The Gas-Star Cycle in Nearby Early-Types: UV, Optical, CO, HI

Martin Bureau, Oxford University

SAURON

(R. Bacon, M. Cappellari, R.L. Davies, E. Emsellem, J. Falcon-Barroso, D. Krajnovic, M. Sarzi, H. Kuntschner, R.M. McDermid, R.F. Peletier, G. van de Ven, P.T. de Zeeuw)

CO

(F. Combes, A. Crocker, L.M. Young)

GALEX

(H. Jeong, Y-K. Sheen, S.K. Yi)

Plans: Optical/SAURON: Stellar populations in E/S0s and KDCs

CO/BIMA, HI: Star formation fuel, gas accretion

UV/GALEX, HI: Current and recent star formation

Summary

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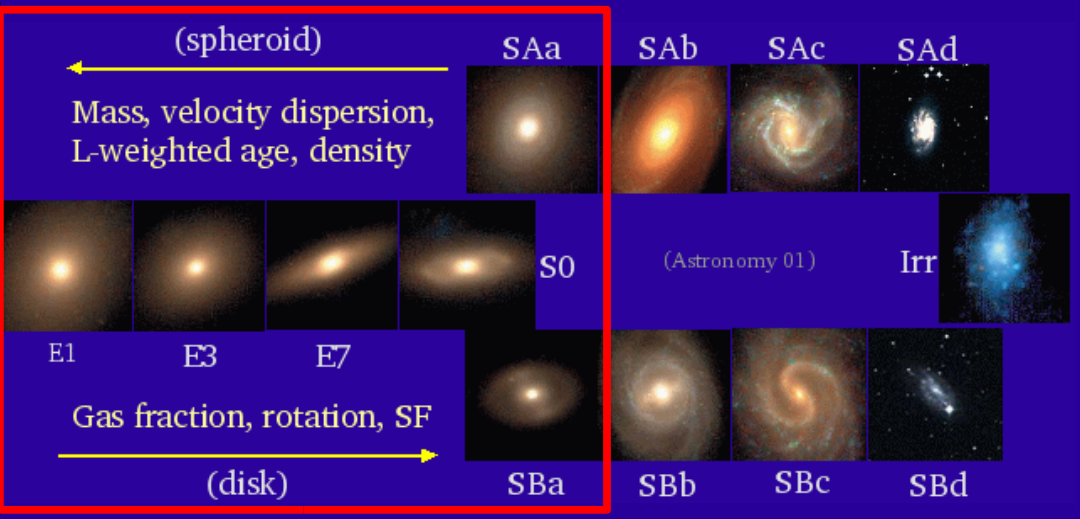
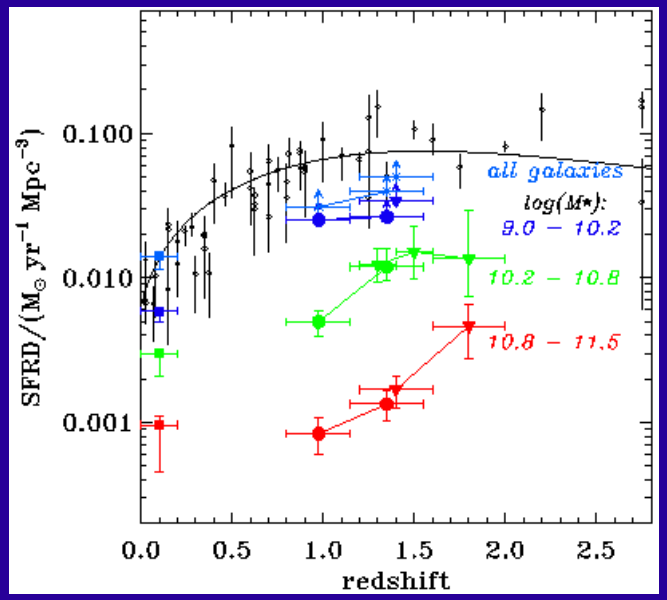
CO/BIMA, HI: Star formation fuel, gas accretion
UV/GALEX, HI: Current and recent star formation
Summary

SAURON: Broad Aims





(Juneau et al 05)

Goals:

- Mass assembly history
  (gas, stars, kinematics)
- Chemical enrichment history
  (age, metallicity, SFH)

Context:

- Hierarchical structure formation
  (merging, harassment, ...)
- Subsequent dynamical evolution
  (BH/triaxiality-driven, ...)

