Quantifying HI Morphology

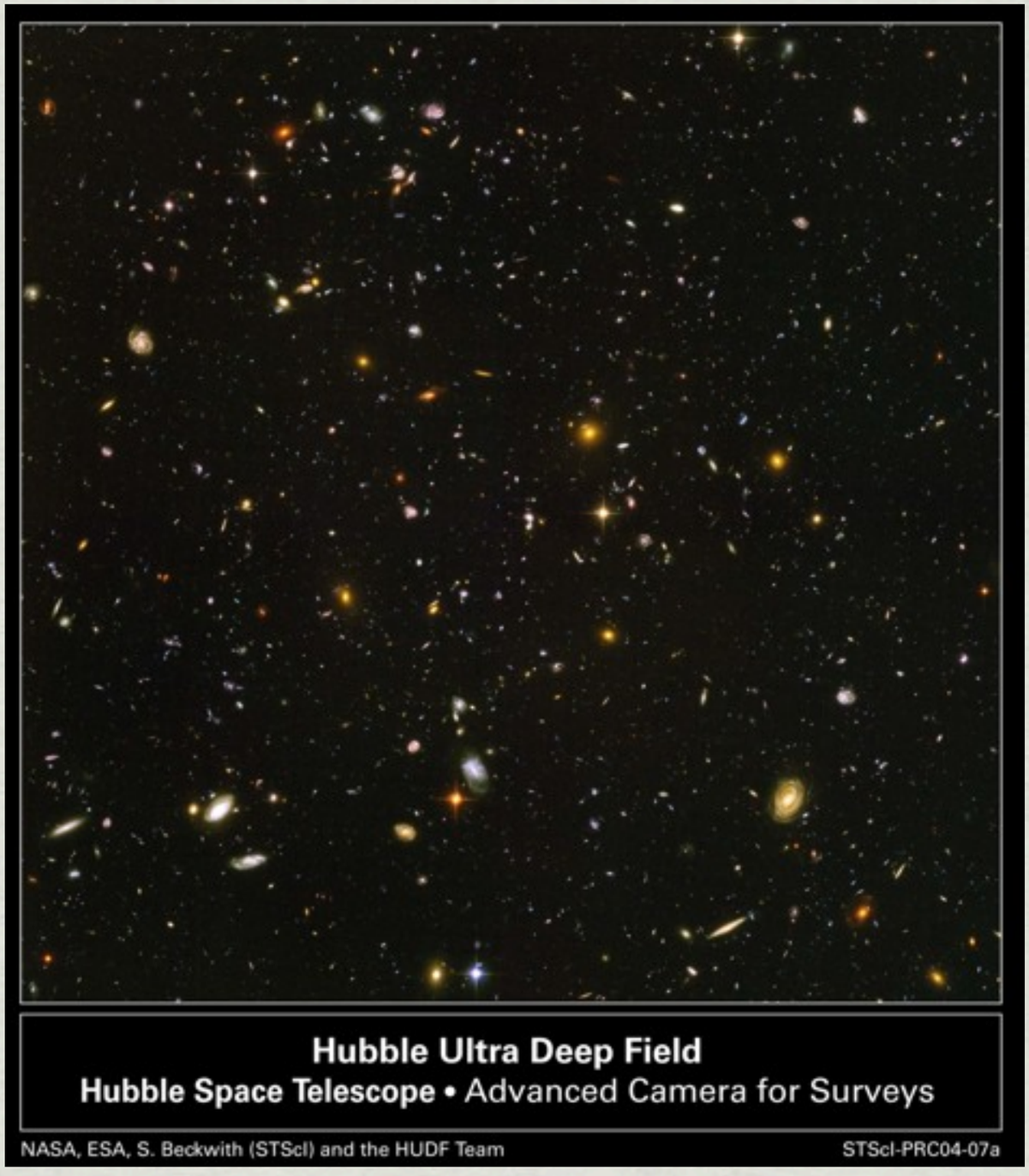
Benne W. Holwerda

N. PIRZKAL, W.J.G DE BLOK, A. BOUCHARD,
S.-L. BLYTH, K. VAN DER HEYDEN, ED ELSON

Motivation

- Interaction is believed to be a driver of galaxy evolution and even small interactions leave a signature in the morphology of galaxy disks.
- To date, the search for signs of interaction to higher redshifts in quantified morphology was in Optical/UV for observational reasons.
- With SKA, MeerKAT and ASKAP millions of galaxies will be well resolved in HI.
- Is there a better signature of interaction in quantified HI morphology?

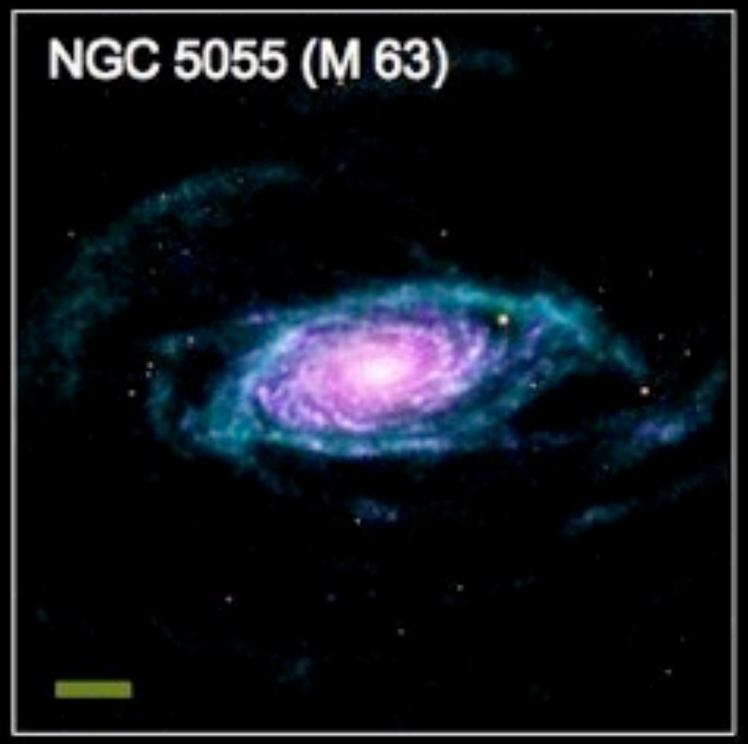
UV Disk Morphology and Interaction



Data

- **T**he **HI** **N**earby **G**alaxy **S**urvey (THINGS): uniform, high-resolution HI maps of nearby galaxies.
- **S**pitzer **I**nfrared **N**earby **G**alaxy **S**urvey (SINGS) infrared data (IRAC and MIPS)
- GALEX's **N**earby **G**alaxy **A**tlas: UV data.
- Optical data from SDSS and/or SINGS ancillary.

Spiral Galaxies in THINGS — The HI Nearby Galaxy Survey



THINGS

The HI Nearby Galaxy Survey

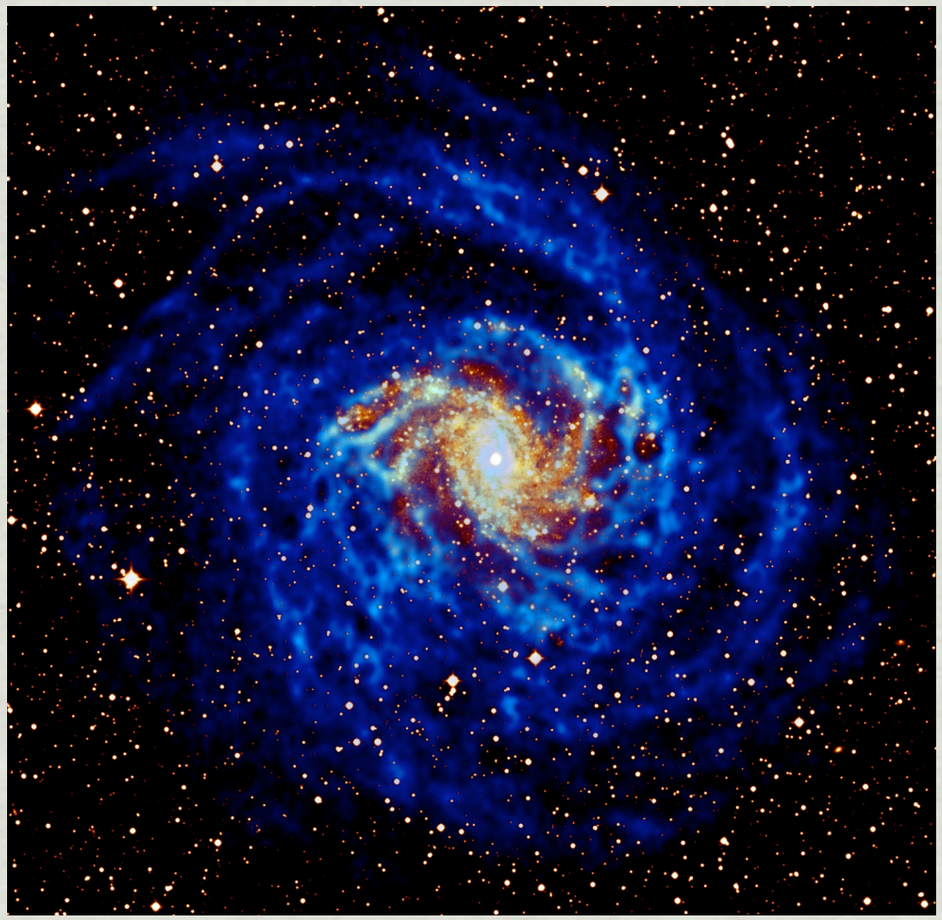
color coding:
THINGS Atomic Hydrogen
(Very Large Array)
Old stars
(Spitzer Space Telescope)
Star Formation
(GALEX & Spitzer)

scale:
15,000 light years

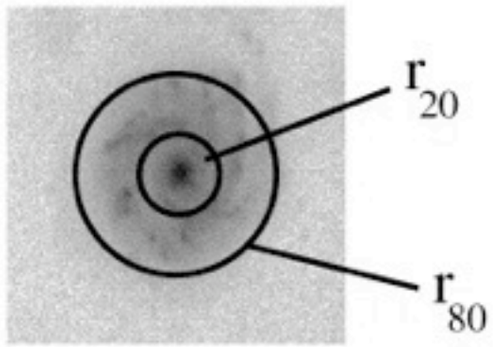
Image credits:
VLA THINGS: Walter et al. 08
Spitzer SINGS: Kennicutt et al. 03
GALEX NGS: Gil de Paz et al. 07

Parameters

- Quantified morphology schemes use a set of scale-invariant parameters:
  - Concentration (**C**)
  - Asymmetry (**A**)
  - Smoothnes (**S**)
  - Gini (**G**)
  - Second order moment of light ($\mathbf{M_{20}}$)
  - Ellipticity (**E**)

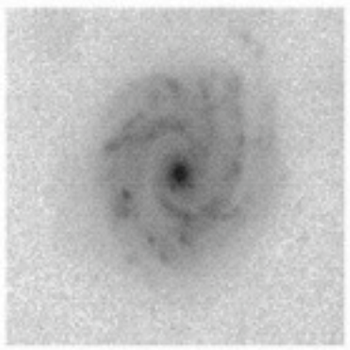


CAS space

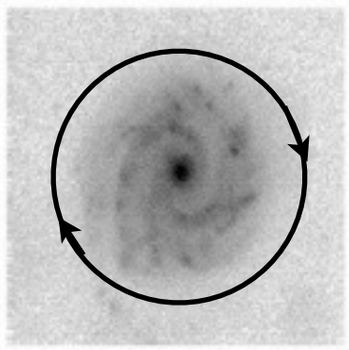


$$C = 5 \log\left(\frac{r_{80}}{r_{20}}\right)$$

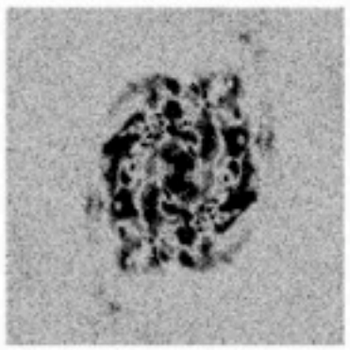
Concentration (**C**)



I



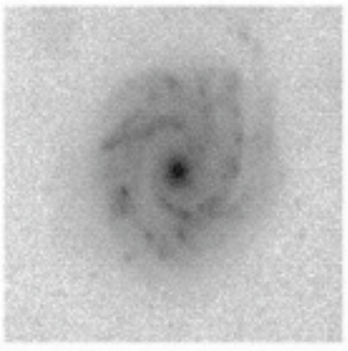
R



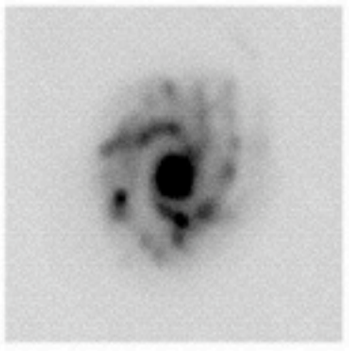
abs(I–R)

$$A = \frac{\text{abs}(I-R)}{I}$$

Asymmetry (**A**)



I



B

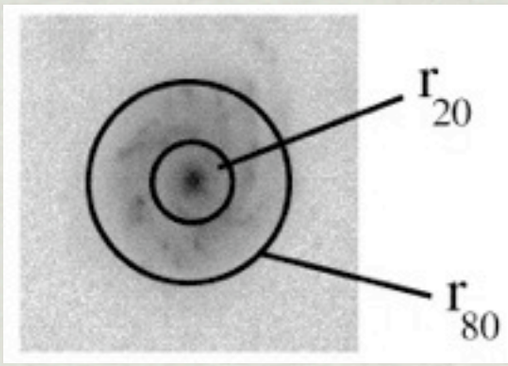
I–B

$$S = \frac{I-B}{I}$$

Smoothness (**S**)

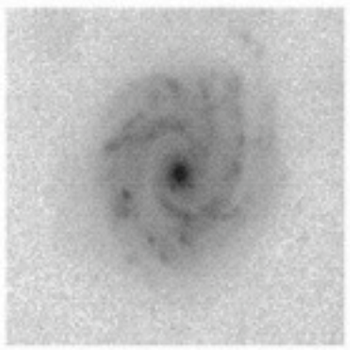
Conselice et al. (2004)

CAS space

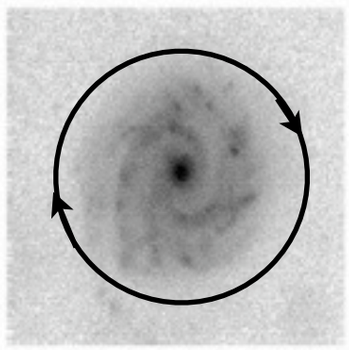


$$C = 5 \log\left(\frac{r_{80}}{r_{20}}\right)$$

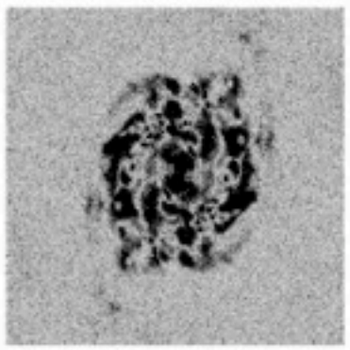
Concentration (**C**)



I



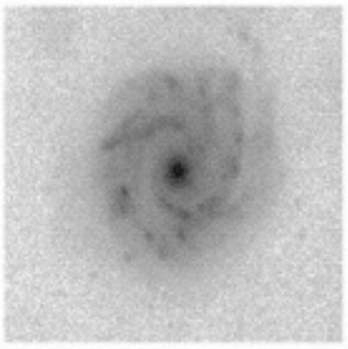
R



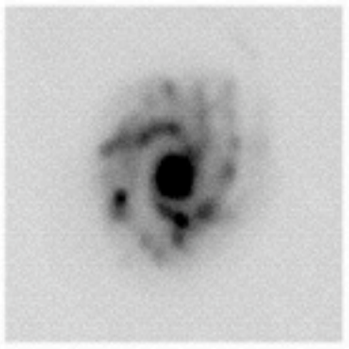
abs(I–R)

$$A = \frac{\text{abs}(I-R)}{I}$$

Asymmetry (**A**)



