



**Decree of the Rector n. 1234 of 28/11/2023**  
Competition for awarding 1 research grant at the University of Udine

**DISCLAIMER:**

The official and legally binding call for applications is in Italian only.  
This document cannot be used for legal purposes and is only meant to provide information in English on the call for applications (Decree of the Rector n. 1234 of 28/11/2023). Please refer to the official call published on: <https://www.uniud.it/it/albo-ufficiale>

Any change and integration will be made available on the above mentioned web page. Therefore, no personal written communication regarding the examination date and/or competition results shall be provided to applicants.

**Annex 1**

**Competition announcement for the assignment of 1 research grant at the University of Udine, entitled "Analysis of strength in set theory, computable analysis and second order arithmetic" SSD: MAT/01 (principal investigator, Alberto Giulio Marccone)**

**Research grant co-funded by the resources of the project PRIN 2022 - Prof. n. 2022TECZJA**

**Art. 1**

A selection procedure is hereby launched for the award of 1 research grant at the University of Udine, as identified in Attachment A which constitutes an integral part of the present announcement.

The research grant is linked to the research project and is subject and conditioned upon the relative funding.

The fellowship may be renewed, in compliance with Art. 22, Law No. 240 of 30 December 2010 (as in the text in force before the implementation of the Conversion Law of the D.L. 36/2022, L. 79/2022), Law No. 11 of 27 February 2015, and the current regulations of the University of Udine for awarding research grants, issued with the Rector's Decree No. 182 of 31 March 2021. The renewal is subject to the scientific coordinator's positive assessment of the researcher's activities, an adequate scientific rationale, and a corresponding financial covering.

The research fellowship does not give rise to any right with regards to accessing University posts.

Any personal communication to candidates related to this selection will be sent exclusively to the email address indicated when registering for the selection, as mentioned in Art. 5.

**Art. 2**

The research grant described in this competition announcement and the required qualifications to apply for the position are identified in Attachment A. The lack of the admission requirements leads to the automatic exclusion from the competition procedure.

Possession of a PhD or equivalent degree obtained abroad or, only for the interested areas, of a medical specialization accompanied by an adequate scientific production, constitutes a preferential qualification for awarding the research fellowship of this selection, if it has not been provided as a mandatory requirement.



For the only purpose of the admission to the competition, the Examining Board (Art. 7) shall assess the equivalence of the qualification obtained abroad, except for the evaluation of the medical specialization qualification to which Article 38 of the Legislative Decree 165/2001 and subsequent modifications and additions, and EU regulations on the matter, shall be applied.

The Examining Board will proceed to the evaluation of the qualification obtained abroad according to the documentation attached to the application form. The Examining Board may exclude the candidate if the submitted documentation does not provide sufficient information for the assessment.

Therefore, applicants must enclose all the documentation in their possession relating to their qualification in order to provide the Examining Board with sufficient information for assessment.

Candidates holding a qualification issued by a **European Research Area country**, if successful, must submit, if not already attached to the application form one of the following options:

- Supplement Diploma in English issued by the competent University.
- CIMEA Certificate of comparability of the foreign qualification, issued by CIMEA (Information Centre on Academic Mobility and Equivalence) via the "diplome" service at <https://cimea.diplo-me.eu/udine/#/auth/login>

Candidates holding a qualification issued by a **non-European Research Area country**, if successful, must submit, if not already attached to the application form one of the following options:

- Declaration of the on-site value of the qualification and the certificate relating to the degree with examinations and grades. A certificate in a language other than Italian or English must be accompanied by an official translation into one of these languages (certified by the competent diplomatic-consular authority or certified by a court in Italy).
- CIMEA Certificate of comparability of the foreign qualification, issued by CIMEA (Information Centre on Academic Mobility and Equivalence) via the "diplome" service at <https://cimea.diplo-me.eu/udine/#/auth/login>

If the Supplement Diploma or the statement/attestation of comparability are not available when signing the contract, the applicant must demonstrate that he/she has requested the documentation and submit it as soon as possible.

Any exclusion from the selection procedure due to lack of eligibility requirements, absence of required documents, failure to sign the selection application or submission of the selection application in a manner different from what is provided for in this call for applications will be communicated to applicants exclusively at the email address indicated in the application form.

