Rodrigo **Carvajal**

Astrophysicist · High-redshift studies · Data analysis

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Summary

I am an astrophysicist studying galaxy evolution through the analysis of high-redshift sources using astroinformatics and machine learning (ML) techniques. My work integrates multi-wavelength data from large-area surveys –including radio (EMU, LoTSS), ALMA, and optical/IR– to identify and characterise active galactic nuclei (AGN) and star-forming galaxies (SFGs). I have developed a robust classification and redshift estimation ML pipeline, published peer-reviewed results, and contributed to international collaborations and public engagement.

Education

I began my studies with a BSc in Astronomy at Universidad de Chile where I complemented my coursework with classes in atmospheric sciences, including atmospheric fluid dynamics and applied meteorology. I moved into research early, and soon developed an interest in galaxy evolution, leading to my MSc in Astrophysics at Pontificia Universidad Católica de Chile, where I studied dust attenuation properties of high-redshift Lyman-Break galaxies. This work, based upon the analysis of ALMA measurements and ancillary photometry, encouraged my strong interest in ALMA science and the study of the early Universe. My PhD studies at the Faculdade de Ciências of the Universidade de Lisboa, Portugal merged data science and astrophysics to build machine learning tools for the study of AGN and SFGs in deep radio surveys. This work employed data-driven approaches for feature engineering and model interpretability, culminating in several first-author publications and a fully operational pipeline for classifying sources and estimating their redshifts.

Instruction

Faculdade de Ciências, Universidade de Lisboa — *Lisbon, Portugal*
PhD in Physics and Astrophysics (Distinction, supvs.: J. Afonso, I. Matute, H. Messias) — *Nov. 2019 - Dec. 2024*
- Thesis: 'Towards better selection and characterisation criteria for high-redshift radio galaxies using machine-assisted pattern recognition'[1].

Pontificia Universidad Católica de Chile — *Santiago, Chile*
MSc in Astrophysics (Maximum distinction, supv.: F. E. Bauer) — *Mar. 2016 - Jan. 2019*
- Thesis: 'Stacking UV-selected Lyman-Break Galaxies in the ALMA Frontier Fields'[2].

Universidad de Chile — *Santiago, Chile*
Licenciado en Ciencias (BSc equivalent. Distinction) — *Mar. 2007 - Jan. 2014*
- Degree in Astronomy (no thesis required).

Prizes and Awards

I received a number of awards during my education, with one of the most relevant and competitive the PhD::SPACE Fellowship, which allowed me to complete my PhD studies. I also was given the opportunity to spend a month in the Joint ALMA Observatory (JAO) offices, working on the implementation of my PhD research on ALMA observations. This visit resulted in the preparation of an article close to submission.

2019 - 2024	**PhD::SPACE Fellowship,** Instituto de Astrofísica e Ciências do Espaço	*Lisbon, Portugal*
May 2024	**JAO Visitor Program,** Joint ALMA Observatory	*Santiago, Chile*
2017	**Teaching Assistant Scholarship (merit scholarship),** Pontificia Universidad Católica de Chile	*Santiago, Chile*
2007 - 2010	**Beca Universidad de Chile (merit scholarship),** Universidad de Chile	*Santiago, Chile*

Publications

My scientific contributions span 14 refereed papers, with three as first author. My MSc work resulted in Carvajal et al. (2020), which challenged the applicability of local dust relations to early galaxies. My PhD yielded Carvajal et al. (2021, 2023), presenting a ML pipeline that identifies radio AGN using photometry alone. These tools have been cited 25 times, used in EMU fields, and downloaded over 200 times from their repository. I have also contributed to collaborative publications, including EMU, the ALMA Frontier Fields, and theoretical AGN studies (NewAthena simulations), and have participated in a conference proceedings article and press release with wide media impact. Citation values from NASA ADS as of June, 2025[3].

Refereed Articles (first author)

Selection of powerful radio galaxies with machine learning
R. Carvajal, I. Matute, J. Afonso, R. P. Norris, et al.
A&A 679 A101. 2023. doi: 10.1051/0004-6361/202245770. Code: https://github.com/racarvajal/RAGN_pipeline_article, https://zenodo.org/records/10220009. Presented a novel machine learning pipeline for radio-detectable AGN classification, which significantly improves the accuracy over traditional methods, while obtaining physical insights from the decisions of the models.

