The WST science drivers: transformational science in the 2040s

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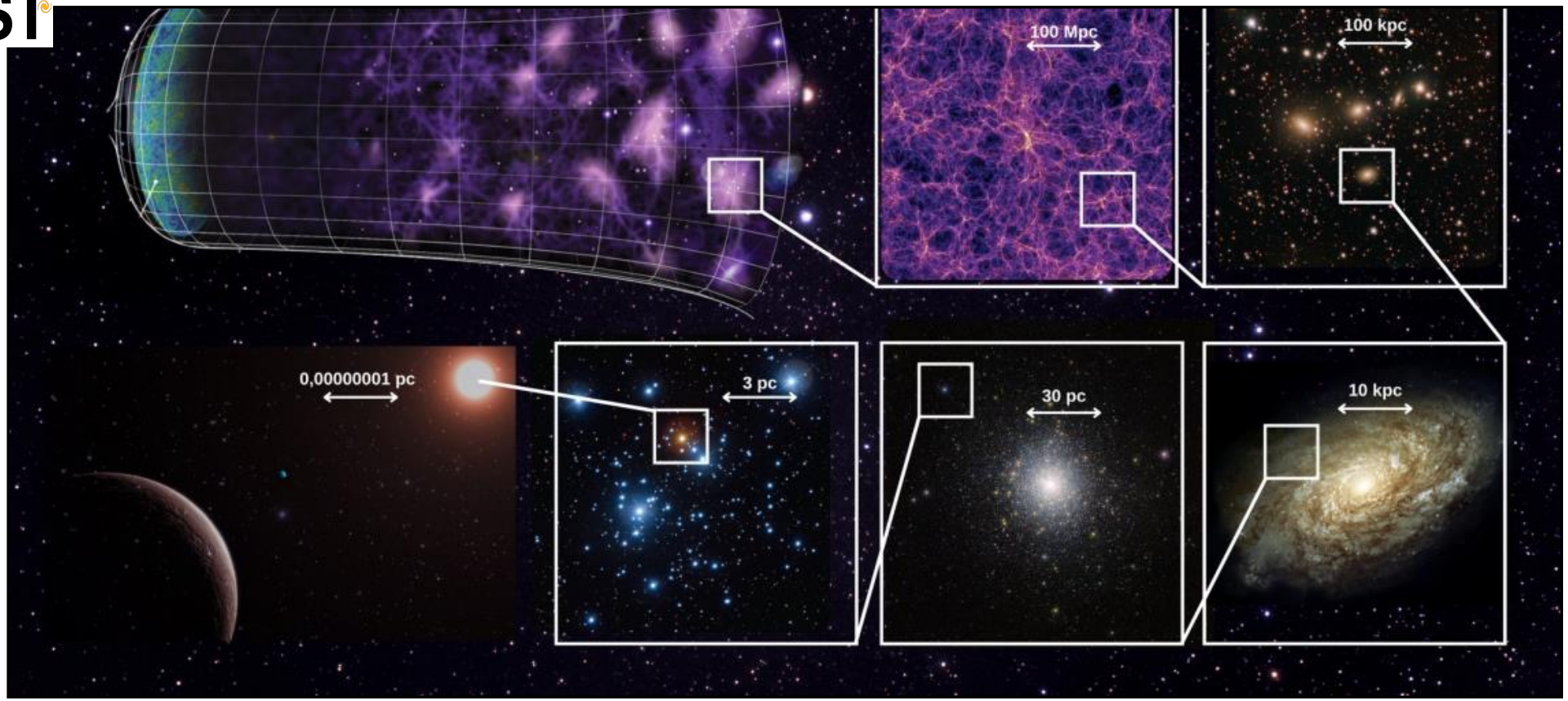


Credit to Rossella Spiga (INAF)

WST: a facility to answer a wide range of cutting-edge scientific questions that cannot be addressed with current or planned facilities

Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 8 Mar 2024]

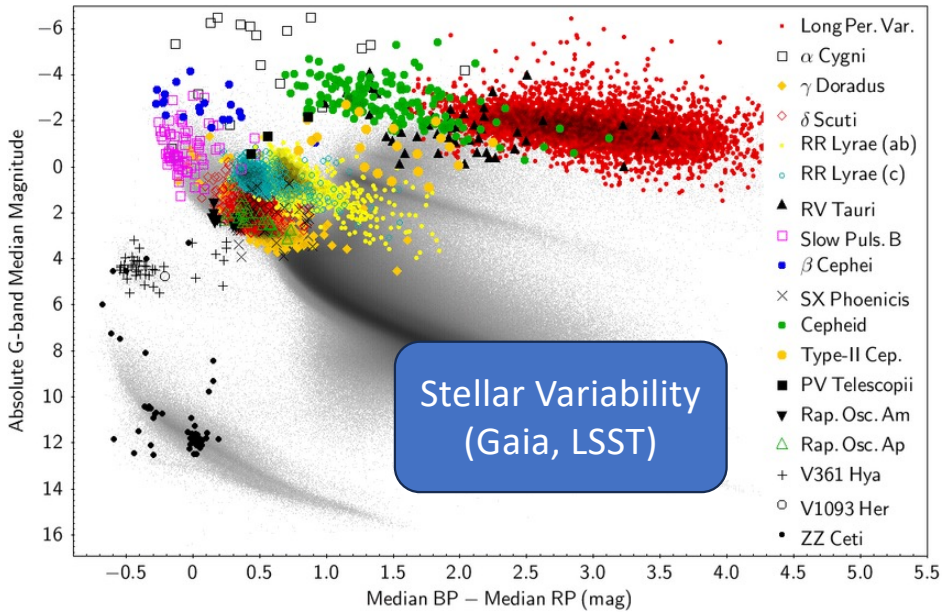
The Wide-field Spectroscopic Telescope (WST) Science White Paper

