The Panchromatic Hubble Andromeda Treasury

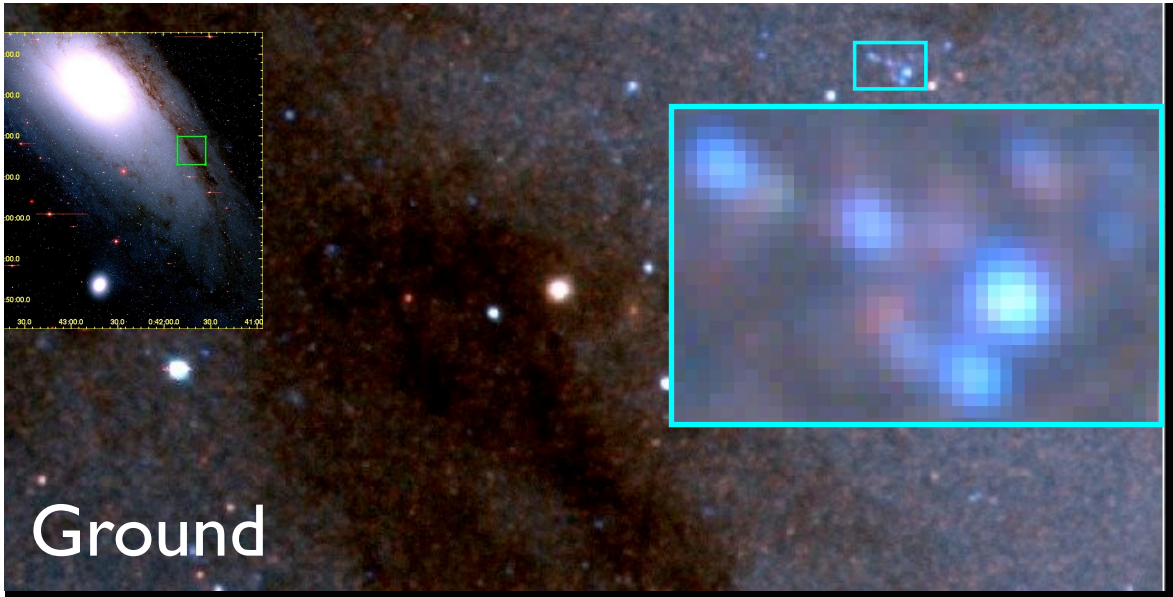
Some People

Key Junior Collaborators

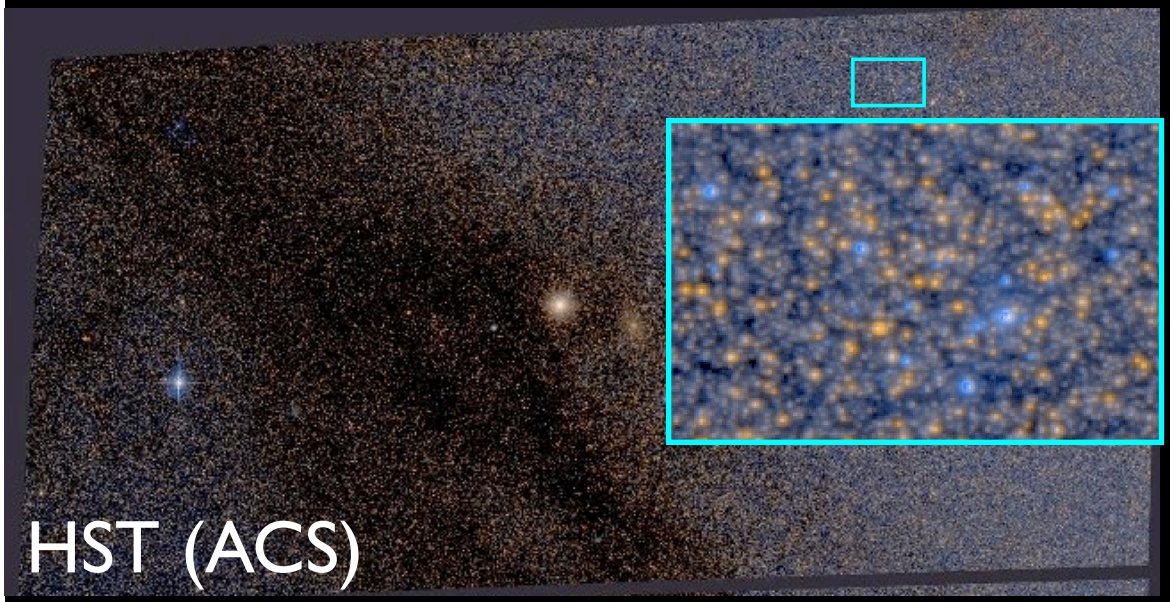
- Ben F. Williams
- Anil Seth
- Dan Weisz
- Jake Simones
- Dustin Lang
- Claire Dorman
- Kirsten Howley
- Phil Rosenfield
- Cliff Johnson

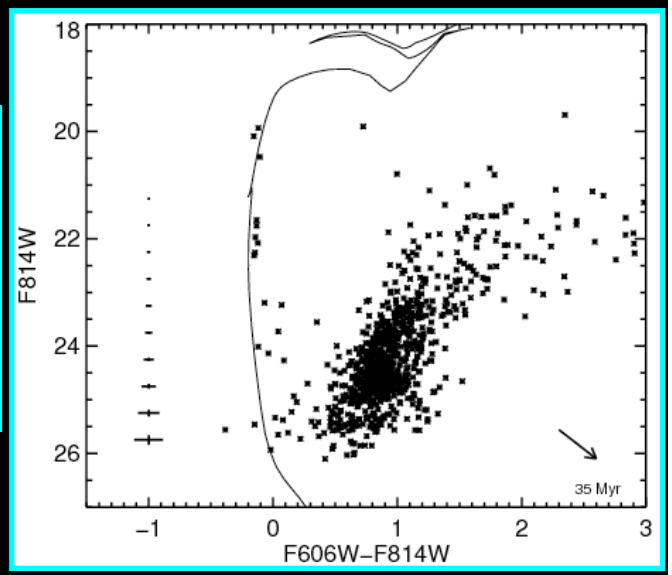
European Collaborators

- Leo Girardi
- Hans-Walter Rix
- Dimitrious Gouliermis
- Soren Larsen

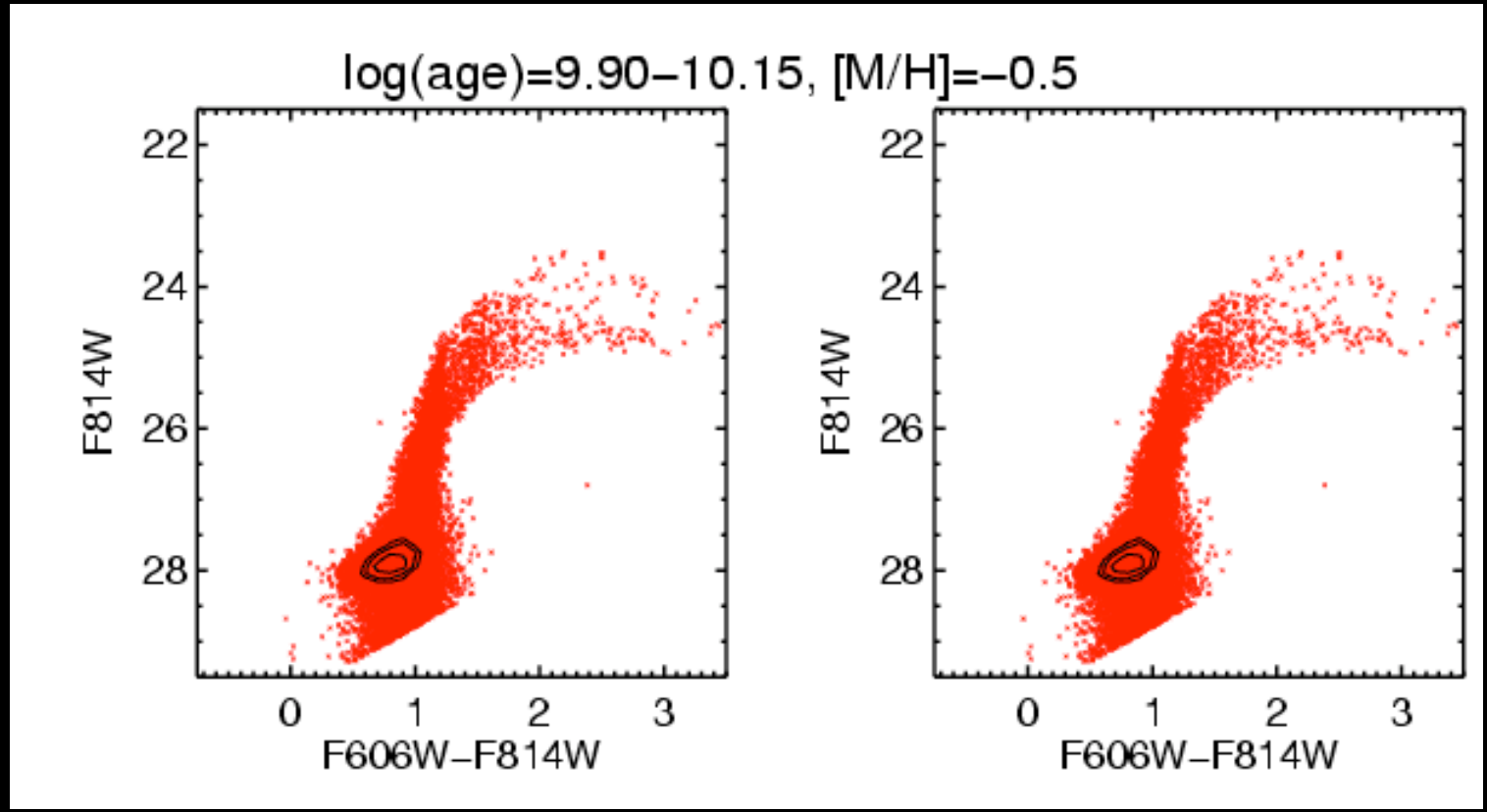


HST is unparalleled for measuring colors and luminosities of stars





CMD Encodes Age, Metallicity, Extinction, Stellar Mass & Evolution

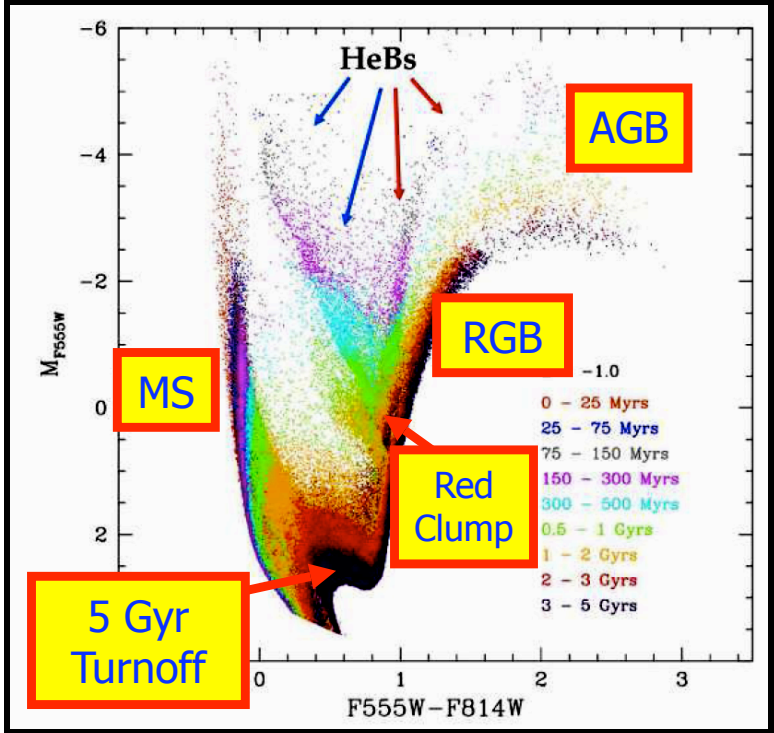


Blue = 0.1 Gyr **Green** = 1 Gyr **Red** = 10 Gyr

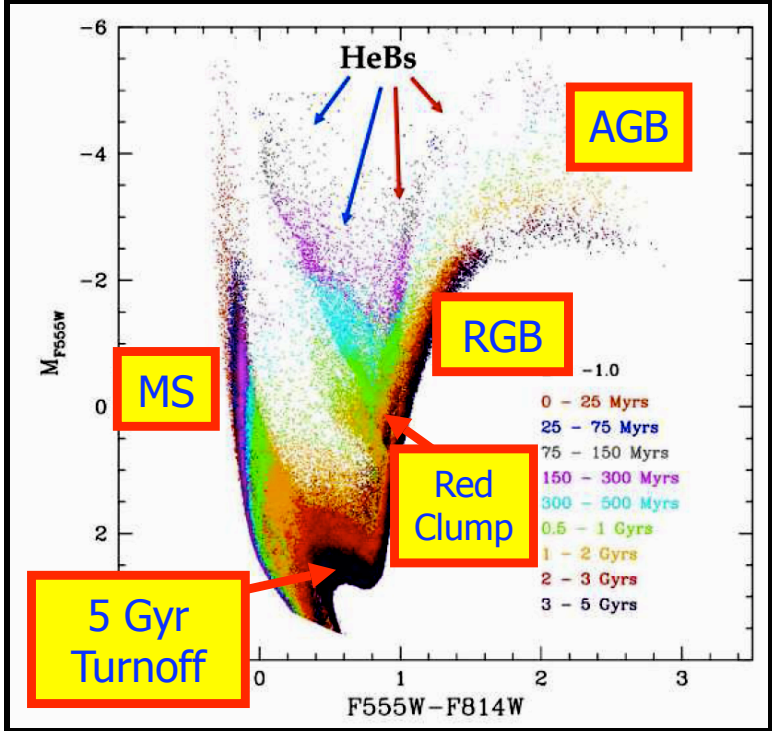
Increasingly younger ages, logarithmically spaced

Resolved Stars Allow Measurements of:

- Star formation histories

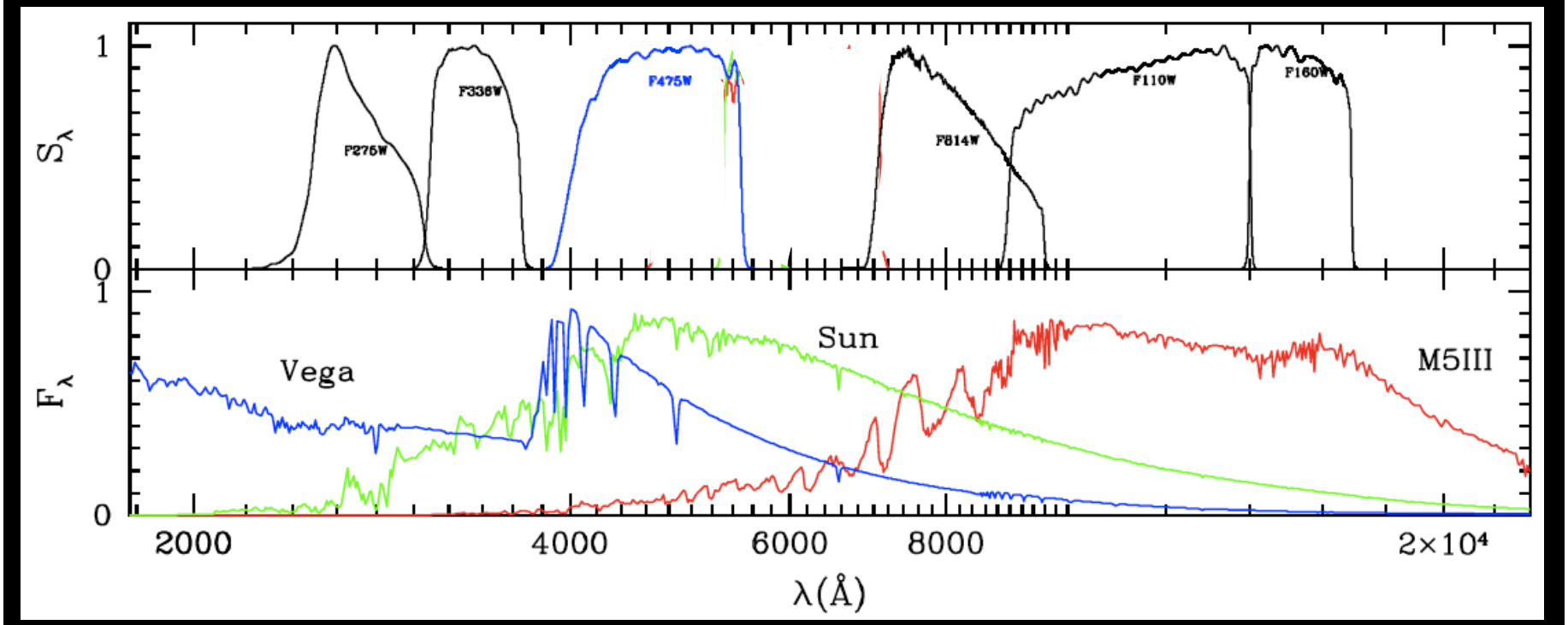


Resolved Stars Allow Measurements of:

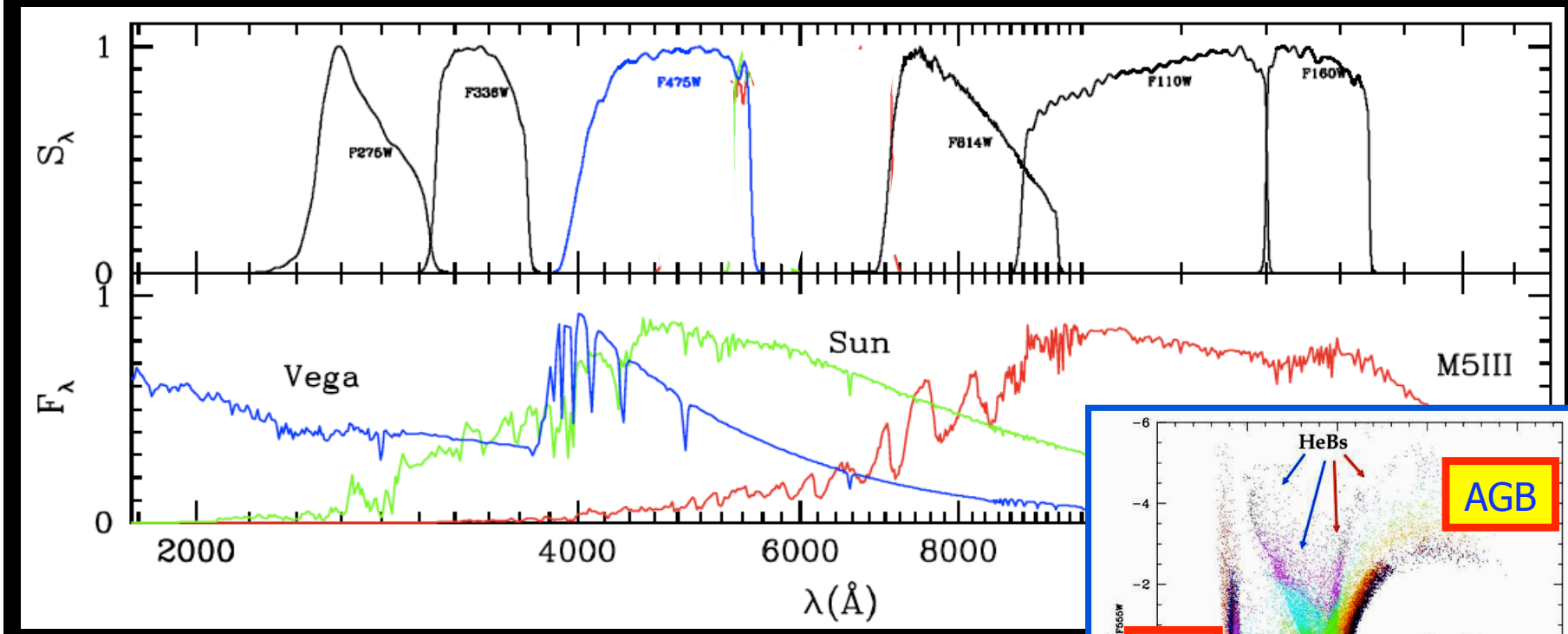


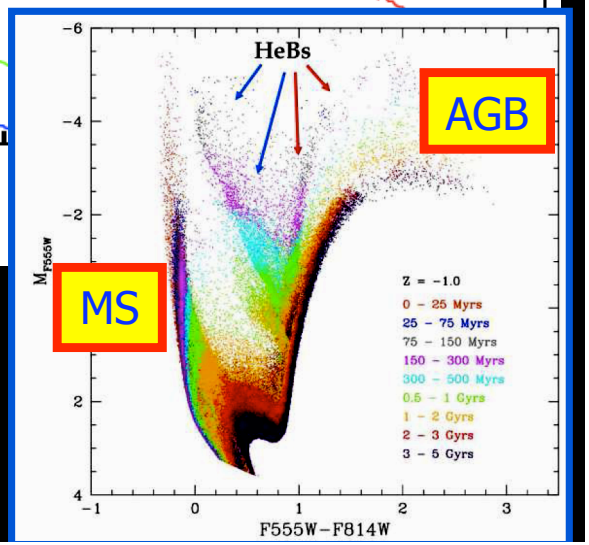
- Star formation histories
- Stellar evolution models
- Extinction maps
- Stellar mass functions
- Cluster mass functions
- Calibration of SF indicators
- SNe progenitors
- Age dating of SN remnants
- Coupling between SF & ISM
- Variable star luminosities

Requirement: Coverage from UV to NIR



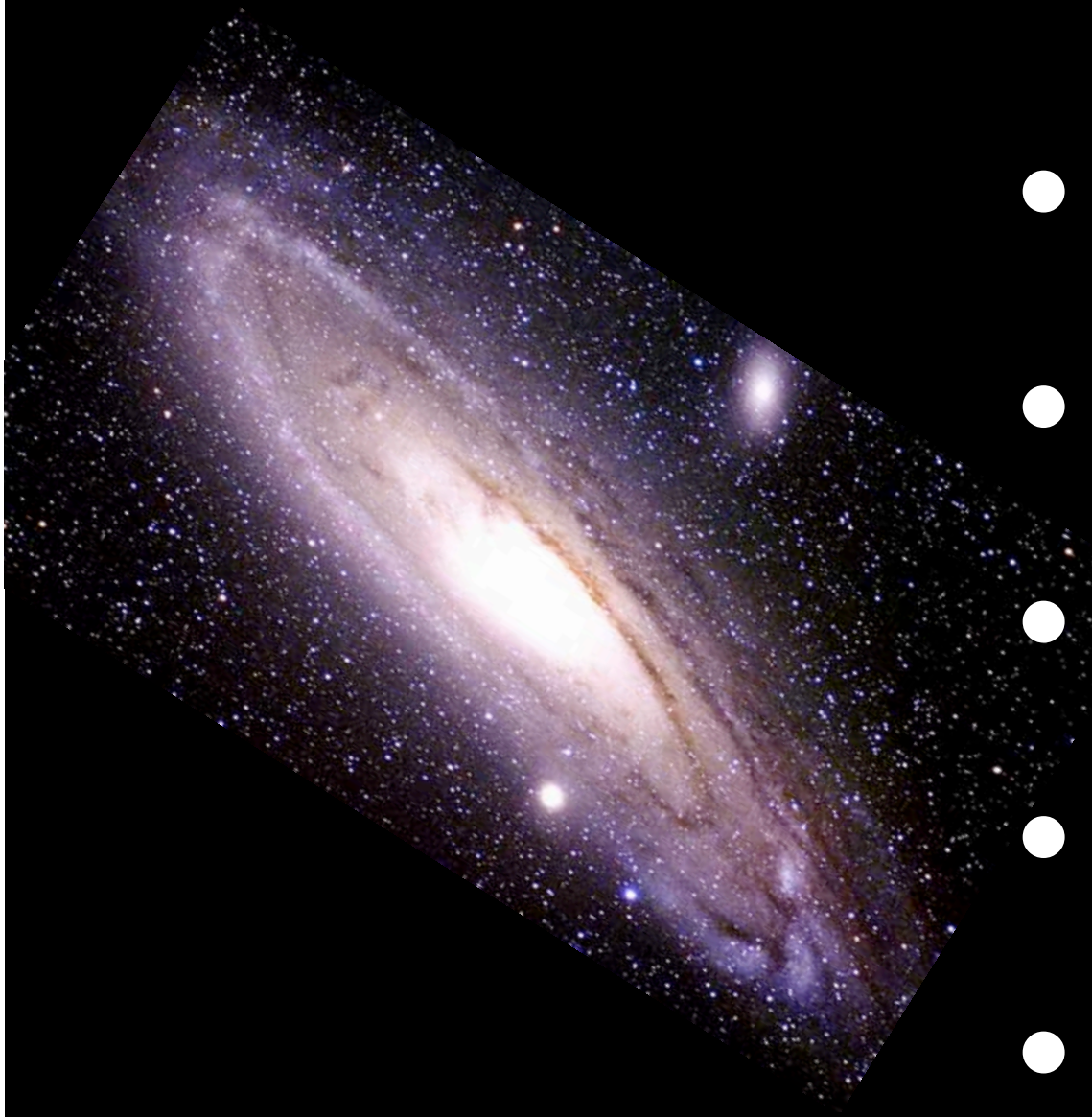
Requirement: Coverage from UV to NIR





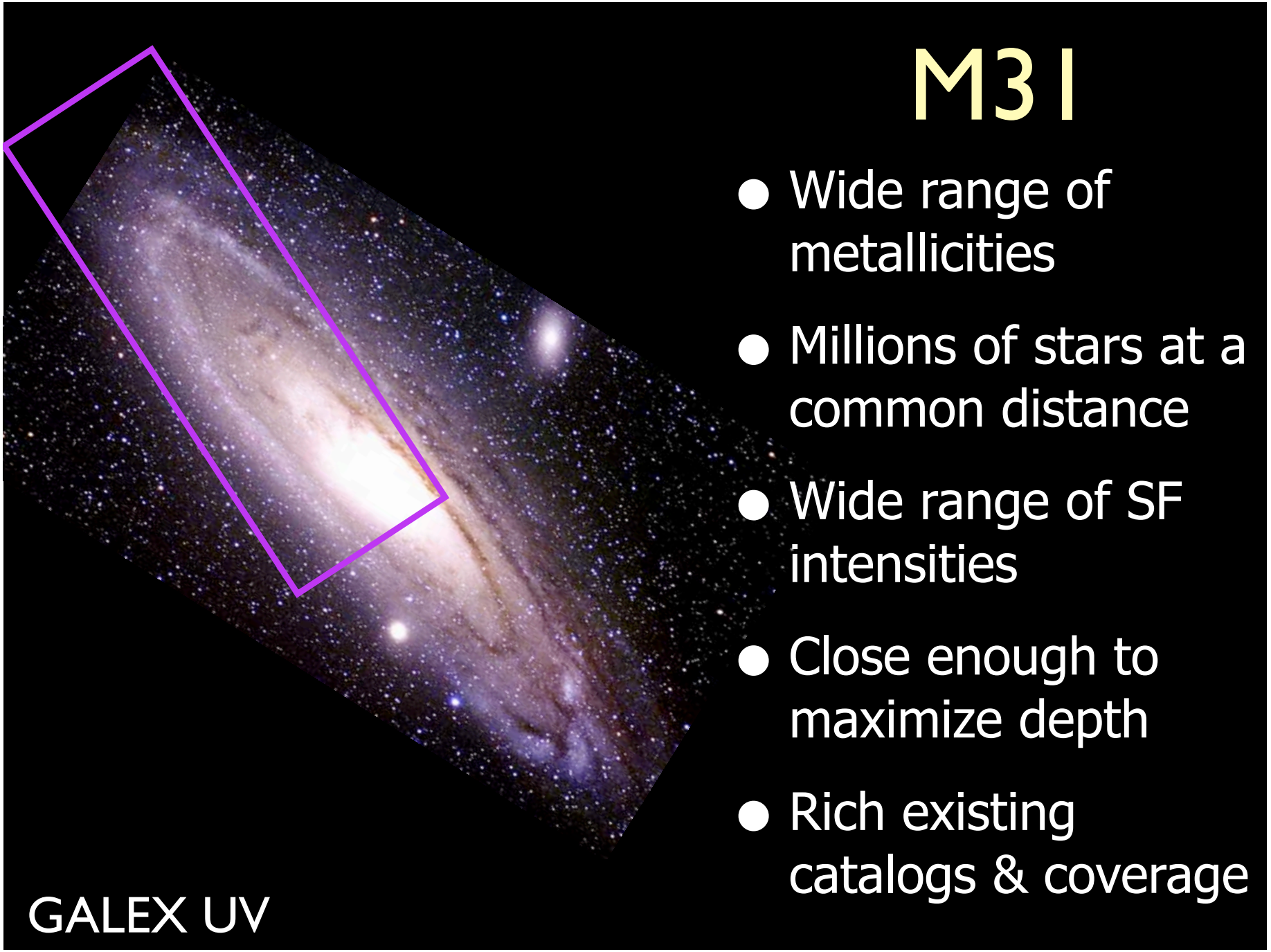
+ Large Areas

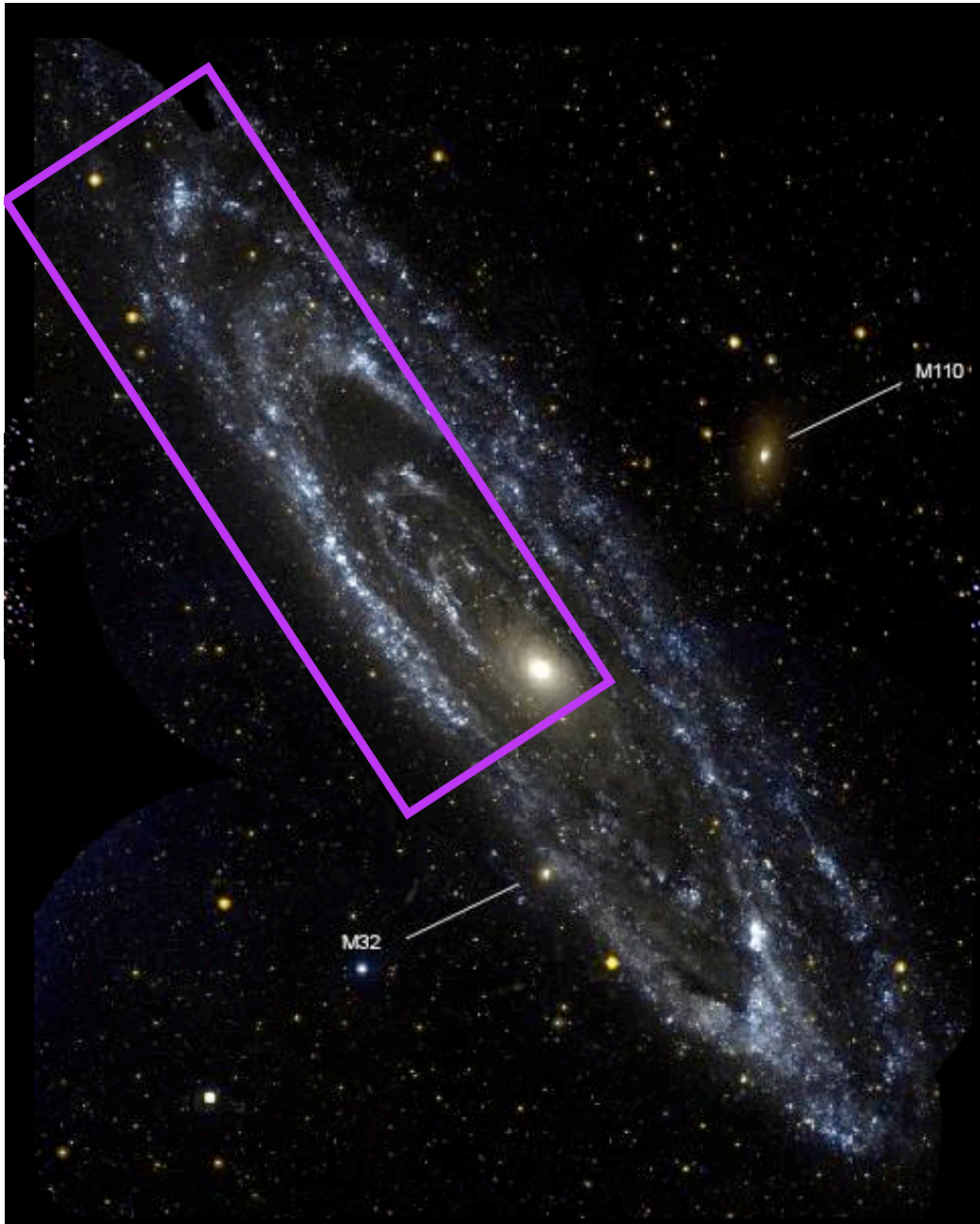
M31



GALEX UV

- Wide range of metallicities
- Millions of stars at a common distance
- Wide range of SF intensities
- Close enough to maximize depth
- Rich existing catalogs & coverage

