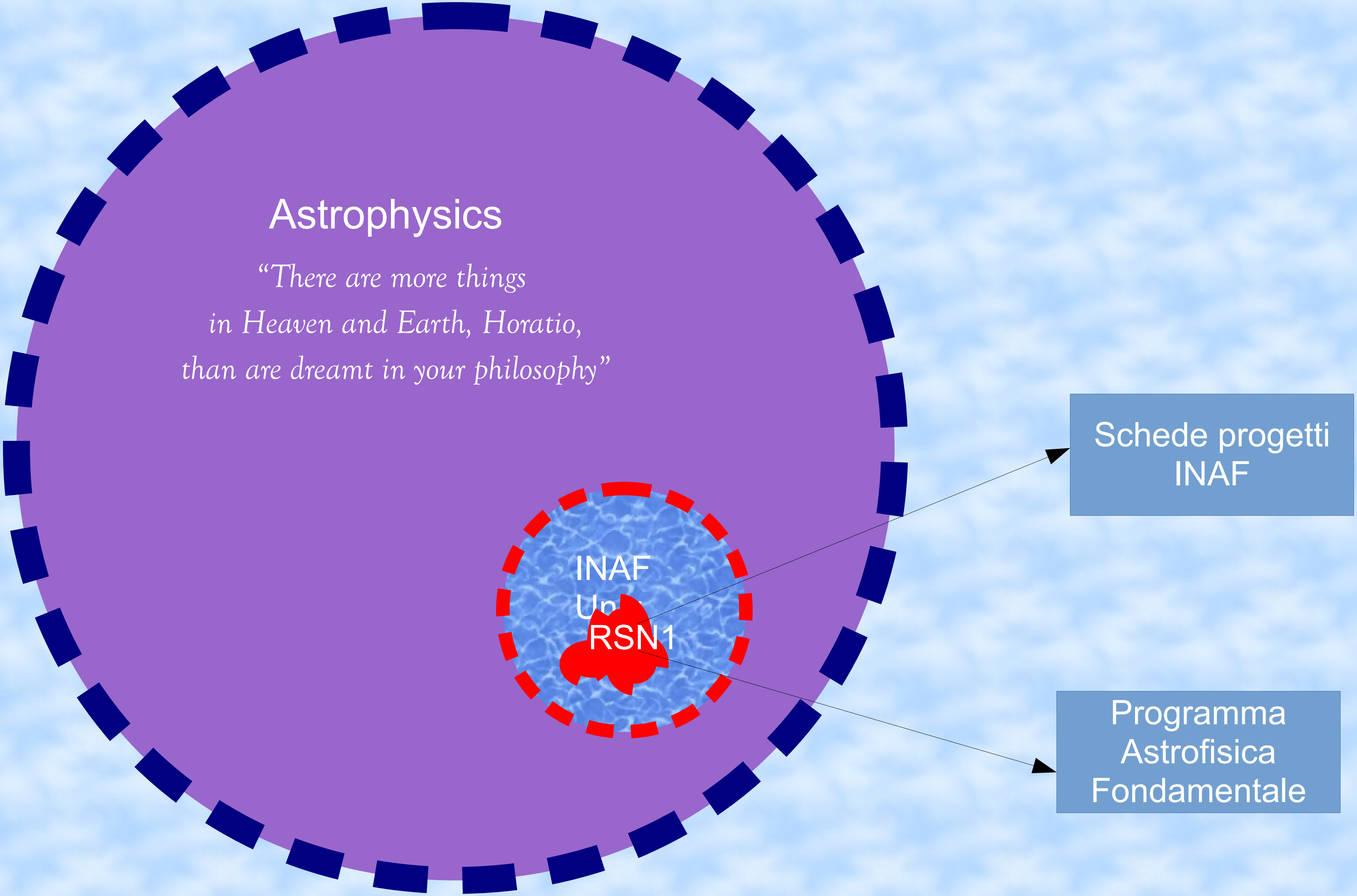
I grandi progetti di interesse per RSN1 nel contesto internazionale

Il punto di vista del CS

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

Consiglio Scientifico INAF

Science


Astrophysics
"There are more things
in Heaven and Earth, Horatio,
than are dreamt in your philosophy"
INAF
RSN1
Schede progetti INAF
Programma Astrofisica Fondamentale

Astronet Roadmap — Preliminary Executive Summary 8/7/22

- What is the nature of dark matter and dark energy?
- Are there deviations from the standard theories and models (general relativity, cosmological model, standard model of particle physics)?
- What are the properties of the first stars, galaxi and black holes in the Universe?
- How do galaxies form and evolve, and how doe the Milky Way fit in this context?
- What are the progenitors of astronomical transients?
- What physical processes control stellar evolution at all stages, from formation to death, and how?
- What are the necessary conditions for life to emerge and thrive? Are we alone?
- How do planets and planetary systems form and evolve?

- What is the impact of the Sun on the heliosphere and on planetary environments?
- What are/were the characteristics and habitability of various sites in the solar system (Mars, Jupiter's icy moons, ...)
- What is the origin of cosmic rays of all energies?
- How can extreme astrophysical objects and processes probe new fundamental physics?

\+ Computing and data management
\+ Technology development

Mid-term review of the European Astroparticle Physics Strategy 2017-2026 (APPEC)

High Energies gamma rays to explore the extreme Universe

High-energy neutrino astronomy

High Energy Cosmic rays

Gravitational Wave astronomy

Elucidating the nature of Dark Matter

Neutrino properties

Cosmic Microwave Background

Nature of Dark Energy

NASA Decadal Survey

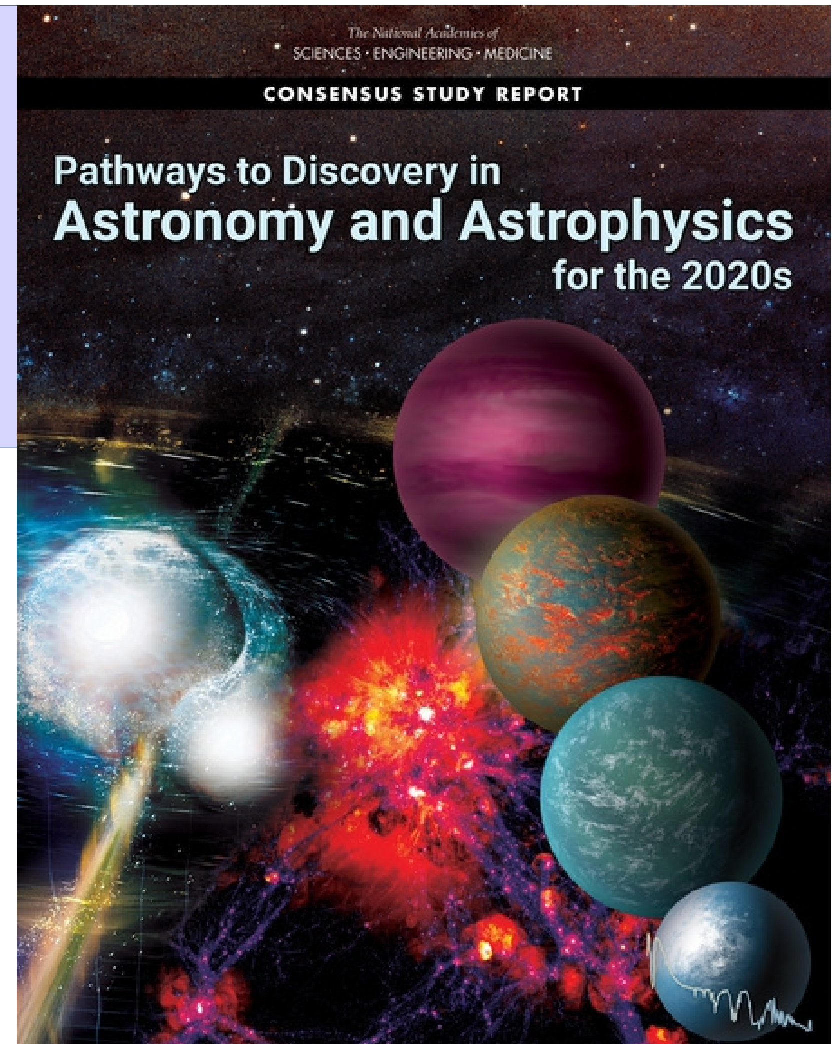
Pathways to Discovery in
Astronomy and Astrophysics
for the 2020s

The decadal survey identifies three important science themes for the next decade:

Investigating Earth-like extrasolar planets, search for habitable Exoplanets and extraterrestrial life

Study the most energetic processes in the universe (black holes and neutron stars)

Study growth and evolution of galaxies



ESFRI
European Strategy Forum on Research Infrastructures

ASTRONOMY AND ASTROPARTICLE PHYSICS

Astronomy & Astroparticle Physics (A&AP) seek to understand the Universe and its components: from its still mysterious beginnings to its growing complexity, with the formation and evolution of galaxies, stars and planetary systems, until the emergence of life. The main science questions addressed by the RIs can be summarized as follows:

- understand the origin of the universe, its main constituents;
- understand the extreme conditions the Universe hosts;
- understand the formation of galaxies and their evolution;
- understand the formation of stars and planets;
- search for planetary systems in our galaxy, study the Solar System and extrasolar planets, search for life and understand the conditions enabling life.

Making a clear recommendation on science themes for the next three Large missions following JUICE, ATHENA and LISA.
Providing a list of possible science themes that could be addressed through Medium missions.
Recommending long-term technology development that would lead to breakthrough science from ESA Space Science missions in the future

1) Moons of the Giant Planets. Exploring the issues of habitability of ocean worlds, searching for biosignatures, and studying the connection of moon interiors, near-surface environments, and the implications mass-energy exchange in the moon-planet system.

2) From Temperate Exoplanets to the Milky Way. Characterisation of Temperate Planets. Galactic Ecosystem with Astrometry in the Near-infrared.

3) New Physical Probes of the Early Universe. How did the Universe begin? How did the first cosmic structures and black holes form and evolve? Our recommendation is for a Large mission deploying gravitational wave detectors or precision microwave spectrometers to explore the early Universe at large redshifts.

Nature of Dark Matter and Dark Energies, and tensions with standard models.

Very early Universe, CMB.

Early Universe and Dark Ages: first stars, first galaxies and black holes, reionization.

Growth and evolution of galaxies and galaxy systems.