Vincenzo Mainieri, Richard I. Anderson, Jarle Brinchmann, Andrea Cimatti, Richard S. Ellis, Vanessa Hill, Jean-Paul Kneib, Anna F. McLeod, Cyrielle Opitom, Martin M. Roth, Paula Sanchez-Saez, Rodolfo Smilljanic, Eline Tolstoy, Roland Bacon, Sofia Randich, Angela Adamo, Francesca Annibali, Patricia Arevalo, Marc Audard, Stefania Barsanti, Giuseppina Battaglia, Amelia M. Bayo Aran, Francesco Belfiore, Michele Bellazzini, Emilio Bellini, Maria Teresa Beltran, Leda Berni, Simone Bianchi, Katia Biazzo, Sofia Bisero, Susanna Bisogni, Joss Bland-Hawthorn, Stephane Blondin, Julia Bodensteiner, Henri M.J. Boffin, Rosaria Bonito, Giuseppe Bono, Nicolas F. Bouche, Dominic Bowman, Vittorio F. Braga, Angela Bragaglia, Marica Branchesi, Anna Brucalassi, Julia J. Bryant, Ian Bryson, Innocenza Busa, Stefano Camera, Carmelita Carbone, Giada Casali, Mark Casali, Viviana Casasola, Norberto Castro, Marcio Catelan, Lorenzo Cavallo, Cristina Chiappini, Maria-Rosa Cioni, Matthew Colless, Laura Colzi, Sofia Contarini, Warrick Couch, Filippo D'Ammando, William d'Assignies D., Valentina D'Orazi, Ronaldo da Silva, Maria Giovanna Dainotti, Francesco Damiani, Camilla Danielski, Annalisa De Cia, Roelof S. de Jong, Suhail Dhawan, Philippe Dierickx, Simon P. Driver, Ulyana Dupletsa, Stephanie Escoffier, Ana Escorza, Michele Fabrizio, Giuliana Fiorentino, Adriano Fontana, Francesco Fontani, Daniel Forero Sanchez, Patrick Franois, Francisco Jose Galindo-Guil, Anna Rita Gallazzi, Daniele Galli, Miriam Garcia, Jorge Garcia-Rojas, Bianca Garilli, Robert Grand, Mario Giuseppe Guarcello, Nandini Hazra, Amina Helmi, Artemio Herrero, Daniela Iglesias, Dragana Ilic, Vid Irsic, Valentin D. Ivanov, Luca Izzo, Pascale Jablonka, Benjamin Joachimi, Darshan Kakkad et al. (117 additional authors not shown)

The Wide-field Spectroscopic Telescope (WST) is proposed as a new facility dedicated to the efficient delivery of spectroscopic surveys. This white paper summarises the initial concept as well as the corresponding science cases. WST will feature simultaneous operation of a large field-of-view (3 sq. degree), a high multiplex (20,000) multi-object spectrograph (MOS) and a giant 3x3 sq. arcmin integral field spectrograph (IFS). In scientific capability these requirements place WST far ahead of existing and planned facilities. Given the current investment in deep imaging surveys and noting the diagnostic power of spectroscopy, WST will fill a crucial gap in astronomical capability and work synergistically with future ground and space-based facilities. This white paper shows that WST can address outstanding scientific questions in the areas of cosmology; galaxy assembly, evolution, and enrichment, including our own Milky Way; origin of stars and planets; time domain and multi-messenger astrophysics. WST's uniquely rich dataset will deliver unforeseen discoveries in many of these areas. The WST Science Team (already including more than 500 scientists worldwide) is open to the all astronomical community. To register in the WST Science Team please visit this https URL

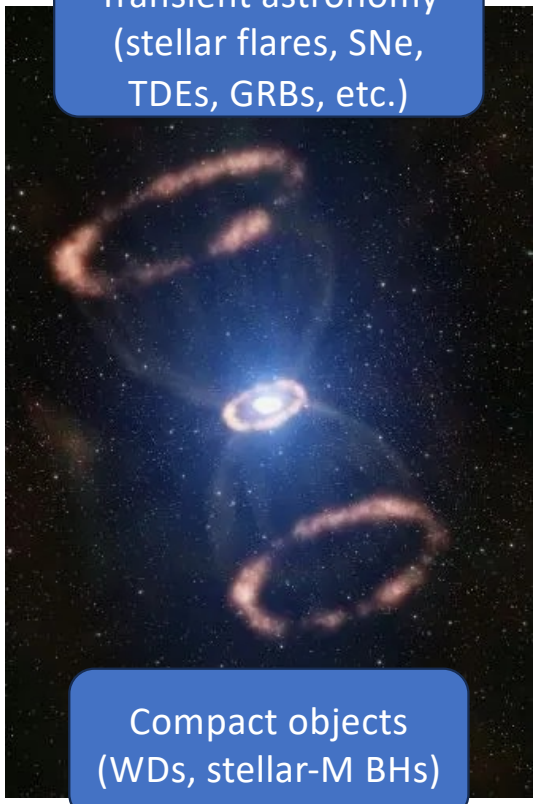
Time-domain: exciting science on all scales

Solar system objects & Exocomets



Stellar Variability (Gaia, LSST)

Transient astronomy (stellar flares, SNe, TDEs, GRBs, etc.)



