

---

# HubbleCLIP: Learning associations between astronomical observations and natural language with multi-modal models

**Siddharth Mishra-Sharma**

*smsharma@mit.edu*

*The NSF AI Institute for Artificial Intelligence and Fundamental Interactions*

*Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*

*Department of Physics, Harvard University, Cambridge, MA 02138, USA*

**Yiding Song**

*ydsong@mit.edu*

*The NSF AI Institute for Artificial Intelligence and Fundamental Interactions*

*Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*

**Jesse Thaler**

*jthaler@mit.edu*

*The NSF AI Institute for Artificial Intelligence and Fundamental Interactions*

*Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*

## Abstract

Abstract

## 1 Introduction

## 2 Dataset and Processing

## 3 Methodology

### 3.1 Language-Image Pre-training

### 3.2 Pre-trained CLIP Model

### 3.3 Fine-tuning Objectives

## 4 Results and Discussion

### 4.1 Fine-tuned Retrieval Accuracy

### 4.2 ‘Zero-shot’ Hypothesis and Object Retrieval

### 4.3 Text-to-Image Retrieval

Hinton et al. (2006)

## Broader Impact Statement

In this optional section, TMLR encourages authors to discuss possible repercussions of their work, notably any potential negative impact that a user of this research should be aware of. Authors should consult the TMLR Ethics Guidelines available on the TMLR website for guidance on how to approach this subject.

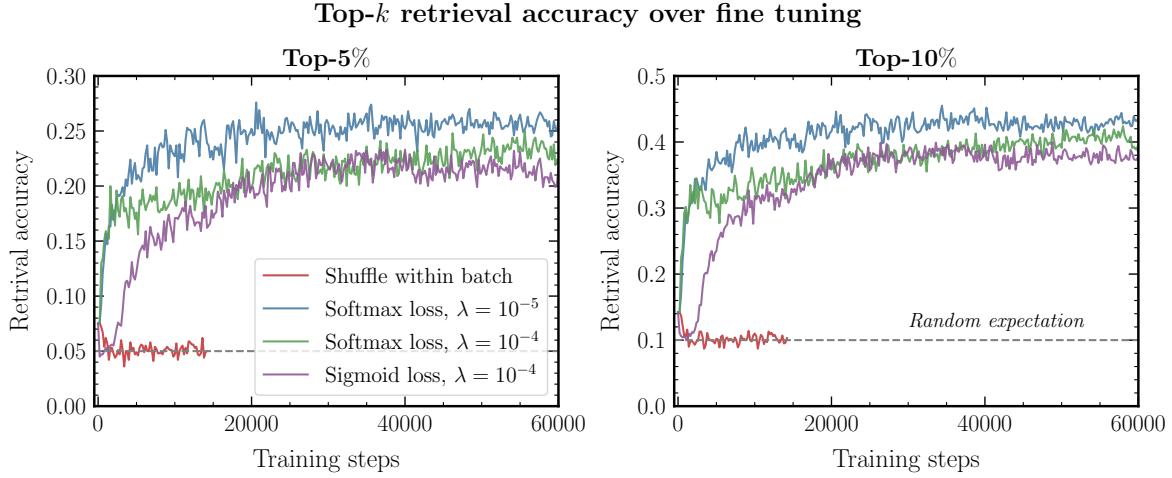


Figure 1: Retrieval accuracy

## Author Contributions

If you'd like to, you may include a section for author contributions as is done in many journals. This is optional and at the discretion of the authors. Only add this information once your submission is accepted and deanonymized.

## Acknowledgments

Use unnumbered third level headings for the acknowledgments. All acknowledgments, including those to funding agencies, go at the end of the paper. Only add this information once your submission is accepted and deanonymized.

## References

Geoffrey E. Hinton, Simon Osindero, and Yee Whye Teh. A fast learning algorithm for deep belief nets. *Neural Computation*, 18:1527–1554, 2006.

## A Appendix

You may include other additional sections here.