Exploring New Redshift Indicators for Radio-Powerful AGN
R. Carvajal, I. Matute, J. Afonso, S. Amarantidis, D. Barbosa, et al.
Galaxies 9.4 p. 86. 2021. doi: 10.3390/galaxies9040086. Presented the application of machine learning models for the estimation of photmetric redshifts from radio-detected AGN in large-area surveys, improving the results and running times over traditional methods.

The ALMA Frontier Fields Survey. V. ALMA Stacking of Lyman-Break Galaxies in Abell 2744, Abell 370, Abell S1063, MACSJ0416.1-2403 and MACSJ1149.5+2223
R. Carvajal, F. E. Bauer, R. J. Bouwens, P. A. Oesch, et al.

[1] Thesis text available at http://hdl.handle.net/10400.5/99439
[2] Thesis text available at https://repositorio.uc.cl/handle/11534/22335
[3] ADS Public Library: https://ui.adsabs.harvard.edu/public-libraries/prom6U0VR26WDYTftnpfYw

A&A 633 A160. 2020. DOI: 10.1051/0004-6361/201936260. Described the study of Lyman-Break Galaxies in the ALMA Frontier Fields and their correlations between galactic properties obtained from SED fitting techniques and dust features from ALMA observations, setting constrains to local relations in high-redshift environments.

Refereed Articles (co-author, selected)

The Evolutionary Map of the Universe: A new radio atlas for the southern hemisphere sky
A. M. Hopkins, A. Kapinska, J. Marvil, T. Vernstrom, … **R. Carvajal**, et al.
PASA (in press) arXiv:2505.08271. 2025. DOI: 10.48550/arXiv.2505.08271. Validated observational data and provided review and edition to manuscript

Unveiling faint X-ray AGN populations in the NewAthena era: Insights from cosmological simulations
N. Covas, I. Matute, S. Amarantidis, J. Afonso, … **R. Carvajal**, et al.
MNRAS (accepted) arXiv:2504.10731. 2025. DOI: 10.48550/arXiv.2504.10731. Provided review and edition to manuscript

Improving machine learning-derived photometric redshifts and physical property estimates using unlabelled observations
A. Humphrey, P. A. C. Cunha, A. Paulino-Afonso, S. Amarantidis, … **R. Carvajal**, et al.
MNRAS 520.1 pp. 305–313. 2023. DOI: 10.1093/mnras/stac3596. Provided review and edition to manuscript

The ALMA Frontier Fields Survey. III. 1.1 mm emission line identifications in Abell 2744, MACSJ 0416.1-2403, MACSJ 1149.5+2223, Abell 370, and Abell S1063
J. González-López, F. E. Bauer, M. Aravena, N. Laporte, … **R. Carvajal**, et al.
A&A 608 A138. 2017. DOI: 10.1051/0004-6361/201730961. Conducted data tests and provided review and edition to manuscript

The ALMA Frontier Fields Survey. I. 1.1 mm continuum detections in Abell 2744, MACS J0416.1-2403 and MACS J1149.5+2223
J. González-López, F. E. Bauer, C. Romero-Cañizales, R. Kneissl, … **R. Carvajal**, et al.
A&A 597 A41. 2017. DOI: 10.1051/0004-6361/201628806. Conducted data tests and provided review and edition to manuscript

Conference Proceedings

Radio Galaxy Detection Prediction with Ensemble Machine Learning
R. Carvajal, I. Matute, J. Afonso, S. Amarantidis, and D. Barbosa
Machine Learning for Astrophysics, 2023, Cham. ISBN: 978-3-031-34167-0. DOI: 10.1007/978-3-031-34167-0_6

Experience

My research career began during my undergraduate studies, with internships and assistantships focused on early galaxy environments and molecular clouds. This early period included the opportunity of direct observational work at Las Campanas Observatory, and the contribution to projects exploring the environmental impact on distant galaxies using background QSO measurements and radio emissions from the Vela Molecular Ridge.

