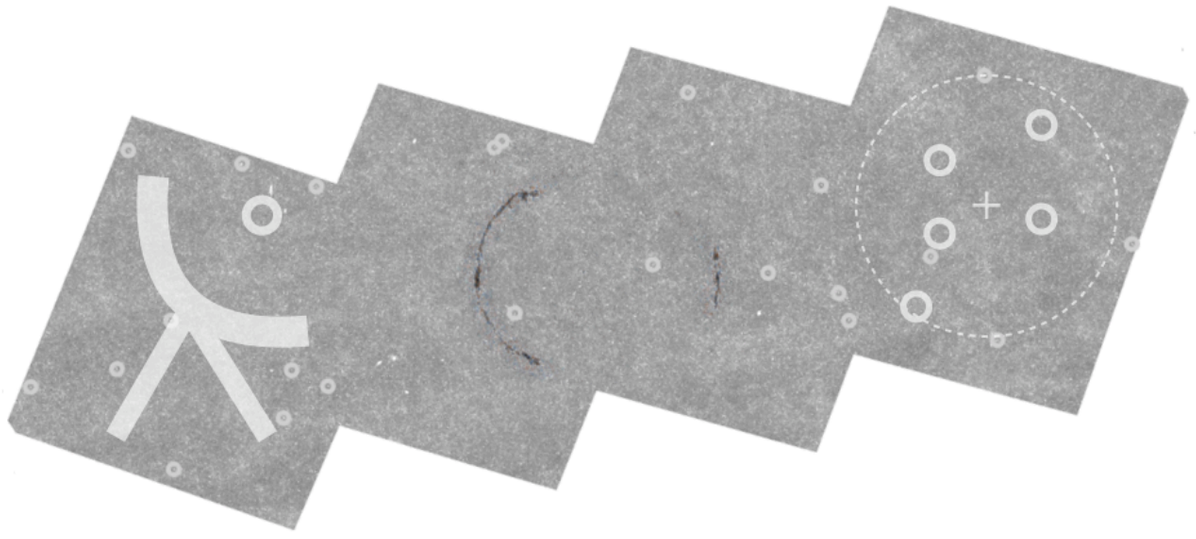
How many gravitational lenses did Herschel detect?

Optical and near-infrared counterparts to sub-mm sources



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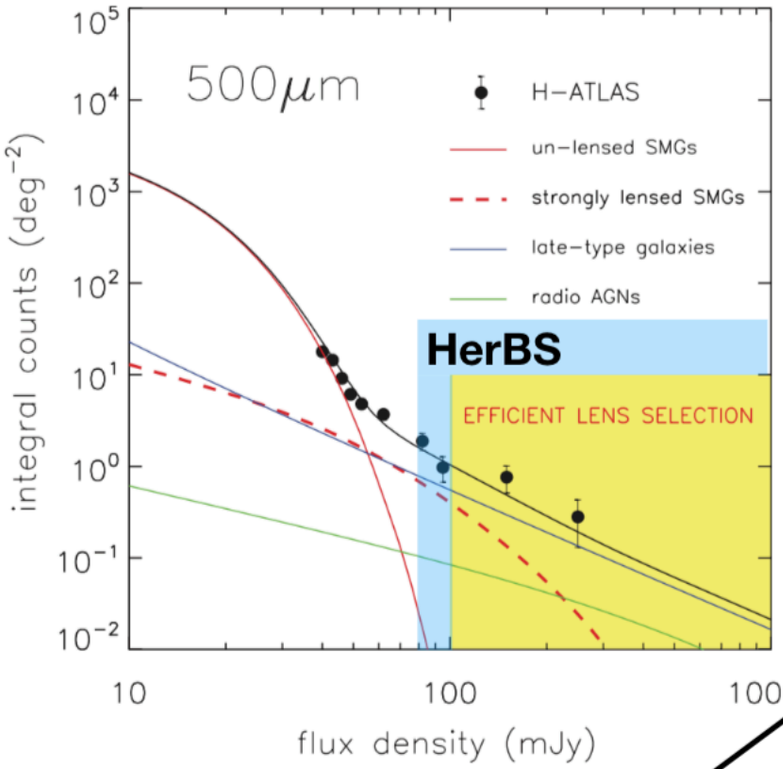
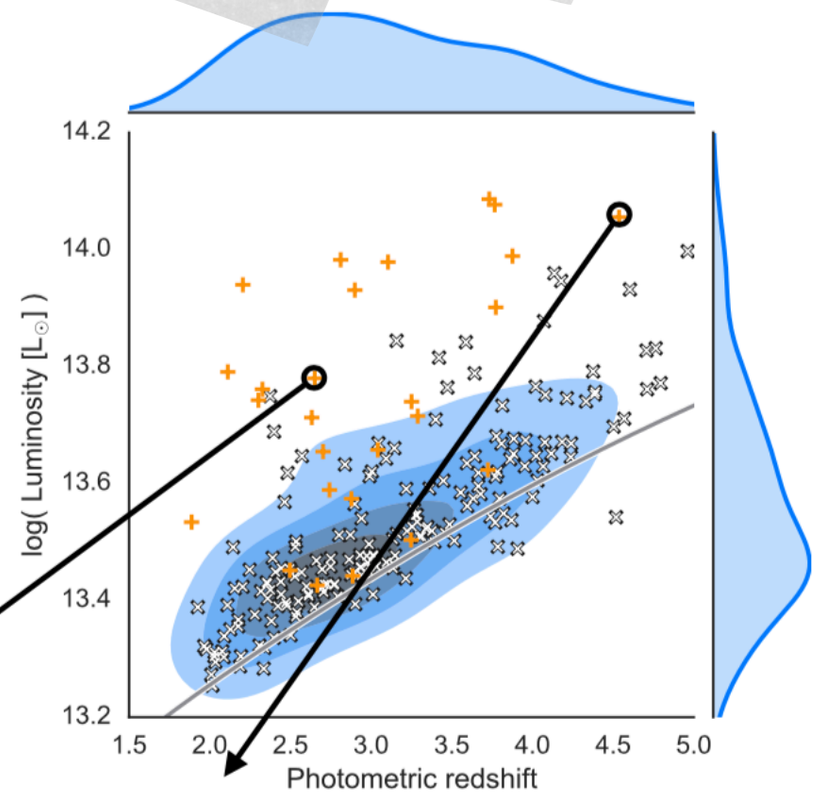
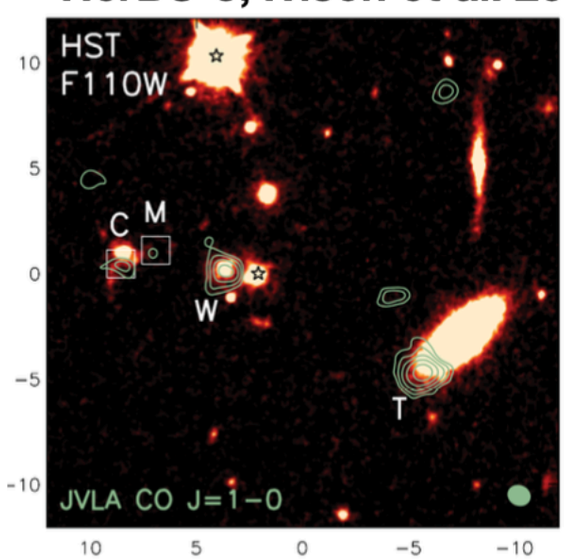
Brightest sub-mm sources are mostly lensed

