PhD name: Antonio Pensabene **Tutor: Roberto Decarli (INAF-OAS)**
PhD Cycle: XXXIV **UNIBO contact person: Marcella Brusa**

RESEARCH PROJECT: QUASARS AT THE DAWN OF COSMIC TIME

Scientific Rationale

Quasars beyond redshift $z\sim6$ (age of the Universe < 1 Gyr) are the most luminous non-transient sources in the Universe and are believed to be the progenitors of present-day early-type massive galaxies. The immense luminosities ($L_{\rm bol} > 10^{13}\ L_\odot$) from their active nuclei (AGN) powered by rapid accretion of matter (at rates > 10 $M_\odot\,{\rm yr}^{-1}$) onto a central supermassive black hole (BH, $M_{\rm BH} > 10^8\ M_\odot$), outshine the starlight emission of any galaxies. The fast growth of the black hole in these quasars pairs with the rapid consumption of huge gas reservoirs through vigorous episodes of star formation (SFR > 100 $M_\odot\,{\rm yr}^{-1}$). Such AGN are able to regulate the star formation activity in the host by expelling gas from galaxy with powerful outflows, thus constraining both the final stellar mass and dynamical properties of the host. This feedback mechanism sets a closely linked evolution between growing BHs and assembling galaxy across the cosmic time, giving place to the BH-galaxy scaling relations observed in the local Universe ($z < 1$). Therefore, the host galaxies of $z > 6$ quasars are ideal laboratories to characterize the physical properties of the interstellar medium (ISM) in extreme conditions, and they provide an insight of the interplay between star formation and BH accretion in massive galaxies emerging from cosmic dawn. The redshift $z \sim 6$ range is of particular interest because it corresponds with the last phase transitions of the Universe, from neutral state at $z > 10$ to a mostly ionized phase at $z < 6$. Hence, $z > 6$ quasars can be used as beacons to shed new light on the properties of intergalactic medium at the end of the epoch of reionization. Models and numerical simulations of massive BHs formation at early epochs predict that $z > 6$ quasars reside at the peak of the large-scale density structure, and therefore, such high-z quasars can also be used to identify the first galaxy overdensities. To date, ~200 quasars have been discovered at $z > 6$. The very presence of such BHs at these early epochs requires rapid built-up of BHs and galaxy assembly, thus challenging our understanding of how BHs form in the first place. The discovery and characterization of quasars beyond $z \sim 6$ therefore opens a powerful window to study the formation and early evolution of BHs and galaxies.

Project Goals

My PhD research project has been primarily focused on characterization of quasar host galaxies in the early Universe ($z > 6$, age of the Universe < 1 Gyr) through the study of their interstellar medium (ISM) and dust physical properties, gas kinematics, and their stellar population. To this purpose, observations at (sub-)mm wavelengths are instrumental to unravel the cold gas and dust emission in $z > 6$ quasar hosts. This approach is crucial to achieve a deep understanding on how the manifold interstellar medium drives the evolution of the quasar hosts under extreme conditions. This also enables to explore the impact of massive accreting BHs on the hosts and their interplay with star formation and the gaseous reservoirs in the early Universe.