### Art. 3

#### **The research grant referred to in this call for applications cannot be awarded:**

- a. to employees of Universities and the entities referred to in Article 22, section 1, of Italian Law no. 240 of 30 December 2010 (in the text prior to the reform introduced by Law no. 79 of 29 June 2022);
- b. to those who have already been awarded research grants pursuant to Italian Law no. 240 of 30 December 2010 (prior to the reform introduced by Law no. 79 of 29 June 2022) for the maximum period provided by law, even if not continuously, excluding the period in which the grant was used in conjunction with the doctorate, up to the legal term of the relative course;
- c. to those who have already benefited from research grants and fixed-term researcher contracts provided for, respectively, in Articles 22 and 24 of Italian Law no. 240 of 30 December 2010 (in the



text prior to the reform introduced by Law no. 79 of 29 June 2022), for a total of 12 years, even if not consecutive;

- d. to anyone who has a degree of kinship or affinity, up to and including the fourth degree, with:
- the Rector, the Director General or a member of the Board of Directors of the University of Udine;
  - the scientific supervisor or a professor/researcher belonging to the department or organisation hosting the research grant in question.

The research grant provided for in this call for applications cannot be combined:

- a) with scholarships of any kind, except for those granted by Italian or foreign institutions to supplement, by means of stays abroad, the fellow's training or research activities;
- b) with other research grants;
- c) with an employment relationship, even if part-time, without prejudice to the relevant provisions for employees of public administrations.

The grant awarded under this call for applications is also incompatible with simultaneous attendance at university degree courses, either Bachelor's degree or Master's degree courses, research Doctorates with scholarships and medical specializations, in Italy or abroad.

#### **Art. 4**

Applicants must enclose with their application, under penalty of exclusion, the following documents:

- a) their professional scientific CV, highlighting the candidate's aptitude for carrying out and implementing the research project (Attachment A);
- b) their identity card, their passport or any other identification document<sup>1</sup>;
- c) (for candidates with a foreign qualification only) certification or self-certification of both the academic qualification required for the admission to the selection, and of the exams (with evaluation) took during the period of study abroad, and of any other document that can be useful to the evaluation of the degree by the Examining Board.

Applicants can attach to the application, publications and any other certification considered useful to demonstrate the qualification based on the research program (Attachment A) and to certify any research activity accomplished at public or private institutes (indicating the starting and ending date and the duration).

The documents and qualifications mentioned above must be submitted in Italian or English. Those that are not as requested will not be evaluated. Documents originally written in a language other than Italian or English must come with a translation in Italian or English, that the candidate will do on its own responsibility. The translation can be an abstract concerning the thesis.

Italian and Community candidates wishing to submit qualifications referring to conditions and facts attested by Public Administrations must proceed exclusively with self-certification.

Non-EU citizens legally residing in Italy may self-certify only data that can be verified or certified by Italian public bodies. They may also use declarations in lieu when provided for by an international convention between Italy and the declarant's country of origin.

Non-EU citizens not residing in Italy cannot self-certify.

Only the qualifications possessed by the candidate on the date the application form is submitted and submitted in accordance with the procedures set out in Article 5 will be assessed.

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<sup>1</sup> Please be aware that the residence permit is not an identification document.



Failure to submit mandatory documents provided for in this article will constitute grounds for exclusion from the selection.

#### **Art. 5**

The submission of the applications for the present call starts on December 14, 2023 at 2:00 pm (Italian time) and ends on March 14, 2024 at 2:00 pm (Italian time).

The application to take part in the selection must be completed, under penalty of exclusion, using the appropriate online procedure, available at the link <https://pica.cineca.it/>. The procedure involves an applicant registration step, for those who do not already have an account, and then an application completion step.

Once completed, the online application must be signed in the manner described in the online procedure (manual signature with attached identity document or digital signature), under penalty of exclusion from selection. The application does not have to be signed if you access the above-mentioned online procedure using your SPID ID.

The qualifications referred to in Article 4 must be attached to the application in .pdf format. Individual .pdf files may not exceed 30MB.

The application for participation in the selection is automatically sent to the University of Udine with the definitive closing of the online procedure.

The University Administration:

- is not responsible if it is impossible to read the submitted documentation in electronic format due to damaged files;
- shall not accept or take into consideration qualifications or documents received in paper form or by any means other than what is specified in this article.