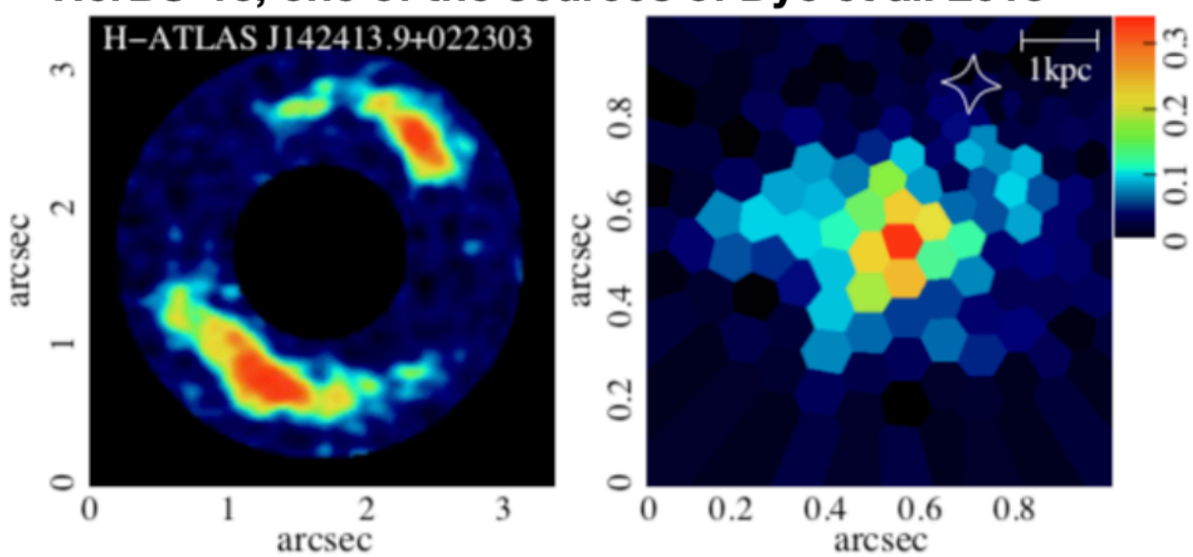




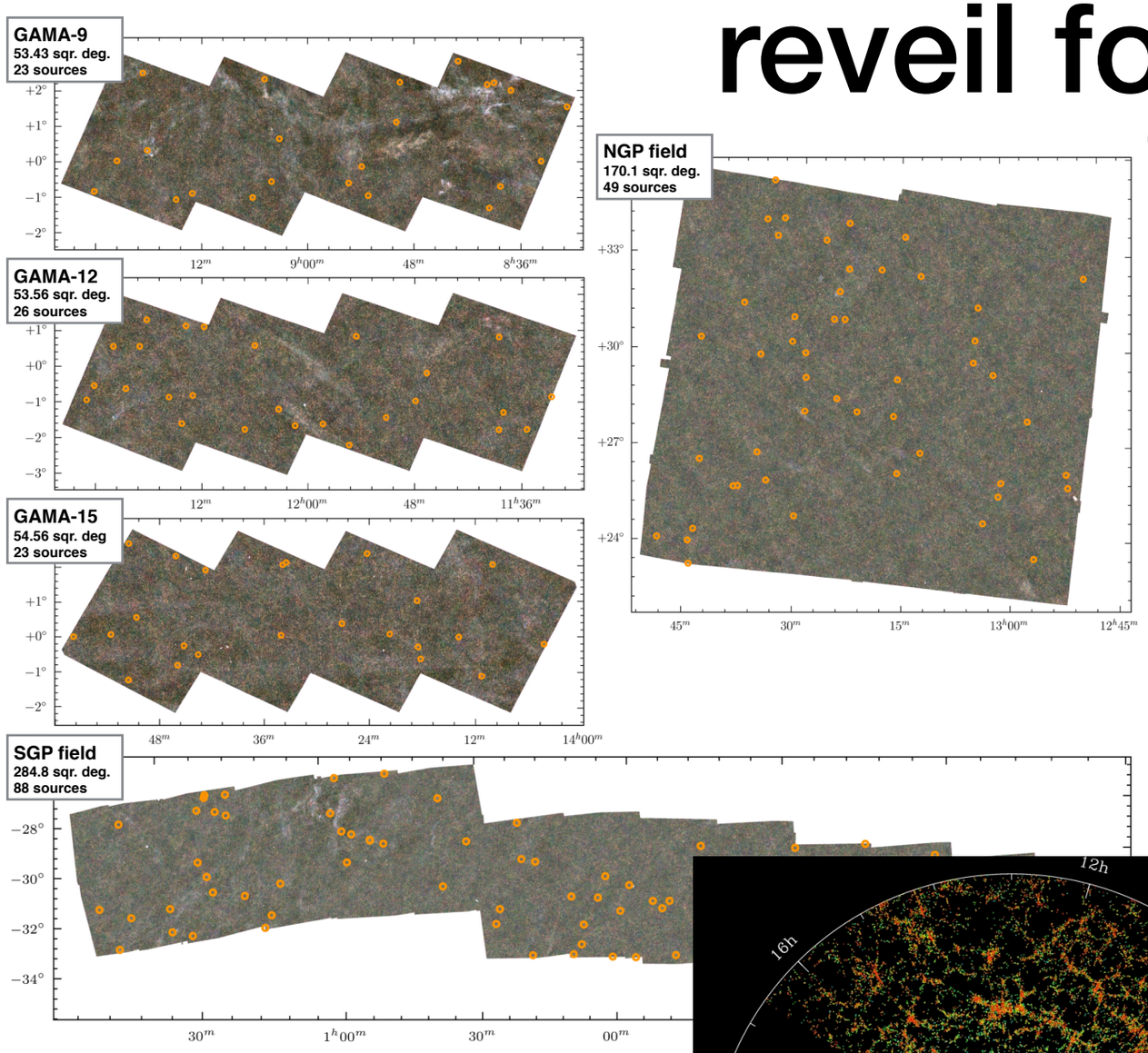
HerBS-8; Ivison et al. 2013

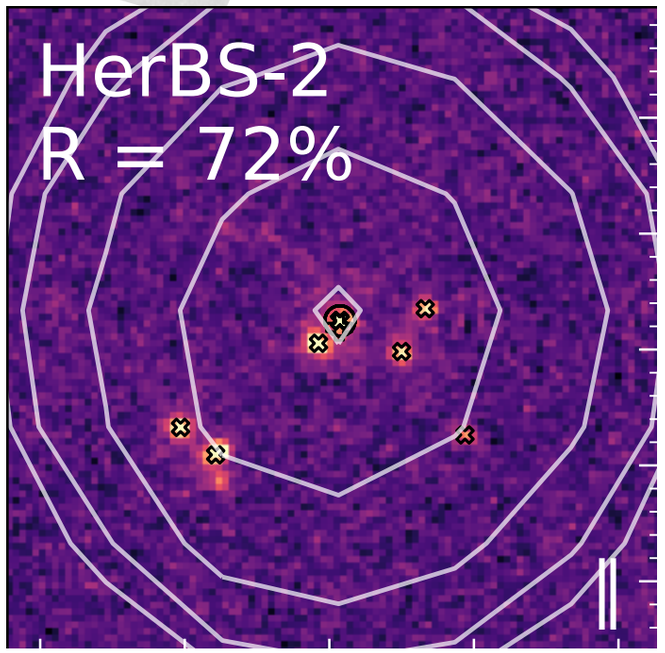


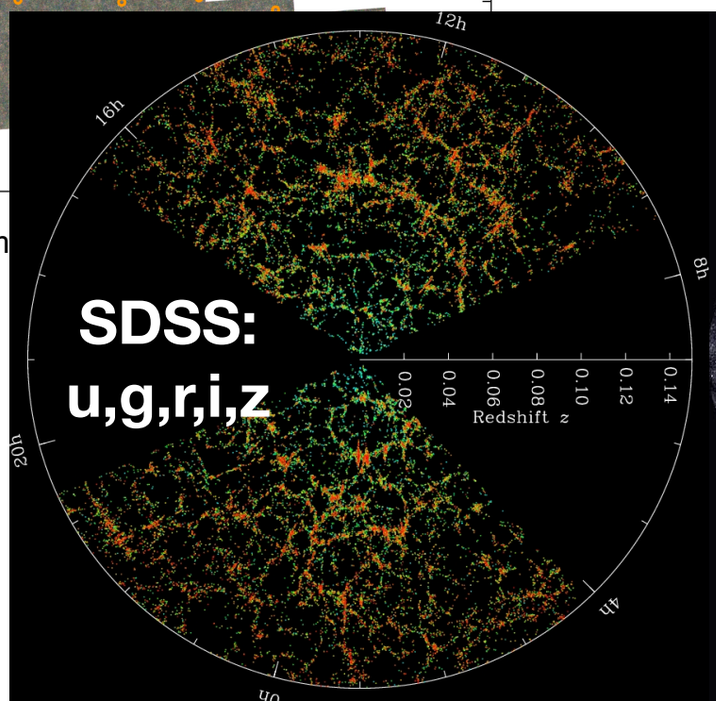
HerBS-13; one of the sources of Dye et al. 2018