I



B

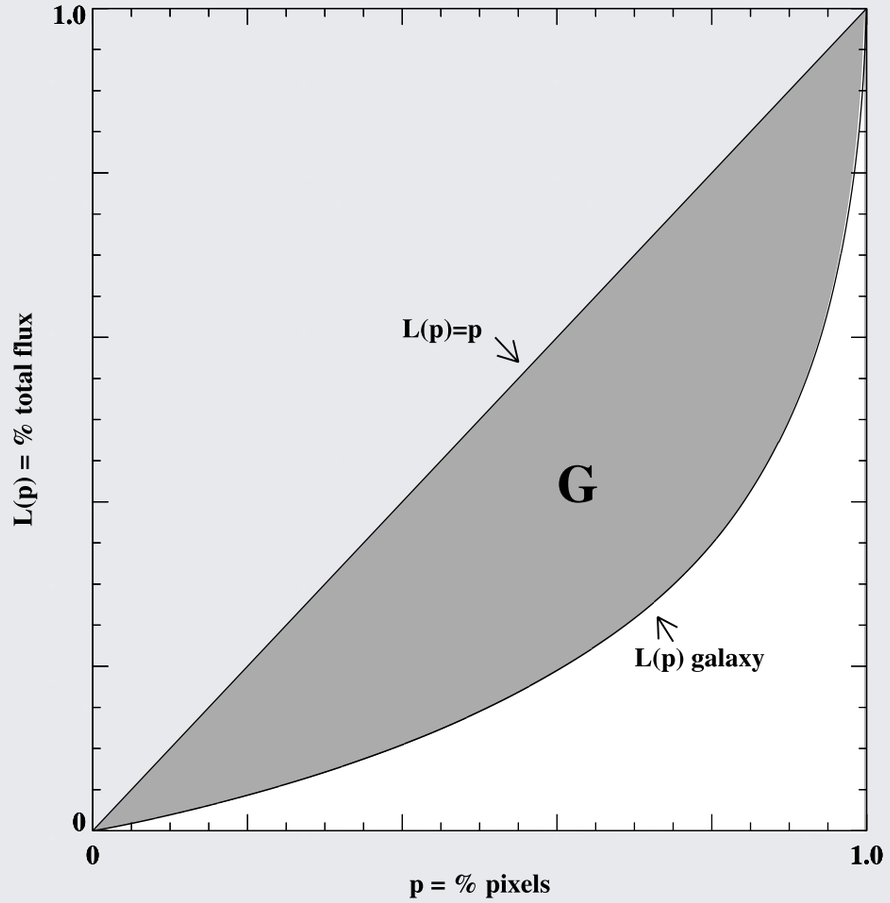
I–B

$$S = \frac{I-B}{I}$$

Smoothness (**S**)

Conselice et al. (2004)

Gini, M_{20} and Ellipticity



$$G = \frac{1}{|\bar{X}|n(n-1)} \sum_{i}^{n} (2i - n - 1)|X_i|. \qquad (6)$$

$$M_{\rm tot} = \sum_{i}^{n} M_i = \sum_{i}^{n} f_i \left[(x_i - x_c)^2 + (y_i - y_c)^2 \right], \qquad (7)$$

$$M_{20} \equiv \log 10 \left(\frac{\sum_i M_i}{M_{\rm tot}} \right), \text{ while } \sum_i f_i < 0.2 f_{\rm tot}. \qquad (8)$$

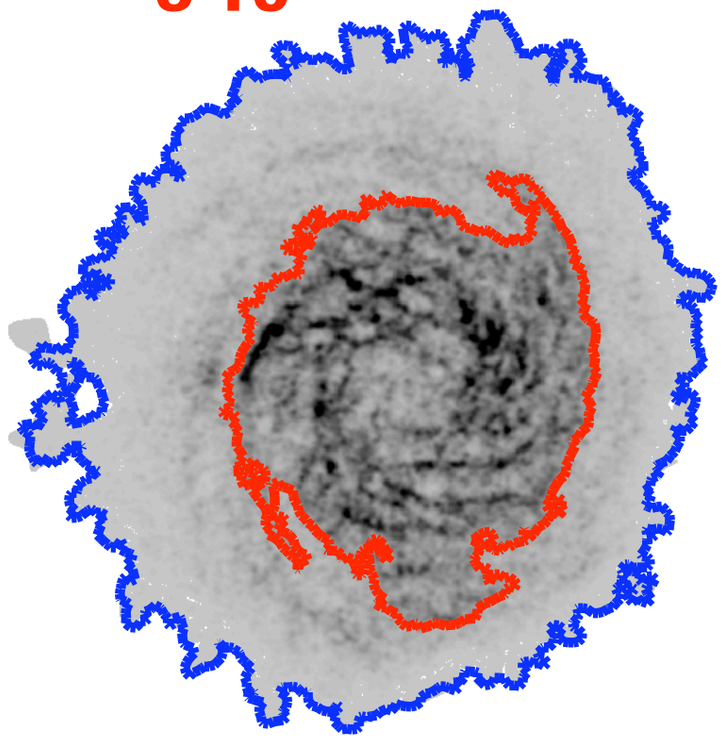
- Lotz et al. (2004):
  - Gini (**G**)
  - Second order moment of light (**M_{20}**)
- Scarlata et al. (2008):
  - Ellipticity (**E**)

A tale of two Galaxies

NGC 3184

HI Disk 10^{19}

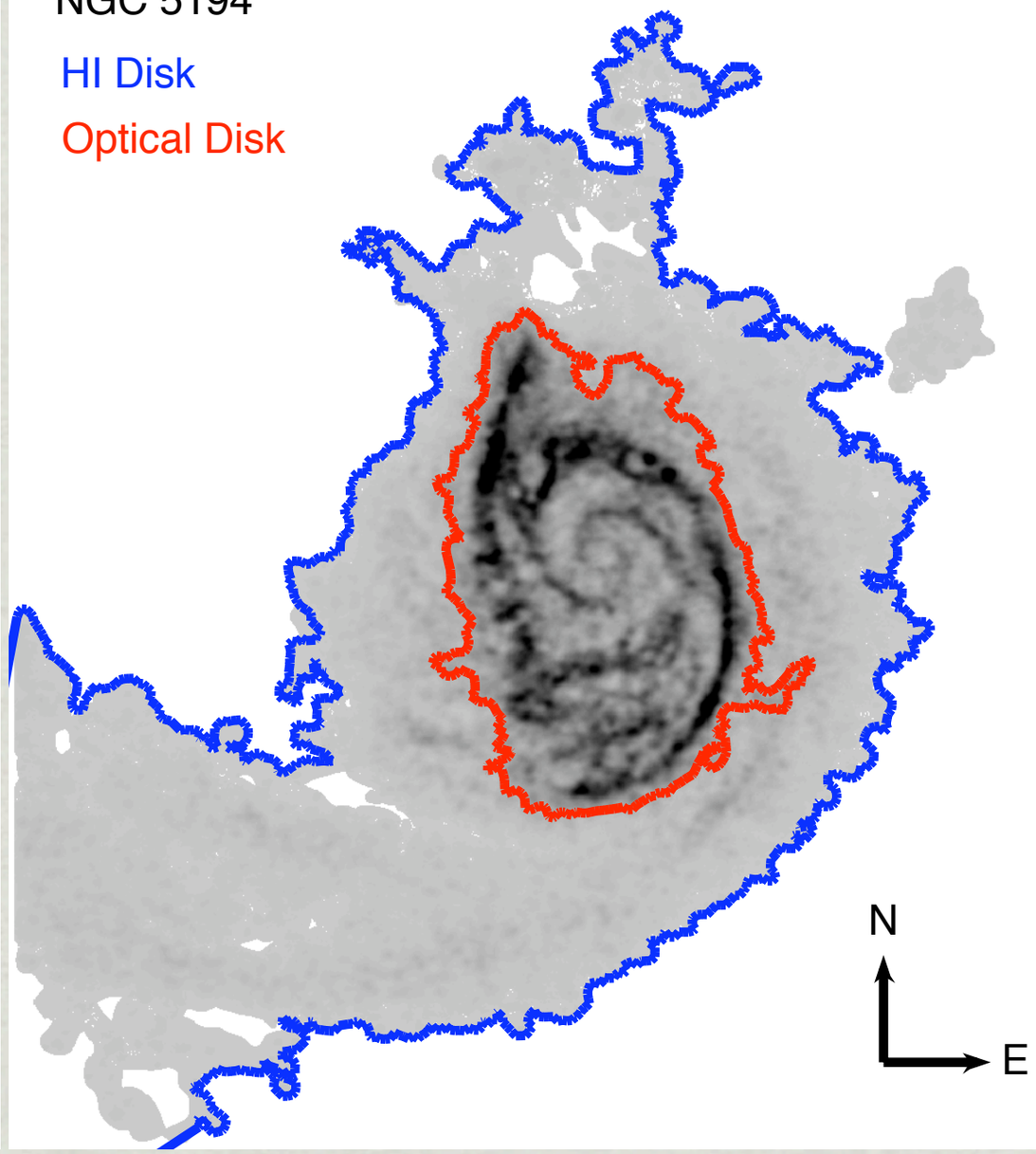
Optical Disk $3\ 10^{20}$



NGC 5194

HI Disk

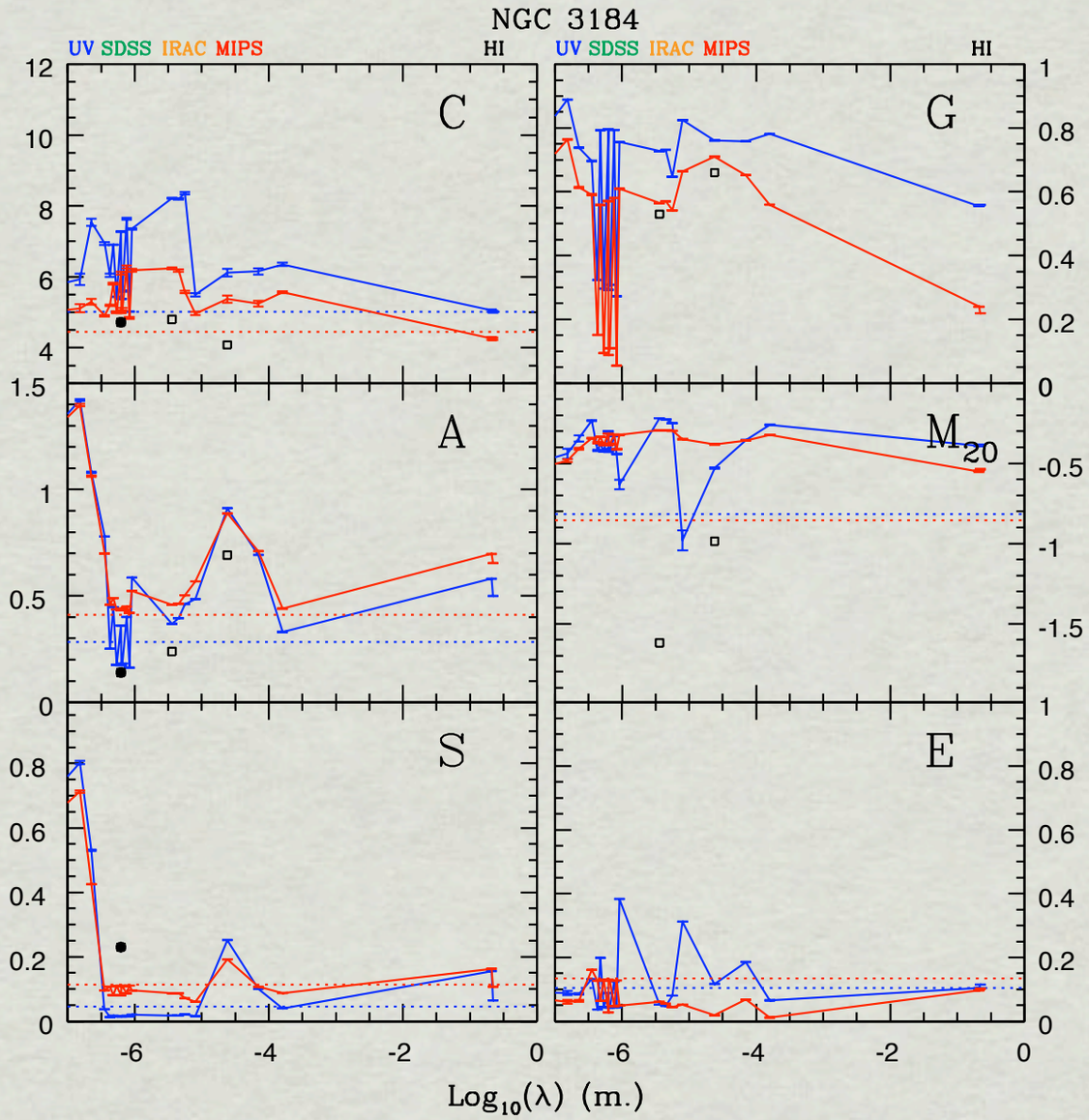
Optical Disk



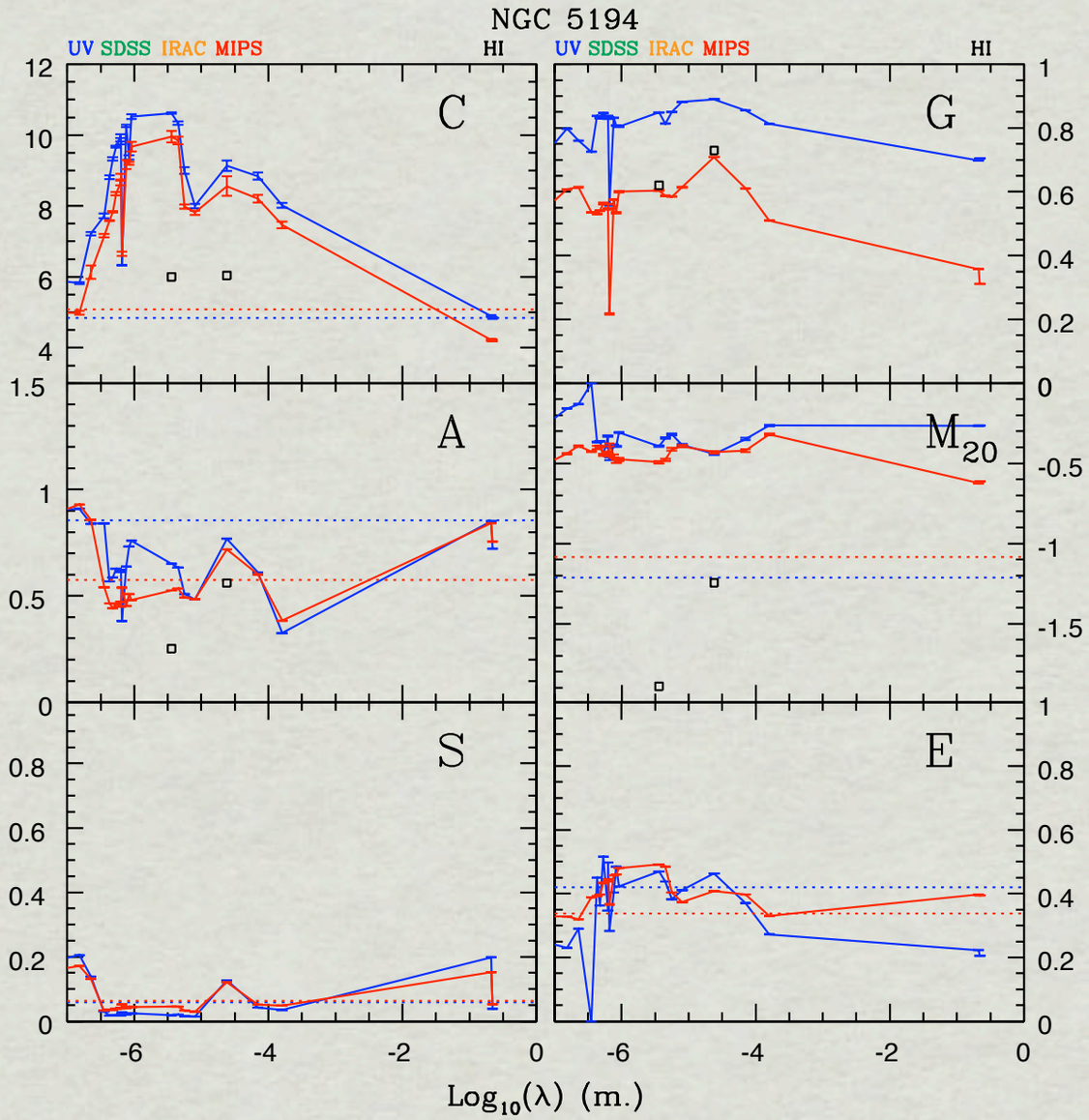
HOLWERDA ET AL. 2010, MNRAS, *IN PREP*

Results

NGC 3184 (ISOLATED)

