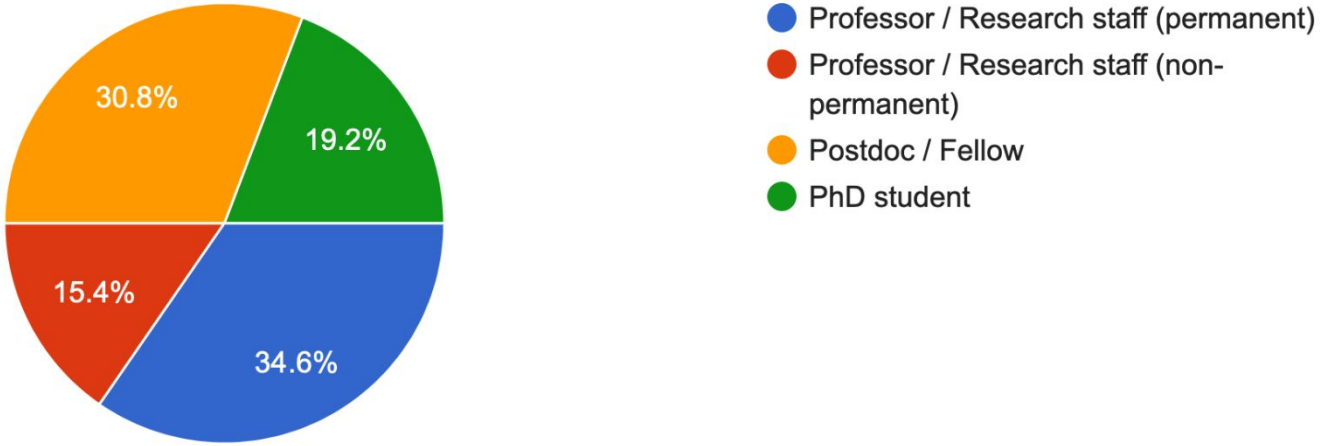
(according to the SKAO SWG definition)



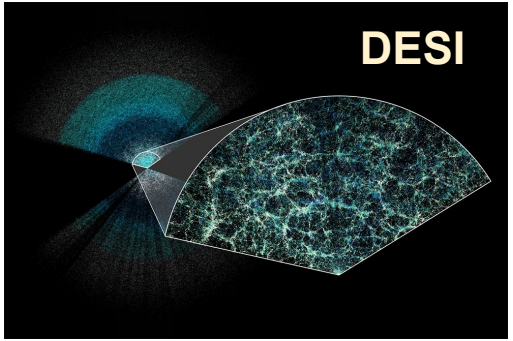
SKACH - 10 institutions across Switzerland

EPFL, UniGE, ETHZ, UniZH, ISSI, UniBE,UniBAS, FHNW, ZHAW, HES-SO

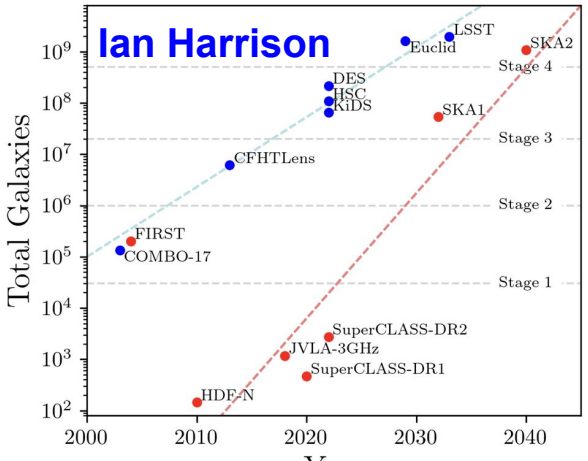
Academic status of the ~100 SKACH science participants



Cosmology and extragalactic Surveys

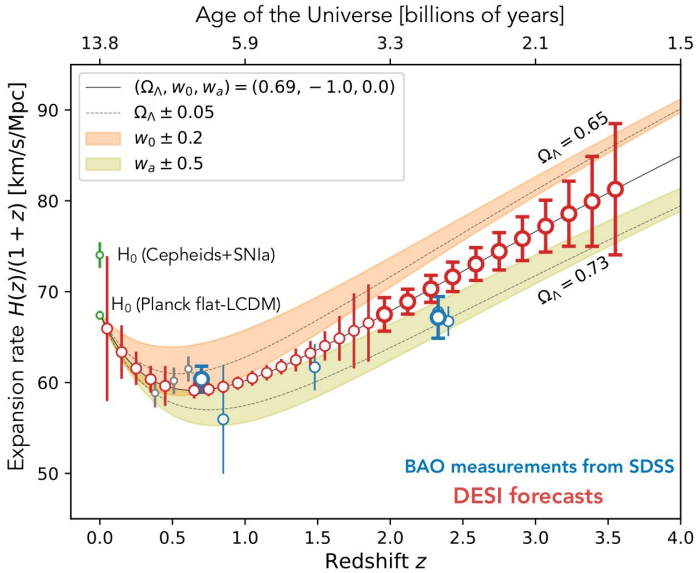


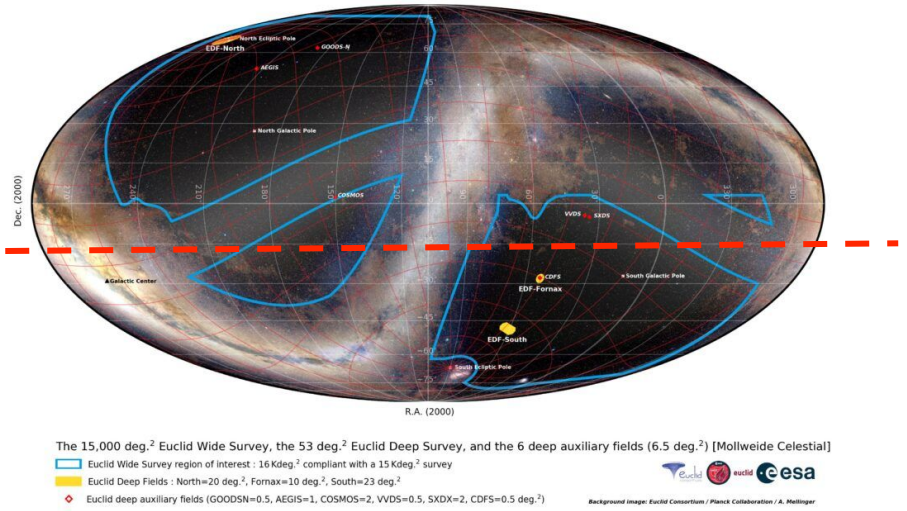
- **Cosmology**
  - LSS - *Synergy with Spectro Surveys*
    - redshift survey/3D-map
    - BAO with HI maps (MeerKLASS, HIRAX)
  - Gravitational Lensing - *Synergy with Euclid*
    (possible with MID-Band 5 but critically needs of AA4)
    - Strong+Weak lensing
  - Epoch of Reionization (Bianco)
- **Extragalactic**
  - HI mapping (Refregier)
  - Continuum science



Synergy with DESI (2019-2026+) and Euclid (2023-2033)

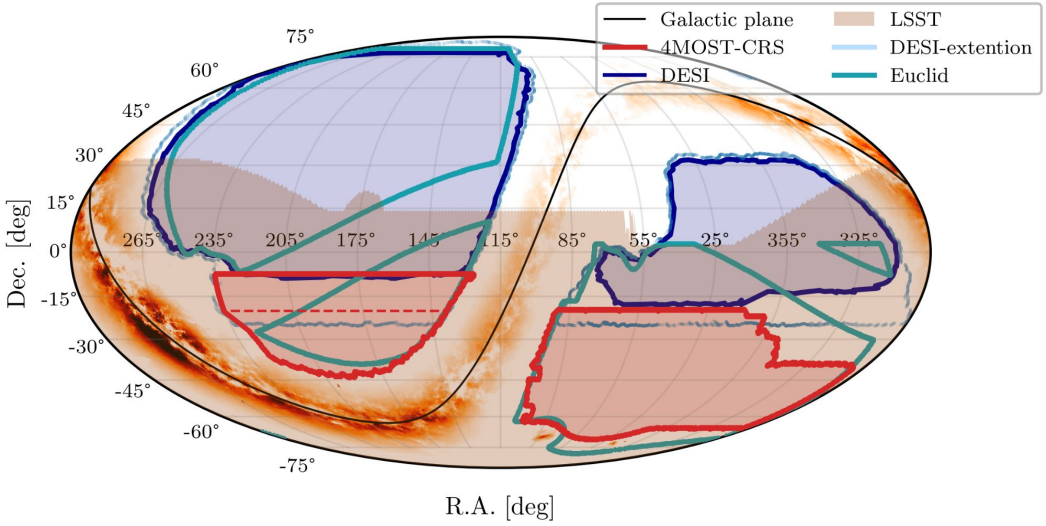
- DESI will ultimately go down to -15 deg dec (50 Millions z)
- Euclid will have its first public data release in October 2026
- Both surveys will deliver new publications and PRs this week





