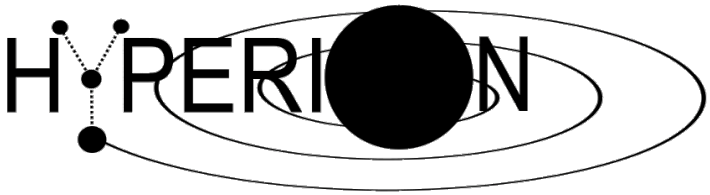
HYPERION Science Collaboration (HSC)

Coordinator: Zappacosta Luca (INAF-OAR)



HSC is…

- Brand new INAF-led international collaboration
- Partnership among highly experienced leading scientists and strong research groups with a high publication record
- Reference project to study the properties of active billion solar masses black-holes at the Reionization Epoch (EoR)

HSC focus and goals

- First quasars (QSO) in the young Universe (< 1 Gyr; z>6)
- Nuclear & host galaxy properties
- Panchromatic investigation (holistic approach)

- Formation mechanisms of first SuperMassive Black-Holes (SMBH)
- Co-evolution quasar/host galaxy
- Subsequent QSO evolution across cosmic time

Luminous quasars at the EoR

- More than 200 QSO at z>6
- $L_{bol}=10^{46\text{-}48}$ erg/s
- $M_{SMBH}>10^{8\text{-}9}\ M_{\odot}$
- 75% at $\lambda_{Edd}=L_{bol}/L_{Edd}>0.2$
- z=6-7.6