AGN, SMBH physics, Extragalactic transients, GW counterparts, GRB

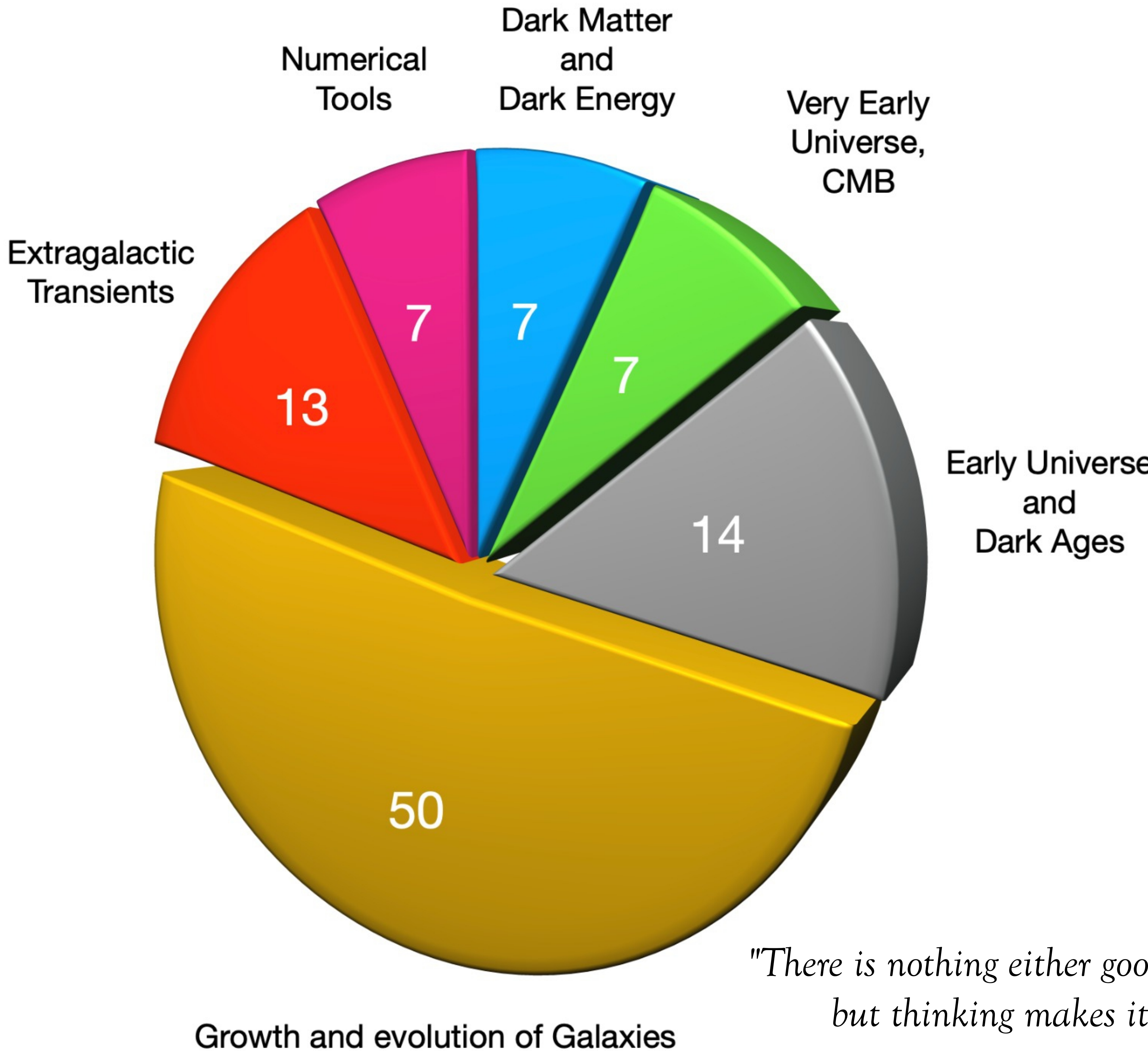
Numerical tools, Computing, Big Data

Le tue Schede Esistenti

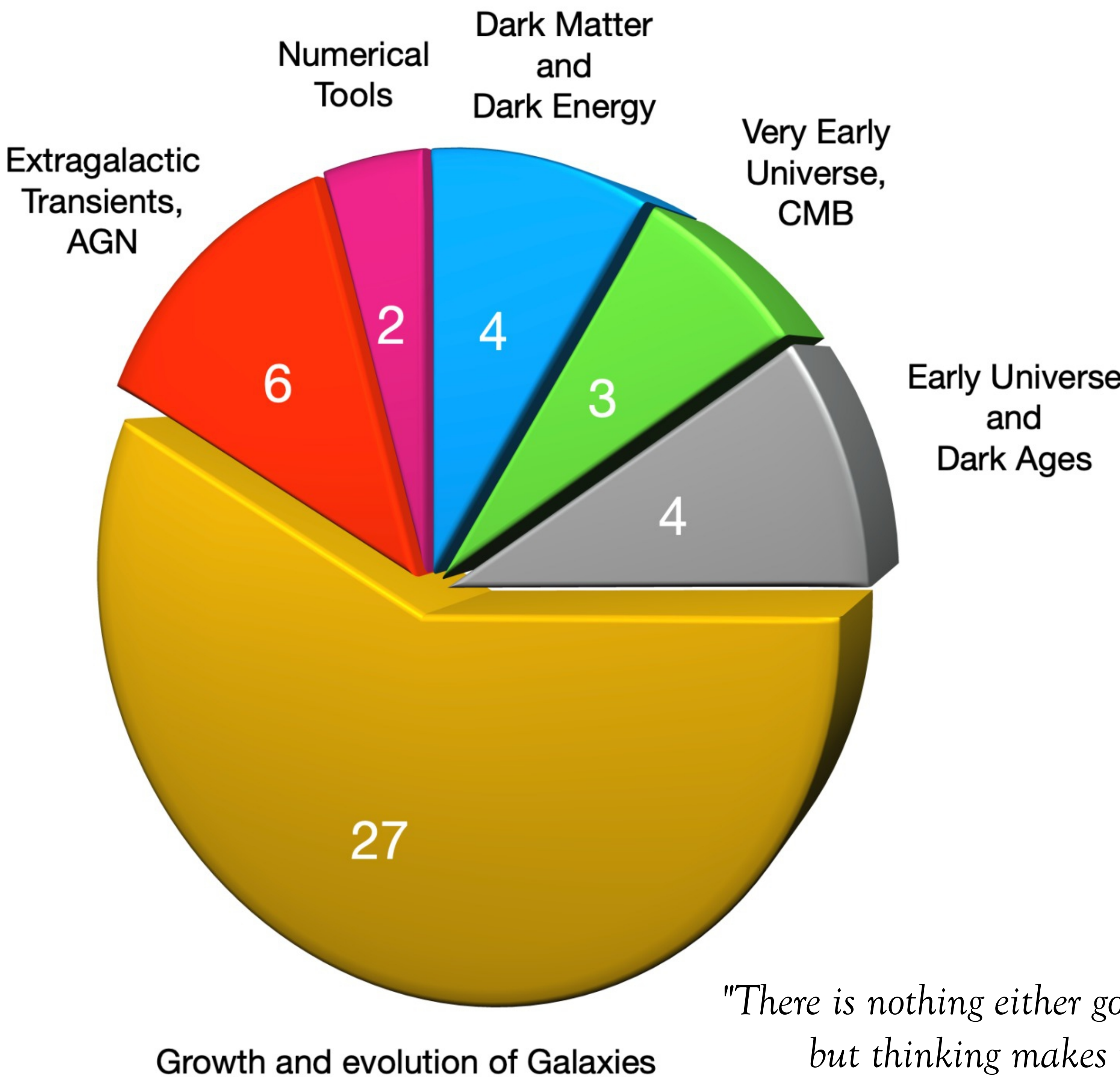
Scegliere la scheda da visualizzare

#	Titolo	Acronimo	Status	Actions
1	Galileo for Science 2.0	G4S_2.0	FINAL	Visualizza
2	Satellite Test of Relativistic Gravity	SaToR-G	FINAL	Visualizza
3	The 4MOST Survey of Young Stars	4SYS	FINAL	Visualizza
4	Segments and Pyramid for Large Aperture Space Telescope Technology - ADONI-5	SPLATT	FINAL	Visualizza
5	XMM-Newton Heritage Galaxy Cluster Project	CHEX-MATE	FINAL	Visualizza
6	M4 - Specchio Adattivo di ELT	M4	FINAL	Visualizza
7	Fisica del Tempo	Tempo	FINAL	Visualizza
8	Novel EOSC Services for Emerging Atmosphere, Underwater & Space Challenges (BIT.ICC-1)	H2020 NEANIAS	FINAL	Visualizza
9	CIRASA PRIN TEC INAF 2019 (RAGA-2)	CIRASA	FINAL	Visualizza