Between my BSc and MSc, I gained crucial experience at the Joint ALMA Observatory (JAO), participating in a pilot project analysing calibration measurements to understand Martian atmosphere wind profiles, successfully reproducing previous dedicated measurements and simulations. My MSc further developed my ALMA expertise through the study of over 1000 Lyman-Break galaxies in the ALMA Frontier Fields. By stacking observations to estimate their rest-frame infrared emission and contrasting these with HST SED fits, I uncovered complexities in dust attenuation relationships at higher redshifts, challenging existing models and contributing to the understanding of dust evolution.

During my PhD, which included a week-long shift leading pooled observations at the 30m Pico Veleta Radio Telescope, I developed a ML pipeline for the multi-wavelength analysis of radio-detectable AGN. This pipeline, trained on LoTSS and applied to Stripe 82 and EMU data, enables source selection and redshift estimation with over 95 % purity and completeness, outperforming other data-driven methods. I also investigated its individual steps using feature importance and extracted a novel colour-colour diagram for rapid AGN/SFG classification. This work has been extended to derive radio luminosity functions from classified sources, demonstrating consistent source densities with traditional methods. Furthermore, I was part of a collaboration with a data analysis company during my PhD to investigate the impact of measurement errors on machine learning. This successful partnership, highlighted in one of my publications, led to the company becoming a collaborator with my institute, sponsoring Erasmus students and their training.

Alongside my research, I have actively contributed to developing others and fostering collaborative relationships. During my BSc, I served as a teaching assistant for first-year Physics and mid-degree Astrophysics courses and laboratories. This commitment continued through my PhD, where I helped co-supervise over 20 MSc and BSc students on projects primarily related to AGN and ML methods, providing direct mentorship in data analysis techniques.

Research Experience

Faculdade de Ciências, Universidade de Lisboa — *Lisbon, Portugal*

Researcher — *Dec. 2024 - Present*
- AGN and machine learning-related investigations, follow-up of PhD work.

PhD Researcher — *Nov. 2019 - Dec. 2024*
- Research as a PhD student. Project ‘The first Radio Galaxies in the Universe’.

Joint ALMA Observatory (JAO) — *Santiago, Chile*

Scientific visitor — *May. 2024*
- Research as scientific visitor for four weeks. Working with H. Messias in the project ‘Identifying giants in ELAIS-S1 with machine learning’.

Research Assistant (supvs. Dr Rüdiger Kneissl, Dr David Rabanus) — *Jan. 2014 - Mar. 2015*
- Studied Mars’ atmosphere and produced profiles for temperature and wind speed using ALMA observations.

Institute of Astrophysics, Pontificia Universidad Católica de Chile — *Santiago, Chile*

Research Assistant — *Jan. 2019 - Oct. 2019*
- Imaged and analysed ALMA data for project ‘Hunting for redshifts of faint DSFGs in A2744’.

MSc Researcher — *Mar. 2016 - Jan. 2019*
- Research as MSc student. Project ‘Lyman-Break Galaxies in the ALMA Frontier Fields’.

Research Assistant (supvs. Prof. Franz Bauer, Dr Jorge González) *Aug. 2015 - Mar. 2016*
- Used image enhancement techniques to improve quality of ALMA observations and study objects with low signal-to-noise ratio.

Departament of Astronomy, Universidad de Chile *Santiago, Chile*

Research Assistant (supv. Prof. Sebastián López) *Aug. 2013 - Oct. 2013*
- Studied differences from outer structures of lensing galaxies through absorbed light of far quasars.

Research Assistant (supv. Dr Isabelle Pâris) *Mar. 2013 - May. 2013*
- Searched quasars pairs at small distances over catalogue of more than 100 000 objects (SDSS-DR9 Quasar Catalog. Pâris et al. 2012).

Research Assistant (supv. Prof. Sebastián López) *Mar. 2012 - Jul. 2012*
- Confirmed influence of thermal-broadening Doppler parameter in turbulent broadening in Intergalactic Medium.
- Measured correlation for results of Voigt curve-fitting procedures in metallic species absorption lines from far quasar emission.

Research Assistant (supv. Prof. Sebastián López) *Aug. 2011 - Dec. 2011*
- Determined influence of thermal-broadening Doppler parameter in turbulent broadening in Intergalactic Medium.

Research Assistant (supv. Dr Nadia Lo) *Jan. 2011*
- Worked in project "A study of the Molecular Properties of the Vela Molecular Ridge (Coud C)" searching possible clumps using data from Mopra Radio Telescope.