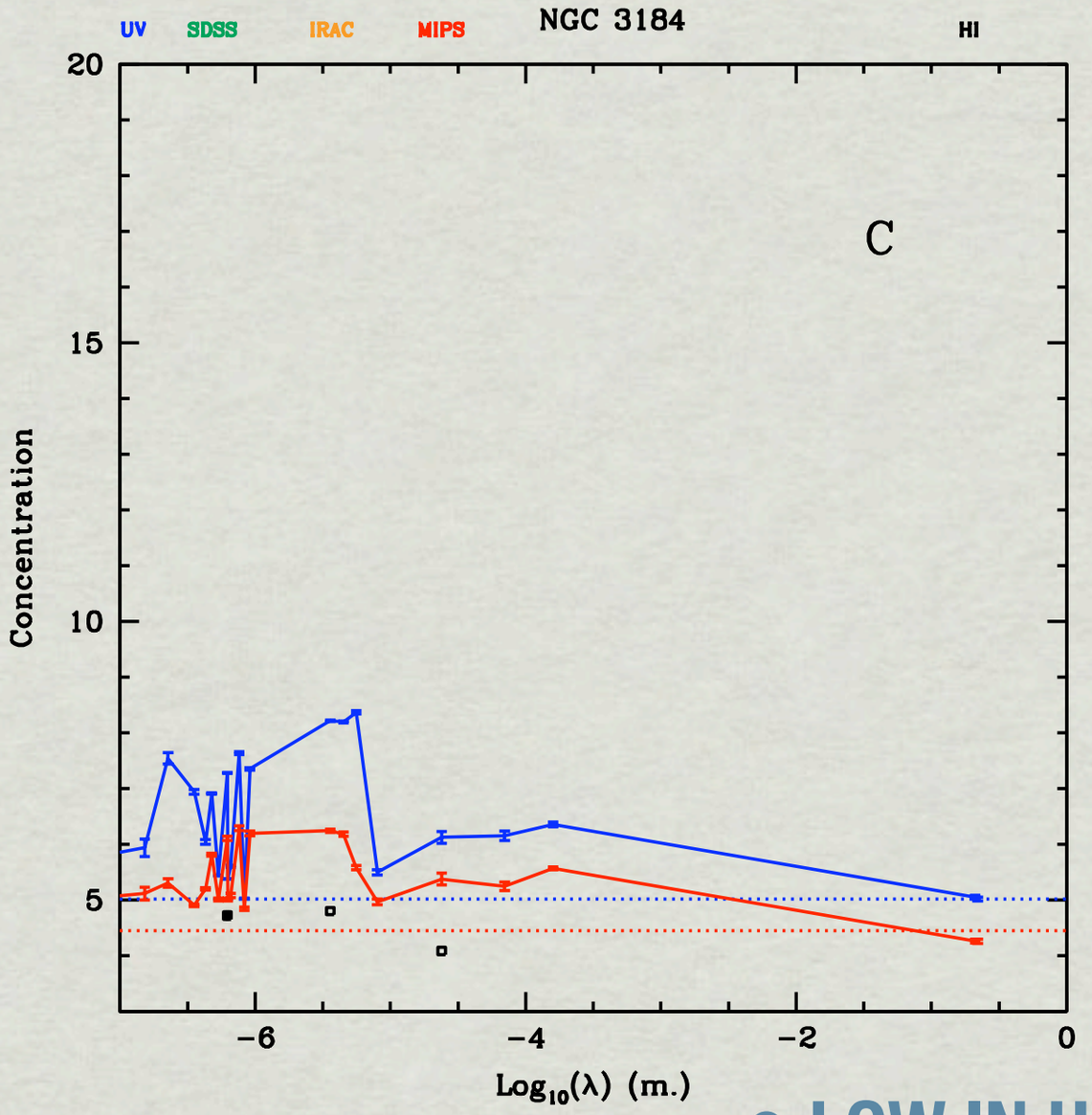


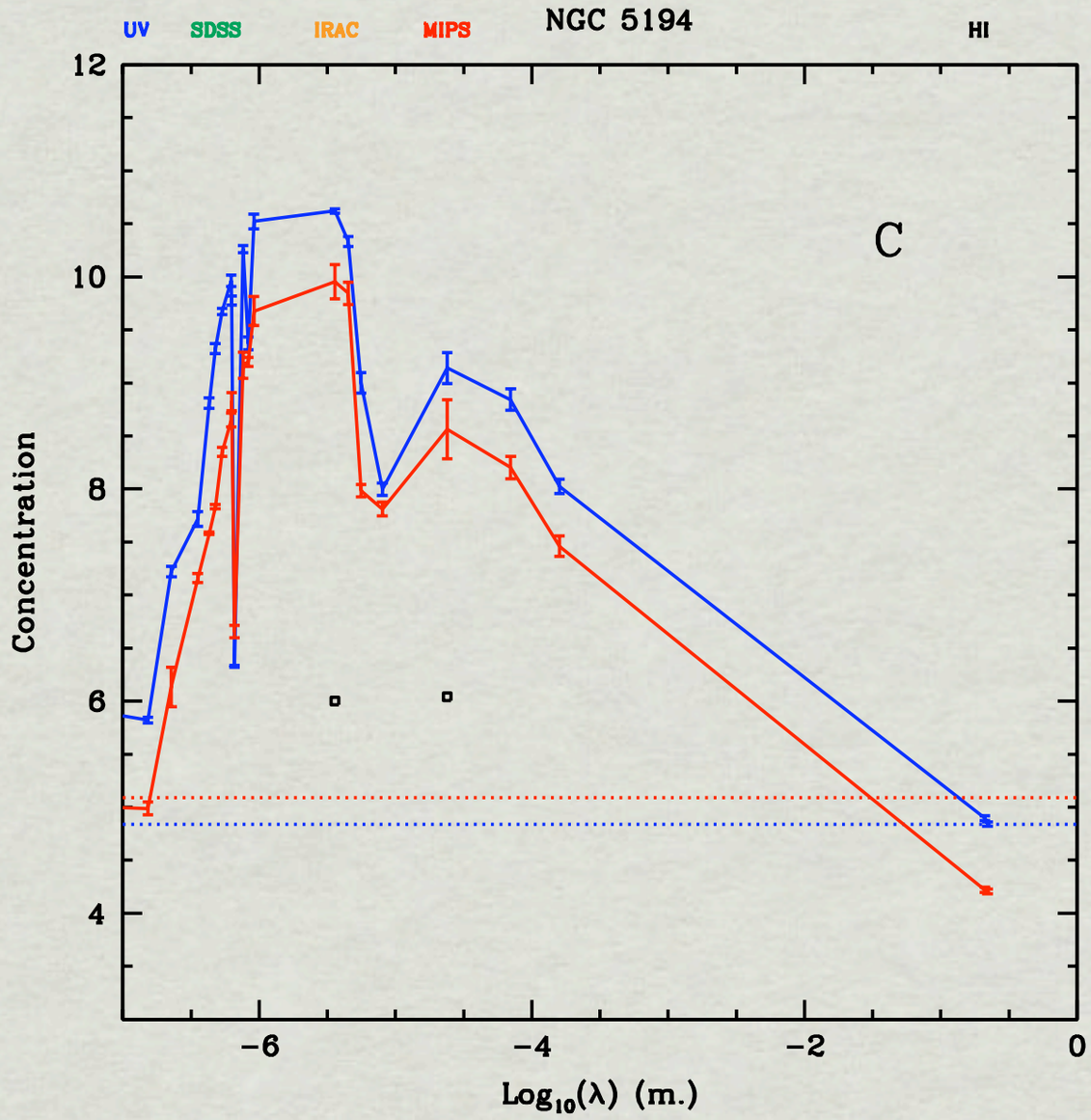
M51 (INTERACTION)