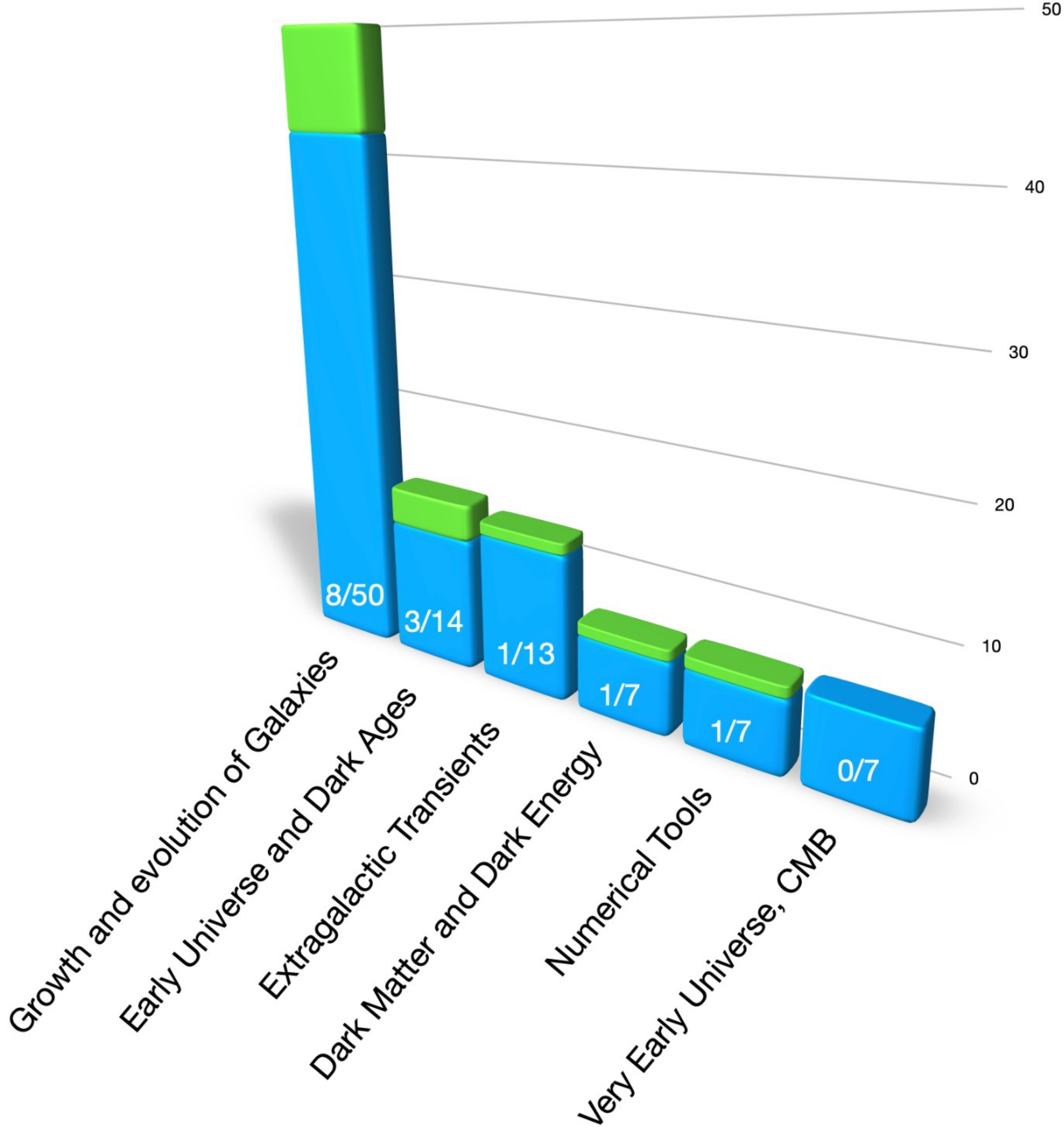
“Though this be madness, yet there is method in't.”



"There is nothing either good or bad but thinking makes it so"



"There is nothing either good or bad but thinking makes it so"



50
40
30
20
10
0
8/50
3/14
1/13
1/7
1/7
0/7
Growth and evolution of Galaxies
Early Universe and Dark Ages
Extragalactic Transients
Dark Matter and Dark Energy
Numerical Tools
Very Early Universe, CMB

Most Relevant Observational Facilities operating as of today:

JVLA/LOFAR/MeerKAT/GMRT/eMERLIN/VLBI

ALMA/ATCA/NOEMA/IRAM/SPT/ACT

VLT(I)/VISTA/WHT/Subaru/Magellan/Gemini/Keck

HST(/JWST)

XMM-Newton/Chandra/SWIFT/eROSITA/NuSTAR/FERMI

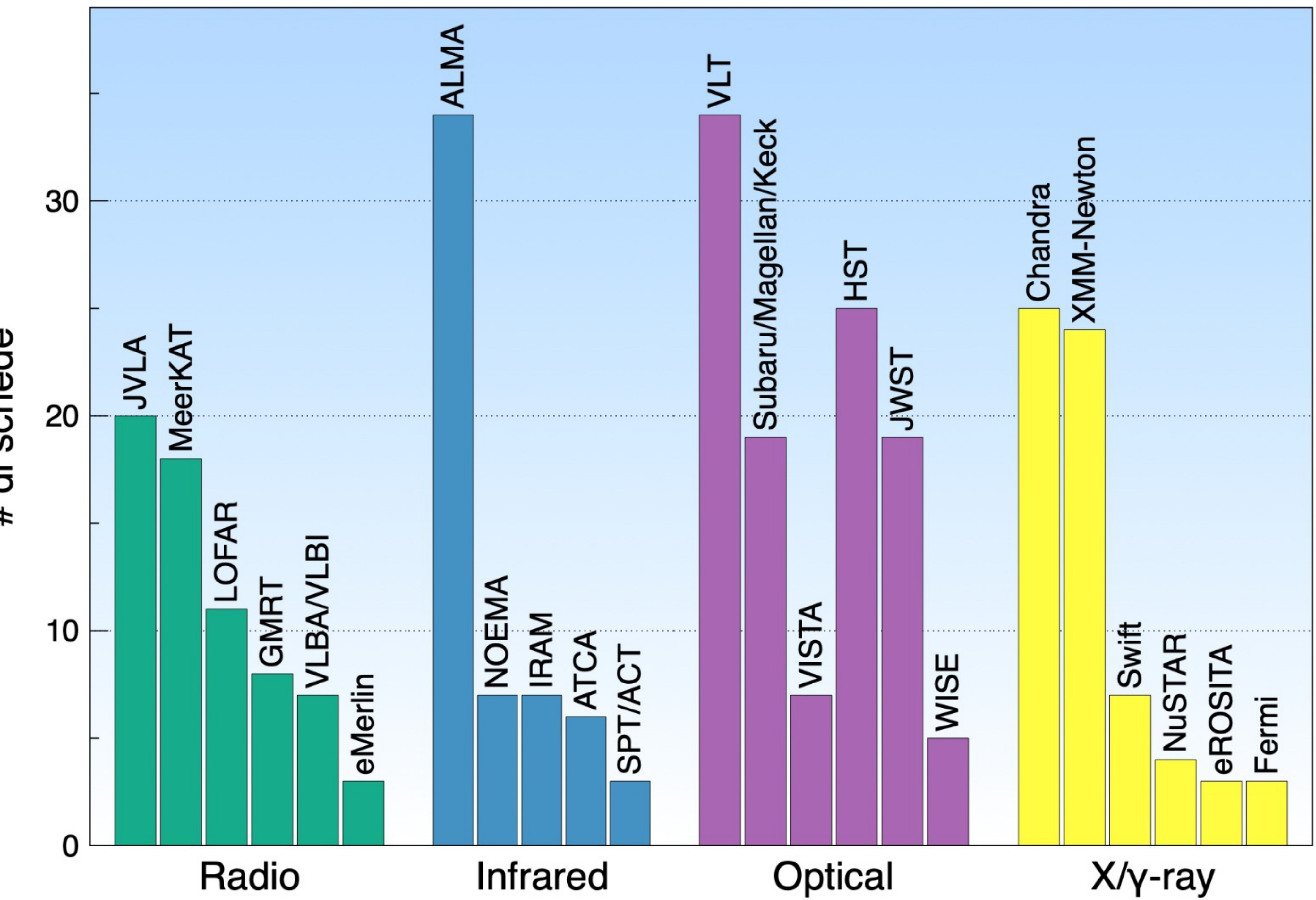
LIGO/VIRGO/KAGRA

Number of RSN1 INAF projects including data from a given facility from the ground

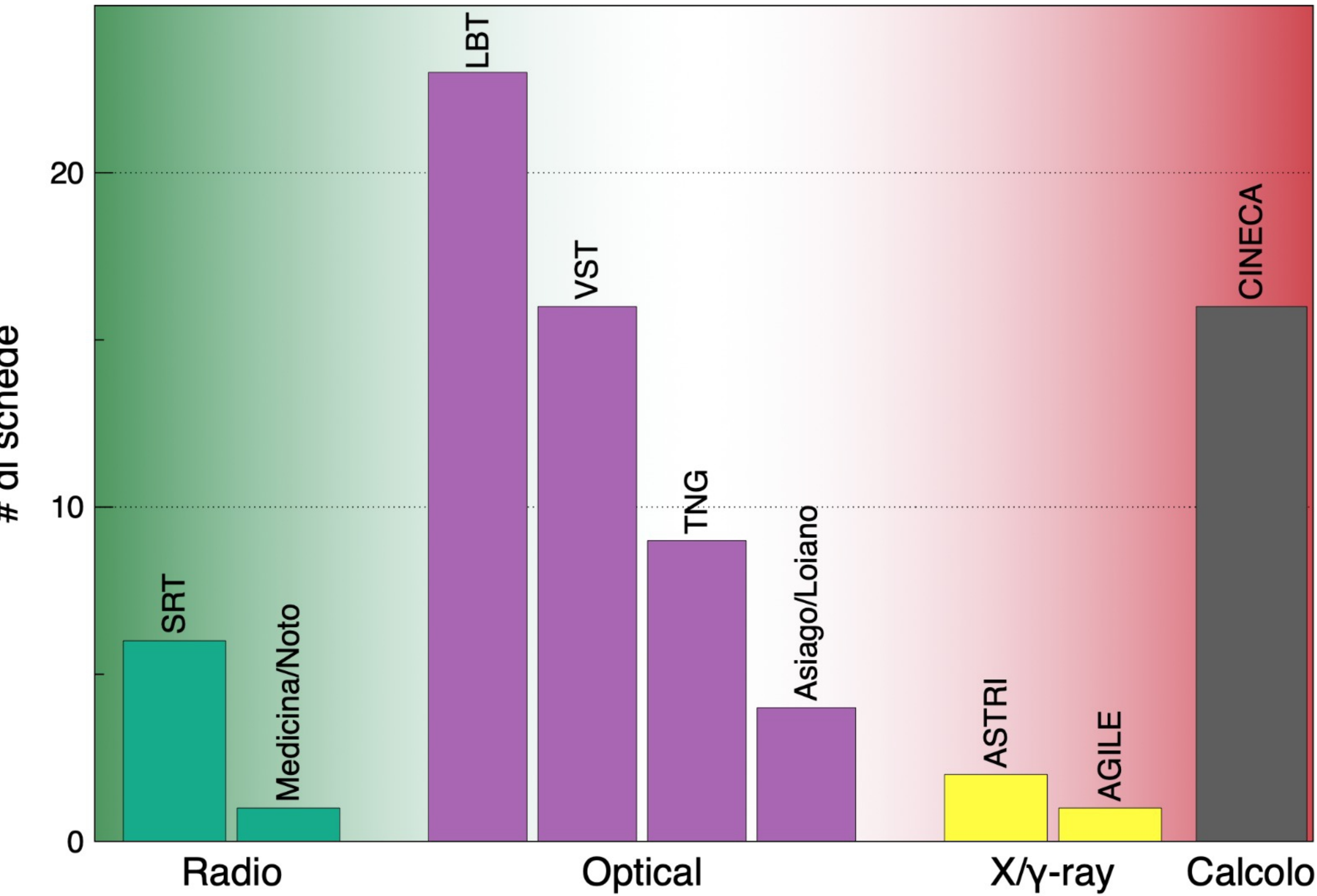
JVLA	20
MeerKAT	18
LOFAR	12
GMRT	8
VLBA/VLBI	7
eMerlin	3
ALMA	34
NOEMA	7
IRAM	7
ATCA	6
SPT/ACT	3
VLT(I)	34
Subaru+Magellan+Keck	19
VISTA	7
LIGO/VIRGO/KAGRA	0

