

Discovering New Strong Gravitational Lenses in the DESI Legacy Imaging Surveys

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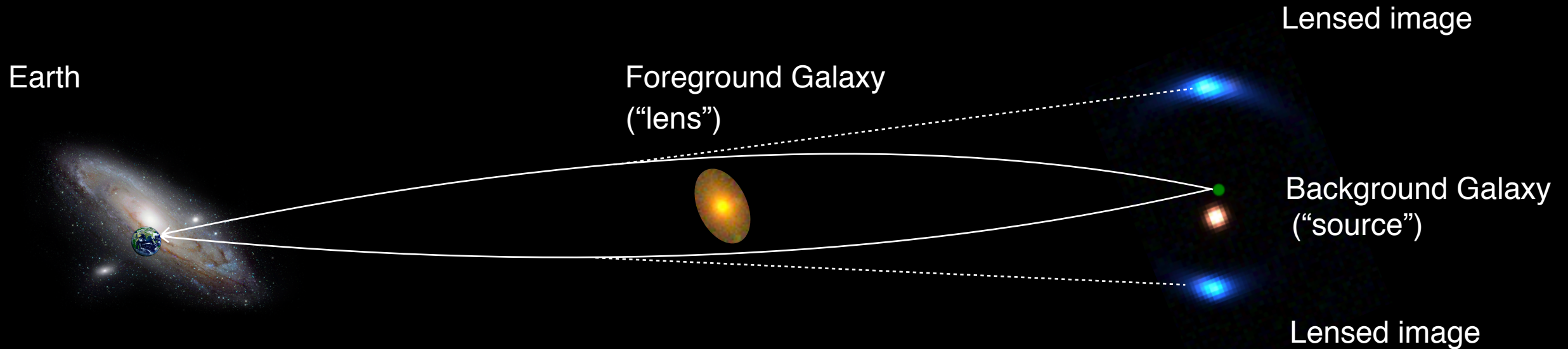


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Gravitational Lensing

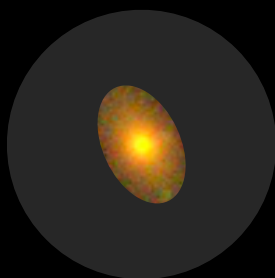


- Chance alignment of earth, foreground galaxy, background galaxy
- Warping of space-time by gravity according to Einstein's General Relativity
- Strong lensing: large arcs and multiple images
- 1 in ~10,000 massive galaxies is a lens

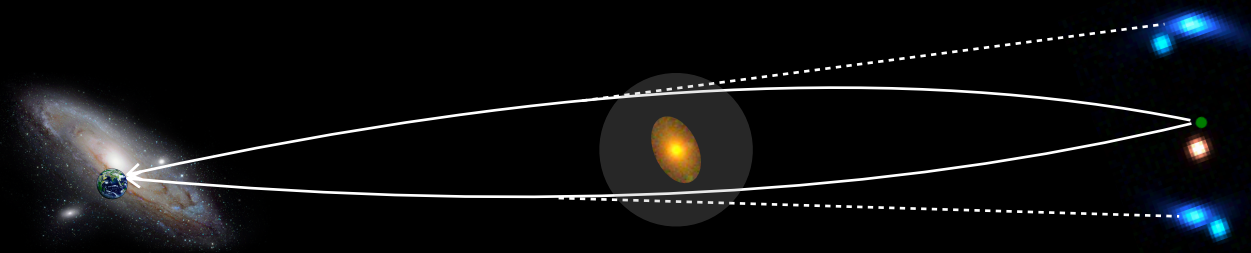


Dark Matter and Cosmic Expansion Rate

- Strong Gravitational Lensing: direct probe of dark matter
- “Time Delay” of multiply-image quasars or supernovae