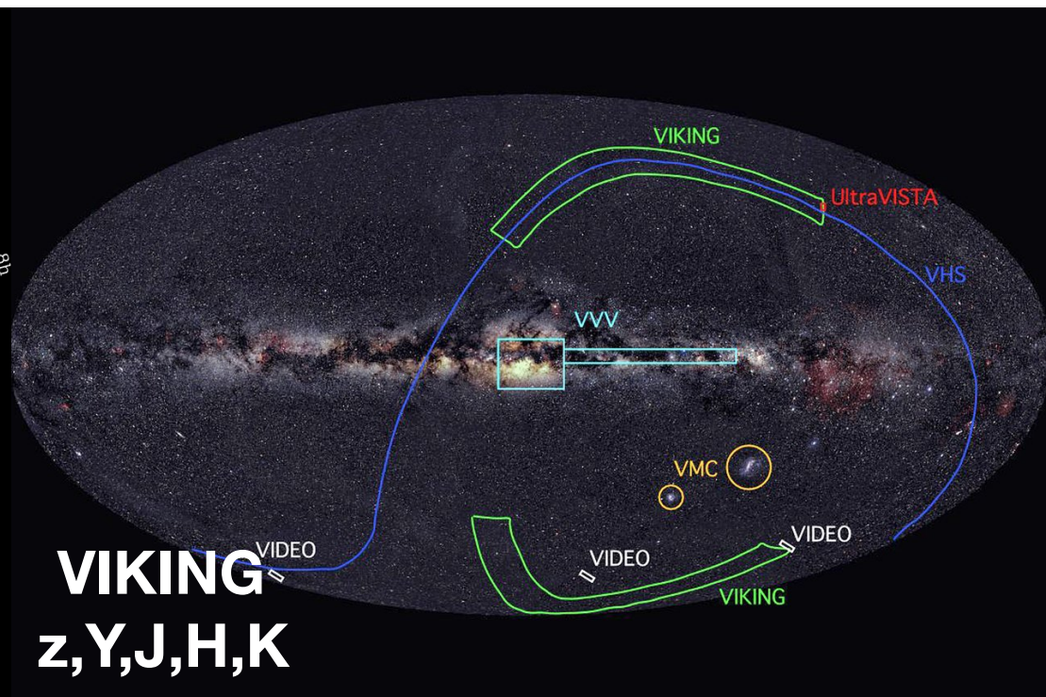


Counterparts in SDSS and VIKING reveil foreground lenses









The probability follows from two ‘simple’ equations

$$L = \frac{q(m) f(r)}{n(m)} \cdot \equiv \frac{\text{Chance of source (m) at distance (r)}}{\text{Chance of a random source (m)}}$$

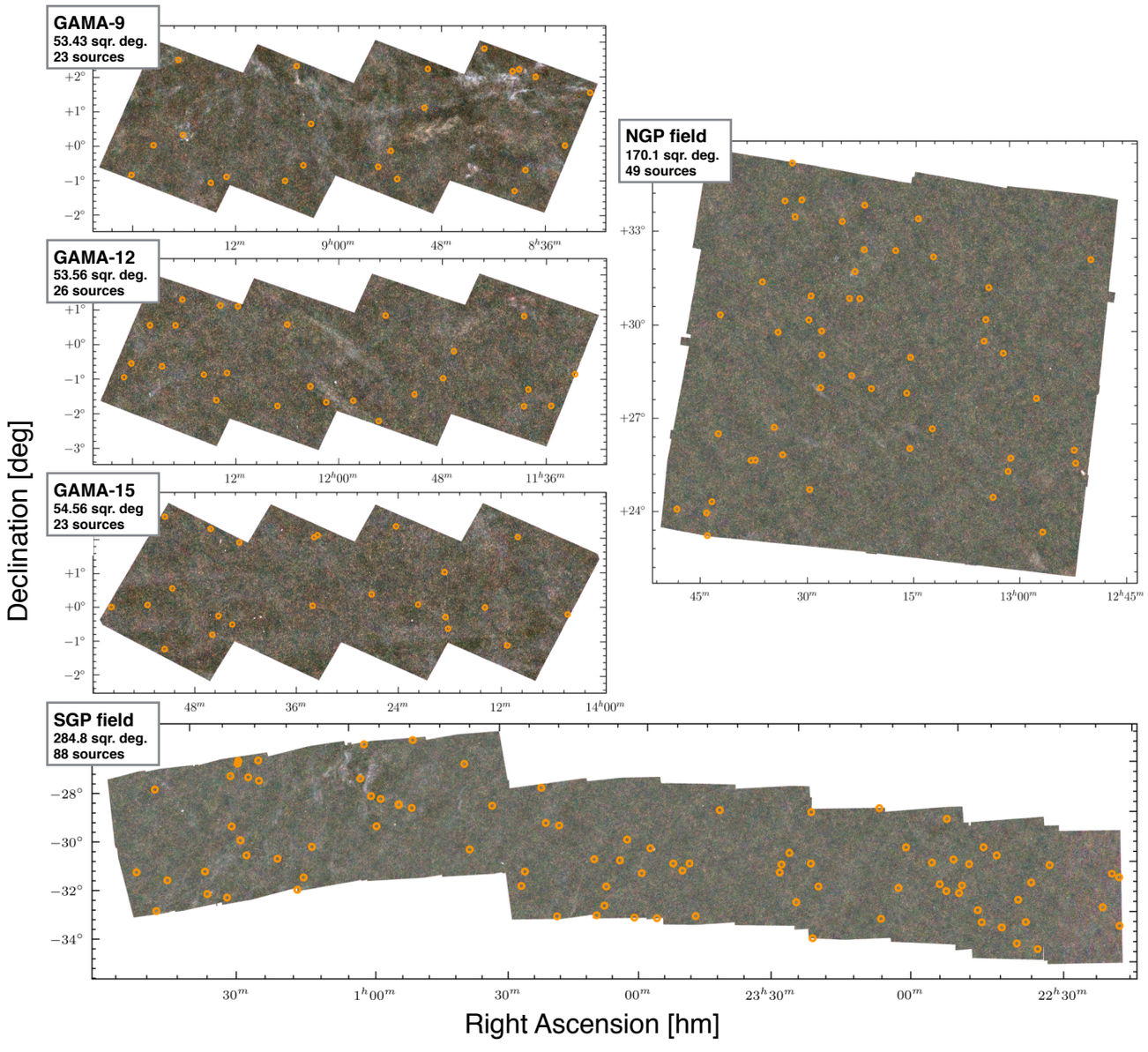
$$R_j = \frac{L_j}{\sum_i L_i + (1 - Q_0)} \cdot \equiv \text{Probability of this source j being a genuine counterpart}$$

Chance the source outside of survey depth

SDSS counterparts already exist, but finds only 35% of counterparts

Table 1. The SDSS reliabilities of Herschel sources.