Number of RSN1 INAF projects including data from a given facility from space

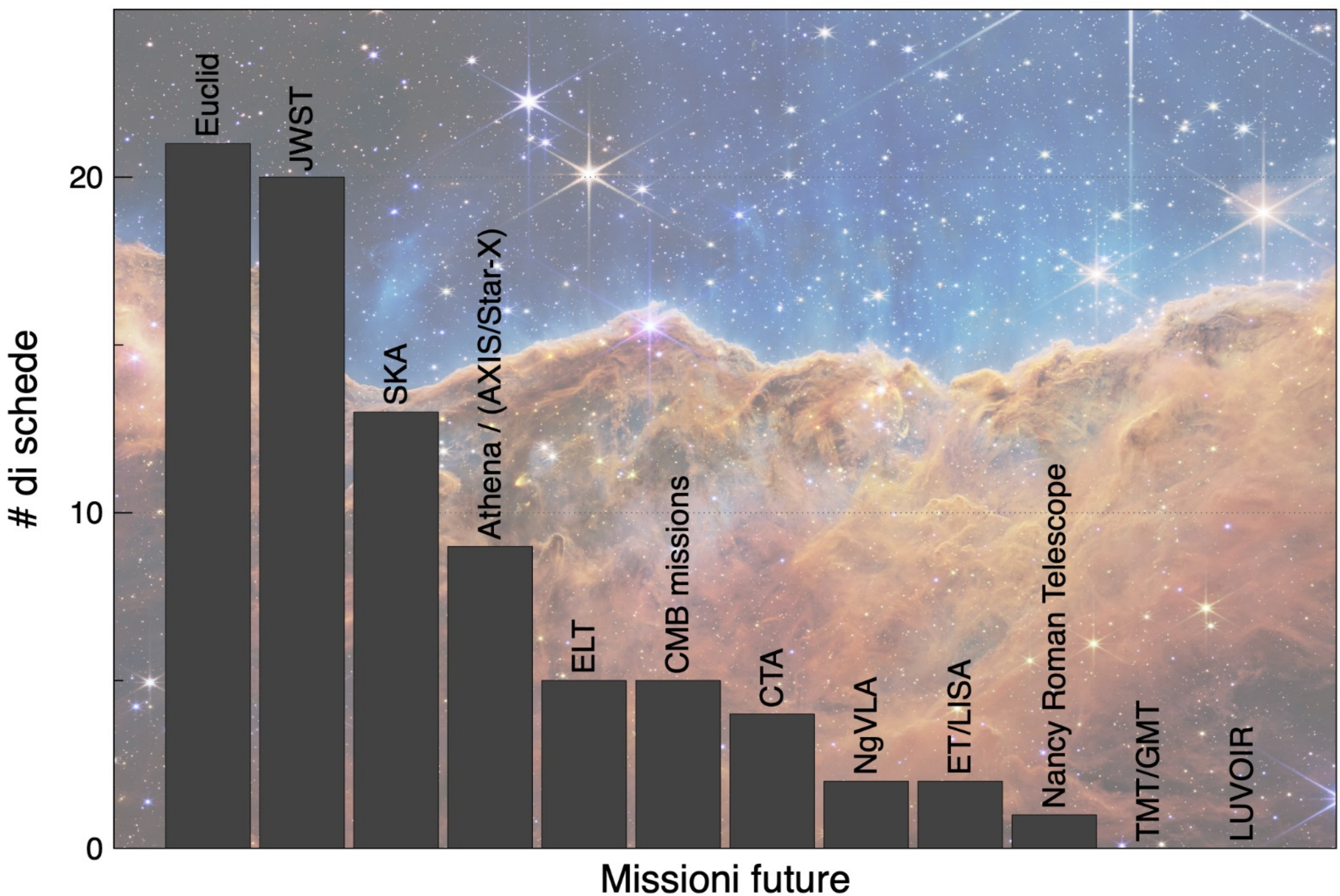
HST	25
JWST	19
WISE	5
XMM-Newton	24
Chandra	25
Swift	7
NuSTAR	4
eROSITA	3
FERMI	3



# of selected
30
20
10
0
JVLA
MeerKAT
LOFAR
GMRT
VLBA/VLBI
eMerlin
ALMA
NOEMA
IRAM
ATCA
SPT/ACT
VLT
Subaru/Magellan/Keck
VISTA
HST
JWST
WISE
Chandra
XMM-Newton
Swift
NuSTAR
eROSITA
Fermi
Radio
Infrared
Optical
X/γ-ray



di schede
0
10
20
SRT
Medicina/Noto
LBT
VST
TNG
Asiago/Loiano
ASTRI
AGILE
CINECA
Radio
Optical
X/γ-ray
Calcolo



di schede
20
10
0
Euclid
JWST
SKA
Athena / (AXIS/Star-X)
ELT
CMB missions
CTA
NgVLA
ET/LISA
Nancy Roman Telescope
TMT/GMT
LUVOIR
Missioni future

Example
INAF (RSN1) use of International facilities
Chandra

Cycle	PI INAF	epxtot	PI INAF(RSN1)	exp tot
AO24	7	(1.2Ms, 8%)	3	(0.96Ms, 6%)
AO23	8	(1.3Ms, 8%)	5	(0.94Ms, 6%)
AO22	7	(2.29Ms, 15%)	3	(0.35Ms, 2.3%)

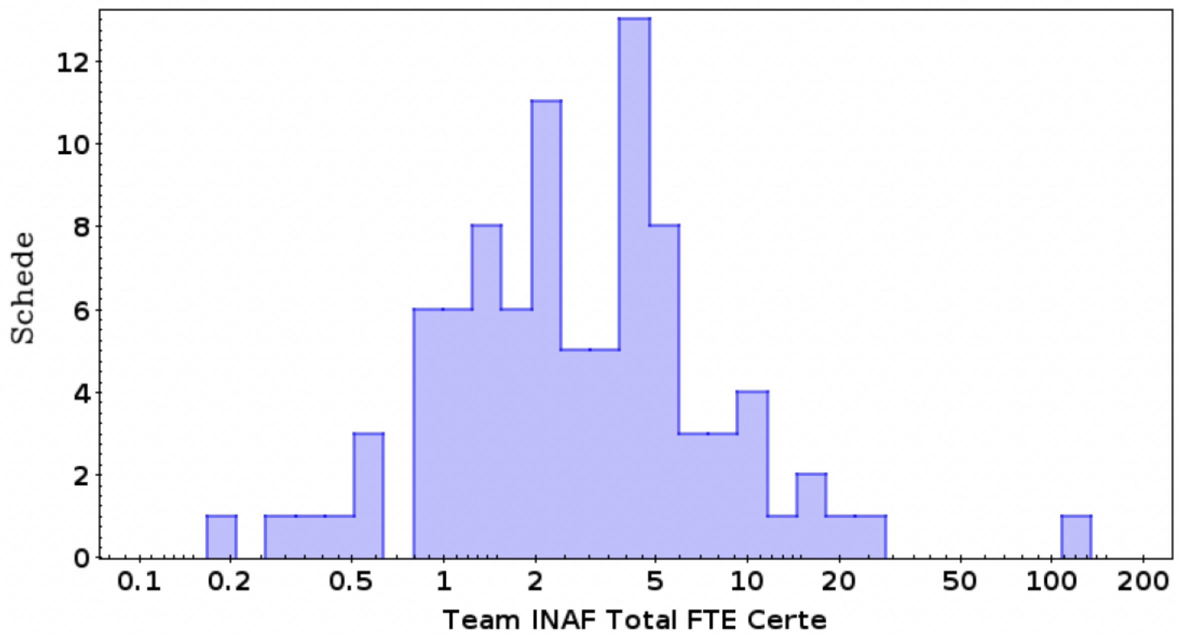
....

LOFAR

66 hr GTO + ~ 800 hr GTO 15%
+ PI LoLSS +coPI LoTSS +coPI Magnetismo

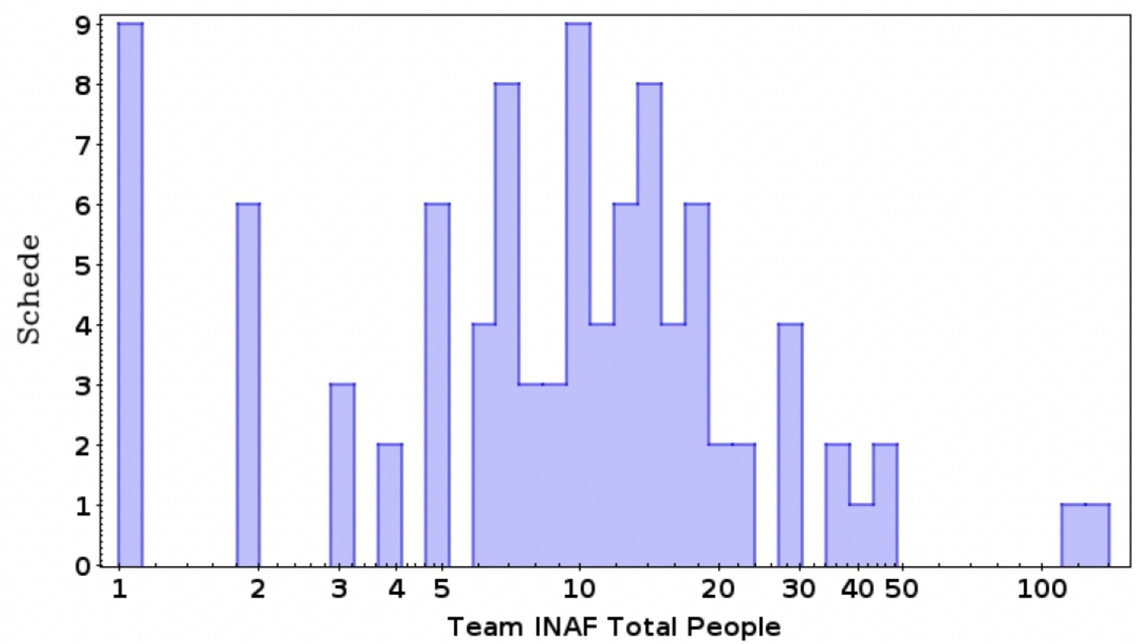
98 Schede Totali con RSN1 come raggruppamento primario.

