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SHALOS: Statistical *Herschel*-ATLAS lensed objects selection★

J. González-Nuevo[1], S. L. Suárez Gómez[2], L. Bonavera[1], F. Sánchez-Lasheras[2], F. Argüeso[2], L. Toffolatti[1], D. Herranz[3], C. González-Gutiérrez[4], F. García Riesgo[5], and F. J. de Cos Juez[5]

[1] Departamento de Física, Universidad de Oviedo, C. Federico García Lorca 18, 33007 Oviedo, Spain
e-mail: gnuevo@uniovi.es
[2] Departamento de Matemáticas, Universidad de Oviedo, C. Federico García Lorca 18, 33007 Oviedo, Spain
[3] Instituto de Física de Cantabria (CSIC-Universidad de Cantabria), Avda. de los Castros s/n, 39005 Santander, Spain
[4] Departamento de Informática, Universidad de Oviedo, C. Federico García Lorca 18, 33007 Oviedo, Spain
[5] Departamento de Explotación y Prospección de Minas, Universidad de Oviedo,, Oviedo 33004 Asturias, Spain

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Presented by: **J. Gonzalez-Nuevo & L. Bonavera**
Universidad de Oviedo - Instituto Universitario de Ciencias y Tecnologias Espaciales de Asturias (ICTEA)

Brief Summary

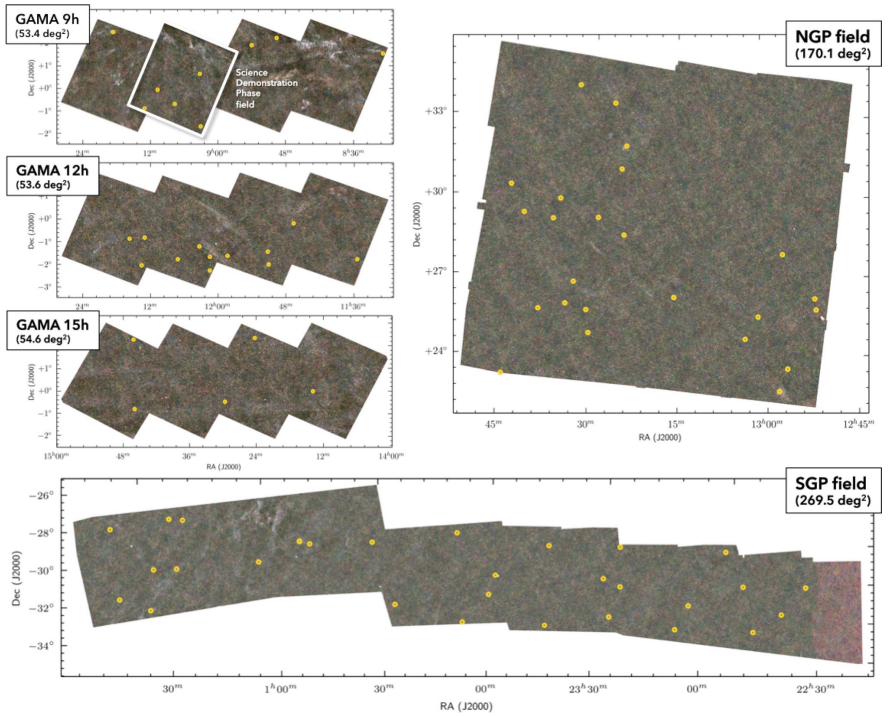
In this work we proposed a new methodology based on a statistical selection approach to increase by a factor of ∼5 the number of galaxy-galaxy strong lensing events within the *Herschel*-ATLAS data set.
Although the methodology can be applied to address several selection applications, it has particular benefits in the case of the identification of strongly lensed galaxies: objectivity, minimal initial constrains in the main parameter space, and preservation of statistical properties.

Contex

- The statistical analysis of large sample of strong lensing events can be a powerful tool to extract astrophysical or cosmological valuable information.