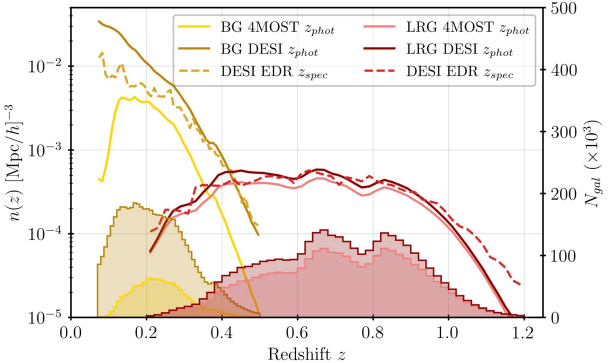
Synergy with 4MOST Spectroscopic Surveys (2025-2032)

- 4MOST is the first comprehensive spectroscopic survey of the Southern Sky (SDSS+DESI North+Equatorial)
- Composed of 18 consortium sub-surveys (Cosmology redshift survey co-lead by Kneib; AGN and Cluster surveys, Waves …)



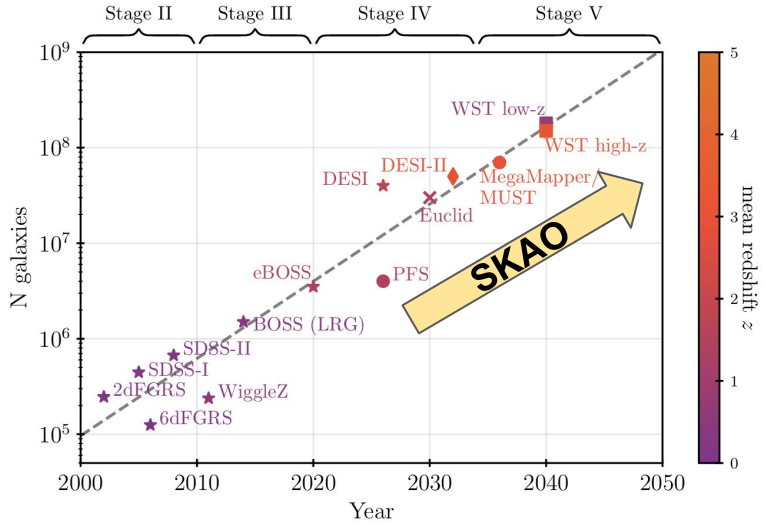
Cross-correlation with HI mapping

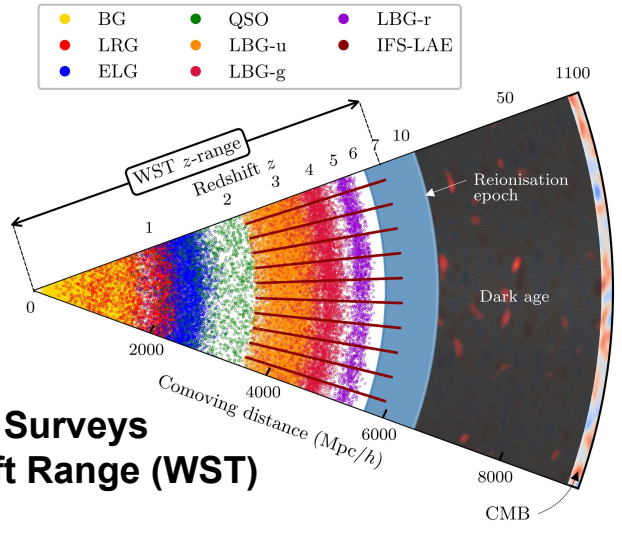
- MeerKLASS (z<0.4)
- HIRAX (2<z<3 with QSOs)



Synergy with future Massive Optical Spectroscopic Surveys

- *Large Scale Structure mapping of the Universe:* Exploring the content of the universe (Dark Matter, Dark Energy) and other fundamental properties (Inflation models, Neutrino masses, Modified Gravity)

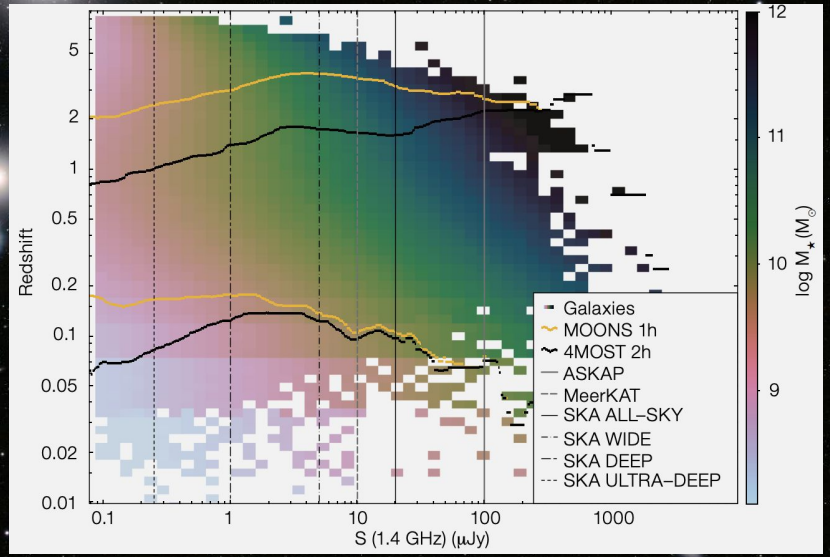


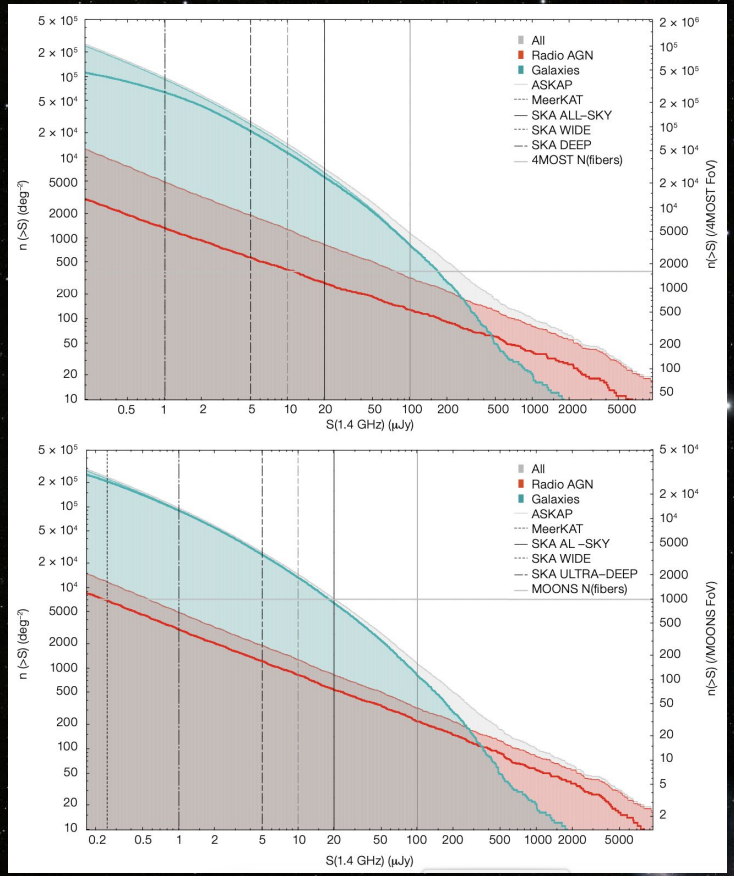


Optical Surveys Redshift Range (WST)