Achievements of the PhD research activity

Quasar host galaxies at z > 6. During my PhD I led the first ALMA multiline study aiming to dissect the multiphase ISM in quasar hosts with nearby non-active companion galaxies at z > 6 (Pensabene et al. 2021). By combining information from different tracers (i.e., $[CII]_{158um}$, $[NII]_{205um}$, $[CI]_{369um}$, CO at mid- and high-J, H_2O, OH, and the far-infrared (FIR) dust continuum), I employed state-of art radiative transfer codes (CLOUDY, RADEX, MOLPOP-CEP) to put constraints on the ISM and the dust physical properties. By modeling FIR continuum, we estimated dust masses, spectral indexes, IR luminosities, and the star-formation rates. Our models suggest that fine-structure lines (FSLs, with the exception of [NII] which traces the fully ionized medium), arise predominantly from the neutral medium in the photo-dissociation regions (PRDs), at the outskirt of molecular clouds. The CO spectral line energy distributions (SLEDs) reveal strong high-J CO excitation associated with high-density medium impinged by intense X-ray radiation field in the central regions of quasar hosts, contrary to the companions which CO SLEDs are comparable with those of local starburst galaxies. Also, CLOUDY models reveal that the molecular mass is dominated by PDRs in all the sources. The multiple H_2O line detections allowed us to explore the water vapor excitation mechanism revealing a significant contribution of radiative pumping by IR photons in PDRs. Finally, models of H_2O SLEDs and OH allowed us to constrain the physical properties of the denser gas-phase ISM in the depths of molecular clouds. This study sheds a first light on the complex and extreme conditions at which ISM is exposed in massive galaxies at the end of Epoch of Reionization (EoR). To further push in this direction, I started a pioneering observational campaign with ALMA (11.5 hours) and NOEMA (80 hours, see Competitive Telescopes section) in order to systematically search for H_2O and OH^+ emission in IR-bright quasar hosts. This study will provide us with an unprecedented view of the warm and dense phase of the ISM that is still largely unknown at high redshifts and will be also instrumental in unraveling shocked medium in AGN-driven molecular outflows. Part of the program has been already executed, and the data have been part of my Marco

Polo program at Leiden University (Netherlands, conducted remotely due to the COVID outbreak) in collaboration with Prof. P. van der Werf and his group. This work is collected in Pensabene et al. (in prep; see Publications section).

Co-evolution between black holes and galaxies. Part of my PhD research activity laid its foundation on my Master Thesis work focused on the investigation of the onset of BH-galaxy relation in the early Universe. To this purpose, I capitalized on publicly available ALMA observations of a large sample of $2 < z < 7$ quasar host galaxies targeted in the atomic fine-structure line [CII] or CO rotational lines, with which I performed accurate modeling of the cold gas kinematics as traced by these bright emission lines (see Pensabene et al. 2020). My work overcomes the large uncertainties related to the rough virial galaxy mass estimates usually adopted so far. The result suggests an evolution of the BH-mass to galaxy-mass ratio increasing the redshift, laying the groundwork for future follow-up investigations in order to assess whether this evolution proceeds all the way into the EoR.

Quasar discovery and identification. During my research I have been involved in several initiatives led by an international team aiming at the discovery of new quasar at $z > 6.5$ and the study of the rest-frame UV variability of known quasars. In this context, I spent part of my research period as visiting astronomer at the Roque de Los Muchachos Observatory (NOT telescope – La Palma, Canary Islands), and La Silla Observatory in (ESO/NTT telescope – Chile) in order to perform NIR photometric observations to clear out contaminants from the drop-out quasar candidates. The success of such program is reported in recent papers to which I contributed as co-author and led to the discovery of the most distant radio-loud quasar known to date (see Andika et al. 2020, Banados et al. 2021; in Publications and Press Releases section). I also acquired additional observing experience at Loiano Observatory (152cm Cassini Telescope – Loiano, Italy) and I took care of several service and delegated visitor mode observations.

Other relevant projects. I started to be part of the J1030 project as an expert of astronomy at (sub-)mm wavelength, aimed at studying the field around the z=6.31 quasar J1030+0524 to search for the first evidence of large-scale overdensity trough mm-spectroscopy of $z\sim6$ galaxy candidates. Also, I have been involved in BLACKOUT project which aims to study the BH feedback mechanism as the driver of BH-galaxy co-evolution across the cosmic time. Some of these activities led to scientific publications to which I contributed as a co-author (see Publications section). I am also currently involved in several JWST initiatives (see approved program for Cycle 1, in Competitive Telescopes section) that will allow us to directly link the gaseous reservoirs to the on-going unobscured star formation and the build-up of the stellar population in quasar hosts, thus providing a benchmark for models of the formation of these early massive galaxies. I also started a project that capitalizes on the rich datasets from HST archive of NIR and optical/UV observations of $z > 6$ quasars, with the goal of searching for any signature of starlight emission from quasar hosts by modeling the PSF of the instrument in existing public data. This project will be carried out in the following years and will be key in view of the forthcoming launch of JWST.

