Rubin Observatory

Sky Subtraction in an Era of Low Surface Brightness Astronomy

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LSB observational challenges

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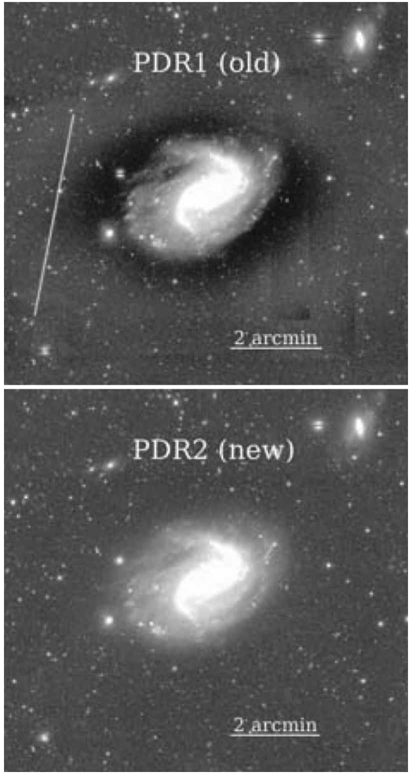
LSB sources (e.g., dwarf galaxies, stellar haloes, ICL) are incredibly faint (<1% sky) and, as such, very difficult to measure.

Issues:

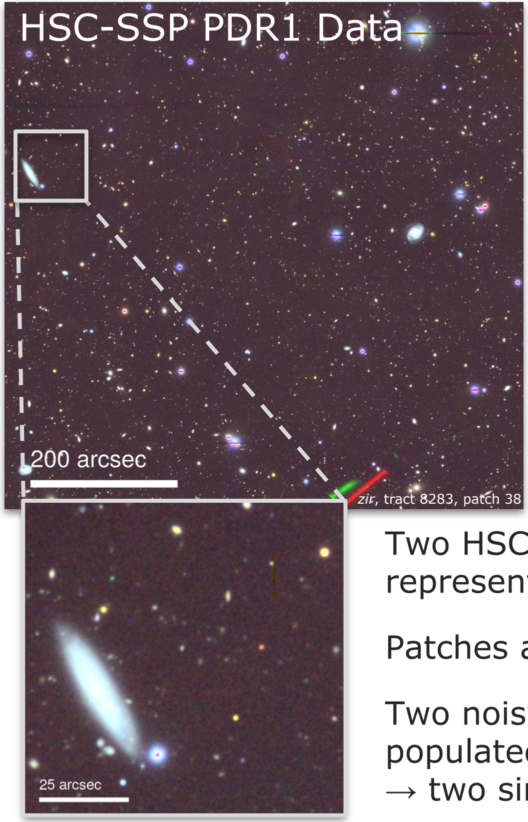
- Appropriate observing techniques
- Imaging ghosts / haloes / diffraction spikes
- CCD artefacts (e.g., edge effects)
- Astrophysical contaminants (e.g., cirrus)
- Crowded fields / extended source profile overlap
- Source extraction and masking / modelling
- **Sky estimation → potential over-subtraction**

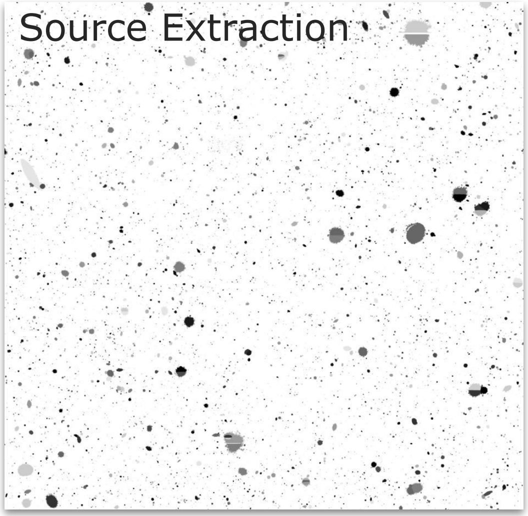
***Question**: What techniques can we adopt to better preserve LSB flux?*