ESO-SKA synergies for galaxy formation & evolution

Exploration of potential for spectroscopic follow-up and characterisation of galaxies and AGN in radio surveys





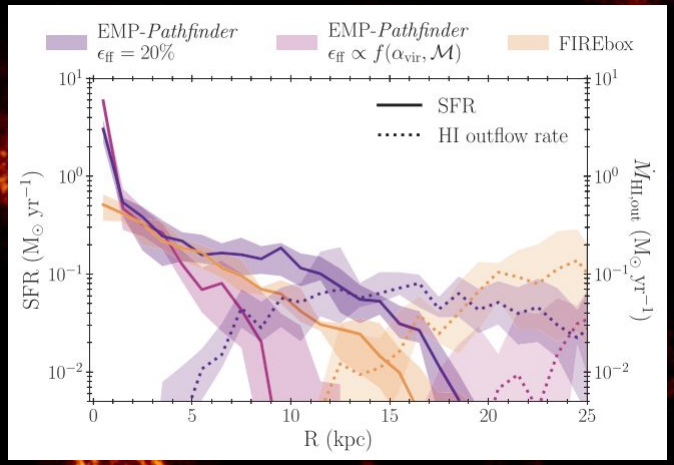
Prandoni, Sargent+24

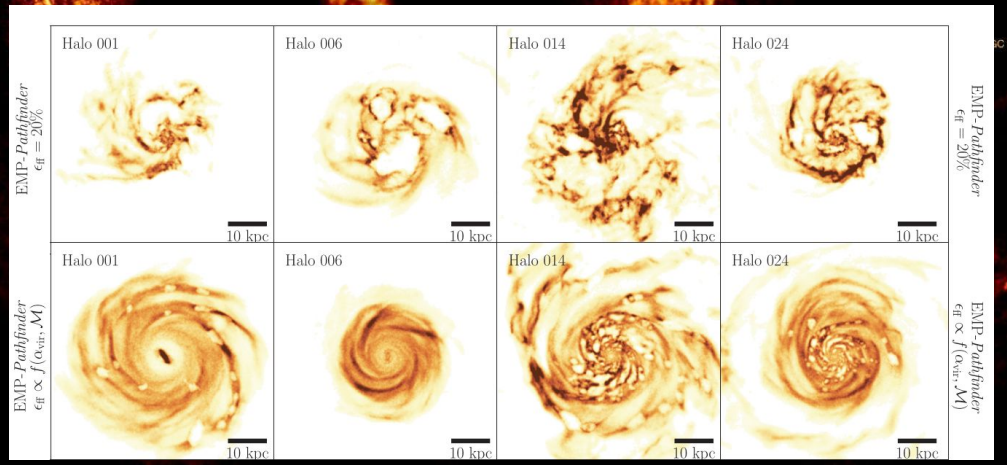
Image credit: ESO/VISTA

Science ideas & SDC

Mark to present

HI distributions as tracers of baryonic physics





Gensior+24

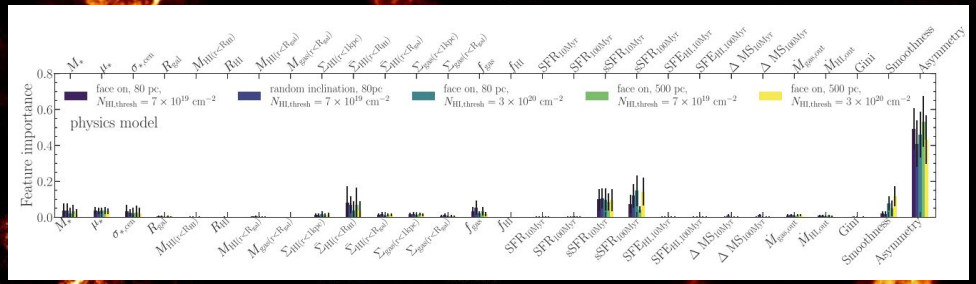
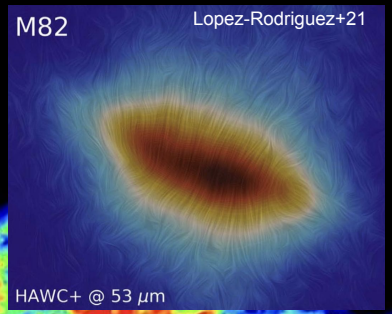
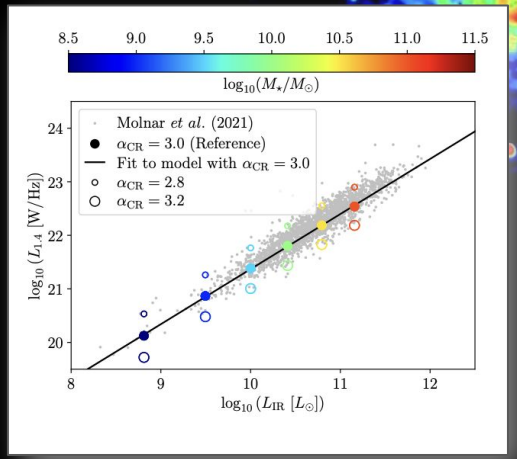