Compact objects (WDs, stellar-M BHs)

Gravitational Wave Source Characterization, Calibration sources

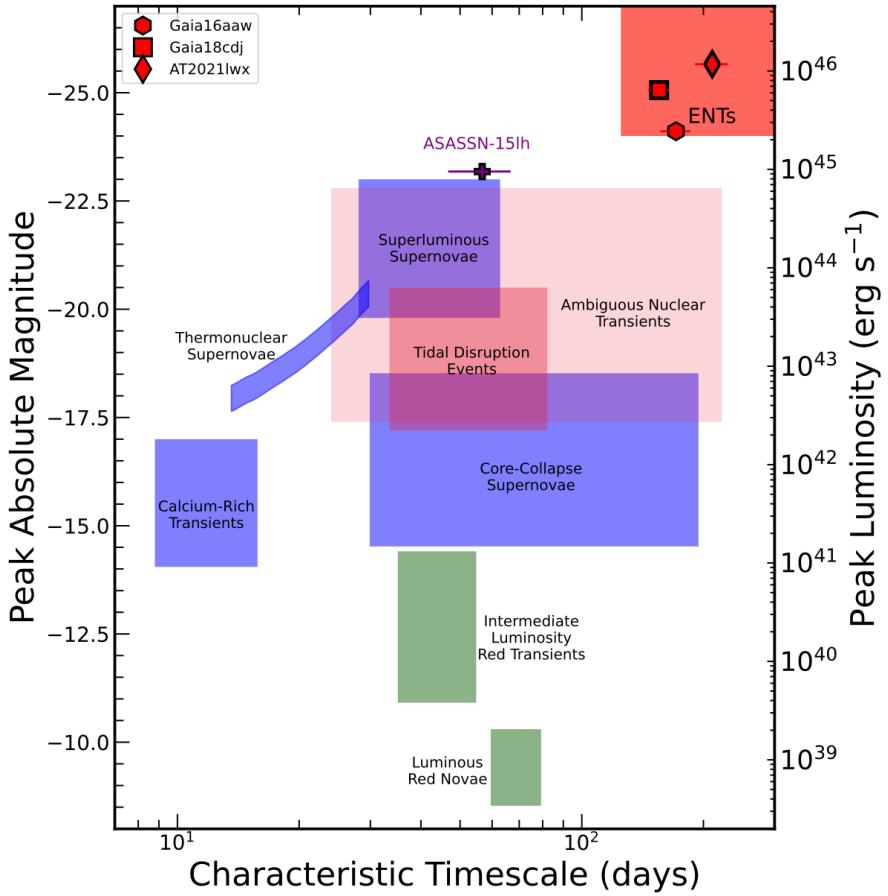
Supermassive BHs (AGN, QSOs)

Transients post LSST/Roman era

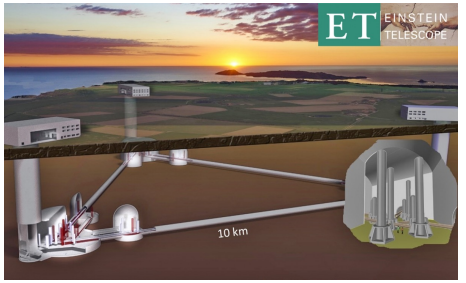
In the 2040s LSST will have discovered hundreds of thousands of transients. Our understanding of transient-related phenomena will be transformed. We will probably have even more questions than today.

Build time-domain capabilities
(e.g., Operational model, fast data processing)
in WST **to enable new science**

- **Fiber-level ToO**: large scale follow-up of transients with WST will be key to get a full picture of their nature.
- **Spectroscopic variability**: WST will issue alerts enabling the detection of new classes of transiets.

