Science with WEAVE

S.C. Trager and the WEAVE Science Team

Currently 114 members of the Science Team...

...and we're always happy to include more!

send email to me & alfonso

university of groningen
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The WEAVE Primary Science Surveys

- These three surveys are the “design reference surveys” driving the requirements for the WEAVE design:
  - Galactic Archaeology
  - Galaxy Evolution
  - Cosmology
- Note that these are the same cases desired by the ASTRONET Wide-Field Spectroscopy report

Galactic archaeology

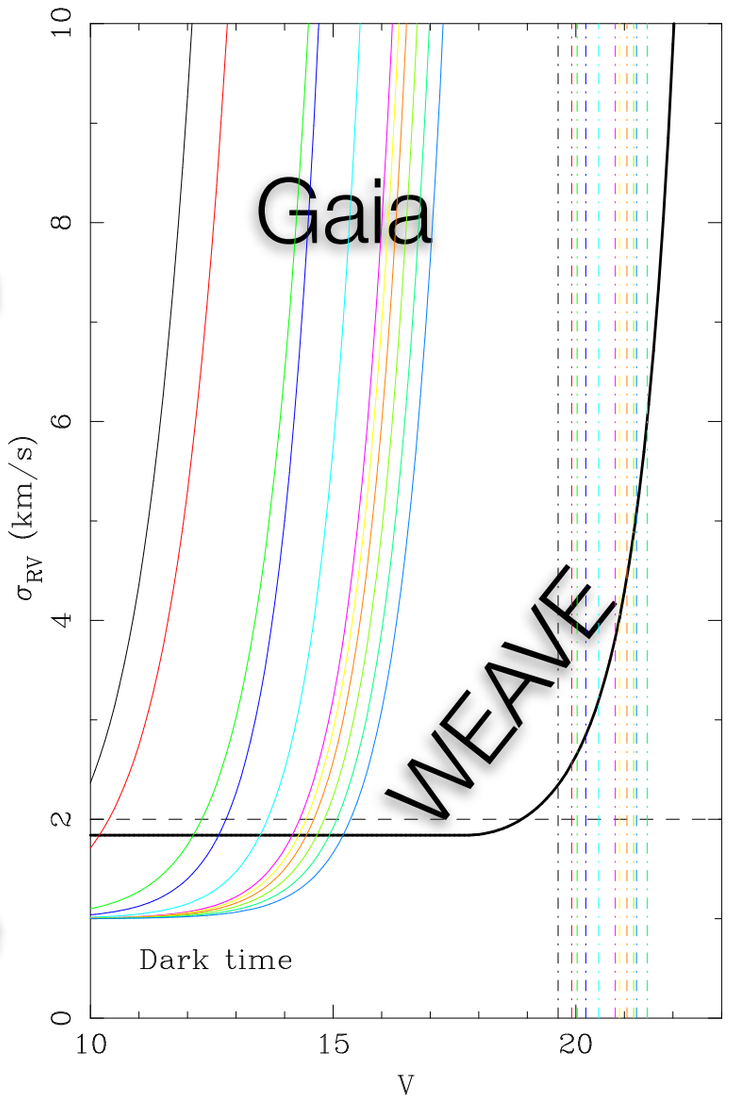
- The Galactic halo
- Dynamics of the Galactic disks
- Chemical labeling
- Open clusters

