BUSTA 1

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Briefly discuss the main observational challenges to the ΛCDM model at galactic and sub-galactic scales.

2. Discuss in a concise way the physical principles of strong gravitational lensing and give an example of an image configuration of a strong gravitational lensing system.

3. Briefly discuss a physical mechanism responsible for variability in Active Galactic Nuclei across different wavelengths and/or timescales.

4. Briefly discuss the challenges posed by currently increasing astronomical datasets and a computational approach adopted to analyse them.

ESTRATTA

BUSTA 2

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Describe in a concise way the "missing satellites problem". For example, what are current observational constraints and the proposed solutions?
2. Briefly discuss one application of strong gravitational lensing in astrophysics and cosmology.
3. Briefly describe the timescales of AGN variability and possible causes.
4. Briefly describe the role of machine learning in modern observational astrophysics, with an example relevant to the topics of this research profile.

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BUSTA 3

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Summarize the cusp-core problem. What could be the best objects to test it?
2. Briefly discuss the role of strong gravitational lensing in probing the distribution of dark matter.
3. Describe in a concise way the role of variability studies to study the structure of AGN.
4. Discuss the use of machine learning for the discovery and classification of strong gravitational lenses.

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BUSTA 4

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Shortly discuss the role of baryonic feedback processes in addressing the small-scale tensions of ΛCDM.
2. Explain what are time delays due to strong lensing and how they can be exploited to constrain the mass of the lensing object.
3. Briefly describe the physical information that can be extracted from the variability of AGN.
4. Describe a computational approach to exploit a large number of AGN light curves to study AGN physics and/or strong lensing applications.

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BUSTA 5

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Compare Cold Dark Matter with alternative dark matter models proposed to alleviate small-scale tensions.
2. Summarize a method to use strong lensing to detect dark matter substructures at high redshift.
3. Describe a statistical method that can be used to characterize AGN light curves.
4. Future surveys with the next generation of instruments are expected to reveal hundreds of thousands of lens candidates. Discuss a possible methodology to efficiently identify and classify these objects.

ESTRATTA

BUSTA 6

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Describe how strong gravitational lensing can be used to detect dark matter substructure and test predictions of the ΛCDM model.
2. Describe in a concise way what are time delays in strongly lensed AGN and an observational requirement for precisely measuring them.
3. Describe a challenge associated with irregularly sampled time series of AGN.
4. Describe a computational tool and/or a statistical technique that could be employed in time-domain astrophysics.

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BUSTA 7

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Discuss why dark matter subhaloes (mass below $10^7 M_{sun}$) are considered a key probe of the nature of dark matter.

2. Discuss in a concise way the contribution of high resolution imaging to strong gravitational lenses to infer the mass model for the lens.

3. Briefly discuss a statistical technique for multi-wavelength variability studies and what we could learn from studying AGN variability at different wavelengths.

4. Machine learning methods are increasingly popular in time domain astrophysics. Briefly discuss what strategies can be used to ensure reliable scientific results.

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ESTRATTA

BUSTA 8

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Briefly discuss the current observational probes of dark matter on sub-galactic scales and their relative strengths and limitations.
2. Briefly describe the importance provided by spectroscopy in strong lensing studies.
3. Explain in a concise way how AGN variability can be exploited in the measurement of gravitational-lens time delays.
4. Explain in a concise way how AGN variability can be exploited in the measurement of gravitational-lens time delays.

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BUSTA 9

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Briefly discuss the impact of observations of satellite galaxies in the Local Group on our understanding of the ΛCDM paradigm.

2. Discuss a technique for discovering new strong gravitational lenses in large astronomical surveys.

3. Discuss possible observational requirements for monitoring campaigns aimed at time-delay measurements of strongly lensed AGN.

4. Briefly discuss the importance and challenges of publicly available software and public data repositories in the era of big data.

NON ESTRATTA

BUSTA 10

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Describe how the abundance and density profile properties of sub-halos can be used to test competing models of dark matter.

2. Discuss how future surveys and facilities are expected to transform the field of strong gravitational lensing.

3. Briefly explain how variability studies can provide information on the structure of AGN emission regions.

4. Discuss the importance of reproducibility in computational astrophysics and possible practices that could be adopted to ensure that the results are reproducible.