R	< 0.8	> 0.8	All
GAMA	52	20	72
NGP	38	11	49
Total	90	31	121



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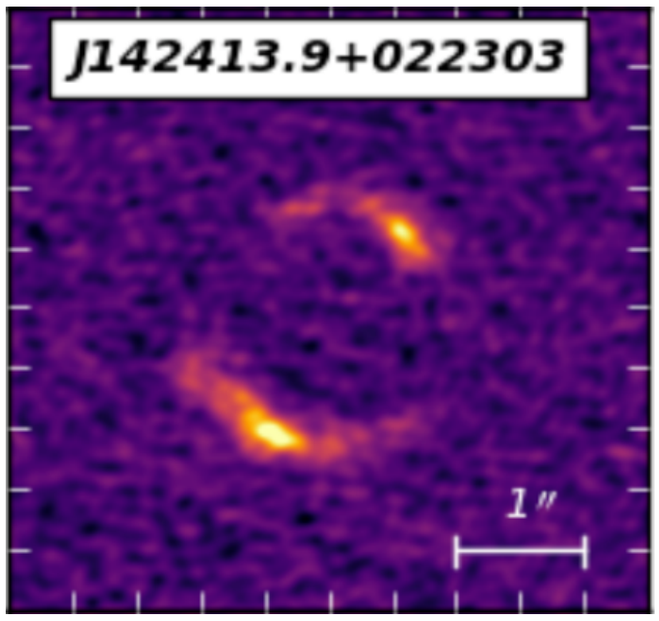
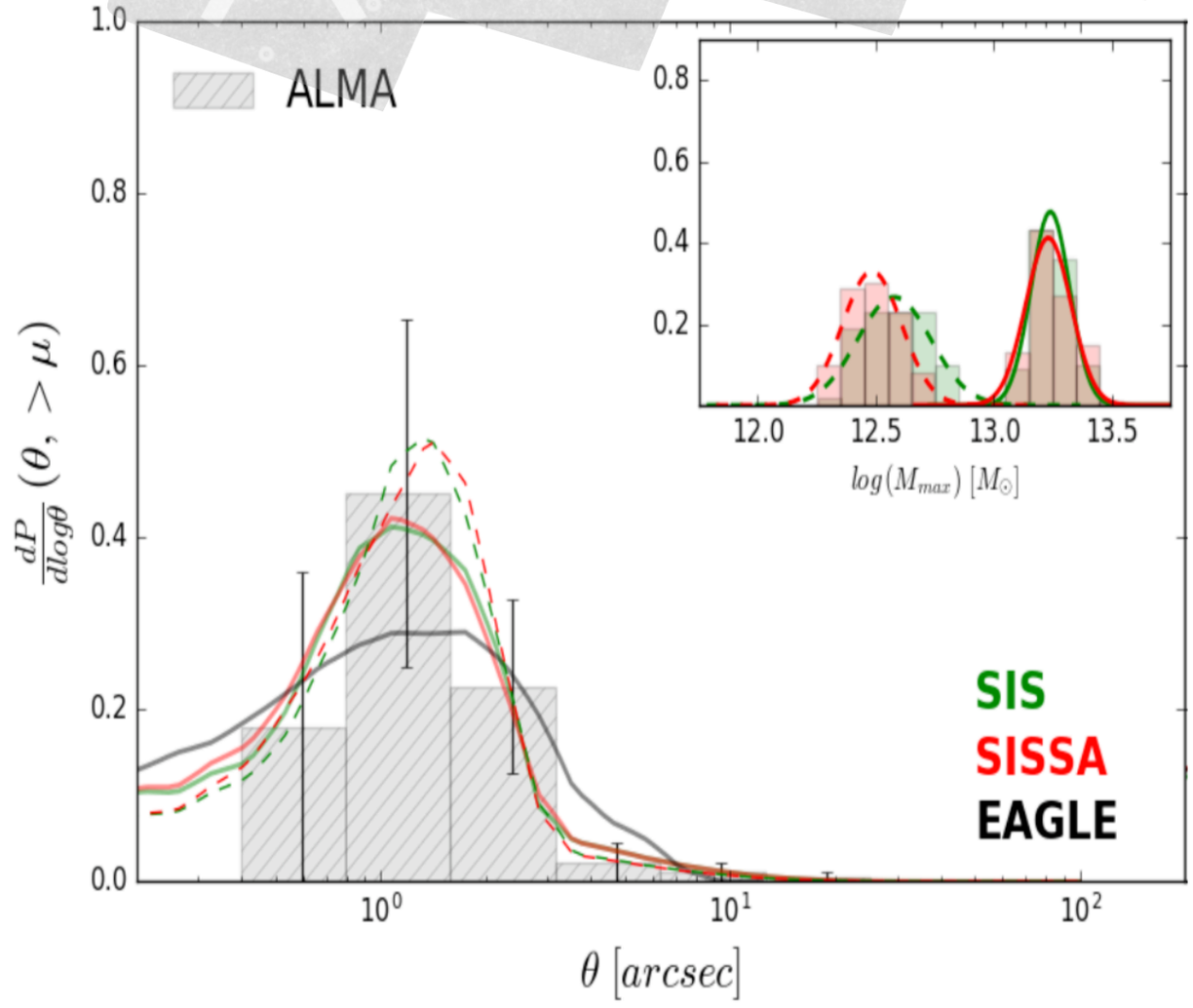
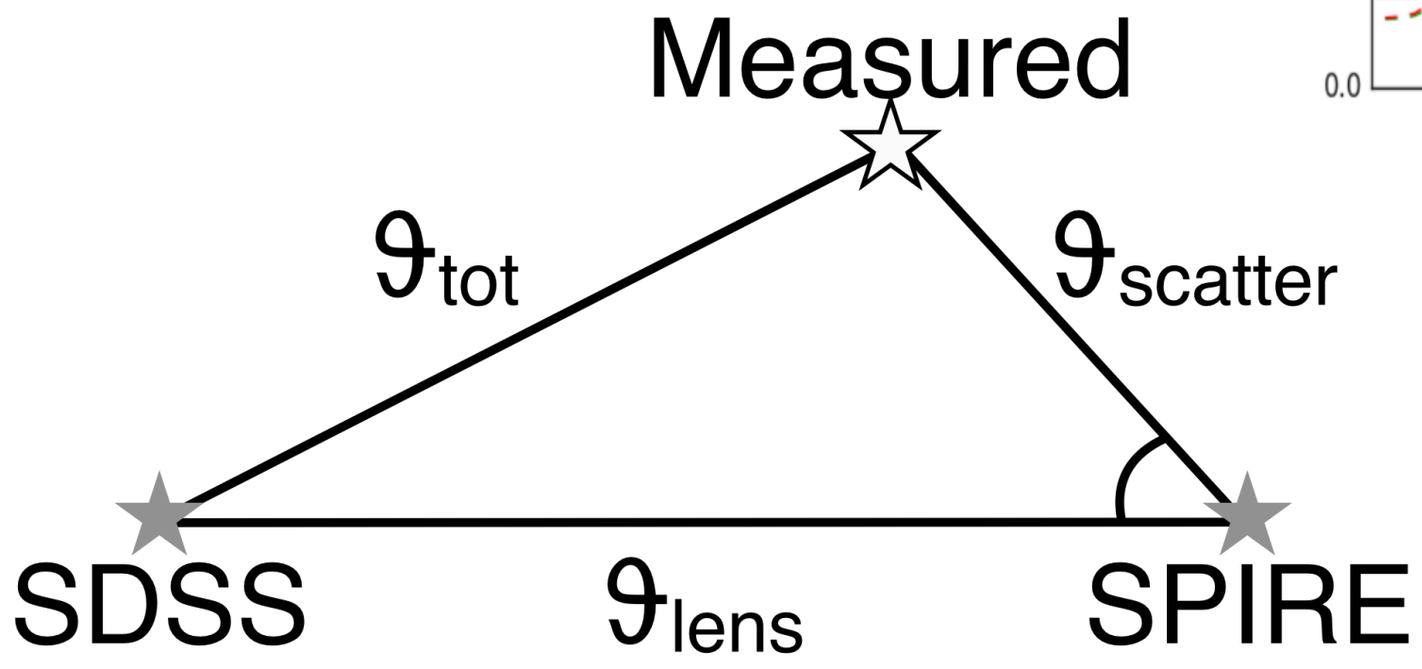
Chance the source outside of survey depth