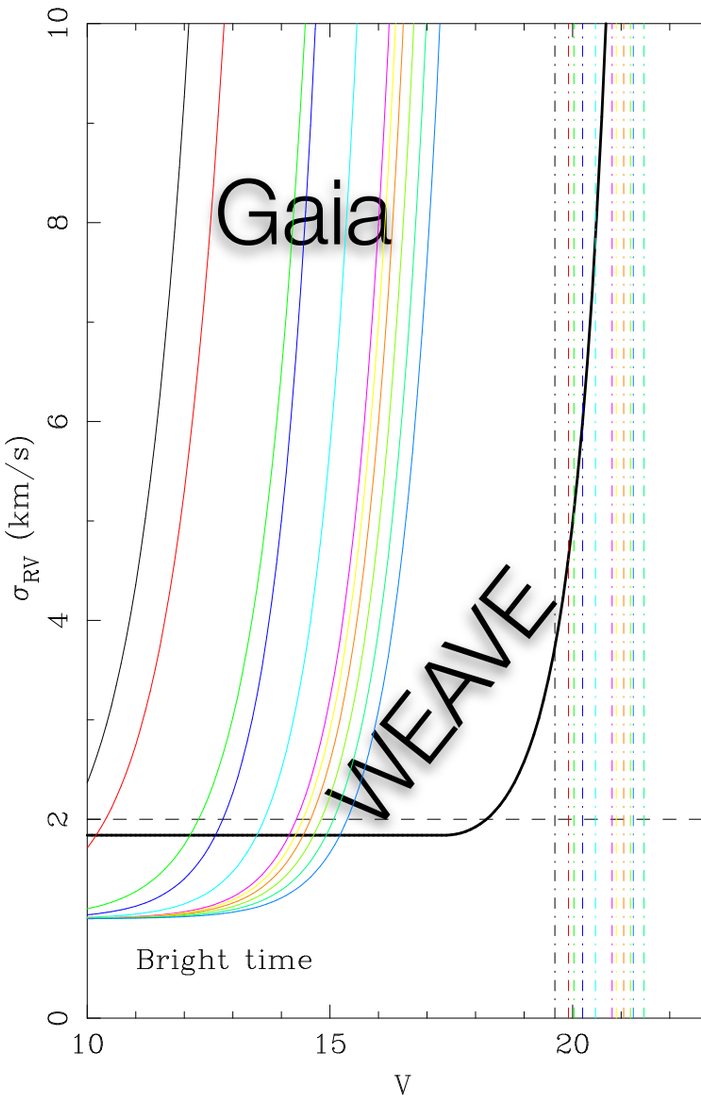
WEAVE at R=5000

Elemental abundances to ~0.2 dex (and [Fe/H]~0.1) possible from R=5000 spectra

- WEAVE will measure radial velocities to $\sigma(v_r)<3$ km/s at V=20 in 1hr of dark time (V=19 in bright time), *closely matching the Gaia photometric limits*

- WEAVE will be able to determine the radial velocities of *any* of the ~10^9 Gaia stars that RVS won't!





Halo survey goals

- How much of the MW's stellar halo was formed in-situ and how much was accreted?
- What is the total mass of the MW out to 200 kpc?
- What is the shape of the MW's potential out to 50-100 kpc?
- How lumpy is the MW's dark matter distribution within 20-50 kpc?
- Can we find extremely metal-poor stars?