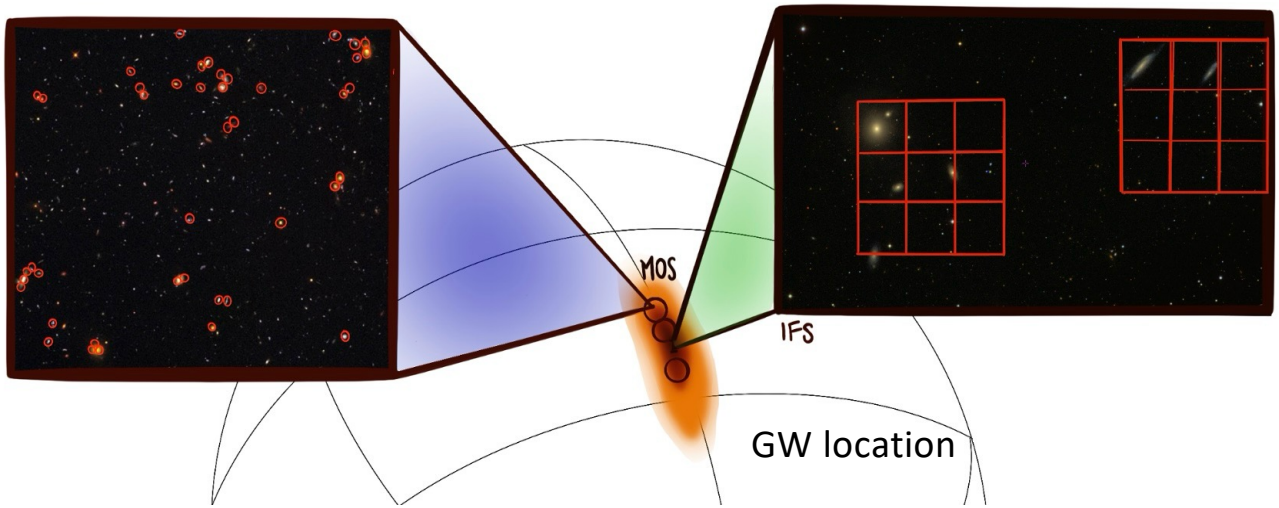


Detection and characterization of the EM of GW events from the next generation of detectors

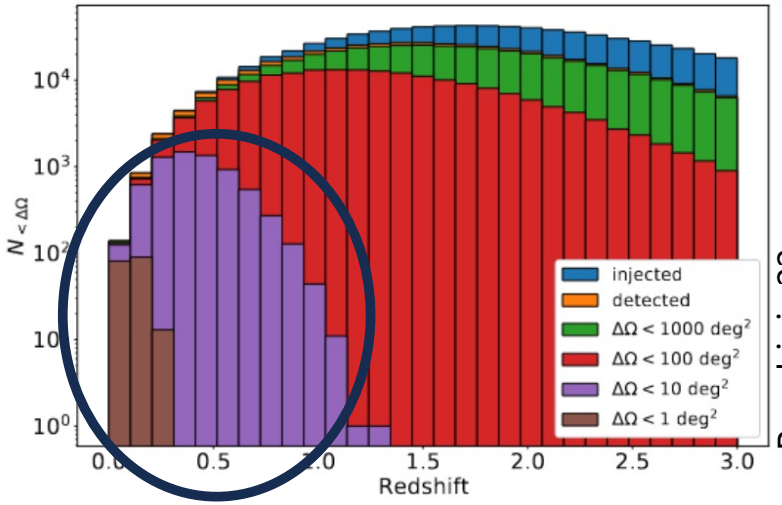


Einstein Telescope will detect 10^5 binary neutron stars mergers per year, also prior of the mergers during the in spiral phase.

WST spectroscopic identification and characterization of the EM counterparts will be crucial for kilonovae population studies and study of the extreme physics during the merger phase.

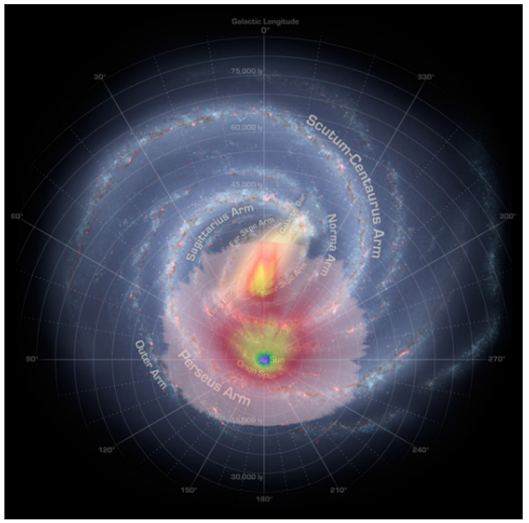


Credit to Sofia Bisero (GEPI)



Detections with ET+CE over 1 year with $\Delta\Omega<10$ deg^2

Galactic science cases



(X. Luri & the DPAC-CU2)

Three science themes:

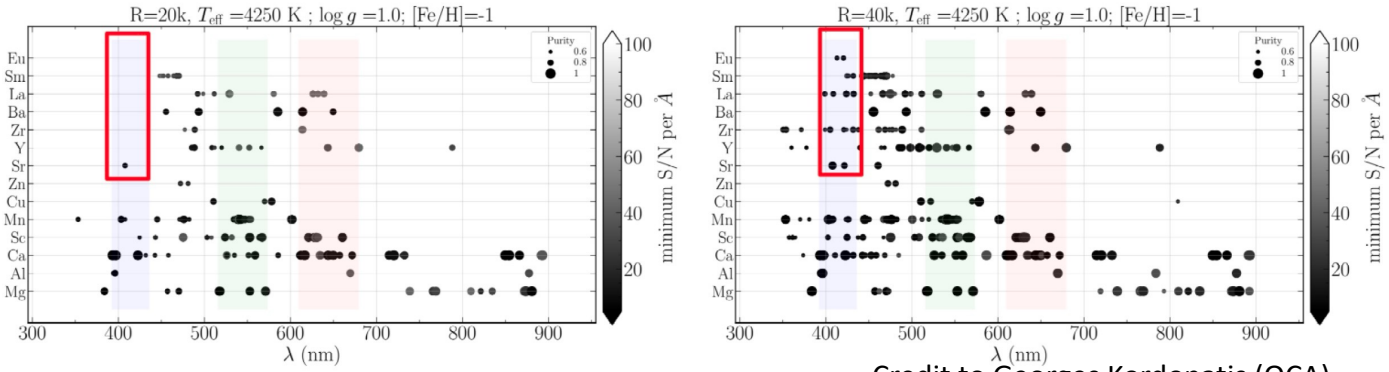
- **Origins of elements**
- **Origin of the Milky Way system**
- **Origin of stars and planets**

Science in the 2040s: Building upon Gaia+4MOST+MOONS+WEAVE

Origins of elements

- Neutron capture elements (r-process, i-process, other yet unknown channels?)
- Type Ia supernovae: how many sub-types? How many of them important as nucleosynthetic sources?