Galaxy embedded in dark matter halo

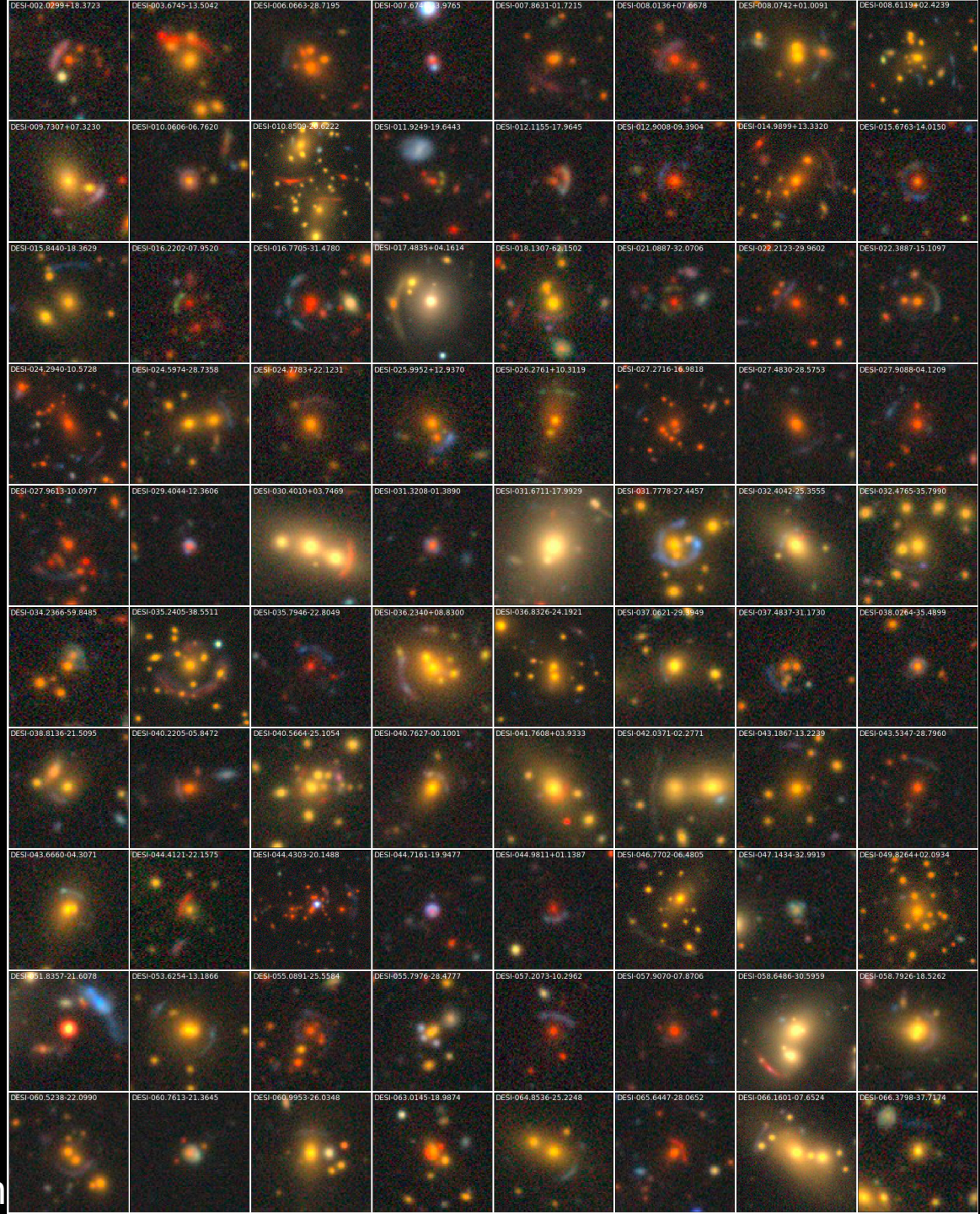
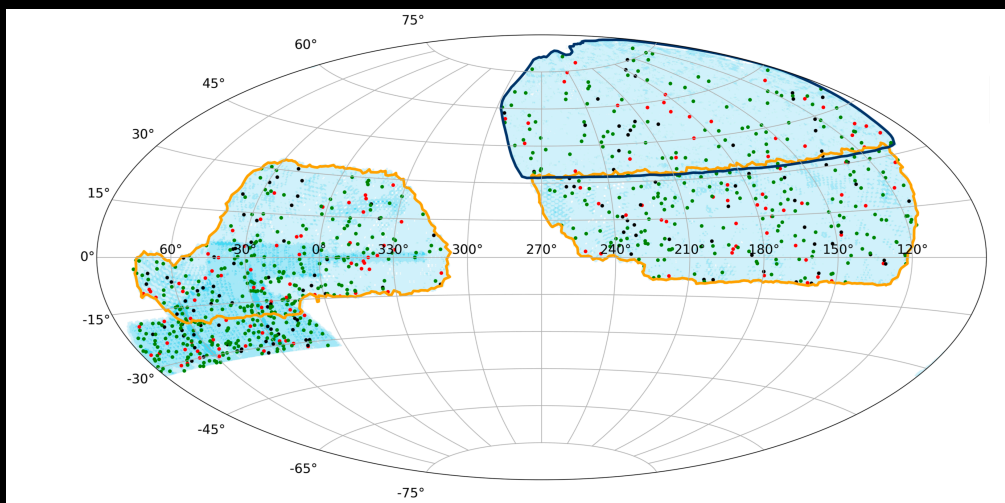