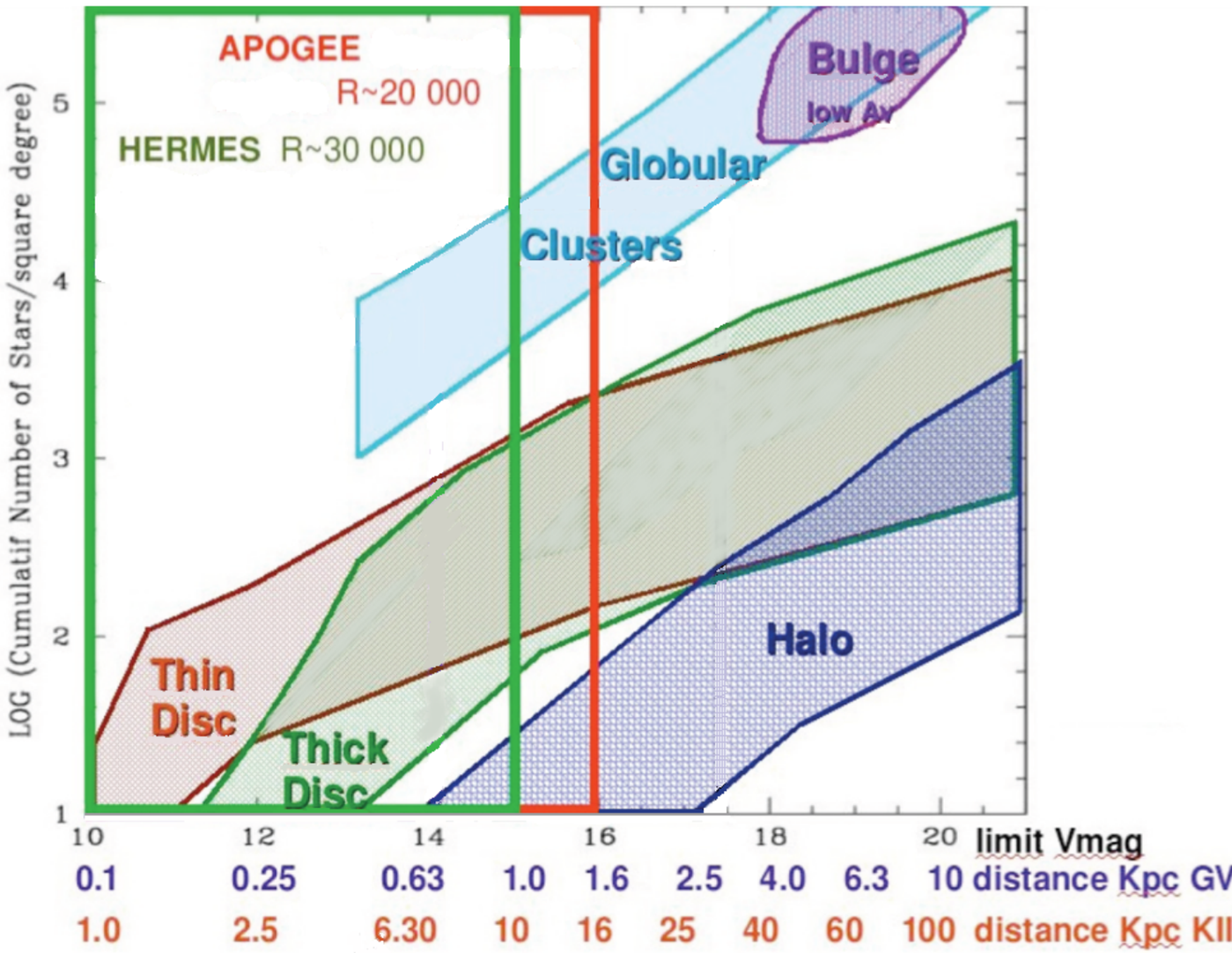
Disk survey goals

- What are the radial and vertical structures of the disks?
  - What are the length scales of the disks? What are the shapes of their potentials, including higher-order non-axisymmetric moments?
    - Need to do this at many locations in the disk, not just SNbhd
- What are the “moving groups”, and how are they formed? How do they relate to accretion events, evaporated open clusters, and other dynamical events?
- Is radial migration a major agent of the evolution of the disk(s)? Can we trace it chemodynamically?

WEAVE at R=20000

Can get >50% of lines at 4000Å, more in red and more at low metallicity

- Abundances to ~0.1 dex accuracy will allow us to chemically label stars
- WEAVE will reach V~17 in ~2 hours at S/N>80/ resolution element at R=20000