- HR needed to probe diverse nucleosynthetic channels
- Not only reaching fainter targets, but adding new key and precise information

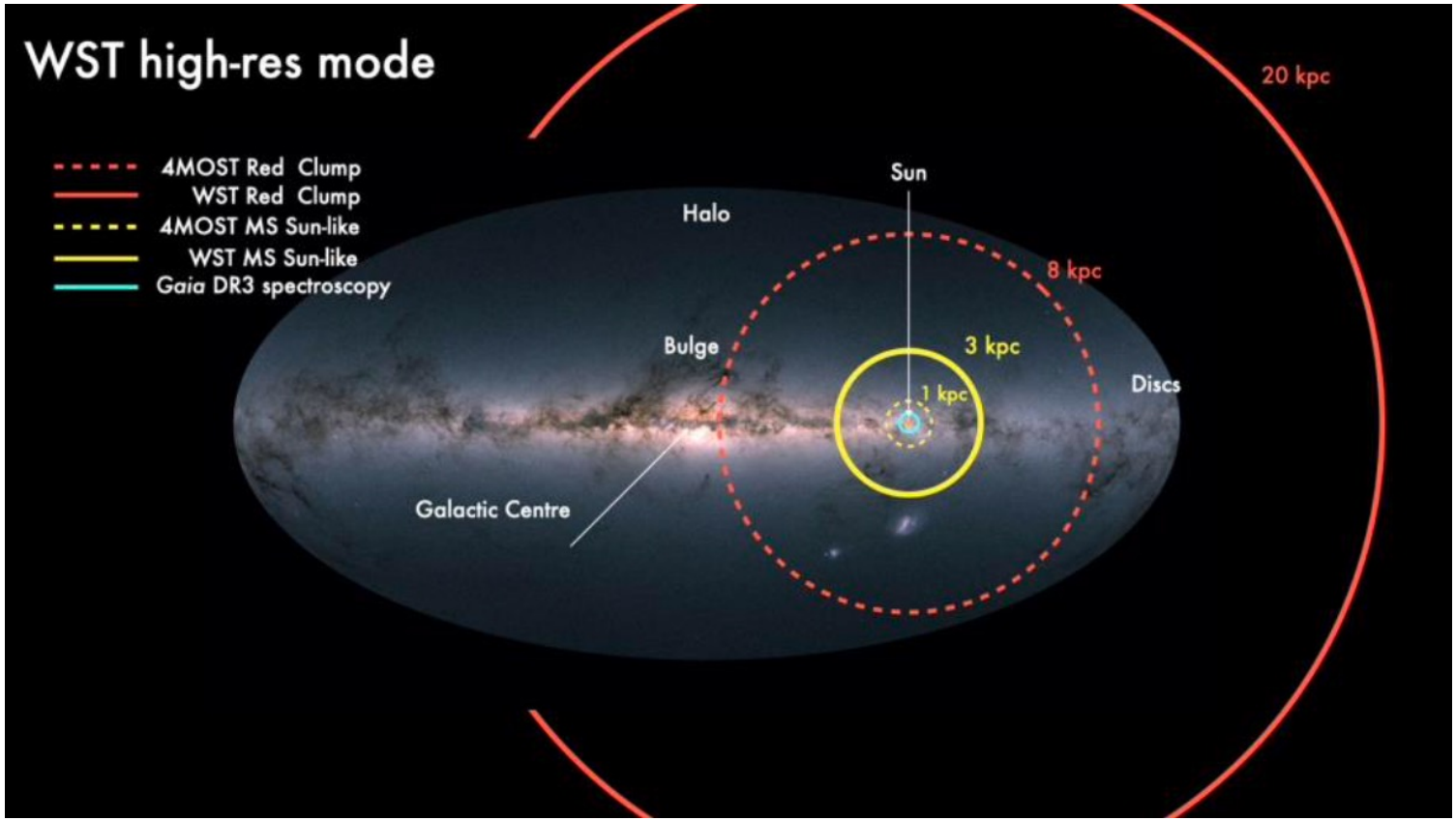


Credit to Georges Kordopatis (OCA)

The formation history of the MW and its satellites

Detailed abundances for studies of the chemical enrichment history of all populations/structures

Whole sky survey (HR+LR)
-Full chemical information and RVs up to G~16-17 mag
- A few element abundances and RVs up to G~18.5 mag
- At larger distances: metallicities and RVs