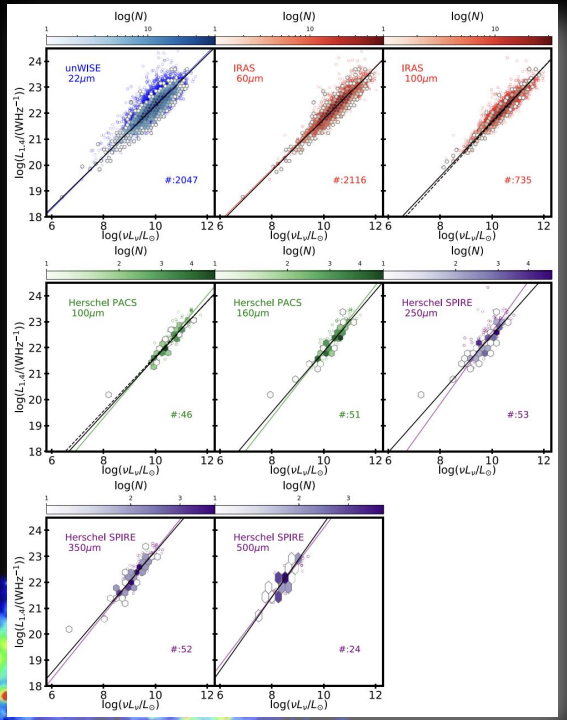
Image credit: THINGS/NRAO

Understanding the radio-SFR calibration with galaxy magnetic field modelling





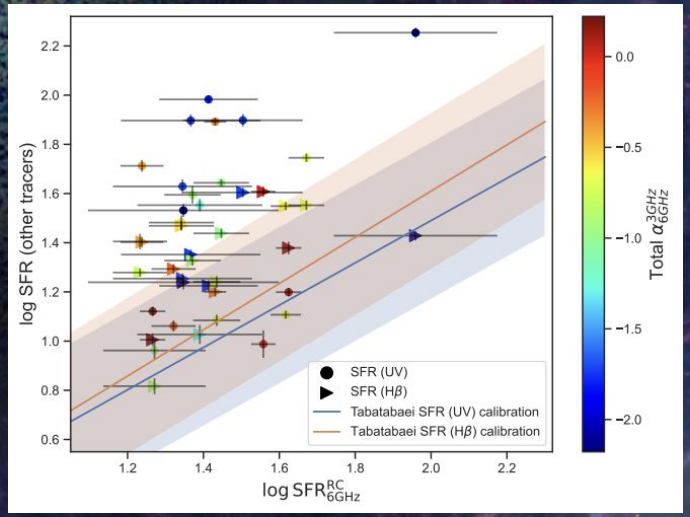
Schober+23



Molnár, Sargent+21

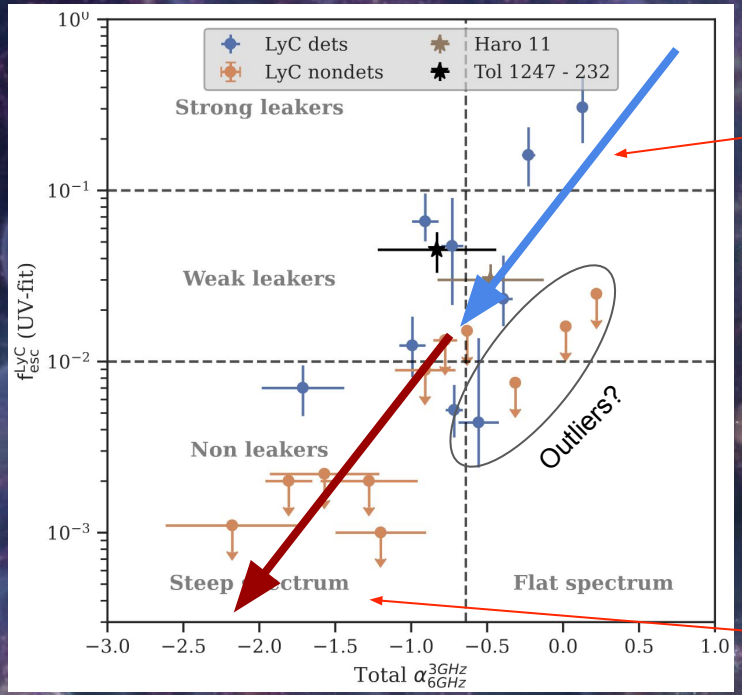
Image credit: T. Muxlow, JBCA (M82)

Radio properties of EoR galaxies



Bait+24

Different SFR calibration for EoR galaxy analogues, and radio spectrum indicative of escape fraction of ionizing photons.



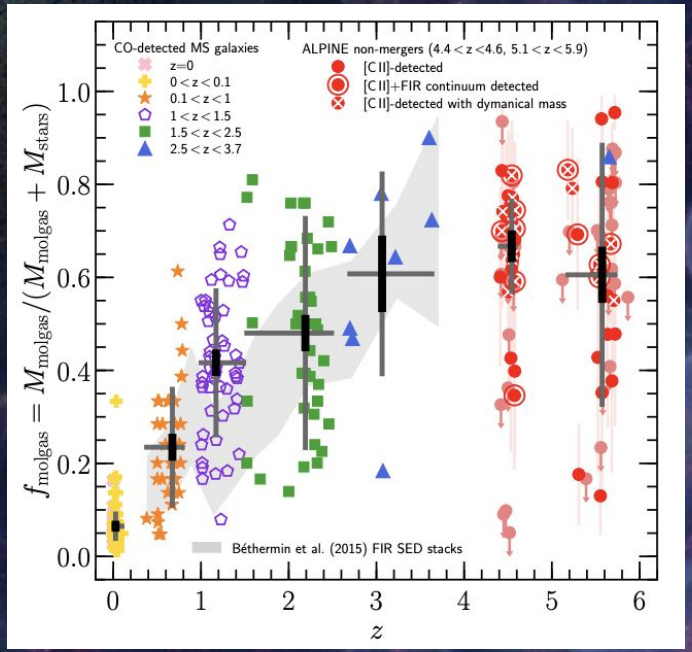
Young & compact starbursts (< 10 Myr)

post-starbursts (≳10 Myr)