CONFERENCES, WORKSHOPS, MEETINGS, SEMINARS & TALKS

1st doctoral year:

17 December 2018, ESO headquarters, Vitacura (Santiago), Chile –
Thirty Minutes Talk (TMT)
Talk: "The ALMA view of quasars host galaxies at the dawn of cosmic time"

25-27 February 2019, Bologna, Italy –
ALMA Science and Proposals Workshop
Talk: "The ALMA view of the high redshift relation between supermassive black holes and their host galaxies"

3-7 June 2019, Viana do Castelo, Portugal –
IAU Symposium 352: Uncovering the Early Galaxy Evolution in the ALMA and JWST era
Poster: "The ALMA view of quasar host galaxies at the dawn of cosmic time"

2-6 September 2019, Bologna, Italy –
Views of the Interstellar Medium in galaxies in the ALMA era
*Talk: "*The ALMA view of quasars host galaxies at the dawn of cosmic time"

2nd doctoral year:

18-19 December 2019, INAF-OAS, Bologna, Italy –
J1030 Team Meeting – The field around the z=6.31 quasar SDSS J1030+0524
Details of the project: http://j1030-field.oas.inaf.it/index.html
Talk: "mm-spectroscopy of z~6 galaxy candidates: ALMA and NOEMA"

25-27 February 2020, INAF-Arcetri Garbasso, Firenze, Italy –
BLACKOUT Team Meeting – Black hole Outflows and the Baryon Life Cycle of Galaxies
Details of the project: http://blackholewinds.inaf.it
Talk: "[CII] observations of z~6 QSOs"
canceled due to the COVID outbreak

1-6 March 2020, Ringberg Castle, Kreuth, Germany (*attended remotely*) –
Black Holes and Galaxies at the Edge of the Universe
Talk: "Unveiling the multiphase ISM of z>6 quasar host galaxies with ALMA"

30 March – 1 April 2020, Nice, France –
Multi-line Diagnostics of the Interstellar Medium
canceled due to the COVID outbreak
6-8 April 2020, online workshop –
JWST Italian Proposal Preparation Workshop
Attended
6-9 July 2020, online conference –
SAZERAC: The Summer All-Zoom Epoch of Reionization Astronomy Conference
Attended

3rd doctoral year:

5-9 October 2020, online workshop –
Dark and Quiet Skies for Science and Society
Attended
12-16 October 2020, online seminars –
AGN Tourneys 2020: Waiting for the Renaissance
Attended
3-4 December 2020, online conference –
SAZERAC-Sip Quasars During Reionisation
Talk: "Unveiling the multiphase ISM of z>6 quasar host galaxies with ALMA"
16-17 December 2019, INAF-OAS, Bologna, Italy –
J1030 Team Meeting – The field around the z=6.31 quasar SDSS J1030+0524
Details of the project: http://j1030-field.oas.inaf.it/index.html
Attended
20 January 2021, online seminars –
"Astro Coffee" at University of Milano-Bicocca
Talk: "Unveiling the multiphase ISM of z>6 quasar host galaxies with ALMA"
24-25 February 2021, online conference –
SAZERAC-Sip CIDER-The Cold ISM During the Epoch of Reionisation
Attended
14-17 June 2021, online conference –
SAZERAC 2.0: The Summer All-Zoom Epoch of Reionization Astronomy Conference
Attended
13 July 2021, online seminars –
Hypatia colloquium: Early Career Astronomer series at ESO
Talk: "Unveiling the multiphase ISM of z>6 quasar host galaxies with ALMA"
12-23 July 2021, online school –
ISM OF GALAXIES: International Summer School on the Interstellar Medium of Galaxies, from the Epoch of Reionization to the Milky Way
Attended and participation to hands-on sessions
List of attended webinars of the series: **QUID ULTRA? Frontiers and Controversies in Astrophysics –**
2 February 2021, **"The astrochemical trail of our origin"**,
by C. Ceccarelli – Université Grenoble Alpes, IPAG
16 April 2021, **"The future of cosmology"**,
by J. Silk **–** Institut d'Astrophysique de Paris, The Johns Hopkins University, University of Oxford
18 May 2021, **"Quenching star formation in galaxies"**,
by R. Maiolino – Cavendish Laboratory, University of Cambridge (UK)
1 June 2021, **"The evolution of massive black holes through cosmic time"**,
by D. Sijacki – Institute of Astronomy, University of Cambridge (UK)
22 June 2021, **"The dark and luminous side of structure formation"**
by P. Madau – Department of Astronomy and Astrophysics, University of California Santa Cruz