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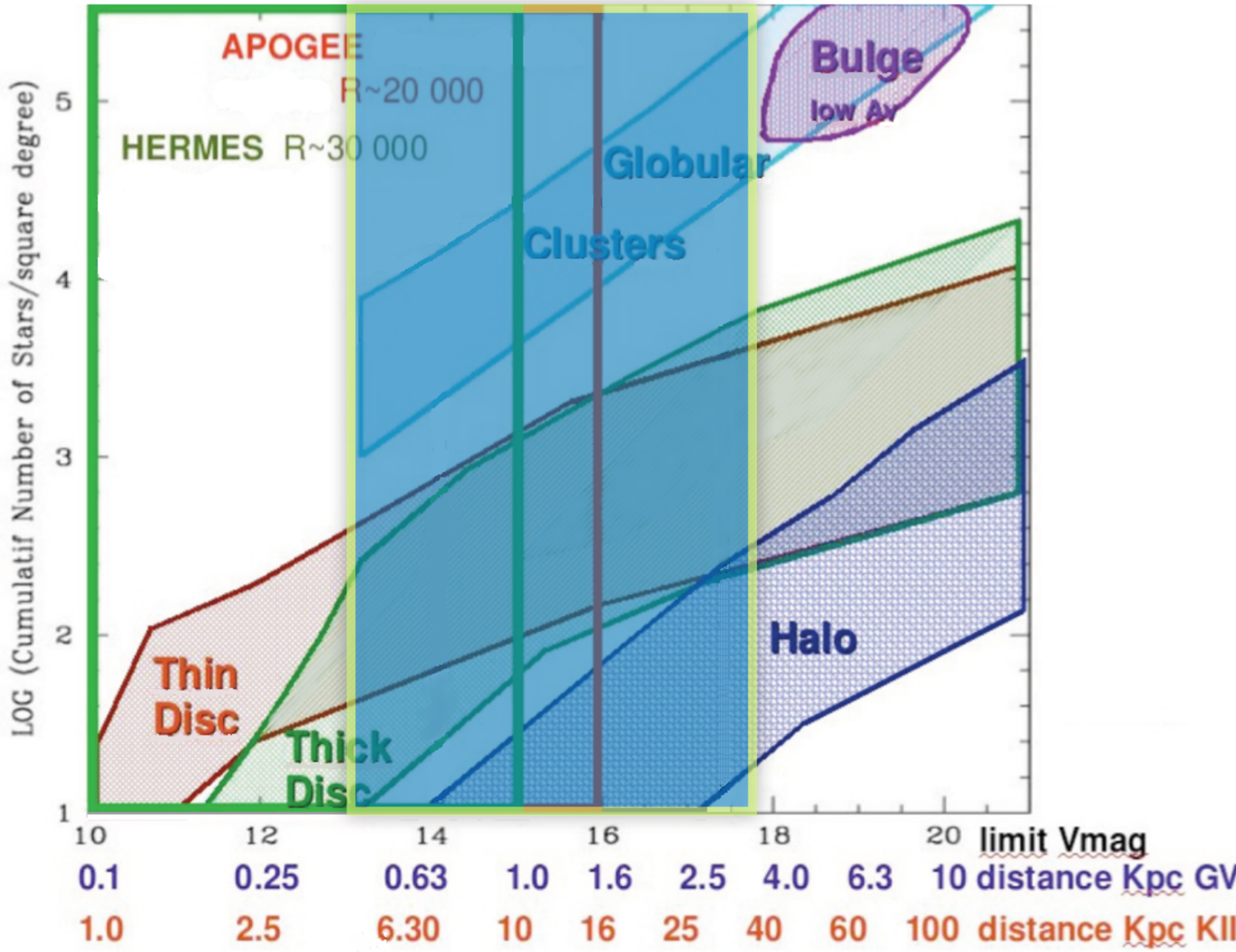