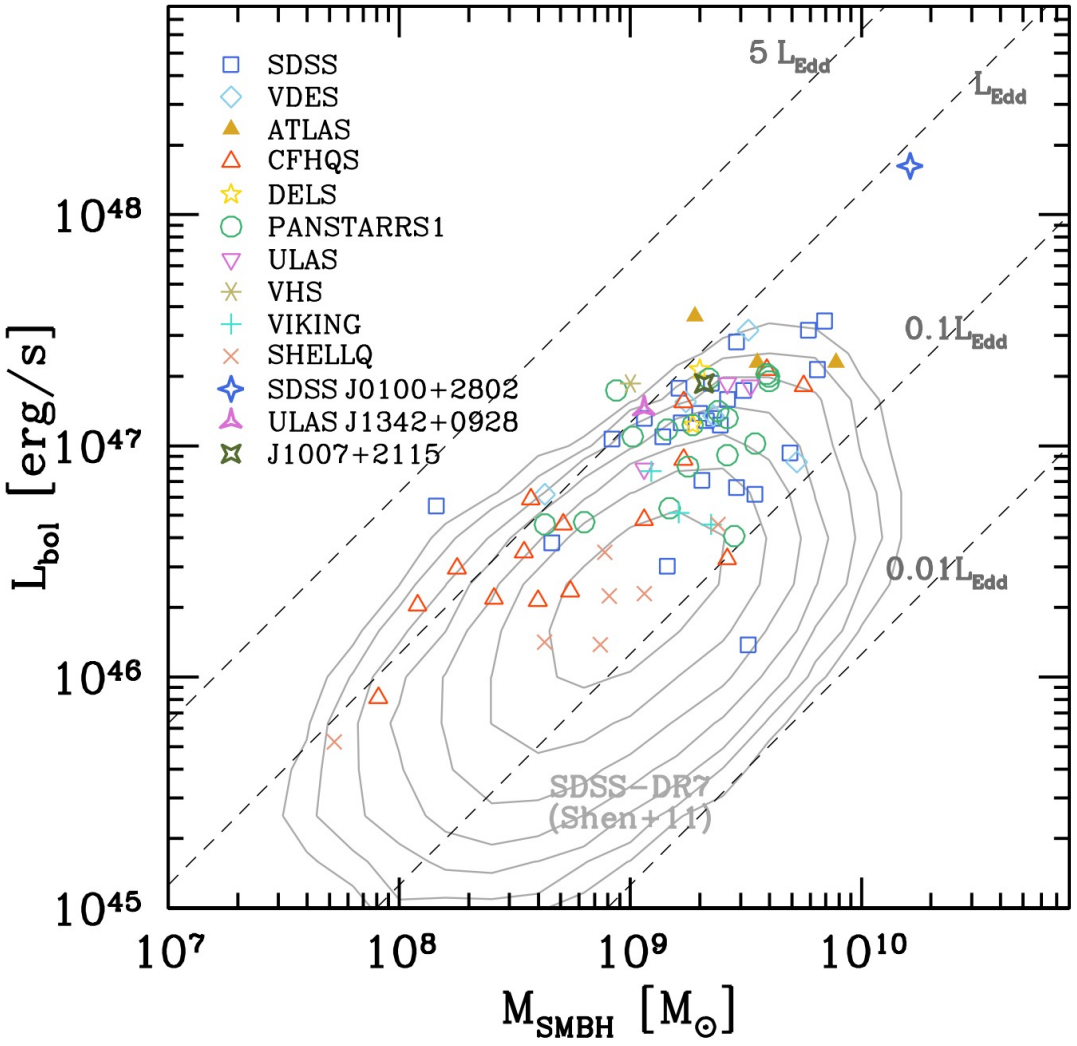
Notable sources

- Mass record holder:

SDSS J0100 $M_{SMBH}\approx 2\times10^{10}\ M_{\odot}$ (*Wu+2015*)

- Redshift record holder:

J0313–1806 z=7.64 (Wang+2021)



z>6 quasars are powered by fully grown SMBH

How can SMBHs grow in < 1Gyr?

The most massive SMBH are problematic to grow!

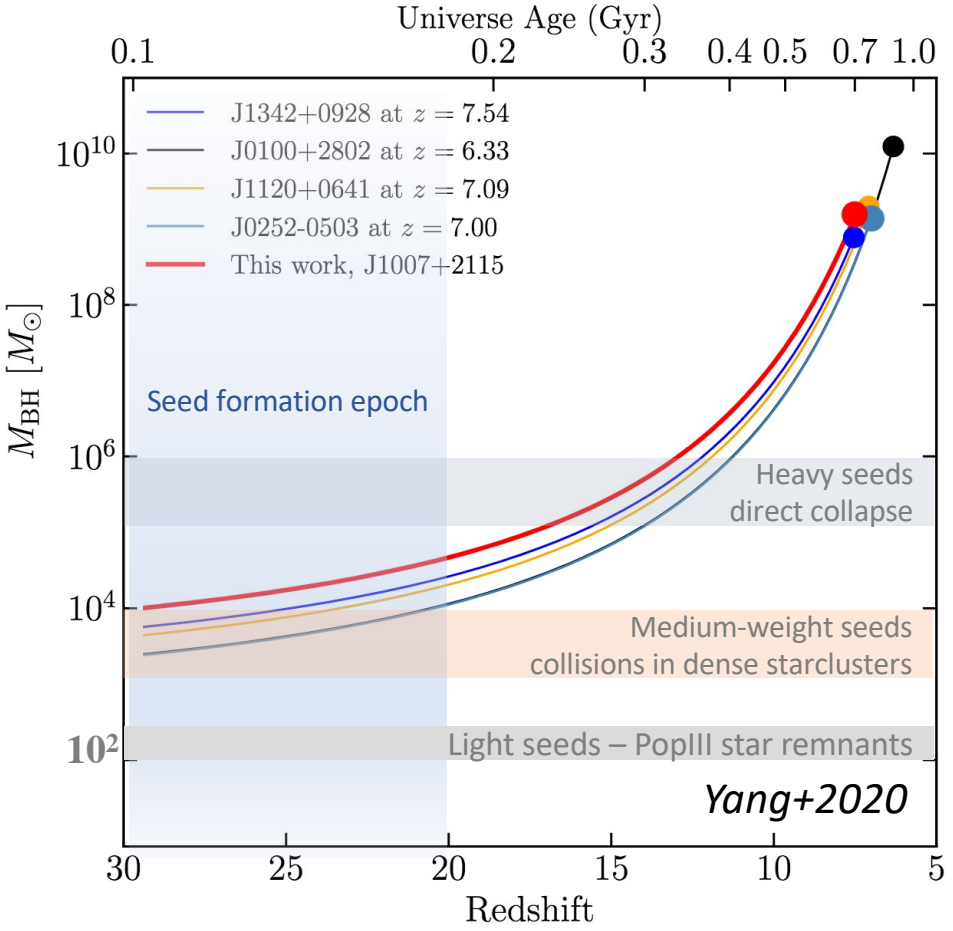
$$M_{BH}(t) = M_0 e^{t/\tau}$$

$$\tau \approx 0.45 Gyr \frac{\eta}{(1-\eta)} \frac{1}{\lambda_{Edd} \times f_{duty}}$$