Student Supervision

Instituto de Astrofísica e Ciências do Espaço *Lisbon, Portugal*

Co-supervisor Summer Internship (supv. Dr I. Matute) *Jul. 2024*
- Guided J. Castelo and F. Rosado. Project: 'Supermassive Black Hole growth on galaxies: Linking AGN phases through Cosmic Time'.

Co-supervisor Summer Internship (supvs. Drs. B. Arsioli, I. Matute) *Jul. 2023*
- Guided L. Rodrigues, G. Monteiro, A. Correia, D. Barreta, and T. Melo. Project: 'Multifrequency Analysis and Machine Learning for the most powerful quasars in the Universe'.

Co-supervisor Summer Internships' students *Jul. 2021*
- Guided J. Sandrin, P. Ferreira, P. Rodrigues, and A. Monteiro. Project: 'Identifying and characterising AGN in next-generation radio surveys using machine and deep learning' (supv. Dr I. Matute).
- Guided A. Labib, M. E. Pimentel, L. Barroso, and J. Rato. Project: 'The 200: exploring the most active supermassive black holes in the first Gyr of the Universe' (supv. Dr J. Afonso).

Faculdade de Ciências, Universidade de Lisboa *Lisbon, Portugal*

Co-supervisor BSc student (supv. Dr I. Matute) *Sep. 2022 - Feb. 2023*
- Guided J. Bagagem. Project: 'Connecting galaxies photometry with Super-Massive Black Hole (SMBH) properties: A machine learning approach'.

Co-supervisor BSc student (supv. Dr I. Matute) *Sep. 2021 - Feb. 2022*
- Guided J. Lopes. Project: 'Modelling Active Galactic Nuclei with Machine Learning'.
- Guided B. Resendes. Project: 'Identifying and characterising AGN in next-generation radio surveys with machine learning'.

Co-supervisor BSc student (supv. Dr I. Matute) *Sep. 2020 - Feb. 2021*
- Guided I. Tiago. Project: 'Understanding triggering Radio emission from AGNs'.

Co-supervisor BSc student (supv. Dr J. Afonso) *Jul. 2020*
- Guided L. Piscarreta on studying radio and X-ray emission of high-z AGN.

Teaching Experience

Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile *Santiago, Chile*

Teaching Assistant FI1001: Introduction to Newtonian Physics. Dept. of Physics (Lecturer: Prof. S. López) *Mar. 2013 - Jul. 2013*
- First-year course for scientists and engineers

Teaching Assistant EI2001: Project Workshop. School of Engineering (Lecturer: Prof. S. López) *Mar. 2013 - Jul. 2013*
- Led hands-on activities on CCD characterisation at university observatory with using real observational data.

Teaching Assistant AS3004–AS758: Intergalactic Medium. Dept. of Astonomy (Lecturer: Prof. S. López) *Mar. 2012 - Jul. 2012*
- Marked evaluations for undergraduate and graduate students in the course.

Time Allocation

PI. ACA@ALMA *115 hours (Graded C)*
2024.1.01181.S. How rich are the environments of high redshift radio galaxies? *Cycle 11*

Co-PI. 12m@ALMA *14 hours (Graded B)*
2017.1.01219.S. Hunting for redshifts of faint DSFGs in A2744 (PI: F. Bauer) *Cycle 5*

Observation Experience

30m Pico Veleta Radio Telescope *IRAM, Spain*
NIKA2 and EMIR instruments - One-week observation run under pooled observations scheme *Nov. 2022*

6.5m Magellan-Clay Telescope *LCO, Chile*
MagE instrument - One-night observation run under the supervision of Dr. Isabelle Pâris *Feb. 2013*

Participation in Conferences and Seminars

I have presented my work at more than 40 national and international conferences, workshops, and seminars, including invited talks at ESO and JAO. My presentations have ranged from radio galaxy detection and photometric redshifts to ML techniques, including the study of early SFGs.