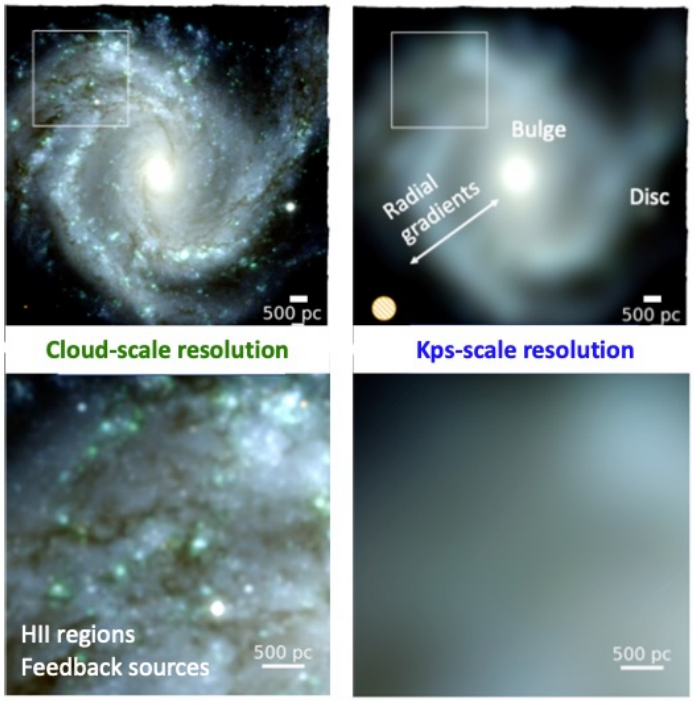


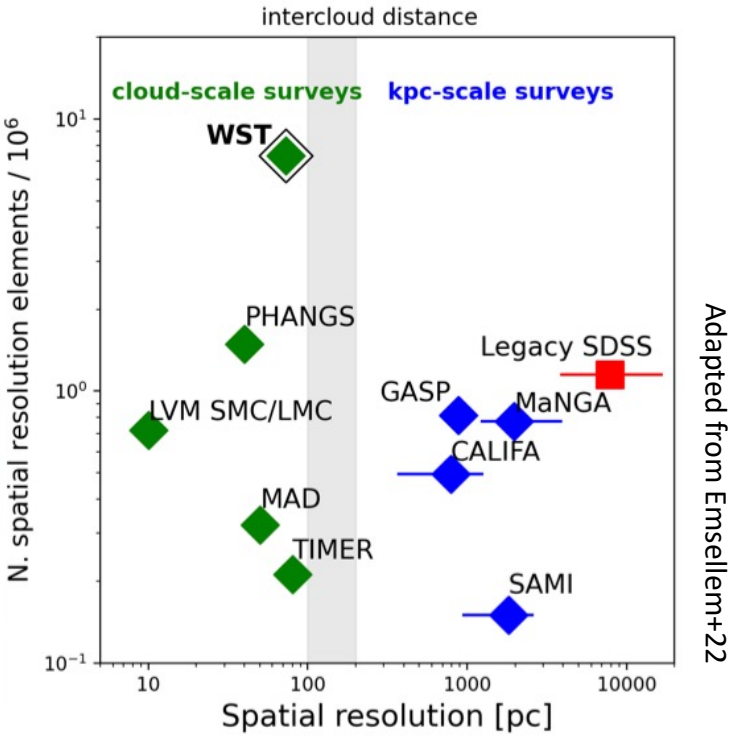
Credit to Laura Magrini (INAF)

The small-scale matter cycle

A ‘cloud-scale’ mapping of a sufficiently large sample of galaxies (>10^3) across a range of morphological features (e.g., spiral arms, bars, bulges) and integrated properties (e.g., Mstar, SFR, local environmental density).

An ambitious spectroscopic survey in the Local Volume (D < 25 Mpc) at better than 100 pc resolution





Adapted from Emsellem+22

To access the relevant physics regulating the consumption of gas, the production of dust and metals and star-formation one needs to reach “cloud-scales” (e.g. average distance between HII regions)

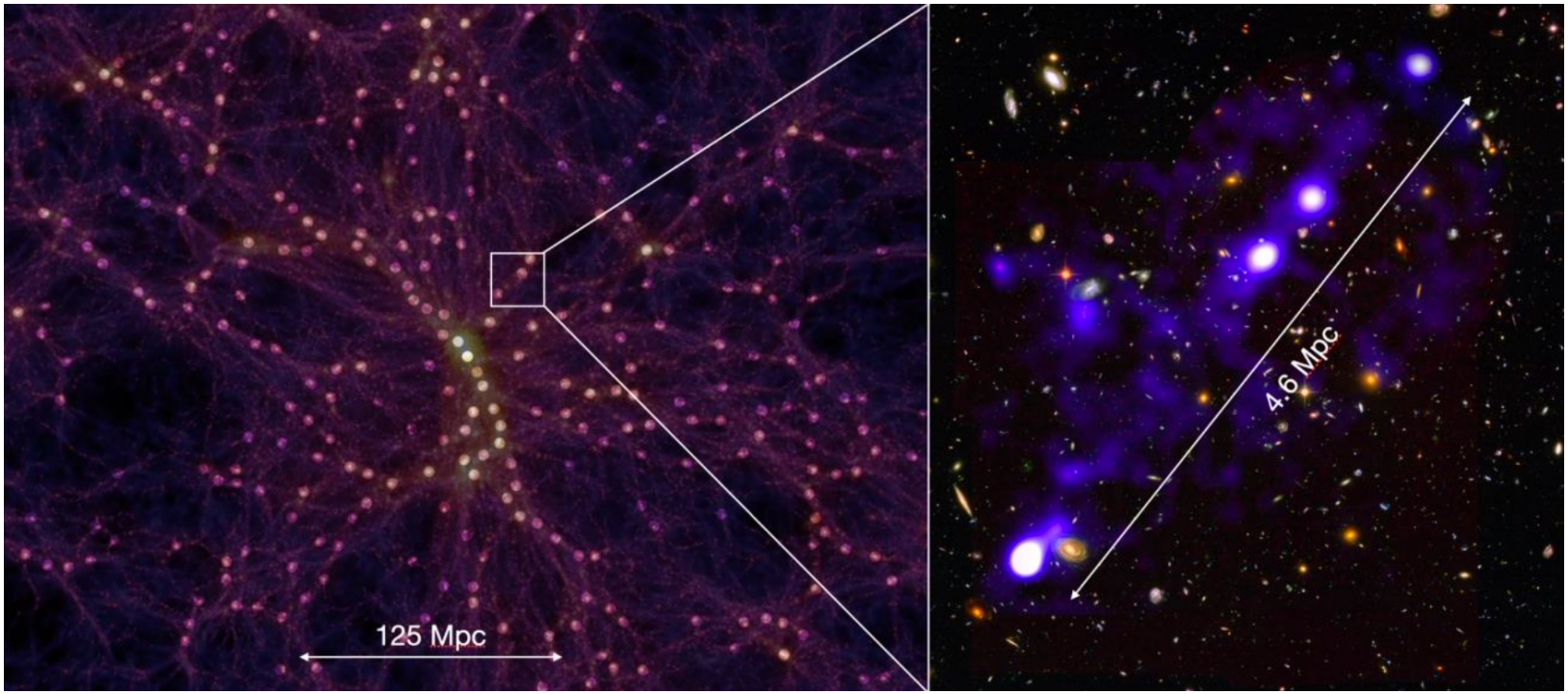
Credit Francesco Belfiore (INAF)