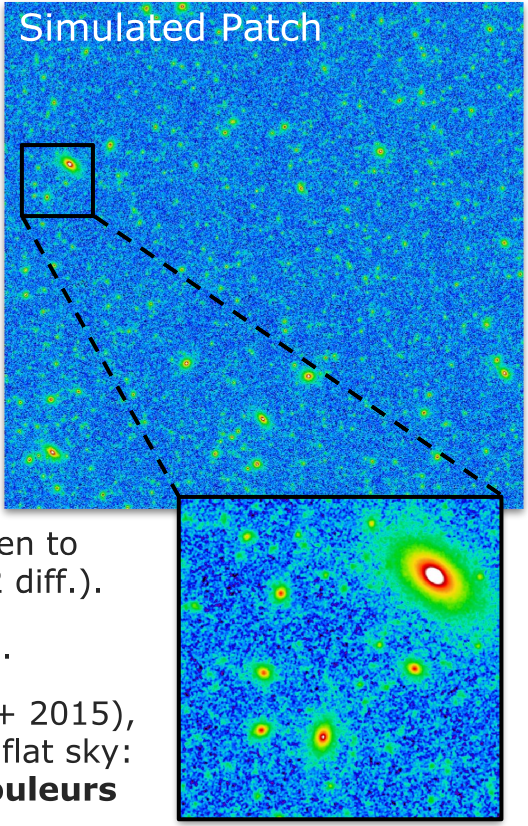


Adapted from Aihara et al. 2019

From HSC data to HSC-type simulations







Two HSC-SSP PDR1 tract/patch regions are selected, chosen to represent a low-density and a high-density field (factor ~2 diff.).

Patches are characterised using SExtractor (Bertin+ 1996).

Two noisy simulated fields are created with GalSim (Rowe+ 2015), populated with $\sim 5\times10^5$ PSF-convolved Sérsic sources and flat sky:
→ two sim. field types per field: **exponential** & **de Vaucouleurs**

Software & techniques

Three software packages are utilised:

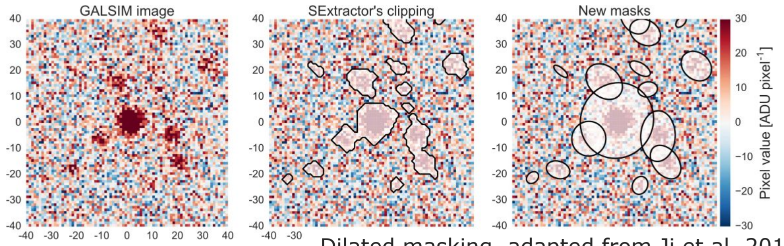
- SExtractor (Bertin+ 1996)
- Gnuastro / NoiseChisel (Akhlaghi+ 2015)
- LSST Science Pipelines (Bosch+ 2018, 2019)

SExtractor and Gnuastro are run in four modes:

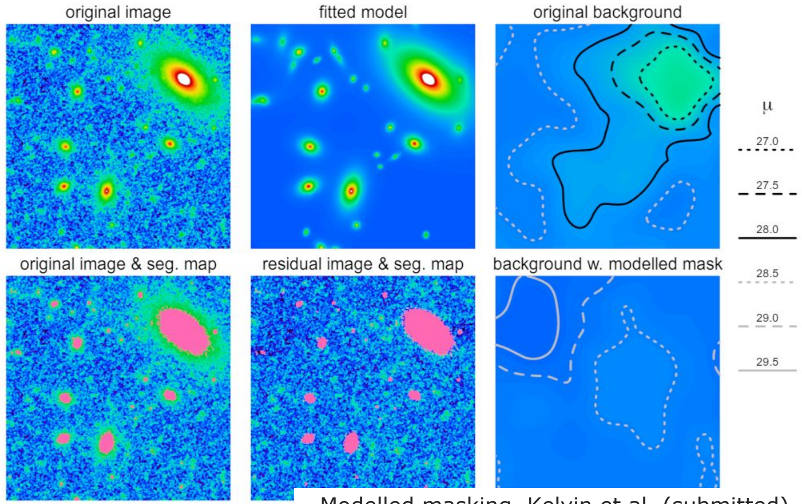
1) Default
2) Modified (e.g., det. thresh, sky mesh size)
3) Dilated masking
4) Modelled masking

LSST Pipelines are run in two sky estimation configs:

1) Sixth degree polynomial fit (P6)
2) 128-pixel spline fit (S128)