Contributed Talks (Selected)

Deep 24. Beyond the Edge of the Universe — *Sintra. Portugal*
'Radio Luminosity Functions from ML Analysis' — *Oct. 2024*

International EMU Collaboration Meeting 2024 — *Perth. Western Australia*
'Enhancing radio luminosity functions with machine learning' — *Sep. 2024*

Debating the potential of Machine Learning in astronomical surveys # 2 — *IAP, Paris/Flatiron Institute, New York*
'Extracting physical rules from ensemble machine learning for the selection of radio AGN' — *Nov. 2023*

SPARCS XI. Meeting of the SKA Pathfinders Radio Continuum Surveys (SPARCS) — *IDIA. South Africa*
'Ensemble Machine Learning for Radio Galaxy detections' — *Nov. 2022*

SPARCS X. Meeting of the SKA Pathfinders Radio Continuum Surveys (SPARCS) — *IDIA. South Africa*
'Using ensemble Machine Learning to predict high-redshift Radio Galaxy detections' — *Nov. 2021*

Debating the potential of Machine Learning in astronomical surveys — *IAP, France*
'Using a series of Machine Learning Models for the detection of high-redshift Radio Galaxy candidates' — *Oct. 2021*

50th Young European Radio Astronomers Conference — *IRAM*
'Using Machine Learning to identify high-redshift Radio Galaxy candidates' — *Aug. 2021*

RGCW: A new window on the radio emission from galaxies, clusters and cosmic web — *INAF. Italy*
'Exploring new redshift indicators for radio-powerful AGNs' — *Mar. 2021*

Distant Galaxies from the Far South — *Bariloche, Argentina*
'Stacking in the ALMA Frontier Fields' — *Dec. 2017*

Invited Talks and Seminars (Selected)

IA/ML Forum - ESO — *Garching, Germany*
'How confident can you be? Calibrating probabilities for the selection of AGN' — *Jun. 2024*

Seminar - Joint ALMA Observatory (JAO) — *Santiago, Chile*
'Identifying giants in ELAIS-S1 with machine learning' — *May. 2024*

Machine Learning in Astronomy Group – SPARCS — *WSU. Sydney, Australia*
'Developing a ML pipeline to detect high-redshift Radio Galaxy candidates' — *Jun. 2021*

Seminar - Instituto de Astrofísica e Ciências do Espaço — *Lisbon, Portugal*
'Stacking UV-selected Lyman-Break Galaxies in the ALMA Frontier Fields' — *Jul. 2020*

Seminar - ESO — *Santiago, Chile*
'Stacking UV-selected Lyman-Break Galaxies in the ALMA Frontier Fields' — *Jun. 2019*

Skills

I specialise in Python-based data pipelines for astrophysical and machine learning applications. My expertise includes model interpretability, ensemble methods, and uncertainty quantification. I also have experience on astrophysical tools such as CASA, TOPCAT, and DS9, and have a working knowledge of C, Java, and bash scripting. More recently, I have explored neural networks using PyTorch to improve prediction results and streamline model training. Furthermore, my knowledge base has been significantly expanded through various training initiatives in radio astronomy, data reduction, advanced data management, and academy-industry transition, broadening my daily toolkit. Additionally, I am a native Spanish speaker, fluent in English (IELTS certified), and have basic Portuguese competences.

Programming — Python, LaTeX, C, Java, Bash, Mathematica, Matlab

Software — Common Astronomy Software Application (CASA), Tool for operations on catalogues and tables (TOPCAT), The Atmospheric Radiative Transfer Simulator (ARTS), SAOImage DS9, Gnuplot, ESO-MIDAS, EsoRex, Astropy

Machine Learning — scikit-learn, XGBoost, LightGBM, CatBoost, PyCaret, SHAP, betacal, ppscore, crepes, PyTorch

Languages — Spanish (native speaker), English (fluent speaker), Portuguese (basic knowledge)

Training

18th Synthesis Imaging Workshop — *Socorro, NM. USA*
National Radio Astronomy Observatory — *May. 2022*

SKilled, Innovative & Entrepreneurial Scientists — *Coimbra, Portugal*
Instituto de Astrofísica e Ciências do Espaço — *Apr. 2022 - May 2022*

SKA regional centre training event. Hands-on Containerisation — *SKAO*
Science User Engagement (SUE) group of SKA Regional Centre Steering Committee — *Feb. 2022*

Cosmology in the Radio Sky: Prospects and Challenges in the SKA Observatory era — *Portugal*
Instituto de Astrofísica e Ciências do Espaço — *Dec. 2021*

ALMA Community Day (Cycle 7 Proposing Workshop) — *Santiago, Chile*
Joint ALMA Observatory (JAO) — *Mar. 2019*

