Observing The Low-Surface Brightness Cosmos With WIYN And The One Degree Imager

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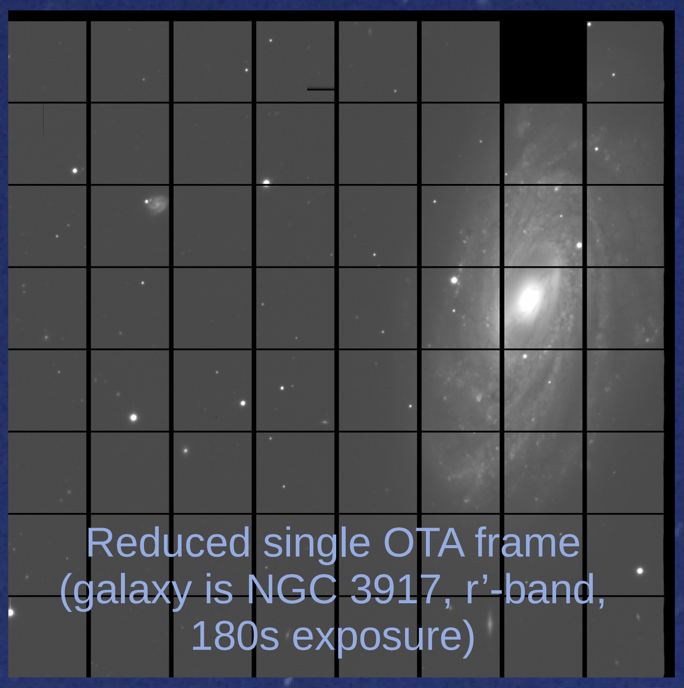
Introduction: WIYN & One Degree Imager


ODI focalplane

WIYN: 3.5m telescope at Kitt Peak National Observatory, optimized for good seeing


Reduced single OTA frame (galaxy is NGC 3917, r'-band, 180s exposure)

ODI: Wide-field imager (~ 40x48 arcmin), made up of 30 Orthogonal Transfer Arrays (OTA)

See Harbeck et al, (2014 & 2018) for details

Each OTA: 64 CCDs (cells)

→ ~1900 CCDs, 480 MPixels

Technical Challenges

Many CCDs: Lots of gaps between cells and detectors; different response functions and detector characteristics require careful data reduction
→ **Lots of dithering, using large and small offsets**

Open optical design of WIYN: Sensitive to scattered light from moon and bright stars
→ **Sky background variations if not dark sky**

Internal reflections between optical surfaces: pupil-ghost in both science and calibration data
→ **Take special dome flat-fields using shutter as internal baffle, and illumination correction frames as sky-template for optimized background removal**

Good data reduction requires intimate knowledge of many different instrument characteristics
→ **dedicated data reduction pipeline with full control by users, run in the cloud via a dedicated portal for pipeline and archive: ODI-PPA → portal.odi.iu.edu**

See Gopu et al (2015), Young et al (2014), Kotulla (2012)