Recalculating the angular probability distribution allows us to find more lenses



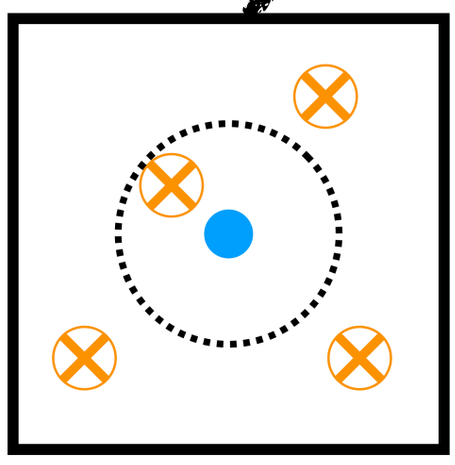




The re-analysis suggests we are missing multiple lensed sources

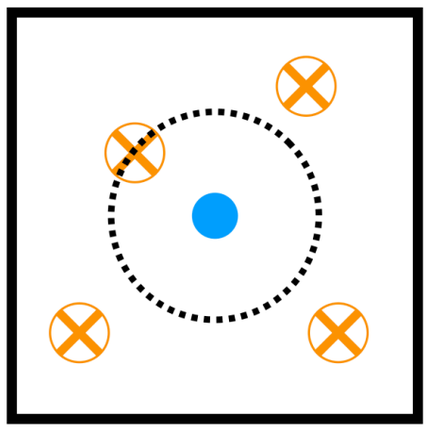
Model	Method 1	Method 2
No lens	31	31
Total model	32.5	41

Statistics on reliable sources

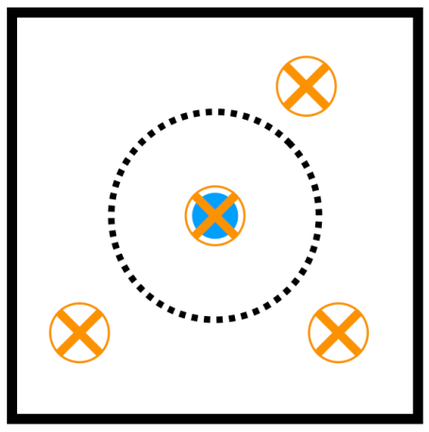


Complete recalculation

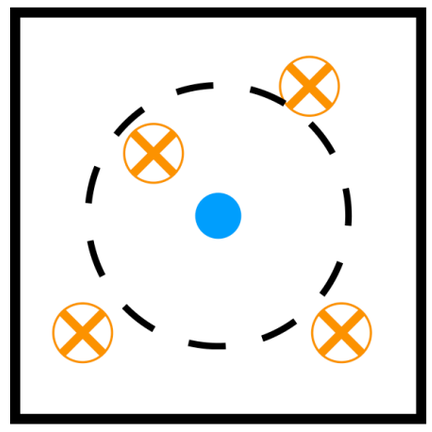
$L \sim e^{-\theta_{\rm sc}^2/2}$



L_0



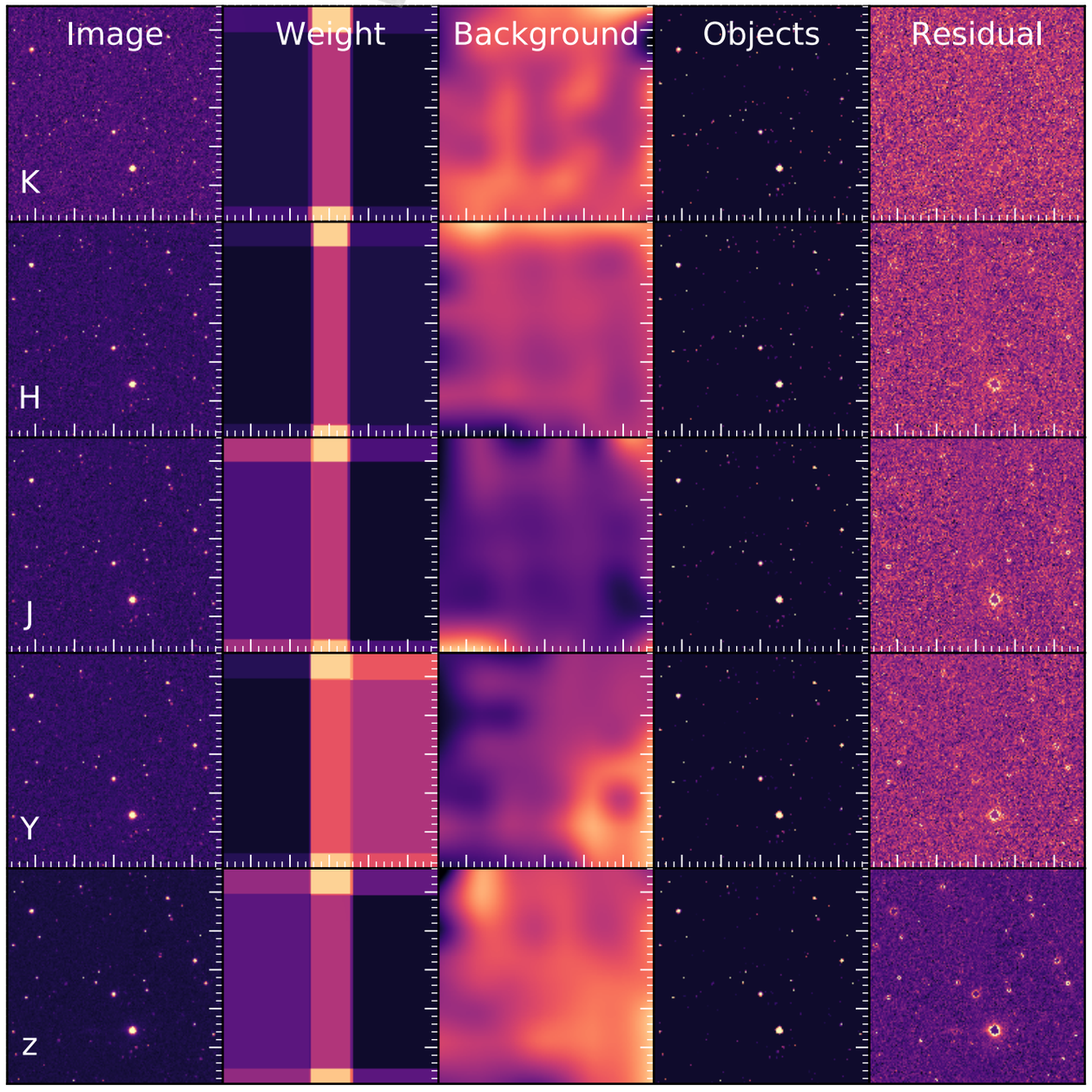
$L' \sim f(\theta_{\rm lens}, \theta_{\rm sc})$