ESTRATTA

BUSTA 11

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Discuss the importance of dwarf galaxies as laboratories for testing the nature of dark matter.
2. Briefly describe a contribution of strong gravitational lensing to our understanding of galaxy evolution.
3. Describe the expected contribution of future facilities to AGN variability research.
4. What could be the scientific benefits and the main challenges associated with open science in the era of big data?

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BUSTA 12

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Choose a current or future observational facility and describe how it can improve constraints on the nature and distribution of dark matter.

2. Describe a possible limitation of high energy instruments in the study of gravitational lenses.

3. Discuss recent developments in time-domain astronomy and their impact on AGN variability studies.

4. Briefly discuss some characteristics that a software for astronomical data analysis should possess to ensure maintainability and scalability.

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Busta 13

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Discuss the current status of the small-scale challenges to ΛCDM. In which way could they be indicative of new physics or of incomplete modelling of galaxy formation?

2. Briefly describe how strong gravitational lensing works and a method that can be used to find strong lenses in current (and future) wide-field surveys.

3. Discuss a current (or future) facility that could be exploited to study AGN variability.

4. Briefly describe the computational infrastructures commonly used in modern astrophysics for the analysis of large datasets.

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BUSTA 14

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Describe the connection between the halo mass function and the small-scale challenges to ΛCDM.
2. Explain the phenomenon of strong gravitational lensing and describe its main observable features.
3. Identify a current (or future) telescope that could improve our understanding of AGN variability in one or multiple observing bands.
4. Discuss a computational strategy to efficiently analyse large datasets produced by current and future astronomical surveys.

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Busta 15

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Discuss the role of hydrodynamical simulations in interpreting observations relevant to the small-scale structure of the Universe.

2. Briefly explain the theoretical framework underlying strong gravitational lensing and discuss one (or more) physical properties that can be extracted from the lensed images.

3. Describe an observational capability that could significantly advance studies of AGN variability.

4. Briefly discuss the importance of software sustainability in computational astrophysics and what practices can contribute to long-term use.

NON ESTRATTA

BUSTA 16

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Briefly describe the prediction of some dark matter models for the innermost density profiles of galaxies and sub-halos.

2. Briefly discuss how a strong gravitational lensing can occur and what are the conditions to observe Einstein rings.

3. Discuss an opportunity and a challenge associated with large time-domain datasets of AGN.

4. Discuss the role of artificial intelligence in the analysis of large datasets. Which scientific problems could be well suited for AI-based approaches?

ESTRATTA

BUSTA 17

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Discuss the main observational and theoretical uncertainties affecting tests of the ΛCDM paradigm at small scales.
2. Discuss a method for finding new strong gravitational lenses in large astronomical surveys.
3. Future observational facilities will produce unprecedented samples of variable AGN. Briefly discuss a possible strategy to analyse the light curves.
4. Could you describe a statistical inference method that could be used for large astronomical datasets?

ESTRATTA

BUSTA 18

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Discuss the prospects for testing the ΛCDM paradigm with next-generation astronomical facilities.
2. Briefly discuss the role of future facilities in increasing the number of known strong lensing systems.
3. Discuss a physical property that we can extract from AGN light curves and in which way future facilities can improve our understanding of them.
4. Discuss the role of synthetic light curves in the validation of computational methods for astrophysical applications.

ESTRATTA

BUSTA 19

Open question:

The candidate shall ***choose one of the topics*** *listed in the "Prova d'esame" (Allegato 1), namely:*

a) Small-scale challenges to LambdaCDM paradigm;

b) Strong gravitational lensing;

c) AGN variability (multi-wavelength) and tools to study it;

d) Big data and computational approaches.

Depending on their professional background, the candidate shall ***develop a discussion on the chosen topic.***

1. Briefly discuss the role of dark matter in the assembly of galaxies and highlight how observations on galactic/sub-galactic scales can be used to test the ΛCDM paradigm.

2. Discuss some observational properties to discern between strong lensing systems and non-lensed objects.

3. Describe a future time-domain facility and highlight a possible challenge (observational, computational or scientific) with exploiting large datasets of light curves.

4. Briefly describe possible computational strategies and computing requirements to process and analyze large astronomical datasets.

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