Time Delay:
Supernova appears to explode twice

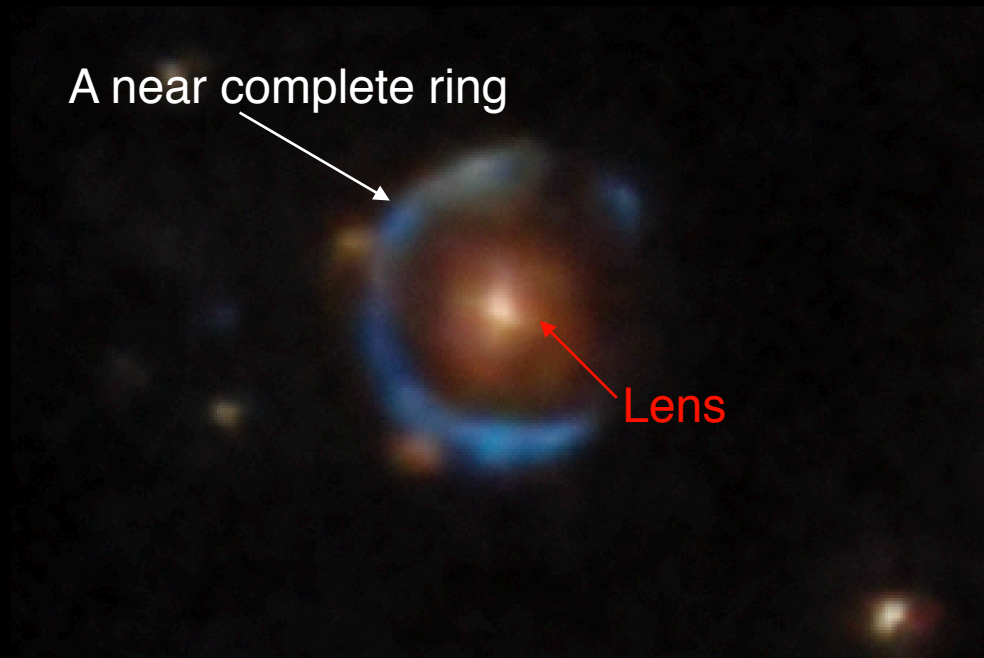


Finding Strong Lenses

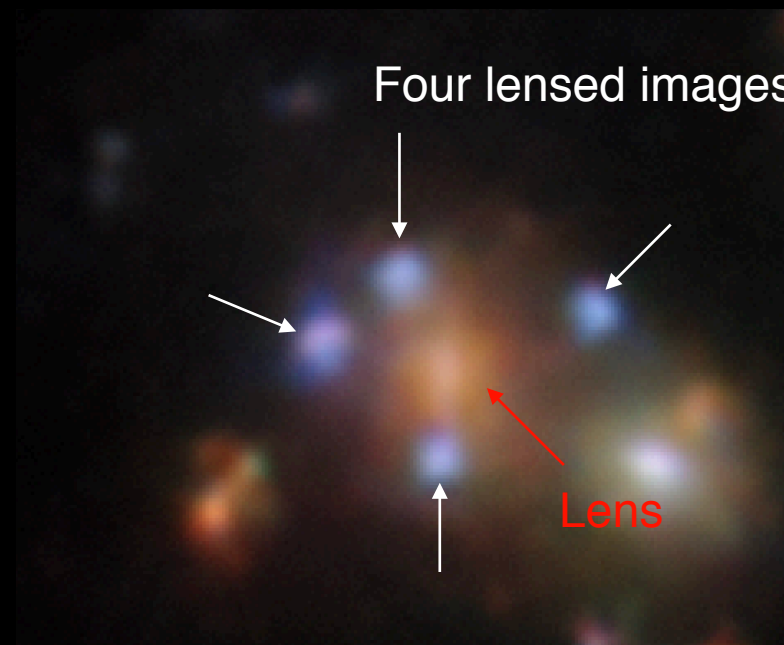
- DESI Legacy Imaging Surveys
- Artificial Neural Networks
- Deploying neural networks on the supercomputer Cori at National Energy Research Scientific Computing Center (NERSC)
