SpaceWarps: crowd sourcing the discovery of gravitational lenses

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SW collaboration

Gravlens
Leiden
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Lenses in large surveys

- We expect to find ~1000s of lenses in large imaging surveys covering ~1000 sq. deg area
- We need efficient and systematic means to find gravitational lenses in these large imaging surveys
- Automated searching techniques are useful but suffer from high rate of false positives
- Visual inspection is a crucial step in filtering candidates even for an automated search
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Blind lens search

- Stage 1: Fast inspection; $O(10^5) \rightarrow O(10^3)$ images
- Stage 2: Careful inspection; $O(10^3) \rightarrow O(10^2)$ candidates

Targeted lens search

- Stage 0: Lens finding algorithm produced candidates are used
- Stage 1: Careful inspection; $O(10^4) \rightarrow O(10^3)$ candidates
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Training Sample: Simulations

https://github.com/anupreeta27/SIMCT

More, et al. (2016)
Space Warps

Training sample: Simulations

- First citizen science project in Zooniverse that
- includes thorough and convincing simulated training material
- uses the training sample to calibrate volunteer performance
- Essential for training users and keeping them alert !!!
- Important for characterizing the selection function of the resulting lens sample

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Results from First lens search
About 60 new lens candidates (30 candidates are more promising) (http://spacewarps.org/#/projects/CFHTLS/discoveries)

- 2 million image classifications in first week (10k per hour), 11 million over 6 months
- Collaboration of now over 27,000 citizen scientists

**P(lens)_SW vs Lens Experts**

More, et al. (2016)
Performance

TPR = #sims detected / #sims
FPR = #duds missed / #duds

sims: simulated lenses, duds: non-lenses

Marshall, Verma, AM et al. (2016)
Image separation distribution (ISD) can put constraints on the statistical mass distribution of lenses.

- Need to understand the selection function to account for any incompleteness.
- The slope of the updated ISD (combining SW + old lens samples) is unchanged, suggesting previous constraints from ISD (More et al. 2012) at group-scales are robust.

More, et al. (2016)
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VICS82

- Launched at the BBC Stargazing Live TV program (lasted for 3 days)
- Targeted search VICS82 (opt+NIR): 40,000 candidates pre-selected with algorithms
- Million classifications in the first hour of its announcement

- Discovered a lensed hyper-luminous IR galaxy at z~2.5, visible in the radio with possible contribution from an AGN

Geach, AM et al. (2015)
Space Warps

Looking ahead

• Space Warps is undergoing an upgrade (interface and analysis pipeline)

• Lens searches are officially happening with
  • DES (5000 sq. deg, r=24.1)
  • HSC (1400 sq. deg, r=26)
  • Possible collaboration with KiDS is being discussed

• To do lens search in your favourite survey - Contact us!
  spacewarps.org
  spacewarpspi@googlegroups.com

• Stay tuned - coming soon with new lens searches !!