Reference to documents or publications already submitted in connection with other competitions is not allowed.

The Administration is not responsible for any missing document or communication because of inaccurate indication of residence and/or address submitted by the candidate during the application. Also, the Administration is not responsible if the candidate has not communicated changes in this information, or has communicated them too late. The Administration is also not responsible for any postal or telegraphic problems not attributable to the Administration itself.

Applicants are advised not to wait until the last few days before the closing date to submit their application. The University accepts no responsibility for any malfunctions due to technical problems and/or overloading of the communication line and/or application systems.

#### **Art. 6**

The selection procedure is held in accordance with the modality indicated in Attachment A.

The test will aim to assess the general preparation, experience and aptitude for research of the candidate. It will consist in the evaluation of the professional scientific curriculum, of the publications and qualifications presented, and of the interview, where foreseen.



### **Art. 7**

The Examining board for the competition is identified in Attachment A of the present competition announcement, of which it is an integral part.

At its first meeting, the Examining board shall appoint its President and Secretary, and establish the criteria and methods for evaluating the qualifications and the interview, where foreseen.

The results of the qualifications assessment must be disclosed to applicants during the interview, where foreseen.

The Examining board can award a maximum of 100 points (one hundred out of one hundred) to the selection.

At the end of the evaluation procedure, the Examining board shall formulate the general merit list based on the overall score of each candidate, and draw up the minutes of the whole competition procedure.

Based on the ranking list, the assignment is awarded to candidates who have obtained a minimum overall score of 70/100 (seventy out of one hundred).

The Examining board's judgement is final.

The ranking list will be made public exclusively through publication on the University's official website.

Applicants will not be notified of the outcome of the evaluation.

Those who do not declare their acceptance of the research grant and do not present themselves at the research centre within the deadline communicated by the latter, even if not formally, shall lose the right to receive it. Exceptions to this term will only be granted in cases of documented force majeure.

### **Art. 8**

The research activity cannot be started before signing the contract defining the terms and conditions of the collaboration.

The activity covered by the research grant must have the following characteristics:

- a) it must be carried out as part of the research programme covered by the grant and not be a merely technical support to it;
- b) it must have a close connection with the realization of the research program for which the winner of the grant has been awarded the contract;
- c) it must be continuous and, in any case, temporally defined, not merely occasional, and in coordination with the overall activity of the University;
- d) it must be carried out autonomously, solely within the limits of the programme prepared by the programme supervisor, without predetermined working hours.

The researcher is required to submit a detailed written report on the work carried out and the results achieved, accompanied by the opinion of the scientific supervisor, to the reference organisation at the intervals set out in the contract. The researcher must also submit interim reports and timesheets, if requested by the reference organisation.

Either the fellow or the reference organisation may withdraw from the contract.



The reference organisation may terminate the contract not only in the cases referred to in Article 9, sections 2 and 3, of the "Internal rules for awarding research grants pursuant to law 240 of 30 December 2010" of the University of Udine, but also in the event the research project and therefore the financial coverage on which the research grant is based cease to exist.

#### **Art. 9**

The following legal dispositions shall apply to the grant referred to in this call for applications:

- for tax matters, the provisions of Article 4 of Italian Law no. 476 of 13 August 1984, as subsequently amended and supplemented;
- for social security matters, the provisions of Article 2(26) *et seq.* of Italian Law no. 335 of 8 August 1995, as subsequently amended and supplemented;
- for mandatory maternity leave, the provisions of the Italian Ministerial Decree of 12 July 2007;
- with regard to sick leave, the provisions of Article 1(788) of Italian Law no. 296 of 27 December 2006 and subsequent amendments.

During the period of mandatory maternity leave, the allowance paid by INPS according to Art. 5 of the Italian Ministerial Decree of 12 July 2007 is supplemented by the University up to the full amount of the research grant.

The grant will be paid in monthly instalments.