Distribuzione del numero totale di FTE certe del personale INAF coinvolto in ciascuna scheda. Il valore mediano della distribuzione è 2.4.



INAF coinvolto in ciascuna sched

valore mediano della distribuzione è 10 persone.



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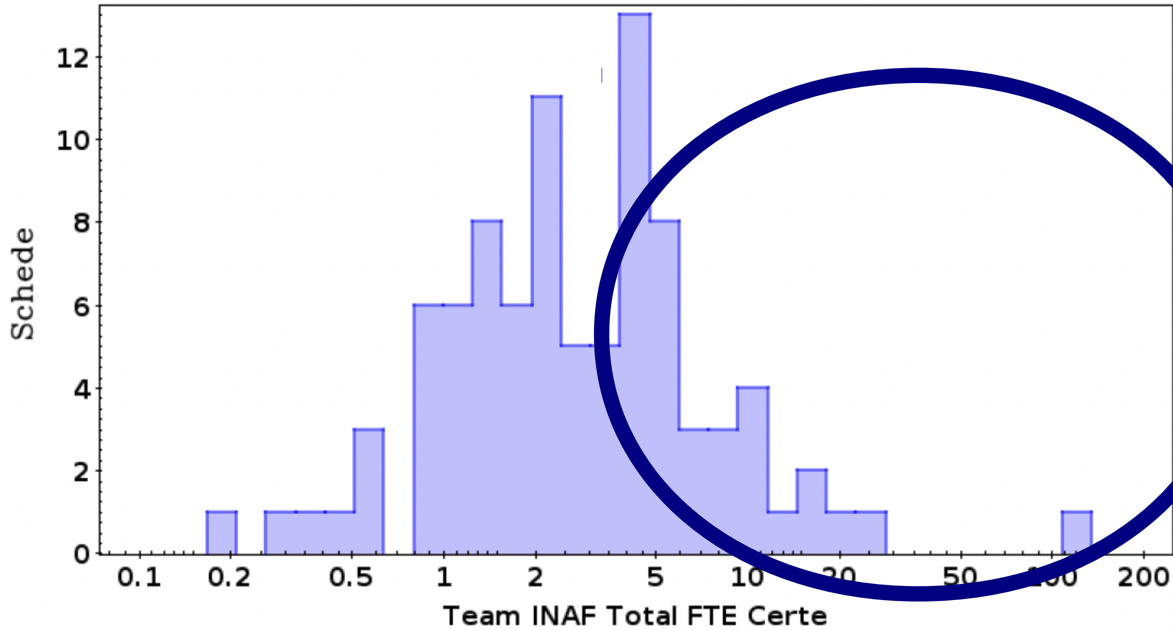

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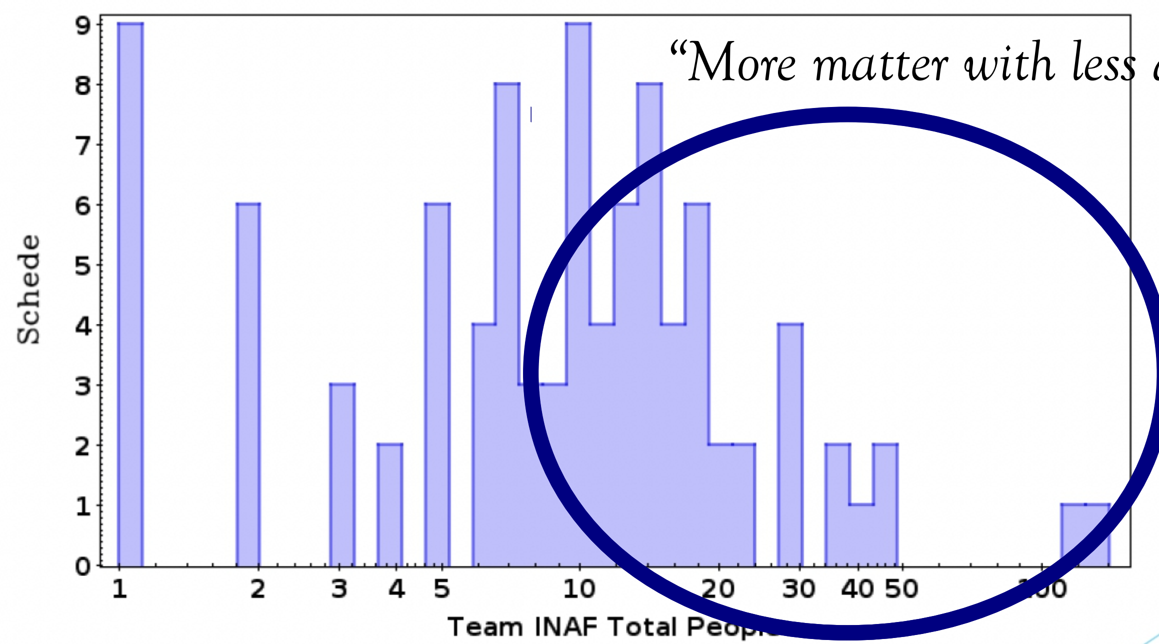
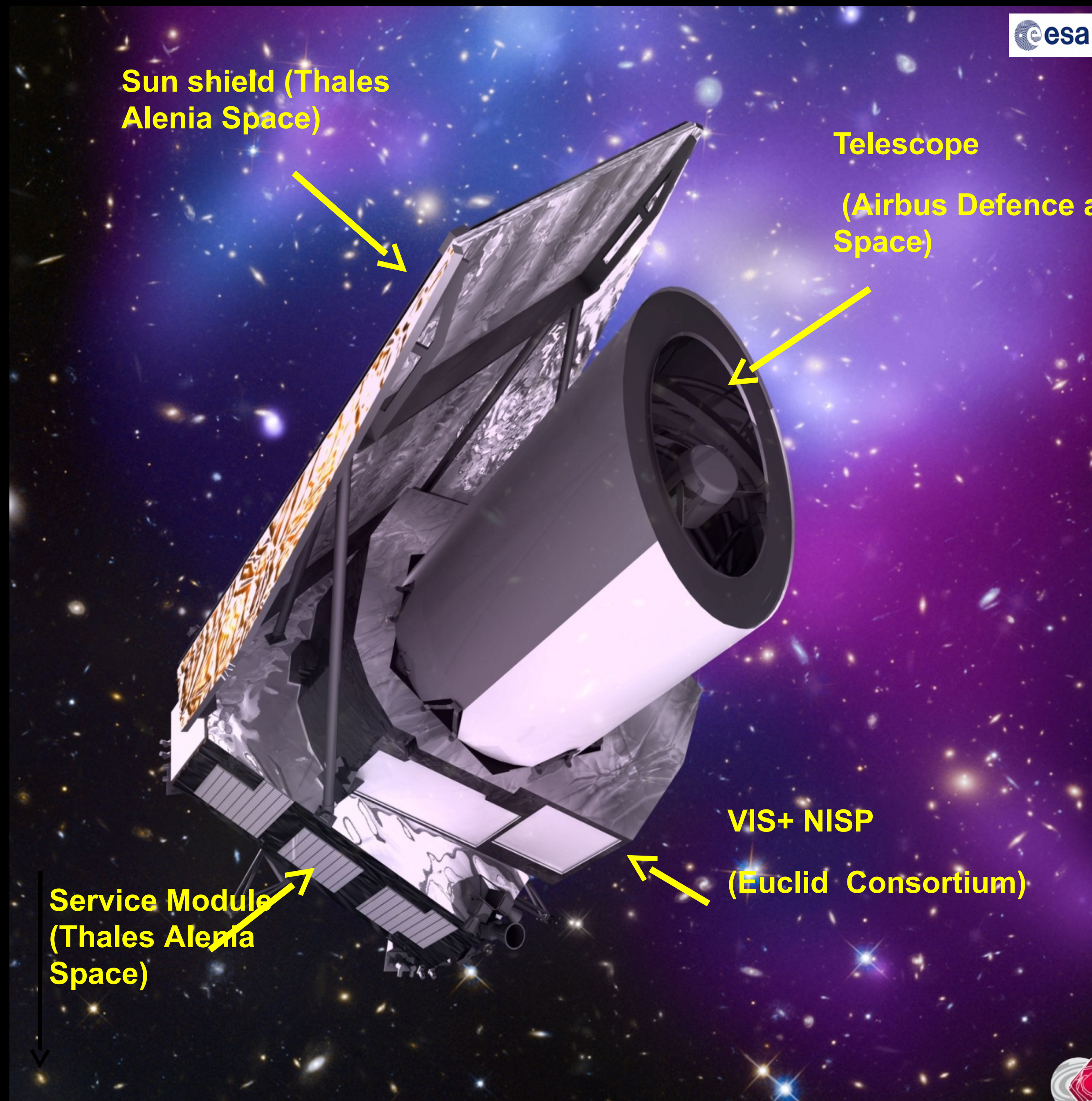


"More matter with less art."