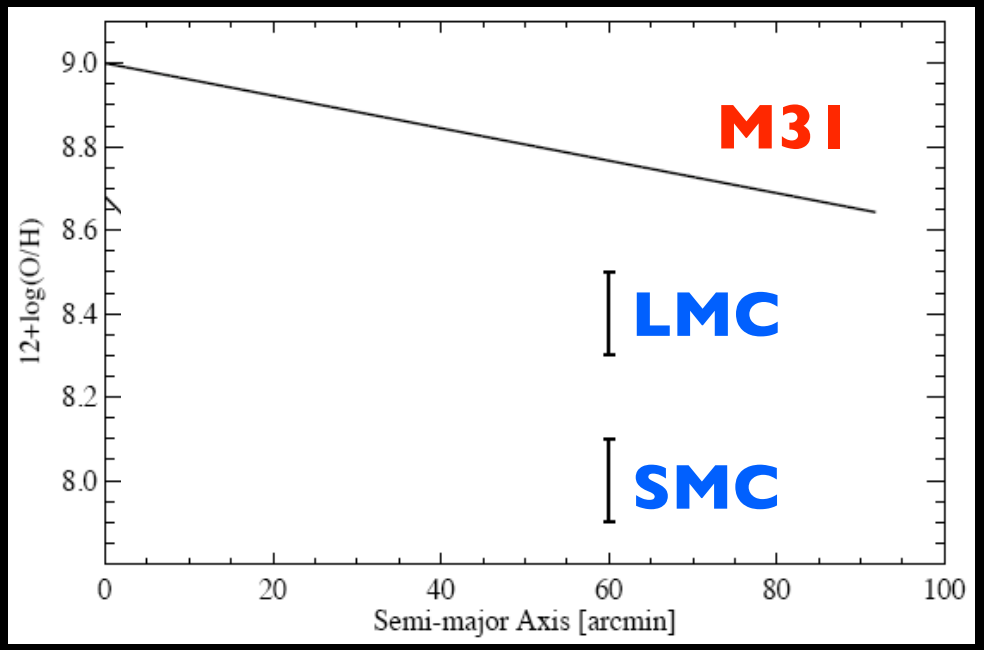

M31
Wide range of metallicities
Millions of stars at a common distance
Wide range of SF intensities
Close enough to maximize depth
Rich existing catalogs & coverage
GALEX UV



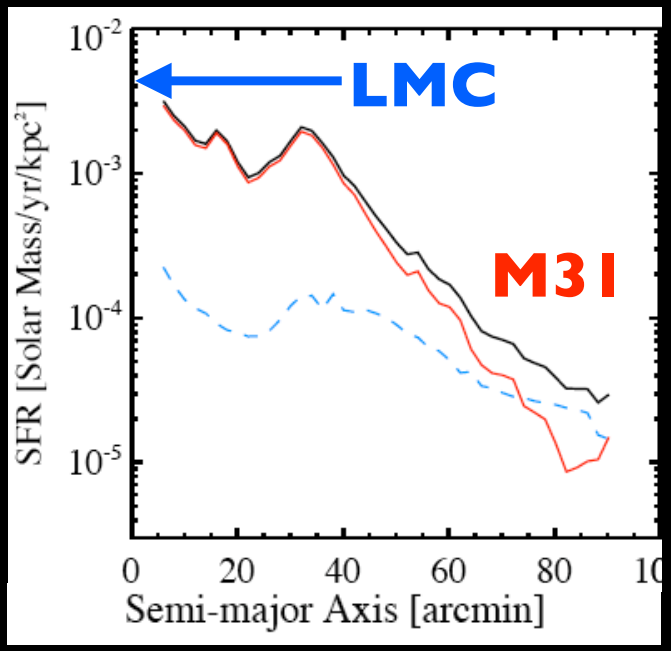
M31

- Wide range of metallicities
- Millions of stars at a common distance
- Wide range of SF intensities
- Close enough to maximize depth
- Rich existing catalogs & coverage

Metallicity



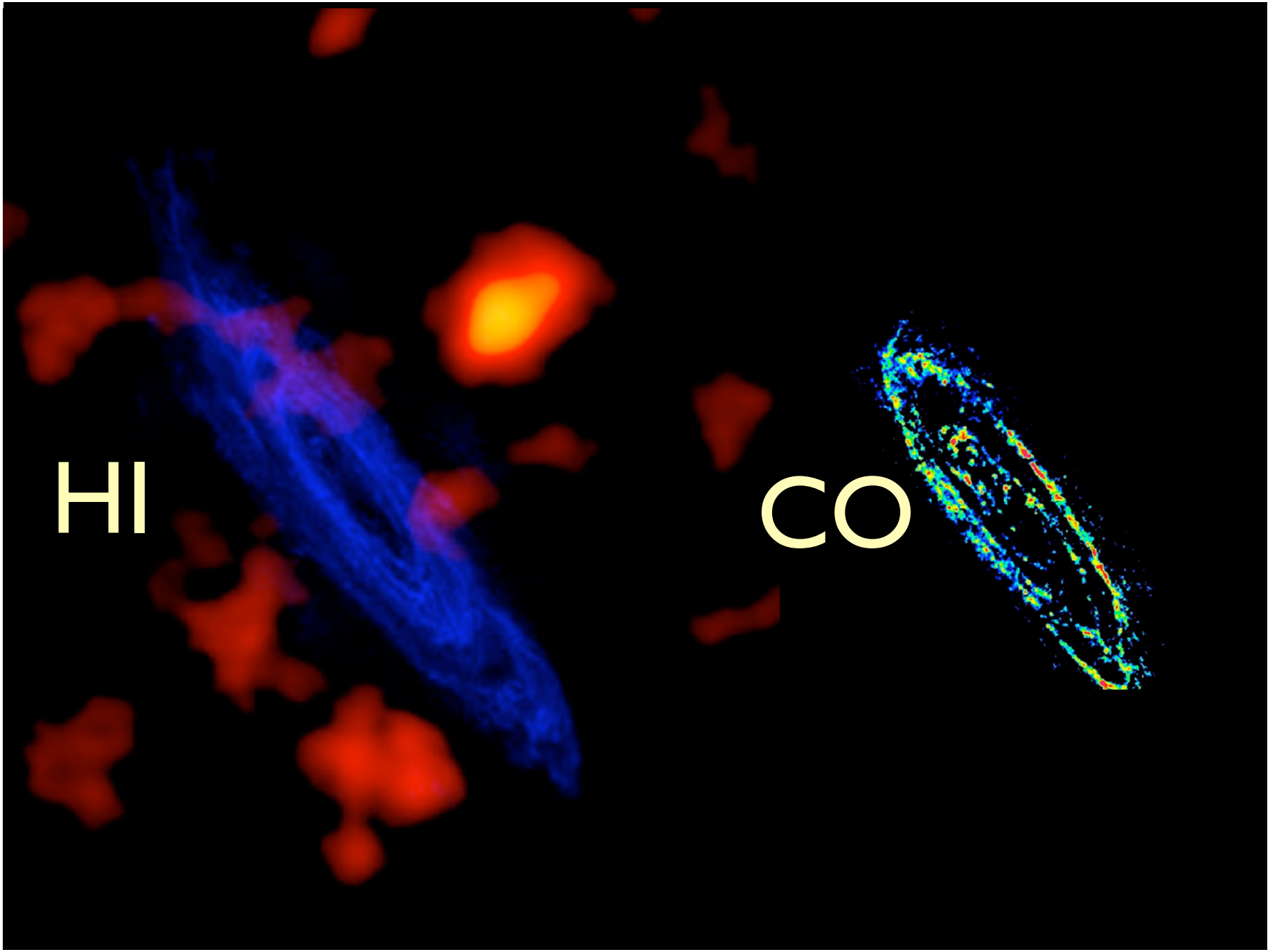
Star Formation Intensity



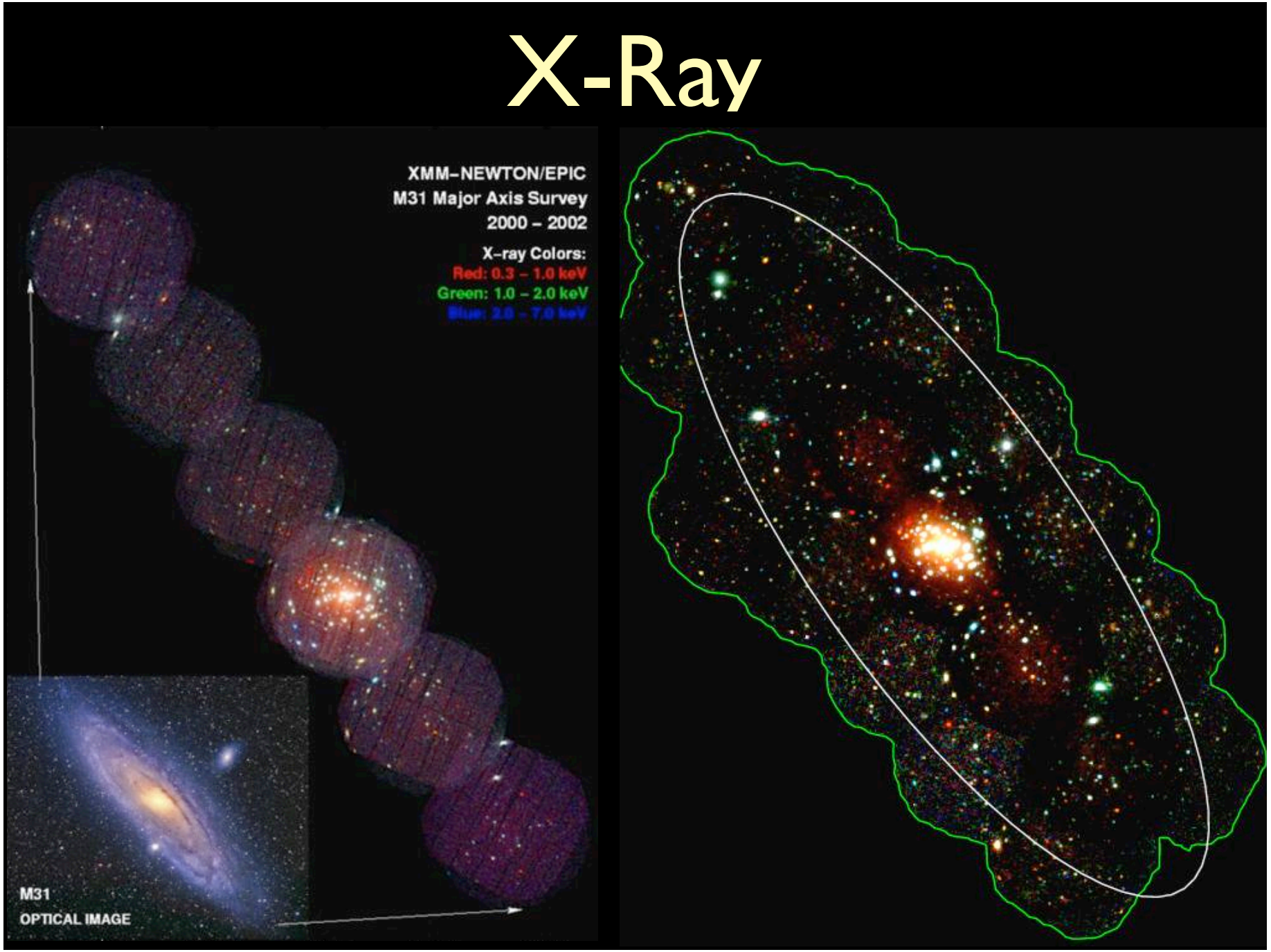
Cliff Johnson

GALEX + Spitzer

Herschel underway (MPIA)


HI
CO

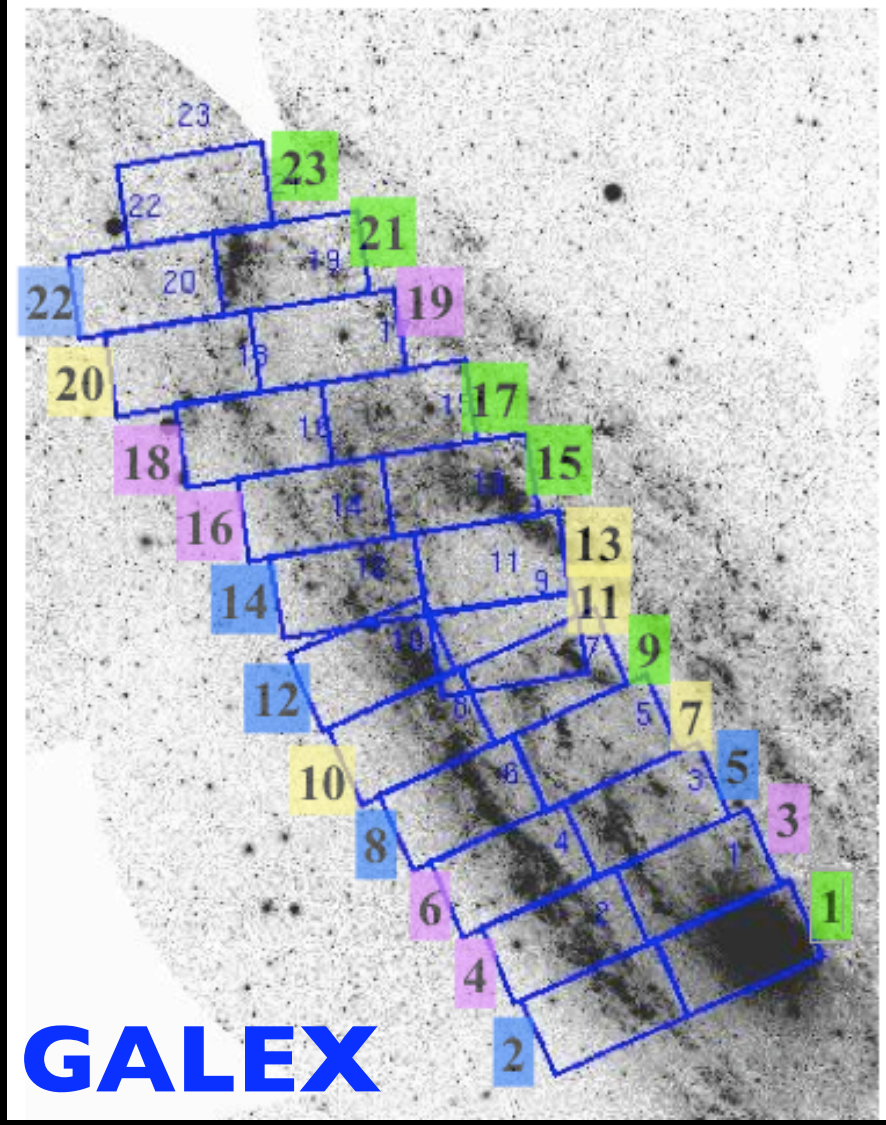
X-Ray


XMM–NEWTON/EPIC
M31 Major Axis Survey
2000 – 2002
X–ray Colors:
Red: 0.3 – 1.0 keV
Green: 1.0 – 2.0 keV
Blue: 2.0 – 7.0 keV
M31
OPTICAL IMAGE

Extensive Catalogs of Interesting Stuff

Catalogued Object Type	Number	Selection
Star forming regions	894	GALEX[1]
OB associations	650	LGS[1]
Stellar Clusters	670	spectroscopy[2]
	285	UBVRI imaging[3]
Globular Clusters	1,164	CMT_1 imaging[4]
WR stars	$\sim$300	objective prism [5]
	86	spectroscopy[6]
Planetary Nebulae	2615	imaging+spectroscopy[7]
X-ray sources	856	XMM[8]
	560	ROSAT PSPC[9]
	204	Chandra ACIS[10]
	142	Chandra HRC[11]
Spitzer Point Sources	$>$250,000	Spitzer 3.6μm[12]
	160,000	Spitzer 8μm[12]
Variable Stars	23,781	RI diff. imaging[13]
	3,964	BV imaging[14]
Cepheids	416	BV imaging[14]
HII regions	967	optical[15]
SN Remnants	178	optical[16]

Plan: 6-Filter HST Tiling of M31



Year 1
- 21
- 15
- 9
- 1
- 17
- 23

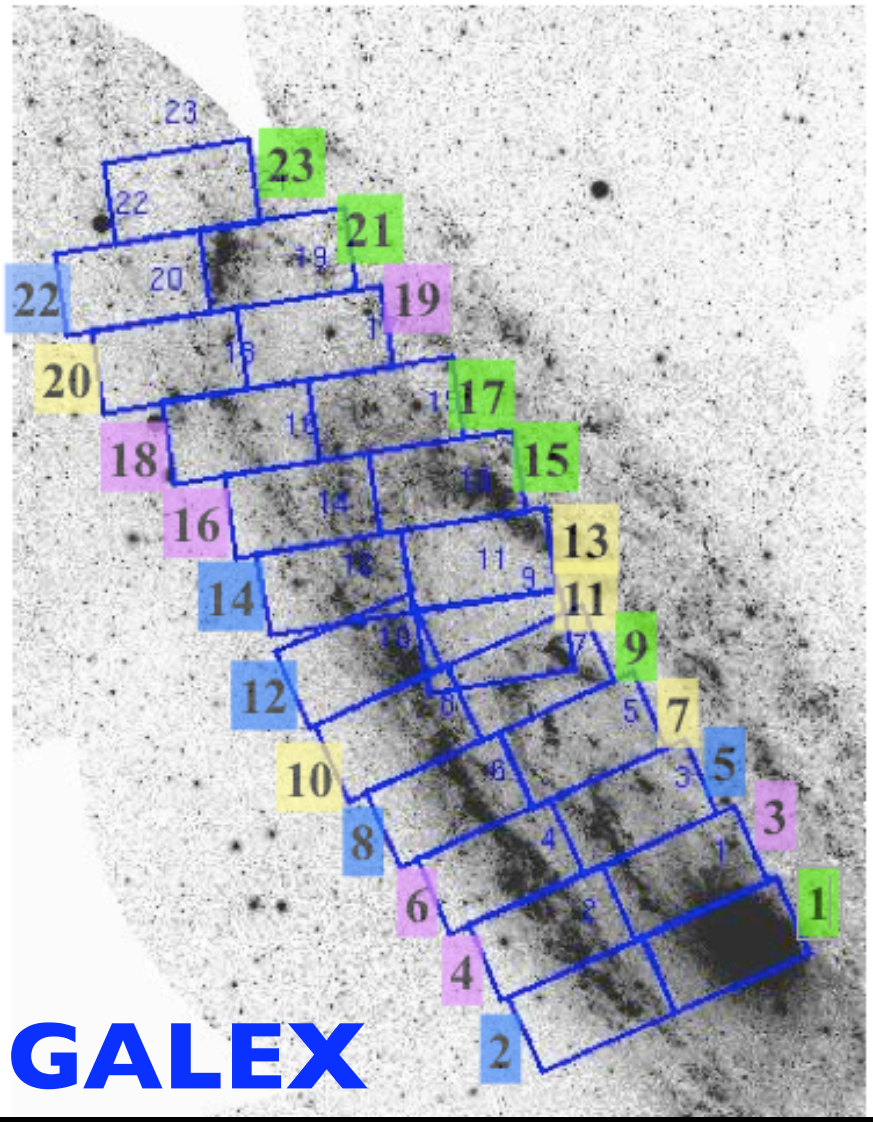
Year 2
- 12
- 14
- 2
- 5
- 8
- 22

Year 3
- 6
- 16
- 4
- 18
- 3
- 19

Year 4
- 10
- 20
- 7
- 13
- 11

828 Orbits

Plan: 6-Filter HST Tiling of M31



Year 1
- 21
- 15
- 9
- 1
- 17
- 23

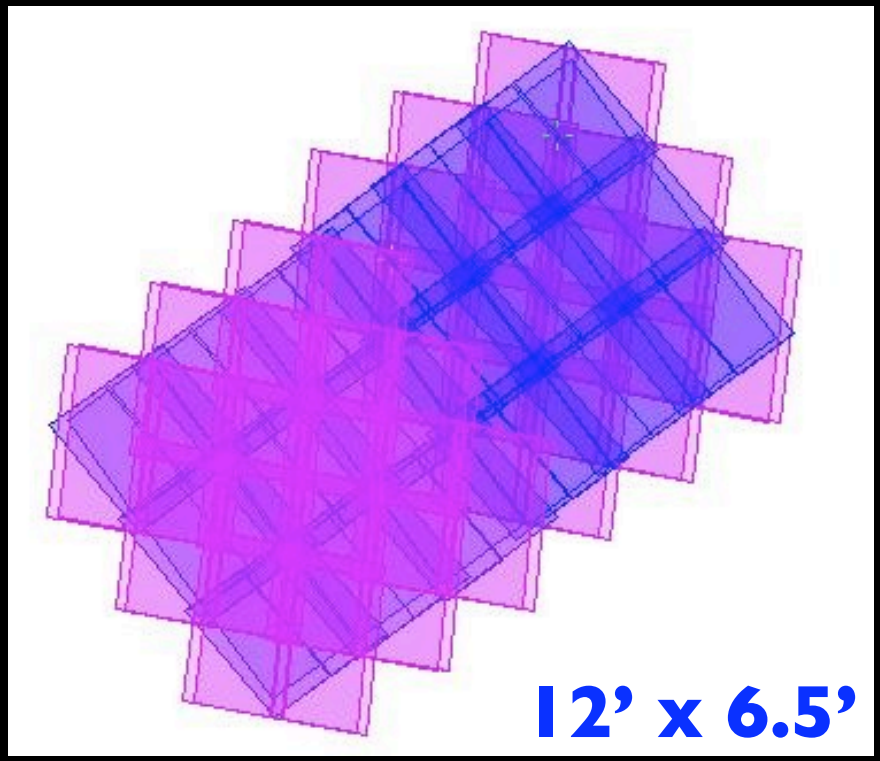
Year 2
- 12
- 14
- 2
- 5
- 8
- 22

Year 3
- 6
- 16
- 4
- 18
- 3
- 19

Year 4
- 10
- 20
- 7
- 13
- 11

828 Orbits

18 pointing tiling "brick"



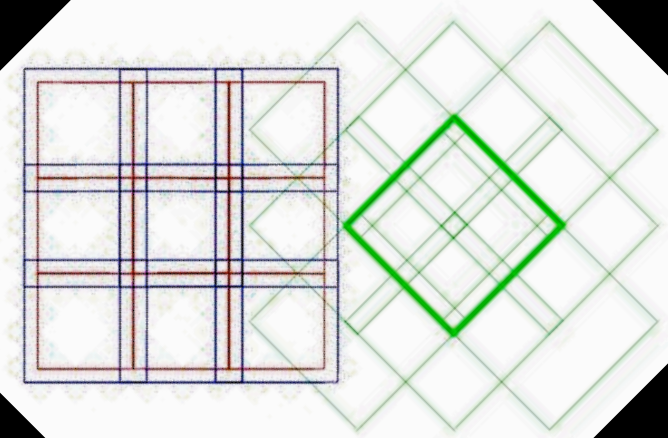
Ben Williams

2 Orbits per pointing

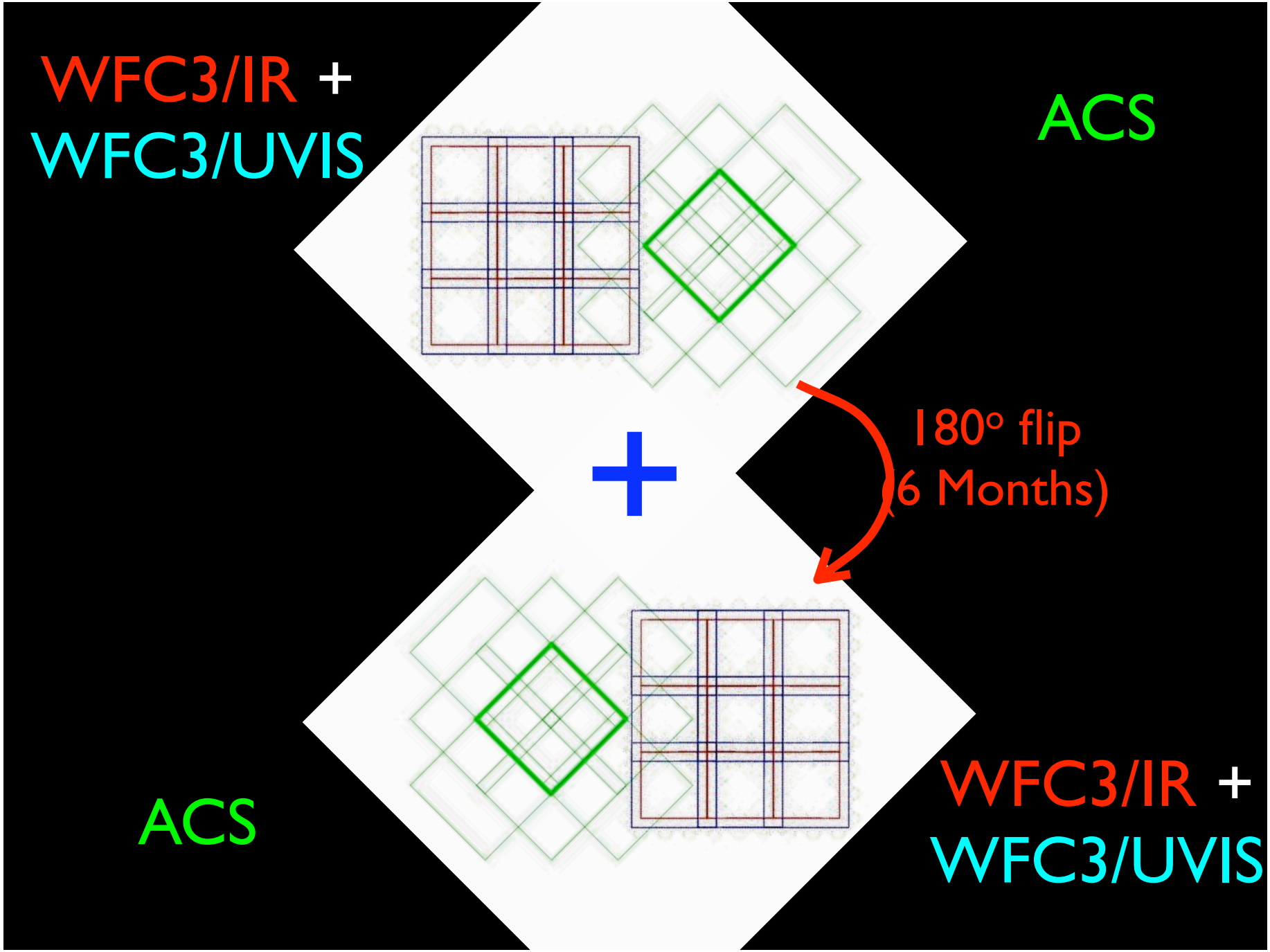
18 orbits at 180° orientation flip from the other 18 orbits

Orbit 1: WFC3/IR (primary) + ACS (parallel)
Orbit 2: WFC3/UVIS (primary) + ACS (parallel)

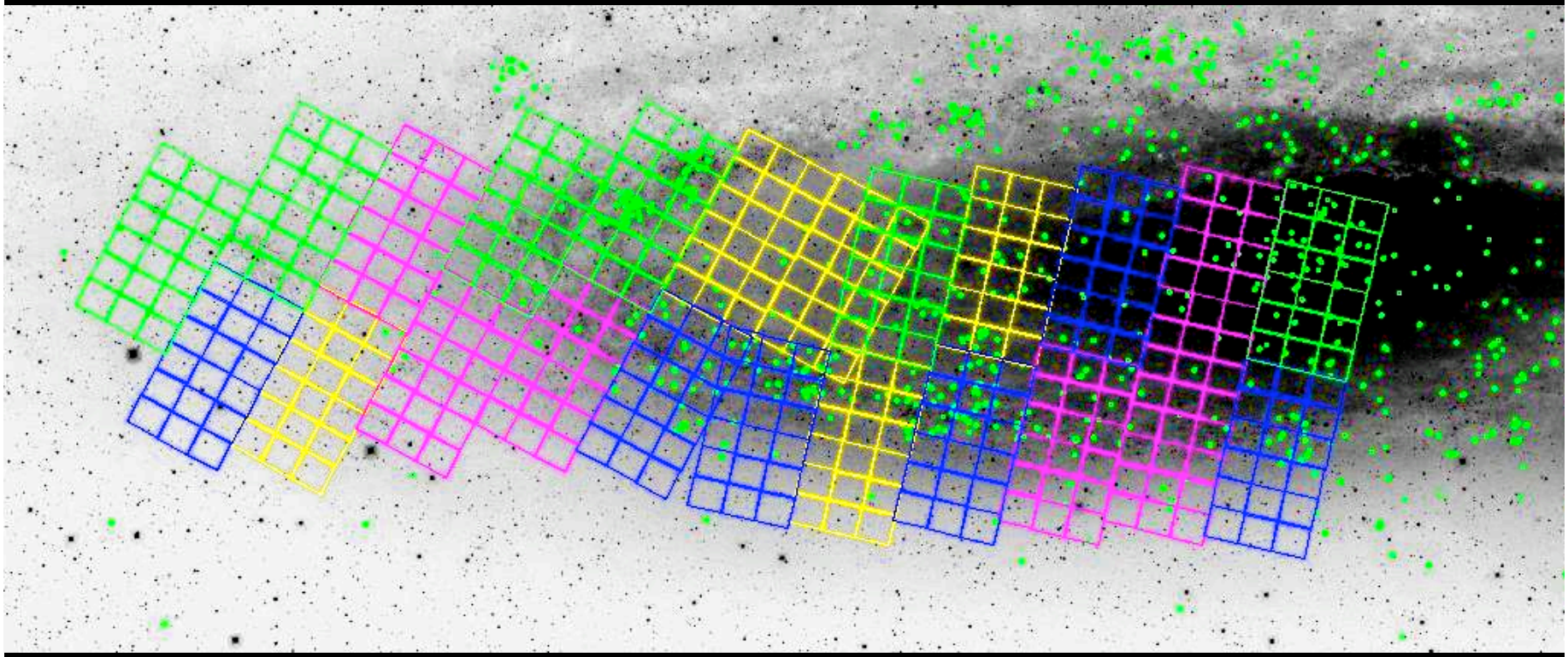
WFC3/IR +
WFC3/UVIS



ACS


WFC3/IR +
WFC3/UVIS
ACS
180° flip
(6 Months)
ACS
WFC3/IR +
WFC3/UVIS

WFC3/IR FOVs



Green Dots = Known Clusters

(466 in planned survey area)

Nelson Caldwell & Anil Seth (CfA)

Status

Status

- Completed Orbits: 72 (<9%) -- Thanks!