- Human Inspection: 1 in 33 neural network “recommendations” is a lens candidate
- Over 1500 strong lenses discovered so far: doubling the number of known lenses



Examples of Our Discoveries



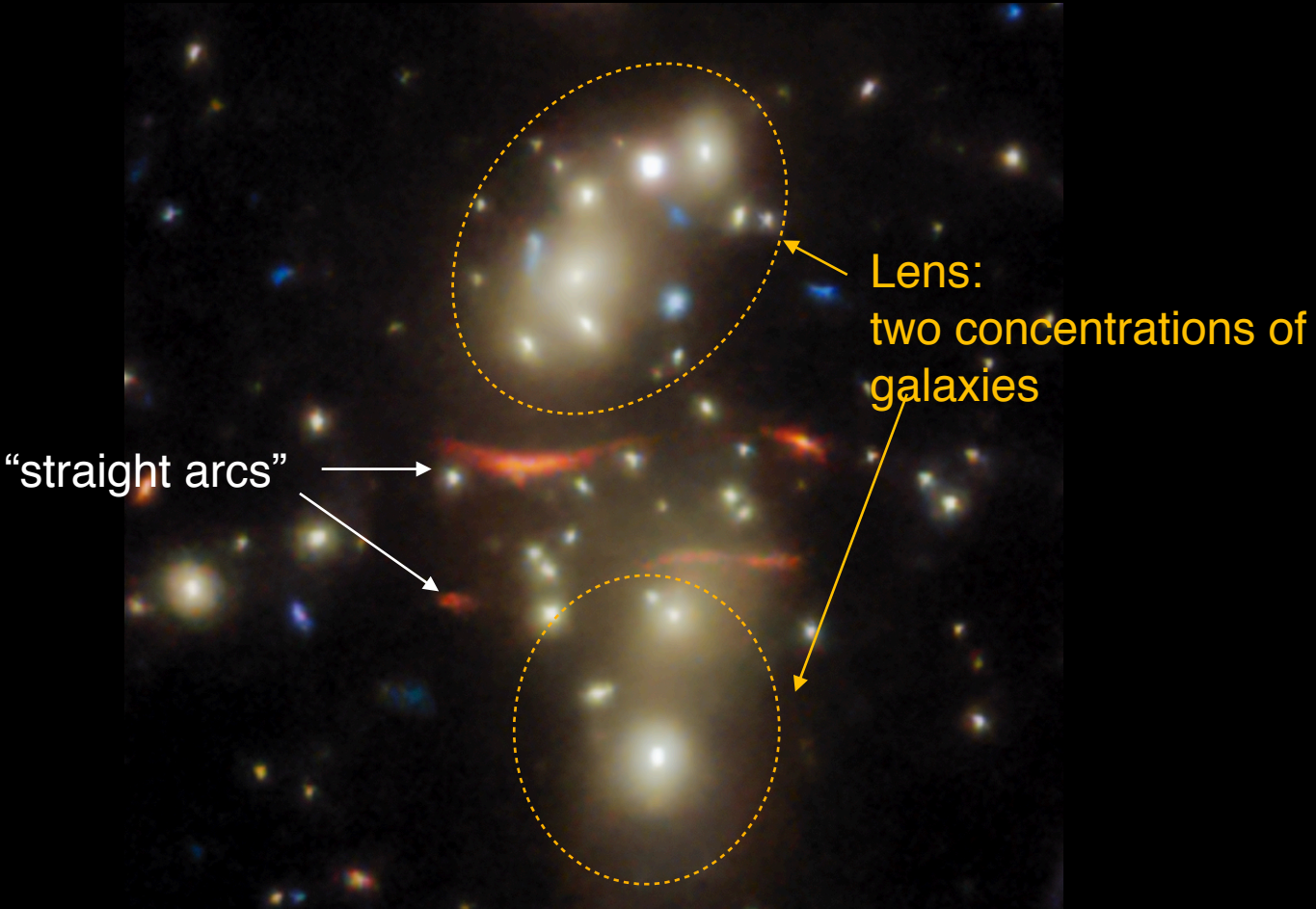
Near-complete Einstein Ring
(DESI-015.6763-14.0150)