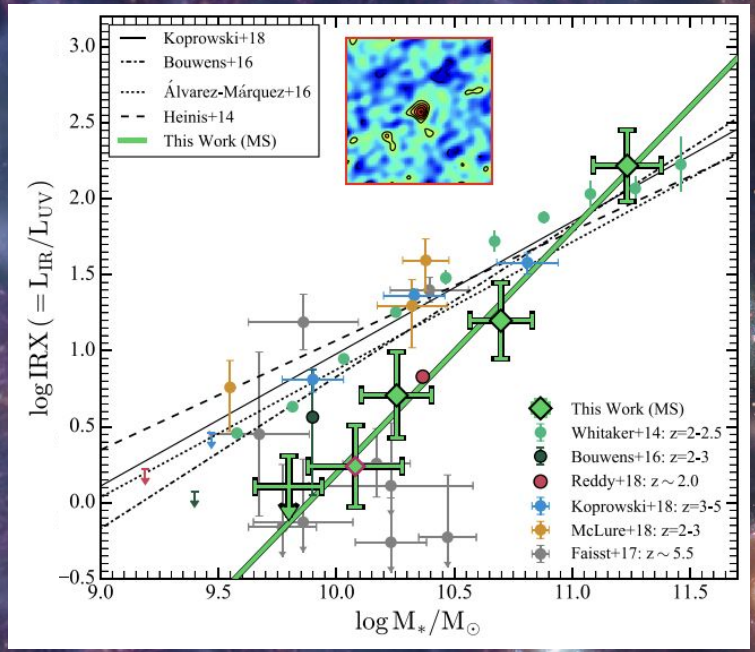
Age of the starburst

Image credit: credit: Jingchuan Yu, Beijing Planetarium

Gas and dust in EoR galaxies as traced by ALMA



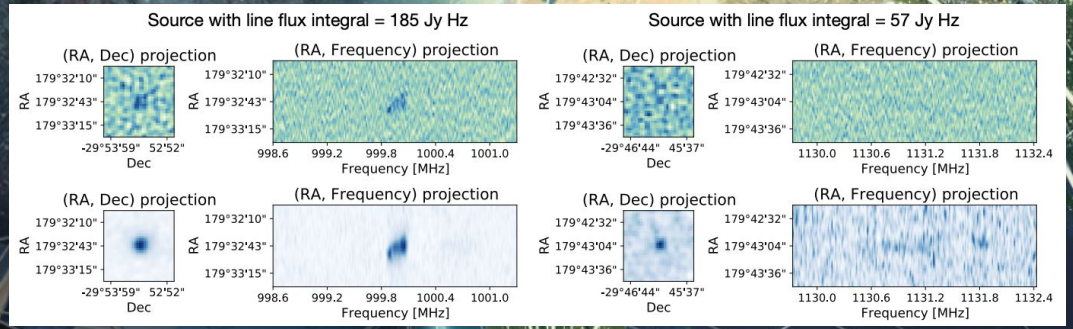
Dessauges-Zavadsky+20



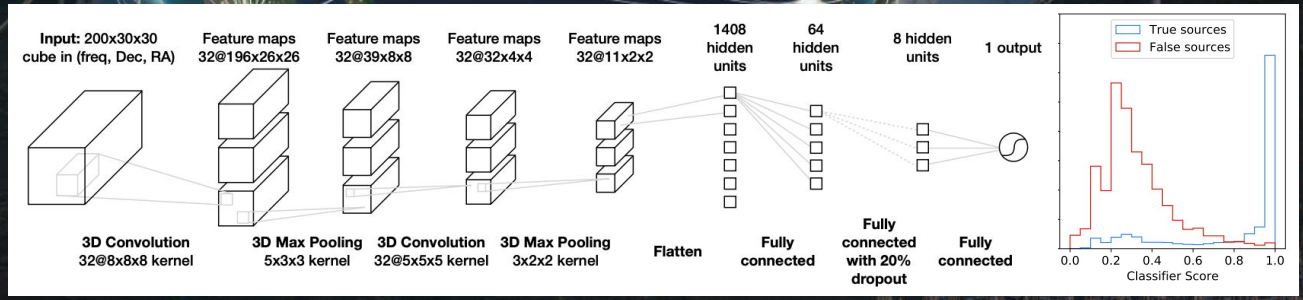
Fudamoto, Dessauges-Zavadsky+20

Image credit: credit: Jingchuan Yu, Beijing Planetarium

Participation in SDCs: Advanced algorithms for denoising and classification

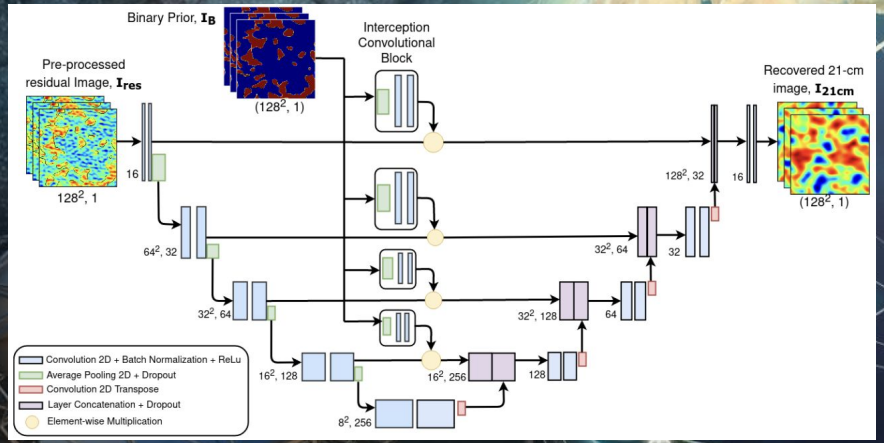


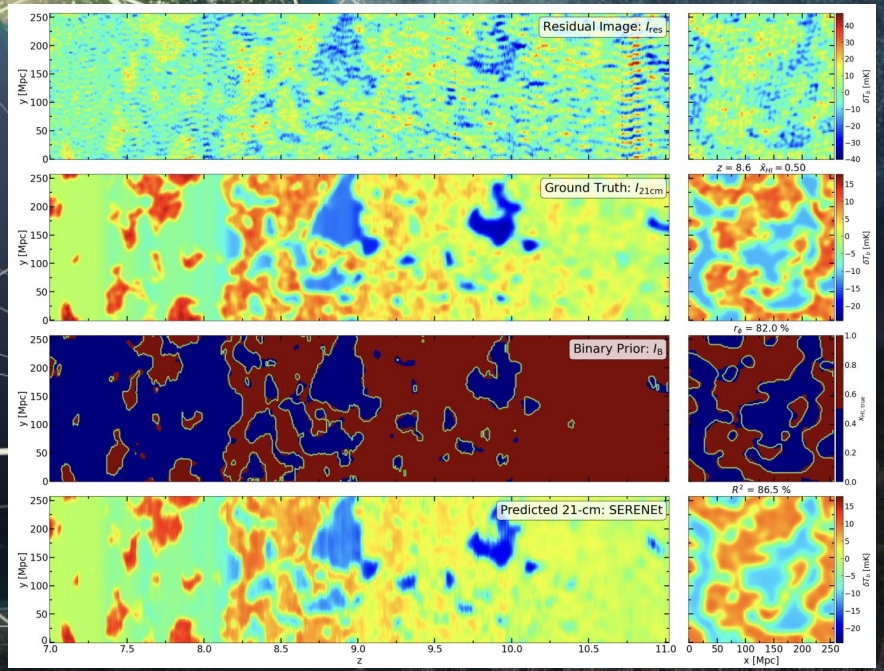
SDC2



Tolley+22

Participation in SDCs: SKA-LOW EOR instrumental observations to cosmological & astrophysical predictions





SDC3a+3b

Bianco+24

Swiss Science with SKA precursors

Mirka to present

Swiss participation in SKA-precursors

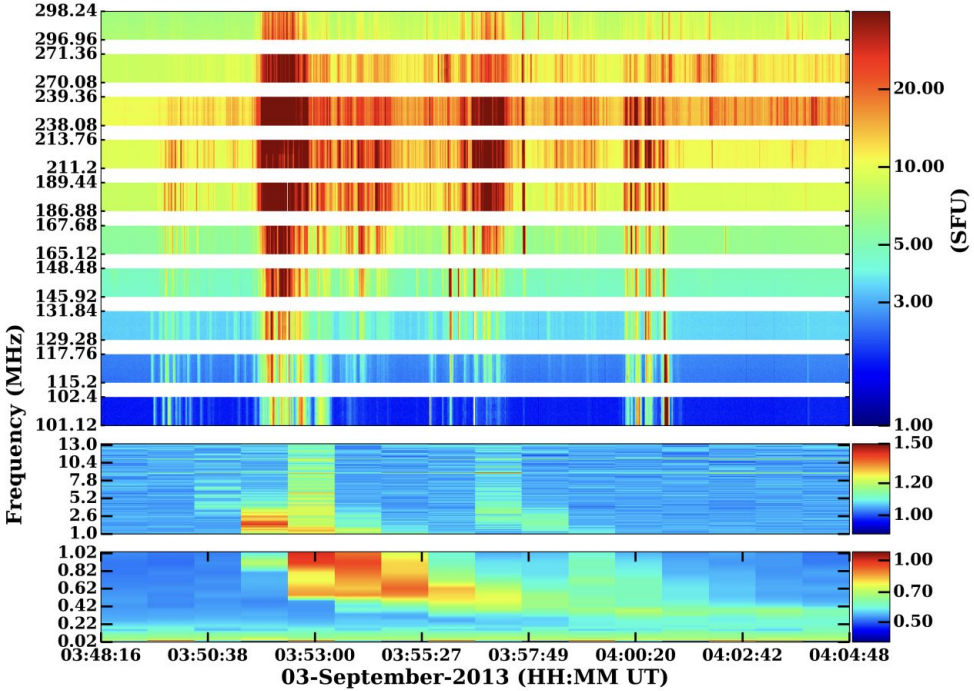
- **MWA** - Switzerland is a member since 2023
  - Solar observation
  - EOR
  - Pulsar detection (E. Tolley's talk)
  - Computing efficiency (E. Tolley's talk)

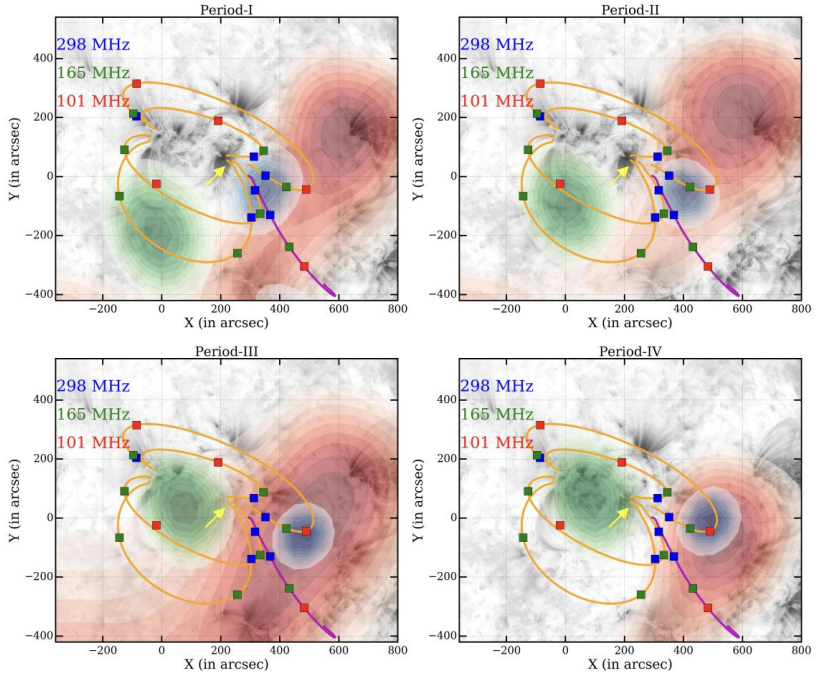
- **MeerKAT** through collaboration or PI programs
  - Participation in MeerKlass, MGCLS, …
  - PIs: M. Dessauges-Zavadsky, P. Jablonka
  - Computing/Imaging (E. Tolley's talk)

- **HIRAX** (see A. Refregier's presentation)
  - HI science
  - Correlator, SPC

Precursor science 1 - Solar physics with the MWA

Spatial association between a solar radio burst and an active region jet





Mulay, Sharma+22

Credit: R. Sharma (FHNW)