Status

- Completed Orbits: 72 (<9%) -- Thanks!
- Photometric measurements so far: 37 million

Status

- Completed Orbits: 72 (<9%) -- Thanks!
- Photometric measurements so far: 37 million
- Total CPU time: ~250 CPU days

Status

- Completed Orbits: 72 (<9%) -- Thanks!
- Photometric measurements so far: 37 million
- Total CPU time: ~250 CPU days
- Typical depths:

Status

- Completed Orbits: 72 (<9%) -- Thanks!
- Photometric measurements so far: 37 million
- Total CPU time: ~250 CPU days
- Typical depths:

  UVIS: F275W ~ 25, F336W ~ 25

Status

- Completed Orbits: 72 (<9%) -- Thanks!
- Photometric measurements so far: 37 million
- Total CPU time: ~250 CPU days
- Typical depths:

  UVIS: F275W ~ 25, F336W ~ 25

  ACS: F475W ~ 27, F814W ~ 25

Status

- Completed Orbits: 72 (<9%) -- Thanks!
- Photometric measurements so far: 37 million
- Total CPU time: ~250 CPU days
- Typical depths:

  UVIS: F275W ~ 25, F336W ~ 25

  ACS: F475W ~ 27, F814W ~ 25

  IR: F110W ~ 24, F160W ~ 23

Status

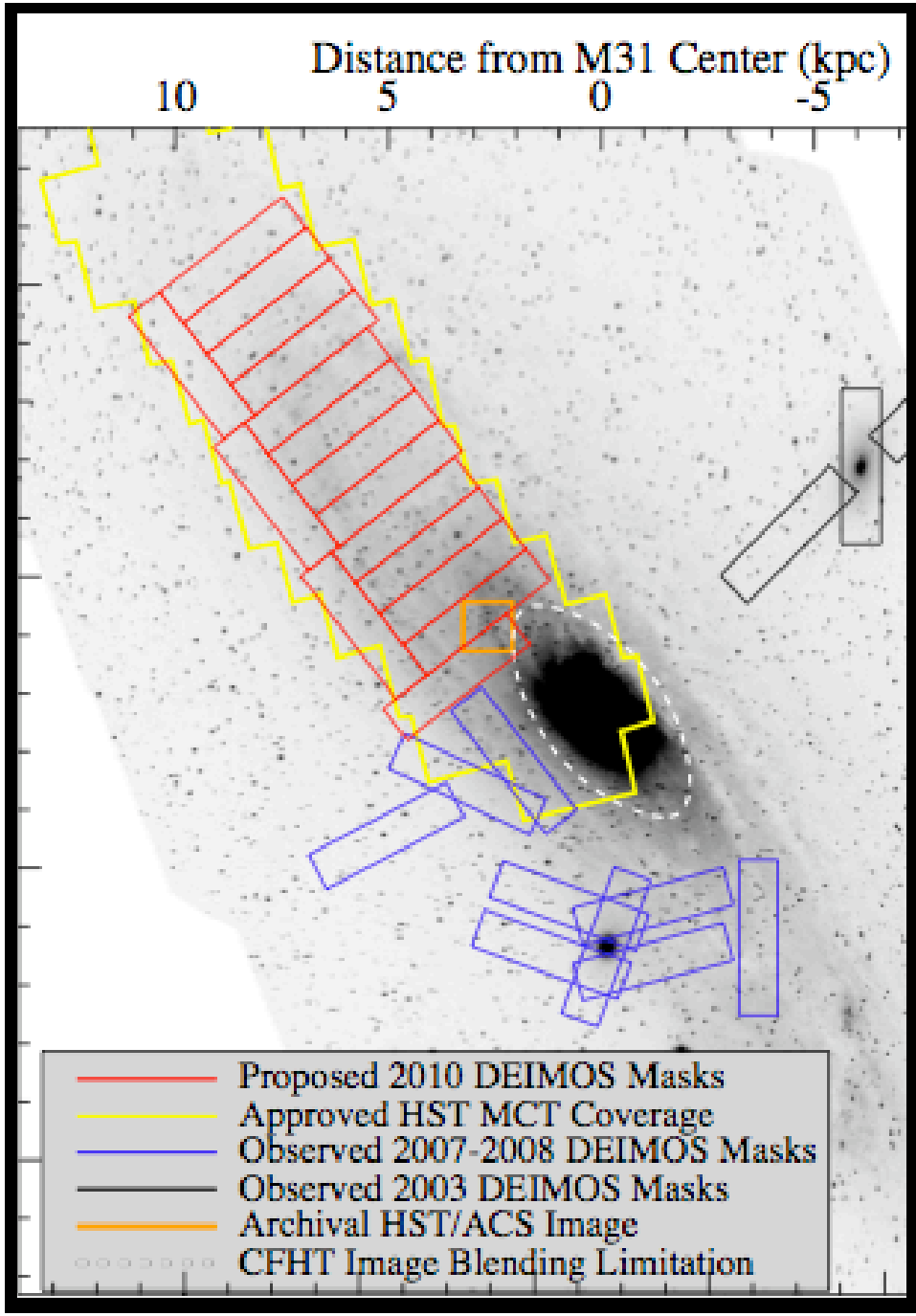
- Completed Orbits: 72 (<9%) -- Thanks!
- Photometric measurements so far: 37 million
- Total CPU time: ~250 CPU days
- Typical depths:

  UVIS: F275W ~ 25, F336W ~ 25

  ACS: F475W ~ 27, F814W ~ 25

  IR: F110W ~ 24, F160W ~ 23

- ~3200 DEIMOS Spectra (Kinematics, mostly)

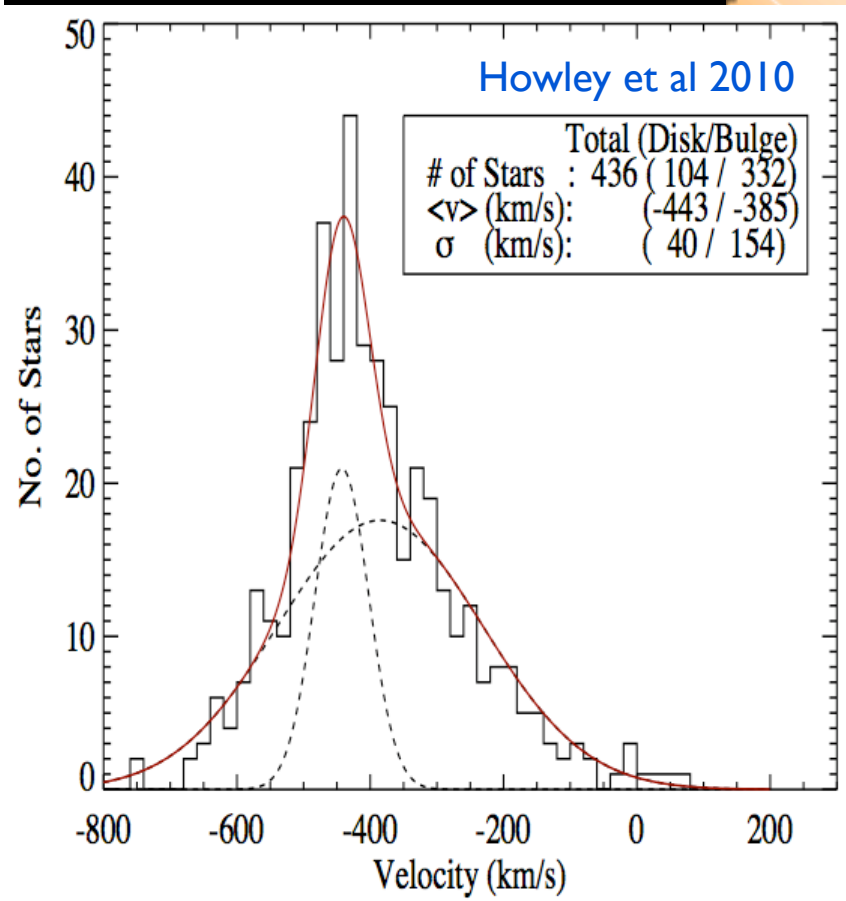


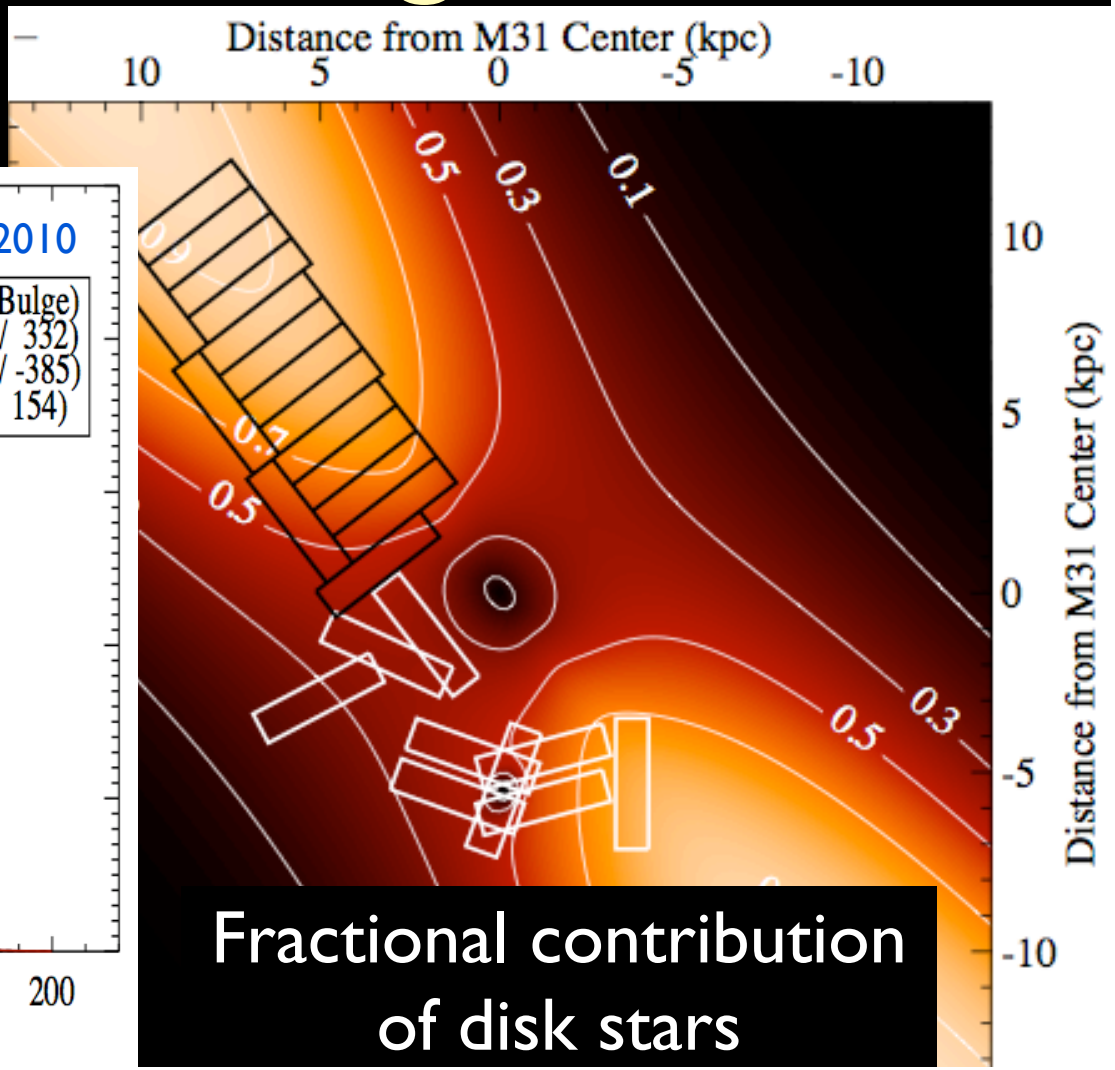
Extensive DEIMOS Spectroscopy

Claire Haliday
Jason Kalirai
Kirsten Howley
Raja Guhathakurta

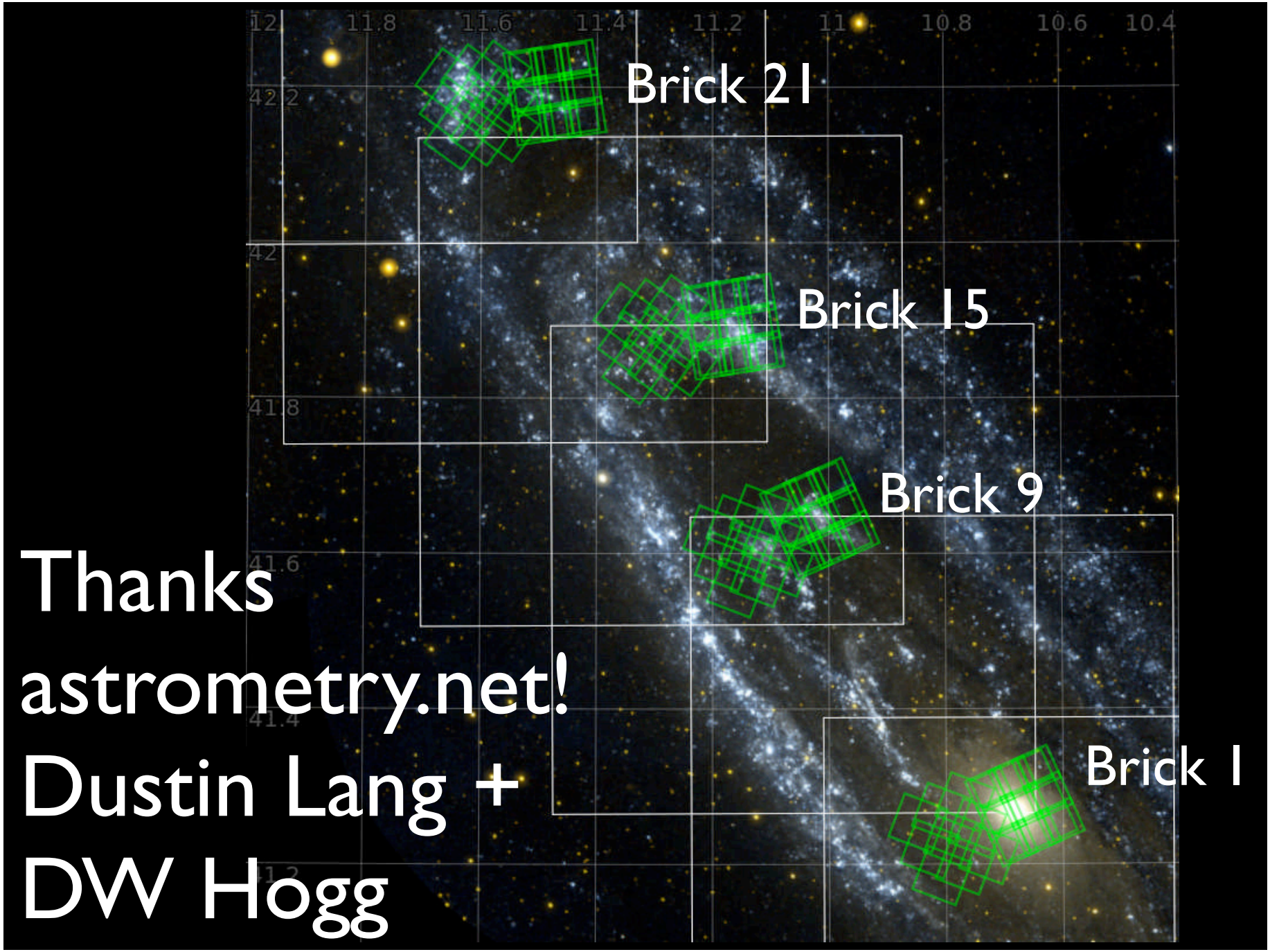
Targets:
Primarily AGB/RGB
X-Ray Counterparts
Candidate PNe

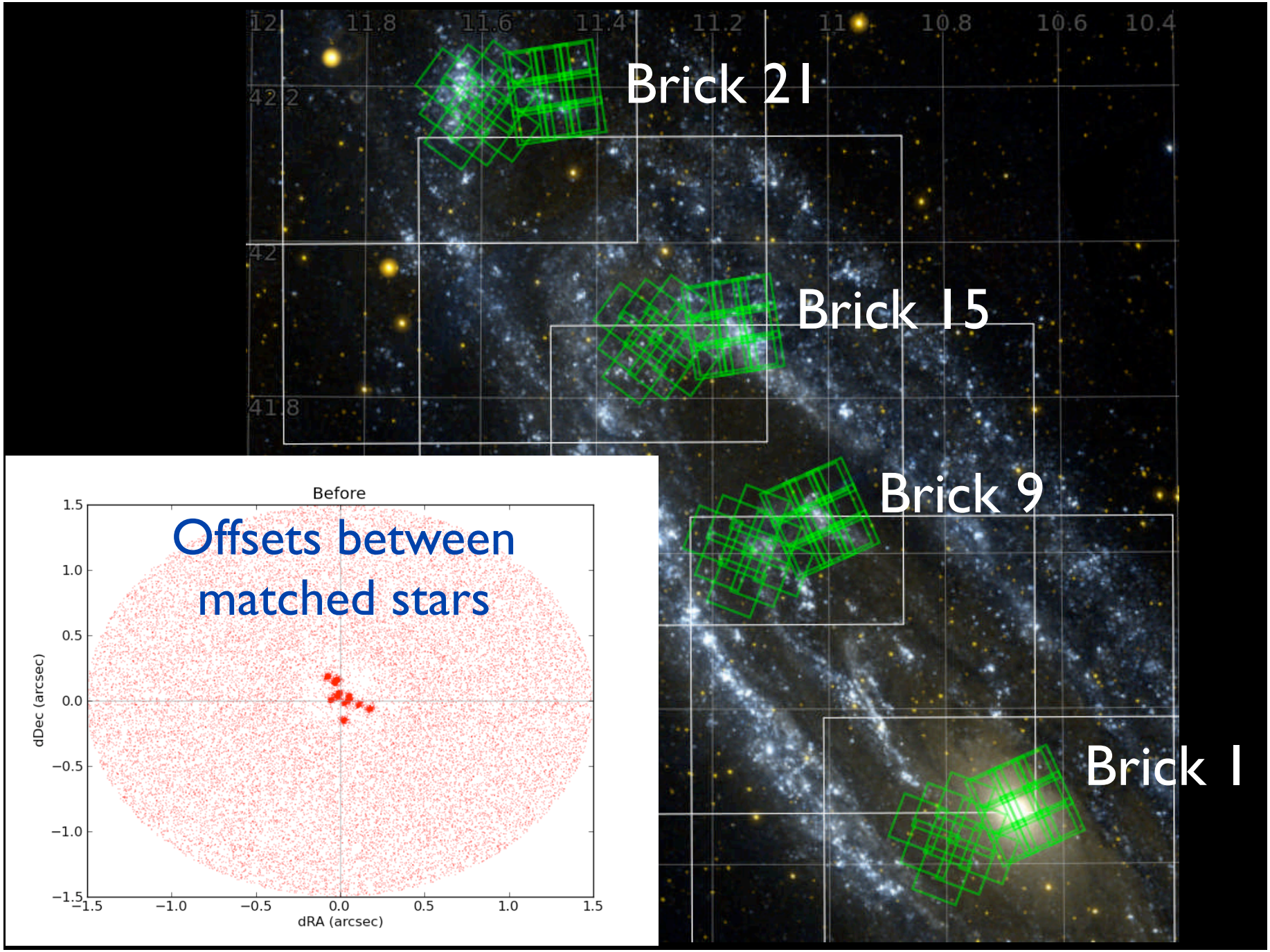
Kinematic Separation of Disk+Bulge

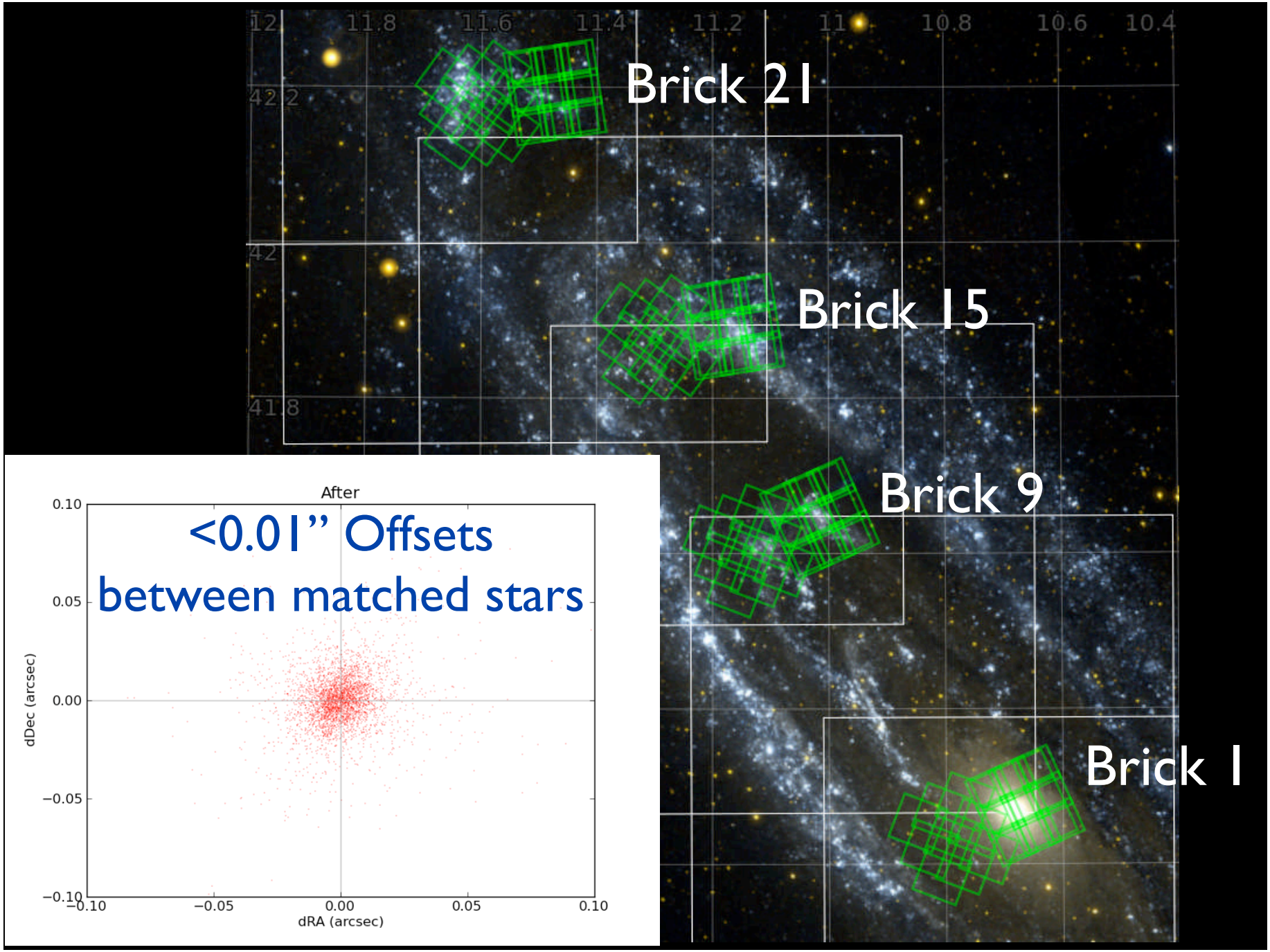




Fractional contribution of disk stars

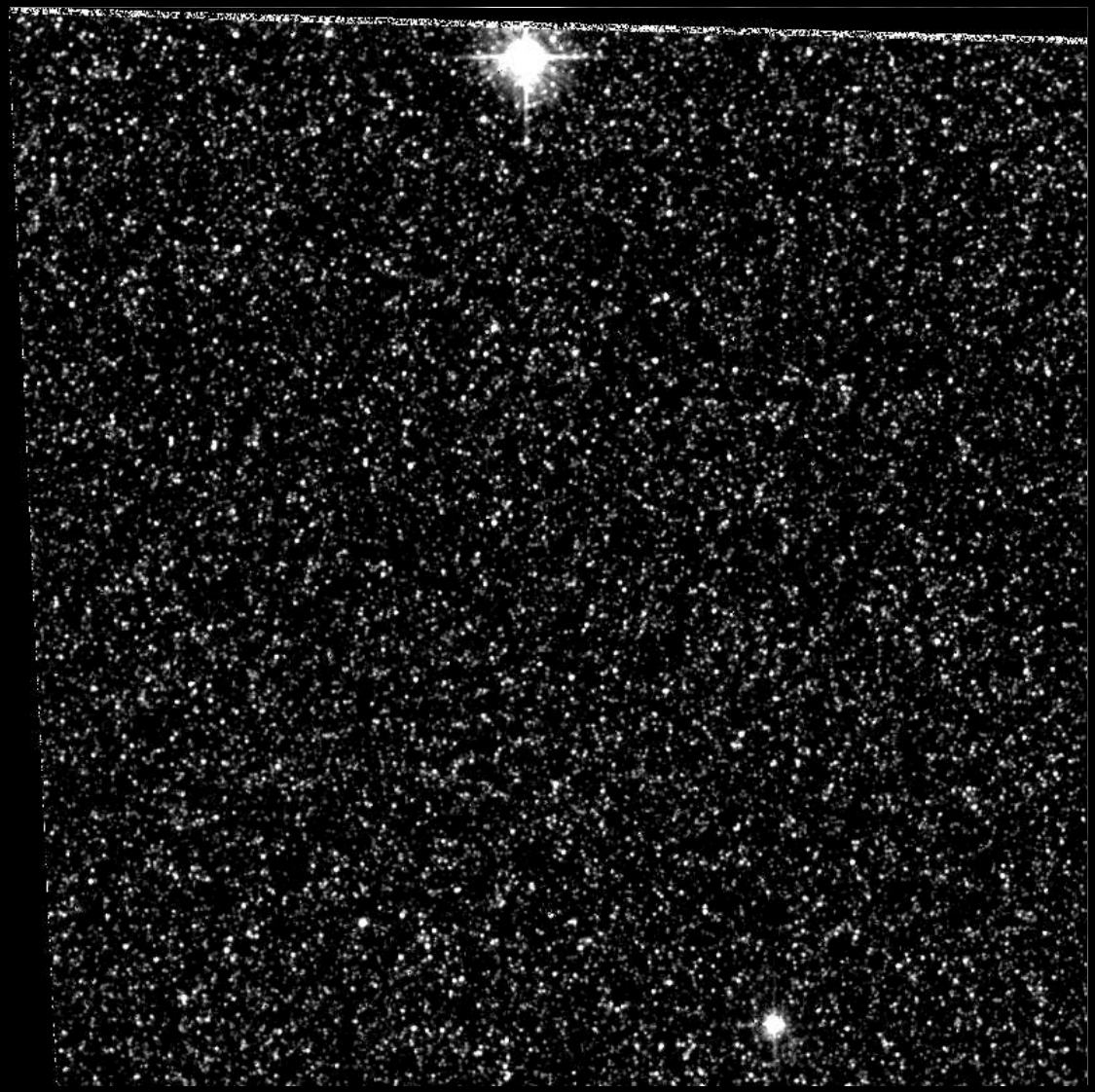

Brick 21
Brick 15
Brick 9
Brick 1
Thanks
astrometry.net!
Dustin Lang +
DW Hogg

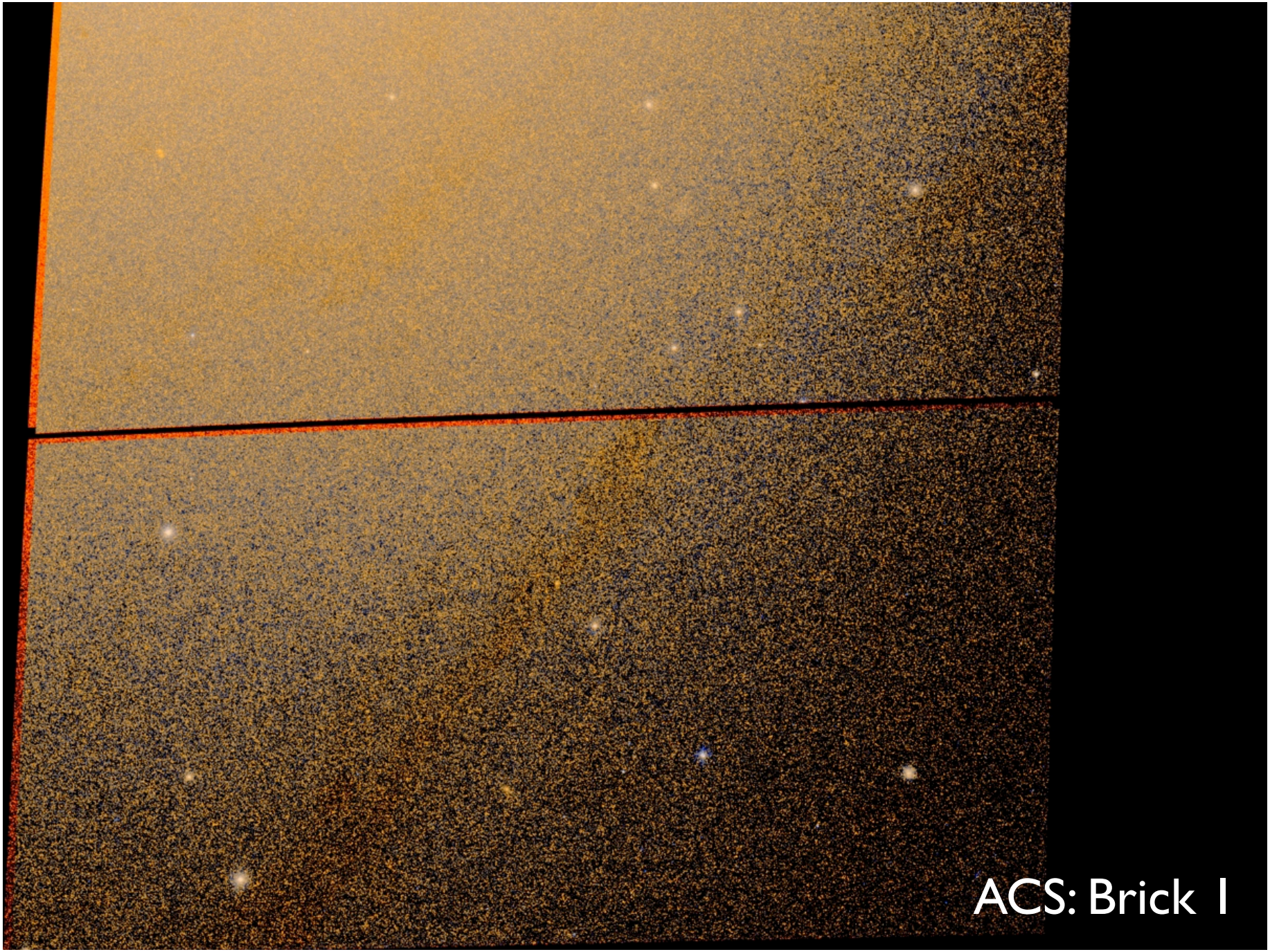

Brick 21
Brick 15
Brick 9
Brick 1
Before
Offsets between matched stars
dDec (arcsec)
dRA (arcsec)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5