#### **Art. 10**

The data collected as part of the procedure referred to in Art. 5 are necessary to properly manage the selection procedure, for any subsequent management of the research grant and for purposes related to managing services provided by the University. The University of Udine is the Data Controller. At any time, the data subject may request access, rectification and, depending on the University's institutional purposes, cancellation and restriction of processing or oppose the processing of their data. The data subject can always lodge a complaint with the Italian Data Protection Authority. The complete disclosure is available on the University of Udine website in the "Privacy" section, accessible from the home page [www.uniud.it](http://www.uniud.it) Direct Link: <https://www.uniud.it/it/it/pagine-speciali/guida/privacy>

#### **Art. 11**

For all matters not expressly mentioned in this call for applications, refer to the regulations in force on the subject cited in the introduction and to the "Internal rules for awarding research grants pursuant to Italian Law no. 240 of 30 December 2010" of the University of Udine, issued by Rector's Decree no. 182 of 31 March 2021.

#### **Art. 12**

The procedure supervisor is Dr Sandra Salvador, Head of the Research Services Area of the University of Udine.

The Responsible office at the University of Udine is "Area Servizi per la Ricerca - Ufficio Formazione per la Ricerca", via Mantica n. 31 - 33100 Udine, Italia.

To request information about the call for applications, please complete the following form available on the University of Udine website:

[https://helpdesk.uniud.it/SubmitSR.jsp?type=req&accountId=universityofudine&populateSR\\_id=42105](https://helpdesk.uniud.it/SubmitSR.jsp?type=req&accountId=universityofudine&populateSR_id=42105)





**Attachment A**

**Responsabile scientifico della ricerca / Principal investigator:**

Nome e cognome / Name and surname: Alberto Giulio Marcone  
Qualifica / Position: Professore Ordinario / Full Professor  
Dipartimento / Department: Scienze Matematiche, Informatiche e Fisiche (DMIF) / Mathematics, Computer Science and Physics  
Area MUR / Research field: 01 – Scienze matematiche e informatiche  
Settore concorsuale e Settore scientifico disciplinare / Scientific sector: 01/A1; MAT/01 – Logica matematica

**Titolo dell'assegno di ricerca / Topic of the research fellowship "assegno di ricerca":**

*I bandi sono consultabili dal sito dell'Ateneo, del MUR e di Euraxess / The calls are available on the University, MUR and Euraxess websites*

Testo in italiano:

Analisi della forza in teoria degli insiemi, in analisi computabile e nell'aritmetica del second'ordine.

Text in English:

Analysis of strength in set theory, computable analysis and second order arithmetic.

**Obiettivi previsti e risultati attesi del programma di ricerca in cui si colloca l'attività dell'assegnista di ricerca / Foreseen objectives and results of the research programme performed by the research fellow "assegnista di ricerca":**

*I bandi sono consultabili dal sito dell'Ateneo, del MUR e di Euraxess / The calls are available on the University, MUR and Euraxess websites*

Testo in italiano:

Abstract del progetto	L'obiettivo del progetto è l'analisi della forza, dal punto di vista della teoria degli insiemi, dell'analisi computazionale e dell'aritmetica del second'ordine, di affermazioni sia della logica matematica che della matematica nel suo complesso. Questo si colloca nel solco della ricerca, nella logica matematica, di modi di stimare e comparare la complessità dei problemi matematici. L'obiettivo sarà avvicinato da due direzioni: il primo approccio consiste nel valutare la forza assiomatica di un'affermazione matematica, dunque classificandola in base al suo livello di dimostrabilità in una gerarchia che include sottosistemi dell'aritmetica del second'ordine e grandi cardinali. Il secondo approccio consiste nel comparare i vari metodi usati per misurare la complessità e fornire stime concrete della complessità associata a problemi significativi. Più in dettaglio, vogliamo stabilire connessioni fra i sottosistemi dell'aritmetica del second'ordine più forti e l'analisi computazionale. Un'ulteriore area di ricerca è l'analisi di forme analoghe della proprietà di Baire e della misurabilità secondo Lebesgue per classi di sottoinsiemi di spazi completamente metrizzabili non separabili: questo dovrebbe avere bisogno di grandi cardinali, anche estremamente potenti.
Obiettivi del progetto	<ul style="list-style-type: none"> <li>• Esplorare nuovi collegamenti fra l'analisi computazionale e i sottosistemi dell'aritmetica del second'ordine più potenti.</li> <li>• Condurre uno studio complessivo della struttura globale del lattice</li> </ul>