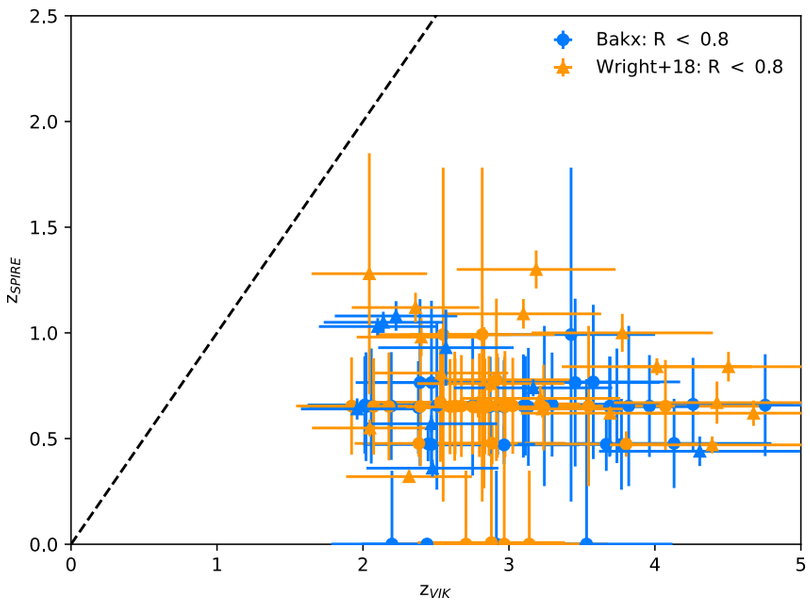
VIKING sources are extracted by minimising the residuals

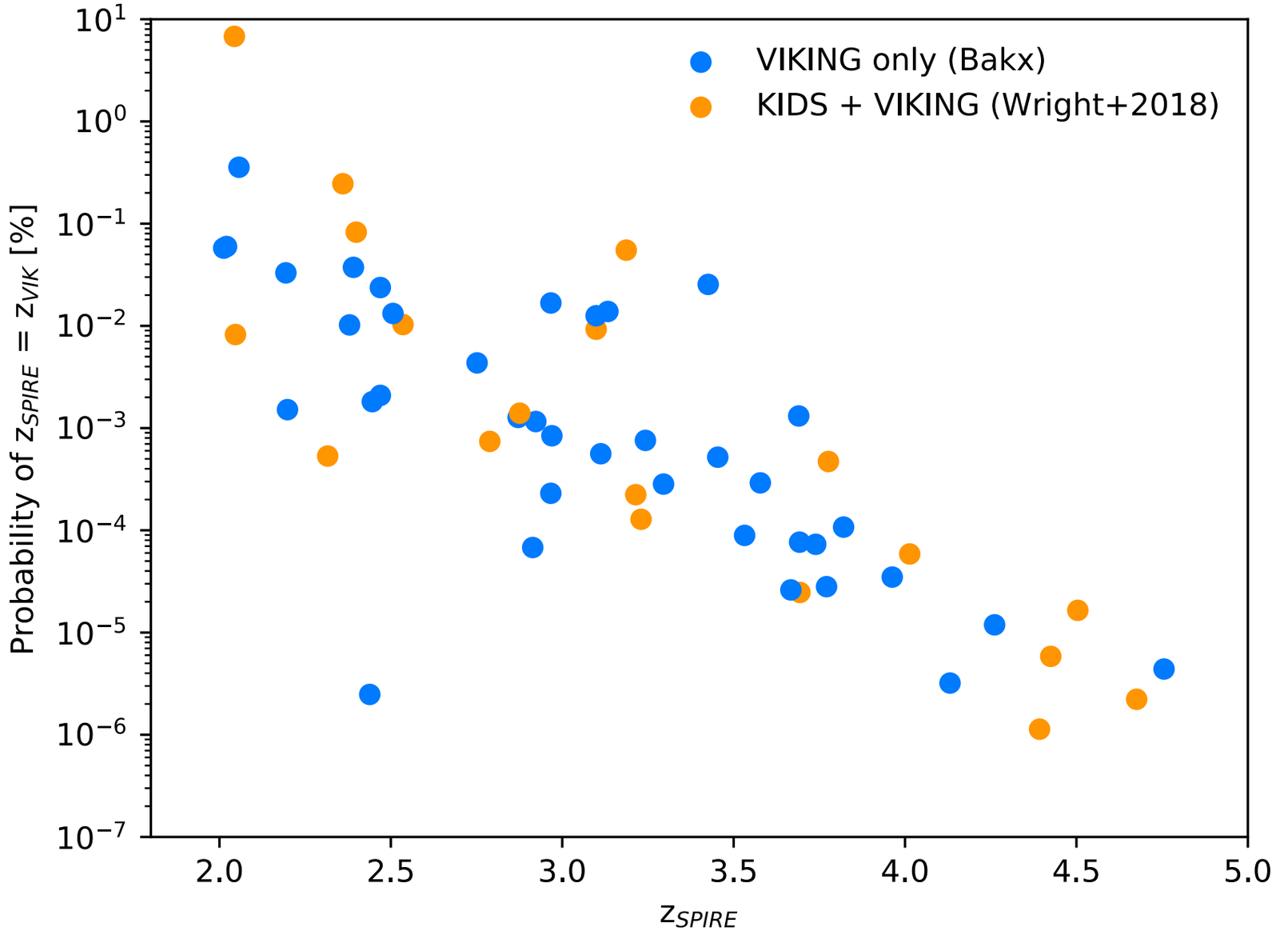
Table 3. VIKING reliabilities

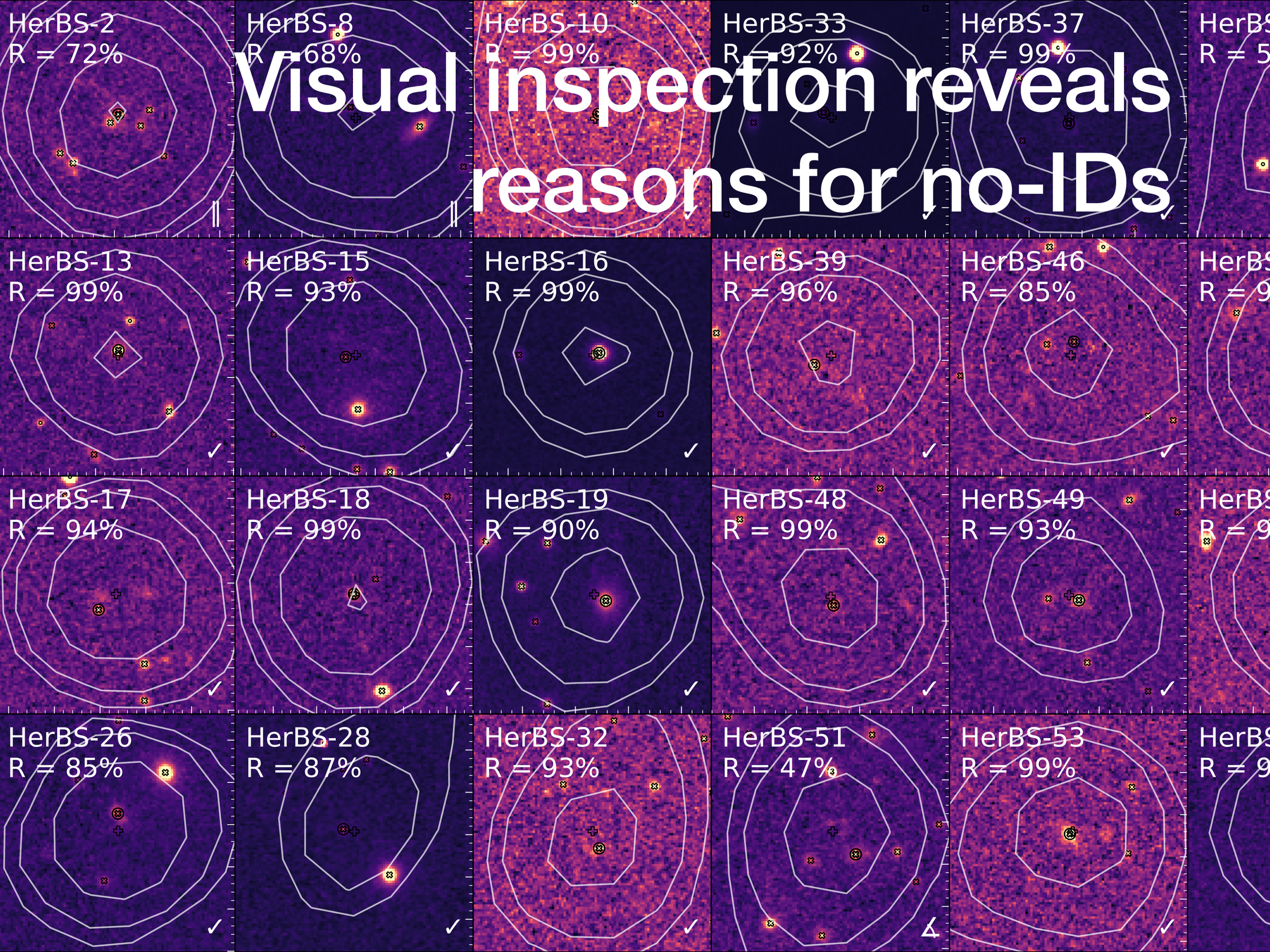
R	< 0.8	> 0.8	All
SGP	6	22	28
GAMA09	13	8	21
GAMA12	9	17	26
GAMA15	10	13	23
Total	38	60	98