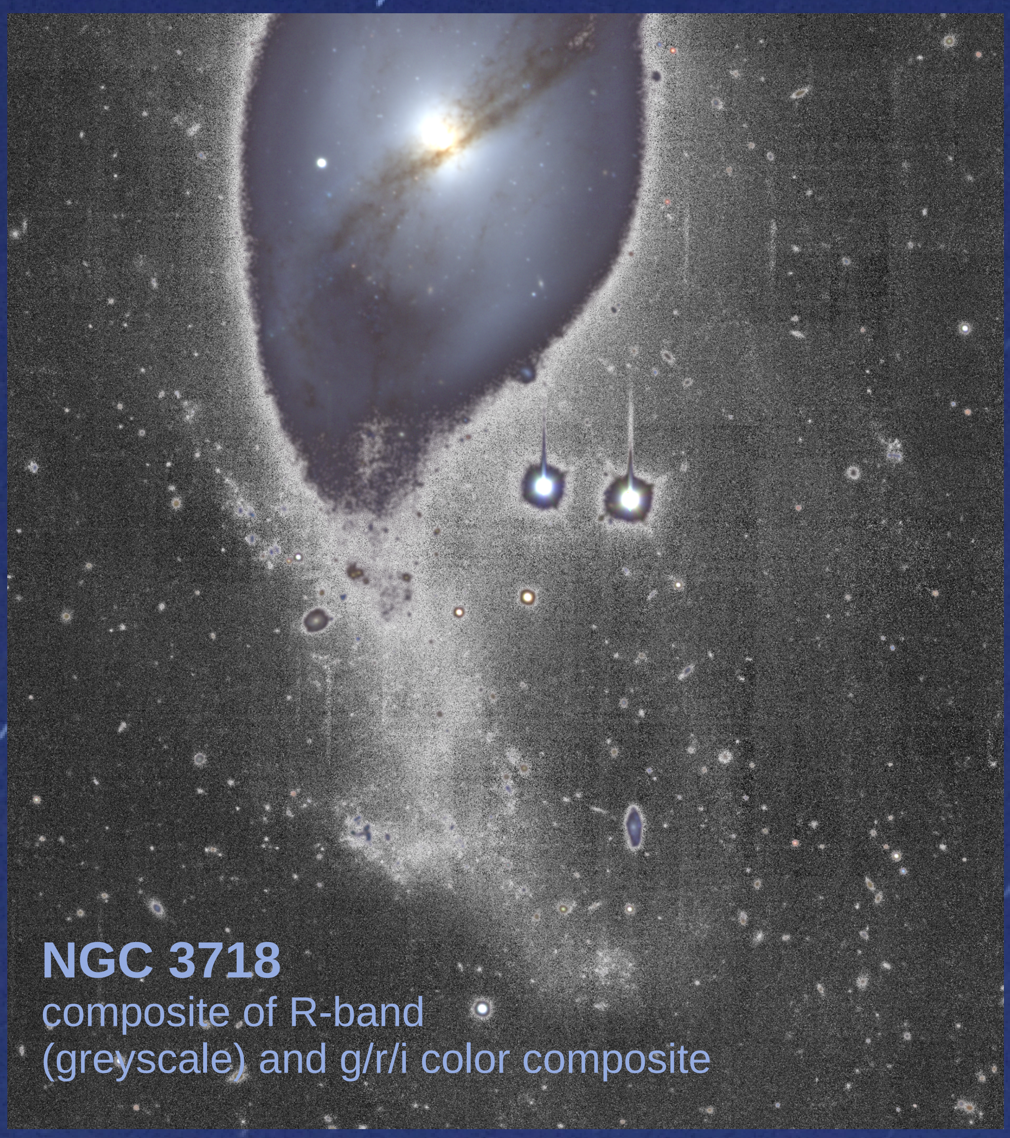
→ Lots of software that can be readily adapted to other data & telescopes

References:
Gopu et al, ASPC 495, 421 (2015)
Jewitt et al, ApJ Letters 850, 36 (2017)
Jewitt et al, AJ 157, 54 (2019)
Jewitt et al, ApJ Letters, 876, 19 (2019)
Harbeck et al, SPIE 9147E, 0 (2014)
Harbeck et al, SPIE 10702E, 29 (2018)
Kotulla, APSC 485, 375 (2014)
Young et al, SPIE 9152, 2 (2014)
Wittmann et al, MNRAS 470, 1512 (2017)

Science Case #1: LSB Galaxy outskirts as indicators of (recent) interactions

Requires deep multi-band imaging with large field-of-view

Increase LSB sensitivity by
- dithering
- Illumination corrections & sky background templates (also fixes pupil-ghost)
- Large-scale model of residual sky background


NGC 3718
composite of R-band (greyscale) and g/r/i color composite

Science Case #2: Faint, low-surface brightness dwarf galaxies in clusters (such as Perseus)

See, e.g., Wittmann et al (2017)