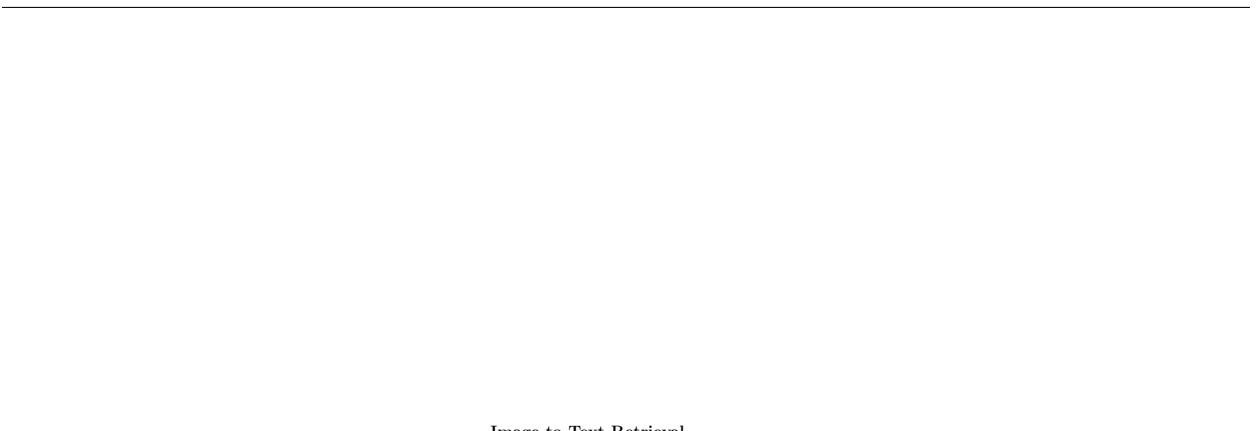


Image-to-Text Retrieval

Image	Top classes (fine-tuned)	Top classes (base)	Abstract
	<ul style="list-style-type: none"> <li>1. dark matter</li> <li>2. Einstein rings</li> <li>3. galaxy mergers</li> <li>4. gravitational lensing</li> <li>5. galaxy clusters</li> </ul>	<ul style="list-style-type: none"> <li>1. galaxy clusters</li> <li>2. ultra diffuse galaxies</li> <li>3. dwarf galaxies</li> <li>4. gravitational lensing</li> <li>5. crowded stellar field</li> </ul>	<p><b>Category: COSMOLOGY.</b> We propose to study the physical nature of dark matter by using massive, merging clusters of galaxies. As shown with the Bullet Cluster (1E0057.56), such massive well-measured systems are critical for our understanding of dark matter. By roughly doubling the number of clusters in the sample, obtaining systems at different observation angles, impact parameters, geometrical arrangements, and merger velocities, the systematic uncertainties in the dark matter cross section calculations can be improved substantially, allowing us to move from rough predictions from numerical simulations, and the constraints on alternate gravity models become unambiguous. Our proposed targets are thus extraordinary, merging galaxy clusters with X-ray and optical offsets that are placed at ideal redshifts for HST observations: A520, A1758N, and A2163. To pin down the position of the dark matter component we require high resolution, absolutely calibrated mass maps. High resolution gravitational lensing data is needed to attain this goal, which can only be achieved with the excellent resolving power of the HST.</p>
	<ul style="list-style-type: none"> <li>1. dark matter</li> <li>2. galaxy mergers</li> <li>3. Einstein rings</li> <li>4. gravitational lensing</li> <li>5. dark energy</li> </ul>	<ul style="list-style-type: none"> <li>1. ultra diffuse galaxies</li> <li>2. galaxy clusters</li> <li>3. gravitational lensing</li> <li>4. high-redshift quasars</li> <li>5. dwarf galaxies</li> </ul>	<p><b>Category: COLD暗物质.</b> We propose to study the physical nature of dark matter by using massive, merging clusters of galaxies. As shown with the Bullet Cluster (1E0057.56), such massive well-measured systems are critical for our understanding of dark matter. By more than doubling the number of clusters in the sample and obtaining systems at different observation angles, impact parameters, geometrical arrangements, and merger velocities, the systematic uncertainties in the dark matter cross section calculations can be improved substantially, allowing us to move from rough predictions from numerical simulations, and the constraints on alternate gravity models become unambiguous. Our proposed targets are thus extraordinary, merging galaxy clusters with X-ray and optical offsets that are placed at ideal redshifts for HST observations: A520, A1758N, and A2163. To pin down the position of the dark matter component we require high resolution, absolutely calibrated mass maps. High resolution gravitational lensing data is needed to attain this goal, which can only be achieved with the excellent resolving power of the HST.</p>
	<ul style="list-style-type: none"> <li>1. crowded stellar field</li> <li>2. supernova remnants</li> <li>3. compact stellar remnants</li> <li>4. primordial black holes</li> <li>5. pre-main sequence stars</li> </ul>	<ul style="list-style-type: none"> <li>1. stellar abundances</li> <li>2. stellar populations</li> <li>3. interstellar medium</li> <li>4. pre-main sequence stars</li> <li>5. Cepheid variables</li> </ul>	<p><b>Category: RESOLVED STELLAR POPULATIONS.</b> Exploiting the full power of the Wide Field Camera 3 (WFC3), we propose deep observations of the central regions of the most luminous and massive star-forming complexes in the Galaxy to resolve stellar populations, using a new set of reddening-free photometric indices we have constructed from broad-band filters across UV, optical, and near-infrared wavelengths. These observations will allow separation of the light of individual stars from thousands of individual bulge stars. Proper motions of these stars derived from multi-epoch observations will allow separation of pure bulge samples from foreground disk contamination. Our catalogs of proper motions and panchromatic photometry will provide a wealth of information on stellar populations, including stellar populations in the outer disk, and the history of star formation history as a function of position within the bulge, and