ESA Euclid mission

Cosmic Vision proposals:
→France and Italy main contributors to Euclid

- - Mirror size: 1.2 m Korsch
- - Total mass satellite : 2 200 kg
- - Dimensions: 4,5 m x 3 m
- - Launch: Q3 2023 TBC
- - Placed in L2
- - Survey: 6 years,



Euclid Wide and Deep Surveys

- **Euclid Wide:**
  - ~15000 deg^2 outside the galactic and ecliptic planes
  - 12 billion sources (3-σ)
  - 1.5 billion galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=24.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 24.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 35 million spectroscopic redshifts of emission line galaxies with
    - 0.001 accuracy
    - Halpha galaxies within $0.7 < z < 1.85$
    - Flux line: 2 . 10^{-16} $erg.cm^{-2}.s^{-1}$; 3.5σ

- **Euclid Deep:**
  - 1x10 deg^2 at North Ecliptic pole + 1x20 deg^2 at South Ecliptic pole

    + 1x10 deg^2 South close to Equatorial area
  - 10 million sources (3-σ)
  - 1.5 million galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=26.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 26.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 150 000 spectroscopic redshifts of emission line galaxies with
    - 0.001 accuracy
    - Halpha galaxies within $0.7 < z < 1.85$
    - Flux line: 5 . 10^{-17} $erg.cm^{-2}.s^{-1}$; 3.5σ

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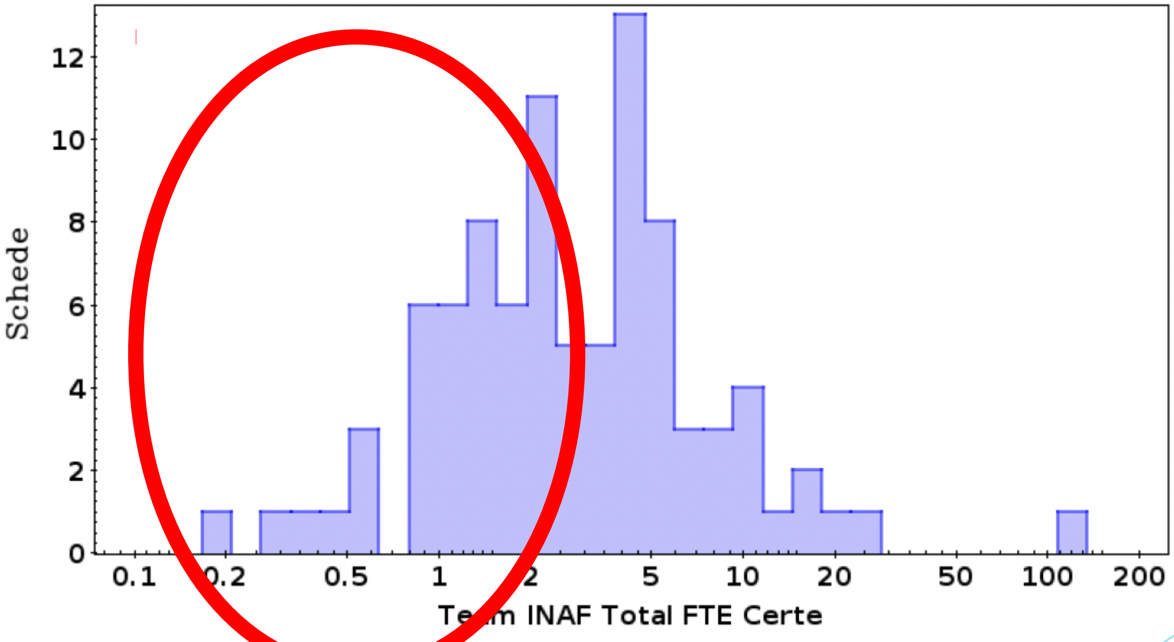
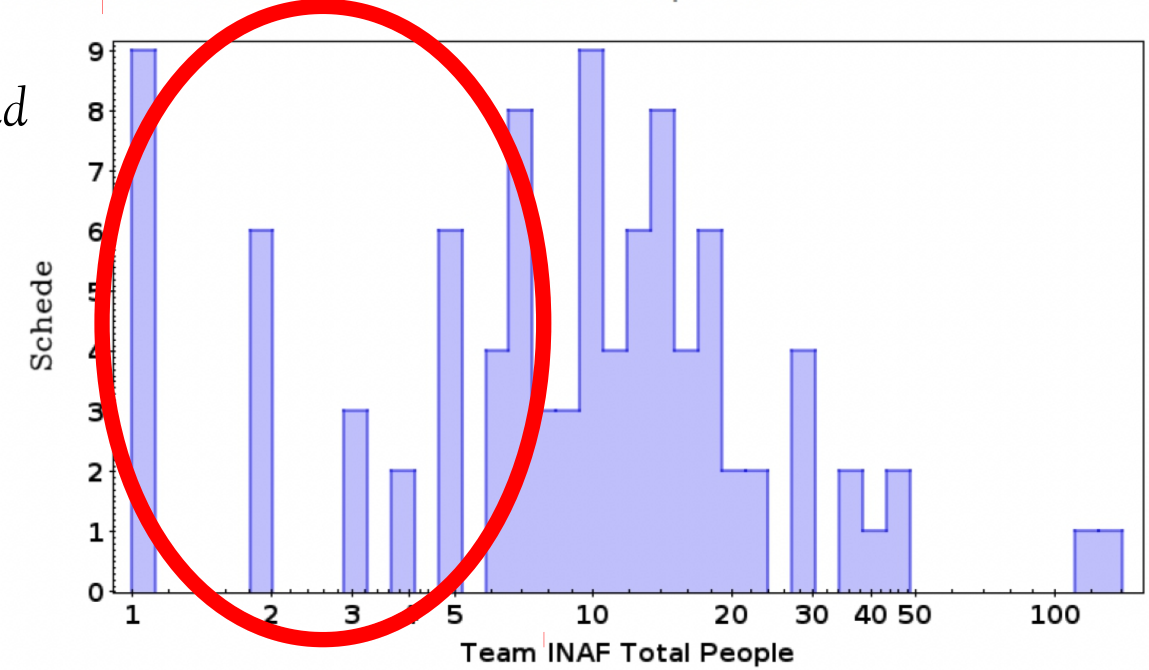


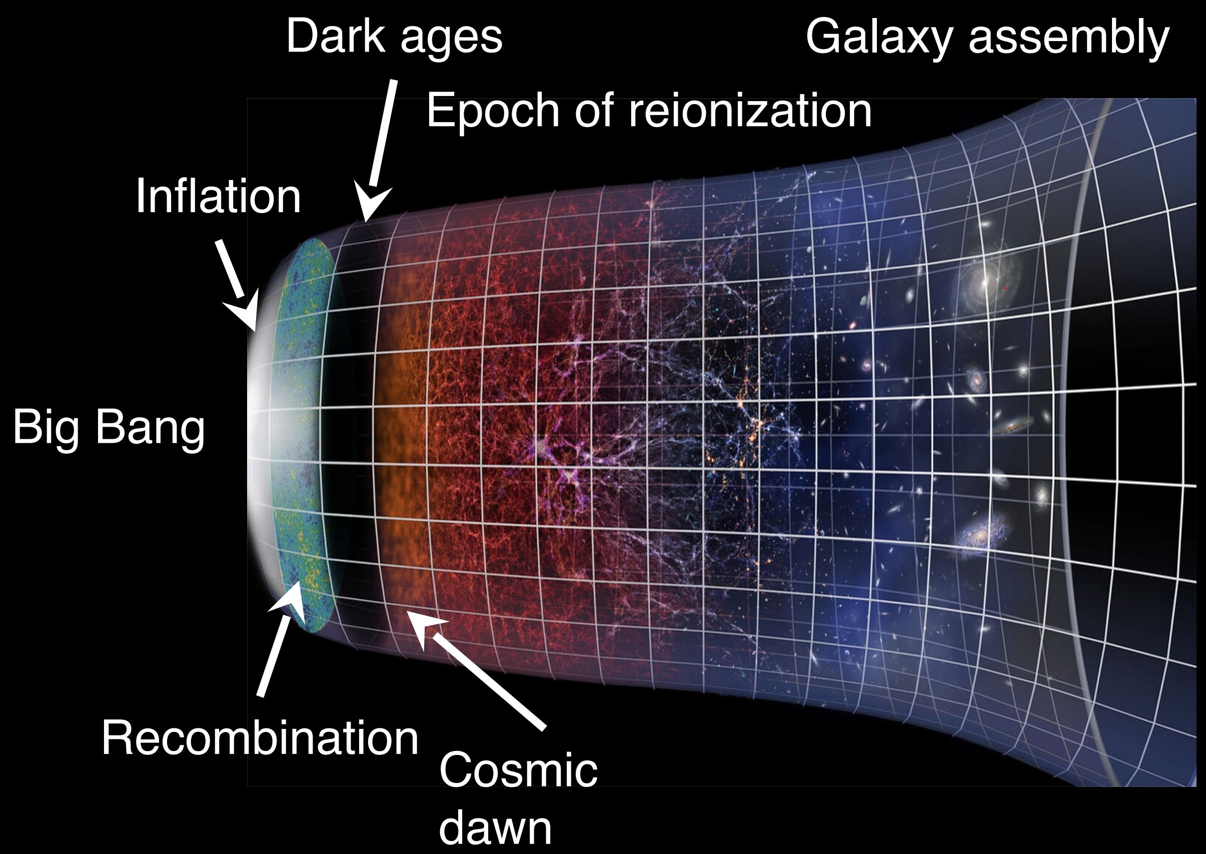
INAF coinvolto in ciascuna sched
valore mediano della distribuzione è 10 persone.

"I could be bounded in a nutshell and count myself king of infinite space."



THE FIRST STARS

The formation of the first stars determines the end of the "dark age" and the beginning of the "cosmic dawn"



They play a key role on the evolution of the Universe because:

- They enrich the IGM with the first metals through core collapse supernova explosions starting the "metal age" of the Universe

- They are luminous objects and produce ionizing photons starting the "epoch of reionization"

What are the properties of the First Stars?

One of the key open questions in the field of the early galaxy formation

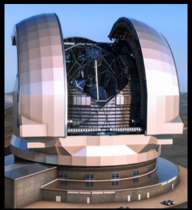
While simulations have made major progress on the fragmentation of metal-free gas, the formation mass of a PopIII star, as well as their initial mass function (IMF) remain challenging open questions.