with λ_{Edd}=1

duty cycle f_{duty}=1

radiative efficiency η=0.1



Need BH seeds of $M_{seed} \sim 10^4 M_\odot$

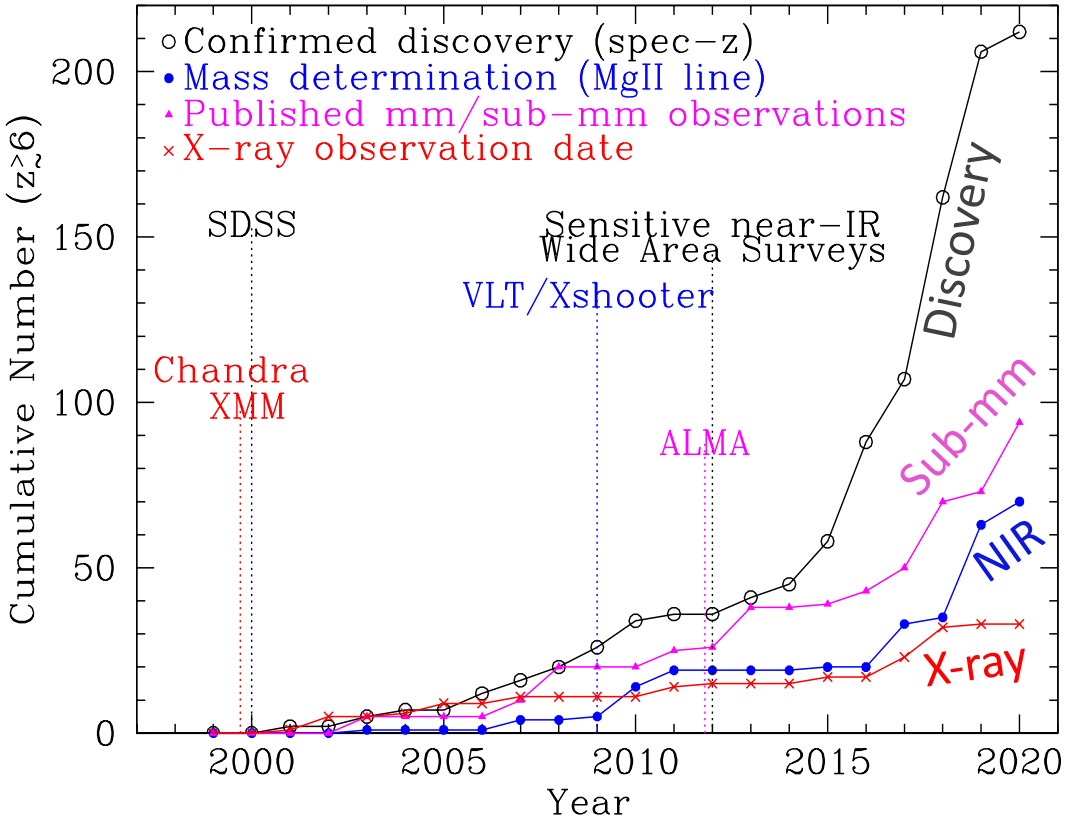
Super-Eddington accretion
(e.g. Volonteri+2015, *Pezzulli+2016, 2017*)

BH-BH mergers
(e.g. *Volonteri+2003, Valiante+2016,+2020*)

Characterizing z>6 QSOs

- Multi-λ compaigns
- Flagship observatories

- Faint fluxes
- Time-consuming observations
- Least efficient/sensitive in X-ray
- Observational bias (brightest, farthest QSOs)