How galaxy evolution is driven by gas flow as a function of environment

How the Cosmic Web impact the evolution of galaxies?

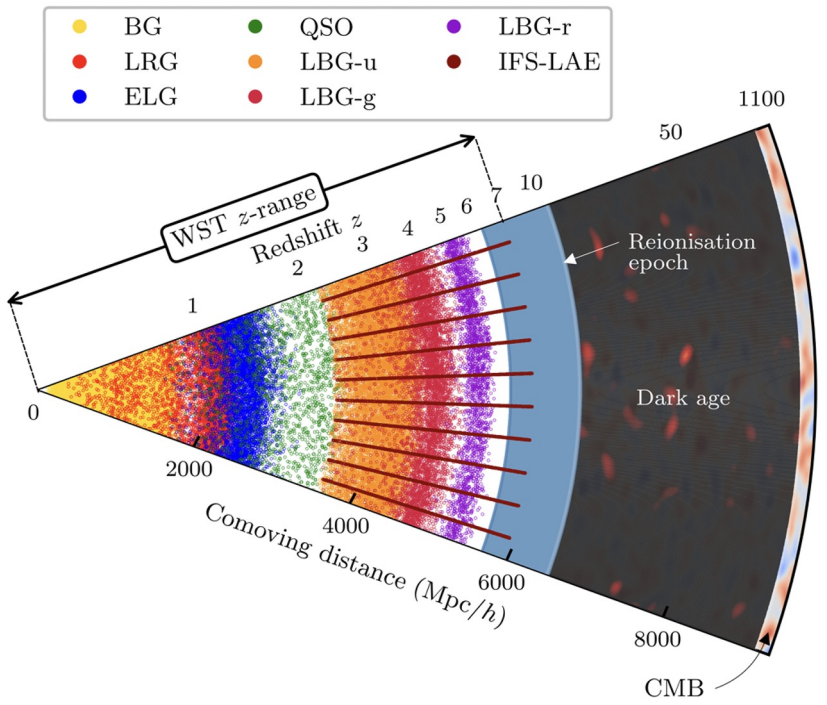
Reconstruct the 3-D density distribution with an SDSS-fidelity from 6 million 1<z<4 galaxies over 200 deg^2

The topology of the dark matter over large volumes from Lyα forest seen in absorption line spectra of background galaxies



MOS: IGM tomography in absorption and LSS in emission
IFS: z=2-7 LAEs, small scale clustering, resolved CGM & IGM emission in Lyα