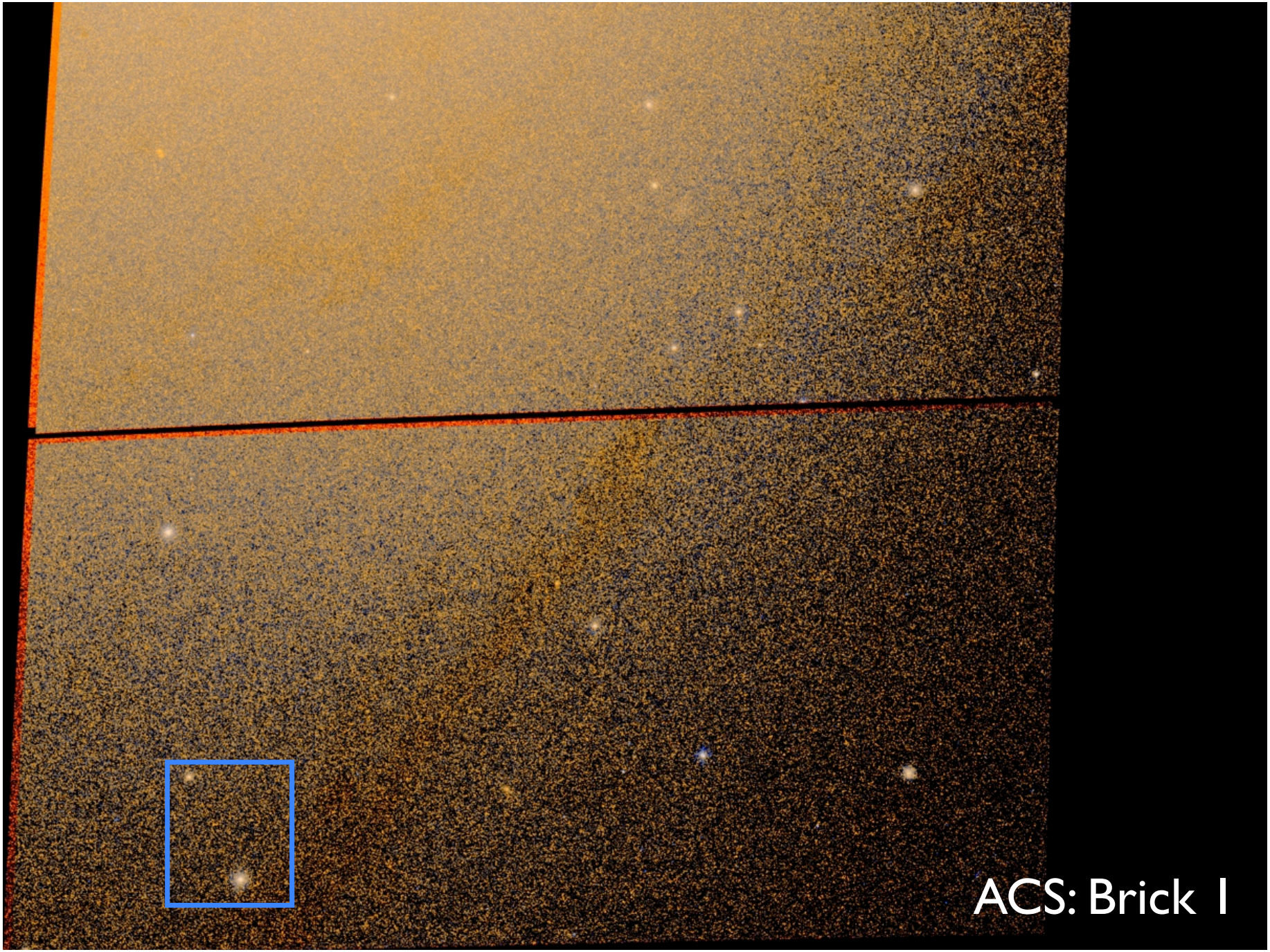

Brick 21
Brick 15
Brick 9
Brick 1
After
<0.01" Offsets
between matched stars
dDec (arcsec)
dRA (arcsec)
0.10
0.05
0.00
−0.05
−0.10
−0.10
−0.05
0.00
0.05
0.10