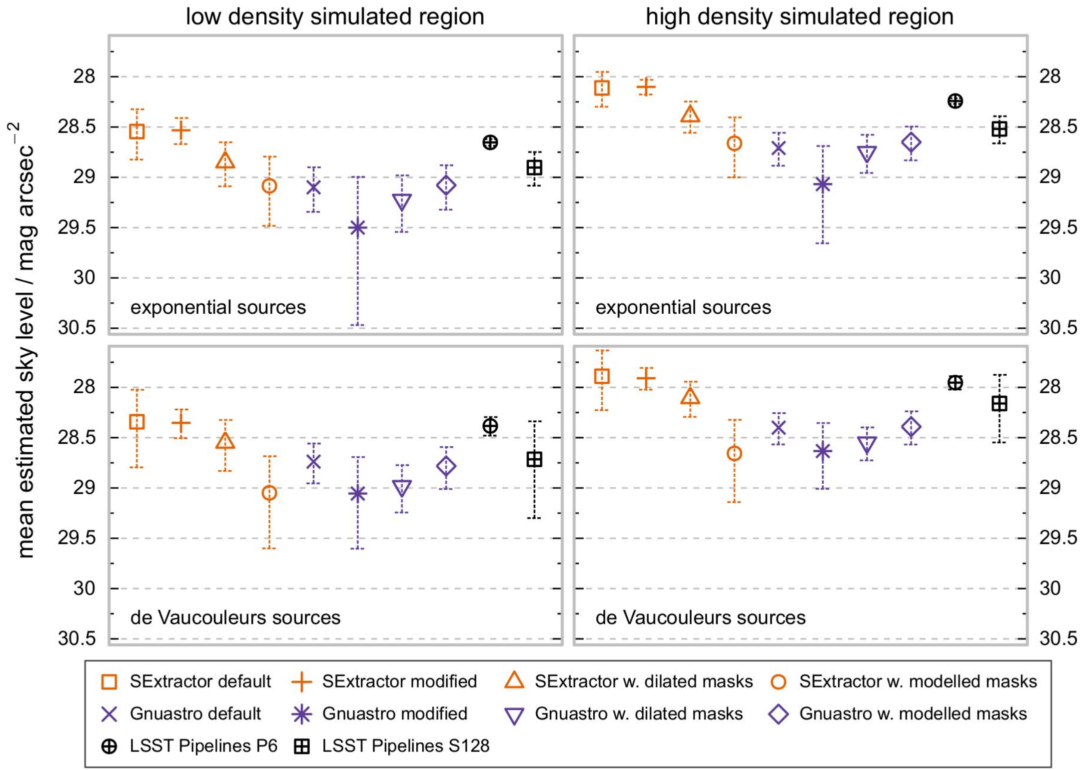


Dilated masking, adapted from Ji et al. 2018



Modelled masking, Kelvin et al. (submitted)

Results: recovered sky map levels



Kelvin et al. (submitted)

Key takeaways:

→ High den. to low den.: ~0.5 mag fainter

→ deV to exp.: ~0.2 mag fainter

→ SExtractor to Gnuastro: ~0.5 mag fainter, with LSST Pipelines intermediate

The 'bottom-up' approach employed by Gnuastro appears to recover a fainter and more accurate sky than the 'top-down' thresholding techniques utilised by SExtractor/LSST Pipelines.

Modifications to Gnuastro/LSST Pipelines do improve sky level estimates, however, the largest gains (~1 mag) are made when applying modelled masks to SExtractor.