- The selection of such events has been demonstrated to be very effective using submillimetre galaxies (SMGs): more than ~200 proposed candidates in the case of Herschel-ATLAS data and several tens in the case of the South Pole Telescope.

- However, the number of confirmed events is still relatively low, i.e. a few tens, mostly because of the lengthy observational validation process on individual events.



Negrello et al. 2017 (MNRAS, 465, 3558)
HerBS (Bakx et al. 2018, MNRAS, 473, 1751)

Methodology

- The proposed methodology is based on the **Bhattacharyya distance** as a measure of the similarity between probability distributions of properties of two different cross-matched galaxies.

- The particular implementation of this technique for the aim of this work is called **SHALOS**.

- It combines the information of four different properties of the pair of galaxies:
  - Angular separation (BC_{pos})
  - Luminosity percentile in a small z bin (L_{perc})
  - Redshift separation ($1\text{-}BC_z$)
  - The ratio of the optical to the submillimetre flux densities ($1\text{-}BC_r$)

$$D_B(p,q) = -\ln(BC(p,q)) = -\ln\left(\int dx \sqrt{p(x)q(x)}\right)$$

Bhattacharyya distance for two continuous probability distributions p and q.
*BC(p,q) denotes de **Bhattacharyya kernel**: $0 \leq BC \leq 1$*

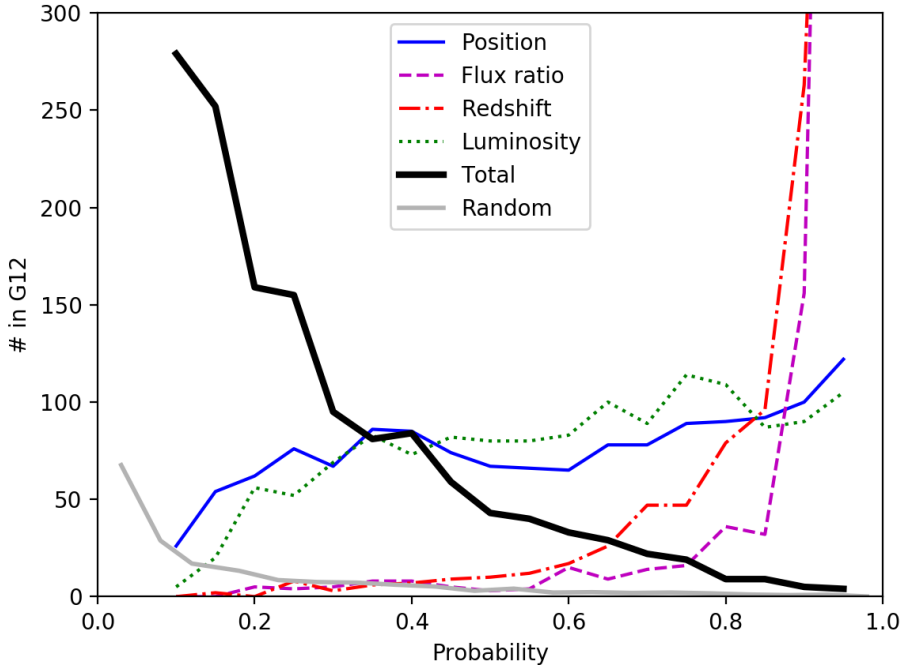
$$D_B(p,q) = \frac{1}{4}\ln\left(\frac{1}{4}\left(\frac{\sigma_p^2}{\sigma_q^2} + \frac{\sigma_q^2}{\sigma_p^2} + 2\right)\right) + \frac{1}{4}\left(\frac{(\mu_p - \mu_q)^2}{\sigma_p^2 + \sigma_q^2}\right)$$