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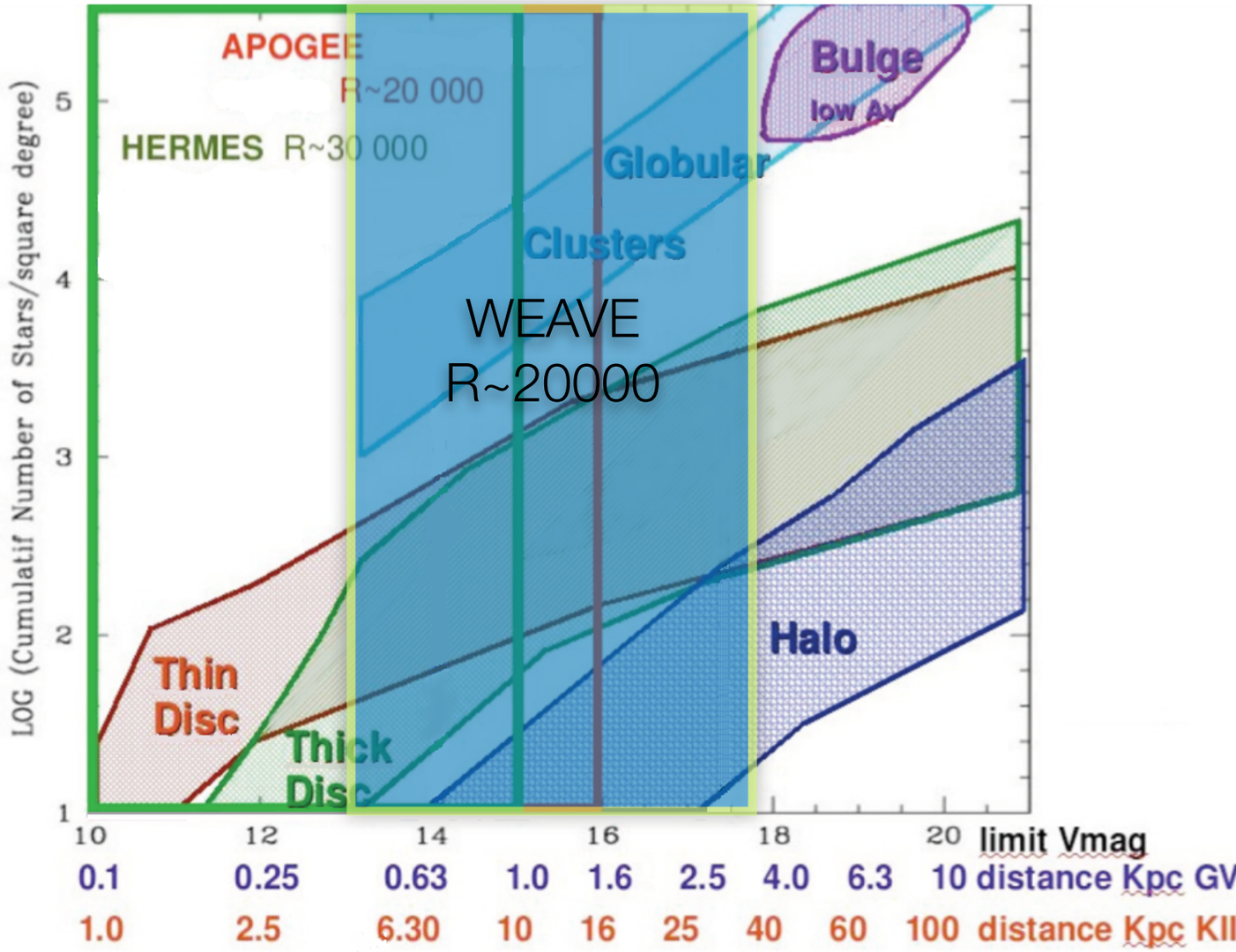