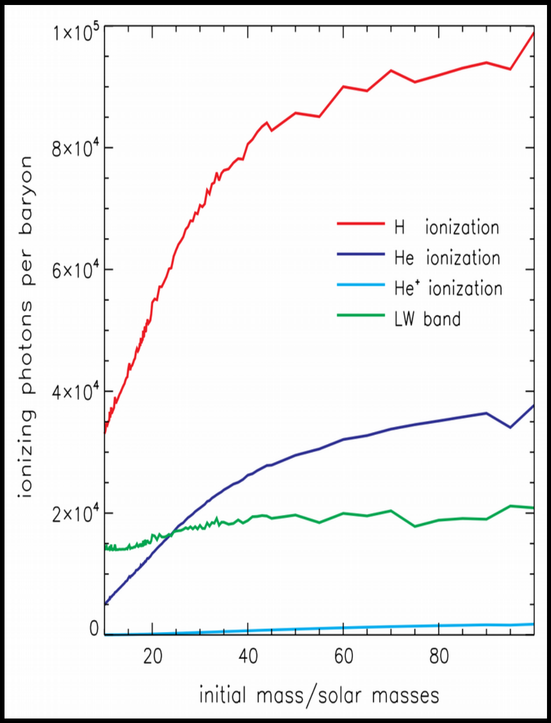
<u>Direct observations of PopIII stars</u>

detect the signatures of PopIII star formation either with ultraviolet emission lines or photometrically

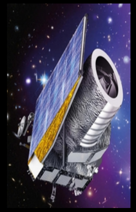
JWST

ELT

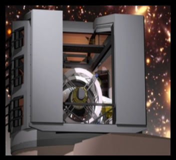




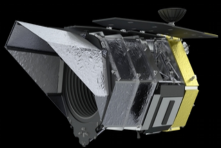
EUCLID



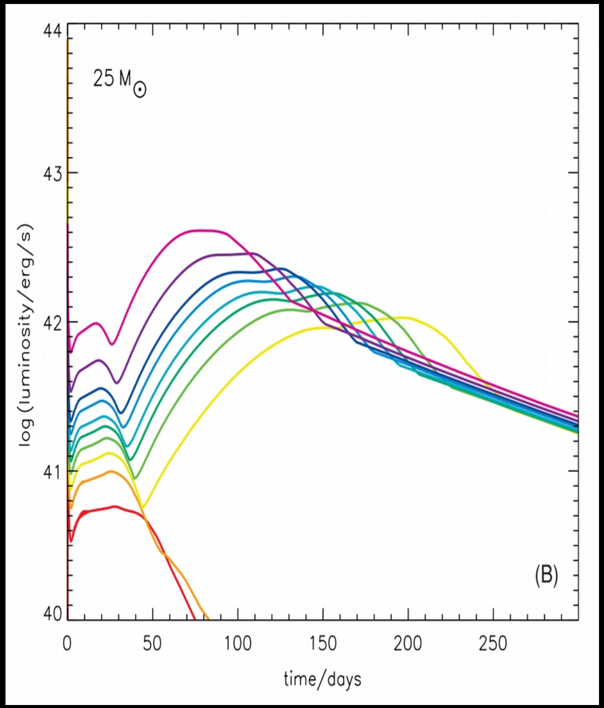
LSST



ROMAN



detection of their explosions (extremely luminous SNe)



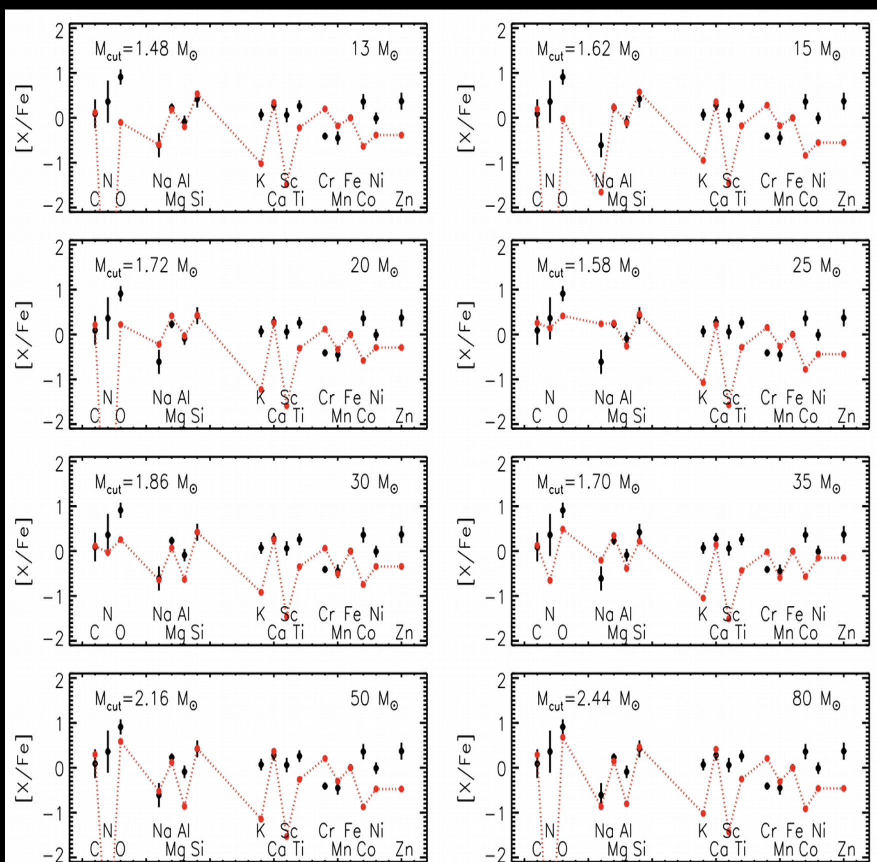
What are the properties of the First Stars?

One of the key open questions in the field of the early galaxy formation

While simulations have made major progress on the fragmentation of metal-free gas, the formation mass of a PopIII star, as well as their initial mass function (IMF) remain challenging open questions.

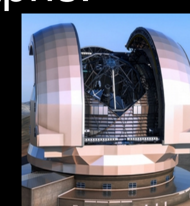
<u>Indirect information on PopIII stars properties</u>

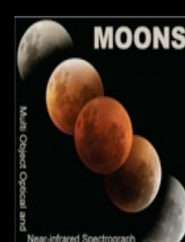
"stellar archaeology": metallicity measurements, together with updated calculations of the yields from the first stars



The abundance patterns of EMP stars could constrain the nucleosynthetic yields of the Pop III supernovae and the mass range of the first stars.

observations provided by by ESA/Gaia among other surveys, and followed up with 4MOST, MOONS, WEAVE, MSE, then ELT spectrographs.

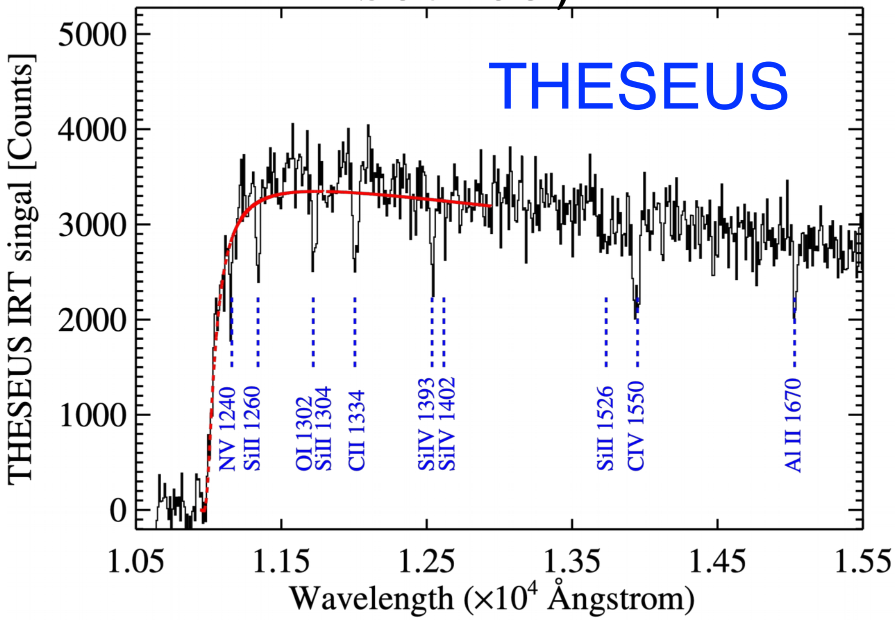


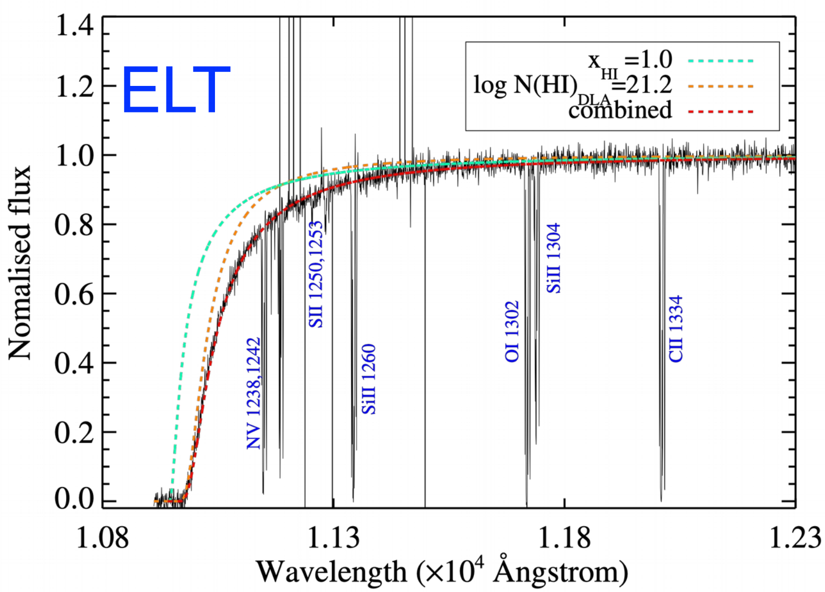


Synergy with stellar evolution community

z > 10 GRB detection w/ THESEUS, ELT, JWST

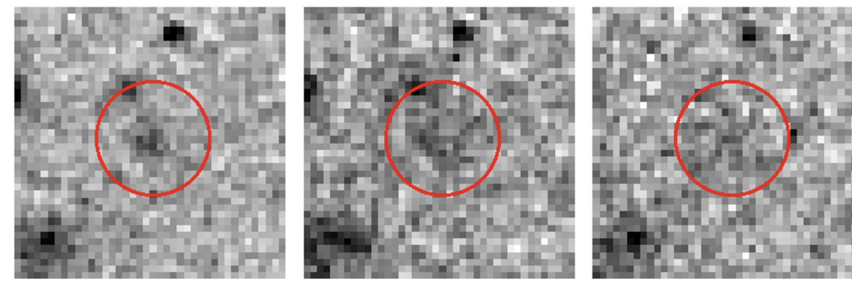
z = 8 GRB (THESEUS simulated source)