Foreground sources
≠
Background sources







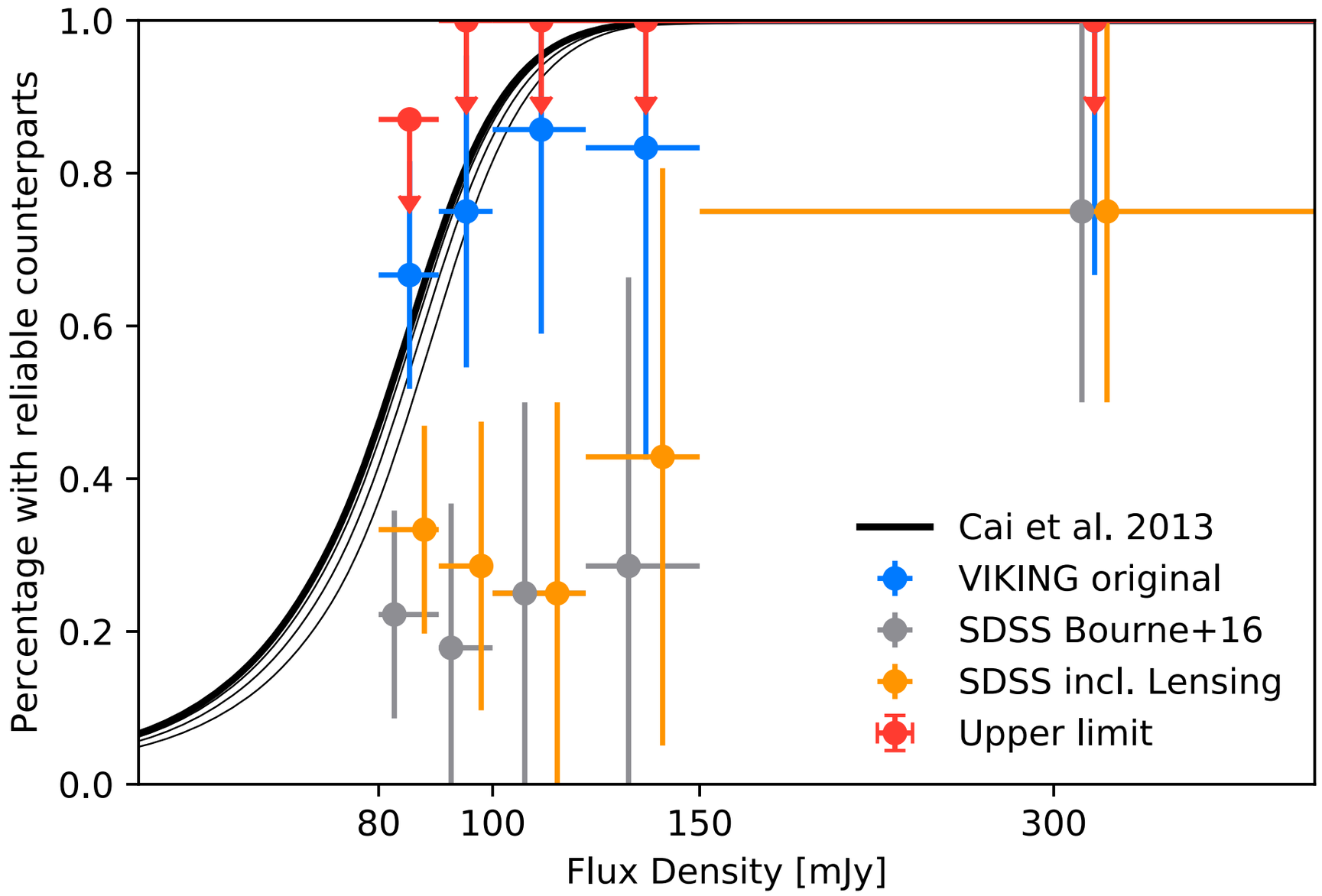
Visual inspection reveals reasons for no-IDs

Why more is less

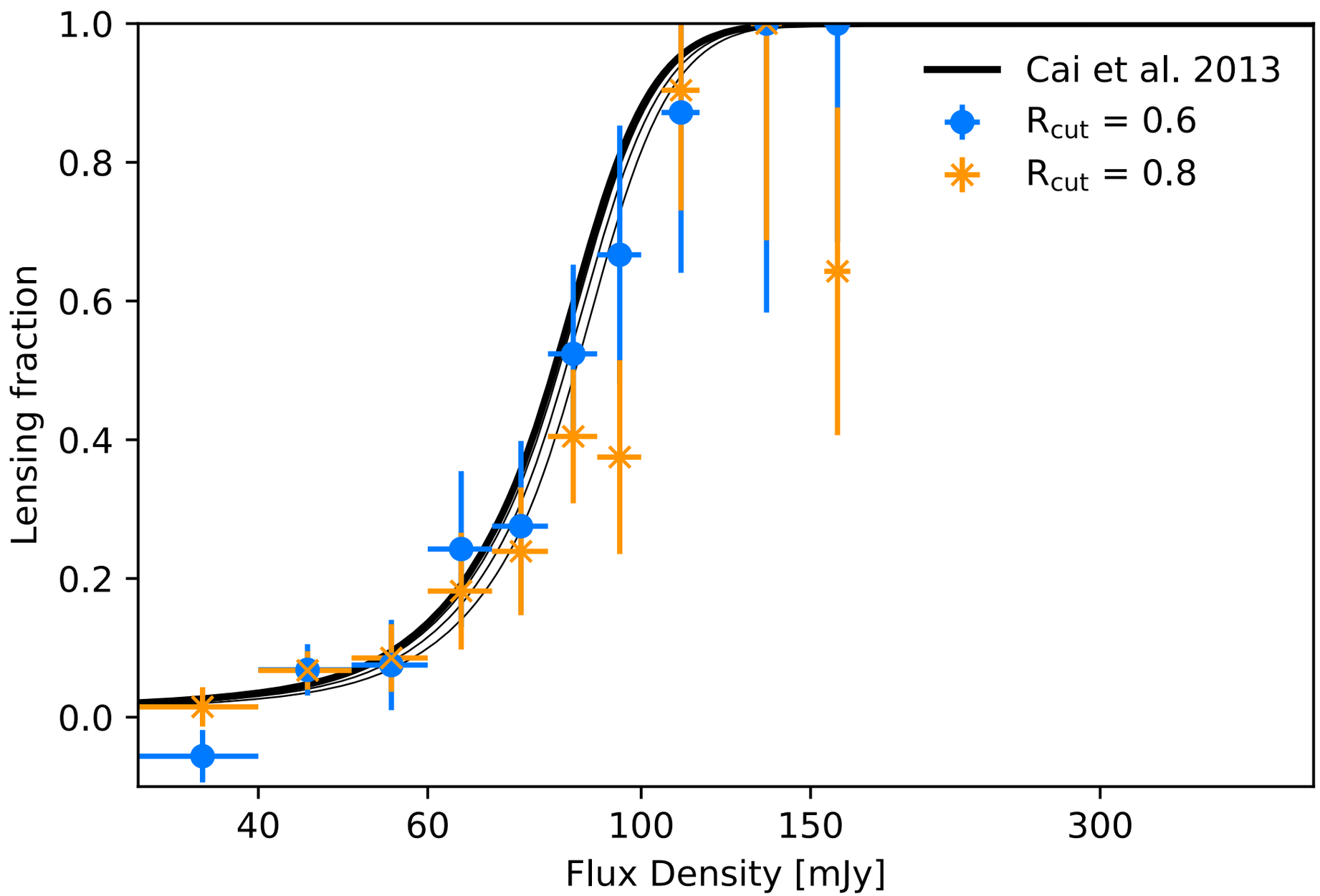
Table 4. VIKING visual inspection results