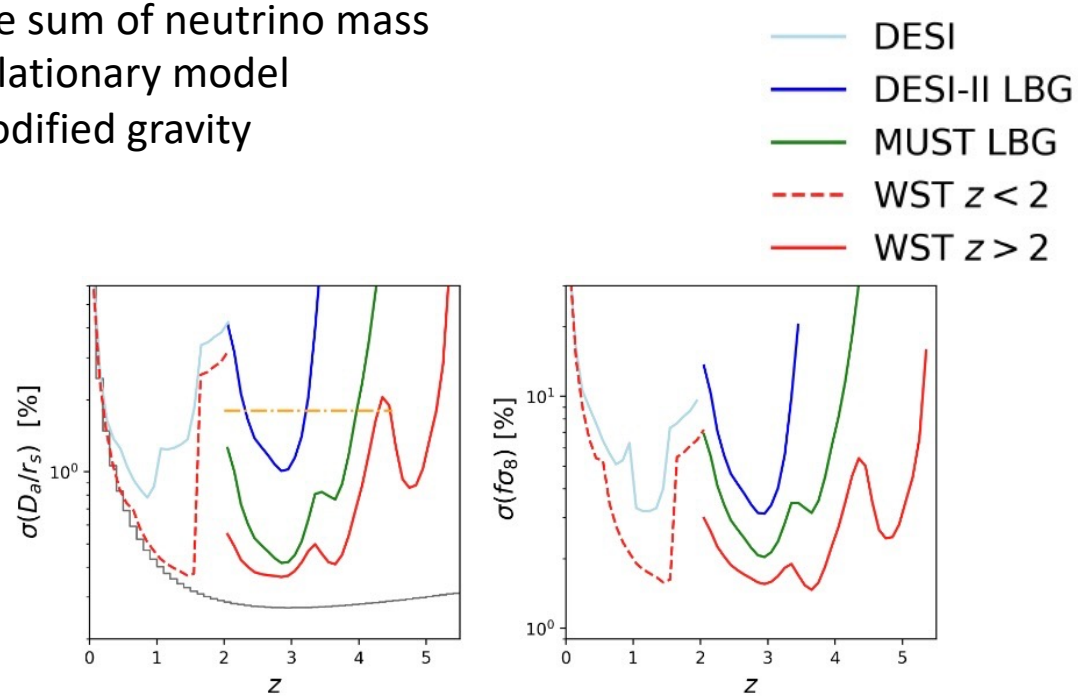
Opening-up high redshift cosmology



WST will conduct sub-percent galaxy clustering measurements beyond redshift of z~2

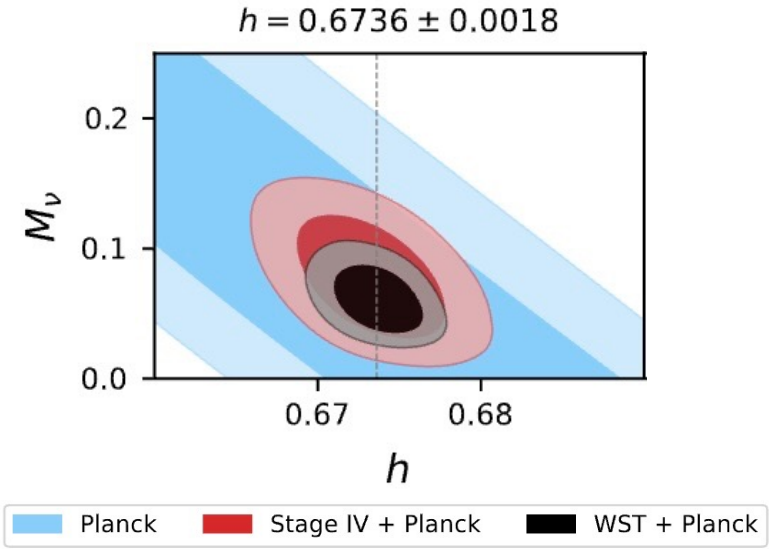
Sensitive constraints will be placed on :

- The level of non-gaussianity
- The sum of neutrino mass
- Inflationary model
- Modified gravity

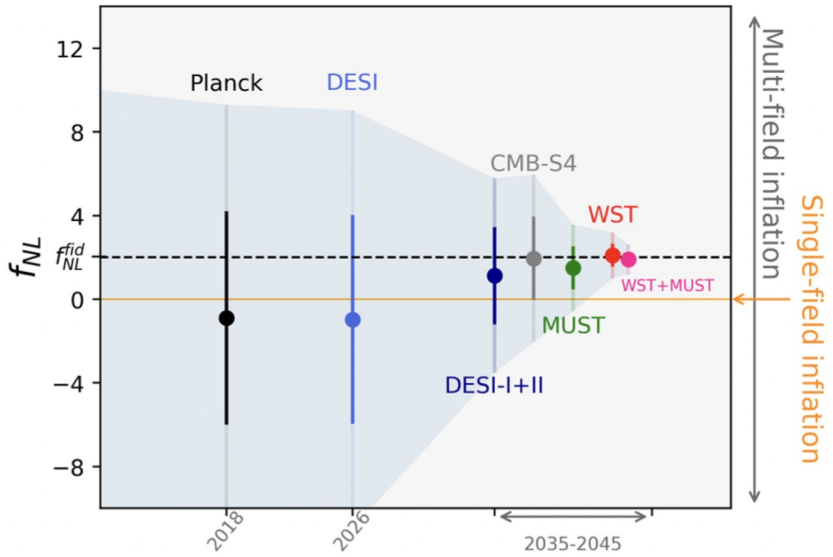


Probing fundamental physics

Neutrinos mass
In the most conservative case (Mv=0.06 eV) WST could provide a 3.5σ evidence of nonnull neutrino masses



Primordial non-Gaussianities
WST will be able to distinguish for the first time between single-field and multi-field inflationary models

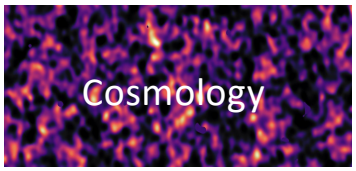


Get involved in WST

WST Special Session (SS7) at the EAS meeting in Cork (Ireland) June 23rd, 2025

New scientific ideas are welcome!

Preparing a winning science case for the ESO Expanding Horizons proposal (due June 2027)



Michele Moresco
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Sofia Contarini

Francesco Belfiore
Richard Ellis

Anna McLeod
Martin Roth

Rodolfo Smiljanic
Eline Tolstoy
Vanessa Hill

Richard Anderson
Paula Sanchez Saez
Cyrielle Opitom

Vincenzo Mainieri – WST Italian workshop

Thanks!