Chemical labeling goals

- Probing the assembly of the Galactic disks with chemical labeling and stellar ages
- Chemical labeling of streams, groups, and substructures
- Nucleosynthetic patterns in (extremely) metal-poor stars

Open cluster goals

- Do all stars form in clusters? How do clusters evolve? How do they disperse their stars to the field? What is the impact of radial migration on this process?
- Open clusters as tracers of MW disk star formation and chemical evolution
- How good are our stellar evolution models?

Galactic archaeology survey strategy

	log(N)	Area (deg^2)	R	Depth
Halo	6	1000	5000	V≤20
Disks	6.7	300	5000	V≤20
Chemical labeling	4.7 (disk) 5.7 (halo)	2000	20000	V≤17
Open clusters	4.7	150	20000	V≤17

Additional Galactic Archaeology science cases

- Hunting the rarest stellar phases
- Dating Galactic populations with white dwarfs
- Pulsating variable stars
- Massive (blue) stars in the MW and Local Group
- IMF of low-mass stars and sub-stellar objects
- Chemodynamics of MW dwarf satellites
- Ultra-faint dwarfs

Galaxy evolution

- WEAVE-Clusters
- WEAVE-Apertif
- WEAVE-LOFAR

WEAVE-Clusters

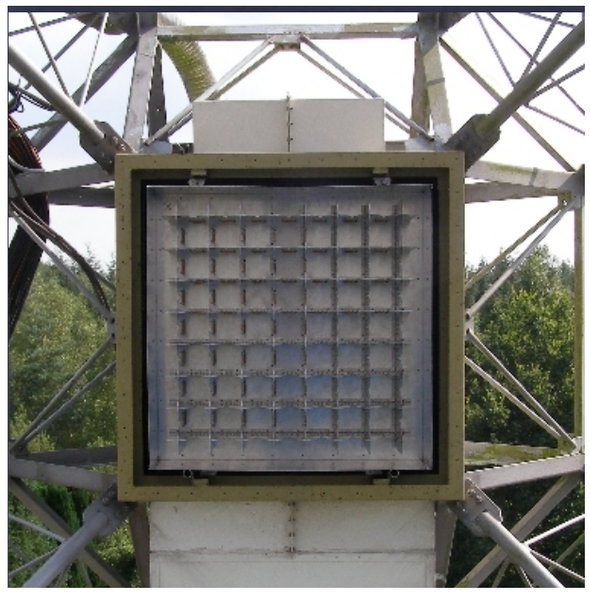
- What is the effect of environment on galaxy evolution?
  - as a function of mass: what is the impact on the scaling relations, kinematics, and stellar populations of dwarf galaxies?
  - as a function of local environment: what happens to galaxies in the infall regions of clusters?
  - as a function of lookback time: how do the kinematics and stellar populations of cluster galaxies evolve?