During the 3 years, regular participation at the seminars organized by the Bologna Astrophysics Campus (*Joint Astrophysical Colloquia* and *Astrophysics Talks*) and, in the past 1.5 years sporadic participation to online seminar series advertised by the Italian Astrophysics community.

INTERNAL COURSES

1st doctoral year:

17-21 June 2019, DIFA-University of Bologna – **Statistics for Astrophysics**
Prof. Ben Metcalf

2nd doctoral year:

May – July 2020, virtual seminars on Multimessanger Astronomy – **Neutrinos and Dark Matter in Astro- and Particle Physics**
The program of the attended lectures can be found at:
http://www.sfb1258.de/graduate-school/virtual-seminar-on-multimessenger-astronomy/

17,18, 21, 22 September 2020, online course – **GAIA: Great Advances in Astrophysics**
M. Bellazzini, A. Bragaglia, C. Cacciari, G. Clementini, D. Massari, R. Sordo, A. Sozzetti

3rd doctoral year:

30 November, 1-2 December 2020, online course – **The Interstellar Medium**
C. Ceccarelli, P. Caselli, R. Decarli

19-23 April 2021, online course – **Gamma Ray Bursts: from observation to physical properties"**
G. Ghirlanda, M. Giroletti

5,6,7,10,12,14 May 2021, online course – **Writing, Talking and Presenting Science**
R. Decarli, F. Walter, J. Hodge, B. Lanzoni

ISA LECTURES

1st doctoral year:

13 November 2018 , Palazzo Marchesini, Bologna – "**A heart attack: can we re-wire the heart?"**
by Prof. Damia Maawad – University of New South Wales, Sydney

7 May 2019, Palazzo Marchesini, Bologna – **"You have to be cool to go to Mars"**
by Prof. Steven John Swoap – Williams College, USA

2nd doctoral year:

3 December 2019, Palazzo Marchesini, Bologna – **"The physics of the vacuum"**
by Prof. Christian Schubert – Università Michoacana di San Nicolás de Hidalgo, Mexico

19 May 2020, online lecture – **"Exploration of small bodies of the Solar System: focus on comets"**
by Dr. Maria Cristina De Sanctis – Institute for Space Astrophysics and Planetology, INAF, Italy

3rd doctoral year:

15 December 2020, online lecture – **"Translating texts which do not exist. Pseudo-originality, multistable Figures, and Fortini's literary reception of Heine and Brecht"**
by Irene Fantappiè – Insitute für Romanische Philologie, Freie Univesität Berlin, Germany

26 January 2021, online lecture, **"RNA: Biological Functions and Therapeutic Potential"**
by Marco Marcia – European Molecular Biology Laboratory (EMBL)

RESEARCH PERIOD ABROAD

1st doctoral year:

Visiting Astronomer in the following observing runs:

18-27 July 2019, ESO/NTT, La Silla Observatory, Chile
Project: "Identification of new z>6.5 quasars in the Southern sky" (PI: Decarli)

20-26 December 2018, ESO/NTT, La Silla Observatory, Chile
Project: "Identification of new z>6.5 quasars in the Southern sky" (PI: Decarli)

2nd doctoral year:

Visiting Astronomer in the following observing runs:

9-13 November 2019, Nordic Optical Telescope, Roque de Los Muchachos Observatory, La Palma (Canary Islands), Spain
Project: "Identification of new z>6.5 quasars in the Northern sky" (PI: Decarli)

15-22 February 2020, 152cm Cassini telescope, Astronomical Observatory of Loiano, Italy
Project: "Variability of quasars in the first Gyr of the universe" (PI: Decarli)

3rd doctoral year:

Marco Polo project - Leiden University (Netherlands)
carried out remotely due to the COVID outbreak

November 2020 – May 2021. Project: "Characterize the warm dense phase of the ISM in quasar host galaxies at the dawn of cosmic time". Supervisor: Prof. P. van der Werf.