UV → HI

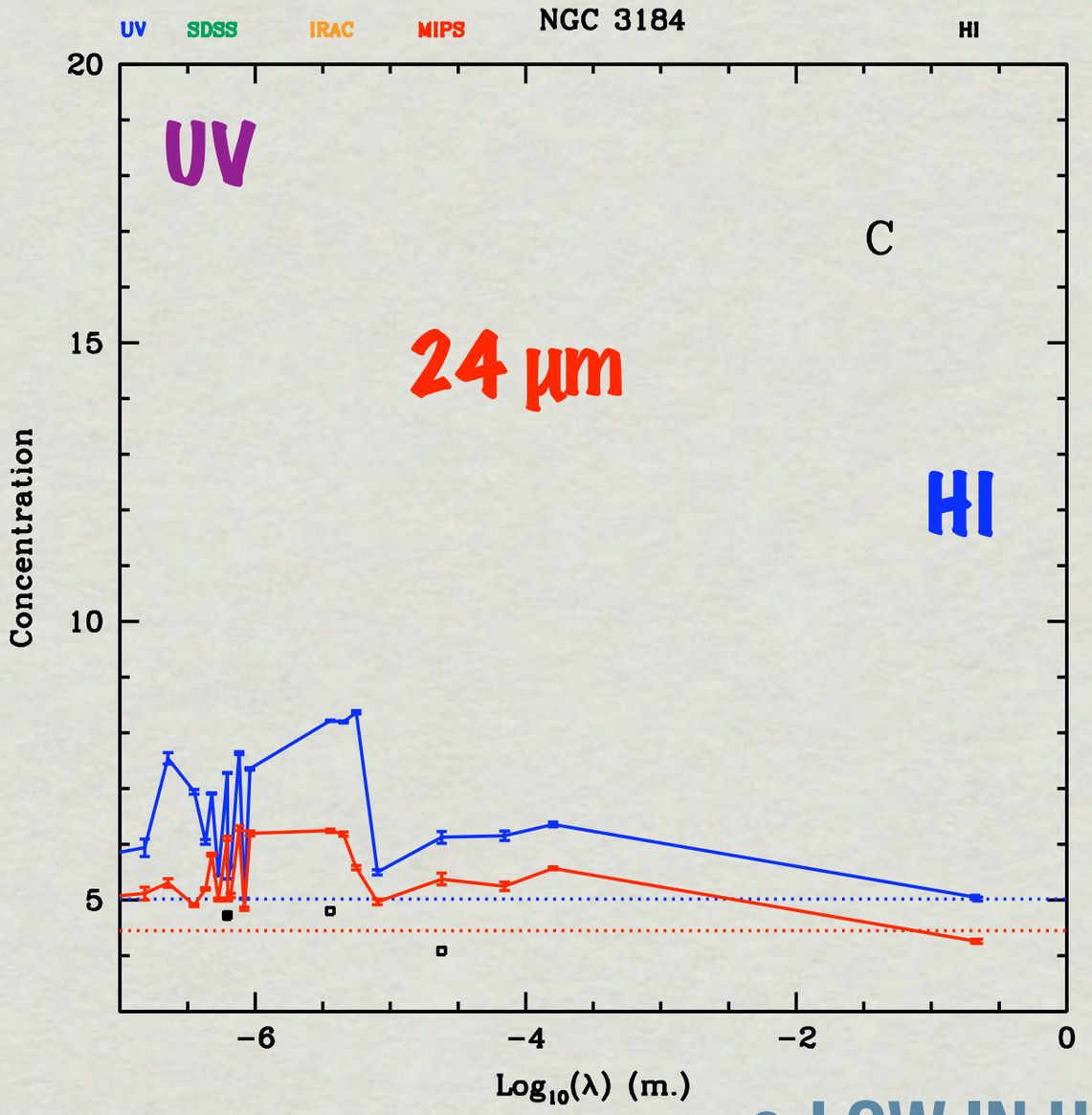
Results: Concentration

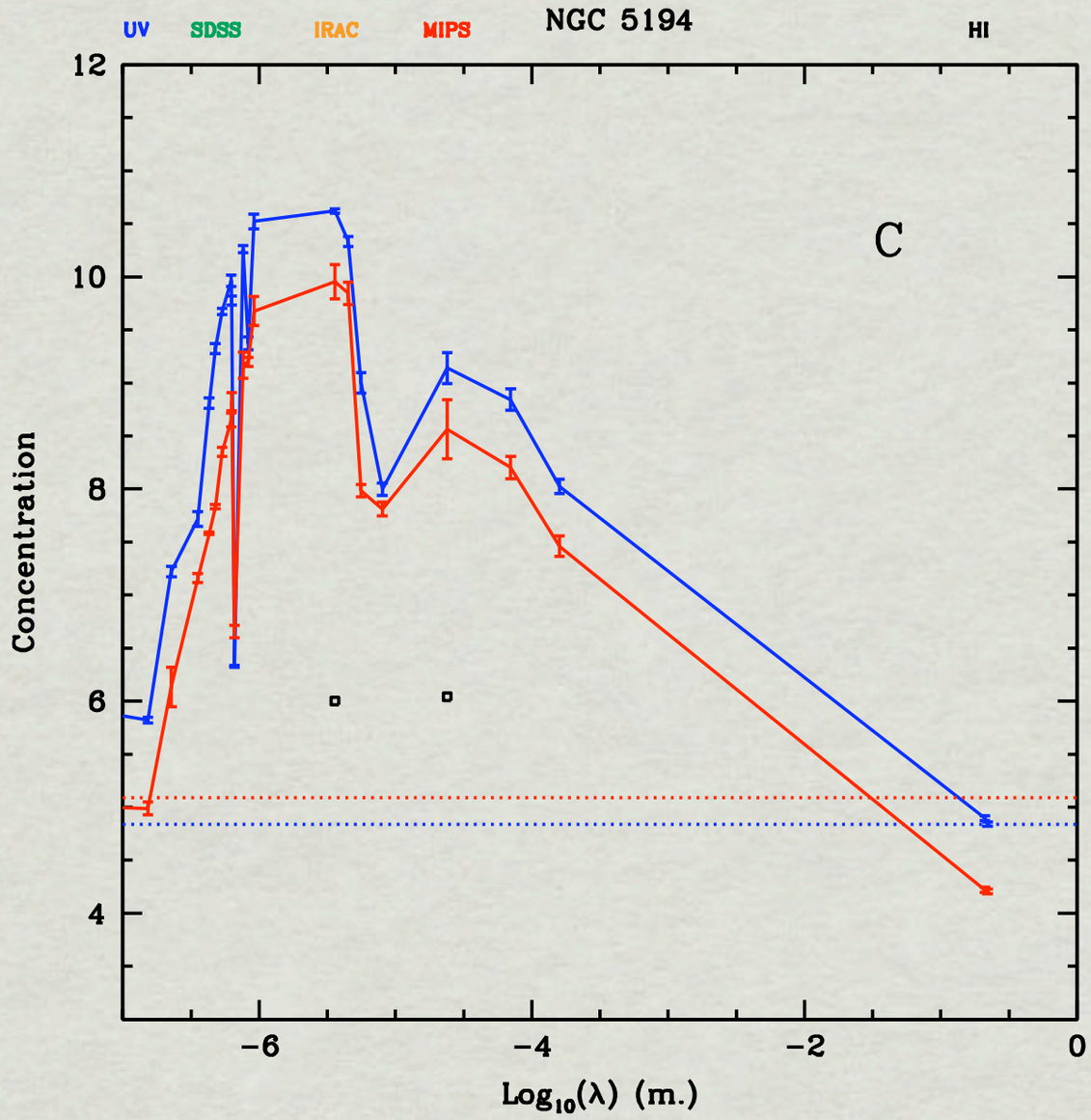




- LOW IN HI
- PEAKS IN OPTICAL WITH INTERACTION

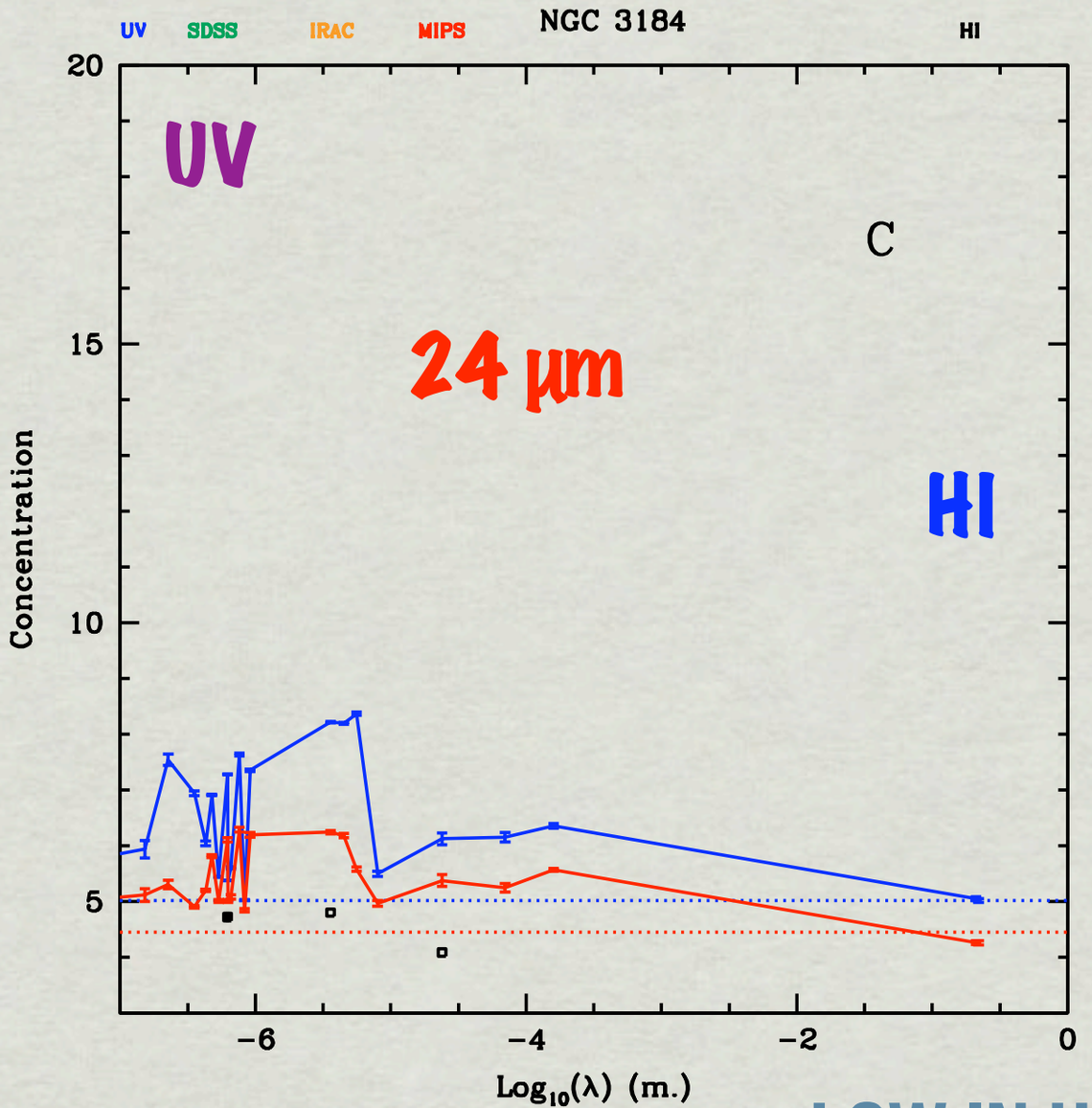
Results: Concentration

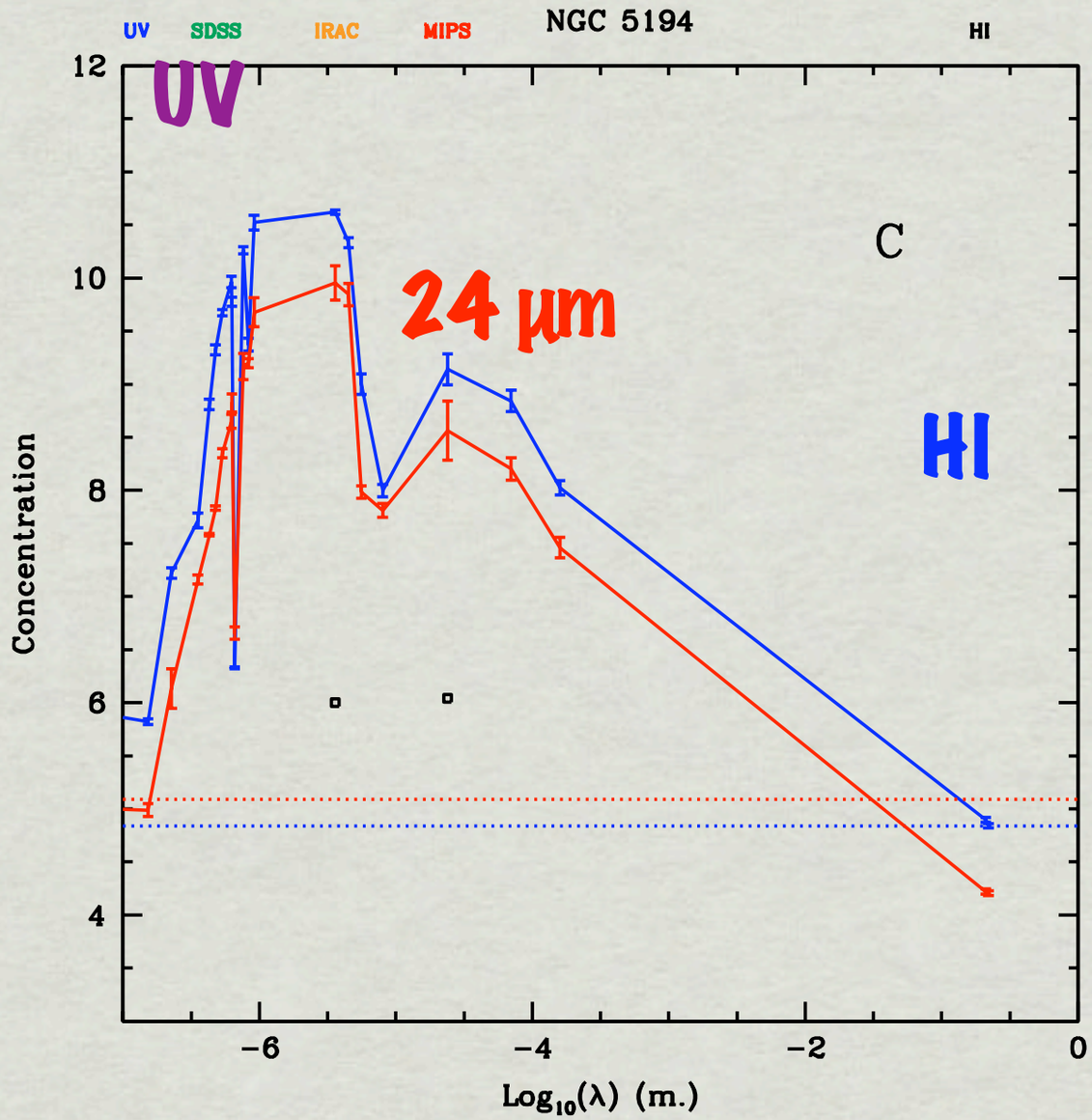




- LOW IN HI
- PEAKS IN OPTICAL WITH INTERACTION

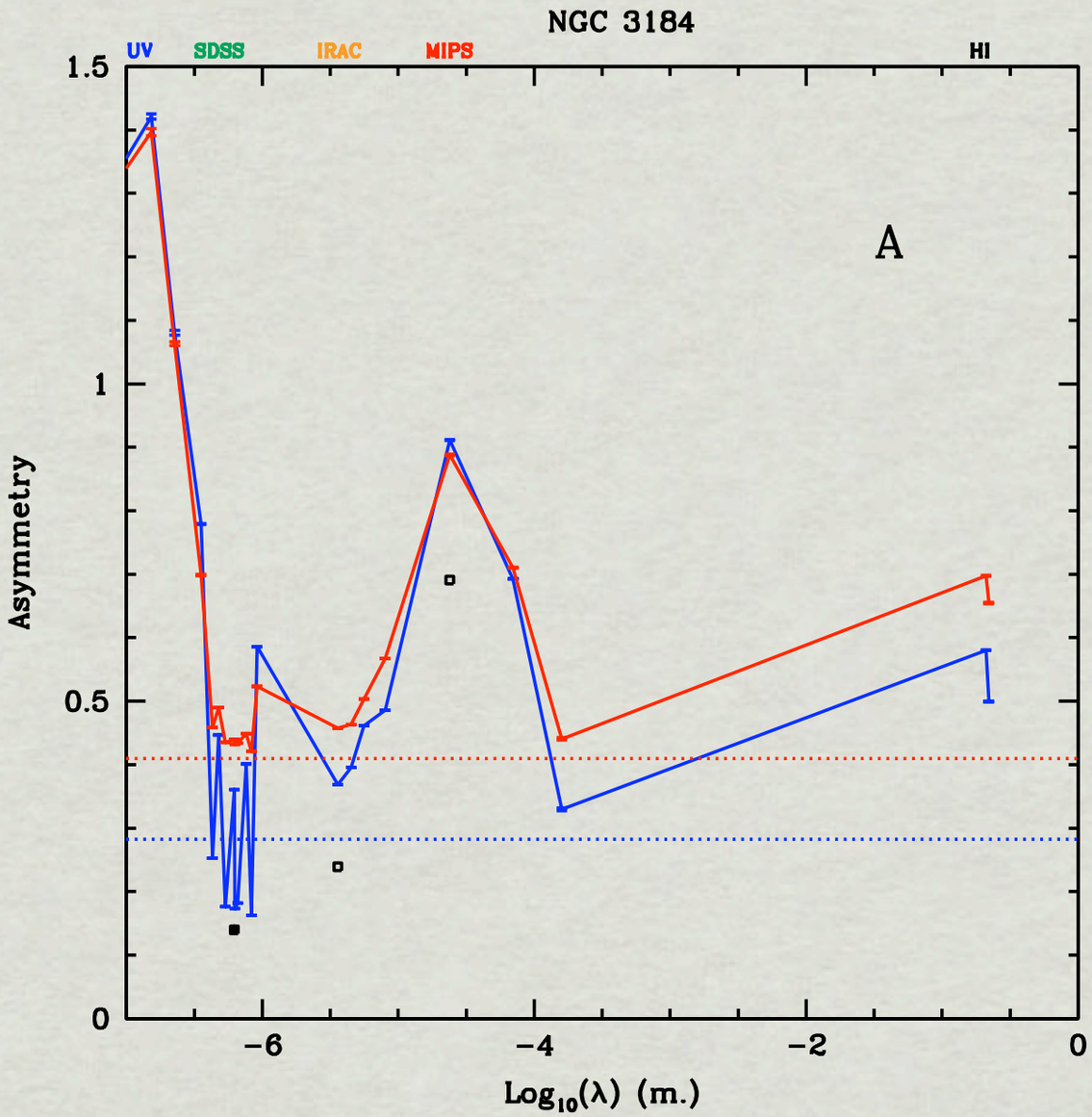
Results: Concentration

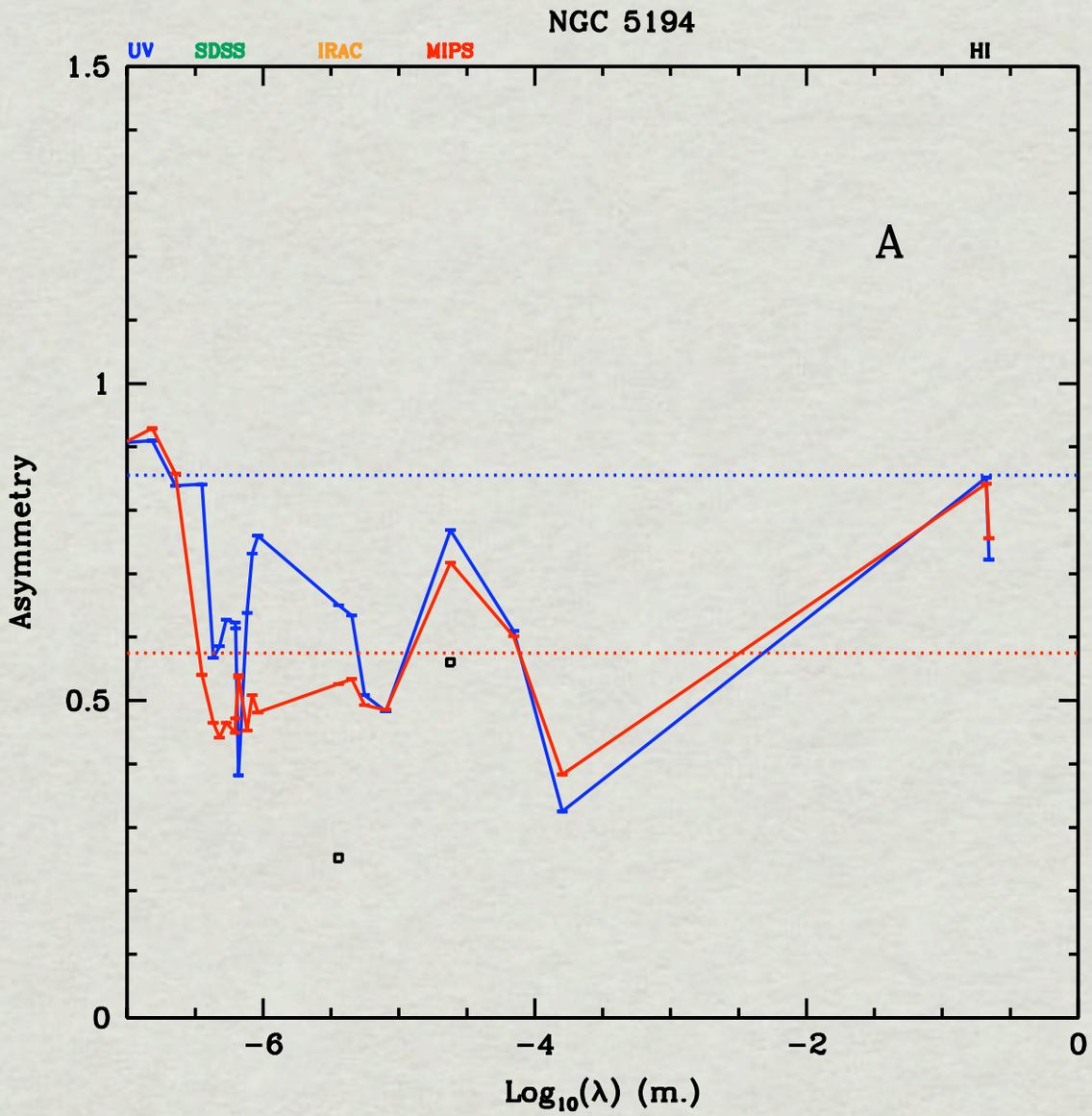




- LOW IN HI
- PEAKS IN OPTICAL WITH INTERACTION

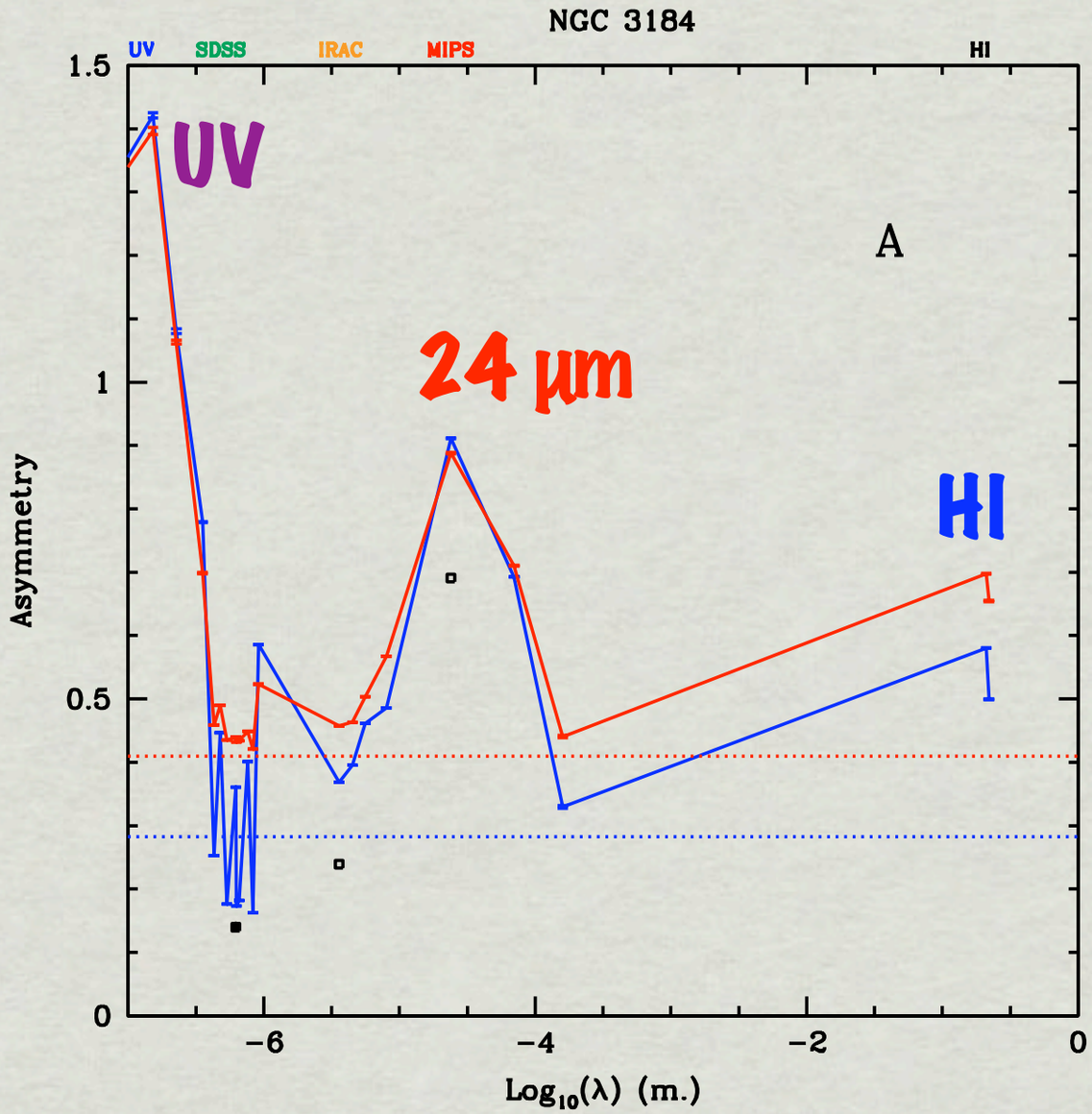