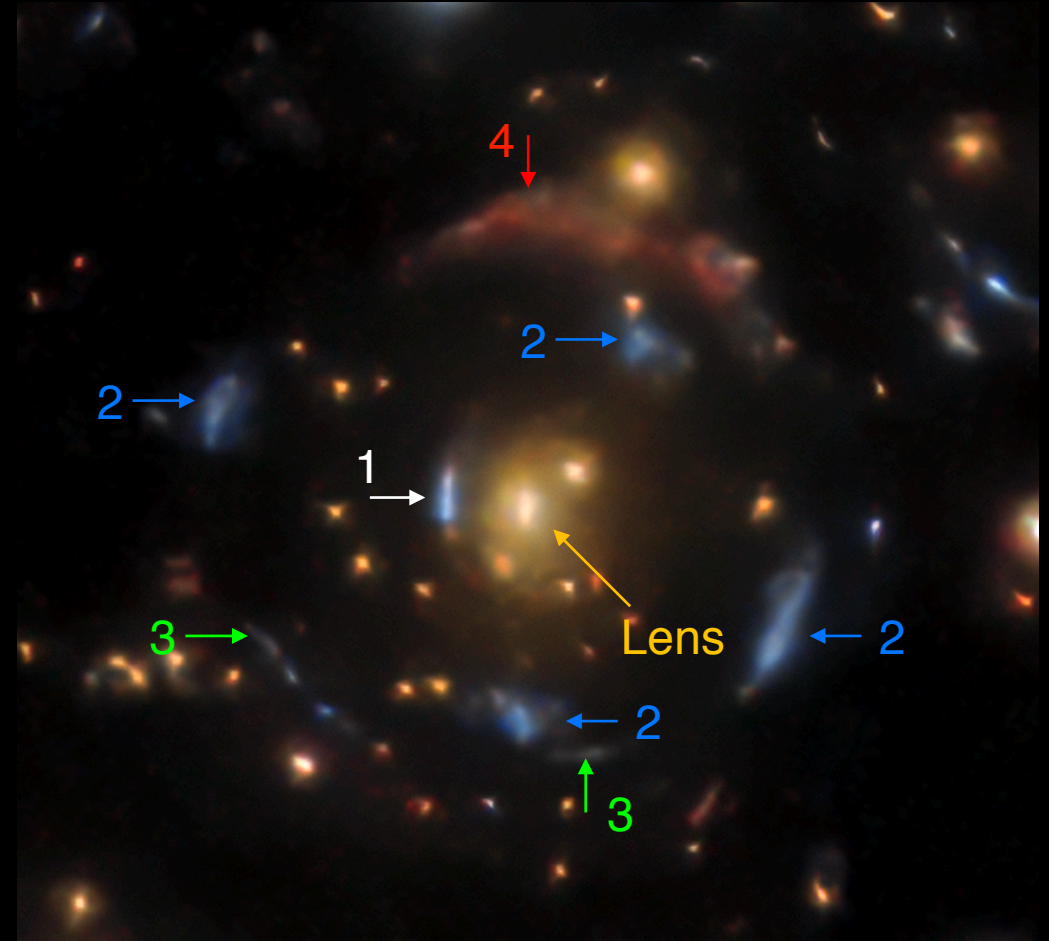
Einstein Cross
(DESI-220.4549+14.6891)