WEAVE-Clusters

- **Layer 1**: Tracing the evolution of dwarf galaxies in clusters
  - >10^4 cluster dwarfs at R=5000 down to M_r<-16 with MOS mode + 10^3 cluster dwarfs with **mIFUs** to derive *spatially-resolved properties*
- **Layer 2**: The infall regime
  - 10^4 galaxies in 10 large superstructures at z~0.1–0.2 at R=5000 to R<21 in **MOS** mode
- **Layer 3**: The evolution of cluster galaxies at z<0.5
  - 25 cluster cores with **LIFU** mode

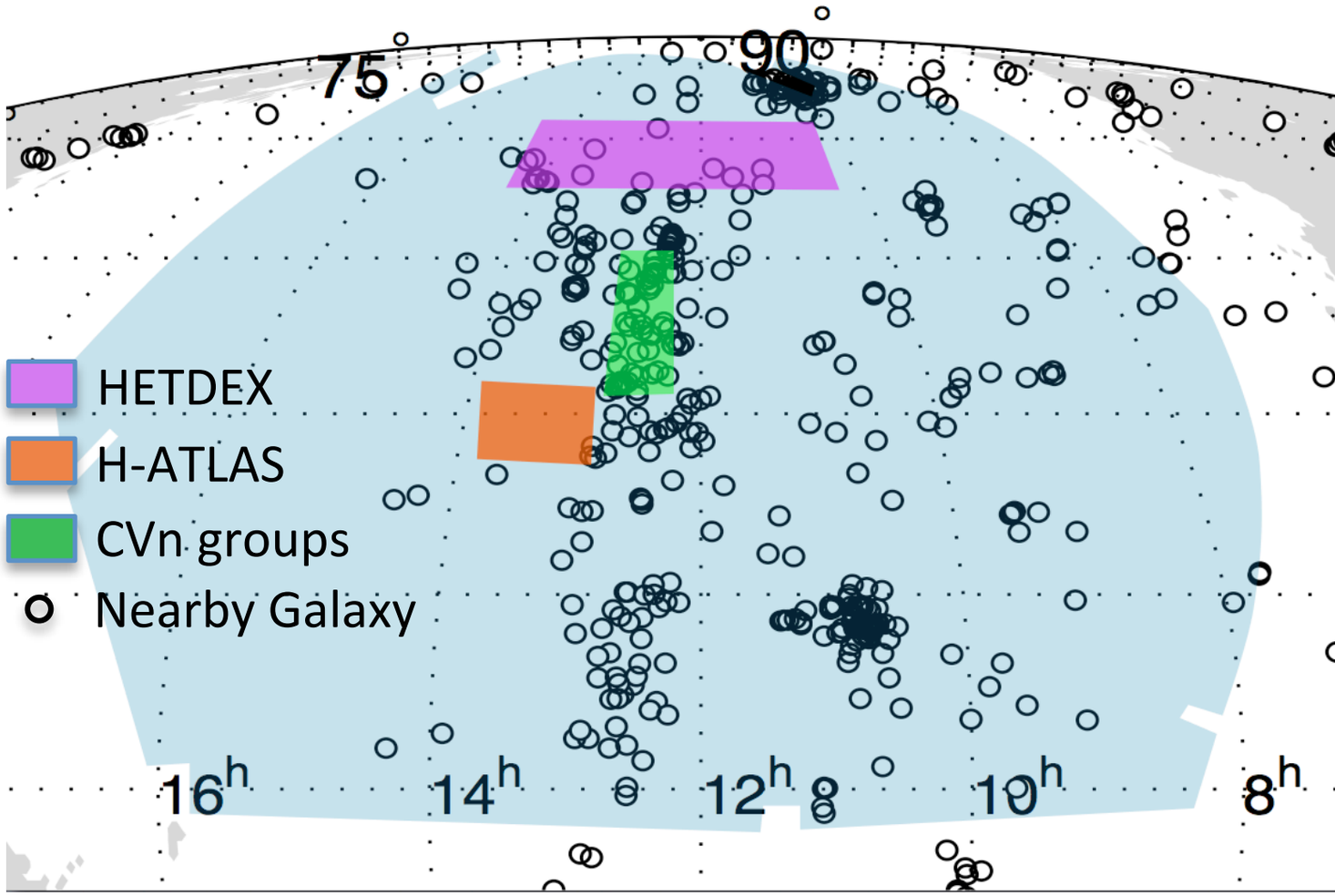
WEAVE-Apertif

- Apertif is the world's first working focal-plane array, capable of full Westerbork resolution (~15") over a single, full 8 deg^2 pointing in the frequency range 1000–1750 MHz with nearly the sensitivity of the present "single-pixel" WSRT front-ends



WEAVE-Apertif

- The APERTIF Medium-Deep Survey will survey 10^4 galaxies at $0.1<z<0.4$ over 500 deg^2 in the 21cm line of HI, while the shallow all-sky survey will survey 10^4 galaxies at $z<0.1$
  - *spatially-resolved* kinematics of the neutral gas



WEAVE-Apertif

- **Tier 1**: 10^4 galaxies, half over 10^4 deg^2, half over 500 deg^2 with **mIFU** at R=5000 to probe star-formation quenching and the fueling of the blue cloud
- **Tier 2**: 50 LSB galaxies with **LIFU** at R=10000 to determine masses of their dark and luminous matter using disk kinematics
- **Tier 3**: 10 nearby disk galaxies with **LIFU** to determine the impact of secular evolution on their gas and stars

WEAVE-LOFAR

- LOFAR is the world's largest low-frequency radio telescope array
- The LOFAR Surveys KSP will deliver ~10^7 continuum targets over ~10^4 deg^2 at 30, 60, 120, 200 MHz
- These will be *strongly* biased towards emission-line galaxies, especially *star-forming galaxies*

WEAVE-LOFAR

- WEAVE can obtain redshifts for ~10^7 emission-line galaxies detected by LOFAR at z<1.3 (OII) and z>2.3 (Ly**α**)
  - Radio continuum fluxes + redshifts = unbiased star-formation rates over large range of cosmic time!
- Spectra will often give metallicities and even stellar velocity dispersions: chemical evolution and stellar masses
- Black hole accretion mechanism can be determined for radio AGN: evolution of BH accretion rate and stellar-BH co-evolution

WEAVE-LOFAR

- A properly-selected sample of ~5x10^6 galaxies over 10^4 deg^2 is critical for effective follow-up of LOFAR
  - select by radio power and, when possible, by optical color
- Depths to V~21 are required (but S/N requirements not strict)

Additional Galaxy evolution science cases

- Extragalactic star clusters
- Stellar populations at intermediate redshifts
- Ultra-deep spectroscopy
- Dwarf galaxies in the local cosmological volume