Results: Asymmetry

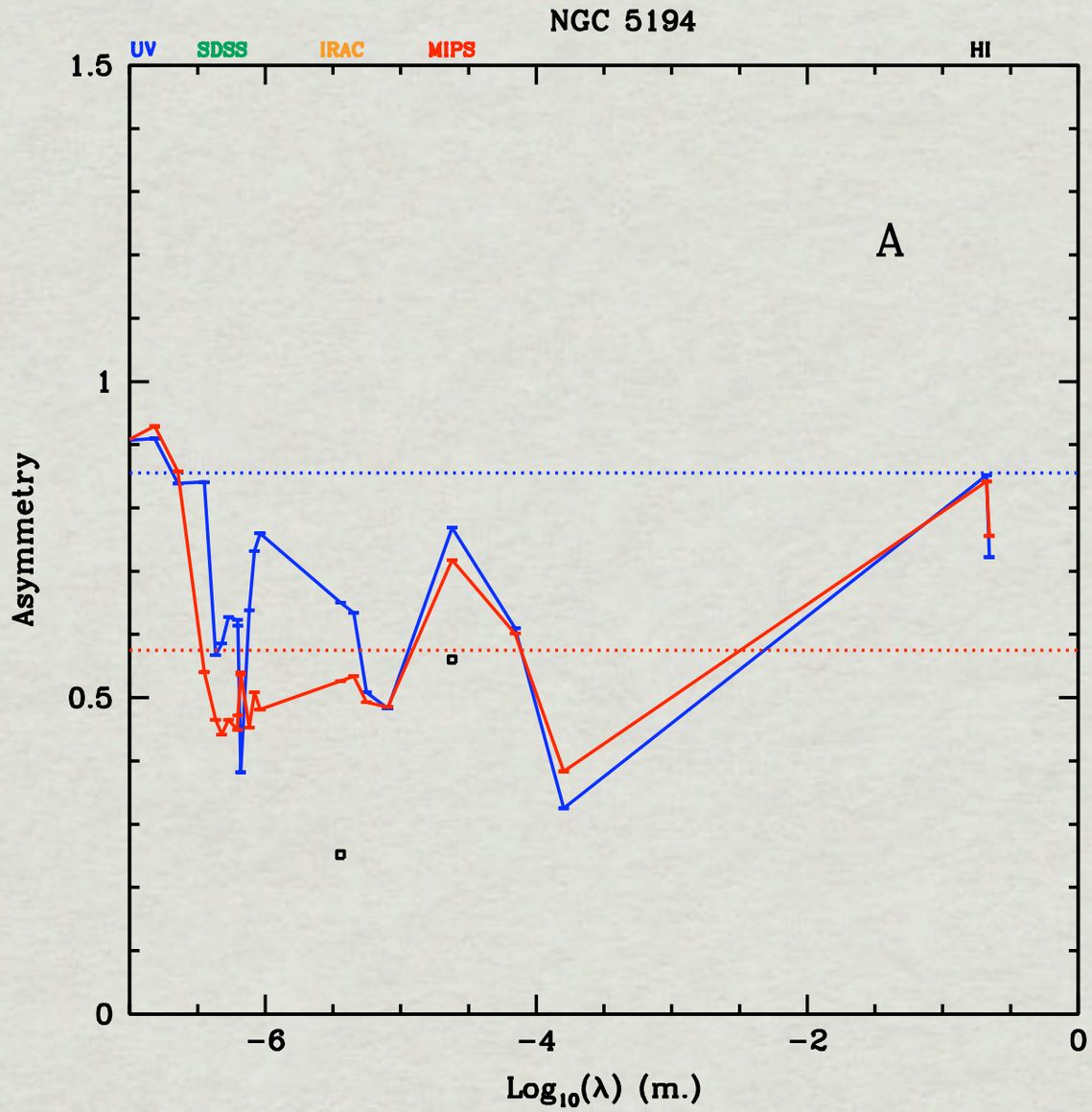




INCREASED IN HI, SIMILAR TO STAR-FORMATION TRACERS

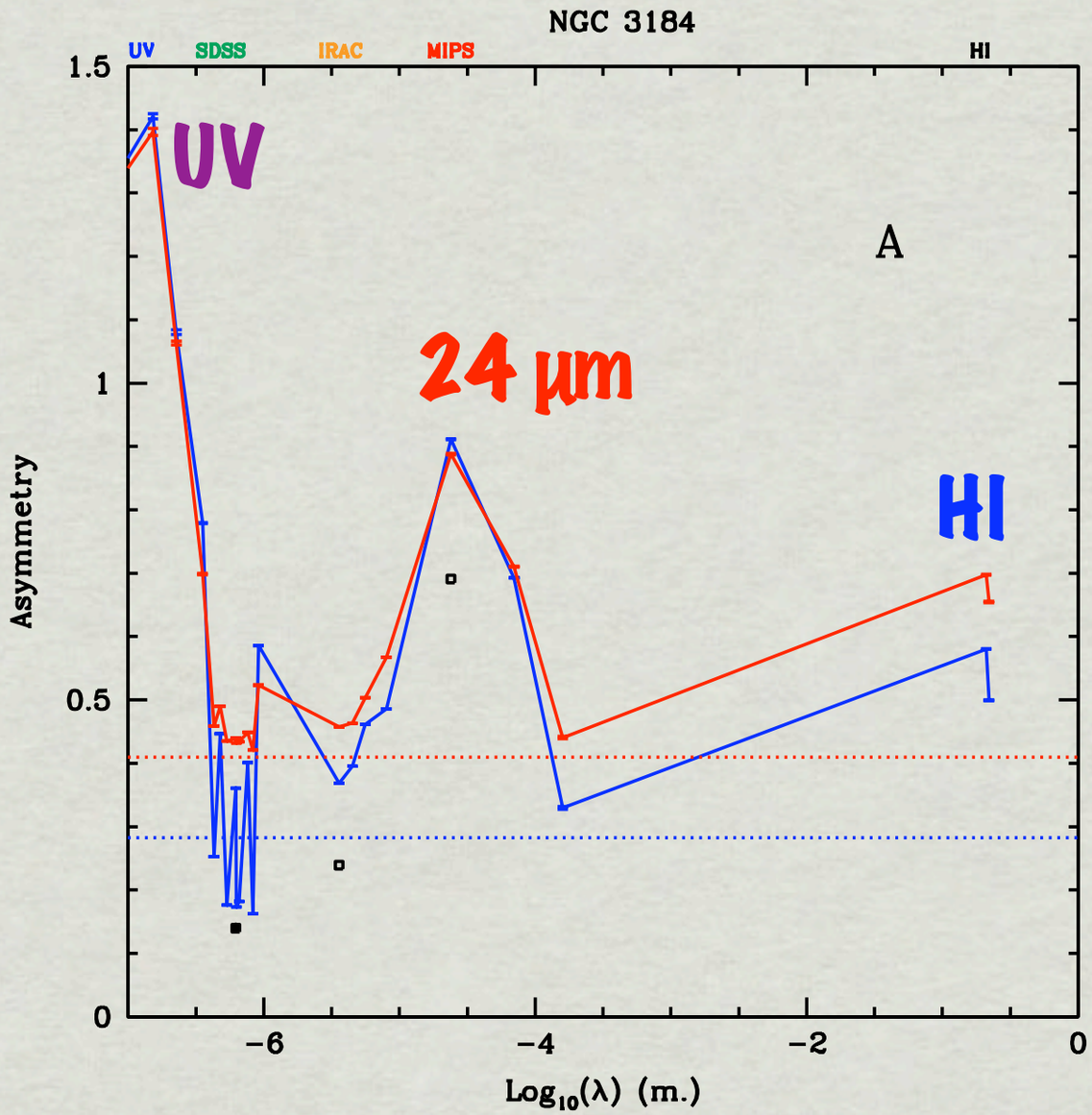
Results: Asymmetry

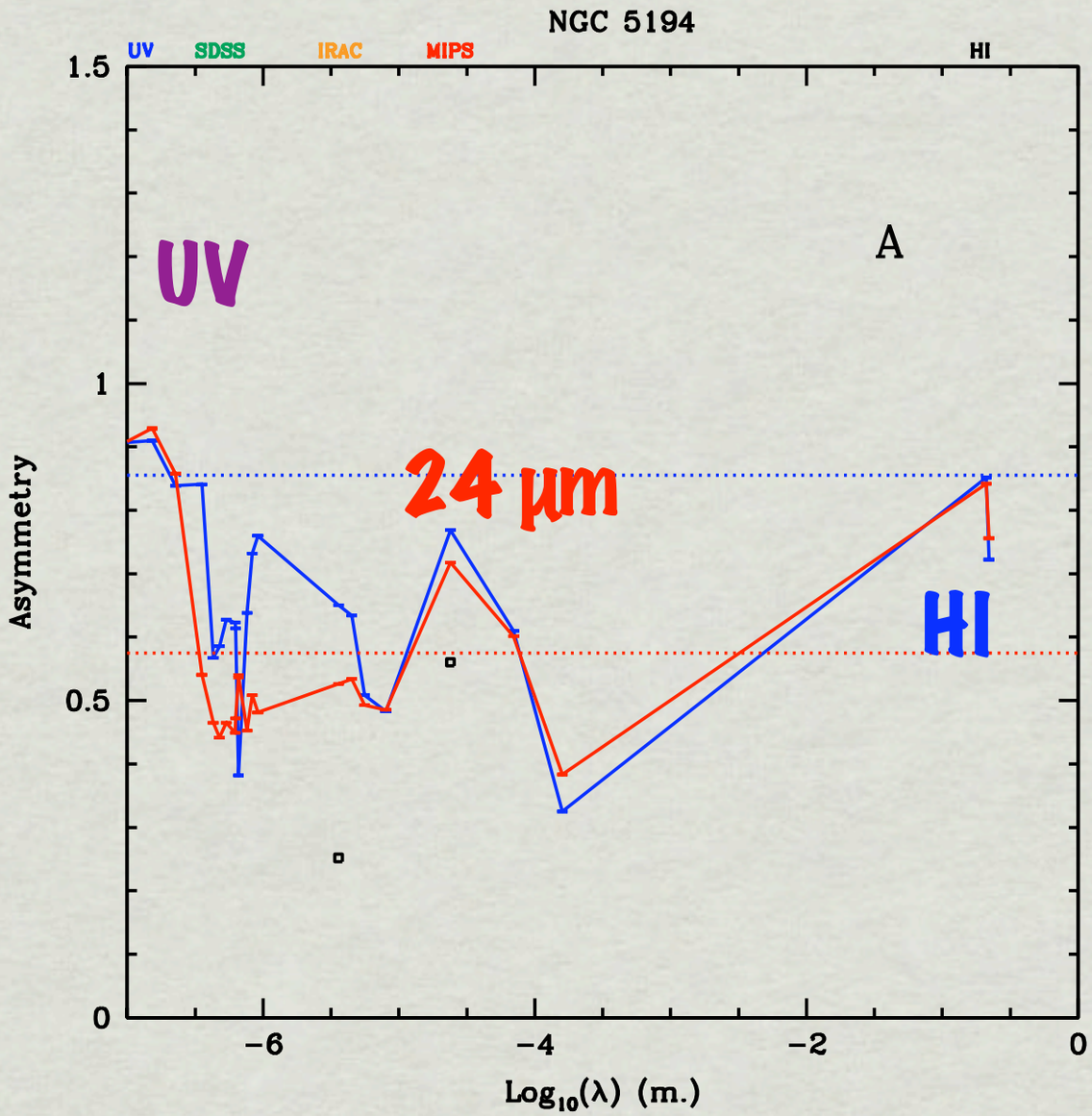




INCREASED IN HI, SIMILAR TO STAR-FORMATION TRACERS

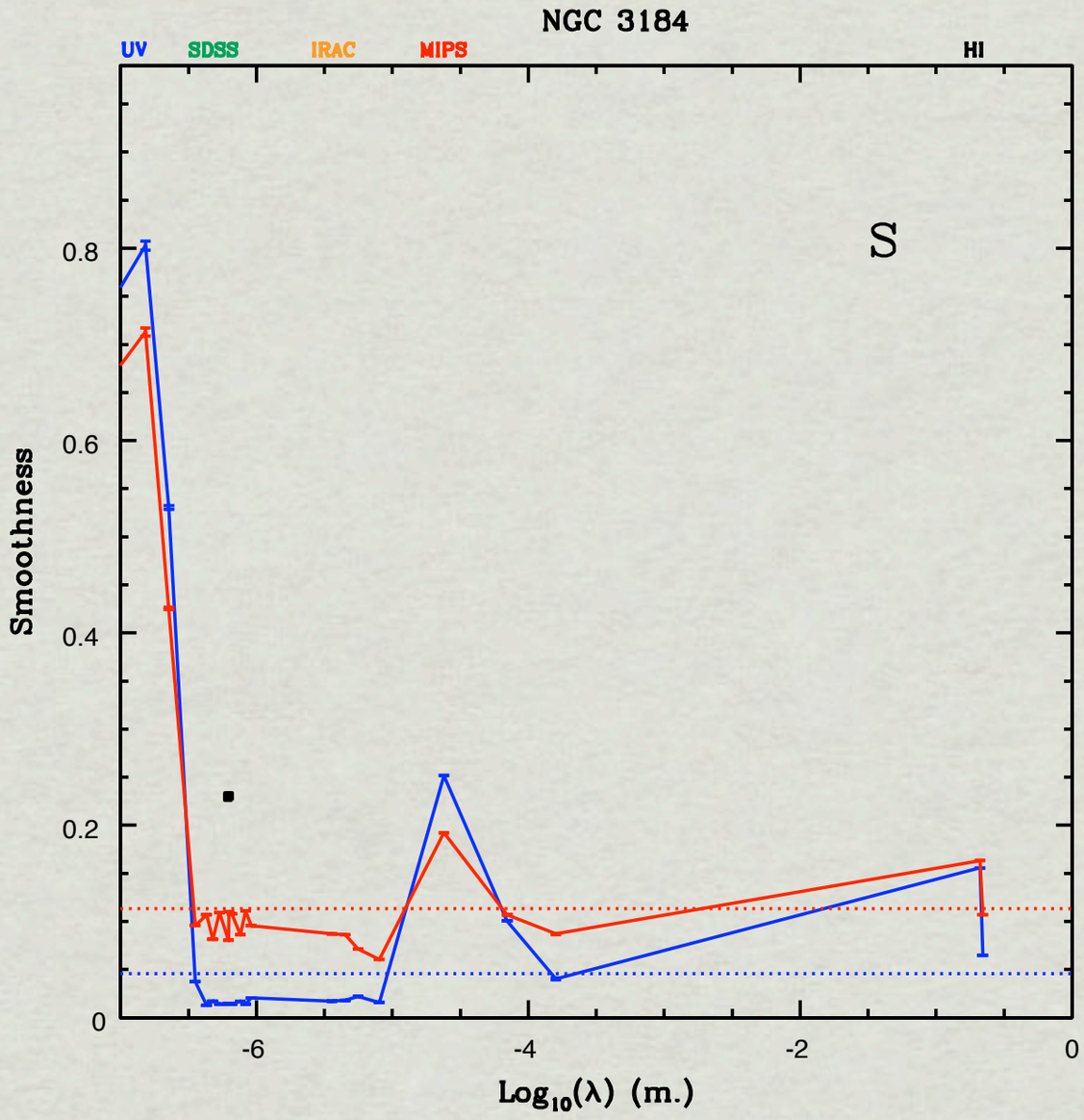
Results: Asymmetry

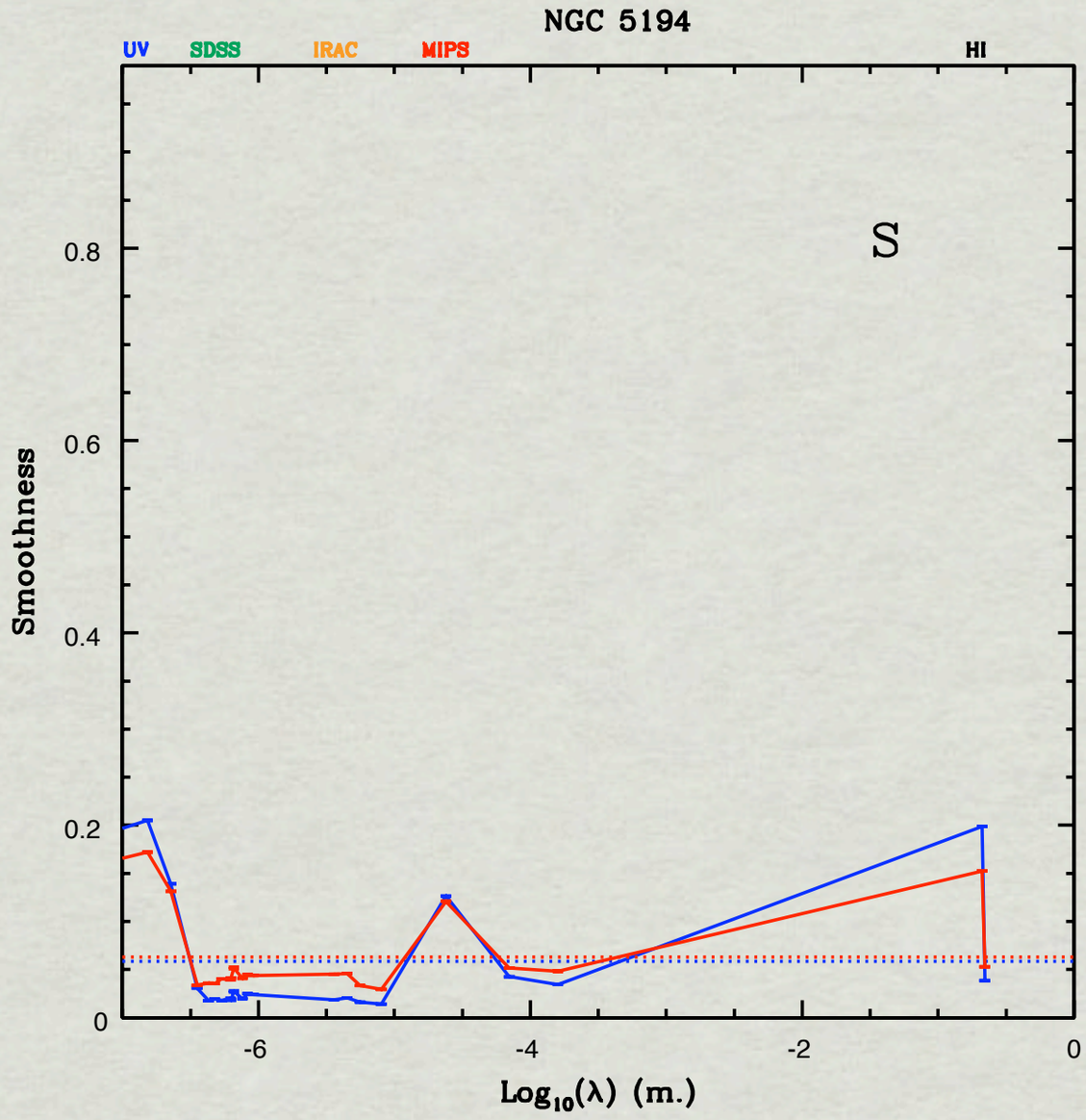




INCREASED IN HI, SIMILAR TO STAR-FORMATION TRACERS

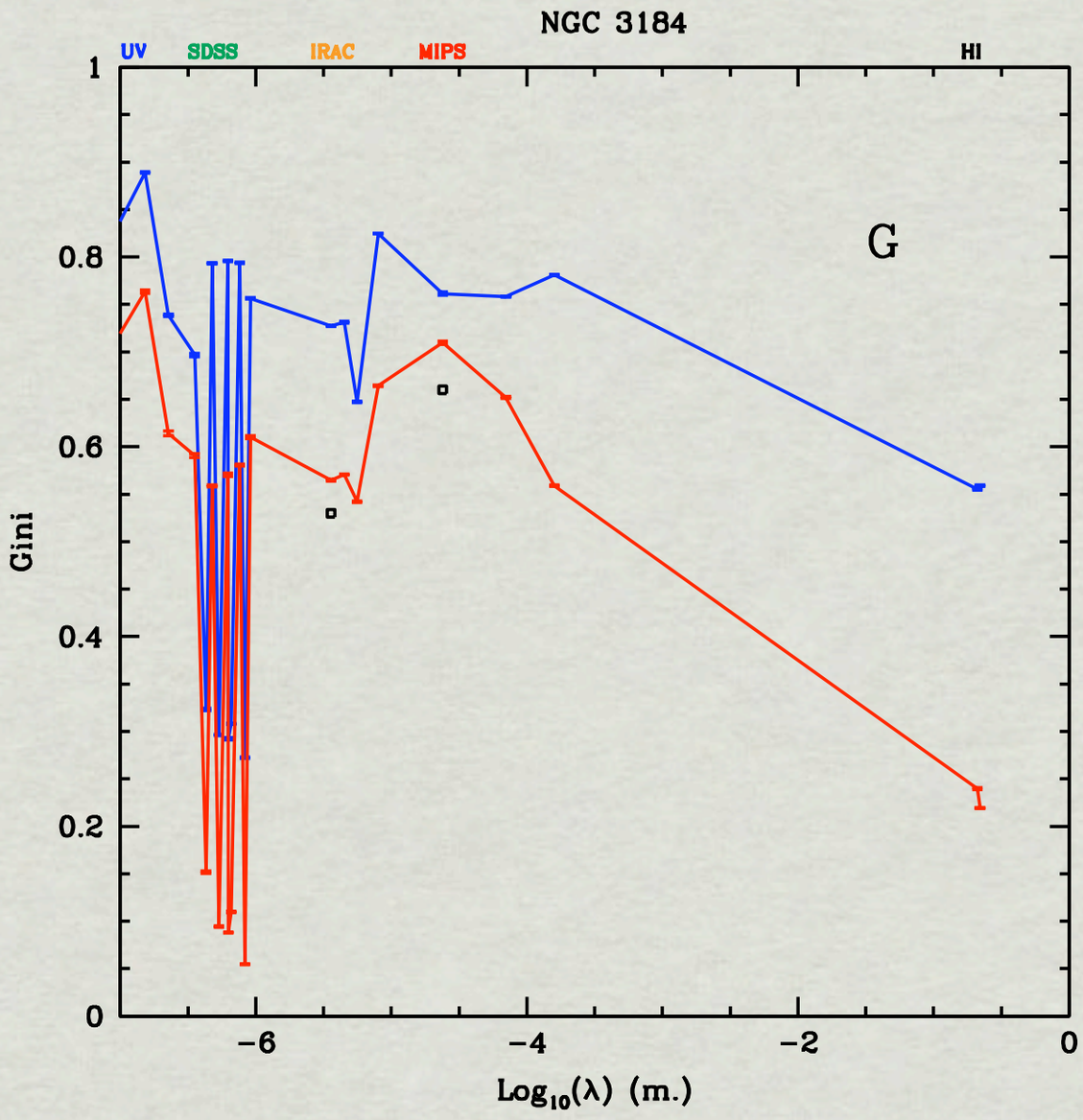
Results: Smoothness

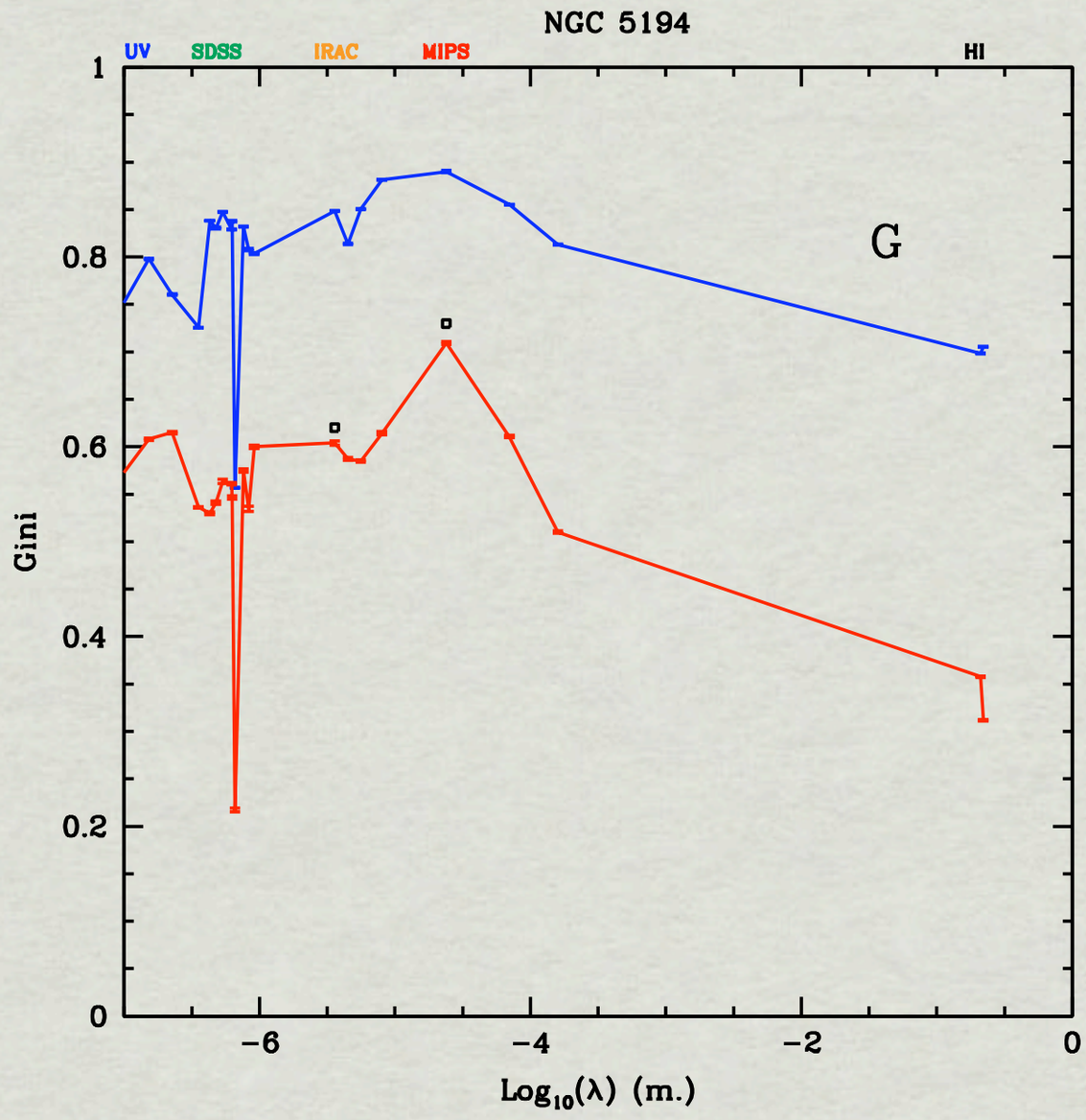