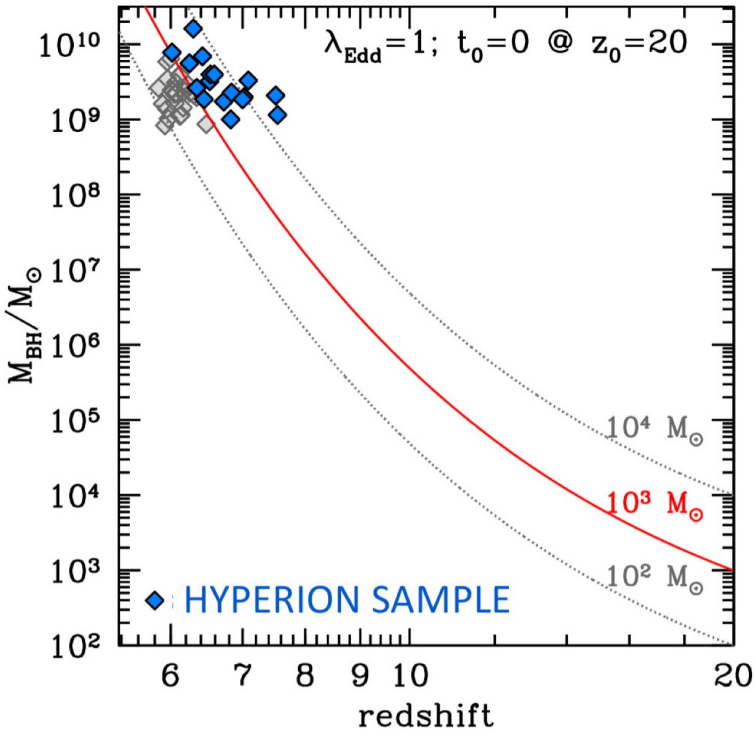
Observationally biased view:

1. etherogeneous QSO samples; 2. poor X-ray characterization

HSC new strategy

- Physically-motivated sample selection
  - Broad-line QSOs which experienced the fastest SMBH growth

HYPERION sample
(HYPerluminous quasars at the Epoch of ReionizatION)



- Panchromatic Homogeneous/high-quality
  - Obtain reliable/high-quality and homogeneous data from X-ray to sub-mm
    → X-rays most needed!

- Comparison with low-z QSO-analogs
  - Luminosity-matched sample at Cosmic Noon (z=2-3)

→ WISSH sample

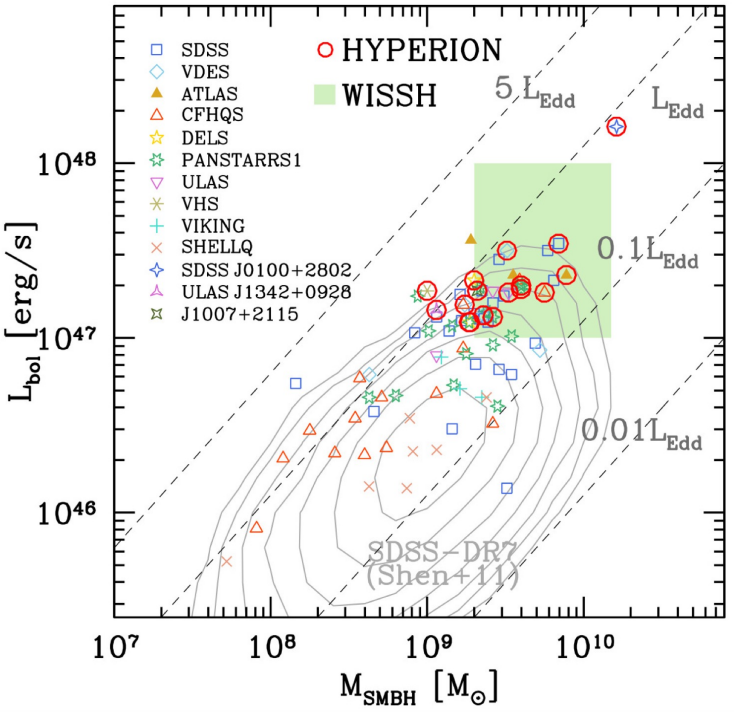
HYPERION Multi-Year Heritage XMM-Newton programme (XMM-HYPE)

- Dec 2020 (PI L. Zappacosta)
- 2.4 Ms (~700 hours) in 3 years

  → the 4th largest XMM programme
- Dramatic spectral quality improvement
  - 10x increase: in average quality
  - 5x increase: number of good quality spectra
- 15 QSOs @ z=6-7.5

Unprecedented constraints at EoR:

- nuclear properties
- accretion/ejection
- disc/corona system



HYPERION
From nuclear to host scales: NIR/sub-mm data

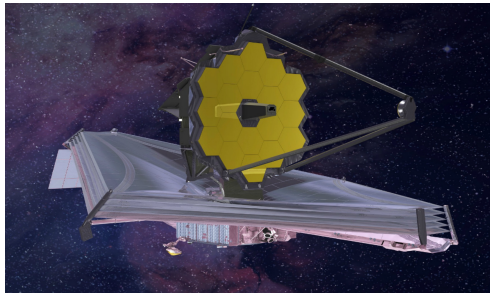
NIR/sub-mm archival etherogeneous datasets (instrumentation, spectral setup, quality, depth, simultaneity)

- Aggressive proposals campaign in 2021 to improve, increase and homogeneize NIR/sub-mm datasets

  → 5 INAF-led proposals accepted!
  (NOEMA, ALMA, TNG, LBT)

- New proposals in 2022 (VLT/X-shooter, ALMA, TNG, NTT, …)

- Many of these sources are JWST GTO targets (members of HSC are involved)



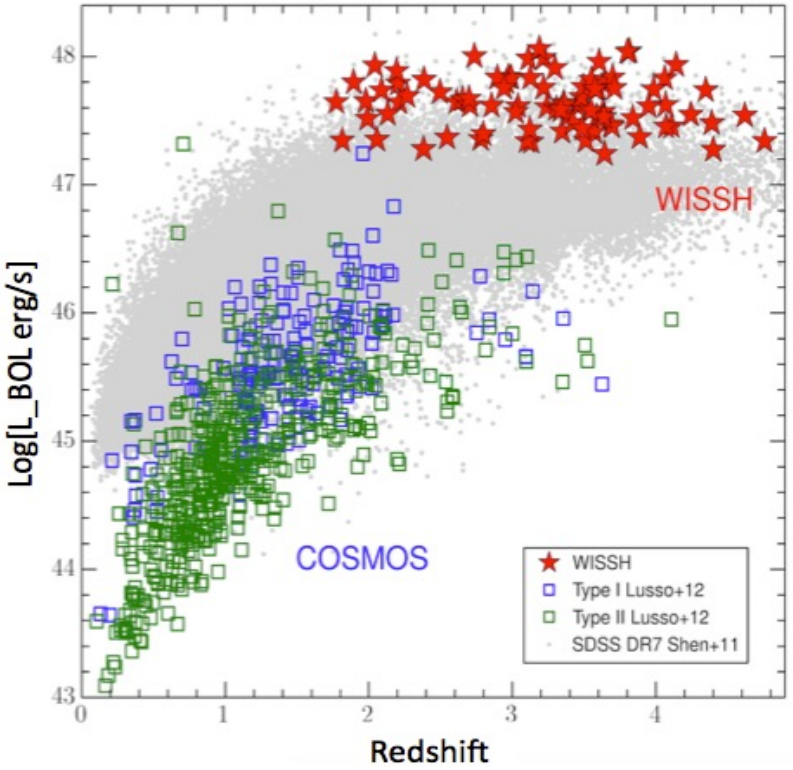
WISSH quasar sample

WISE/SDSS-Selected Hyperluminous quasar sample
(Coordinator: E. Piconcelli, INAF-OAR)

- Well established program (2016)
- The most luminous 85 broad-line quasars at z>1.5
- 1.9< z < 4.5 (peak @ z≈3)

Extensive multi-wavelegth coverage with proprietary/archived observations

Accepted 2021 proposals: Chandra, LBT, NOEMA (all INAF-led)



HSC team

- Young collaboration
- INAF-led
- international

- 20 institutes
- 5 INAF
- 7 foreign

- 44 scientists
- 22 INAF researchers

Scheda INAF

Total: 4.0 FTE/yr
INAF: 2.5 FTE/yr
INAF Associates: 1.5 FTE/yr

Coordinator: Luca Zappacosta (INAF-OAR)

Univ. Insubria, Italy
Francesco Haardt

ASI, Italy
Simonetta Puccetti

IAP, France
Marta Volonteri

CfA, USA
Francesca Civano
Martin Elvis

ESO
Michele Ginolfi

INAF-OAPD, Italy
Andrea Grazian

INAF-OAA, Italy
Simone Bianchi

SNS, Italy
Stefano Carniani
Simona Gallerani
Livia Vallini

Univ. Tor Vergata, Italy
Francesco Tombesi
Simone Mestici

INAF-OAR, Italy
Angela Bongiorno
Marco Castellano
Emanuele Giallongo
Nicola Menci
Fabrizio Nicastro
Laura Pentericci
Enrico Piconcelli
Vincenzo Testa
Rosa Valiante
Giustina Vietri