Examples of Our Discoveries



Straight Arcs
(DESI-010.8534-20.6214)



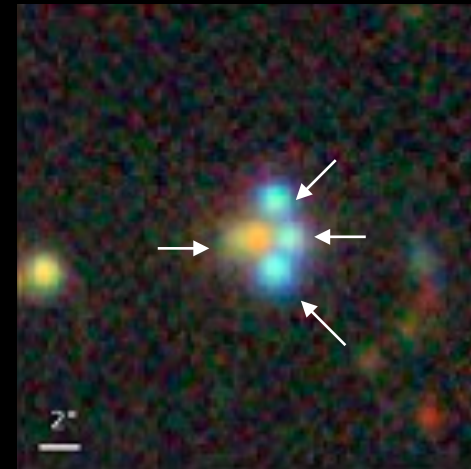
Four distinct background galaxies
(DESI-090.9854-35.9683)



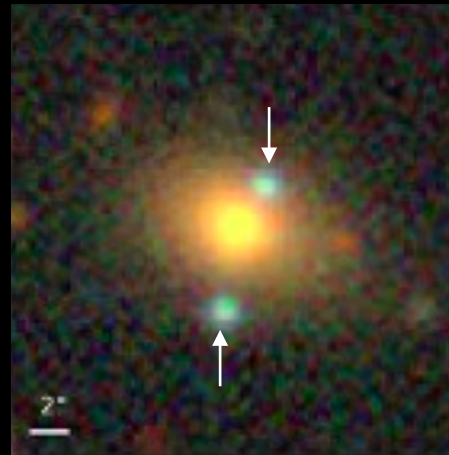
Examples of Lensed Quasar Candidates



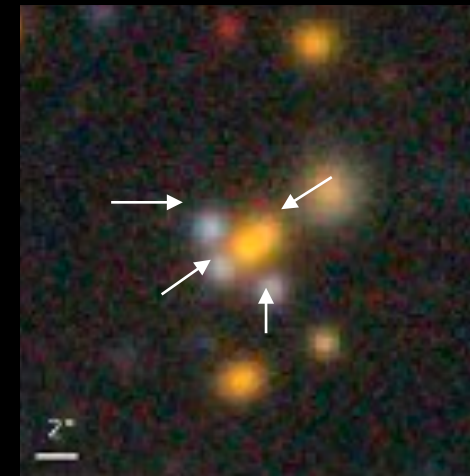
DESI-7.6741-33.9765



DESI-218.3457+60.1209



DESI-273.3831+34.2652



DESI-55.7976-28.4777



Conclusions

- Undergraduate students from two universities (Univ. of San Francisco & Univ. of California, Berkeley) made significant discoveries using machine learning and public data
- Approved Hubble program with students as Co-I's



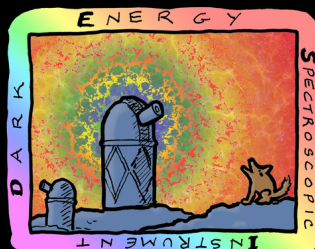
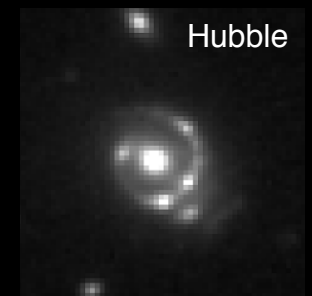
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National Energy Research
Scientific Computing Center

Hubble



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Links

- NSF's NOIRLab Press release:
<https://noirlab.edu/public/news/noirlab2104/>
- Papers reporting our discoveries:
 - Huang, Storfer, Ravi, et al. 2020, [The Astrophysical Journal, 894, 78](#)
 - Huang, Storfer, Gu, et al. 2021, ApJ accepted (<https://arxiv.org/abs/2005.04730>)
- All of our candidates are on our project website:
<https://sites.google.com/usfca.edu/neuralens/>