INCREASED IN HI, 24 MICRON AND UV

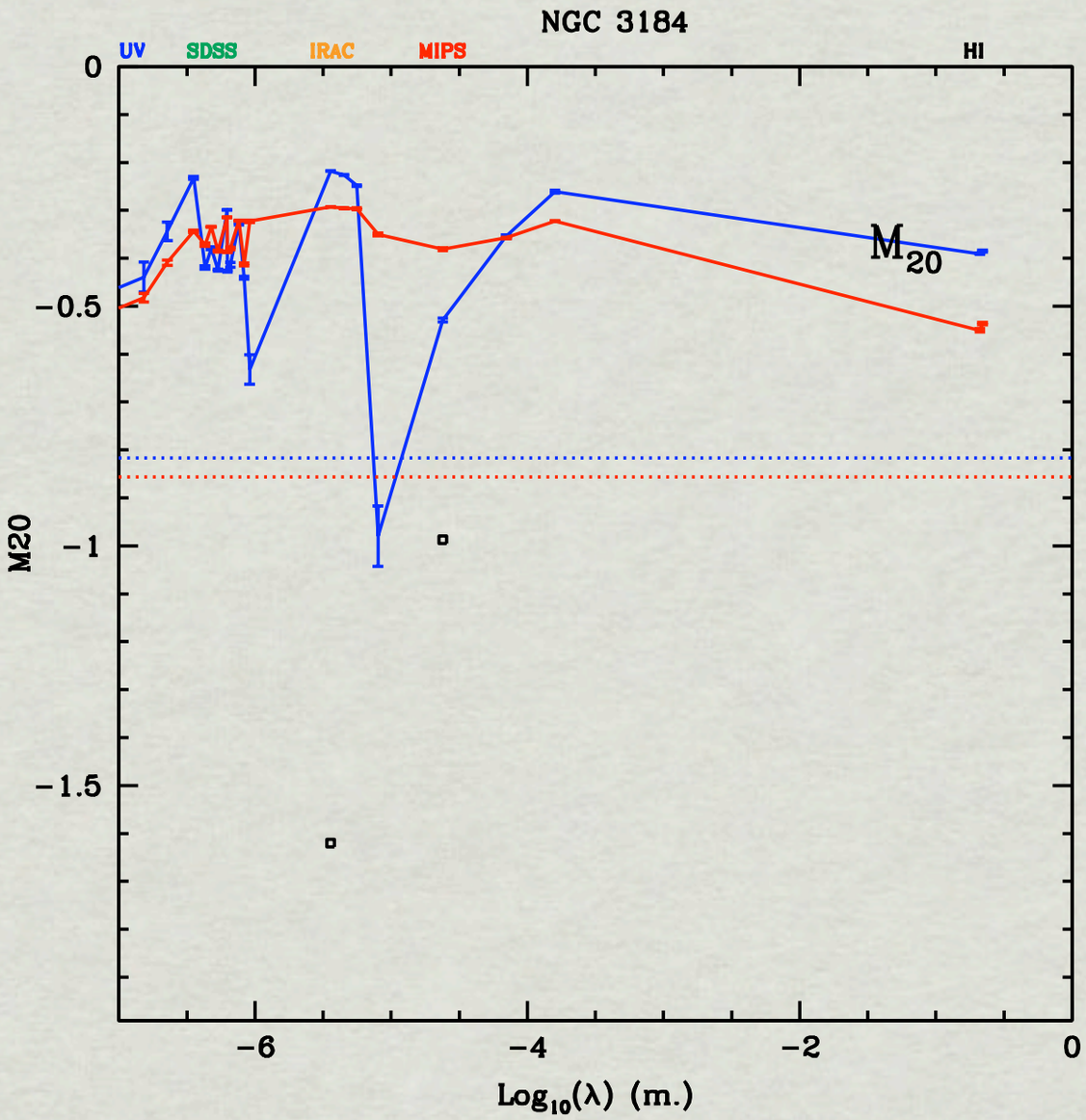
Results: Gini

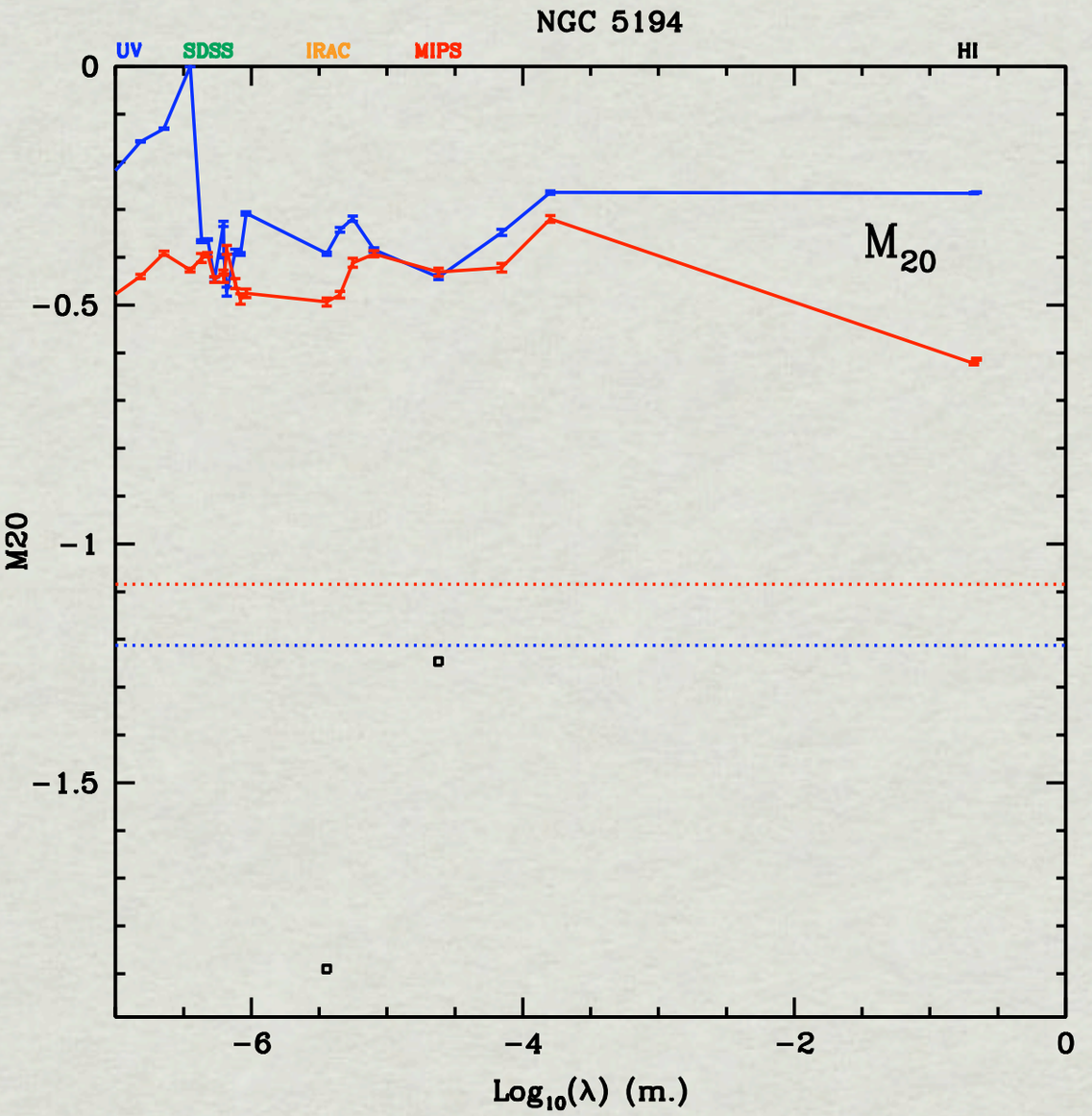




INTERACTION ENHANCES HI INEQUALITY

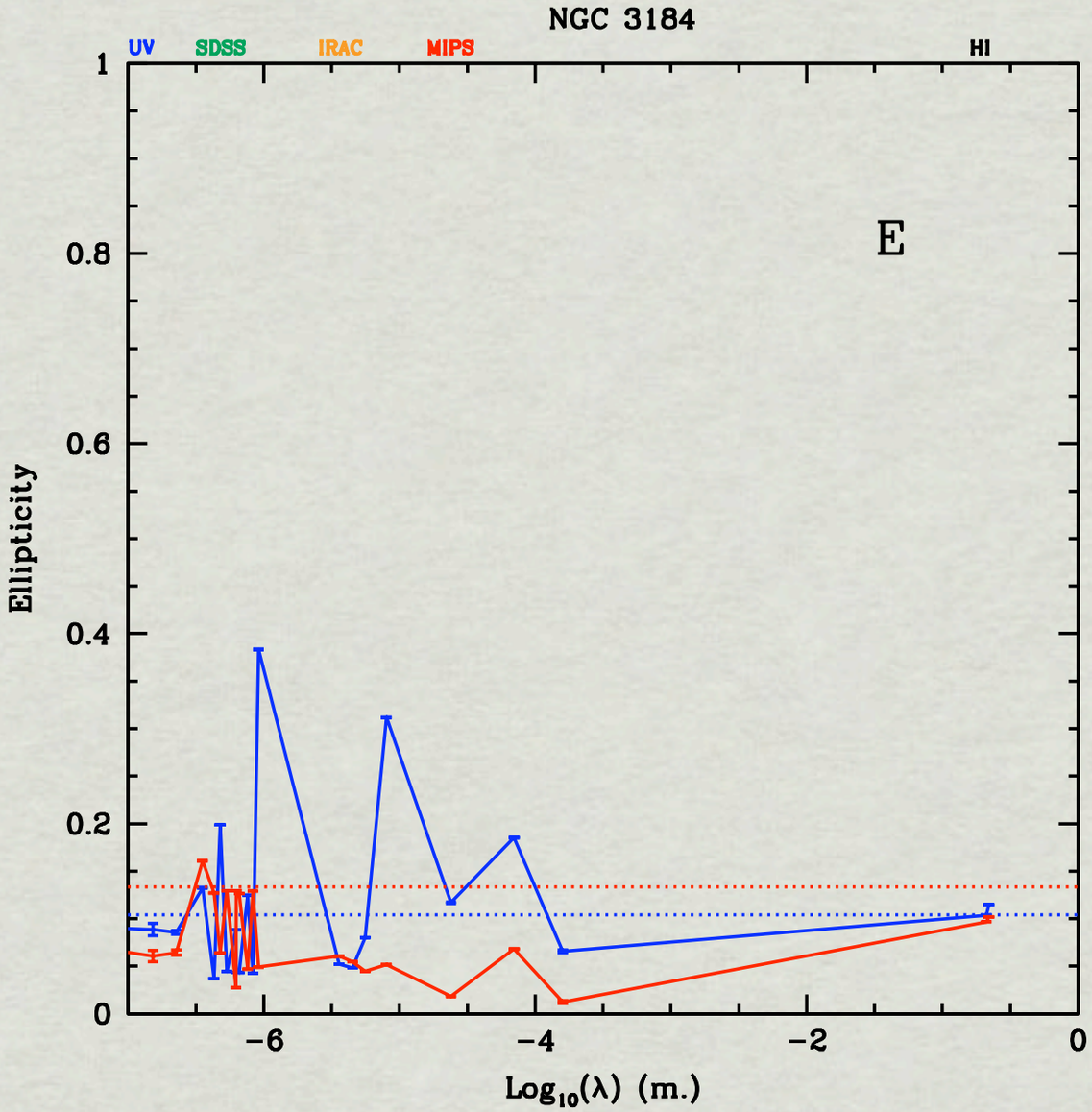
Results: M20

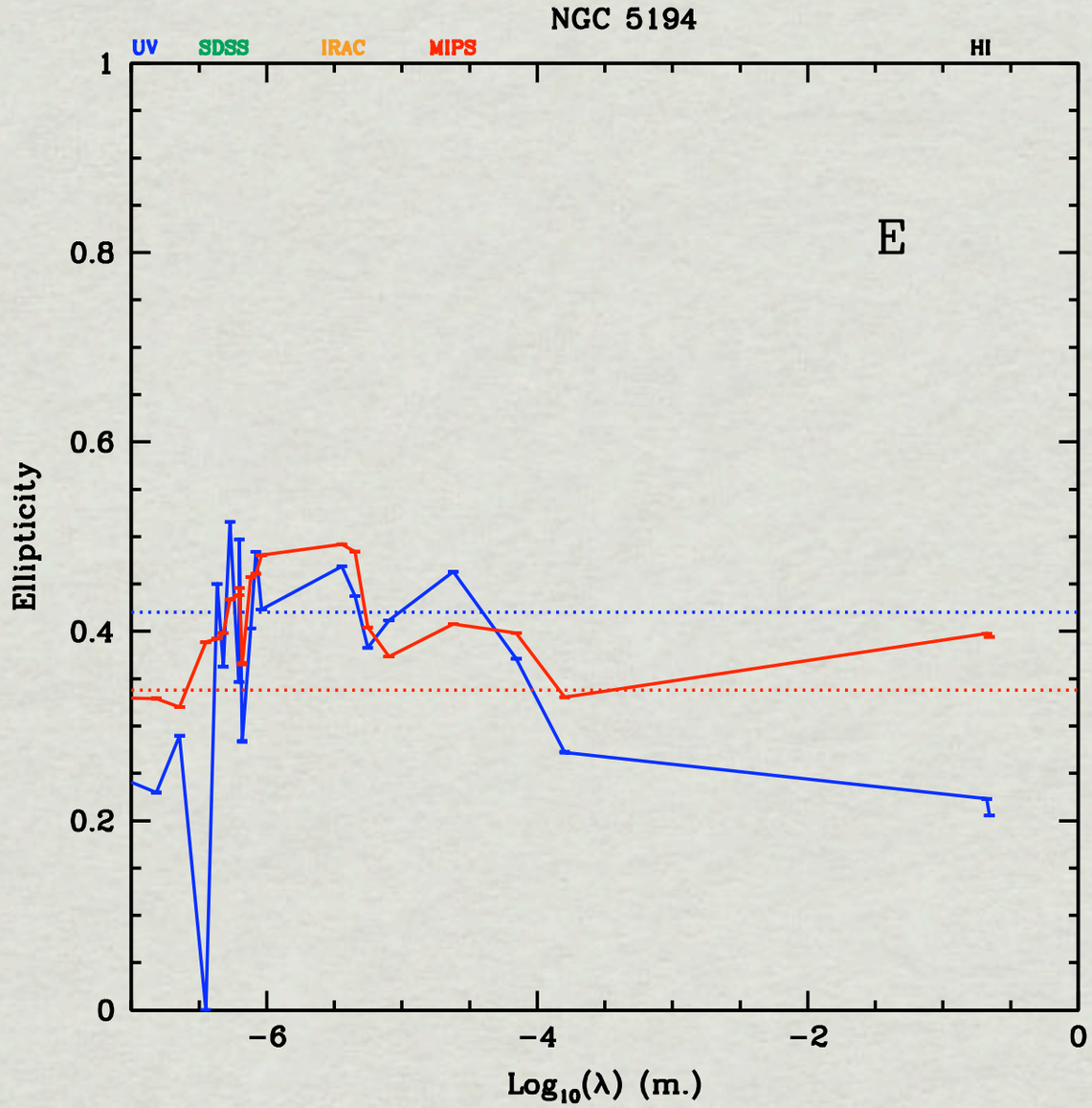




INTERACTION ADDS MOMENT TO HI MAP

Results: Ellipticity





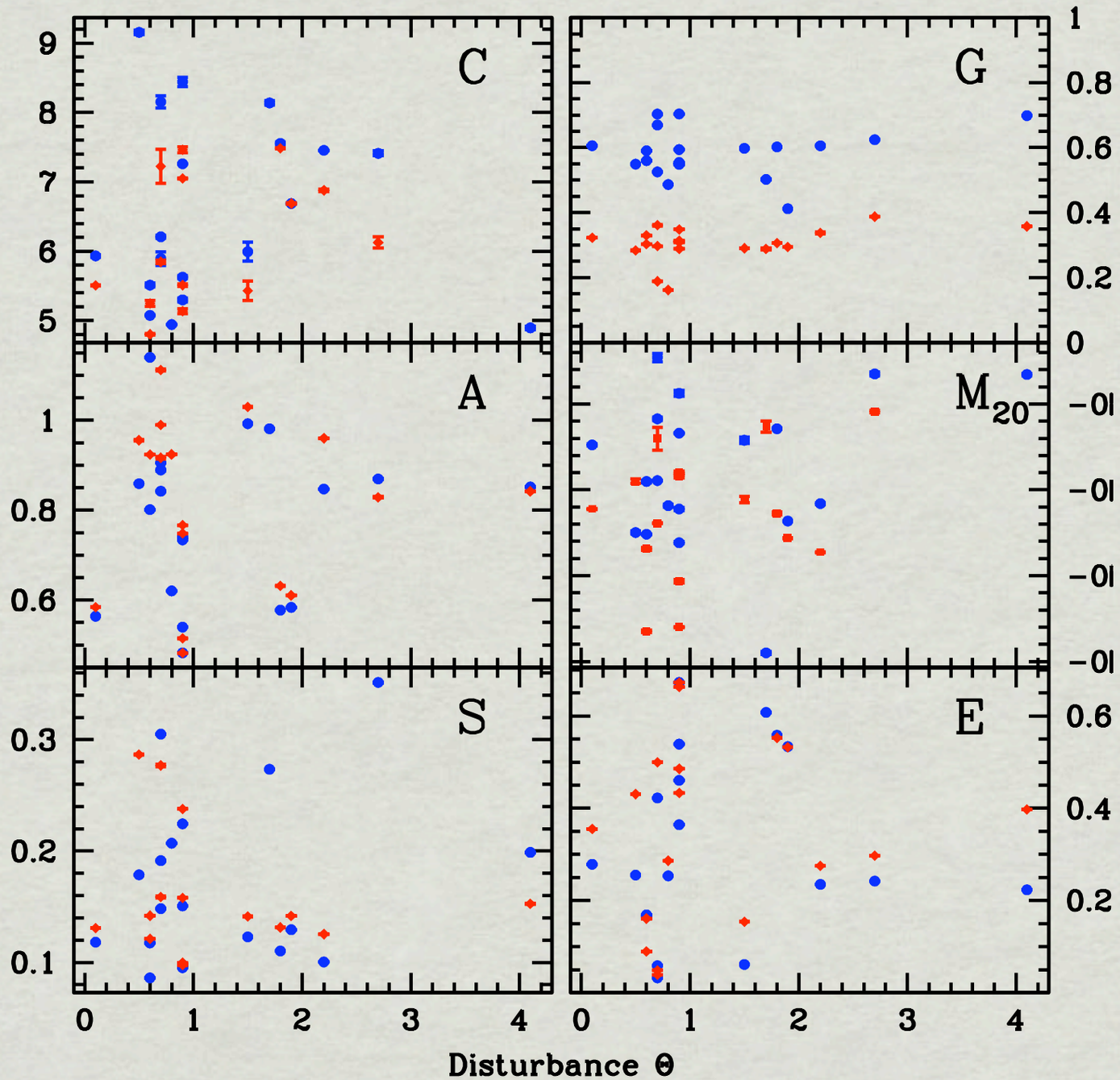
GENERALLY THE GALAXY IMAGE IS ELONGATED

Conclusions

- Quantified morphology over a range of wavelengths within two HI contours in two galaxies, isolated NGC 3184 and interacting M51.