Some example dwarfs we are looking for are shown in yellow circles

before correction halos around bright stars are clearly visible

Problem:
Condensation during observing caused bright scattered light halos

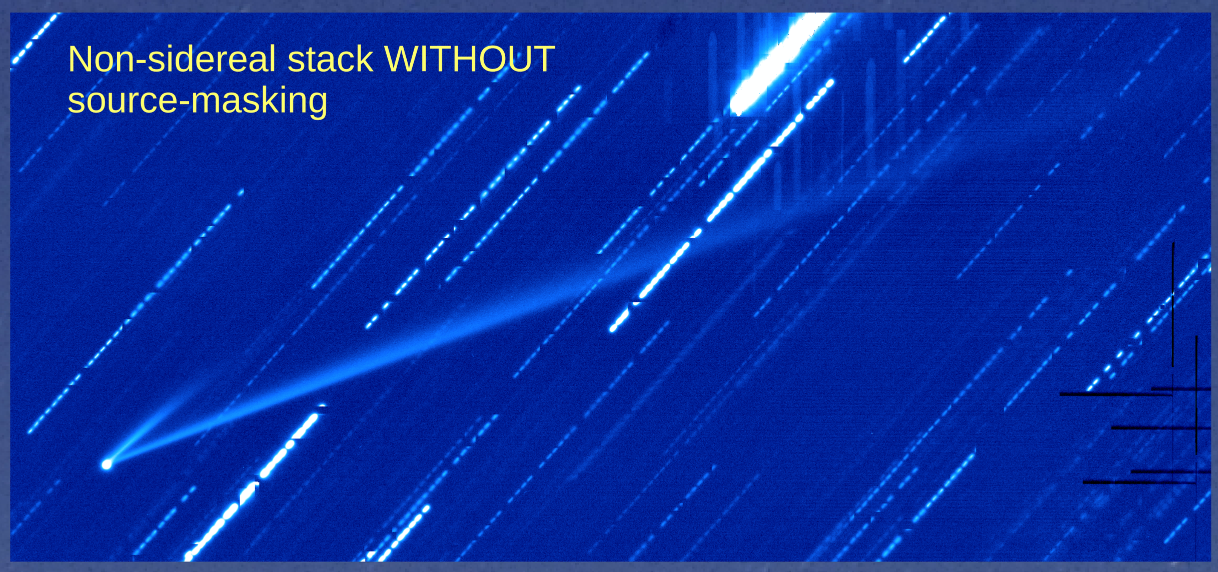
Solution:
1) Construct halo template from bright stars
2) Reconstruct intensity of bright/saturated stars
3) Convolve image with halo-kernel
4) Subtract halo-frame to reduce light-halos to 2nd order effect

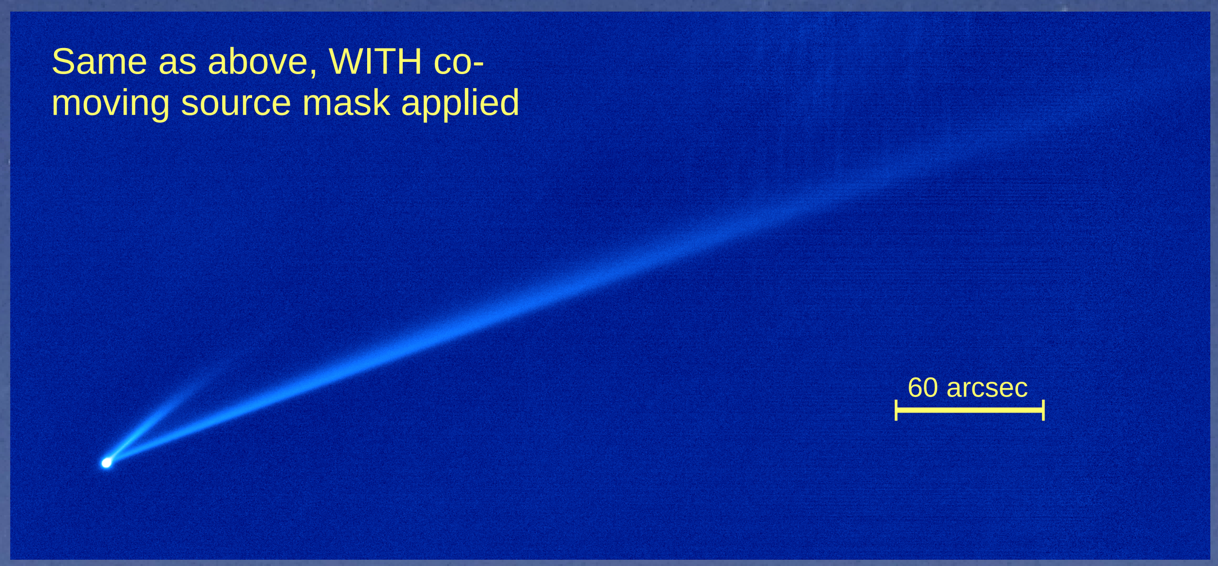

after correction halos much less prominent, results can be improves with more data

Science Case #3: Time-resolved studies of comets and (active) asteroids

Particular challenge:
- Moving objects
- often lots of (trailed) stars
- object falls in gap between cells or detectors

Solutions:
- Non-sidereal stacking
- Illumination corrections & sky background templates
- Co-moving source masks created from median-combined sidereal stacks to reject non-moving sources (e.g. stars & galaxies)


Non-sidereal stack WITHOUT source-masking



Same as above, WITH co-moving source mask applied

See Jewitt et al (2017, 2019a,b)