thus differentiate between rapid and slow star formation. This will allow us to probe the physical properties of the bulge, revealing how the characteristic mass of star formation varies with chemistry. Our sample of bulge stars with accurate metallicities will include 12 candidate hosts of extrasolar planets. Planet frequency is correlated with metallicity in the solar neighborhood; our observations will allow us to test this correlation. Our observations will also serve as a reference catalog for the Galaxy. This includes observations of six well-studied globular and open star clusters; these observations will serve to calibrate our photometric and kinematic measurements. Our observations will also serve as a reference catalog for the Galaxy. This includes observations of six well-studied globular and open star clusters; these observations will serve to calibrate our photometric and kinematic measurements. Besides enabling our own program, these products will provide powerful new tools for a host of other stellar-population investigations with HST/WFC3. We will deliver all of the data from this Treasury Program to the community in a timely fashion.</p>
	<ul style="list-style-type: none"> <li>1. low surface brightness galaxies</li> <li>2. star formation histories</li> <li>3. galaxy formation</li> <li>4. ultra diffuse galaxies</li> <li>5. circumgalactic medium</li> </ul>	<ul style="list-style-type: none"> <li>1. gravitational lensing</li> <li>2. high-redshift quasars</li> <li>3. brown dwarfs</li> <li>4. trans-Neptunian objects</li> <li>5. Kuiper Belt objects</li> </ul>	<p><b>Category: Stellar Populations and the Interstellar Medium.</b> Observations of the ultra-faint dwarfs (UFDs), as relics of the early environment of the Galaxy, are key to understanding the evolution of the Galaxy and the environmental conditions in the SF environments for most of their lifetimes provide unique tools to probe the effects of early environmental conditions on the SF history of the Galaxy. We propose to obtain deep ACS and UVIS imaging in F606W and F814W for 2 LMC satellite UFDs that are on their first approach to our Galaxy, and thus resided in the outskirts of the Local Group at high redshift. We will use the same filters and observing strategy as the Hubble Ultra Deep Field (HUDF) survey, but with longer term MW satellite data available from previous programs by using high-fidelity color-magnitude diagrams constructed from the same filters. This will allow us to compare the SF history of the UFDs with the MW. (1) Estimate whether SF is quenched at different times with different rate in UFDs in low density environment at early times, perhaps the patchiness of reionization by directly comparing with theoretical predictions. (2) Identify variations in the sub-Solar IMF across UFDs born in different environments. (3) Pave the way for a more accurate constraint on the MW halo mass.</p>
	<ul style="list-style-type: none"> <li>1. supernovae</li> <li>2. Cepheid variables</li> <li>3. star clusters</li> <li>4. star forming galaxies</li> <li>5. dust</li> </ul>	<ul style="list-style-type: none"> <li>1. high-redshift quasars</li> <li>2. gravitational lensing</li> <li>3. Kuiper Belt objects</li> <li>4. compact stellar remnants</li> <li>5. ultra diffuse galaxies</li> </ul>	<p><b>Category: RESOLVED STELLAR POPULATIONS.</b> We propose to test two of the deepest predictions of the theory of evolution of massive-star evolution: (1) The formation of Wolf-Rayet stars depends strongly on their start metallicity (23), with relatively fewer WR stars forming at lower Z, and (2) Wolf-Rayet stars die as Type Ib or Ic supernovae. To carry out these tests we propose a deep, narrowband imaging survey of the massive star population in the Scd spiral galaxy M101. Just as important, we propose to use the same filters and observing strategy as the Hubble Ultra Deep Field (HUDF) survey, but with long-term MW satellite data available from previous programs by using high-fidelity color-magnitude diagrams constructed from the same filters. This will allow us to compare the SF history of the UFDs with the MW. (1) Estimate whether SF is quenched at different times with different rate in UFDs in low density environment at early times, perhaps the patchiness of reionization by directly comparing with theoretical predictions. (2) Identify variations in the sub-Solar IMF across UFDs born in different environments. (3) Pave the way for a more accurate constraint on the MW halo mass.</p>