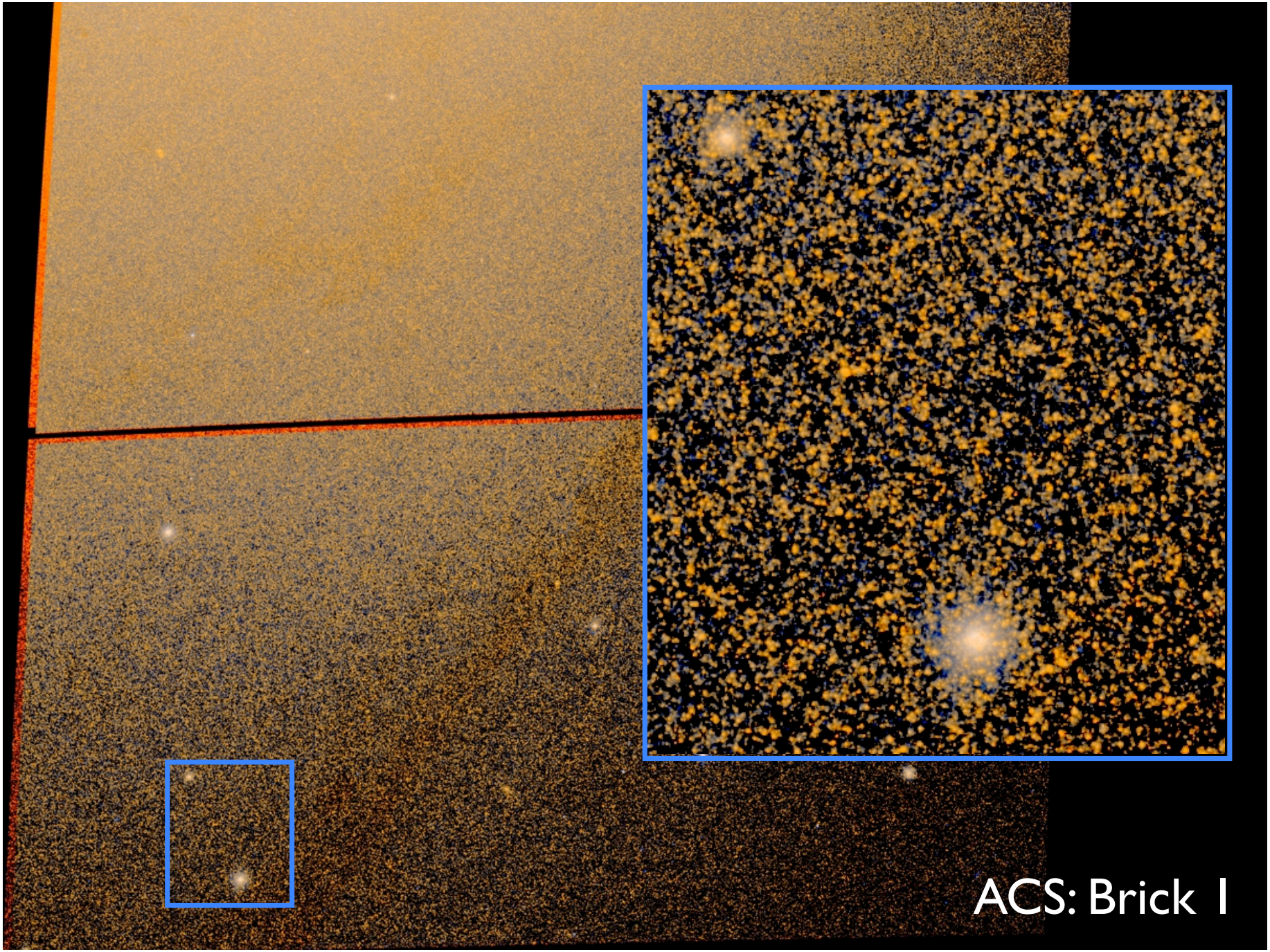
HST is a Good Thing

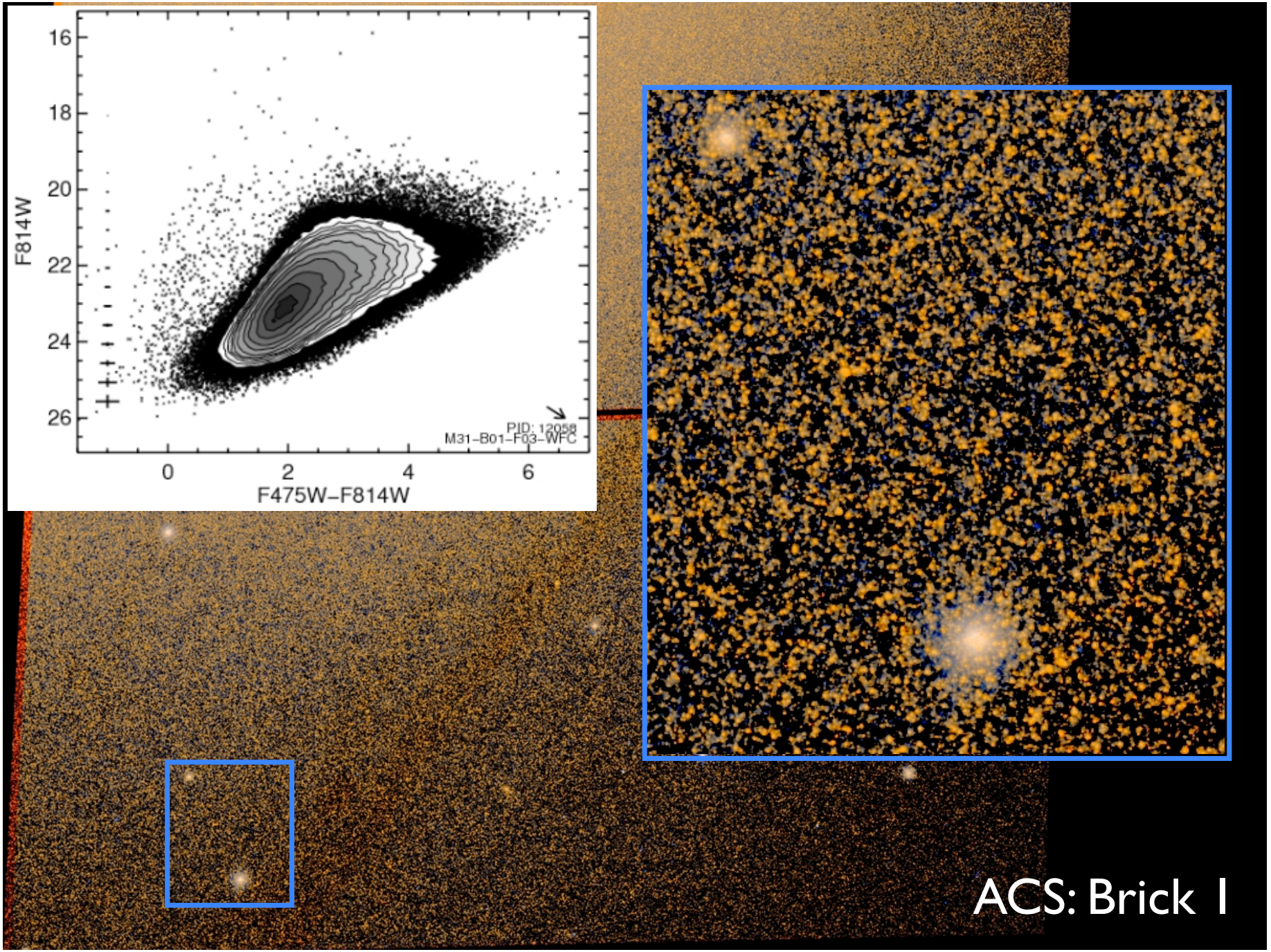
HST is a Good Thing

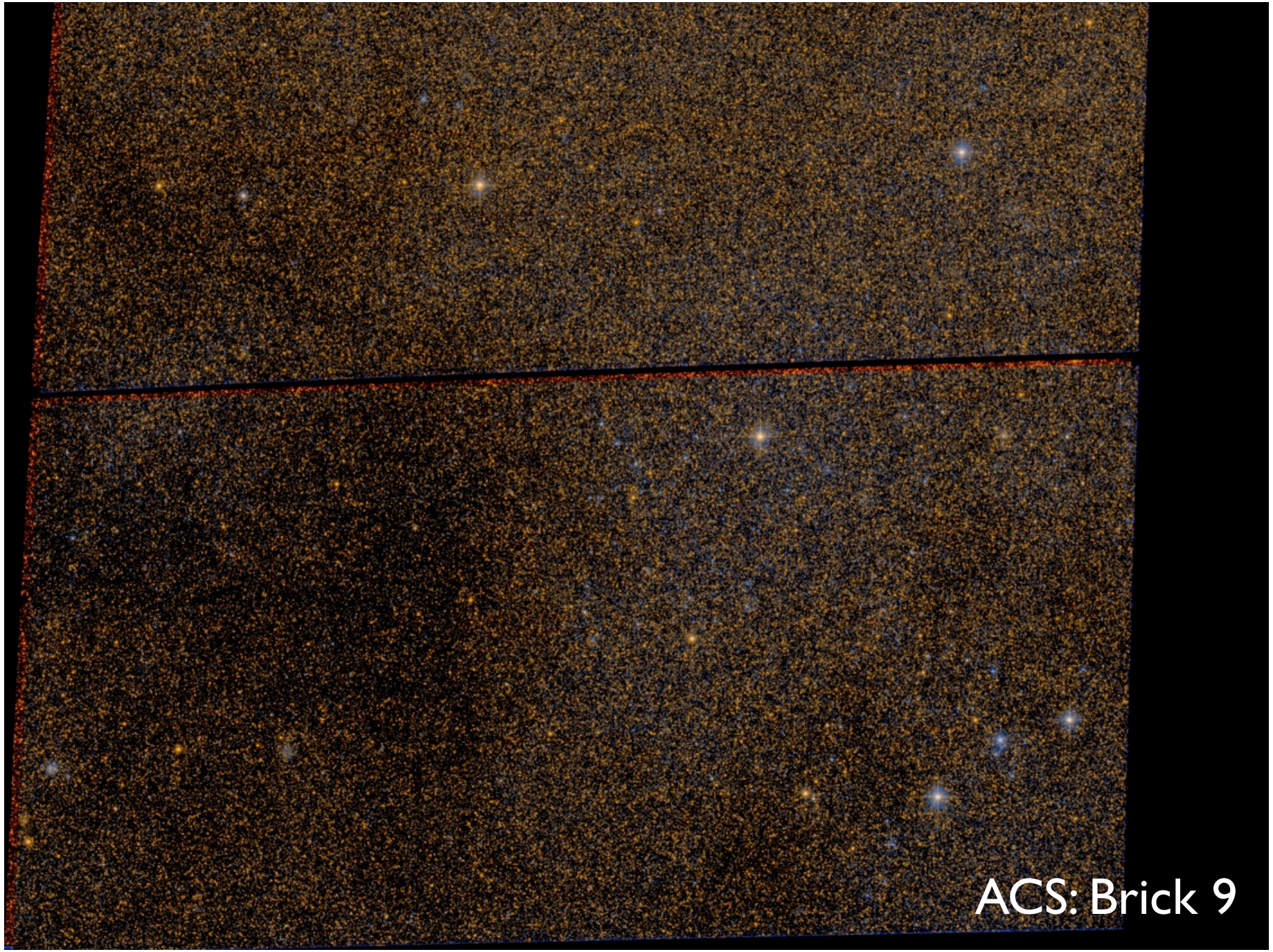


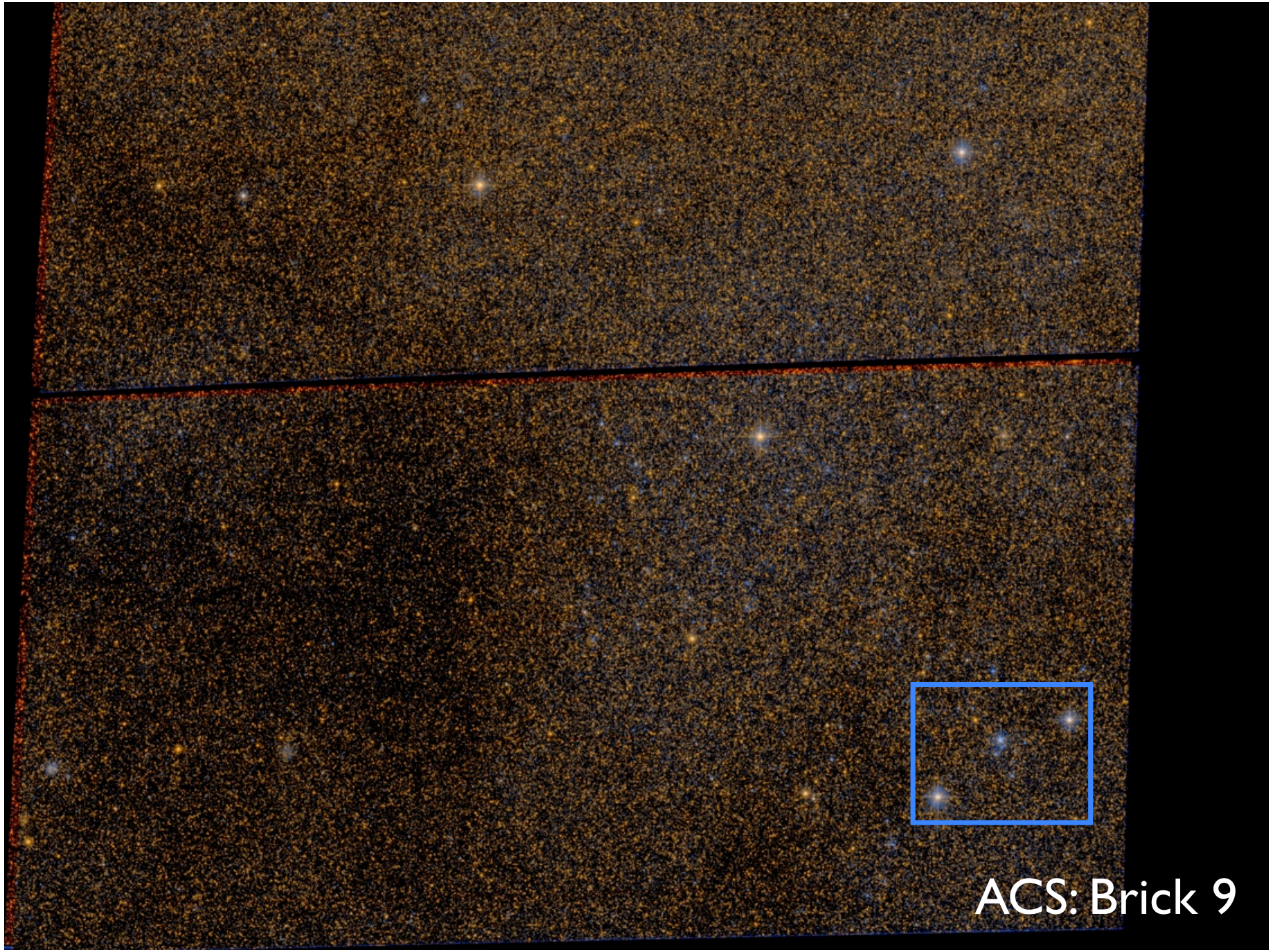

ACS: Brick 1

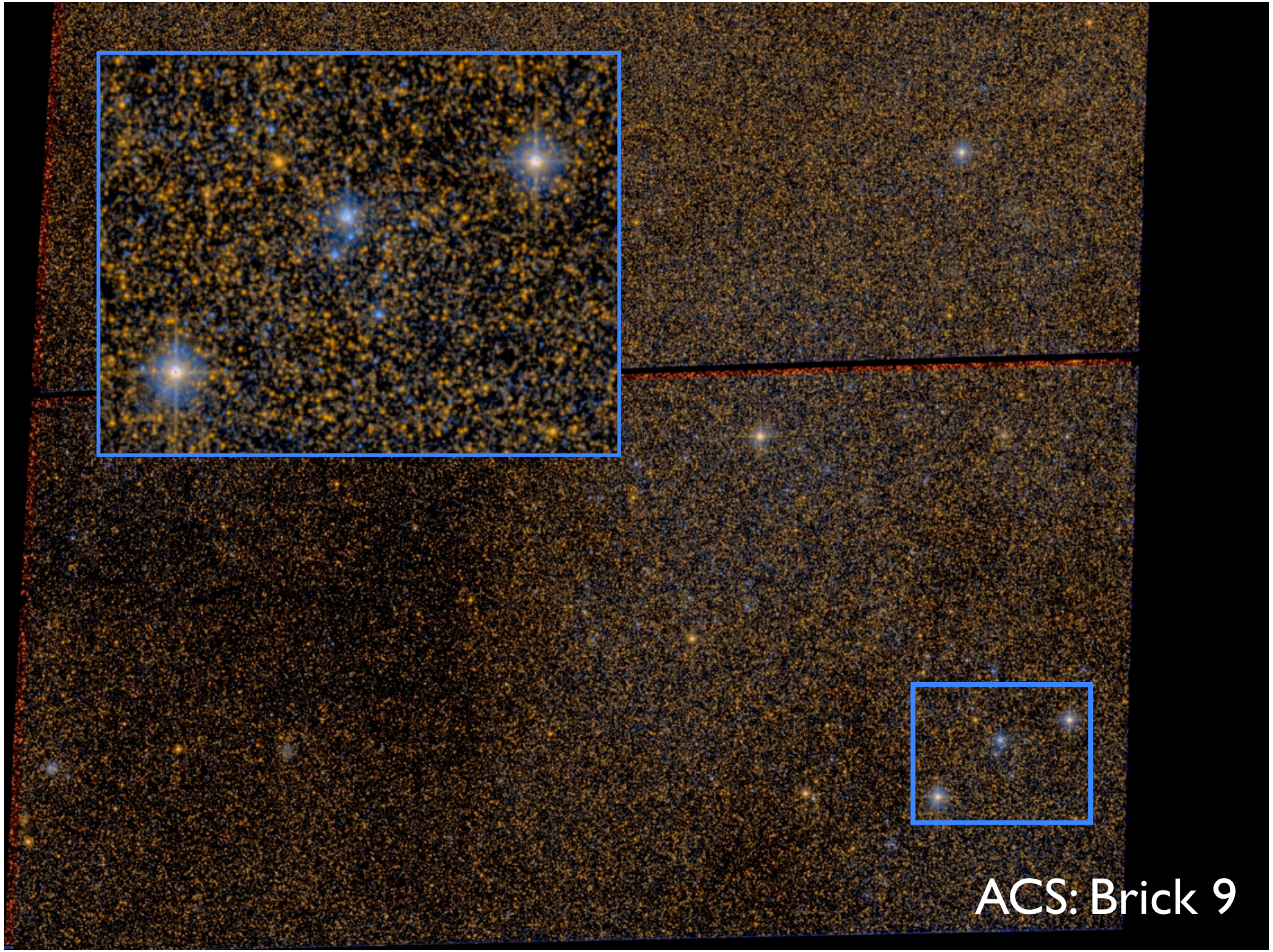

ACS: Brick 1

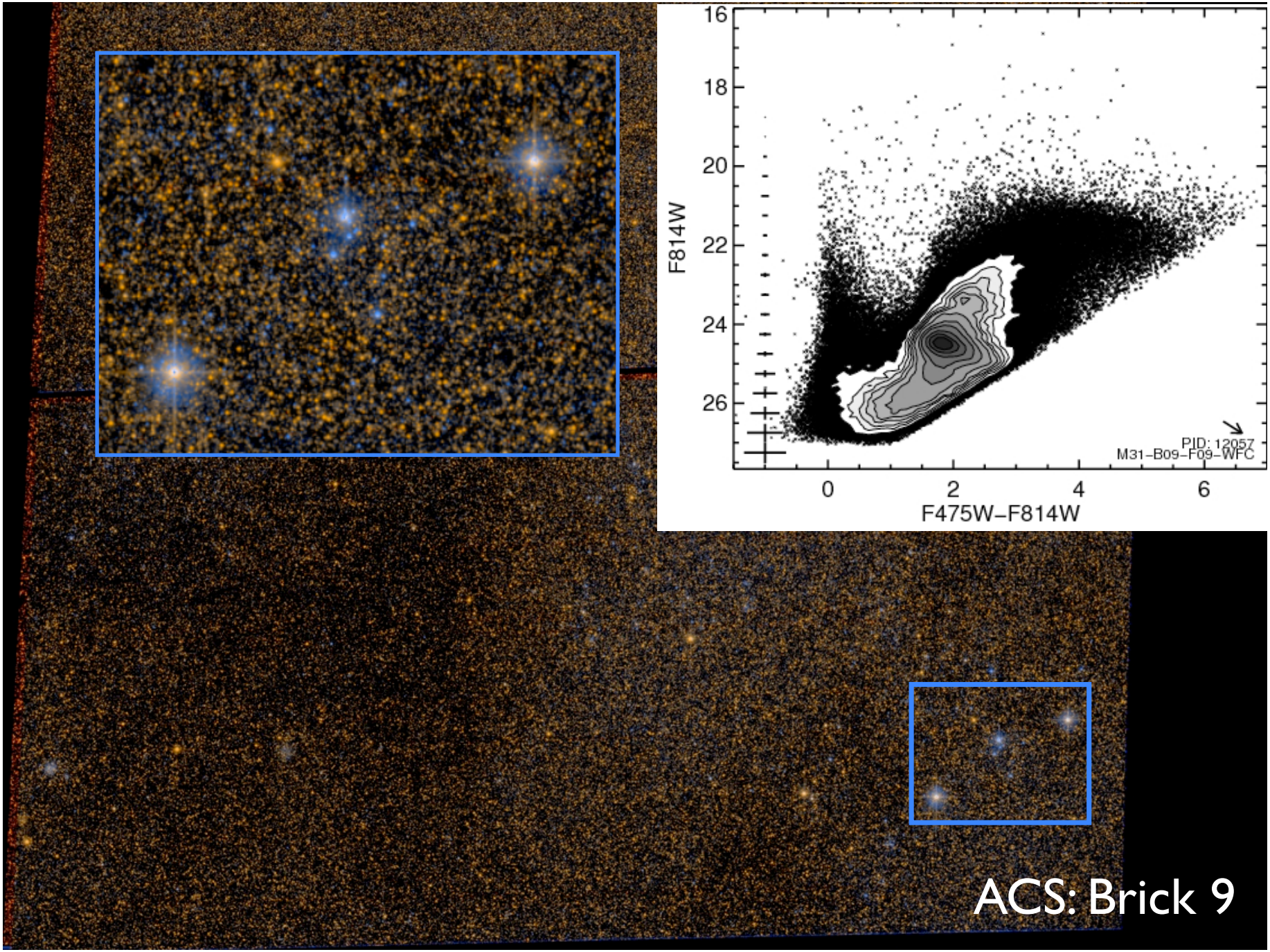

ACS: Brick 1

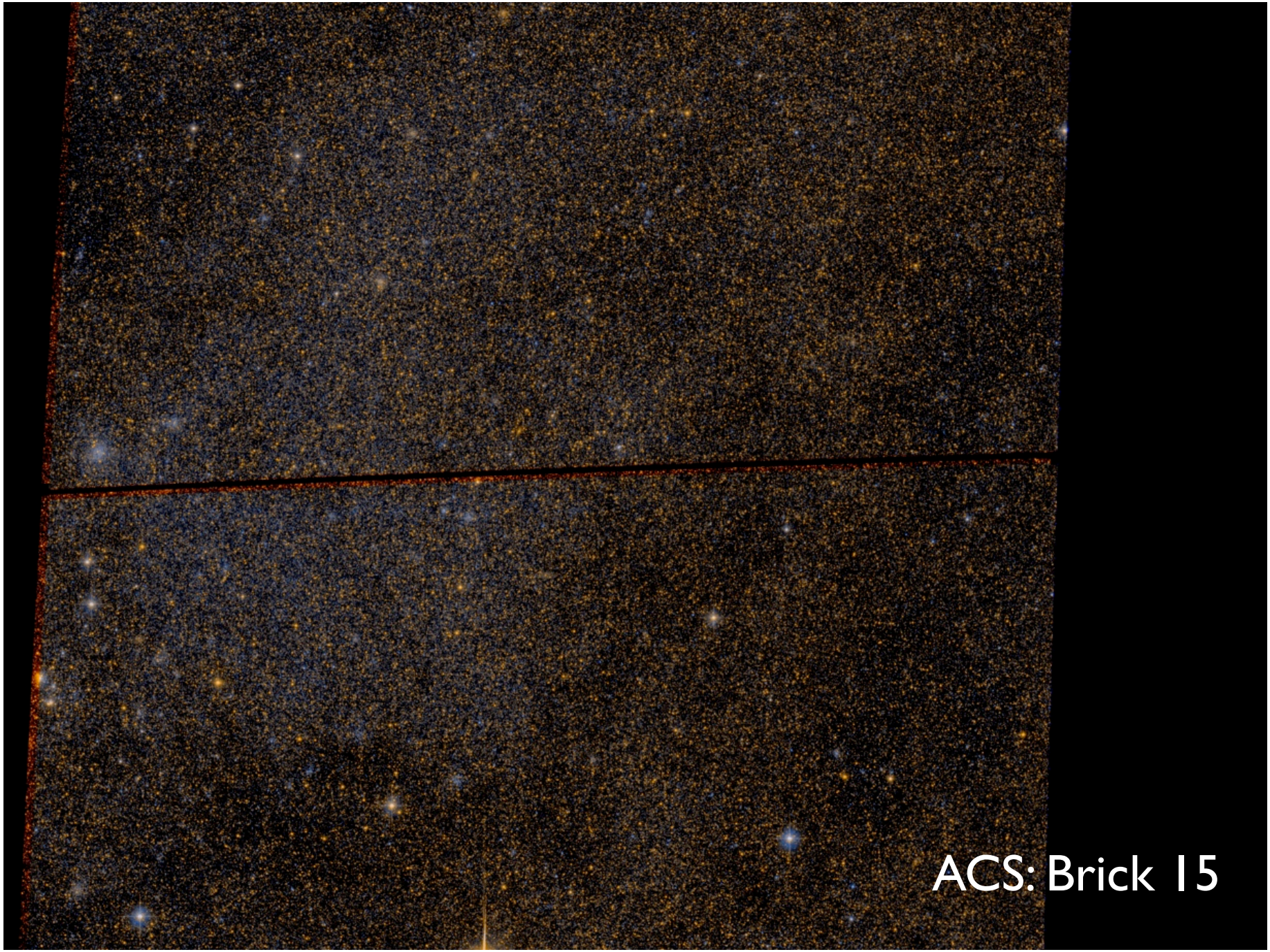

16
18
20
22
24
26
F814W
0
2
4
6
F475W–F814W
PID: 12058
M31–B01–F03–WFC
ACS: Brick 1

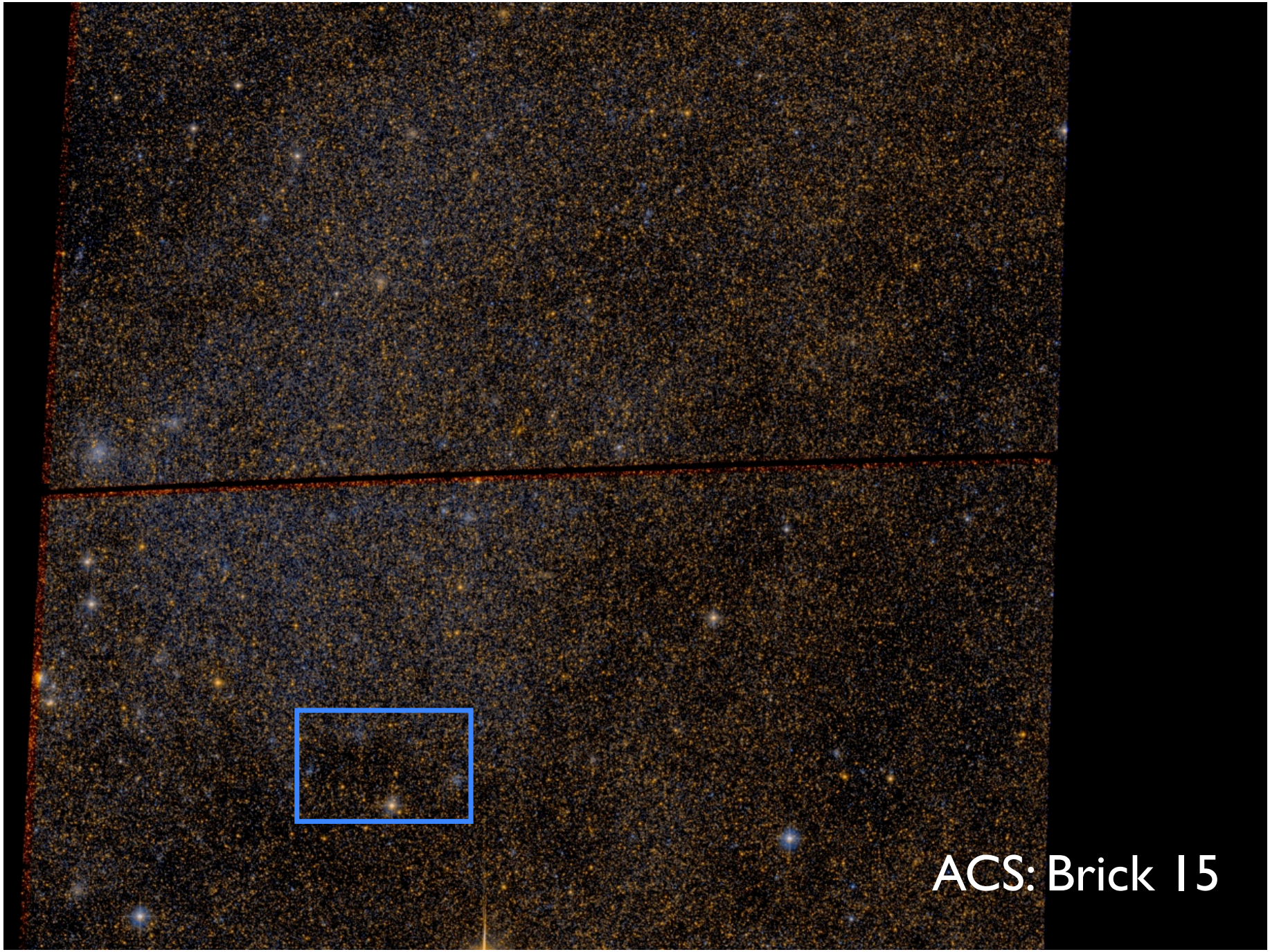

ACS: Brick 9

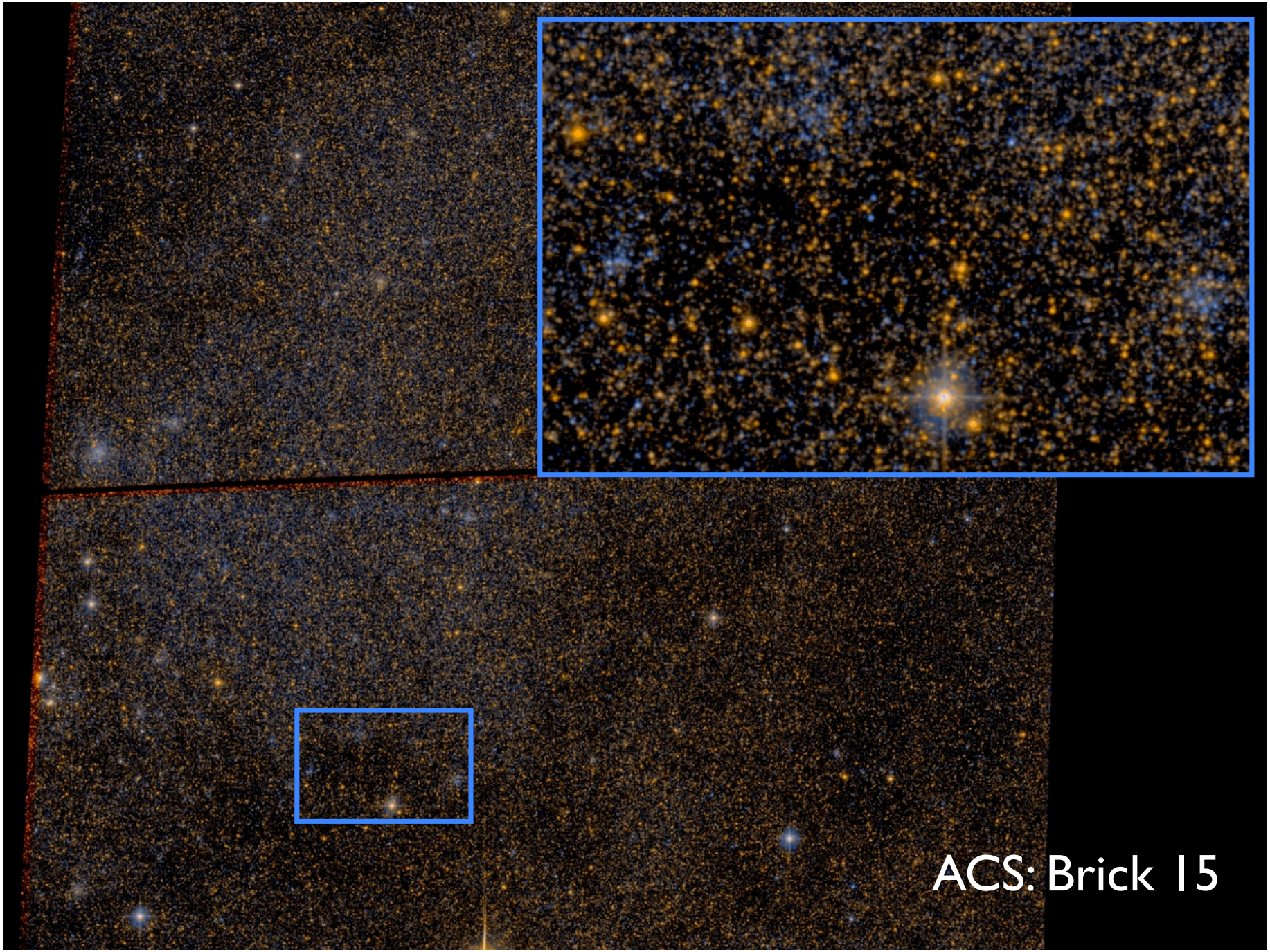

ACS: Brick 9

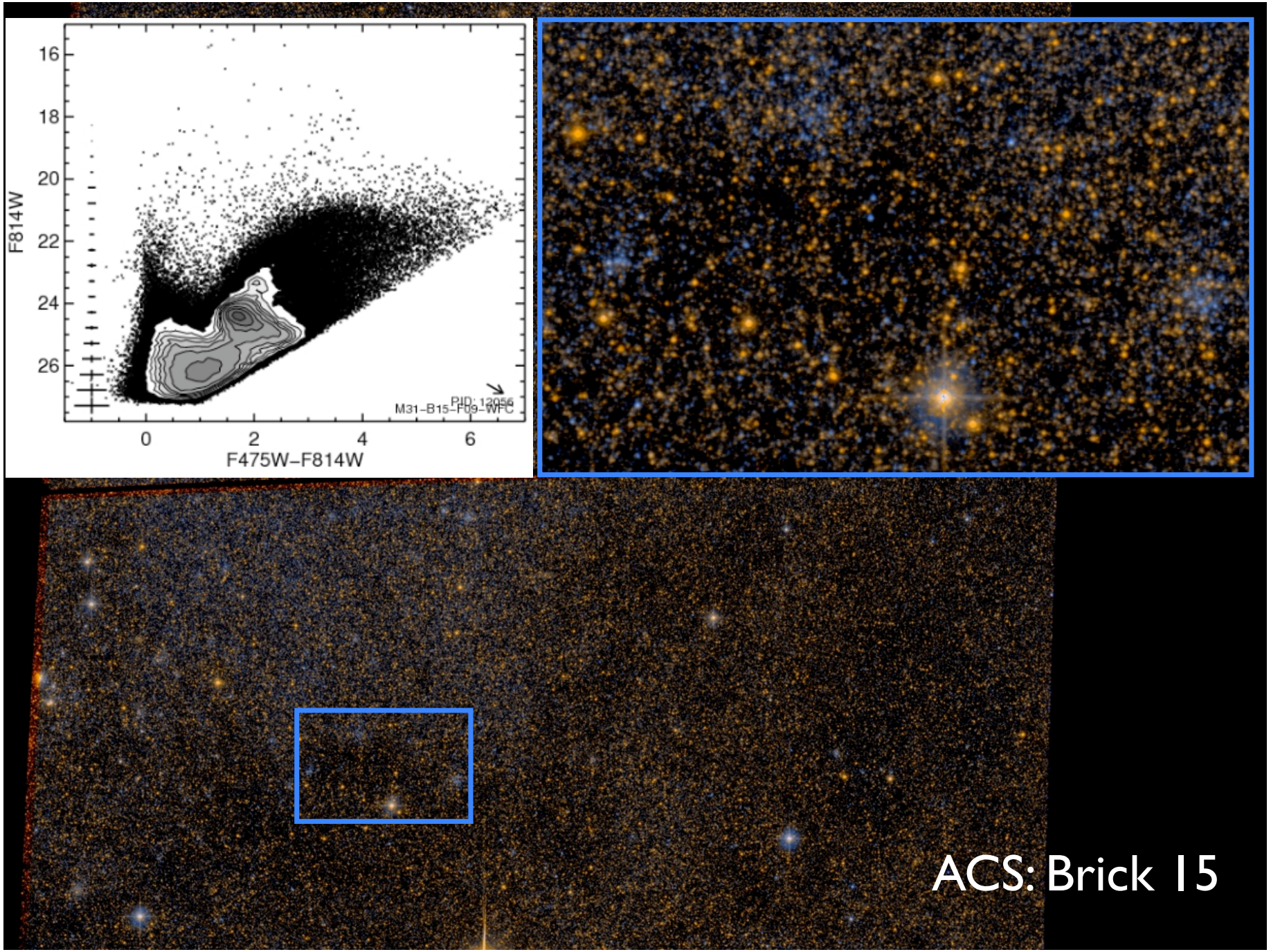

ACS: Brick 9

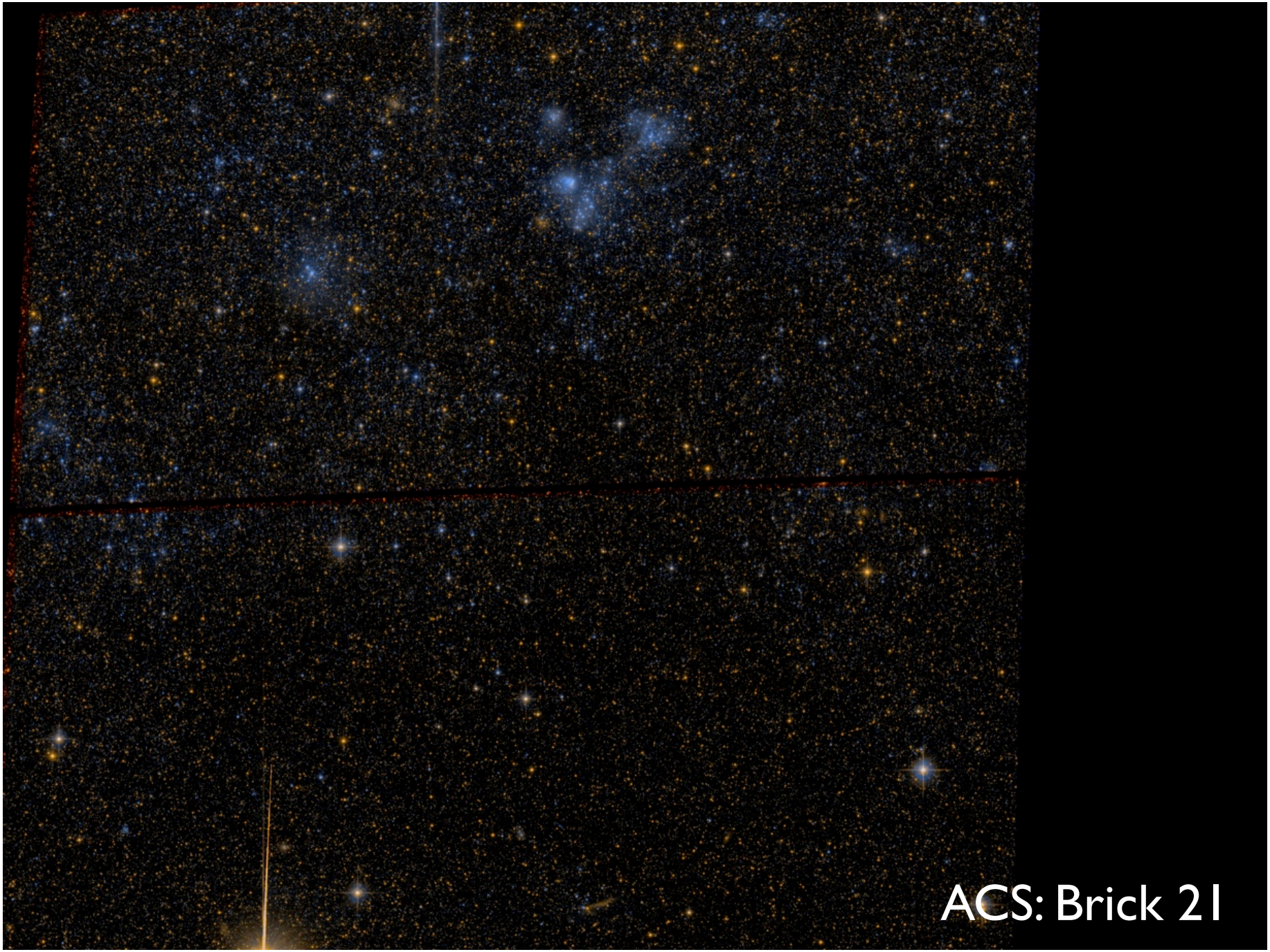

16
18
20
22
24
26
F814W
0
2
4
6
F475W–F814W
PID: 12057
M31-B09-F09-WFC
ACS: Brick 9

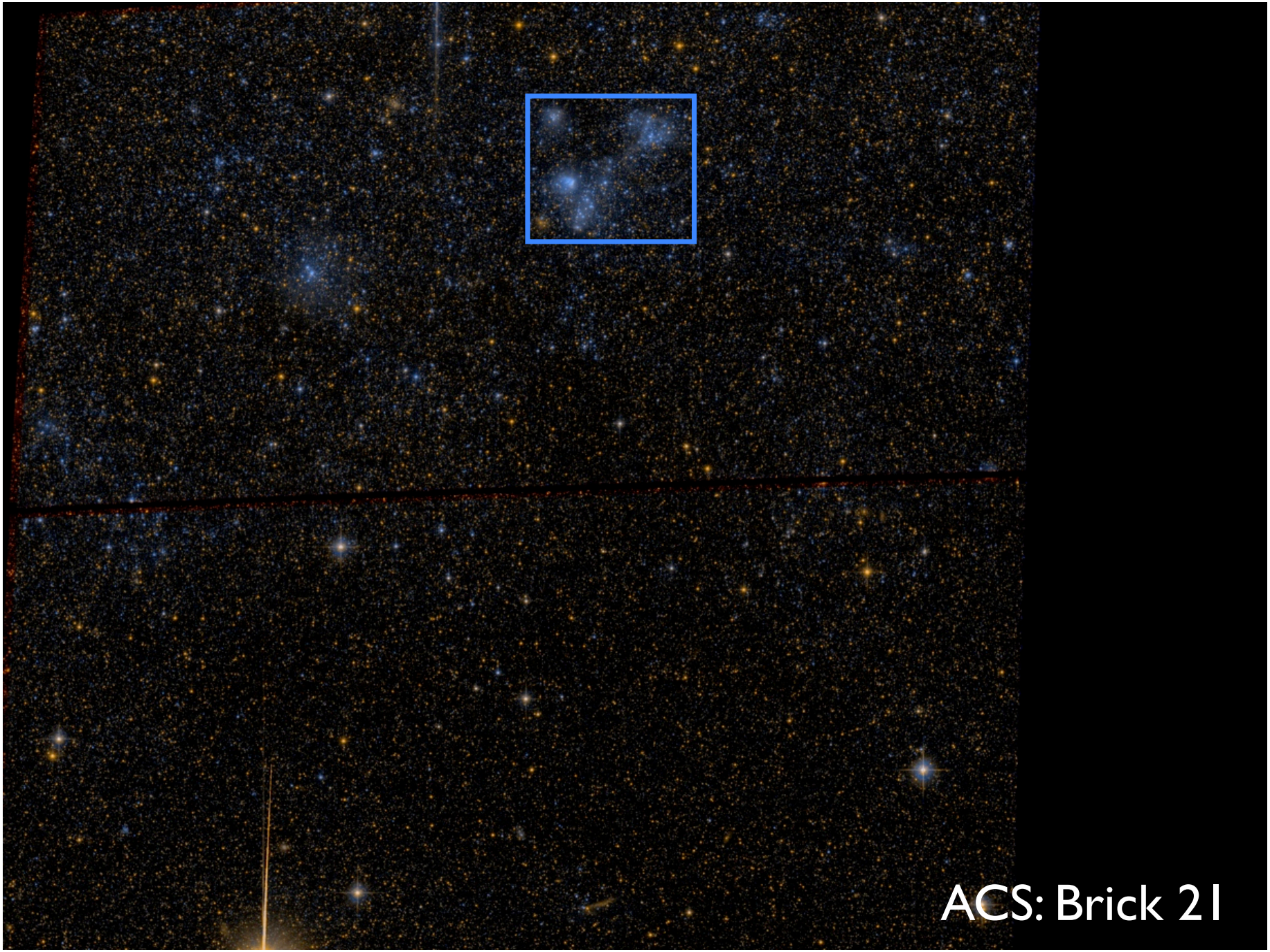

ACS: Brick 15

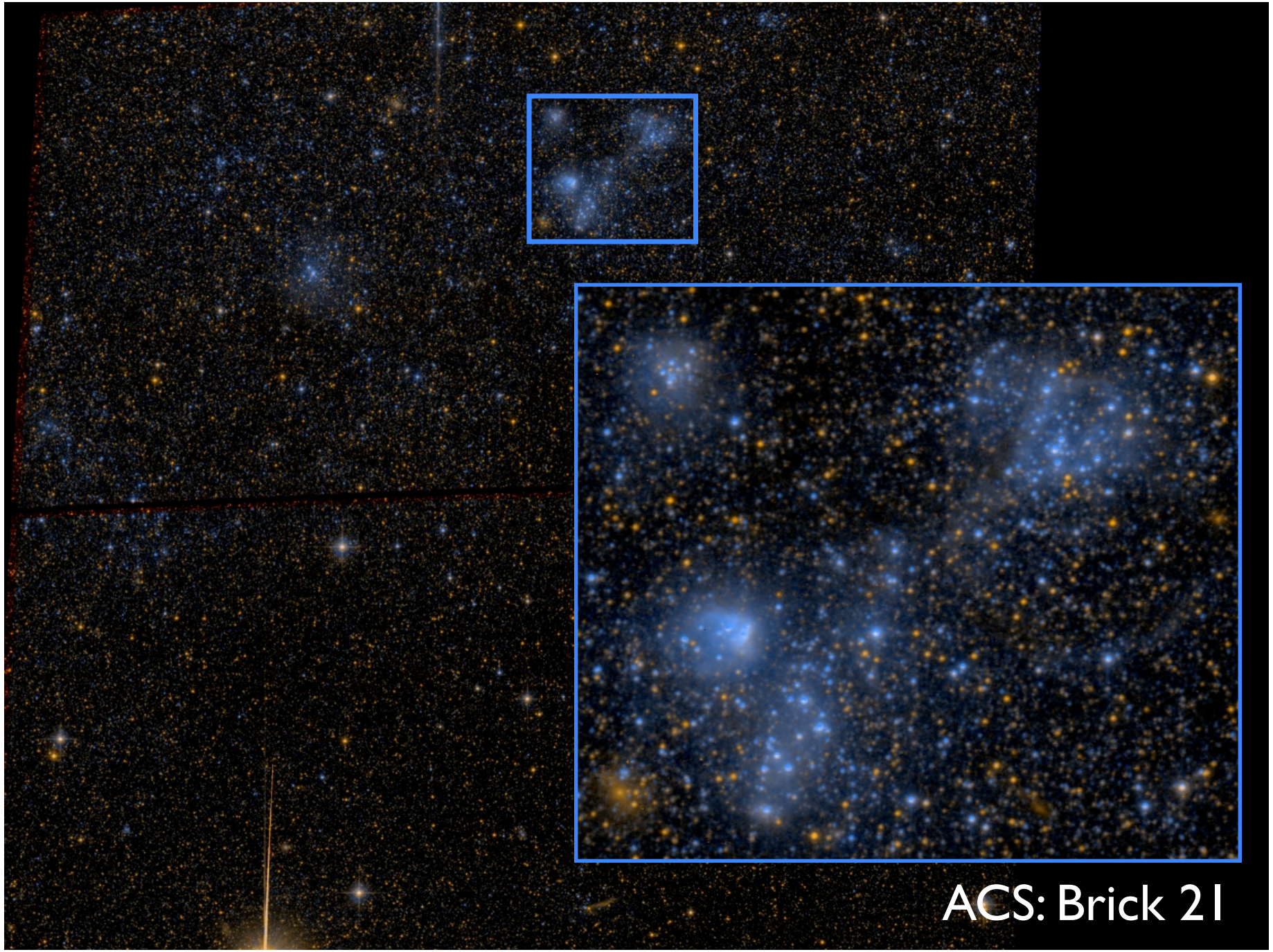

ACS: Brick 15

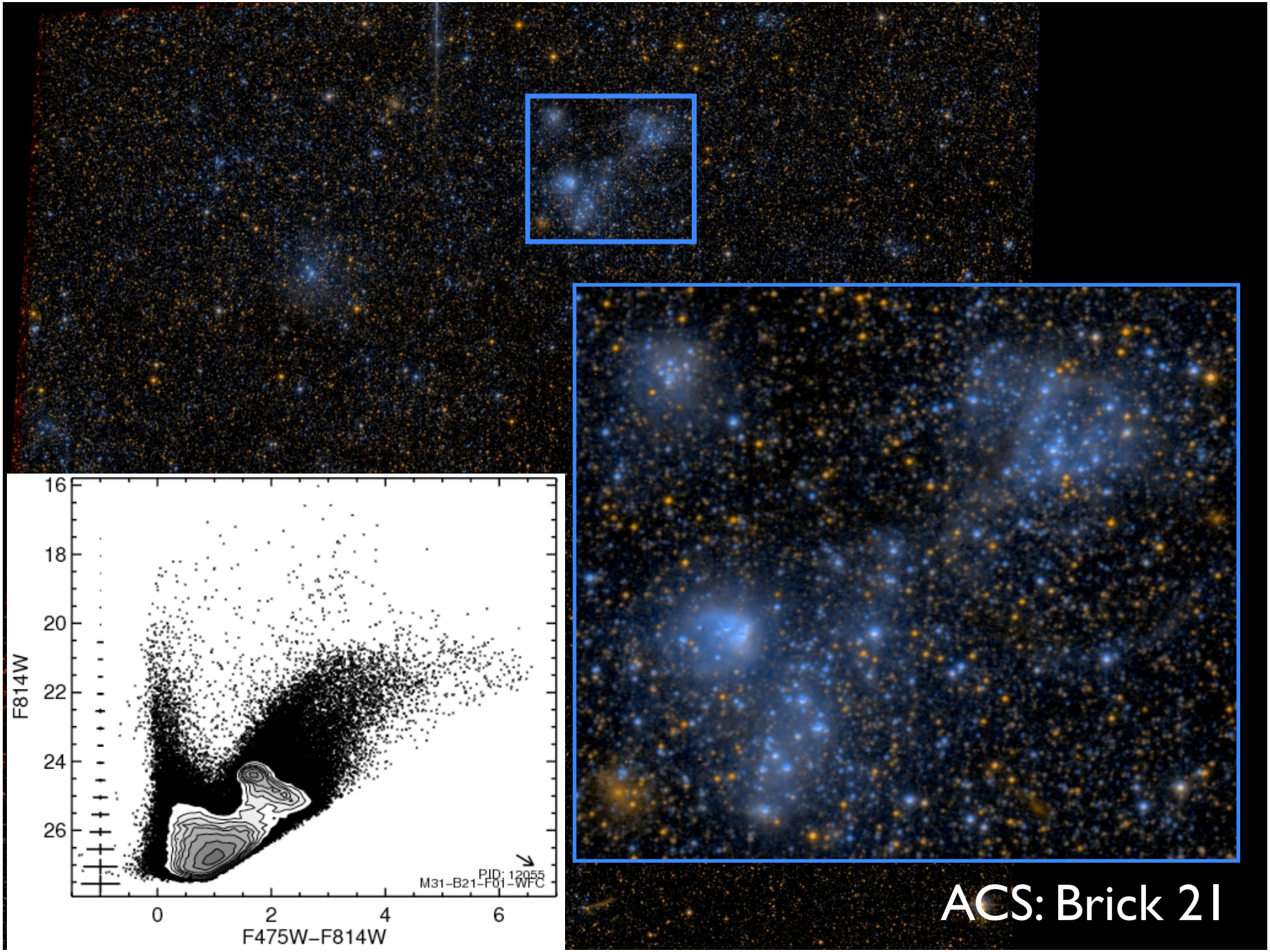

ACS: Brick 15


16
18
20
22
24