MUSE Data Reduction Workshop — *Santiago, Chile*
Insituto de Astrofísica, Pontificia Universidad Católica de Chile (taught by E. Johnston) — *Aug. 2019*

Certificates

Responsible Conduct of Research. Stage 1 - Basic Course - Collaborative Institutional Training Initiative (CITI) — *2016*

Human Subjects Research. Stage 1 - Basic Course - Collaborative Institutional Training Initiative (CITI) — *2016*

IELTS Academic 7.5/9.0 — *2017*

Outreach

I have engaged diverse audiences through guided observatory visits, science festivals, and classroom activities. I have also led outreach at high-schools, taught in an Astronomy school, and engaged with press. Such activities have reached hundreds of people and the press coverage of the results from my PhD were reproduced in about a dozen mass media in different countries and my work was also featured in an interview for the Portuguese edition of the National Geographic magazine.

Press Release: 'Black holes are missing in the early Universe, and computers are after them' — *Portugal*
Institute of Astrophysics and Space Sciences · Faculdade de Ciências, Universidade de Lisboa · *Dec. 2023*
Reproduced in local and international media, including National Geographic Portugal

IX Ecuadorian School of Astronomy and Astrophysics — *Quito, Ecuador*
Lecturer: 'Looking for galaxies in a Universe of data' (in Spanish) — *Aug. 2023*

Ser Cientista (Being a Scientist) - Faculdade de Ciências, Universidade de Lisboa — *Lisbon, Portugal*
Co-supervision of high school students — *Jul. 2022*
Guiding students on project 'O FADO das Galáxias' through one week of work (supv. C. Pappalardo)

Festival Internacional de Ciência (FICA) - International Festival of Science — *Oeiras, Portugal*
Answered questions about observatories in the stand of the Instituto de Astrofísica e Ciencias do Espaço — *Oct. 2021*

Observatorio Astronómico Andino (OAA) — *Santiago, Chile*
Tourist guide — *2013 - 2019*
Showed visitors main features of night sky and answered questions on Astronomy and Astrophysics in both Spanish and English.

Service

I have served as reviewer for three journals as well as in the Distributed Review Process of the ALMA observatory. Additionally, I have been a member of the data validation team of EMU, guaranteeing the quality of observations before being released. I have also been part of the organising committee of Deep24 international conference, chair of a session of the EMU International Virtual Meeting, and I was in charge of organising the Journal Club discussions in my research team during my PhD.

Referee

Astronomy and Computing	*2025 - Present*
Astronomy & Astrophysics	*Mar. 2013 - Jul. 2013*
Open Research Europe (by European Commission)	*2024 - Present*
Cycles 11 and 12 distributed review process - ALMA Observatory	*2024 - Present*

Professional

Member of LOC in Deep24 conference	*2024*
Member of data validation team - Evolutionary Map of the Universe	*2023 - Present*
Co-organiser Journal Club - Galaxies research team - Instituto de Astrofísica e Ciencias do Espaço	*Sep. 2022 - Jul. 2023*
Chair of KS8 session - EMU International Virtual Meeting	*Jul. 2022*

Collaborations and Funded Projects

I contribute to several international collaborations, mostly involved in extra-galactic and AGN-specific science or working groups, including EMU, where I participate in the data validation team.

Projects

Finding Lyman-alpha emitters through machine learning — *FCT, Portugal*
PTCRIS: EXPL/FIS-AST/1085/2021 - P.I. A. Paulino-Afonso — *Jan. 2022 - Dec. 2023*
- Aimed at finding and characterising Lyman-alpha emitters using data-driven techniques from photometric data and direct imaging.
- This project has, so far, led to the production of one refereed publication (Vale et al. A&A, in press).

Collaborations

NewAthena Science Community - Galaxies and Supermassive Black Holes Working Group	*2025 - Present*
Multi-Object Optical and Near-infrared Spectrograph (MOONS)	*2023 - Present*
Evolutionary Map of the Universe (EMU)	*2020 - Present*
Square Kilometre Array Observatory (SKAO) - Extragalactic Continuum Science Working Group	*2020 - Present*
SKA Pathfinders Radio Continuum Surveys Working Group (SPARCS)	*2020 - Present*