Precursor science 2 - Galaxy clusters with MeerKAT + AI

Develop AI methods to automatically detect & analyse these structures

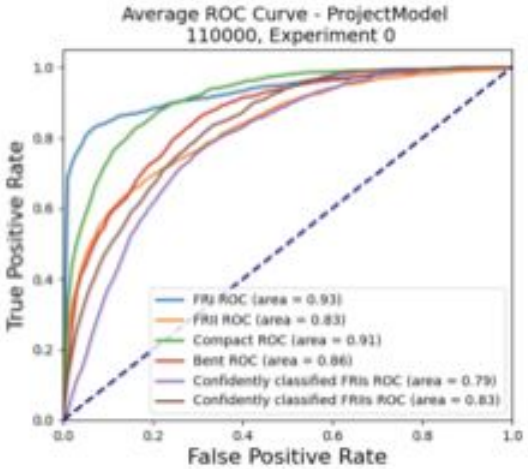
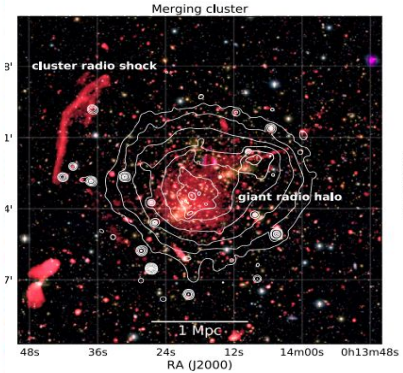


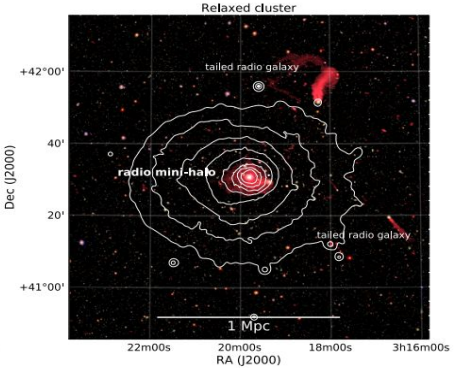
Figure by M. Bredberg (EPFL)

Credit: M. Bredberg/E. Tolley (EPFL)

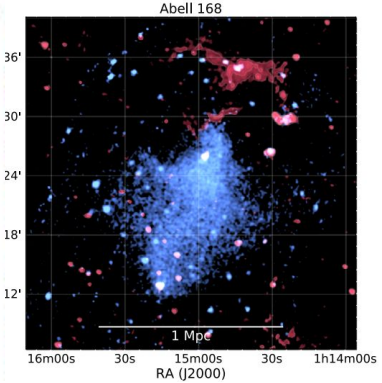
Radio halo



Mini-halo



Radio relic



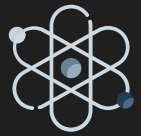
Credits: van Weeren+19; Gendron-Marsolais +17; GMRT 323 MHz and XMM-Newton 0.4–2.3 keV (Dwarakanath+18)

Precursor science 2 - Galaxy clusters with MeerKAT + AI

Scientific goals

Dynamics, demographics and evolution of clusters

Cluster magnetic fields



Particle acceleration

Technical goals

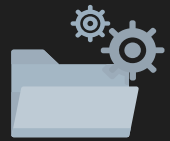
Independent cluster detection

Classify cluster radio emission

Visibility-independent

Handle small, unlabelled datasets

Multi-modality

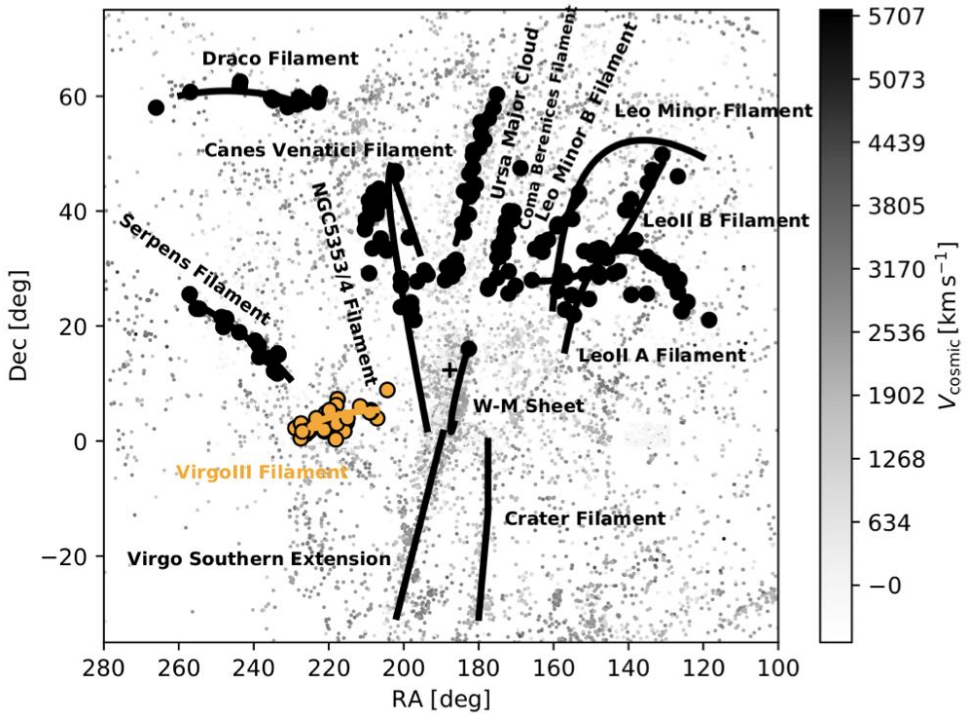


Generate unbiased samples

Credit: M. Bredberg/E. Tolley (EPFL)

Precursor science 3 - Galaxies in Clusters with MeerKAT

High spatial resolution view of the gas



Looking for evidence of:

- shocks due to ram-pressure, tidal interactions, and subsequent perturbations, as well as asymmetries in the main bodies of the galaxies. (HR - 9 arcsec beam)
- tails due to gas swept out by the filament or intra-group hot wind, or tidal tails in the outskirts of galaxies.

includes 1.4 GHz radio continuum star formation rate

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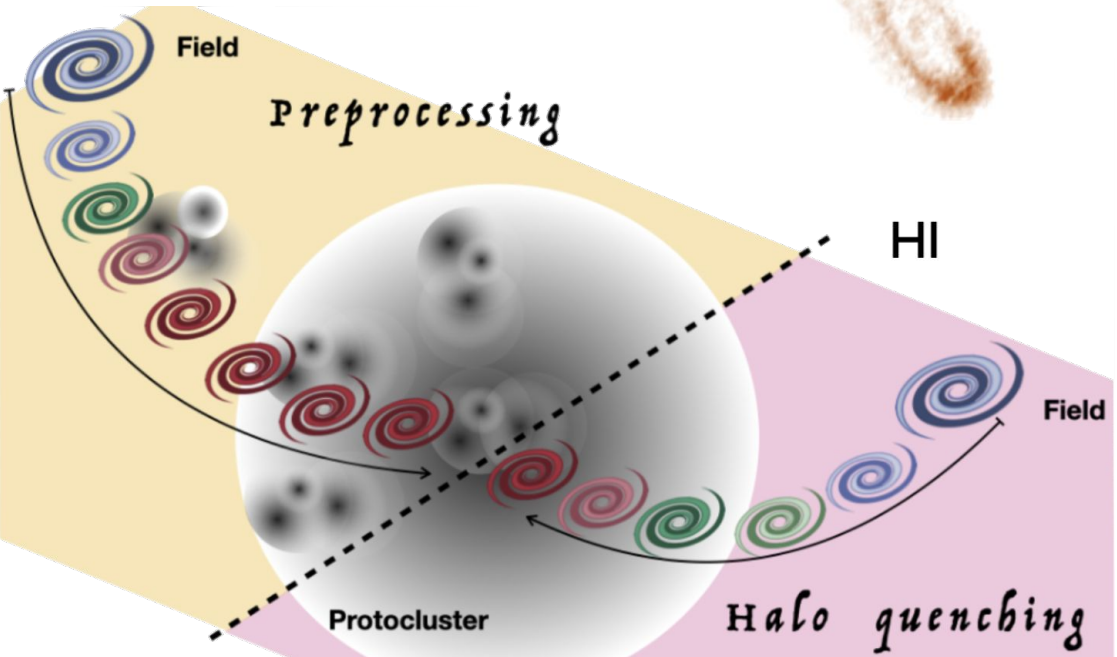
expectation: ≳ N_{HI} ~ 2 x10^{20} atoms/cm^2