INAF-OATS, Italy
Manuela Bischetti
Stefano Cristiani
Valentina D'Odorico
Chiara Feruglio
Fabrizio Fiore
Roberta Tripodi

INAF-OAS, Italy
Andrea Comastri
Roberto Gilli
Eros Vanzella
Fabio Vito

Univ. Bologna, Italy
Marcella Brusa
Cristian Vignali

Univ. La Sapienza, Italy
Raffaella Schneider

Univ. Roma Tre, Italy
Fabio La Franca
Ivano Saccheo

Univ. Milano-Bicocca, Italy
Sebastiano Cantalupo
Andrea Travascio

Cambridge Univ., UK
Roberto Maiolino

CSIC-INTA, Spain
Giovanni Miniutti

Durham Univ., UK
Christine Done

ESTEC/ESA
Matteo Guainazzi

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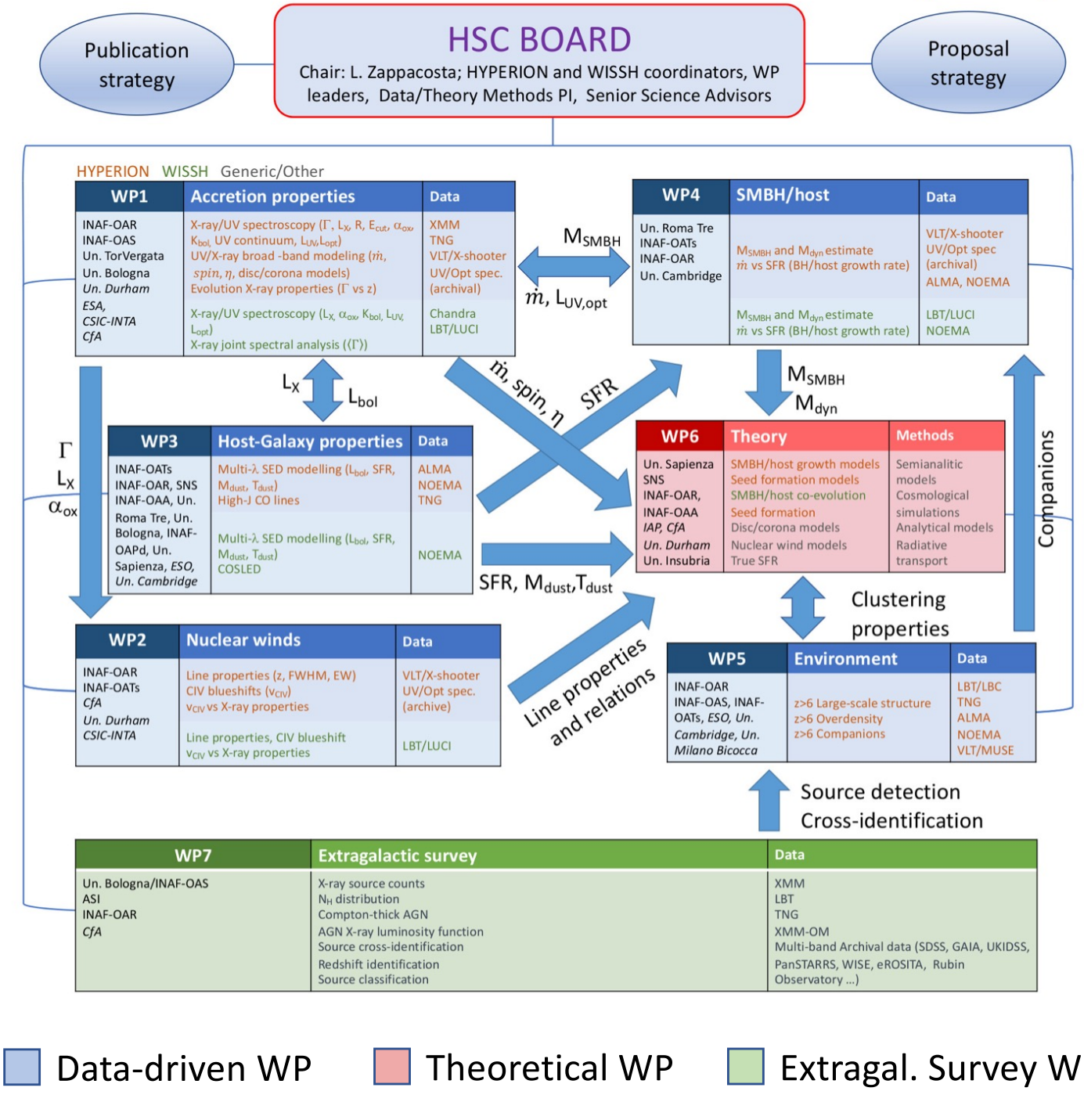