26
F814W
0
2
4
6
F475W–F814W
M31–B15–F09–WFC
ACS: Brick 15

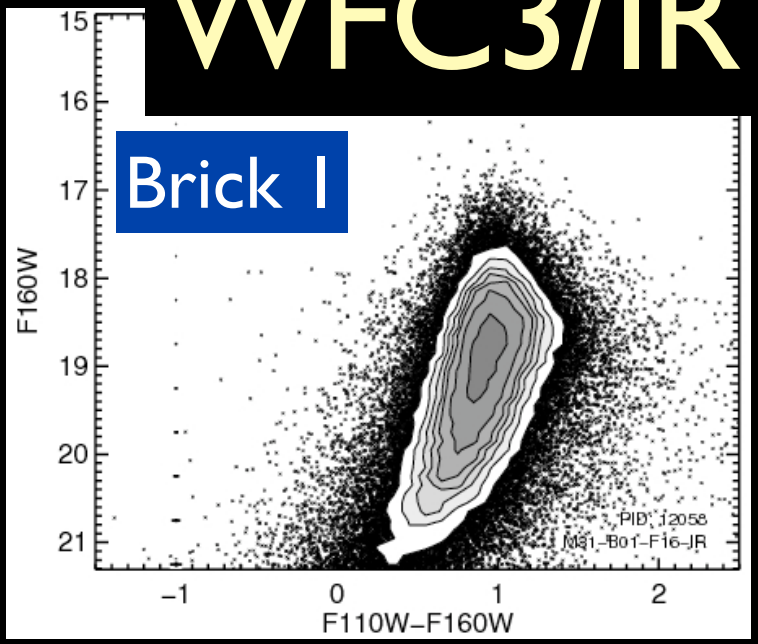

ACS: Brick 21

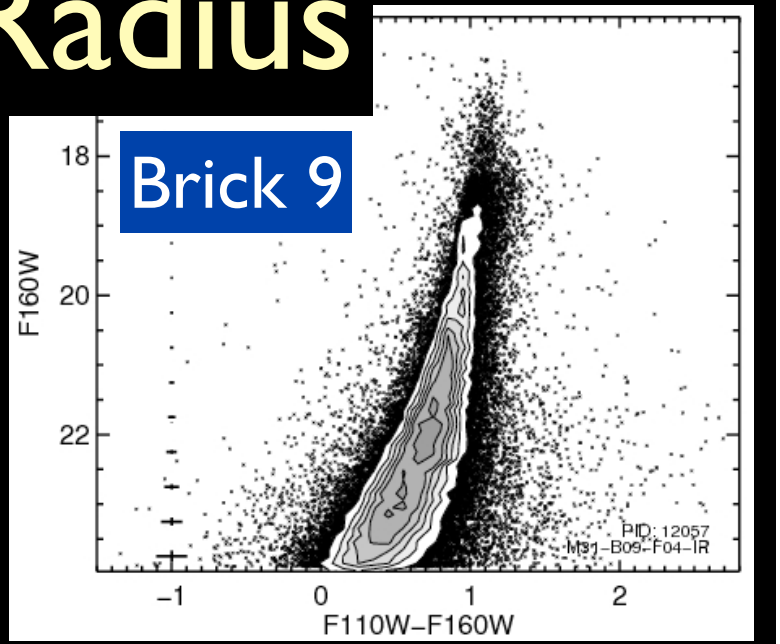

ACS: Brick 21

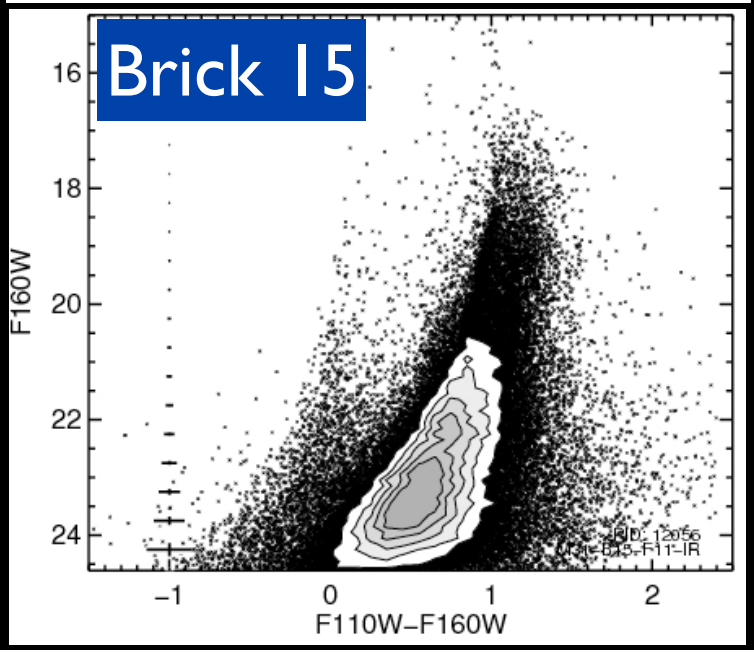

ACS: Brick 21

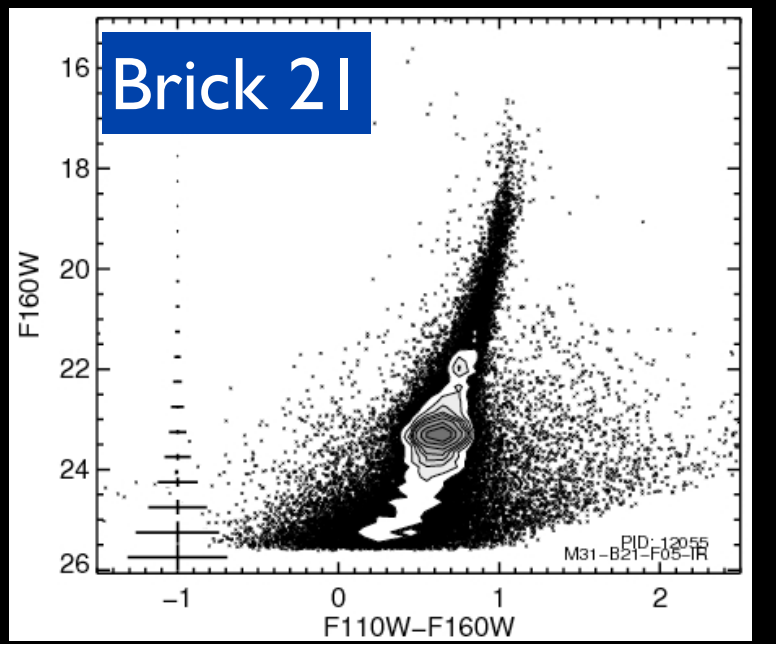

16
18
20
22
24
26
F814W
0
2
4
6
F475W–F814W
PID: 12055
M31-B21-F01-WFC
ACS: Brick 21

WFC3/IR vs Radius



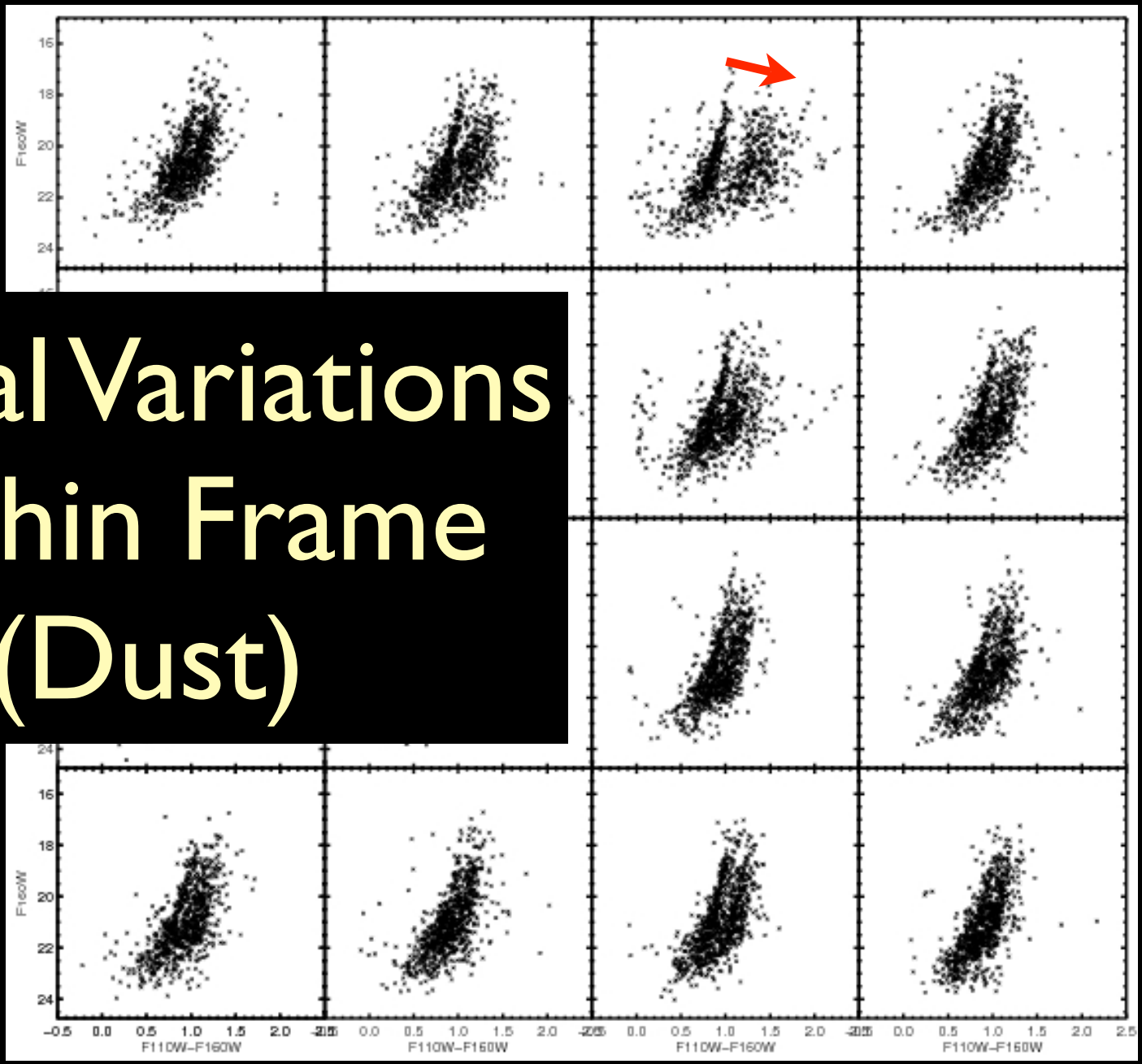


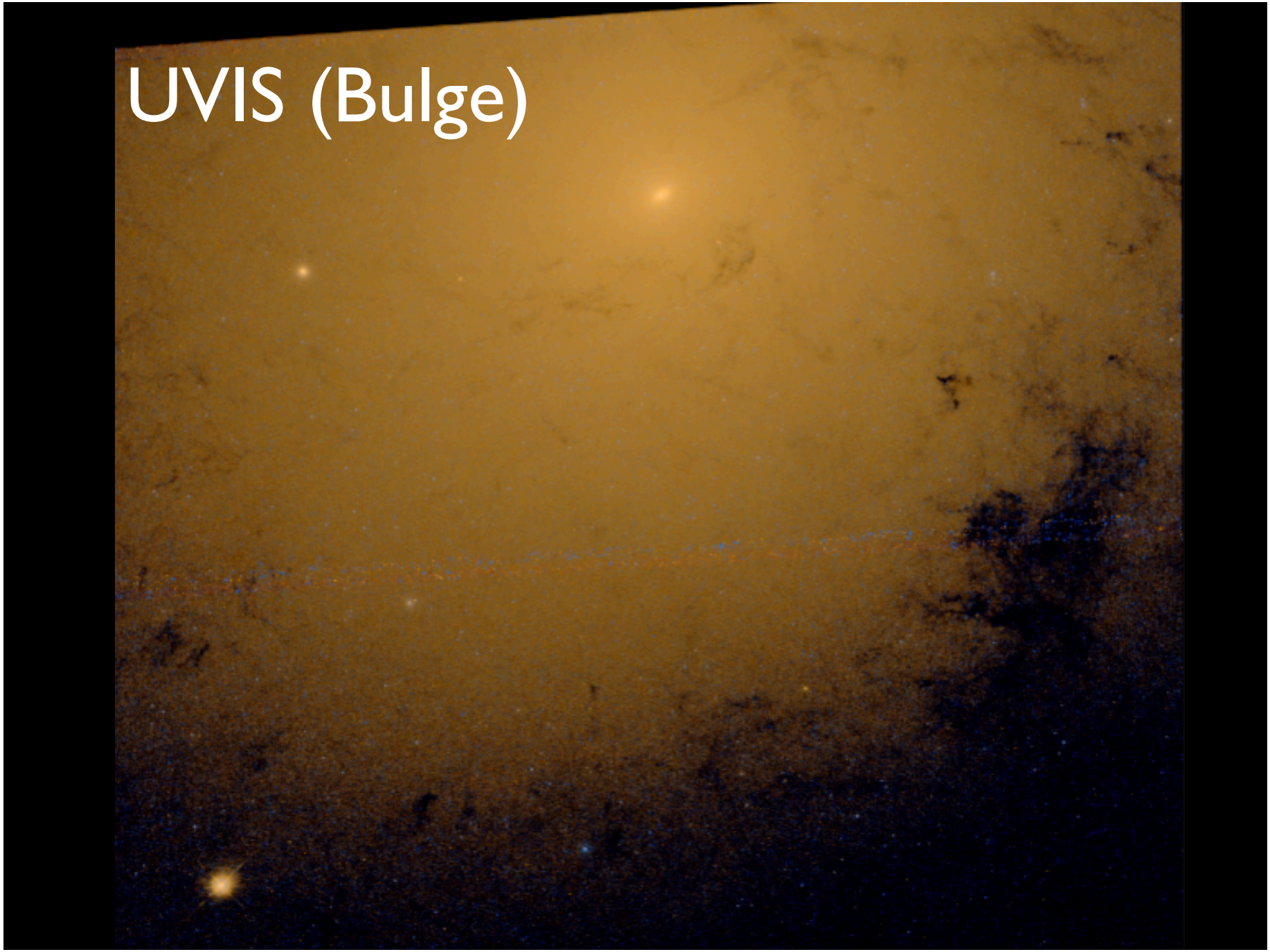


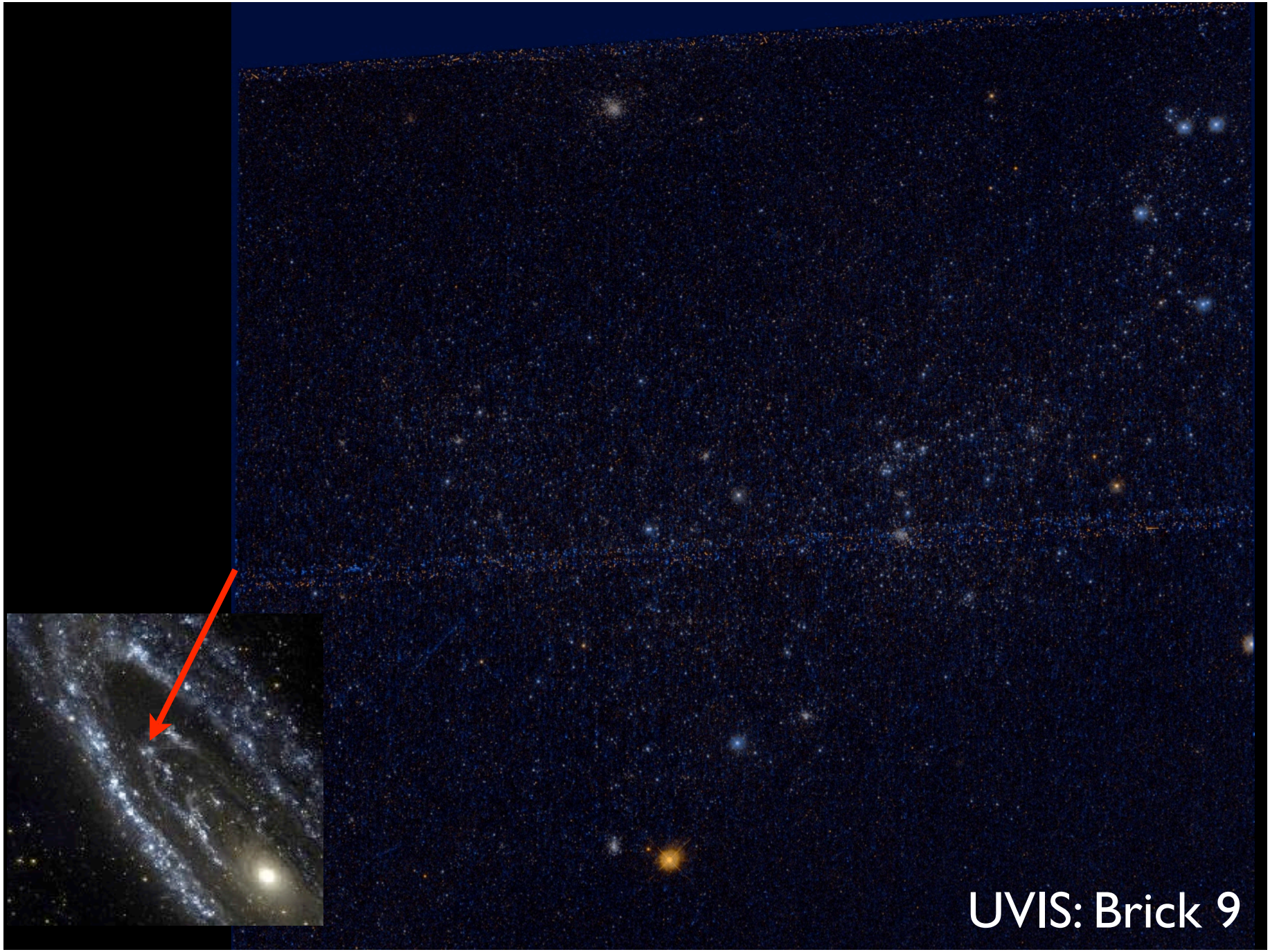


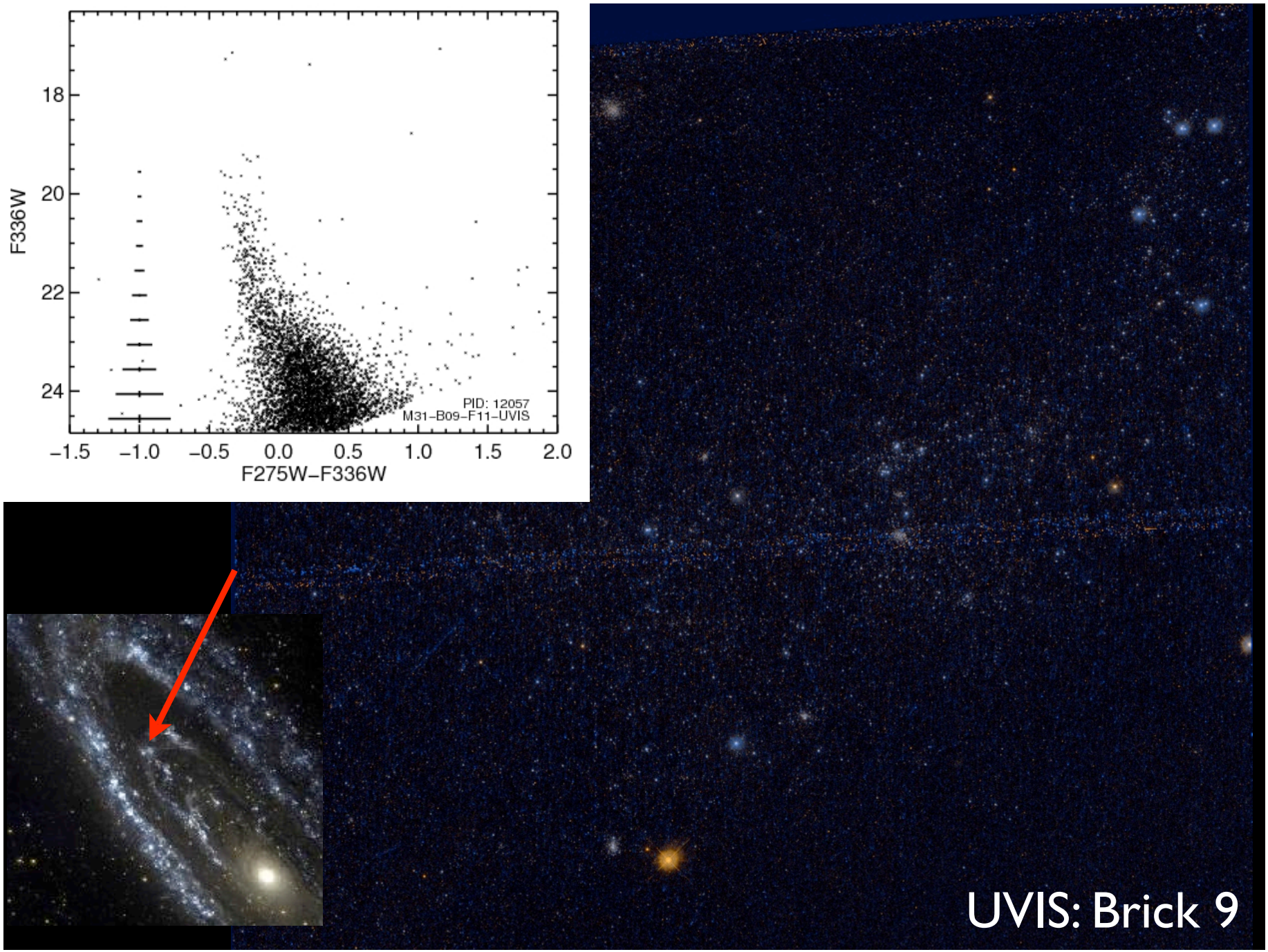
Spatial Variations Within Frame (Dust)

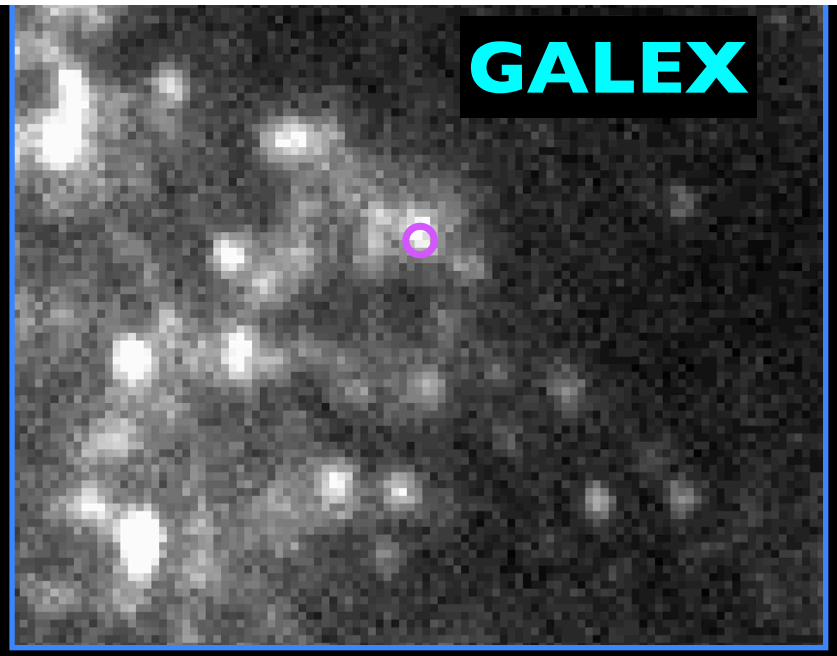
Higher Quality Photometry Only

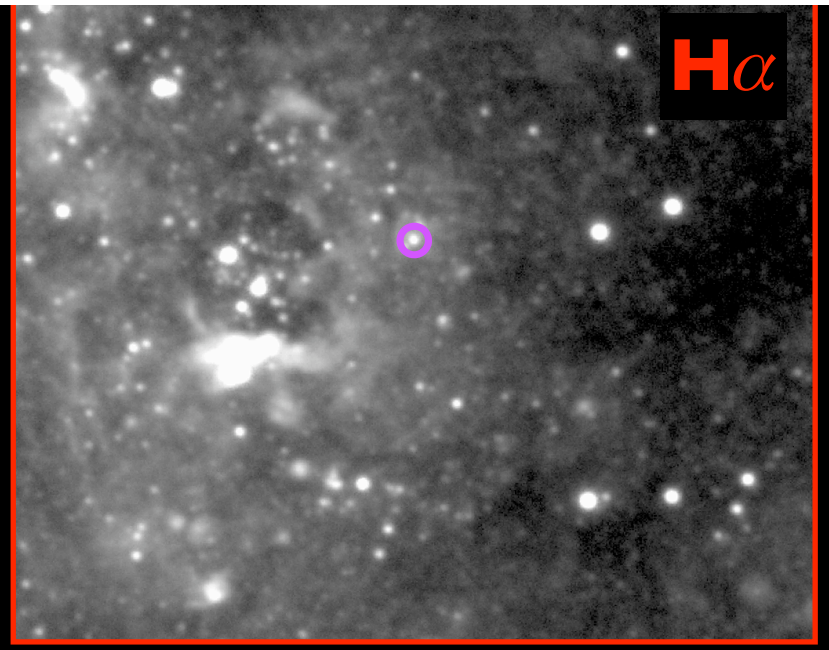



UVIS (Bulge)

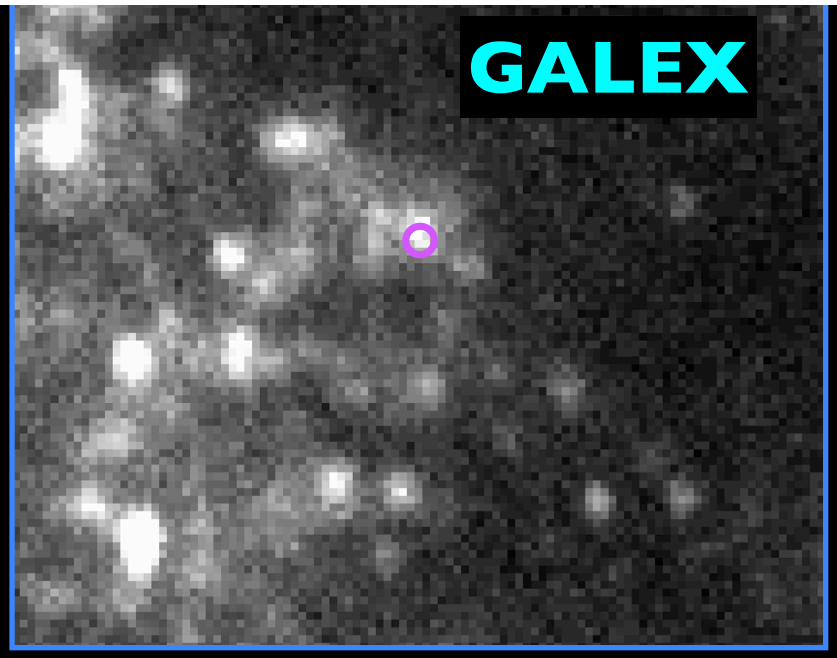

UVIS: Brick 9

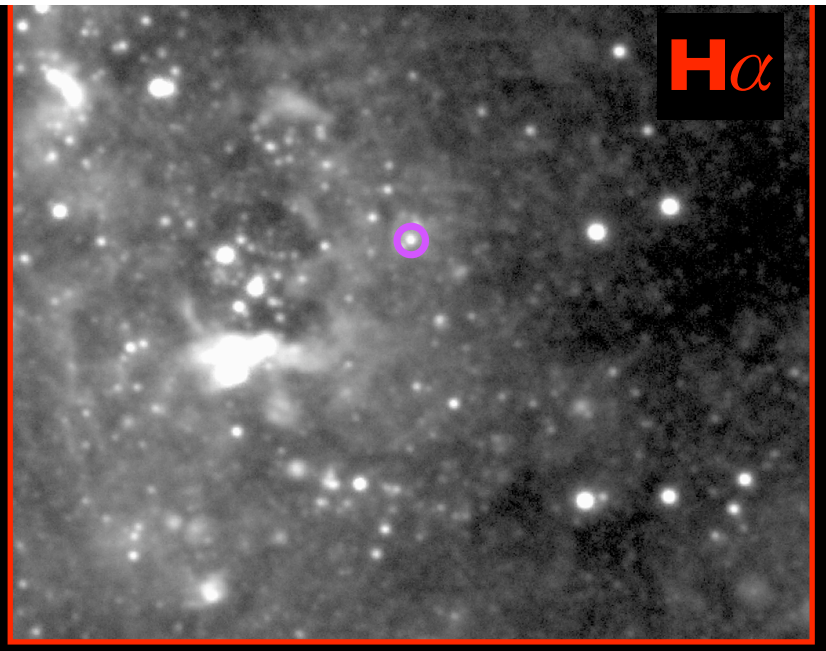

F336W
18
20
22
24
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
F275W−F336W
PID: 12057
M31−B09−F11−UVIS
UVIS: Brick 9