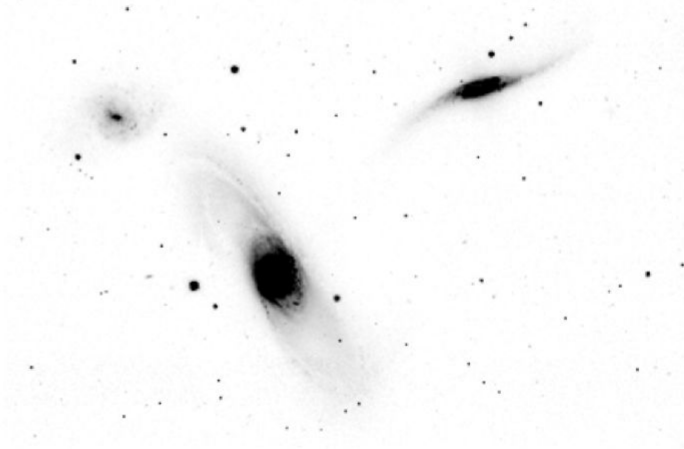
5 hours @ 3σ with 9arcsec (~0.9 kpc) 22km/s line width, 0.22mJy/bm
Smoothing the data to ~90 arcsec (9 kpc) …. N_{HI} ~ 1 x10^{18} atoms/cm^2

Credit: P. Jablonka (EPFL)

Precursor science 3 - Galaxies in Clusters with MeerKAT



HI



g-band

Credit: P. Jablonka (EPFL)

Precursor science 4 - Evolution of galaxy HI content with MeerKAT

Context

- Until 2020 only **estimates of HI column densities measured in absorption** (through the damped Lyman-alpha line) along lines-of-sight of luminous quasars and gamma-ray bursts **are available at z>0.4**.
- **HI mass measurements of individual galaxies *via the 21cm emission line*** are still **very challenging at z>0** with current radio facilities because of the line faintness.
- Recently, independent teams developed **stacking techniques of the HI 21cm signal of thousands of galaxies** to measure the HI mass based on 2 main surveys.

MIGHTEE-HI survey with MeerKAT

Field : COSMOS
galaxies : 9'023
Redshift range : **0.23<z<0.49** / <z>=0.37
Integration time : 16 h
Frequency range (L-band) : 950-1050 MHz
References : Maddox+21; Heywood+22,24
HI stacking : Sinigaglia+22,24

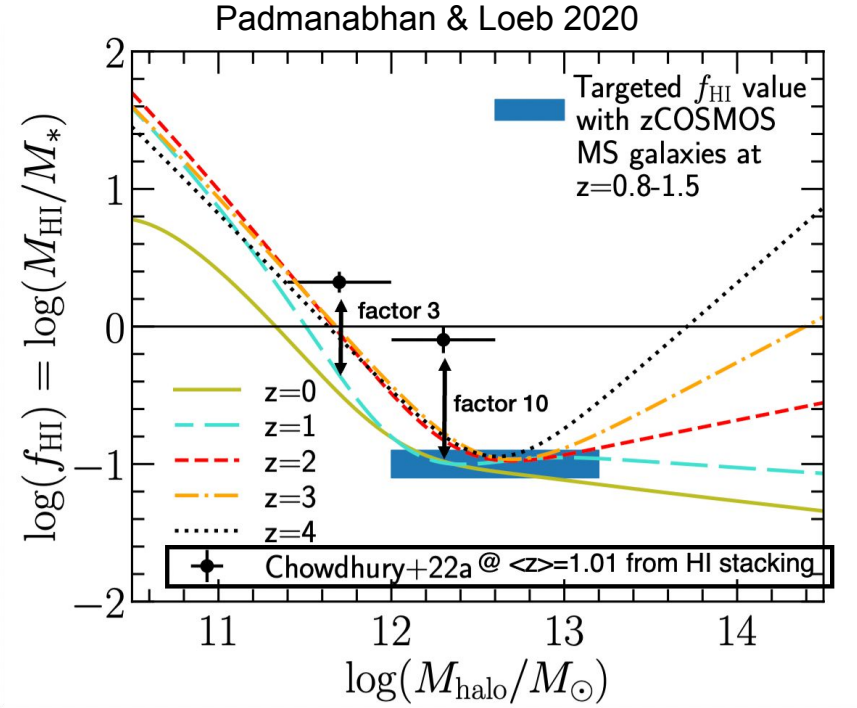
CATz1 survey with GMRT

Field : DEEP2
galaxies : 11'419
Redshift range : **0.74<z<1.45** / <z>=1.01
Integration time : 510 h
Frequency range : 550-850 MHz
References : Chowdhury+20,22b
HI stacking : Chowdhury+20,21,22abcd

Credit: M. Dessauges-Zavadsky (UniGE)

Precursor science 4 - Evolution of galaxy HI content with MeerKAT

CATz1 HI stacking results in tension with the cosmological halo mass model.



- Predicting the evolution of the HI fraction (f_{HI}) with halo mass over z=0–4 that is **a factor of ~3–10 smaller than f_{HI} at <z>=1.01 measured from HI stacking**.

Credit: M. Dessauges-Zavadsky (UniGE)

Precursor science 4 - Evolution of galaxy HI content with MeerKAT

Goal — Obtain a consensus in our understanding of the baryonic cycle between observations and model predictions.

Need of an <u>independent</u> 21 cm HI mass measurement from HI stacking at z~1 !

Uband COSMOS-HI survey with MeerKAT

Field : 2 deg^2 COSMOS
galaxies : 2'514
ALMA detections (A^{3}COSMOS) : 74
Redshift range : **0.8<z<1.5** / <z>=1
galaxies : 6'000
Redshift range : **0.4<z<0.8** / <z>=0.6
Integration time : 110 h (89 h on-source)
Frequency range (U-band) : 544-1088 MHz
PI : M. Dessauges-Zavadsky

Expected sensitivities :

—HI line sensitivity of 36 uJy/beam (100 km/s channel)

—Thermal RMS noise of 1.2 uJy/beam in the continuum (confusion noise of 3.1 uJy/beam)

2–3x deeper than MIGHTEE-HI and CATz1

- Proposal ***submitted*** for the MeerKAT Open Call in May 2023.
- Proposal ***accepted*** in August 2023.
- Observations ***started*** in June 2024.
- Observations ***ended*** in November 2024.

110 hours of observing time sub-divided in 21 Observing Blocks (OBs) [32K channels]:

105 TB (tar/zip) to be downloaded

The complete transfer completed this week!!!

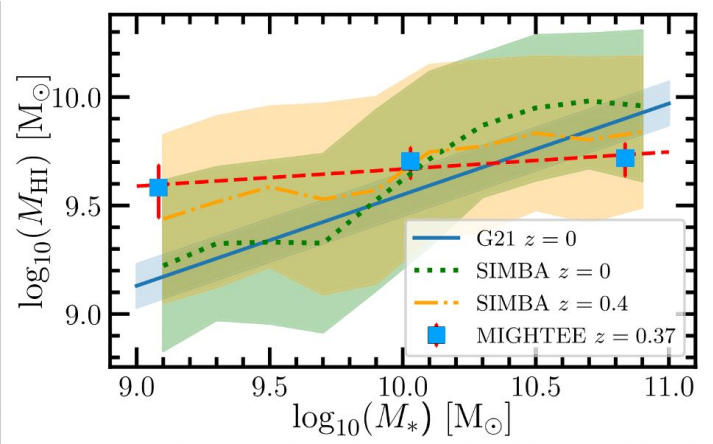
Credit: M. Dessauges-Zavadsky (UniGE)

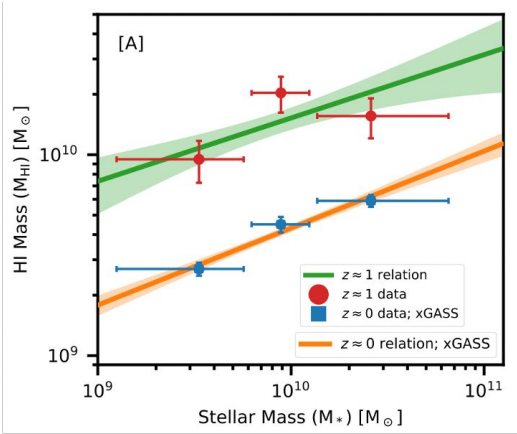
Summary

- Swiss Interest centered on Cosmology/Extragalactic
  - Synergy with spectroscopic redshift surveys (DESI, 4MOST), and gravitational lensing (Euclid)
  - Strong simulation group *(see SPH-EXA talk)*
- Involvement in precursors (MWA, MeerKat, HIRAX)
- Strong participation in SKA Data Challenges
- Strong involvement in Data Science *(see following presentations)*
- *Science preparation for MID-Band 6*

