

# cluster-lensing: A Python PACKAGE FOR GALAXY CLUSTERS AND MISCENTERING

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## ABSTRACT

We describe a new open source package for calculating properties of galaxy clusters, including NFW halo profiles with and without the effects of cluster miscentering. This pure-Python package, `cluster-lensing`, provides well-documented and easy-to-use classes and functions for calculating cluster scaling relations, including mass-richness and mass-concentration relations from the literature, as well as the surface mass density  $\Sigma(R)$  and differential surface mass density  $\Delta\Sigma(R)$  profiles, probed by weak lensing magnification and shear, respectively. Galaxy cluster miscentering is especially a concern for stacked weak lensing shear studies of galaxy clusters, where offsets between the assumed and the true underlying matter distribution. This software has been developed and released in a public GitHub repository, and is licensed under the permissive free MIT license. The `cluster-lensing` package can be downloaded through the Python Package Index, <https://pypi.python.org/pypi/cluster-lensing>, or directly from GitHub, at <https://github.com/jesford/cluster-lensing>. Full documentation is available at <http://jesford.github.io/cluster-lensing/>.

*Subject headings:* gravitational lensing: weak, galaxies: clusters: general, dark matter, methods: data analysis, methods: numerical

## 1. INTRODUCTION

- Background about clusters and weak lensing.
- NFW halos (Navarro et al. 1997; Wright & Brainerd 2000)
- composite-NFW fits for weak lensing (Ford et al. 2012, 2014, 2015)
- What is new = miscentering (Johnston et al. 2007; George et al. 2012; Ford et al. 2014, 2015)

## 2. DESCRIPTION OF THE CODE

- Purpose and general use.
- Relation to existing code
- `SurfaceMassDensity()` class, generic to all NFW halos
- `ClusterEnsemble()` class
- mass-richness functions
- mass-concentration functions
- We use units from the `astropy.units` package (Astropy Collaboration et al. 2013).

## 3. EXAMPLES

- No miscentering
- With miscentering
- others...

## 4. FUTURE DEVELOPMENT

Plans for the future.

## 5. SUMMARY

Summary goes here.

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