Data-driven WP Theoretical WP Extragal. Survey WP

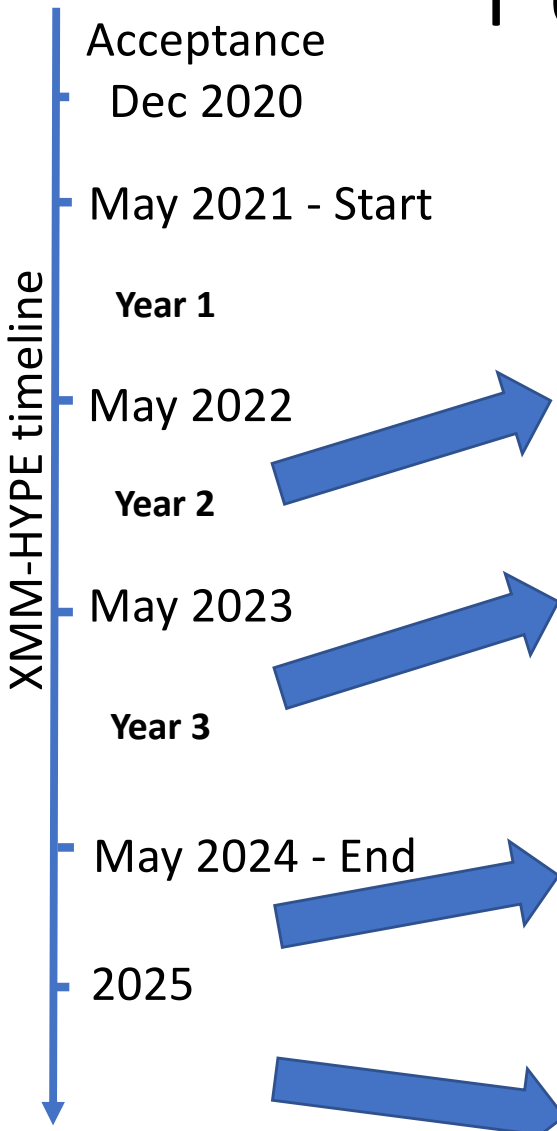
HSC proposals awarded (Dec 2020-Jan 2022)

INAF Large grant

for the exploitation of this large amount of data

Observational program ID	Instrument band	PI	Awarded time (hours)	Proposal code	Acceptance date	Proposal title	Observation dates	Sample
OP1	XMM X-ray	Zappacosta INAF-OAR	667	088499	Dec 2020	HYPerluminous quasars at the Epoch of ReionizatION (HYPERION)	May2021- May2024	HYPERION
OP2	NOEMA Sub-mm/mm	Feruglio INAF-OATS	4	S21DH	May 2021	HYPerluminous quasars at the Epoch of ReionizatION (HYPERION) Survey with NOEMA	Nov 2021	HYPERION
OP3	LBT/LBC Otptical/NIR	Castellano INAF-OAR	30	IT-2021B-033	Jul 2021	The large-scale environment of the titans among QSOs in the Reionization Epoch	2021-2022	HYPERION
OP4	Chandra X-ray	Piconcelli INAF-OAR	61	23700190	Jul 2021	The Chandra route towards defining the X-ray properties of the most luminous quasars in the universe	Jan 2022-Dec2022	WISSH
OP5	LBT/LUCI NIR	Piconcelli INAF-OAR	5.5	IT-2021B-011	Jul 2021	Probing the role of nuclear winds in shaping the AGN radiation output in luminous quasars	2021-2022	WISSH
OP6	NOEMA Sub-mm/mm	Feruglio INAF-OATS	16.6	W21ED	Oct 2021	Dust masses of z~6 QSOs from the HYPERION sample	Dec2021-May2022	HYPERION
OP7	NOEMA Sub-mm/mm	Piconcelli INAF-OAR	21	W21CZ	Oct 2021	The circum-galactic environment of the most luminous quasars	Dec2021- May 2022	WISSH
OP8	NOEMA Sub-mm/mm	Bischetti INAF-OATS	10	*W21DG*	Oct 2021	Building the CO SLED of the most luminous QSOs at Cosmic noon	Dec2021- May 2022	WISSH
OP9	ALMA-7m Sub-mm/mm	Feruglio INAF-OATS	20	2021.2.00151.S	Dec2021	An ACA pilot study of dust properties and SFR in QSOs at EoR	Jan 2022-Dec 2022	HYPERION
OP10	TNG NIR	Zappacosta INAF-OAR	20.5	A45TAC_28	Jan 2022	The TNG view of luminous quasars at the Epoch of Reionization	Apr 2022-Sept 2022	HYPERION