Precursor science 4 - Evolution of galaxy HI content with MeerKAT

PI: M. Dessauges-Zavadsky / CoIs: D. Schaerer, O. Bait, M. Sargent, H. Padmanabhan





MIGHTEE-HI survey with MeerKAT

Field : COSMOS
galaxies : 9'023
Redshift range : **0.23<z<0.49** / <z>=0.37
Integration time : 16 h
Frequency range (L-band) : 950-1050 MHz
References : Maddox+21; Heywood+22,24
HI stacking : Sinigaglia+22,24

CATz1 survey with GMRT

Field : DEEP2
galaxies : 11'419
Redshift range : **0.74<z<1.45** / <z>=1.01
Integration time : 510 h
Frequency range : 550-850 MHz
References : Chowdhury+20,22b
HI stacking : Chowdhury+20,21,22abcd

Precursor science 4 - Evolution of galaxy HI content with MeerKAT

PI: M. Dessauges-Zavadsky / CoIs: D. Schaerer, O. Bait, M. Sargent, H. Padmanabhan

Objectives of the program:

I. Detect **the model-predicted f_{HI}** by stacking 2'514 galaxies.

II. **Detect HI from the stack of 74 ALMA-detected galaxies** and *get the first complete HI+H2 census for the same galaxy sample* in case the GMRT HI detection at z=1 is correct.

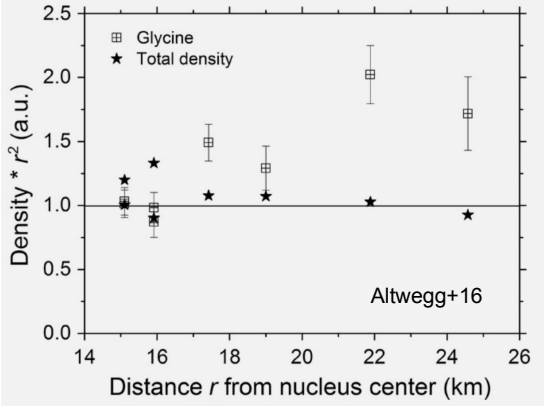
III. **Detect HI at <z>=0.6 by stacking 6'000 galaxies** yielding *the first observational constraint of the HI mass evolution* from low redshift (MIGHTEE-HI) to cosmic noon (this Uband program) in the same COSMOS field.

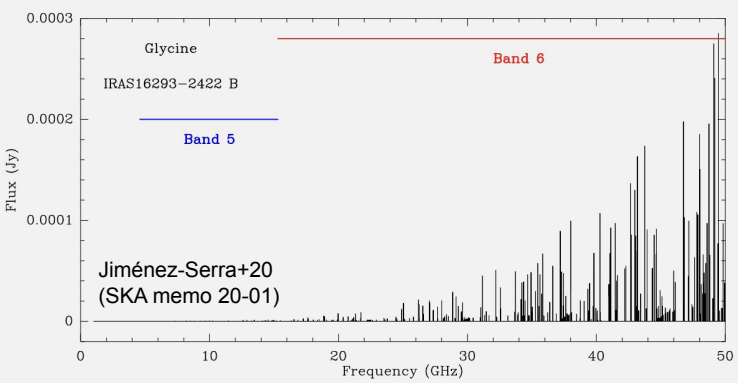
IV. Possible HI detections of **individual most gas-rich galaxies** at 0.4<z<1.5.

V. Expected **radio continuum detections for ~10K individual galaxies** allowing to trace *the 800 MHz continuum luminosity function evolution*.

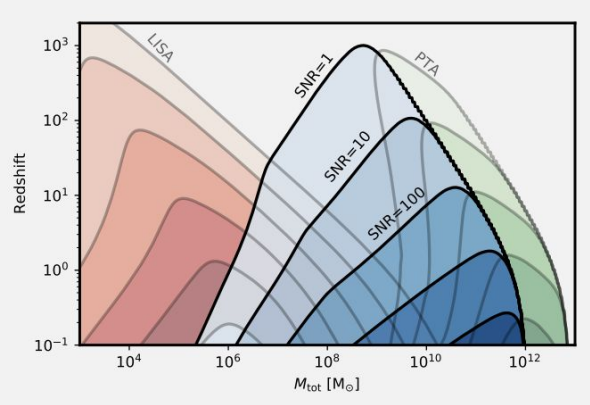
Future high-frequency science: MID-Band 6

Amino acids in space:





Gravitational wave science via Ka-band deep space ranging to an Uranus mission:



Zwick+24

Draft talk outline of topics - main ideas

- breadth of SKA science: overview of SKA SWG membership distribution [*would you have such a slide based on the community surveys you conducted, Mirka?*]

- map of CH with SKACH institutions listed, plus their main science foci

- on-going observational work:
  . galaxy clusters (Emma)
  . MeerKAT surveys of intermediate-z galaxy HI content (Mirka, Francesco), etc. (can be a couple of slides, one of of them (or a third) can add a mention here of the HI simulations work (Jindra, Robert) of HI asymmetries in galaxies as a tracer of galaxy formation processes and SF recipes)
  . MWA [*which project could we highlight here? Pulsar work - see, e.g., presentation at the Jan. consortium meeting in Bern?; or work on BIPP algorithm presented by Emma and January meeting*]

- deep continuum surveys:
  . observational calibration, and theoretical understanding of radio emission as an SFR tracer (Jennifer, Mark)
  . ESO-SKA synergies (based on recent ESO Messenger paper(s) and highlight Swiss involvement in large spectro surveys)

- spectroscopic surveys for cosmology

- synergistic astro+computing science highlights

- Swiss participation in science data challenges (HI challenge in 2021, plus EoR challenges)

- EoR research (Michele, many others), EoR galaxies (esp. UniGE - see radio SED studies of high-z analogues on prev. page; some reference to ALMA studies at high-z @ UniGE)

- high-frequency science interests (e.g., contributions to white paper SKA memo 20-01) - link with MID-Band 6 development work

Draft topic ideas

- SWG membership (see stats in Mirka's and Devin's surveys presented at previous SKACH meetings)

- SKA science data challenges (Swiss involvement in SDC2 & SDC3)

- science topics:

. on-going observational work: galaxy clusters (Emma), MeerKAT surveys of intermediate-z galaxy HI content (Mirka, Francesco), etc.

. simulations: HI asymmetries in galaxies as a tracer of galaxy formation processes and SF recipes (Jindra, Robert)

. gravitational waves WG (Lucio)

. mm/ALMA surveys of distant galaxies (Mirka, Mark); of IRX-beta relations at high-z (Pascal)

. radio SFR calibration (Mark, Jennifer S.); can be combined with a teaser of high-res continuum fields - see next page

. radio SEDs of early-Universe analogues (Omkar, Daniel)

Draft topic ideas

- science topics (cont'd):

. resolved imaging/galaxy continuum surveys (Mark)

. ESO-SKA synergies (Mark)

. HIRAX, (Tianlai?)

. MWA

. EoR simulations (Michele, many others), EoR galaxies (esp. Geneva - see radio SED studies of high-z analogues on prev. page)

. spectroscopic surveys for cosmology (can be combined with brief mention of HI simulation work - see previous page)

. strong lensing survey in radio - joint Euclid/SKA approach + VLBI follow-up (point out the limited SKA performance because of lack of long baselines in AA*)

. cradle of life science (astrobiology - Susanne; Galactic star formation - Marc)

. high-frequency science interests (e.g., contributions to white paper *SKA memo 20-01*) - link with MID-Band 6 development work

Draft topic ideas

- Also we should add stuff from D+Cosmos/Astrosignal approach of astro+computing science - this is very relevant stuff