- The interaction signal is strongest in UV, 24 micron and HI: star-formation and its fuel.
- HI morphology is equal or better indicator of interaction (Asymmetry, GINI and M_{20}) compared to any other wavelength.
- Interaction rate local volume with MeerKAT/ ASKAP/APERTIF, SKA up to redshifts of z=1.

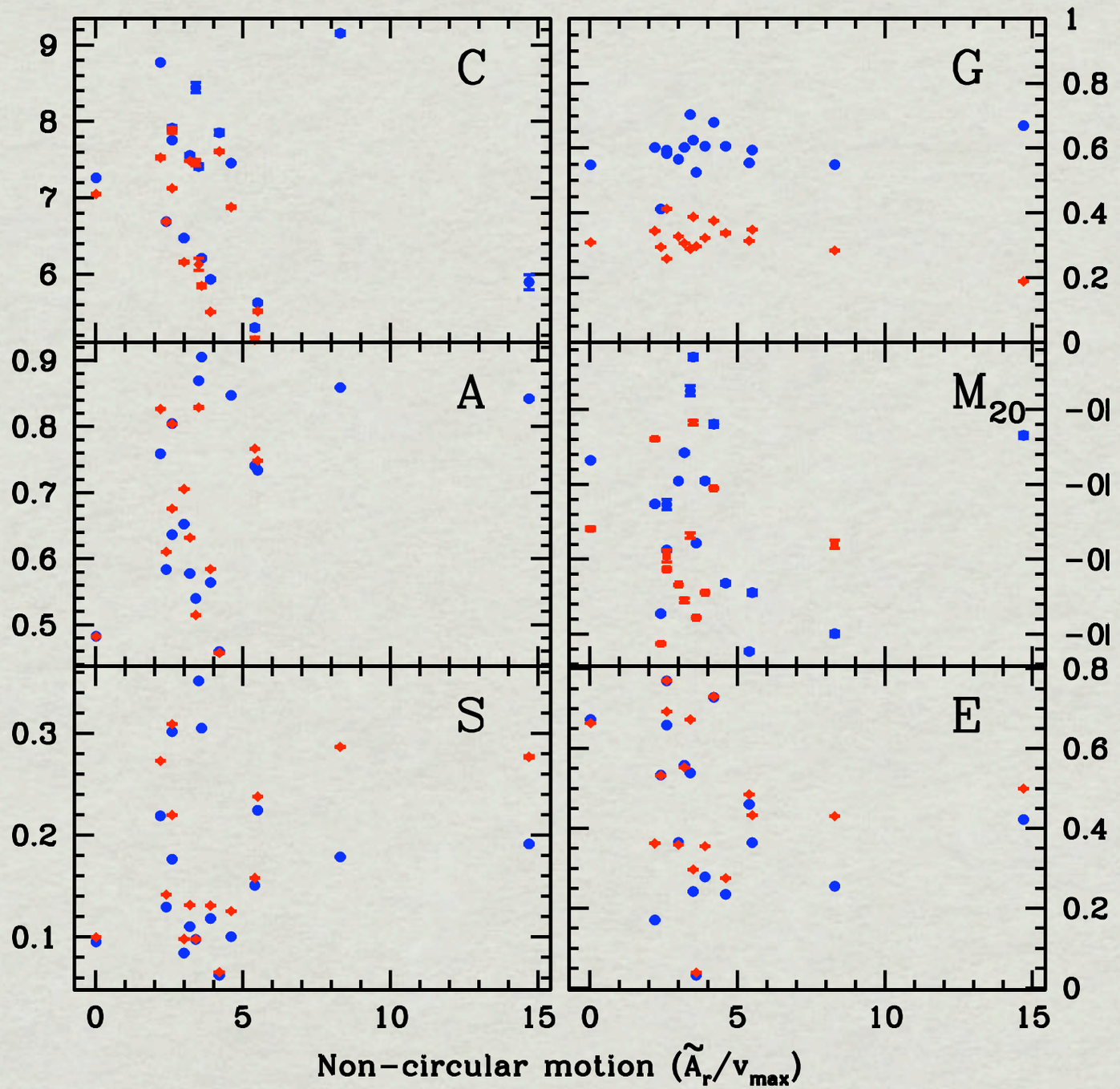
Disturbance

- Karenchentsev et al. 2004
- High value of Θ implied close-by and massive neighbour.
- Gini and M_{20}