Visiting PhD student at Max Planck Institute for Astronomy (MPIA), Heidelberg (Germany)

4-10 July 2021. Invited by Dr. F. Walter to collaborate on projects related to the highest-redshift quasars in the Universe.

COMPETITIVE TELESCOPES

1st doctoral year:

Successful service mode proposals (as Principal Investigator):

IRAM PdBI/NOEMA – "Shocked and warm molecular gas in hyper-luminous infrared quasars at z>6", *35 hours*, Summer 2019

Other proposals (as Principal Investigator):

ALMA – "Systematic search for H2O emission in quasar host galaxies at z>6", rejected in Cycle 7

IRAM PdBI/NOEMA – "Shocked and warm molecular gas in hyper-luminous infrared quasars at z>6", rejected for Winter 2019 semester

Proposals as Co-I:

ALMA:

- "CO(7-6) and [CI] survey in z>6 quasars", PI: Decarli, accepted in Cycle 7
- "An unexpected guest: redshift and dust properties of one of the most extreme galaxies in the Universe", PI: Mingozzi, rejected in Cycle 7
- "Constraints on AGN-galaxy coevolution through resolved dynamical mass of high-z QSOs", PI: Perna, rejected in Cycle 7
- "A dust map of the field around the z=6.3 quasar J1030+0524", PI: Decarli, rejected in Cycle 7
- "First direct measurements of dust temperature in quasars at cosmic dawn", PI: Decarli, accepted in Cycle 7

IRAM PdBI/NOEMA:

- "Unraveling the power mechanism of the cold ISM in z>6 quasars", PI: Decarli, accepted for Summer 2019 semester
- "Witnessing the formation of the first large-scale structures in the universe", PI: Decarli, accepted for Winter 2019 semester

NOT (Nordic Optical Telescope):

- "Identification of new z>6.5 quasars in the Northern sky", PI: Decarli, accepted for period 59
- "Identification of new z>6.5 quasars in the Northern sky", PI: Decarli, accepted for period 60

ESO/NTT – "Identification of new z>6.5 quasars in the Southern sky", PI: Decarli, accepted for period 104

NRAO/JVLA – "The molecular gas content in unobscured QSOs at z=2", PI: Perna, rejected for semester 2020A

152cm Cassini telescope of Loiano:

- "Variability of quasars in the first Gyr of the Universe", PI: Decarli, accepted for February-July 2019
- "Variability of quasars in the first Gyr of the Universe", PI: Decarli, accepted for August 2019-January 2020

2nd doctoral year:

Successful service mode proposals (as Principal Investigator):

IRAM PdBI/NOEMA – "Unveiling the dense phase of the ISM in z>6 quasar host galaxies", *45 hours*, Summer 2020,

Other proposals (as Principal Investigator):

IRAM PdBI/NOEMA – "Unveiling the dense phase of the ISM in z>6 quasar host galaxies", rejected in Winter 2020

Proposals as Co-I:

IRAM PdBI/NOEMA:

- "High-density tracers in the most IR-luminous galaxy in the Universe", PI: Decarli, rejected in Summer 2020
- "High-density tracers in the most IR-luminous galaxy in the Universe", PI: Decarli, rejected in Winter 2020

ESO/NTT:

- "Identification of new z>6.5 quasars in the Southern sky", PI: Decarli, accepted for period 105
- "Identification of new z>6.5 quasars in the Southern sky", PI: Decarli, accepted for period 106

NASA/ESA HST – "The HST-J1030 mosaic: a legacy survey for early structure formation", PI: Chiaberge, rejected in Cycle 28

NOT (Nordic Optical Telescope) – "Identification of new z>6.5 quasars in the Northern sky", PI: Decarli, accepted for period 61

152cm Cassini telescope of Loiano:

- "Variability of quasars in the first Gyr of the Universe", PI: Decarli, accepted for February-July 2020
- "Variability of quasars in the first Gyr of the Universe", PI: Decarli, accepted for August 2020-January 2021

3rd doctoral year:

Successful service mode proposals (as Principal Investigator):

ALMA – "Systematic search of H2O emission in quasar host galaxies at z>6", *11.5 hours*, Cycle 8

Other proposals (as Principal Investigator):

IRAM PdBI/NOEMA – "Unveiling the dense phase of the ISM in z>6 quasar host galaxies", rejected in Summer 2021

Proposals as Co-I:

ALMA:

- "A comprehensive survey of [OIII] and dust temperature in quasars at cosmic dawn", PI: Decarli, rejected in Cycle 8
- "Unveiling a Massive Node of Cosmic Web at z=3", PI: Cantalupo, accepted in Cycle 8

- "An unexpected guest: redshift and dust properties of one of the most extreme galaxies in the Universe", PI: Mingozzi, rejected in Cycle 8
- "Outside the halo: Tracking with ALMA the Mpc-scale structure of a z∼1.7 protocluster", PI: Marchesi, rejected in Cycle 8
- "Dissecting the build-up of z∼7 galaxies", PI: Farina, accepted in Cycle 8

IRAM PdBI/NOEMA:
- "A molecular line scan on the IR-luminous quasar PJ083+11 at z=6.34", PI: Decarli, accepted in Summer 2021
- "Obscured AGN in an assembling protocluster at cosmic noon", PI: Decarli, accepted in Summer 2021
- "Obscured AGN in an assembling protocluster at cosmic noon", PI: Decarli, submitted for Winter 2021

ESO/NTT:
- "Identification of new z>6.5 quasars in the Southern sky", PI: Decarli, accepted for period 107
- "Identification of new z>6.5 quasars in the Southern sky", PI: Decarli, accepted for period 108

NASA/ESA HST – "The HST-J1030 mosaic: a legacy survey for large scale structure formation from cosmic dawn to cosmic noon", PI: Chiaberge, rejected in Cycle 29

NASA/ESA/CSA JWST:
- "Nebular line diagnostics in a merger at cosmic dawn", PI: Decarli, approved for Cycle 1
- "A snapshot survey of quasars and their host galaxies at cosmic dawn", PI: Decarli, rejected for Cycle 1

NOT (Nordic Optical Telescope):
- "Identification of new z>6.5 quasars in the Northern sky", PI: Decarli, accepted for period 63

GTC/NOT CCI International Time Programme – "The Canarias search for the first quasars: pushing the redshift frontiers to z>8", PI: Banãdos, accepted for semesters 2021B to 2023A.

152cm Cassini telescope of Loiano:
- "Variability of quasars in the first Gyr of the Universe", PI: Decarli, accepted for February-July 2021

Delegated visitor mode observing runs:

3-6 March 2021, 152cm Cassini telescope, Astronomical Observatory of Loiano, Italy
Project: "Variability of quasars in the first Gyr of the universe" (PI: Decarli)

23-28 May 2021, NOT, Roque de Los Muchachos Observatory, La Palma (Canary Islands), Spain
Project: "Identification of new z>6.5 quasars in the Northern sky" (PI: Decarli)

FUNDING APPLICATIONS

Included in the following applications for funding:

PRIN INAF 2019 – "The environments of first quasars: shedding light on the large scale structures around the most distant cosmological beacons", 129.000€, PI: R. Decarli (rejected)

PRIN MIUR 2020 – "Quasars beyond redshift 6: beacons on the Universe at cosmic dawn", 1.054.962€, PI: R. Decarli, (submitted)

OTHER RELEVANT ACTIVITIES

1st doctoral year:

Member of the Local Organizer Committee (LOC) of:

2-6 September Bologna, Italy – "Views of the Interstellar Medium in galaxies in the ALMA era"

2nd doctoral year:

Coordinator of the Weekly PhD Seminars (WPS) and PhD Journal Club

WPS were held from January 8th until February 21st and were then suspended due to the COVID-19 outbreak
Detailed summary of each meeting can be found at:
https://docs.google.com/document/d/139TWNBnvkZBJoiET-6XxuQtCcBzyAt2qs-2FVmZHs8o/edit