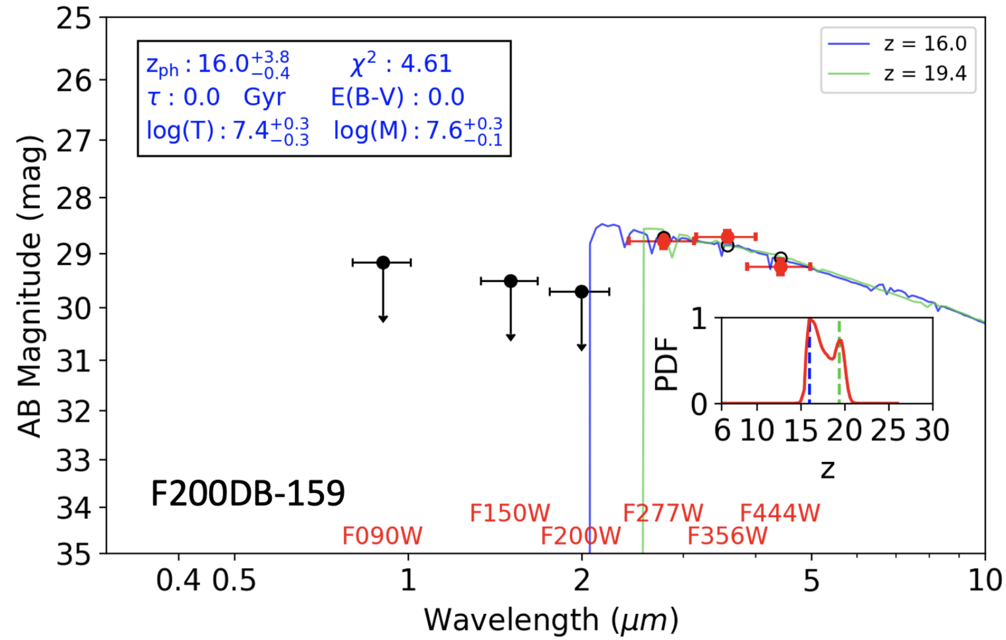


z = 16

JWST/NIR



$m_{AB} = 28.8$



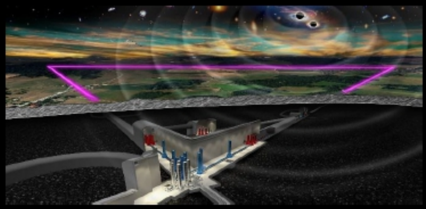
Stellar mass: $M_{\star} = 10^{7.6}\ M_{\odot}$

Tanvir et al. (2021)

Amati et al. (2019)

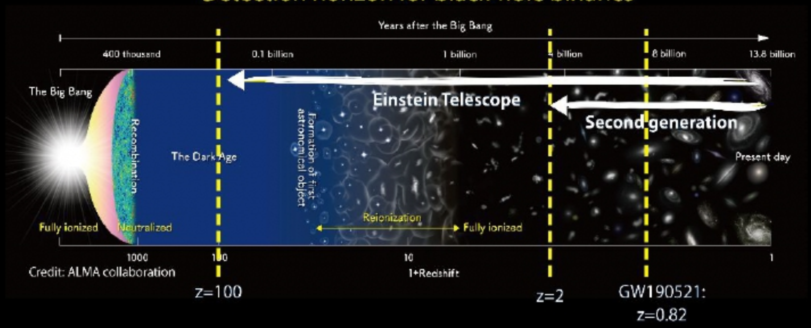
Yan et al. (2022)

The ET sensitivity will make it possible:

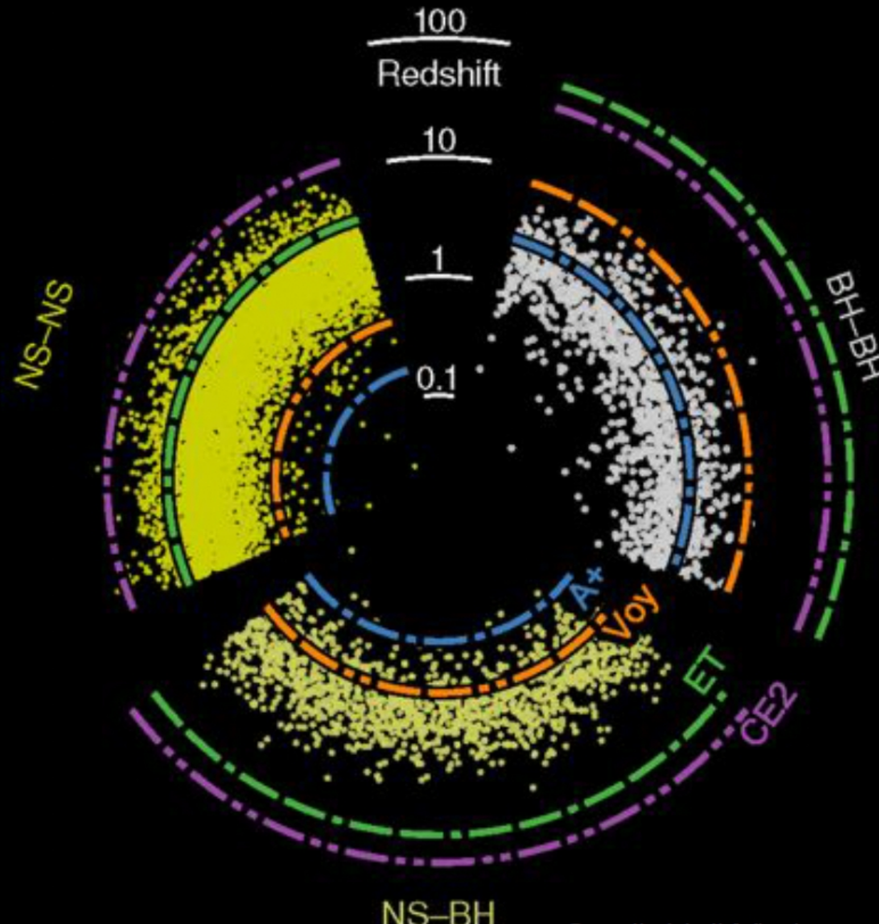


- Large distances back to the EARLY UNIVERSE

Detection horizon for black-hole binaries



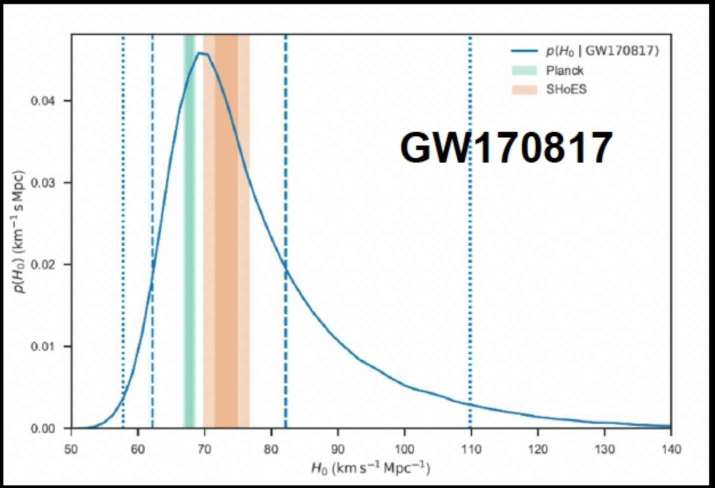
- POPULATION:
  increase number of detections



Credit:Hall/Vitale

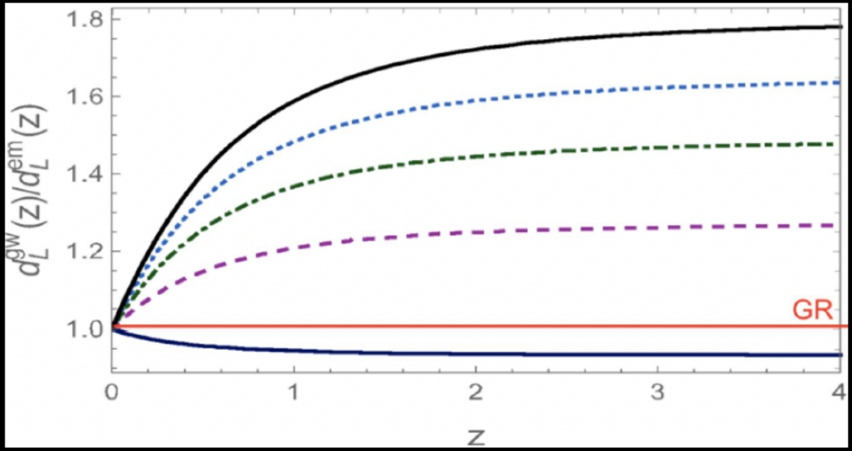
UNIVERSE EXPANSION, DARK ENERGY, MODIFIED GRAVITY AT COSMOLOGICAL SCALE

Standard sirens

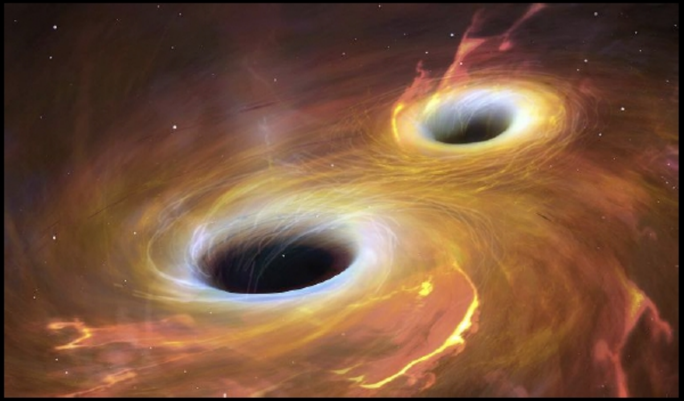


Abbott et al. Nature 2017

Modified GW propagation



Belgacem et al. JCAP 2019



BBH as probe of LSS

Where should we go from here?
Invest in a large range of scientific topics, increasing, for example, the interdisciplinary projects?

Or try to compact some of the projects into larger ones?

Note: the RSN with the smaller number of projects are those with national congress on science topics (?)

AGN (RSN1)
Clusters (RSN1)
Cosmology (RSN1)
GEE (RSN1)
Compact objects (RSN4)
GRB (RSN4)
Congresso Nazionale Ottica Adattiva (RSN5)

RSN1 107
RSN4 114
RSN3 142
RSN2 152
RSN5 186

“Conclusions”

“Brevity is the soul of wit.”

RSN1 is working on all the most relevant scientific topics according to international roadmaps, but with most of the weight on the astrophysics of galaxies, less on cosmology/ fundamental physics. Well balanced?

RSN1 is ready to exploit new facilities in the radio, submm and optical (ESO), but CTA and ET are not significantly involved. Is it worth to put weight on interdisciplinary projects?

Small vs large projects vs scientific opportunities.

X-ray community strong but future is still uncertain. Why are we still growing X-ray astronomers?

Support theoretical astrophysics.

Reinforce collaboration with universities.