Figure 2: Retrieval accuracy

---

### Text-to-Image Retrieval: Base Model

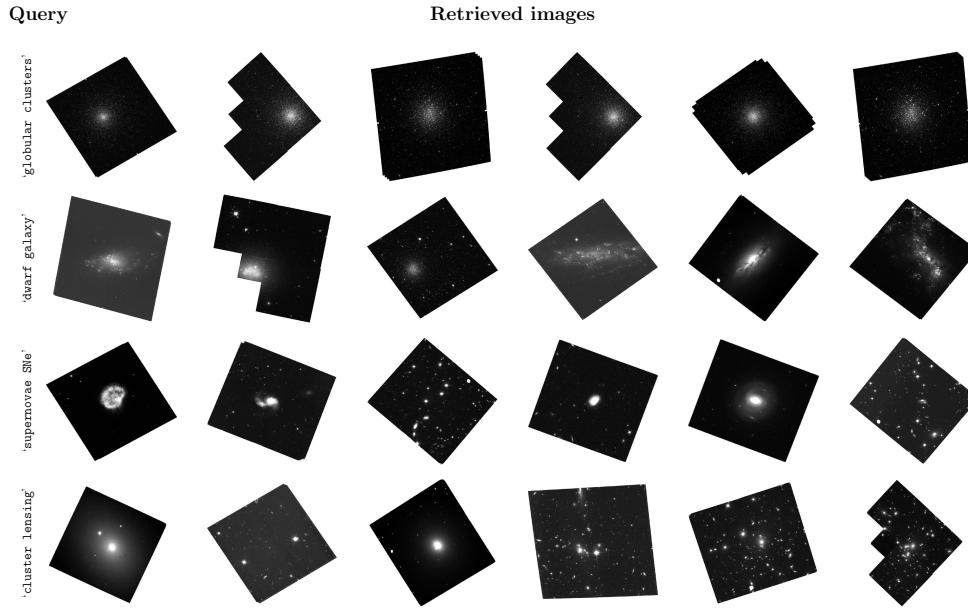


Figure 3: Retrieval accuracy

### Text-to-Image Retrieval: Fine-Tuned Model

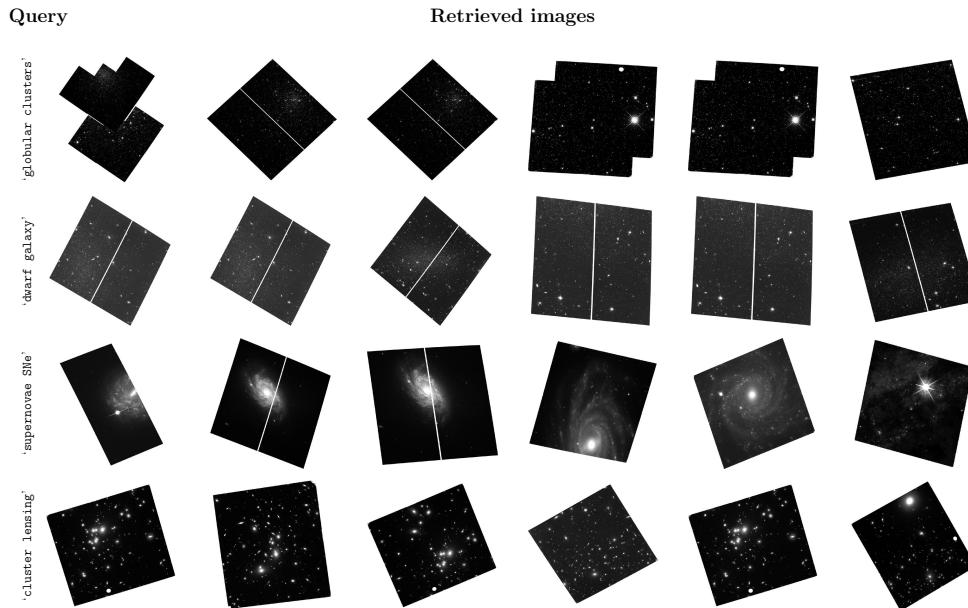


Figure 4: Retrieval accuracy