Results: recovered source luminosity fractions

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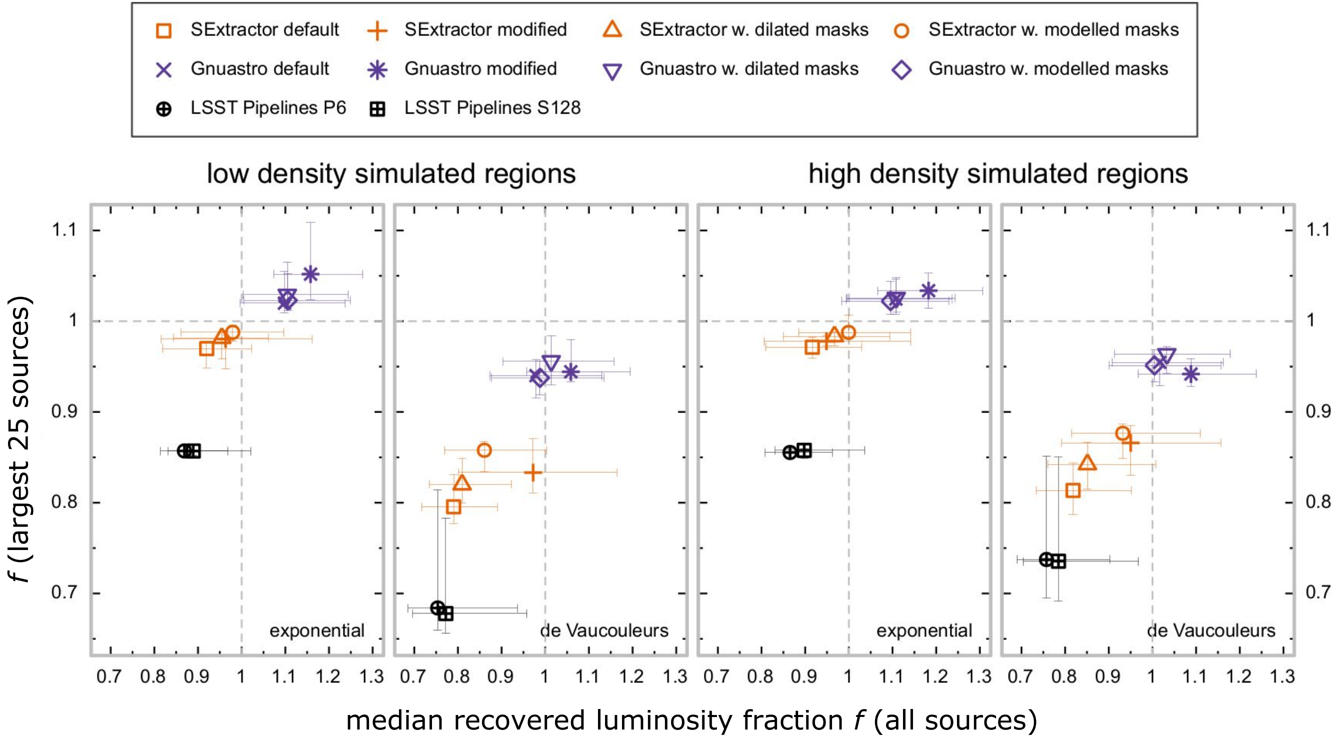

Kelvin et al. (submitted)

Gnuastro optimised towards accurate recovery of extended de Vaucouleurs sources.

Conversely, SExtractor (& LSST Pipelines) perform better with more compact exponential type

With de Vaucouleurs type sources, SExtractor/LSST Pipelines miss ~20% of the input light.

For exponential type sources, Gnuastro *over-estimates* flux by ~10%.

Summary

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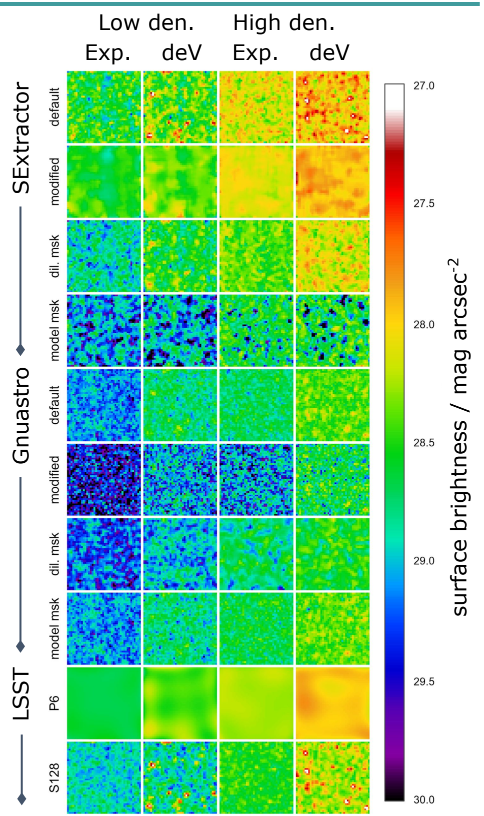
The potential for new and exciting LSB science with Rubin Obs is vast, however, its faint nature makes it very difficult to characterise
→ LSB light is particularly susceptible to sky over-subtraction.

What techniques can we adopt to better preserve LSB flux?

Using simulated HSC-SSP data, we test three software packages (SExtractor, Gnuastro and the LSST Science Pipelines) and multiple configuration modes.

Gnuastro recovers the faintest sky map levels out of the box, however, SExtractor performs comparably when adopting a modelled masking procedure.

The 'top-down' approach (SExtractor/LSST Pipelines) optimised towards exponential source recovery, whilst the 'bottom-up' approach (Gnuastro) performs best with de Vaucouleurs type sources.



Kelvin et al. (submitted)