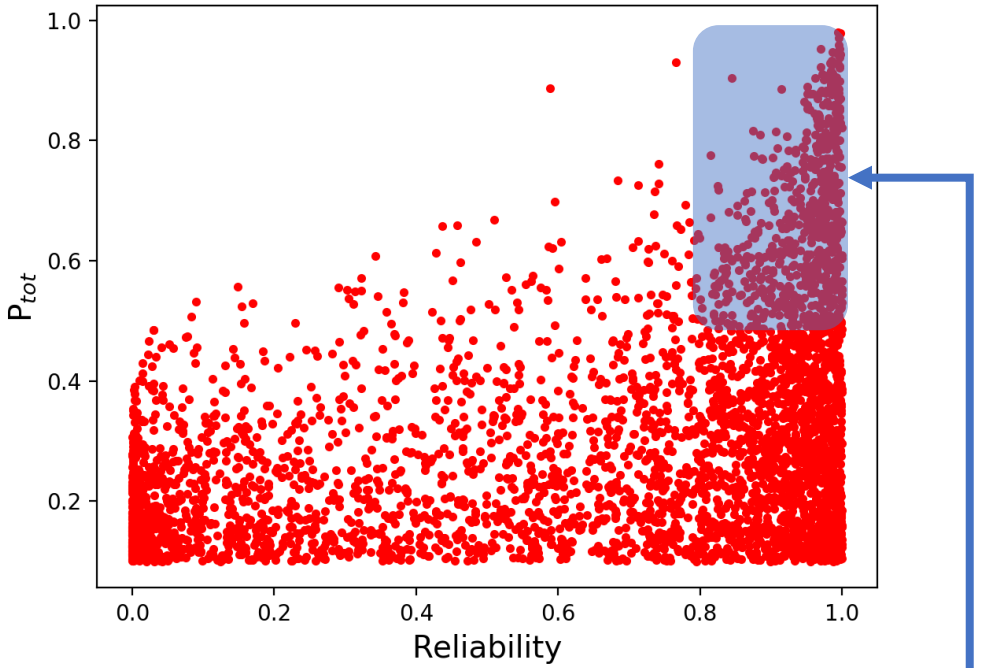
Bhattacharyya distance for two normal distributions, with μ_x and σ_x^2 as the mean and variance.

$$P_{tot} = BC_{pos} * (1 - BC_z) * (1 - BC_r) * L_{perc}$$

Final probability associated with each strong lensed galaxy candidate.