	<p>di Weihrauch.</p> <ul style="list-style-type: none"> <li>• Espandere la nostra comprensione della reverse mathematics di strutture combinatoriali numerabili, includendo l'analisi della congettura di Fraïssé.</li> <li>• Investigare la forza della coerenza di aspetti della GDST singolare.</li> <li>• Introdurre analoghi della misurabilità secondo Lebesgue e della proprietà di Ramsey per spazi non separabili, calibrandone la coerenza della loro esistenza.</li> </ul>
Stato dell'arte	<p>Marcone è stato attivo nel campo della reverse mathematics fin dai primi anni Novanta. Uno degli sviluppi più significativi dell'area è un articolo di Gherardi e Marcone del 2009 [5], che ha dato il via a un esteso programma che mira ad utilizzare la riducibilità di Weihrauch per classificare teoremi matematici. A partire da queste fondamenta, un successivo articolo del 2020 di Kihara, Marcone e Pauly [6] ha esteso questo progetto per comprendere i livelli più alti della gerarchia della reverse mathematics.</p> <p>Recentemente, è aumentato di molto l'interesse verso la generalizzazione delle tecniche della teoria descrittiva degli insiemi a spazi non separabili. Questa estensione, nota come Teoria Descrittiva Generalizzata degli Insiemi (GDST), ha già prodotto numerose applicazioni significative. Per esempio, ha facilitato connessioni fra la complessità topologica della relazione di isomorfismo fra modelli non numerabili di una data teoria <math>T</math> e le proprietà di stabilità di <math>T</math>, come rilevato in [4].</p> <p>Articoli come [1,3] hanno allargato ulteriormente gli orizzonti della GDST per incorporare anche i cardinali singolari. Questo avanzamento ha aperto nuove possibilità di esplorazione delle connessioni fra la topologia generale, lo studio di grandi cardinali come <math>\aleph_0</math> (introdotto da Woodin), e la ricerca della classificazione di strutture non separabili. GDST continua a svelare nuove informazioni utili e costruire collegamenti fra diverse aree della matematica.</p>
Descrizione del progetto	<p>La reverse mathematics fornisce una struttura per classificare teoremi basati sui sottosistemi dell'aritmetica del second'ordine necessari per dimostrarli. La riducibilità di Weihrauch, invece, inizialmente sviluppata nell'ambito dell'analisi computazionale, è uno strumento per comparare la complessità di funzioni multivalori, tenendo conto di aspetti topologici e computazionali: considerando i teoremi come "problemi", la riducibilità di Weihrauch offre un approccio naturale per stimare la loro complessità. Marcone e Gherardi hanno intrapreso il tentativo di investigare le relazioni fra questi due approcci in [5], e più recentemente Marcone, i suoi studenti di dottorato e altri ricercatori hanno esteso l'esplorazione di teoremi classificati più in alto nella reverse mathematics [6]. Vogliamo dare ulteriori contributi a questa linea di ricerca ottenendo nuovi risultati in questa direzione. Inoltre, vogliamo ottenere informazioni globali sul lattice di Weihrauch, incluso lo studio dell'esistenza di catene cofinali massimali e di un operatore jump invariante sui gradi.</p> <p>Marcone ha da molto tempo un interesse nella reverse mathematics di grafi, ordini parziali e ordini parziali ben fondati. Ha di recente scritto un survey [7] su aspetti specifici di questo argomento. Il progresso significativo di Montalbán del 2017 riguardante la forza</p>