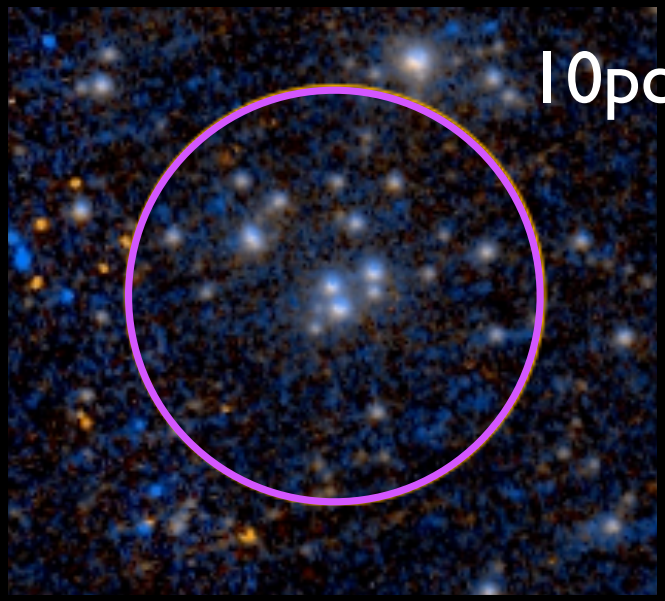




Calibrating SF Indicators: Sources and Timescales of UV and Hα emission

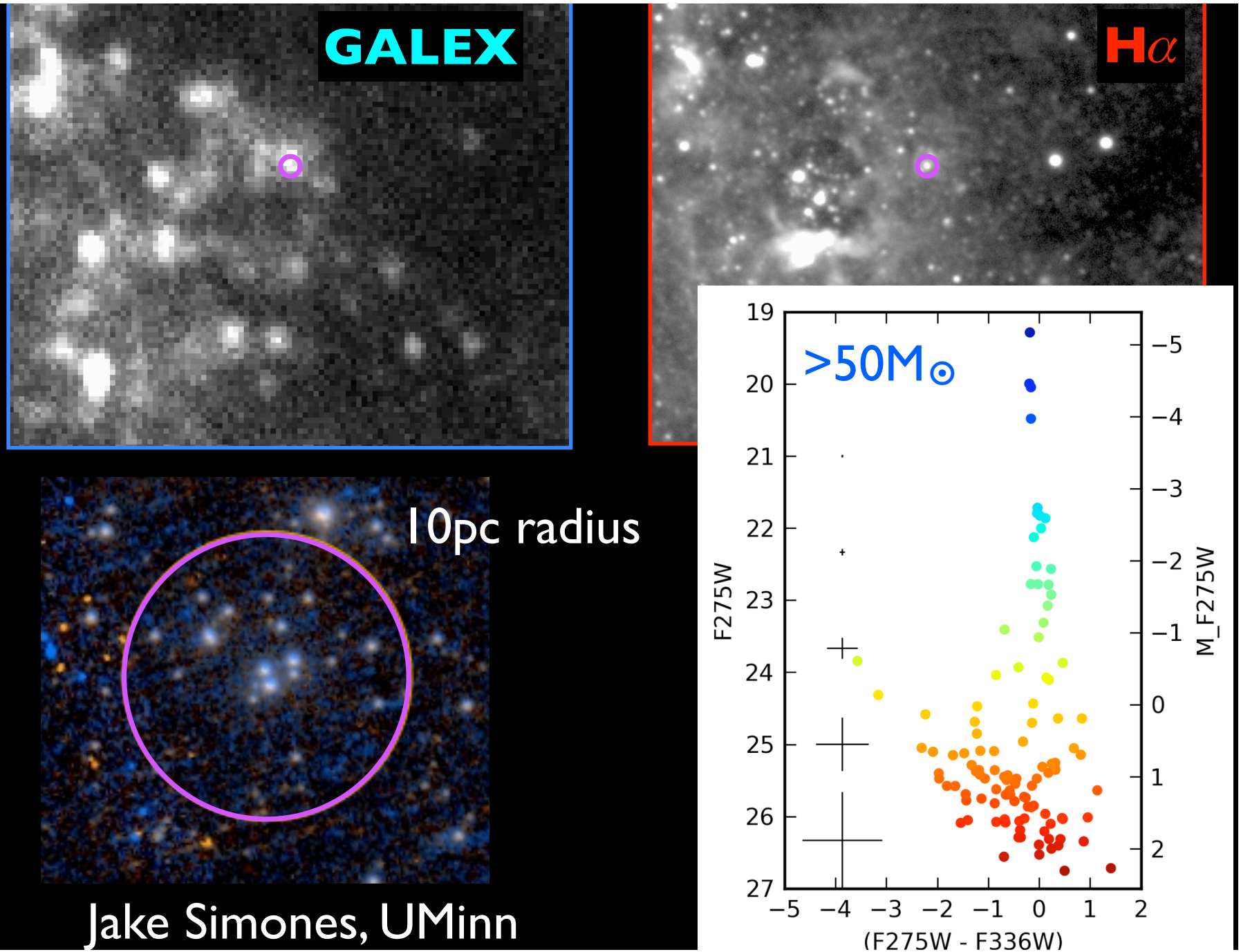


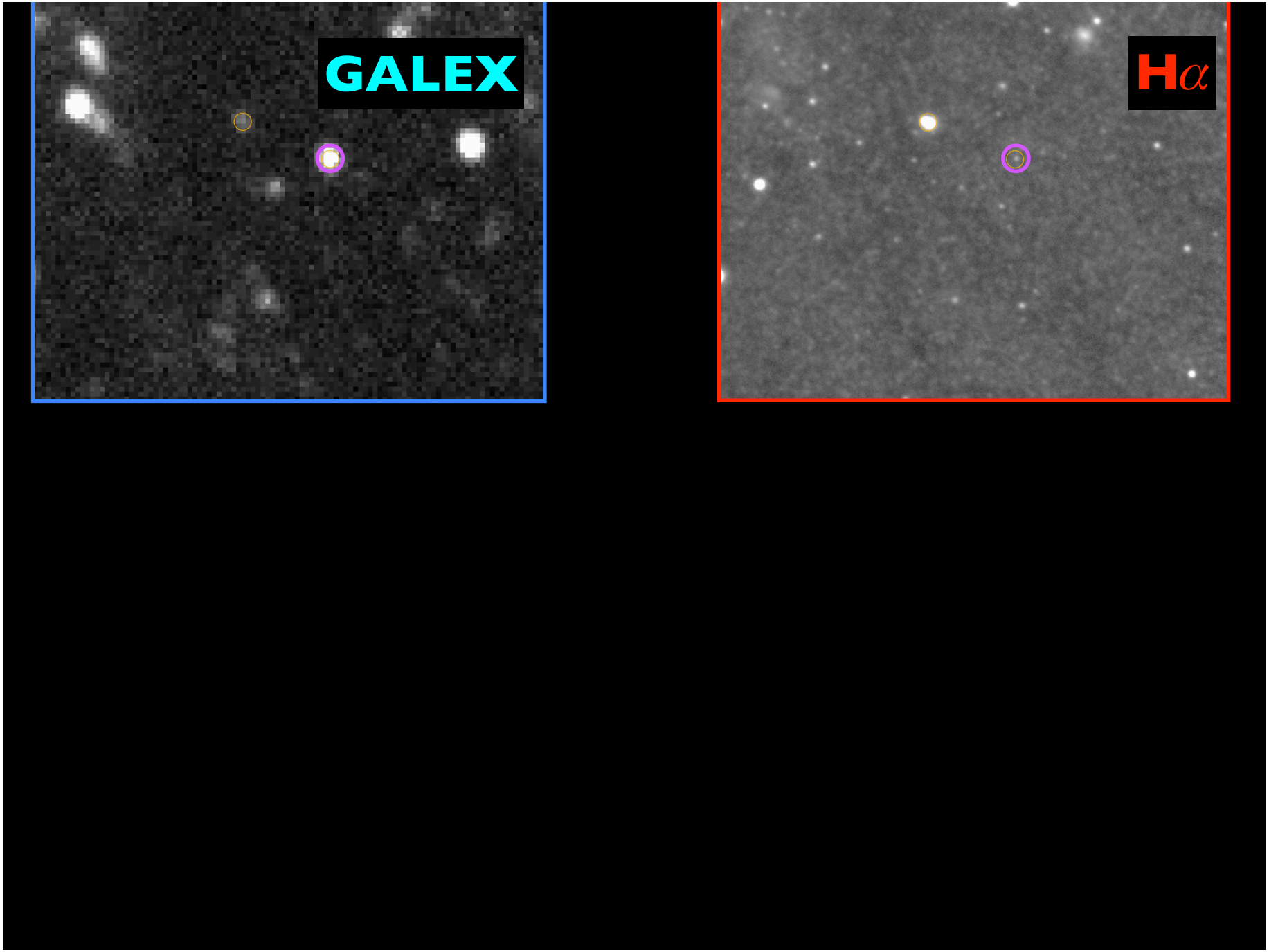


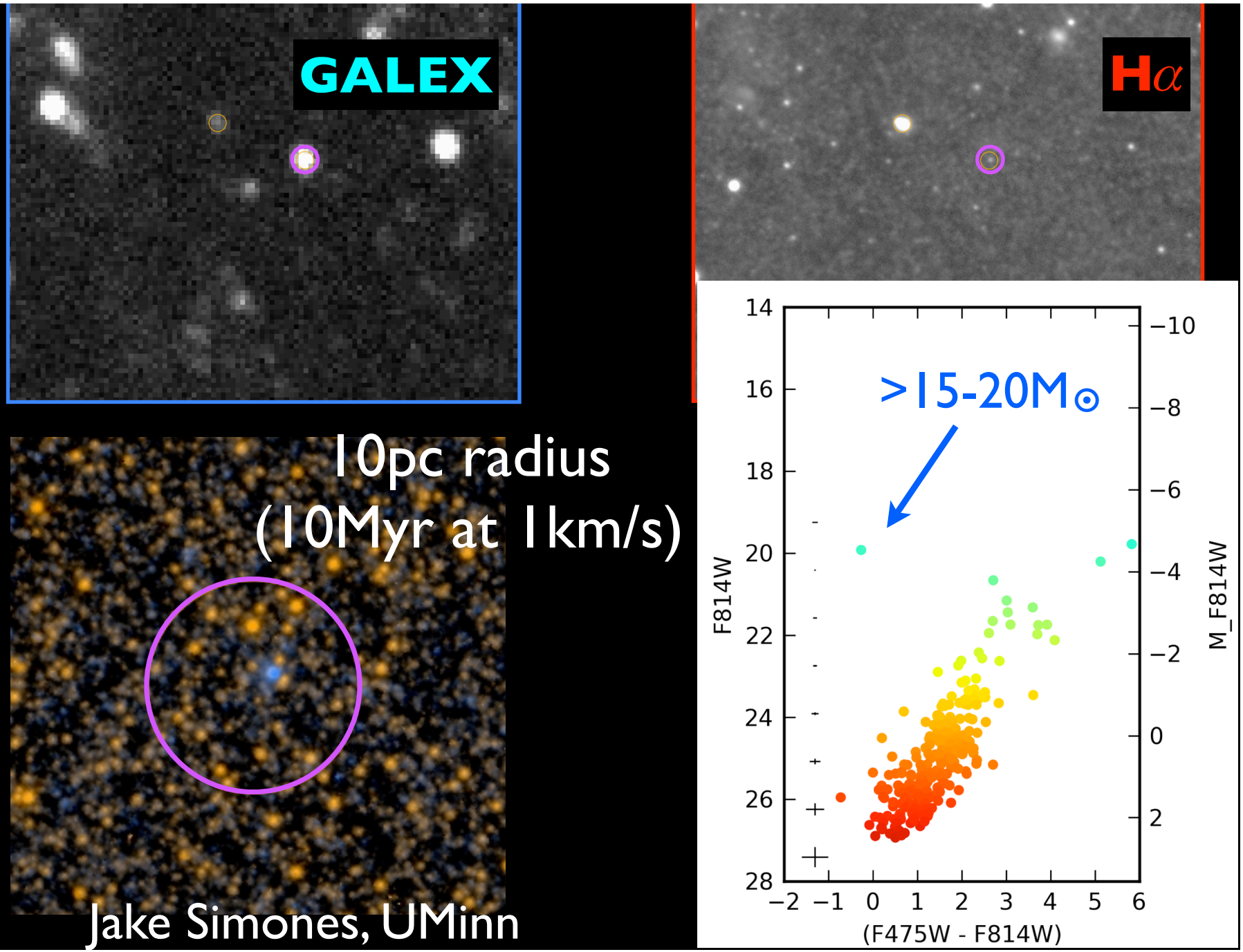


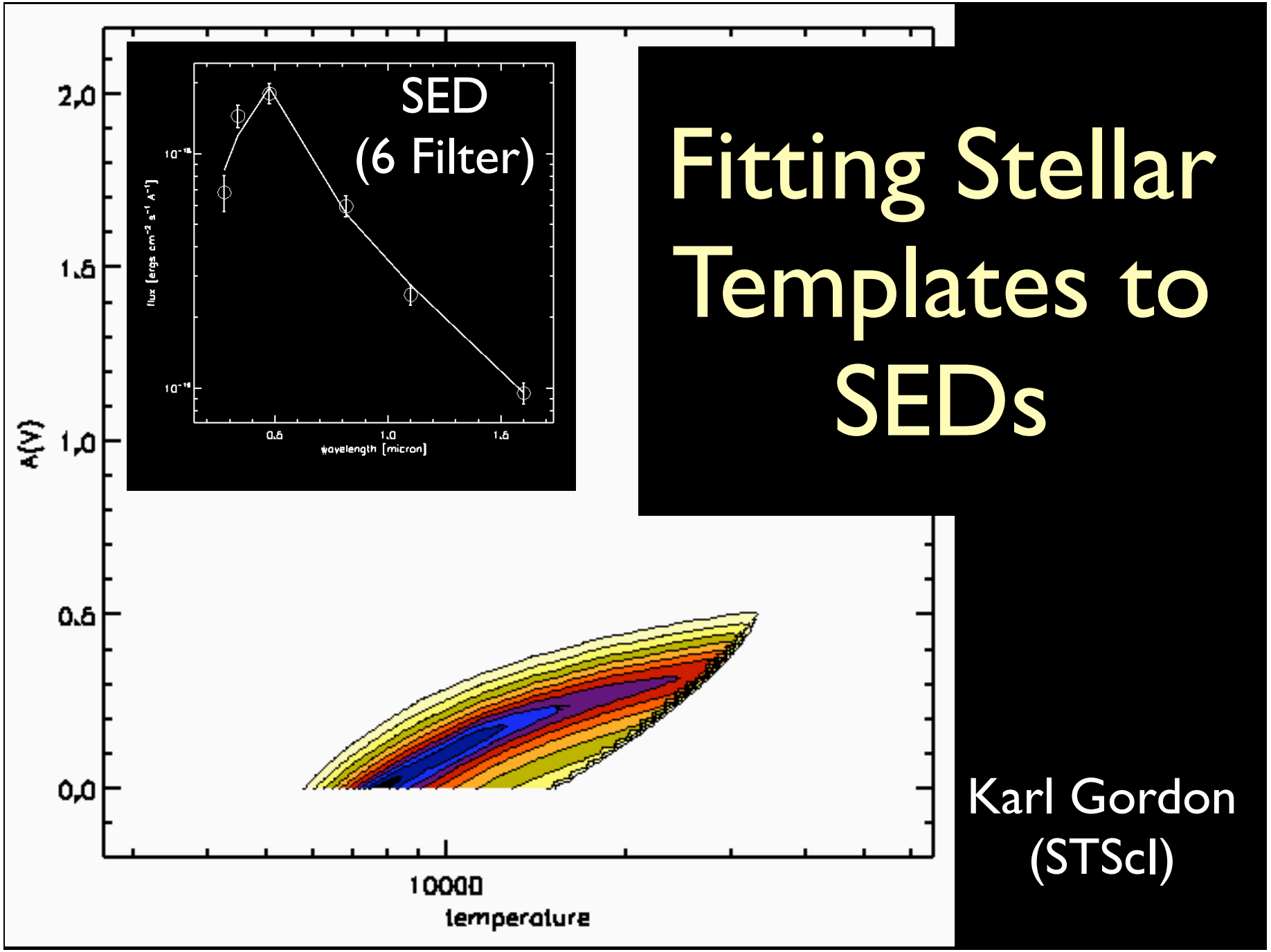
10pc radius

Jake Simones, UMinn


GALEX
Hα
10pc radius
Jake Simones, UMinn
>50M⊙
F275W
M_F275W
(F275W - F336W)
19
20
21
22
23
24
25
26
27
−5
−4
−3
−2
−1
0
1
2

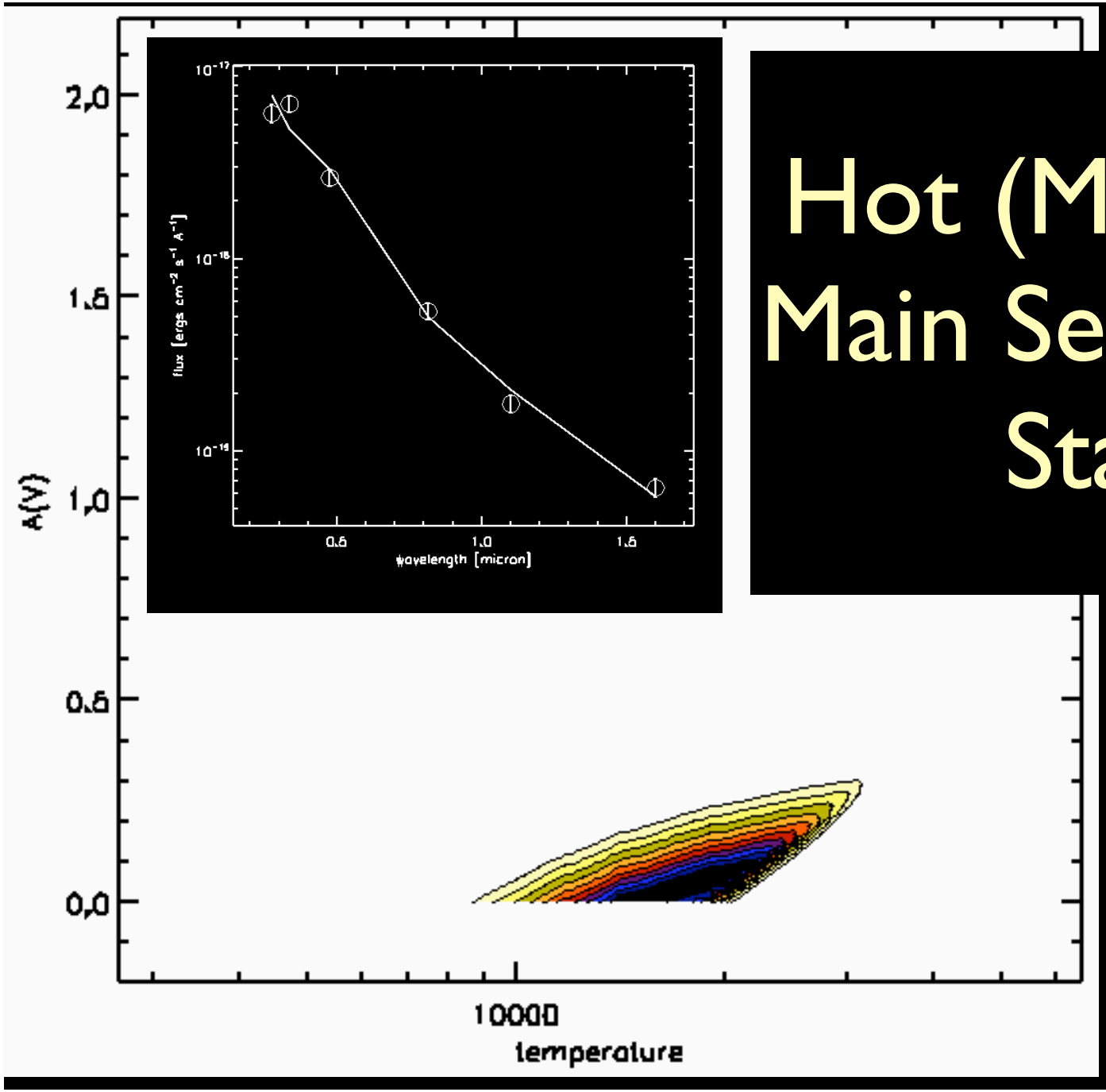

GALEX
Hα


GALEX
Hα
10pc radius
(10Myr at 1km/s)
Jake Simones, UMinn
>15-20M⊙
F814W
M_F814W
(F475W - F814W)
14
16
18
20
22
24
26
28
−10
−8
−6
−4
−2
0
2
−2
−1
0
1
2
3
4
5
6



Fitting Stellar Templates to SEDs

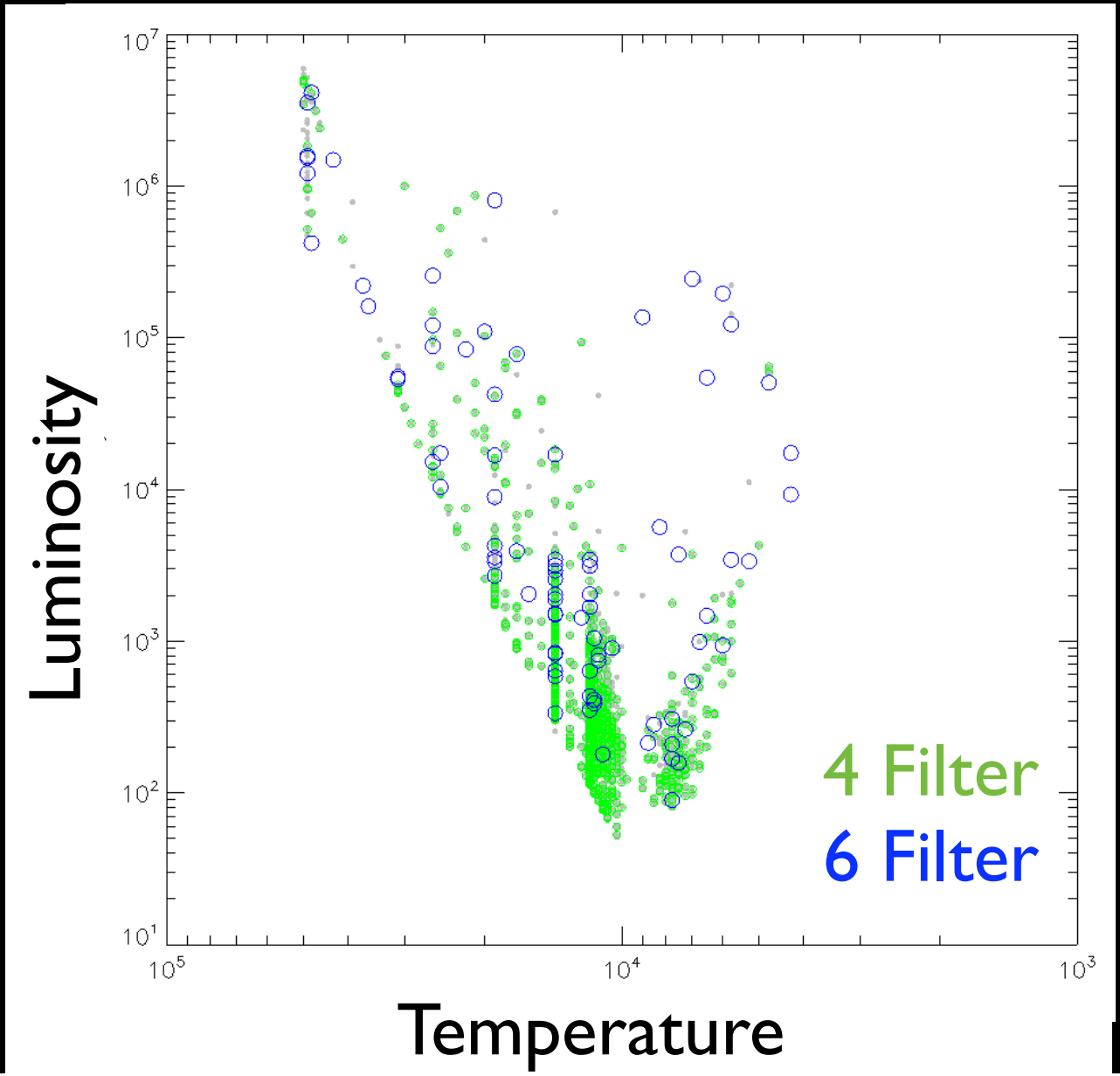
Karl Gordon
(STScI)



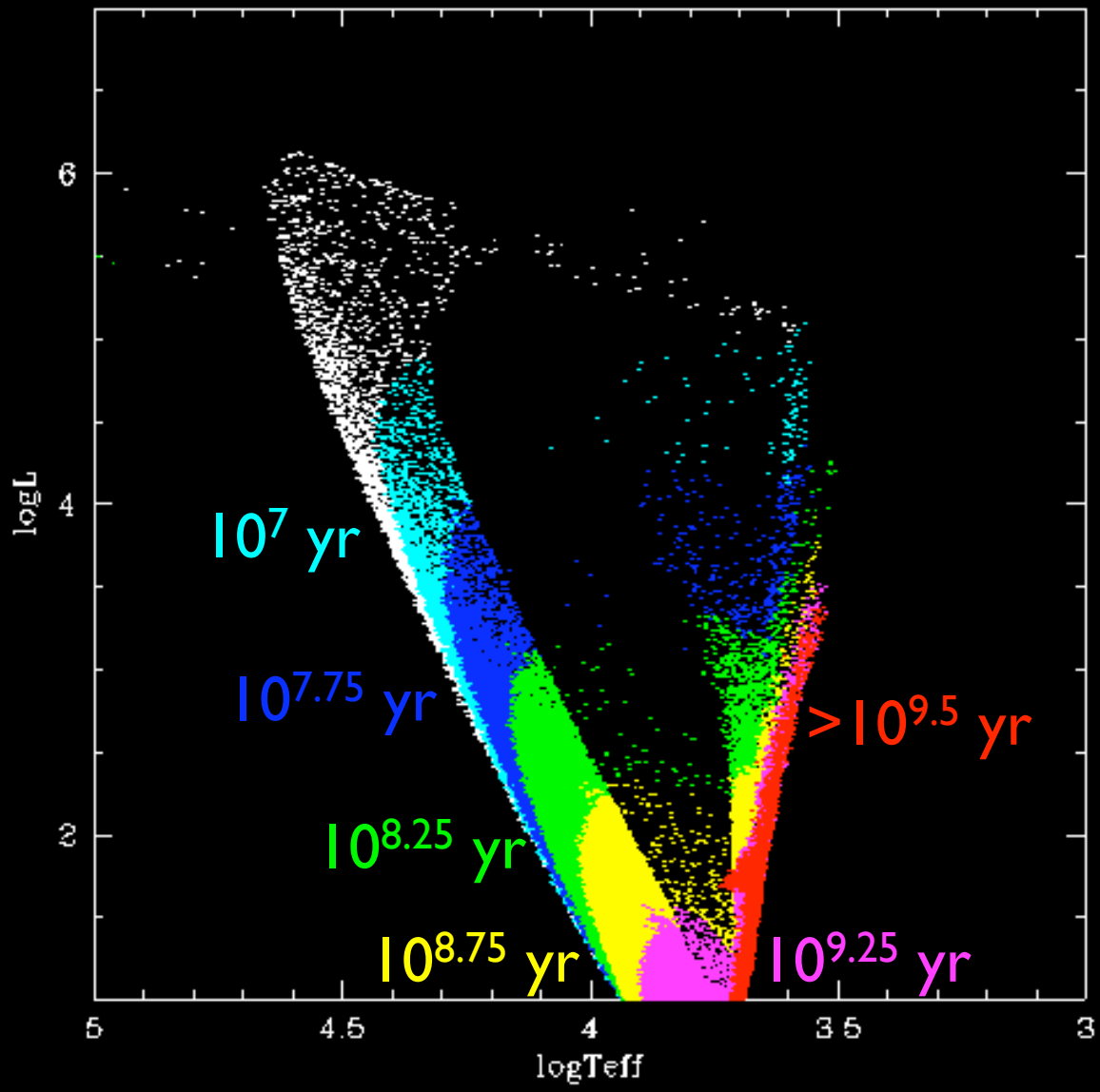
Hot (Massive) Main Sequence Star

Karl Gordon
(STScI)

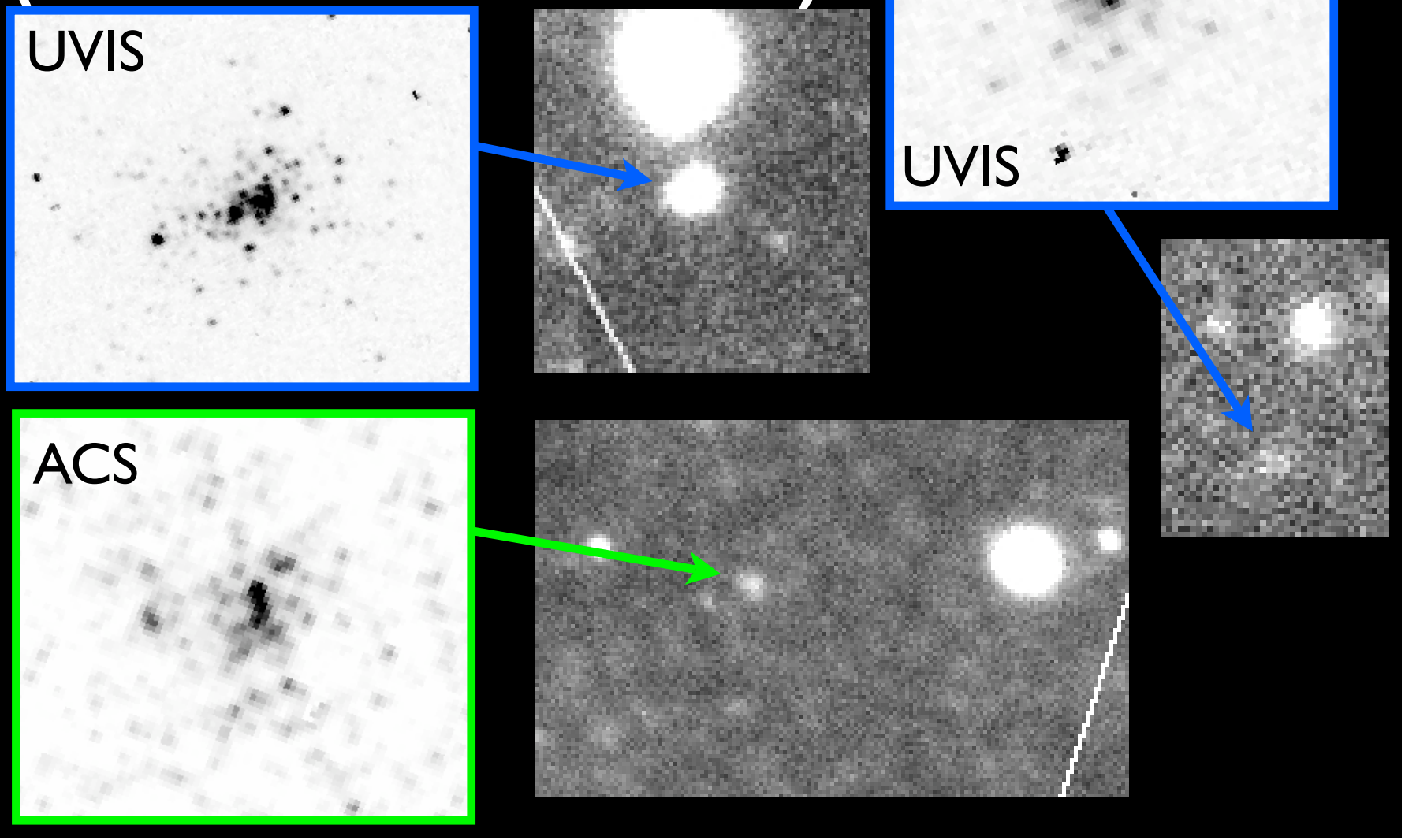
Multi-filter SED Fitting



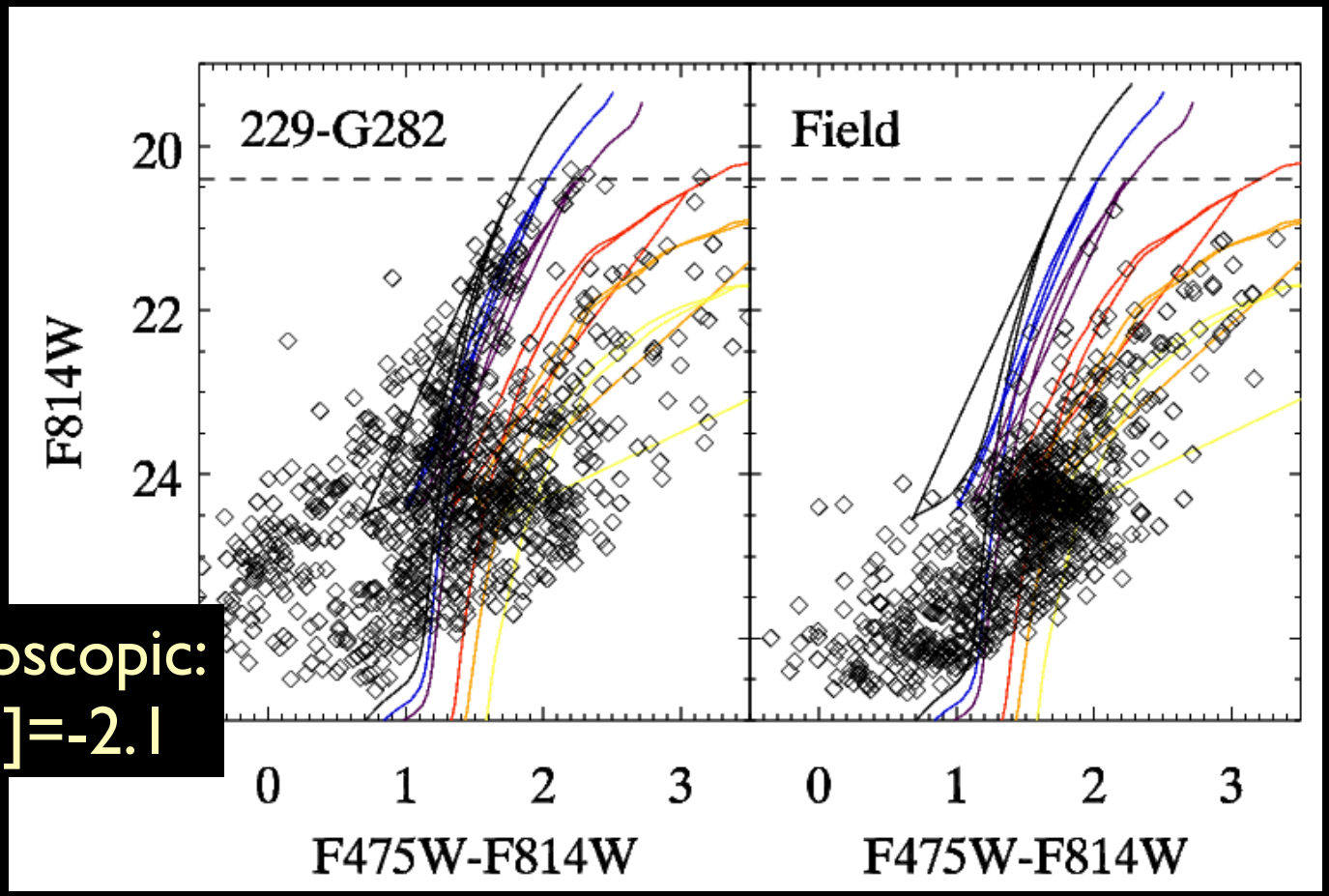
Models: Leo Girardi



Young Clusters (HST vs Ground)