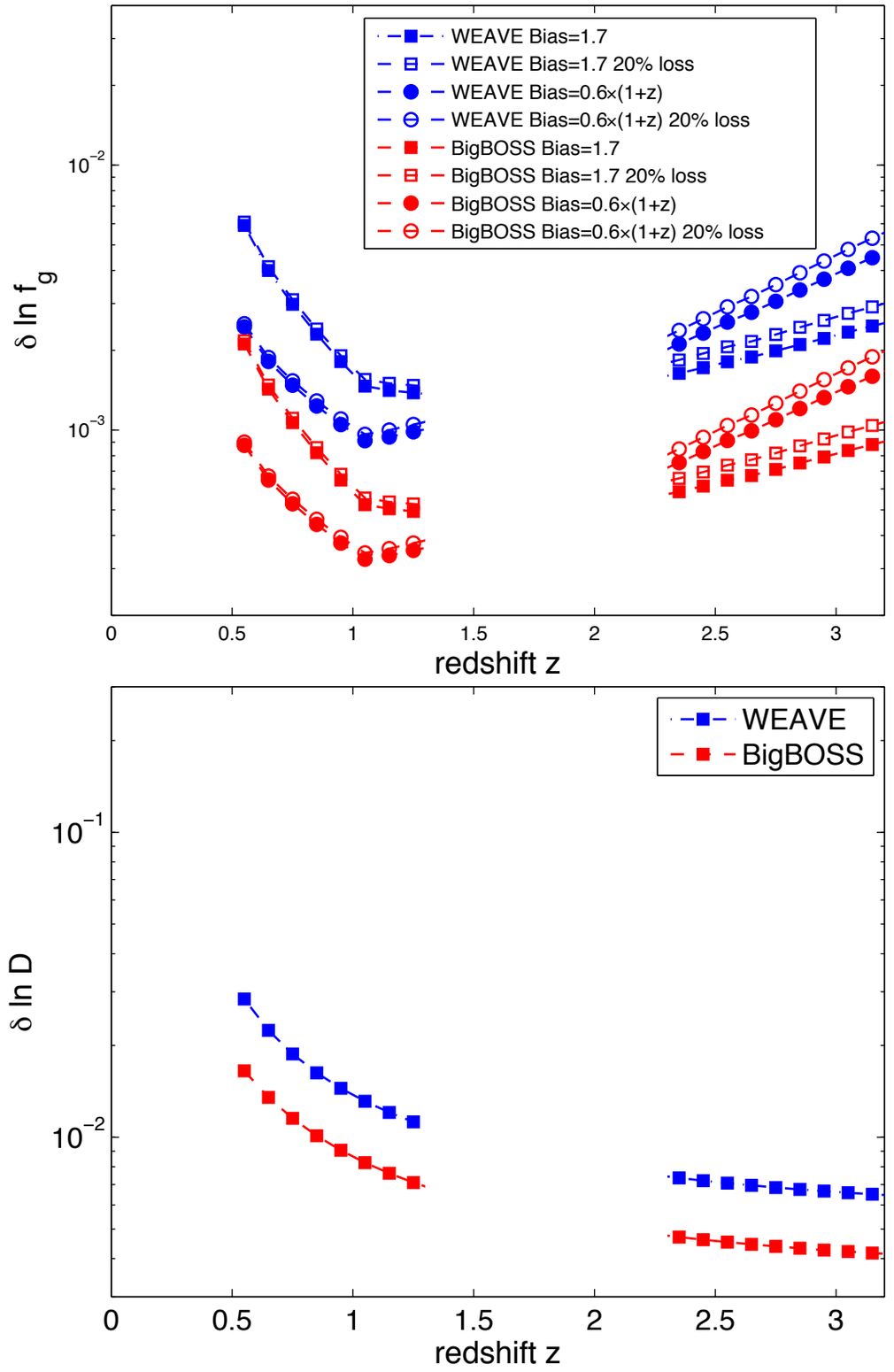
Cosmology

WEAVE-LOFAR as a BAO survey

- Given the expected efficiency of the WEAVE-LOFAR Survey in determining redshifts – emission-line redshifts are *much* easier to determine than absorption-line redshifts – we will have an exceptional *baryon acoustic oscillation* survey

BAO constraints

- Baryon acoustic oscillations (BAOs) provide a *standard ruler* for measuring the size of the Universe
- By comparing the BAO spectrum at different epochs, the expansion of the Universe can be measured
- WEAVE-LOFAR will fill the gap in BAO surveys between BOSS ($z<0.7$) and Euclid ($z>1.2$)



Redshift-space distortions

- Distortions in redshift space are caused by the imprint of infall velocities on the *apparent* clustering
  - This allows for measurement of the growth rate of cosmological structures
- The WEAVE-LOFAR survey is capable of setting constraints of ~0.3% on the derivative of the growth rate $dD/d\log a \propto f(z)\sigma_8(z, \mathrm{mass})$ and providing a direct test of gravity models

Additional Cosmology science cases

- Spectroscopic confirmation of J-PAS photometric redshifts
- Observations of Euclid strong lenses
- Dark energy with the Lyman-α Forest

What can you do for WEAVE?

- Contact us!
- sctrager@astro.rug.nl
- jalfonso@iac.es

And one more case: Transients

- WEAVE-Transients
  - WEAVE's IFU systems provide an excellent rapid *spectroscopic* follow-up mode
    - LIFU can be moved into beam in <2-3 minutes, when large survey areas (~3 arcmin^2) desired
    - mIFUs can be rapidly configured (<15 minutes) when higher spatial and spectral resolution desired

What will *you* get from the WEAVE surveys?

- Reduced, archived data!
- Searchable, easy-to-use databases with raw and reduced spectra and data cubes + derived parameters