	<p>della congettura di Fraïssé ha avvicinato a una potenziale risoluzione di questo annoso problema aperto nella reverse mathematics. Inoltre, diverse aree interessanti della combinatorica numerabile rimangono inesplorate secondo la reverse mathematics.</p> <p>Il concetto di espandere la classificazione di problemi da strutture numerabili e spazi separabili a strutture non numerabili e spazi non separabili ha dato luce a quella che ora si chiama Teoria Descrittiva Generalizzata degli Insiemi (GDST). Mentre questa teoria finora si era focalizzata soprattutto su cardinali regolari, trovando connessioni interessanti fra GDST e la teoria della stabilità di Shelah, questo successo ha motivato l'avventurarsi di GDST oltre i cardinali regolari. Lo spostamento dai cardinali regolari a quelli singolari rappresenta uno degli sviluppi più interessanti della teoria.</p> <p>Al contrario del caso regolare, dove fenomeni di indipendenza spesso complicano risultati desiderabili [4], è stato dimostrato che nel caso singolare di cofinalità omega la teoria è più robusta. Molti risultati della teoria descrittiva classica possono essere generalizzati a questo nuovo contesto, anche se con tecniche nuove e più intricate [3]. Questo include la Proprietà dell'Insieme Perfetto per insiemi definibili o la dicotomia di Silver per relazioni di equivalenza analitiche. Il nostro obiettivo consiste nel continuare questa analisi in varie direzioni, stabilendo una fondazione solida che ci permetterà di approcciare specifici problemi di classificazione.</p> <p>Esploreremo proprietà di regolarità che vanno oltre la Proprietà dell'Insieme Perfetto, come la proprietà di Baire, la misurabilità secondo Lebesgue o la proprietà di Ramsey. Il nostro obiettivo è di identificare gli analoghi più appropriati di queste proprietà, e determinare i grandi cardinali necessari affinché diverse famiglie canoniche di insiemi possiedano queste regolarità. Un obiettivo fondamentale è di vagliare la coerenza dell'espressione "Tutti gli insiemi sono X", dove X è una proprietà di regolarità, una ricerca iniziata con la Proprietà dell'Insieme Perfetto in [2]. Questo studio coinvolge tecniche di combinatorica infinita (specialmente singolare), forcing di Prikry e teoria dei modelli interni. La Proprietà di Baire sarà particolarmente preziosa dal punto di vista pratico, dato che è uno degli strumenti fondamentali della teoria descrittiva degli insiemi.</p>
<p>Possibili potenzialità applicative</p>	<p>La classificazione dei problemi è un aspetto centrale della pratica matematica, e una struttura teorica gioca un ruolo vitale nel formulare le giuste domande e potenzialmente trovare risposte accurate.</p> <p>La riducibilità di Weihrauch è uno strumento più fine della reverse mathematics per valutare la forza di teoremi attraverso diverse aree matematiche. Nel farlo, affronta significative questioni fondazionali. Per esempio, la riducibilità di Weihrauch identifica casi in cui un certo ammontare di non uniformità è necessario e determina se molteplici applicazioni di un'affermazione sono necessarie per dedurre un'altra affermazione. Mentre diversi esempi di questo fenomeno sono già stati scoperti, un'ulteriore esplorazione potrà illuminare l'intricata rete di relazioni fra teoremi matematici.</p> <p>La Teoria Descrittiva Generalizzata degli Insiemi (GDST) per cardinali singolari ha il potenziale per rivoluzionare lo studio degli spazi non separabili e stabilire una fondazione solida per la classificazione di</p>



	strutture non numerabili. Inoltre, può fare luce sulle peculiarità della combinatorica cardinale singolare e offrire maggiore comprensione sulla connessione fra IO e la teoria descrittiva.
Bibliografia	<p>[1] Andretta, Motto Ros. Souslin quasi-orders and bi-embeddability of uncountable structures. Mem. Amer. Math. Soc. 2022; Volume 277, Number 1365.</p> <p>[2] Dimonte. A Solovay-like model for singular generalized descriptive set theory. Topology Appl., 323(2023), Paper No. 108284.</p> <p>[3] Dimonte, Motto Ros. Generalized Descriptive Set Theory at Singular Cardinals of Countable Cofinality. In preparation.</p> <p>[4] Friedman, Hyttinen, Kulikov. Generalized Descriptive Set Theory and Classification Theory. Mem. Amer. Math. Soc., 230, 2014.</p> <p>[5] Gherardi, Marcone. How Incomputable Is the Separable Hahn-Banach Theorem? Notre Dame J. Form. Log., 50:393-425, 2009.</p> <p>[6] Kihara, Marcone, Pauly. Searching for an analogue of ATR0 in the Weihrauch lattice. J. Symb. Log., 85:1006-1043, 2020.</p> <p>[7] Marcone. The reverse mathematics of wqos and bqos. Trends in Logic 53, 189–219, 2020.</p>

Text in English:

Abstract	Our focus is the analysis of the strengths, via set theory, computable analysis and second order arithmetic, of statements both in mathematical logic and in general mathematics. This is part of a more general pursuit in mathematical logic, that involves finding ways to assess and compare the complexity of mathematical problems. There will be two approaches on this subject: the first approach consists in evaluating the axiomatic strength of a mathematical statement, therefore classifying it on the basis of its level of provability within a hierarchy that ranges from subsystems of second order arithmetic to large cardinals. The second approach consists in comparing the various methods used to measure complexity and to provide concrete assessments of the complexity associated with significant problems. Specifically, we wish to establish connections between the higher levels of second order arithmetic and computable analysis. An additional topic of research is the analysis of the analogous of the Baire property and Lebesgue measurability for classes of subsets of non separable completely metrizable spaces: this should involve large cardinals up to the higher extremes.
Objectives of the project	<ul style="list-style-type: none"> <li>• Exploring new connections between computable analysis and the higher levels of second order arithmetic.</li> <li>• Conducting a comprehensive study of the global structure of the Weihrauch lattice.</li> <li>• Expanding our understanding of the reverse mathematics of countable combinatorial structures, including the examination of Fraïssé's conjecture.</li> <li>• Investigating the consistency strength of content of singular Generalized Descriptive Set Theory (GDST).</li> <li>• Introducing the analogue of Lebesgue measurability and Ramsey-ness for non-separable spaces, as well as gauging the consistency of their existence.</li> </ul>





<p>State of the art</p>	<p>Marcone has been actively involved in the field of reverse mathematics since the early 1990s. A significant development in this area occurred with a paper by Gherardi and Marcone in 2009 [5], which initiated a widespread program focused on utilizing Weihrauch reducibility to classify mathematical theorems. Building upon this foundation, a subsequent paper in 2020 by Kihara, Marcone, and Pauly [6] extended this project to encompass the higher levels of the reverse mathematics hierarchy.</p> <p>In recent times, there has been a notable surge in interest surrounding the generalization of descriptive set theory to non-separable spaces. This extension, known as Generalized Descriptive Set Theory (GDST), has already yielded numerous significant applications. For instance, it has facilitated connections between the topological complexity of the isomorphism relation over uncountable models of a given theory <math>T</math> and the stability properties of <math>T</math> within the realm of model theory, as highlighted in [4].</p> <p>Expanding upon these achievements, papers such as [1, 3] have further broadened the scope of GDST to incorporate singular cardinals. This advancement has opened up avenues for exploring profound connections with general topology, studying very large cardinals like Woodin's <math>\aleph_1</math>, and delving into the classification of non-separable structures. As a result, GDST continues to unveil new insights and forge links between diverse areas of mathematics.</p>
<p>Project description</p>	<p>Reverse mathematics provides a framework for classifying theorems based on the subsystems of second order arithmetic required to prove them. Meanwhile, Weihrauch reducibility, initially developed in computable analysis, serves as a tool for comparing the complexity of multi-valued functions taking into account both topological and computational aspects. By viewing theorems as "problems," Weihrauch reducibility offers a natural approach to assess their complexity. Investigating the relationship between these two approaches, Marcone and Gherardi embarked on this endeavor in [5], and more recently, Marcone, his graduate students, and other researchers extended the exploration to theorems with higher classifications in reverse mathematics [6]. We intend to further contribute to this line of research by obtaining additional results in this direction. Additionally, we aim to obtain global insights into the Weihrauch lattice, including the study of the existence of cofinal and maximal chains and of a degree-invariant jump operator.</p> <p>Marcone has a longstanding research interest in the reverse mathematics of graphs, partial orders, and particularly well-partial orders. Recently, he authored a survey [7] on a specific aspect of this topic. The significant progress made by Montalbán in 2017 regarding the strength of Fraïssé's conjecture brings us closer to potentially resolving this long-standing open problem in reverse mathematics. Moreover, many captivating areas of countable combinatorics remain unexplored within the realm of reverse mathematics.</p> <p>The concept of expanding the classification of problems from countable structures and separable spaces to uncountable structures and non-separable spaces gave rise to what is now known as Generalized Descriptive Set Theory (GDST). While the theory has</p>