Results

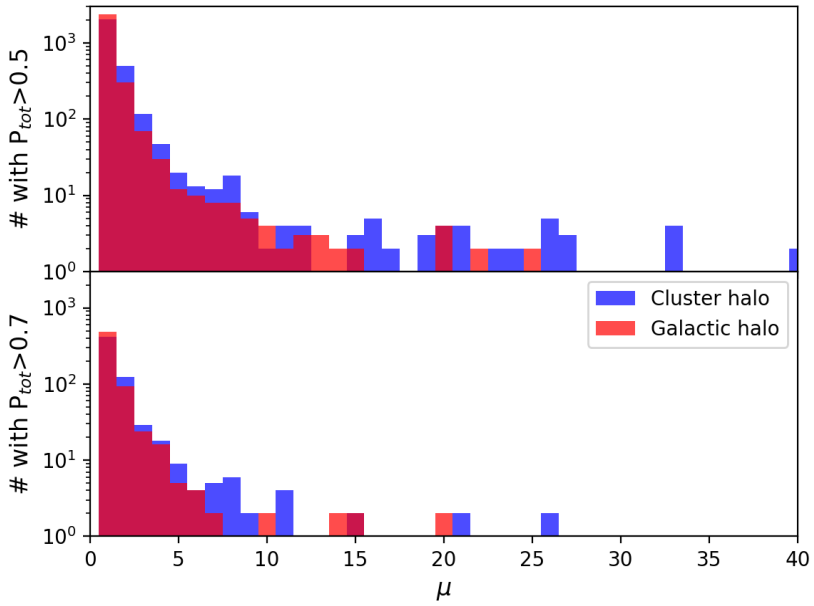


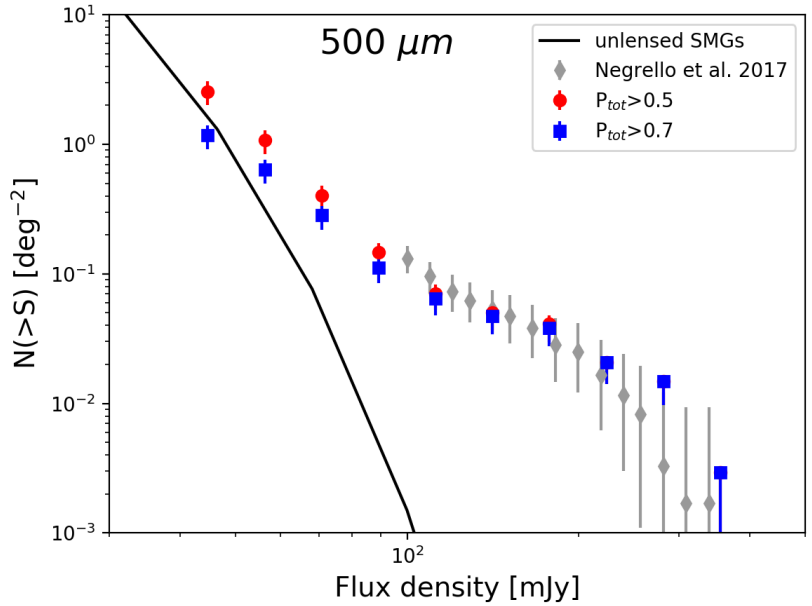


- Probability feedback provided by each observable.
- Redshift separation and Flux ratio are the most important ones.
- Total probability is compared with the number of random pairs expected.

- SHALOS total Probability vs. traditional cross-match likelihood Reliability.
- Confirmation of an already known problem: **Strongly lensed galaxies are usually identified as the sub-mm counterpart of the lenses.**

Results





- Tentative amplification factors derived assuming a galactic and cluster halo masses.
- For P_{tot}>0.7, they have an estimated mean amplification factor of 3.12 (2.28) for a halo with a typical cluster (galaxy) mass.

- Integrated source number counts at 500 µm of the SHALOS candidates with P_{tot} >0.5 & 0.7.
- These counts are compared with the integrated number counts of candidate lensed galaxies derived by Negrello et al. (2017) from all the H-ATLAS fields (grey diamonds).
- The black line is the model for the unlensed SMGs (Lapi et al. 2011; Cai et al. 2013).

Impact & Future

- The SHALOS method provides a ranked list of strongly lensed galaxies.
- The number of candidates within ~340 deg^2 of the Herschel-ATLAS surveyed area for a total probability, $P_{tot} > 0.7$ is 447.
- Statistical properties of the SHALOS candidates are in agreement with previous studies indicating the **statistical lensing nature of the selected sample**.

- The SHALOS method is very versatile!
- It can adopt additional observables.
- **It can be adapted to different selection scenarios** (not just lensing)

Field	Initial (#)	Sample (#)[%]	$P_{tot} > 0.1$ (#)[%]	$P_{tot} > 0.5$ (#)[%]	$P_{tot} > 0.7$ (#)[%]
G09	39660	2808 [7.08%]	1374 [3.46%]	240 [0.61%]	73 [0.18%]
G12	38961	2924 [7.50%]	1377 [3.53%]	213 [0.55%]	68 [0.17%]
G15	41609	3059 [7.35%]	1506 [3.62%]	243 [0.58%]	70 [0.17%]
NGP	118980	8437 [7.09%]	4129 [3.47%]	755 [0.63%]	236 [0.20%]
ALL	239210	17228 [7.20%]	8386 [3.51%]	1451 [0.61%]	447 [0.19%]