3rd doctoral year:

Coordinator of "UNI-PhDcast"

Project funded by University of Bologna for scientific dissemination via podcasting activities.
The first pilot project focused on PhD student activities is available at:
https://open.spotify.com/show/0xlXMTrCbMvpGm2wzCm7J0?si=JHLmXw5wR8Ks5doIjC8PuQ&dl_branch=1

PUBLICATIONS

First-author publications:

1) **The ALMA view of the high-redshift relation between supermassive black holes and their host galaxies**
Pensabene A., Carniani S., Perna M., Cresci G., Decarli R., Maiolino R., and Marconi A., 2020, A&A, 637, A84.
2) **ALMA multiline survey of the ISM in two quasar host—companion galaxy pairs at z>6**
Pensabene A., Decarli R., Banãdos E., Venemans B., Walter F., Bertoldi F., Fan X., Farina E. P., Li J., Mazzucchelli C., Novak M., Riechers D., Rix H.-W., Strauss M. A., Wang R., Weiß A., Yang J., and Yang Y., 2021, A&A, 652, A66.

3) **Unveiling the warm dense phase of the ISM in z>6 quasar host galaxies**
Pensabene A., van der Werf P., Decarli R., et al., in prep.
Latest version available at: https://www.overleaf.com/read/yyymhngvzhwq

Other publications:

4) **Testing the paradigm: First spectroscopic evidence of a quasar—galaxy Mpc-scale association at the cosmic dawn**
Decarli R., Mignoli M., Gilli R., Balmaverde B., Brusa M., Capelluti N., Comastri A., Nanni R., Peca A., *Pensabene A*., Vanzella E., and Vignali C., 2019, A&A, 631, L10.
5) **Discovery of molecular gas fueling galaxy growth in a proto-cluster at z=1.7**
D'Amato Q., Gilli R., Prandoni I., Vignali C., Massardi M., Mignoli B., Cucciati O., Morishita T., Decarli R., Brusa M., Calura F., Balmaverde B., Chiaberge M., Liuzzo E., Nanni R., Peca A., *Pensabene A*., Tozzi P., and Norman C., 2020, A&A, 641, L6.
6) **Probing the Nature of High Redshift Weak Emission Line Quasars: A Young Quasar with a Starburst Host Galaxy**
Andika I. T., Jahnke K., Onoue M., Banãdos E., Mazzucchelli C., Novak M., Eilers A., Venemans B., Schindler J., Walter F., Neeleman M., Simcoe R. A., Decarli R., Farina E. P., Marian V., *Pensabene A*., Cooper T. M., and Rojas A. F., 2020, ApJ, 903, 34.
7) **The discovery of a highly accreting radio-loud quasar at z=6.82**
Banãdos E., Mazzucchelli C., Momjian E., Eilers A.-C., Wang F., Schindler J.-T., Connor T., Andika I. T., Barth A. J., Carilli C., Davies F., Decarli R., Fan X., Farina E. P., Hennawi J. F., *Pensabene A.*, Stern D., Venemans B. P., Wenzl L., and Yang J., 2021, ApJ, 909, 80.
8) **New constraints on the interstellar medium and the associated outflow in the z=6.42 quasar J1148+5251**
Meyer R. A., Walter F., Cox P., Decarli R., Neri R., Novak M., *Pensabene A.,* Riechers D., Weiß A., ApJ, submitted.
9) **Mass and excitation of the molecular gas in z>6 quasar host galaxies**
Decarli R., et al., including *Pensabene A.*, in prep.

PRESS RELEASES

8 March 2021 – **INAF/MPG/MPIA/ESO**

The discovery of the most distant radio loud quasar (z=6.82)
INAF: https://www.media.inaf.it/2021/03/08/quasar-p172/
MPG: https://www.mpg.de/16478716/the-most-distant-radio-beacon-in-the-early-universe
MPIA: http://www.mpia.de/news/science/2021-04-quasar
ESO: https://www.eso.org/public/news/eso2103/