Publication schedule



XMM-HYPE (3 years time span) + proposals awarded

➔ up to 15 publications in the next 3-4 years

2022 (after Year 1)

1. XMM-HYPE program presentation, 1st year results (Zappacosta et al. in prep.)
2. Disc/corona modelling of the most luminous HYPERION QSO (Mestici et al.)
3. Dust properties and SFR of high redshift QSOs (Tripodi et al. in prep.)

2023 (after Year 2)

2. X-ray spectroscopy for z>7 quasars (Year 2 of XMM-HYPE).
3. UV-to-FIR rest-frame SED modeling of HYPERION QSOs (Saccheo et al.)
4. sub-mm high-resolution maps, kinematics, line spectra, companions for HYPERION

2024 (after Year 3)

5. sub-mm dust properties and SFR in HYPERION
6. Co-eval UV/X-ray broad-band disc/corona modelling of HYPERION QSOs;
7. Broad-line winds and X-ray emission for HYPERION and WISSH QSO
8. dust properties and companions in WISSH
9. Full X-ray spectroscopic analysis of XMM-HYPE
10. investigation of the environment of the most luminous/massive QSO at z>6
11. X-ray variability study of HYPERION QSOs

2025

12. multi-band (from X-ray to sub-mm) characterization of the sample;
13. semi-analytical/numerical modeling of the SMBH and host galaxy assembly;
14. extragalactic X-ray survey of the HYPERION fields
15. X-ray clustering and environment at EoR

HSC programme strength

- HSC will open the frontiers of X-ray spectroscopic population studies in the EoR (a decade earlier than ATHENA)

  → will allow first holistic view of z>6 QSO population

- Establish INAF leadership in the z>6 AGN studies

- Experienced team members
  - Broad expertise and international leadership in high-z Universe, EoR, AGN, host galaxy, CGM environment, winds and feedback and SMBH formation (both on the observational and theoretical side)
  - Optimal exploitation and interpretation of data

- Strong legacy value for the community
  - Preparatory for ATHENA and next-gen X-ray missions targeting z>6 Universe
  - Reliable X-ray data quality → will support other bands studies for a decade (e.g. JWST, ELT)
  - Multi-band homogeneity of datasets → reference for QSO/host studies at EoR
  - Crucial for improving models for SMBH/host-galaxy formation

Critical issues

Need to be competitive at international level

- Many proprietary data + 1 year data rights (optimization reduction/analysis)

→ fast publication track

- Need NOW dedicated, relatively experienced, manpower (currently 2, partly dedicated, PhD students and 1 Master Thesis student)

→2 post-docs for nuclear and host galaxy properties

- No dedicated fundings to support and consolidate our leadership (applied to INAF Large grant, PRIN2022)

→Need dedicated funds

(Hiring, internal meetings, participation to conferences, publication, computers and backup storage)

Conclusions

- Unique opportunity to characterize and study the formation and co-evolution of SMBH/host-galaxy systems at EoR
  - One of the largest X-ray programme ever awarded
  - Multiple proprietary and complementary datasets

- Team with well established expertise and leadership on many AGN/high-z universe observational and theoretical topics
  - Optimization of the data exploitation
  - Capability to interpret data (both from observational and theoretical side)

- INAF at the forefront of the EoR exploration

Criticalities

- Lack of manpower

  → need dedicated post-docs manage large amount of data

- No dedicated fundings
- 1 yr proprietary data from observation

  → need funding/manpower ASAP to be competitive at international level.