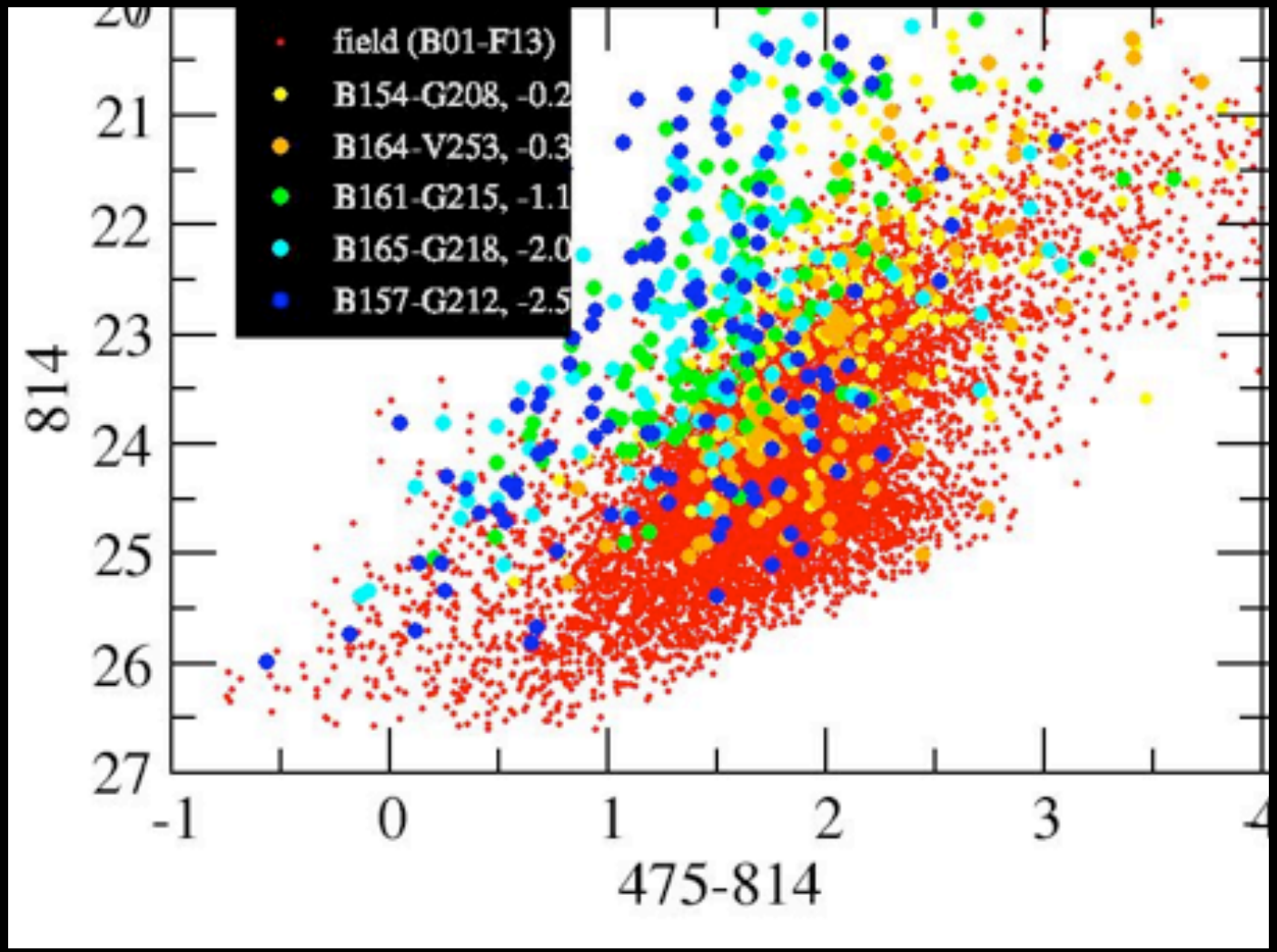
Old Stellar Clusters



Spectroscopic:
[Fe/H]=-2.1

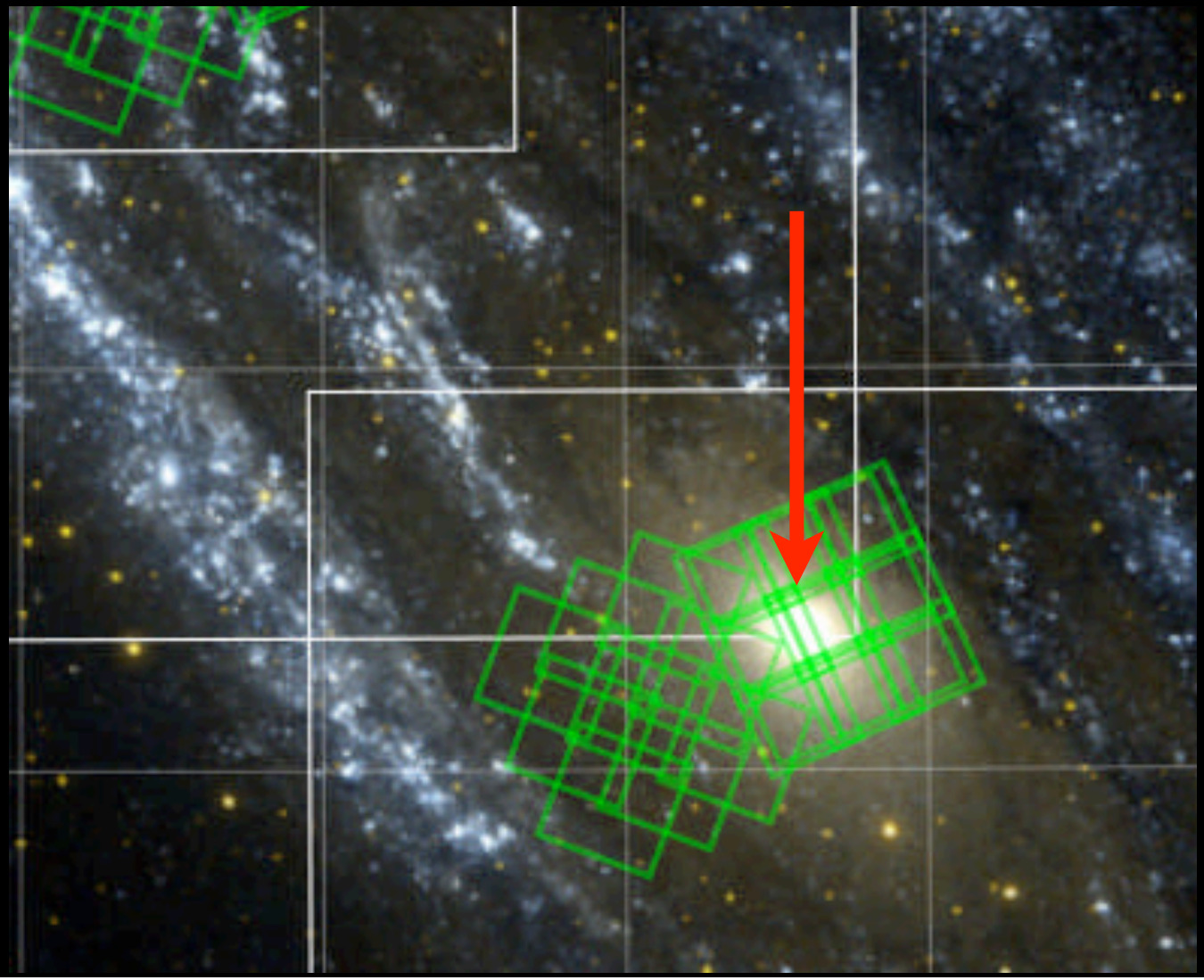
10 Gyr Isochrones
[Fe/H]=-2.3, -1.7, -1.3, -0.7, -0.4

Old Stellar Clusters



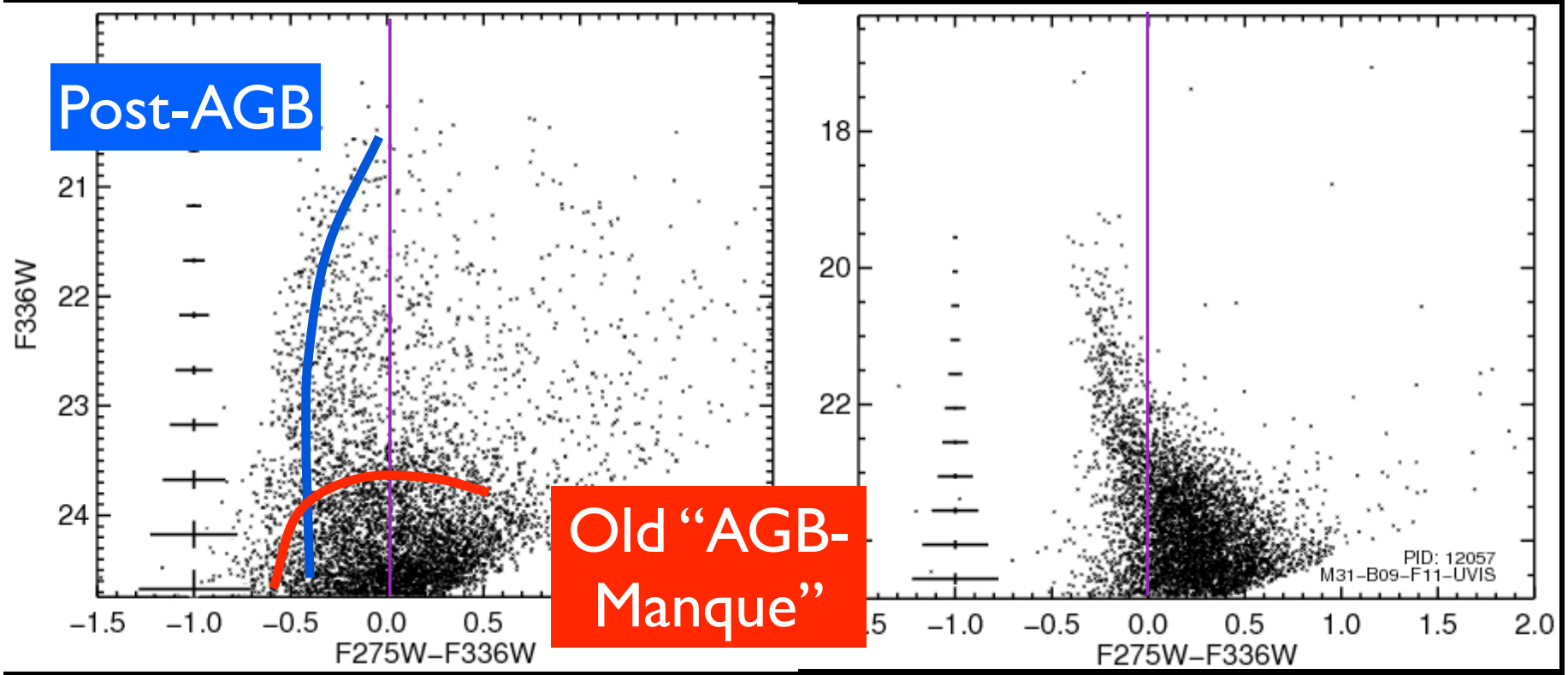
Brick 9

M31 Bulge: IR + UV



M31 Bulge: IR + UV

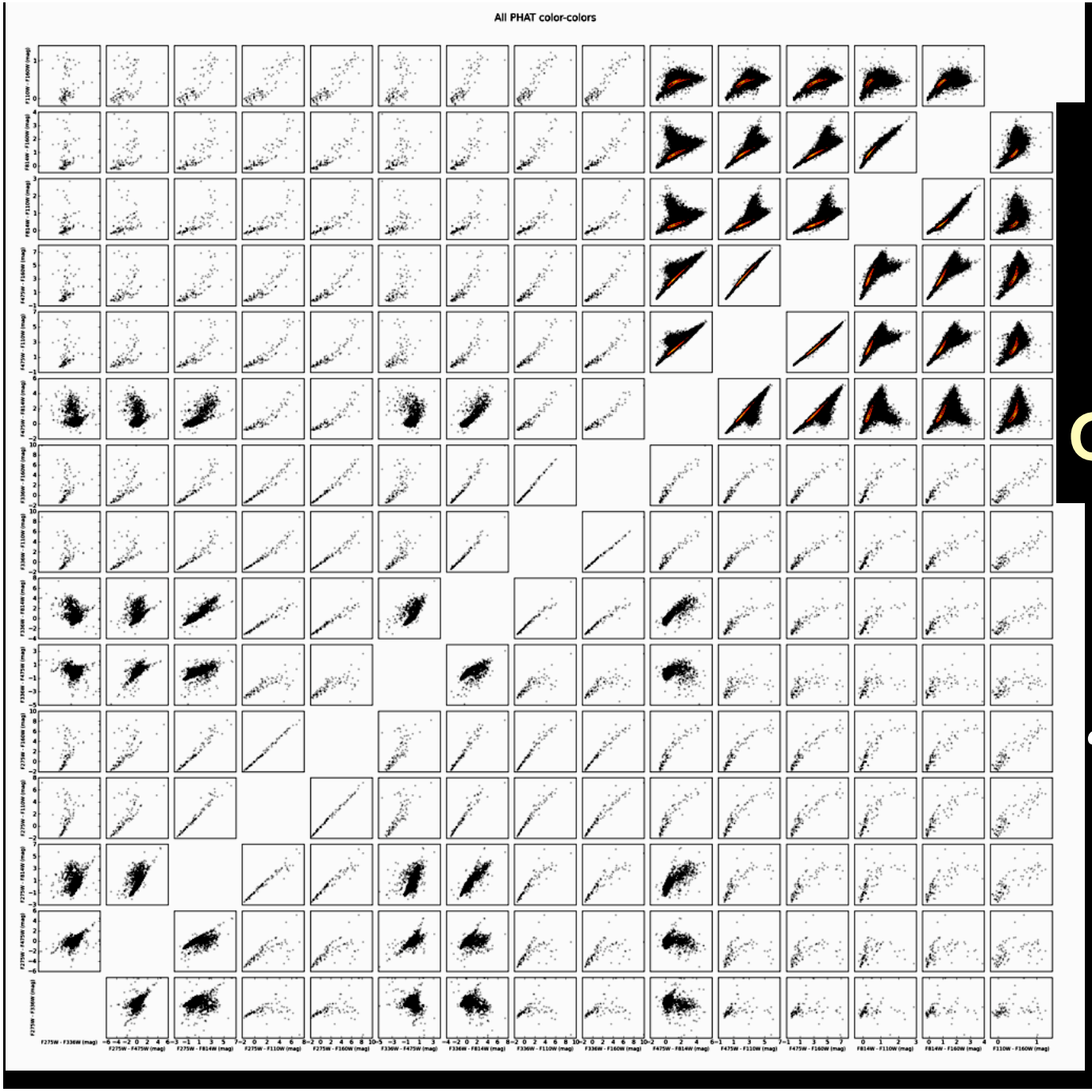
UV Bulge Stars != MS Stars



Bulge Center

Brick 9

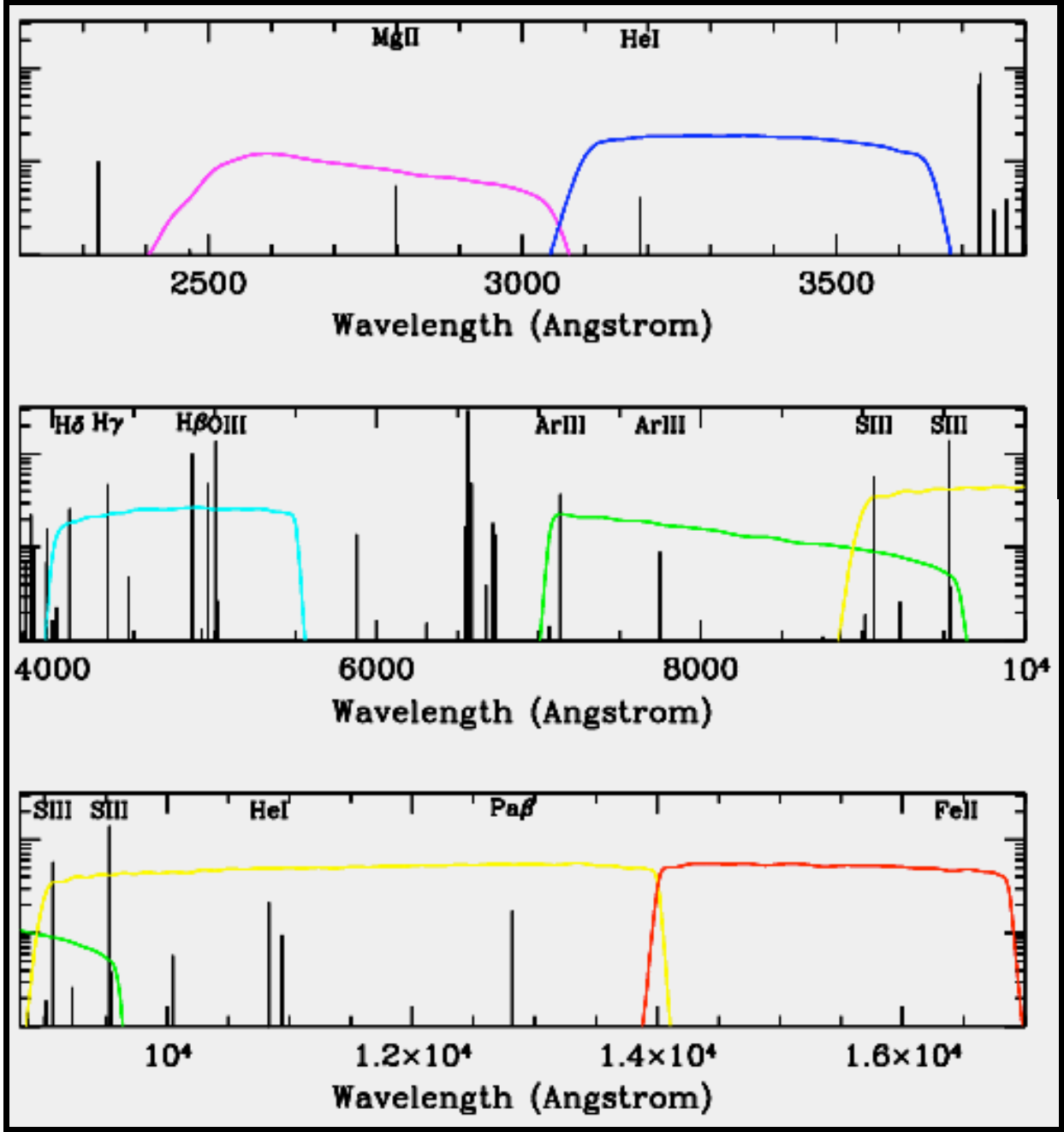
Leo Girardi, Anil Seth, Phil Rosenfield, Nelson Caldwell



Color-color diagrams

From overlapping "teeth" with 6-filter coverage

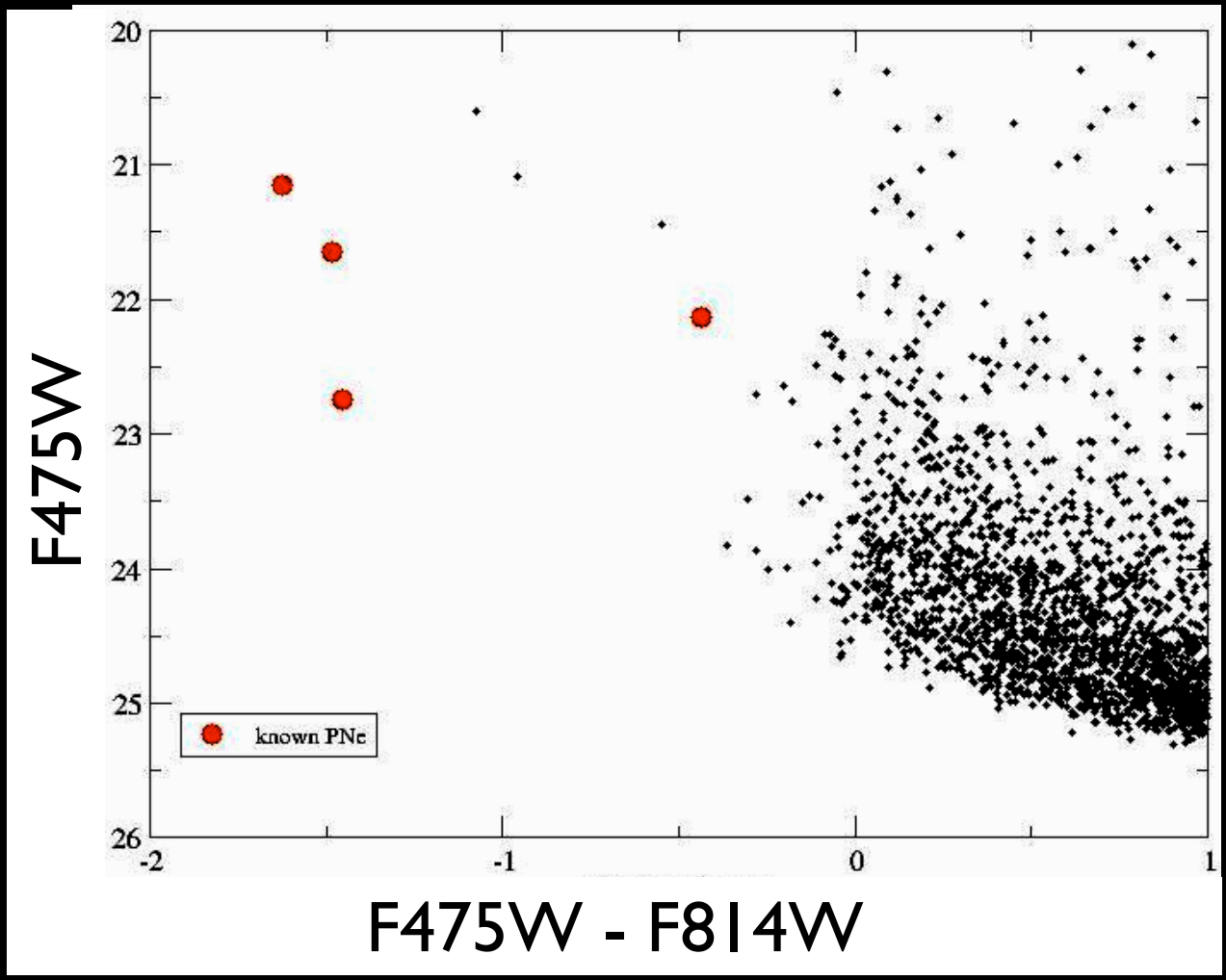
Dustin Lang



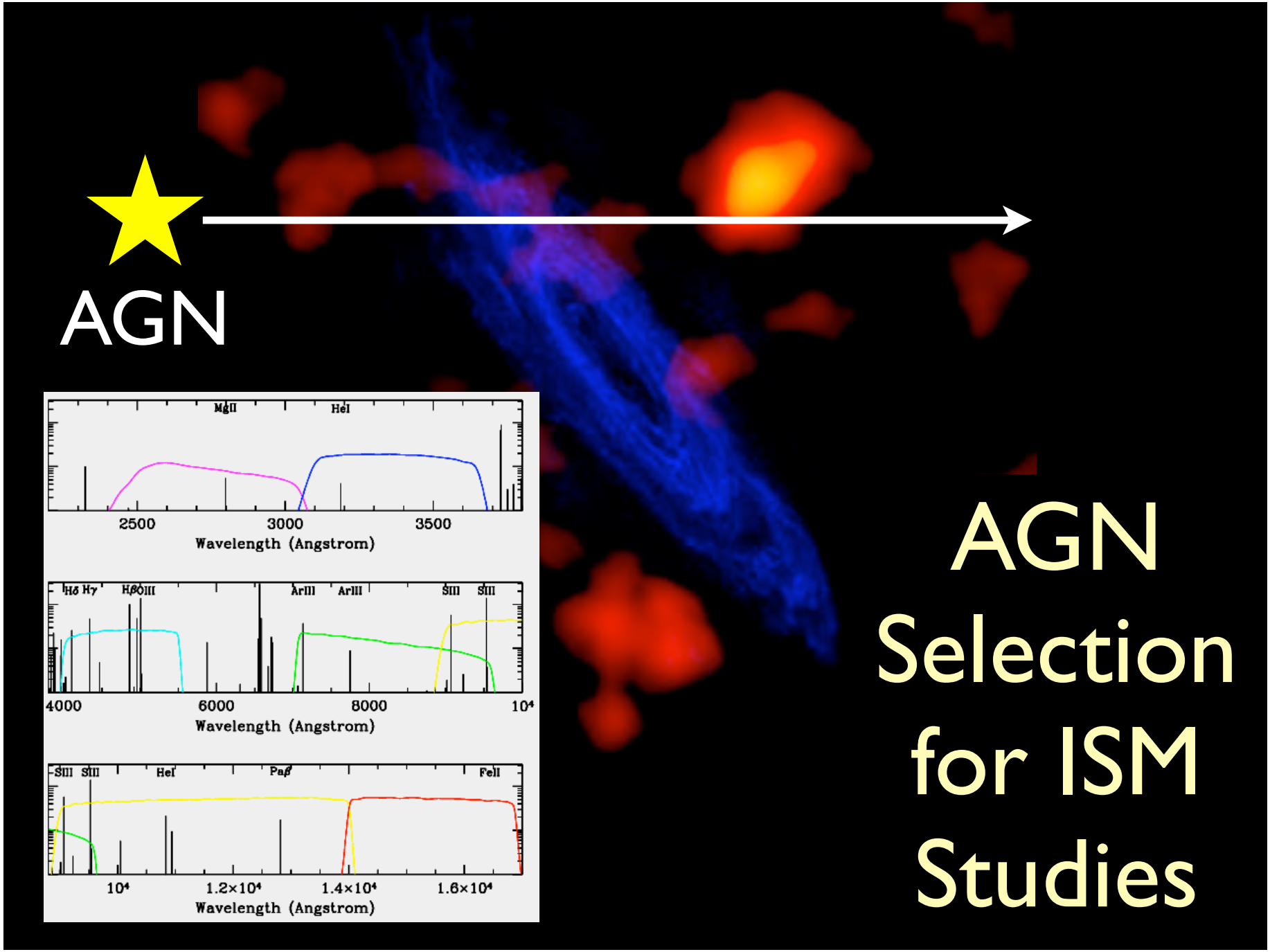
Emission Line Sensitivity

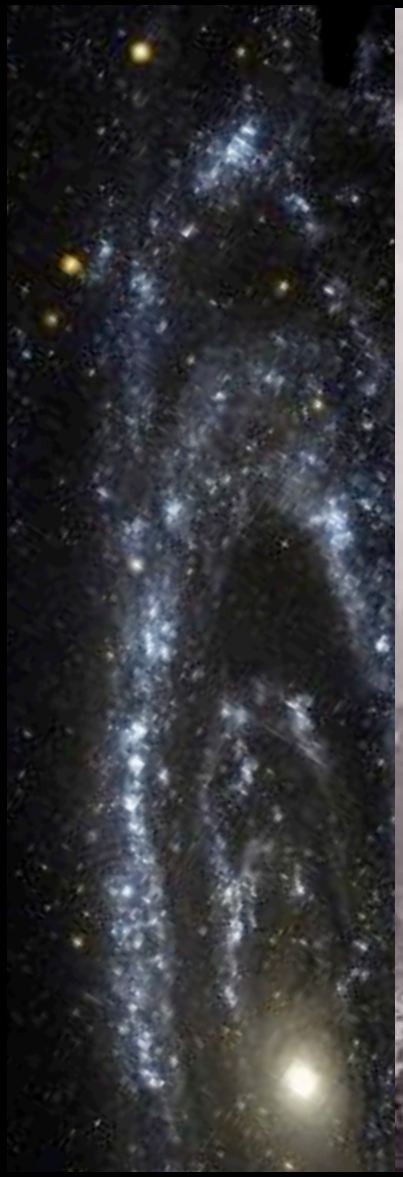
Blue in F475W-F814W, and F110W-F160W

Known Planetary Nebulae



Nelson Caldwell


AGN
MgII
HeI
2500
3000
3500
Wavelength (Angstrom)
Hδ Hγ
HβOIII
ArIII
ArIII
SIII
SIII
4000
6000
8000
10⁴
Wavelength (Angstrom)
SiII SiII
HeI
Paβ
FeII
10⁴
1.2×10⁴
1.4×10⁴
1.6×10⁴
Wavelength (Angstrom)
AGN Selection for ISM Studies



Thanks!

(and please use the data!)