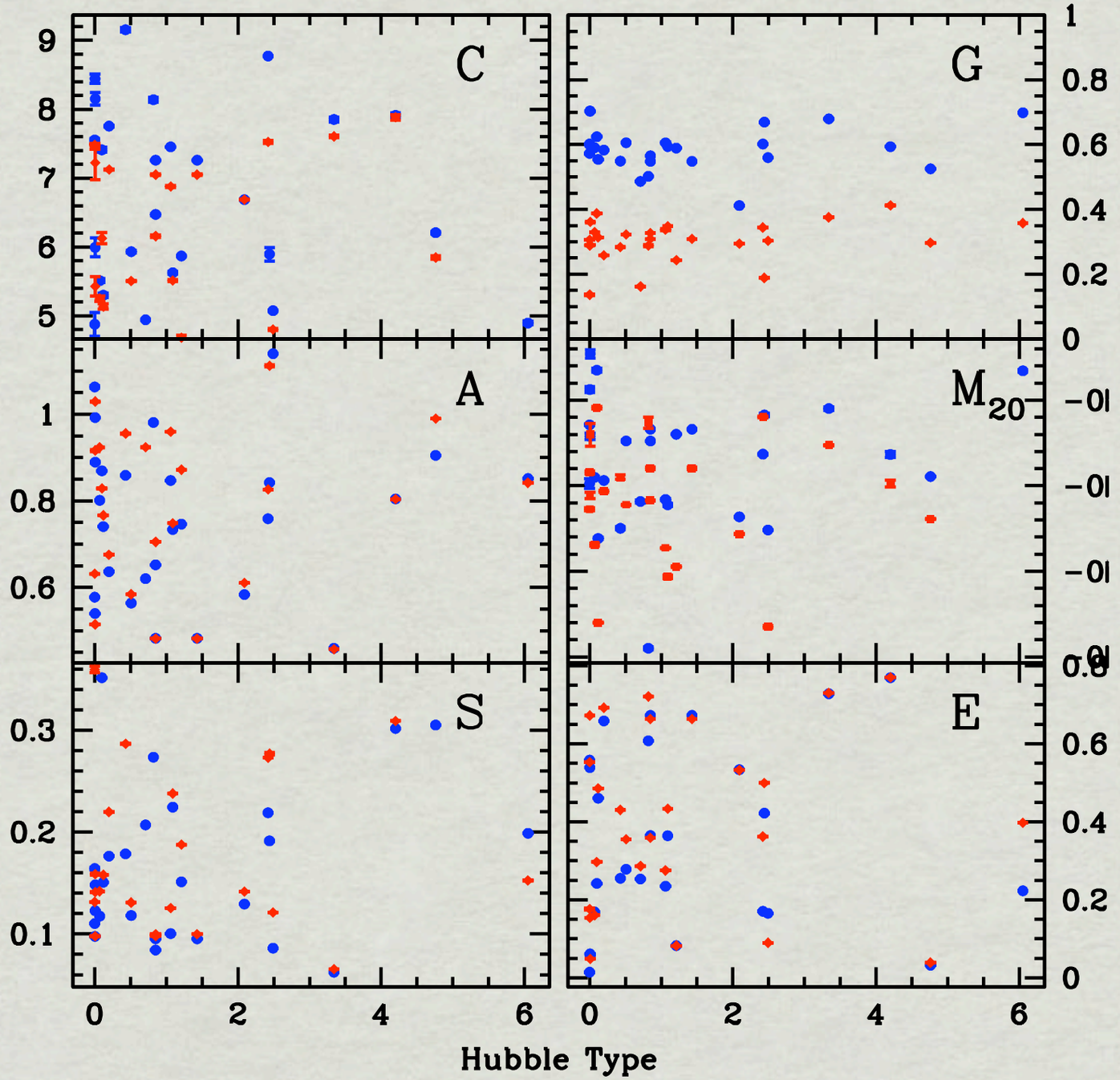
Non-circular Motion

- Relative estimate of non-circular motion (A_r / v_{max})
- correlates with A, $1/M_{20}$



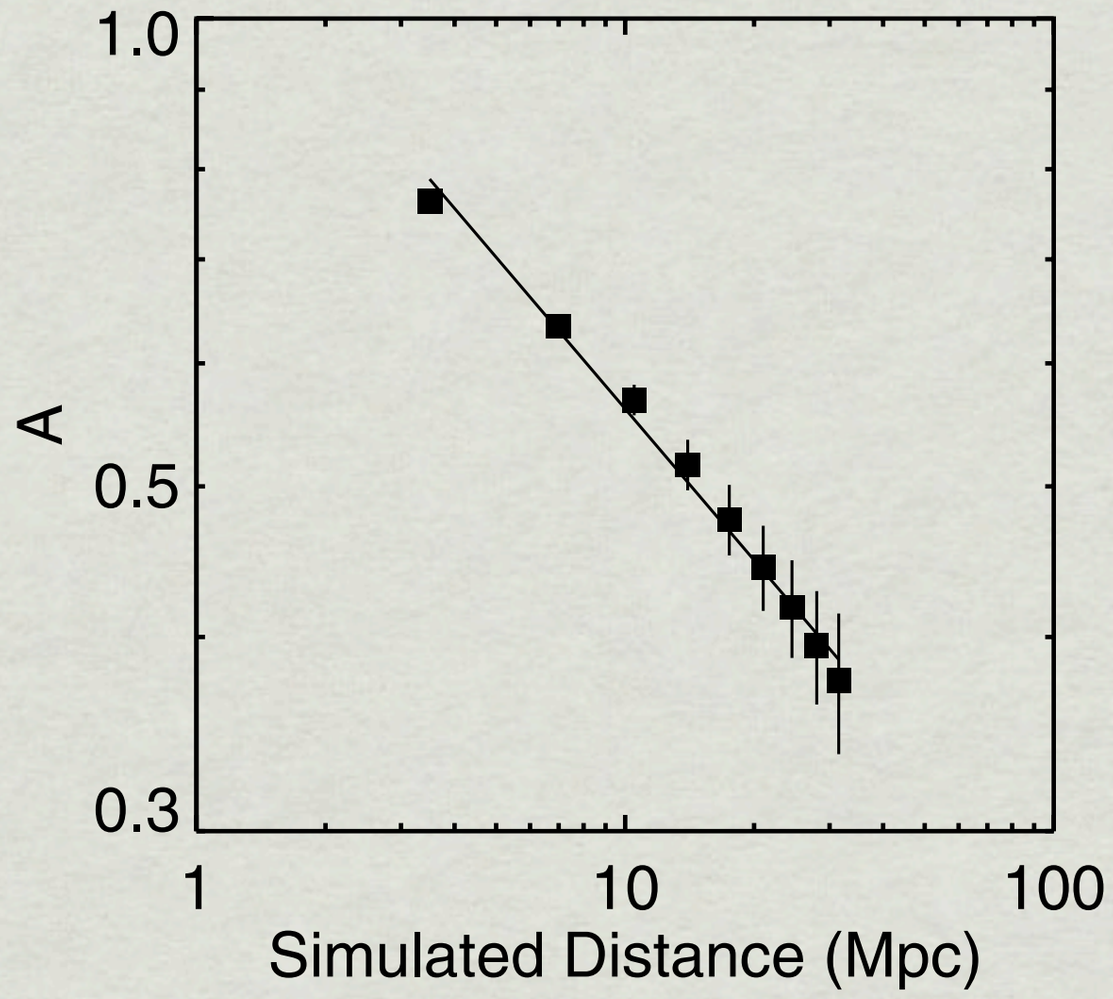
Hubble Type

- Parameters in HI do not correlate well with Hubble (sub)type.



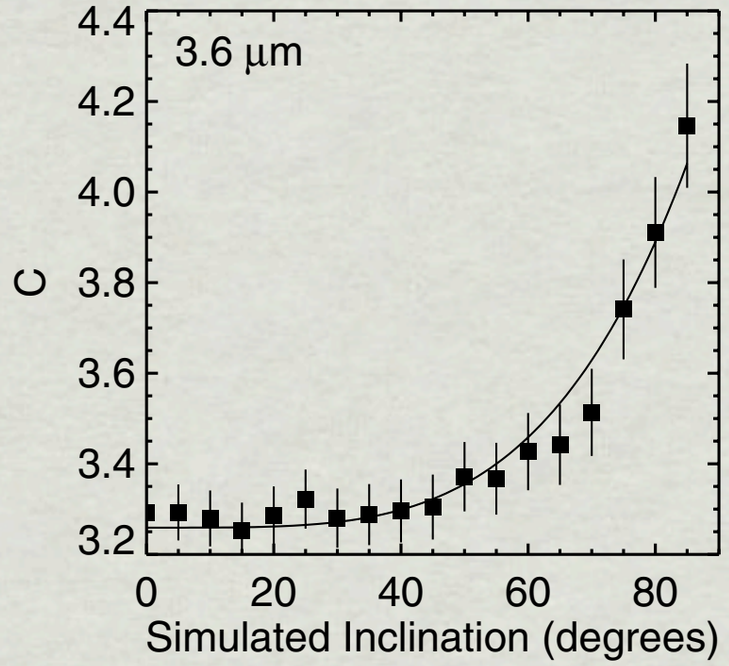
Distance Effects

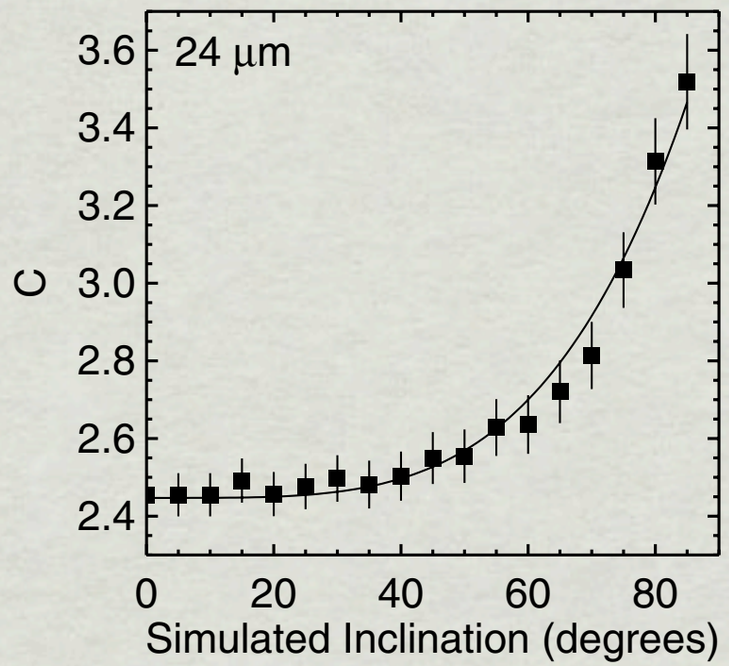
- Bendo et al. 2008
- Asymmetry most strongly depends on distance
- Correction workable.
- Local Volume (< 60 Mpc)



Inclination Effects

- Bendo et al. 2008
- Affects Concentration
- Not really an issue below 60 degrees
- HI inclination estimate vital.

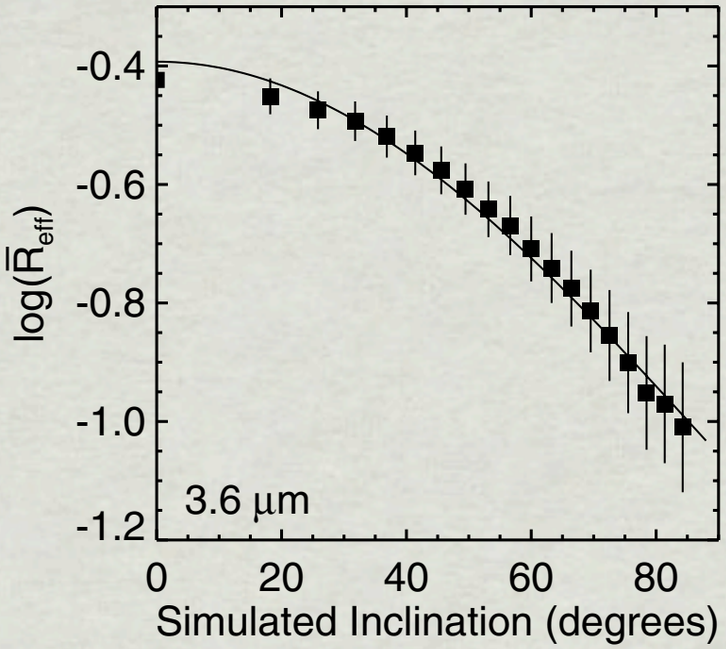


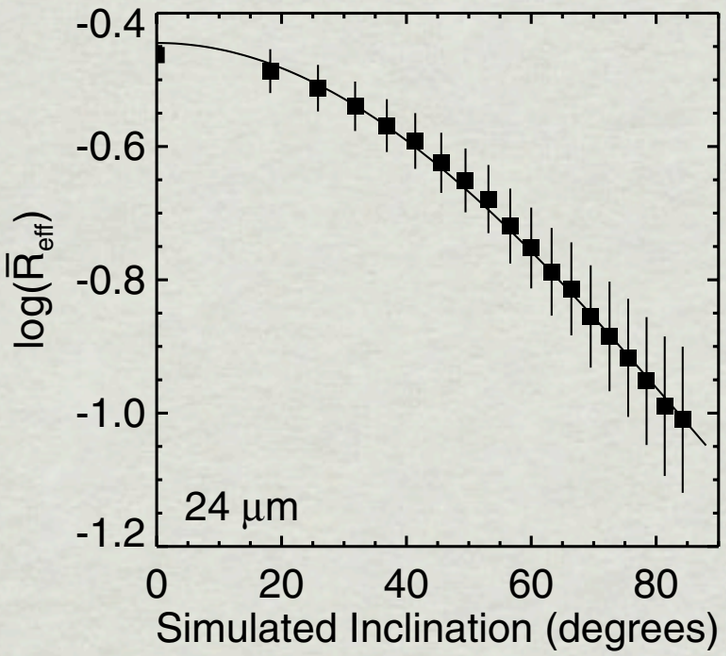


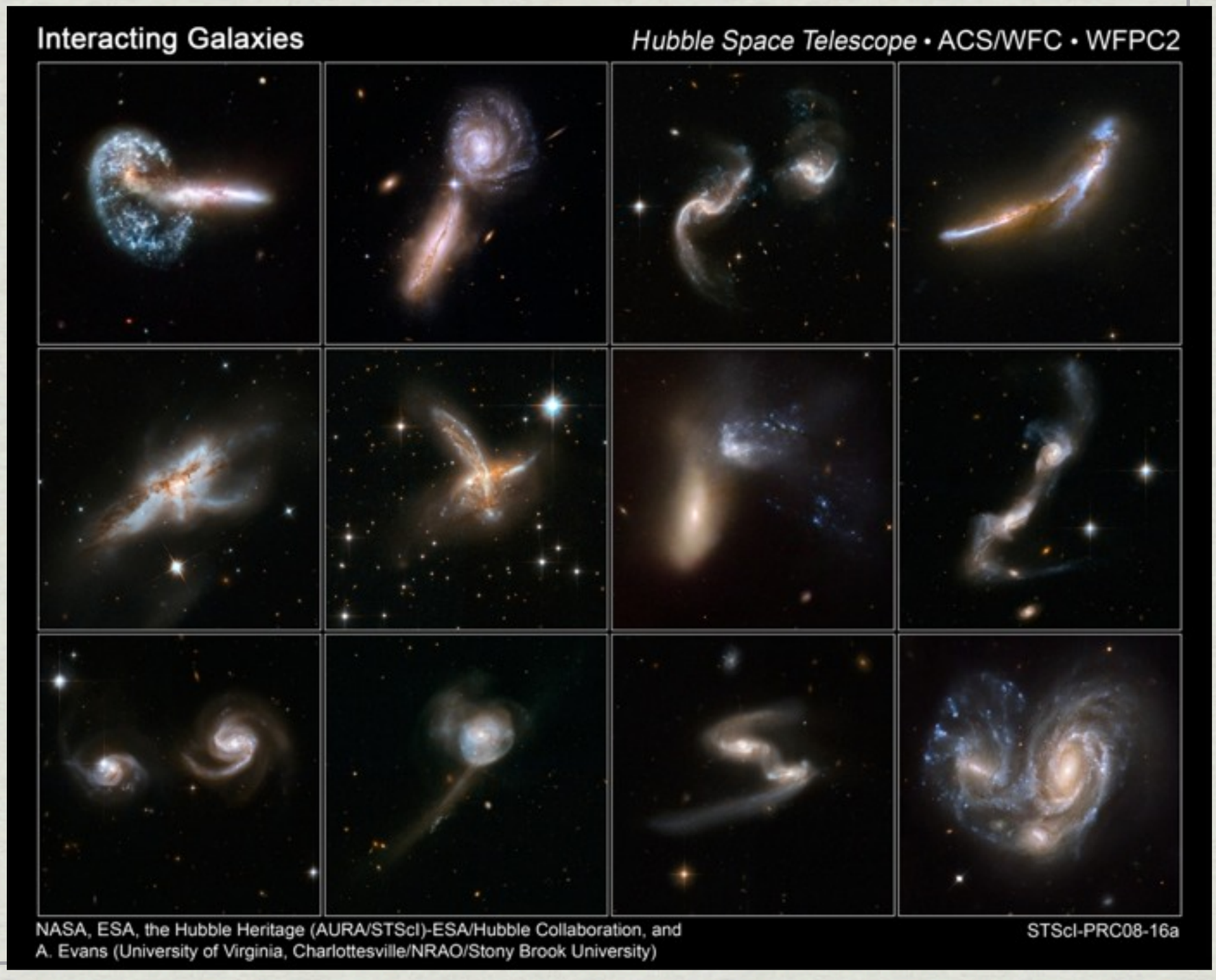
Conclusions (2)

- Initial results from the THINGS sample:
  - Morphology will give a likelihood for interaction, see how well combination with dynamical info
  - Hubble (sub)type classification problematic
  - Inclination not a major issue till > 60º
  - Distance & resolution not an issue for Local Volume.

Inclination






Interacting Galaxies
Hubble Space Telescope • ACS/WFC • WFPC2
NASA, ESA, the Hubble Heritage (AURA/STScI)-ESA/Hubble Collaboration, and
A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)
STScI-PRC08-16a

Multi-wavelength

GALEX HUBBLE SPITZER FIR & HI