Counterpart with R < 0.8 because . . .	Amount
. . . i. large angular separation	$\measuredangle$: 9
. . . ii. nearby, competing sources	$\|\|$: 14
. . . iii. close source not picked up	$\otimes$: 6
. . . iv. close source with J - $K_S < 0$	$\leq$: 2
. . . v. nothing nearby is detected	$\varnothing$: 7

While SDSS does not see all foreground sources, VIKING appears complete

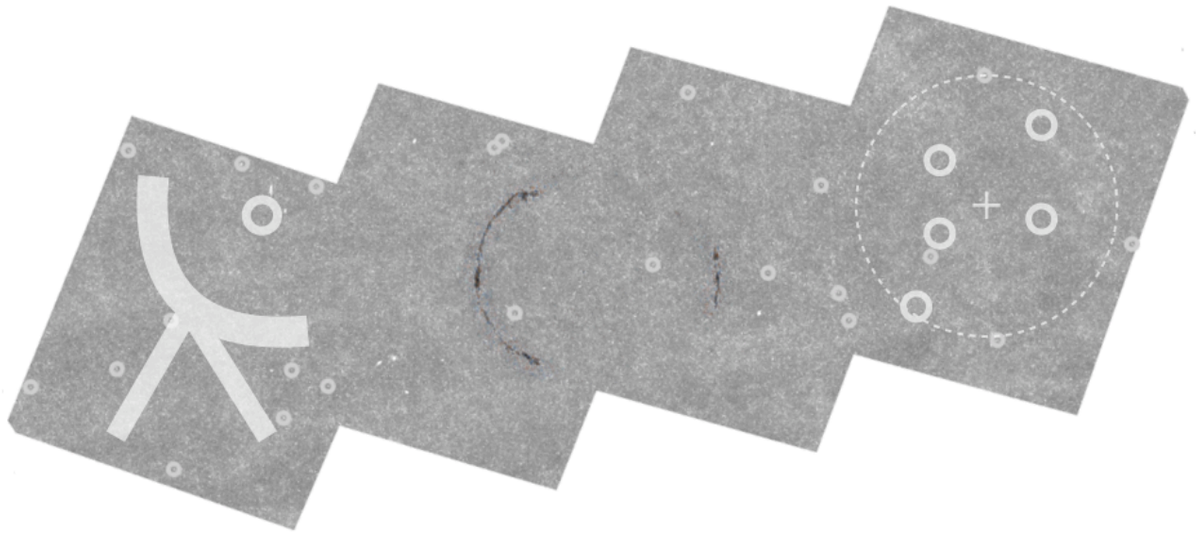


Using all Herschel sources reveals the lensing fraction



How many gravitational lenses did Herschel detect?

Optical and near-infrared counterparts to sub-mm sources



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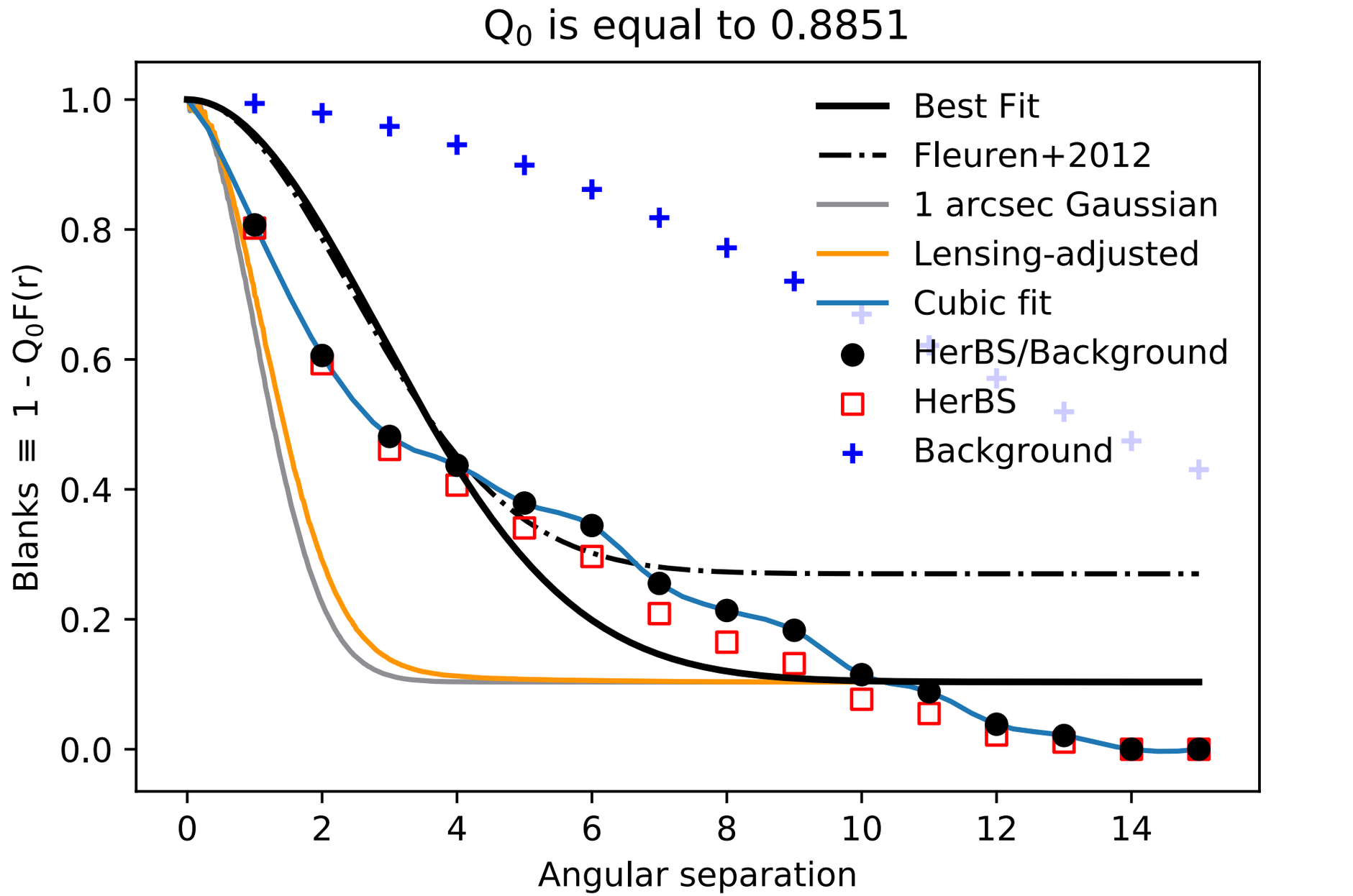
The sources extend out to high angular scales



Recalculated angular distribution