	<p>mainly focused on regular cardinals, resulting in remarkable connections between GDST and Shelah's stability theory in model theory, this success motivated to venture into the realm of GDST beyond regular cardinals. The shift from regular to singular cardinals represents one of the most exciting developments in the theory.</p> <p>Unlike the case of regular cardinals, where independence phenomena often complicate desirable results [4], it has been demonstrated that when kappa is uncountable with countable cofinality, the theory becomes more robust. Many key results from classical descriptive set theory can be naturally generalized to this new context, albeit with different and more intricate techniques [3]. This includes properties such as the Perfect Set Property for definable sets and Silver's dichotomy for kappa-analytic equivalence relations. Our objective is to further advance this analysis in various directions, establishing a solid foundation that will ultimately enable us to tackle specific classification problems.</p> <p>Firstly, building upon the work in [3], our aim is to prove additional fundamental dichotomies and structural results. This includes the Burgess' trichotomy and the Glimm-Effros dichotomy, while also assessing their set-theoretical strength in terms of large cardinals.</p> <p>In another line of investigation, we will explore regularity properties that go beyond the Perfect Set Property, such as the Baire Property or being Ramsey. Our goal is to identify the appropriate analogues of these properties in the GDST setting, identify definable sets that possess such properties, and determine the precise large cardinal strength required for various canonical families of sets to exhibit regularity. A fundamental objective is to ascertain the consistency strength of the statement "All sets are regular," a task that has been partially achieved for the Perfect Set Property [2]. This study will involve techniques from infinite combinatorics, especially singular cardinal combinatorics, Prikry-like forcing, and inner model theory. The Baire Property will prove particularly valuable from a practical standpoint, as it constitutes one of the foundational tools in descriptive set theory.</p>
Possible application potentialities	<p>At the heart of mathematical practice lies the classification of problems, and a theoretical framework plays a vital role in formulating the right questions and potentially finding accurate answers.</p> <p>Weihrauch reducibility refines reverse mathematics as a tool for evaluating the strength of theorems across diverse mathematical areas. In doing so, it addresses significant foundational issues. For example, Weihrauch reducibility identifies when a certain amount of non-uniformity is and determines whether multiple applications of a statement are required to deduce another statement. While several examples of these phenomena have already been discovered, further exploration will illuminate the intricate network of relationships between mathematical theorems.</p> <p>Generalized Descriptive Set Theory (GDST) for singular cardinals has the potential to revolutionize the study of non-separable spaces and establish a solid foundation for classifying uncountable structures. Moreover, it has the capacity to shed light on the peculiarities of singular cardinal combinatorics and offer insights into the connection</p>





	between Woodin's I0 and descriptive set theory.
References	<p>[1] Andretta, Motto Ros. Souslin quasi-orders and bi-embeddability of uncountable structures. Mem. Amer. Math. Soc. 2022; Volume 277, Number 1365.</p> <p>[2] Dimonte. A Solovay-like model for singular generalized descriptive set theory. Topology Appl., 323(2023), Paper No. 108284.</p> <p>[3] Dimonte, Motto Ros. Generalized Descriptive Set Theory at Singular Cardinals of Countable Cofinality. In preparation.</p> <p>[4] Friedman, Hyttinen, Kulikov. Generalized Descriptive Set Theory and Classification Theory. Mem. Amer. Math. Soc., 230, 2014.</p> <p>[5] Gherardi, Marcone. How Incomputable Is the Separable Hahn-Banach Theorem? Notre Dame J. Form. Log., 50:393-425, 2009.</p> <p>[6] Kihara, Marcone, Pauly. Searching for an analogue of ATR0 in the Weihrauch lattice. J. Symb. Log., 85:1006-1043, 2020.</p> <p>[7] Marcone. The reverse mathematics of wqos and bqos. Trends in Logic 53, 189–219, 2020.</p>

**Struttura dell'Università di Udine presso la quale verrà sviluppata l'attività di ricerca / Department or other structure of the University of Udine where research activities will be carried out:**

Dipartimento di Scienze Matematiche, Informatiche e Fisiche (DMIF) / Department of Mathematics, Computer Science and Physics

**Importo dell'assegno di ricerca (al lordo oneri carico assegnista) / Total grant gross for the research fellowship:**

€ 19.367,00

**Durata dell'assegno di ricerca / Duration of the research fellowship "assegno di ricerca":**

12 mesi / months

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- Progetto/fondi: PRIN 2022 – "Models, sets and classifications"; Prot. n. 2022TECZJA. Decreto di finanziamento n. 973 del 30/06/2023 - Settore PE1. Codice CUP G53D23001890006. Ministero dell'Università e della Ricerca (Finanziato dall'Unione Europea, NextGenerationEU).

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