⇒ Exploit "fossil record"
(near-field cosmology)

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SAURON: Stellar Linestrengths

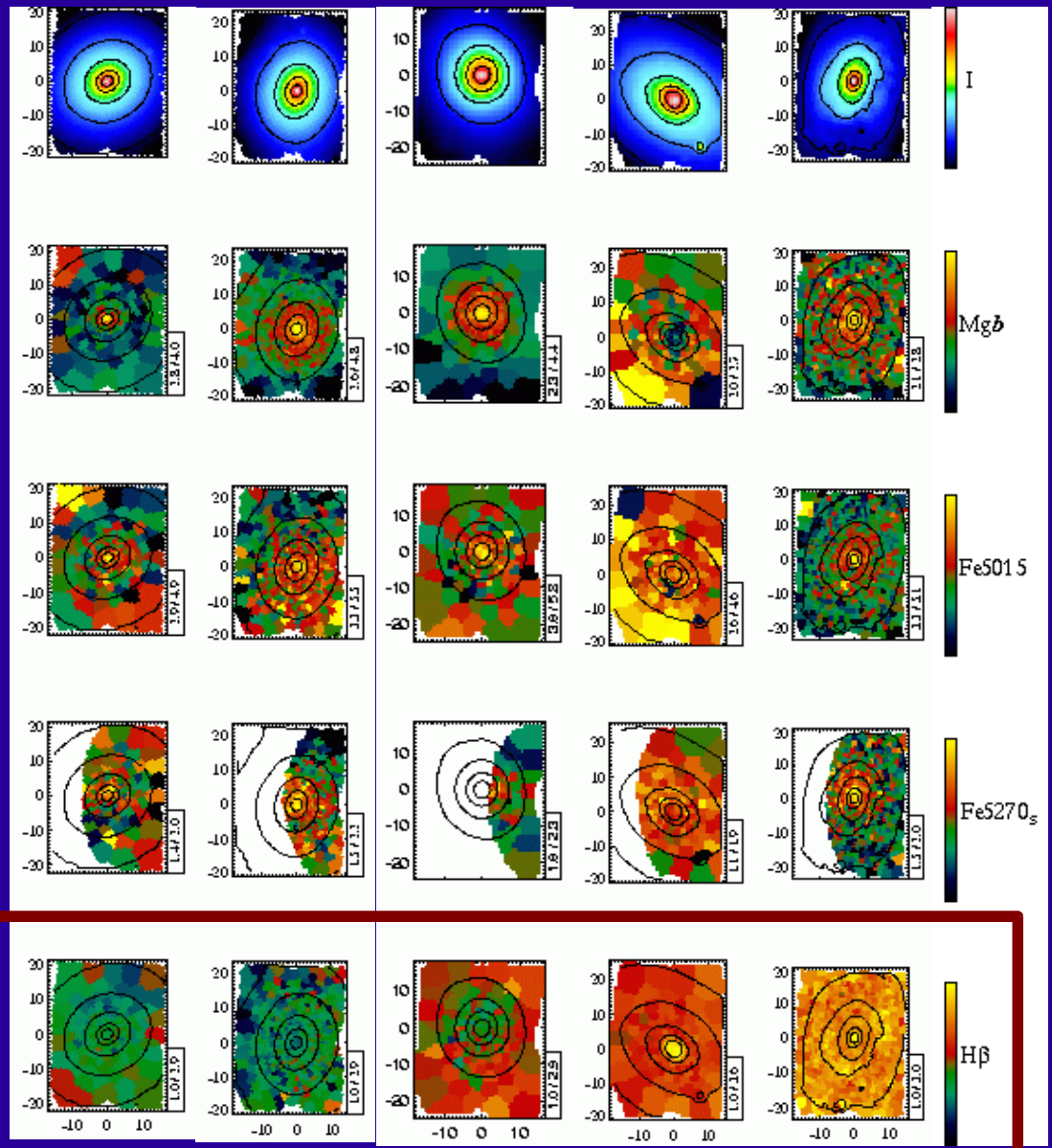
(Kuntschner et al. 06, 08)

Main results:

- Standard:
  Homogeneously old,
  decreasing metallicity
  (larger spread among S0s)

- Occasional:
  Young core/body,
  increasing metallicity

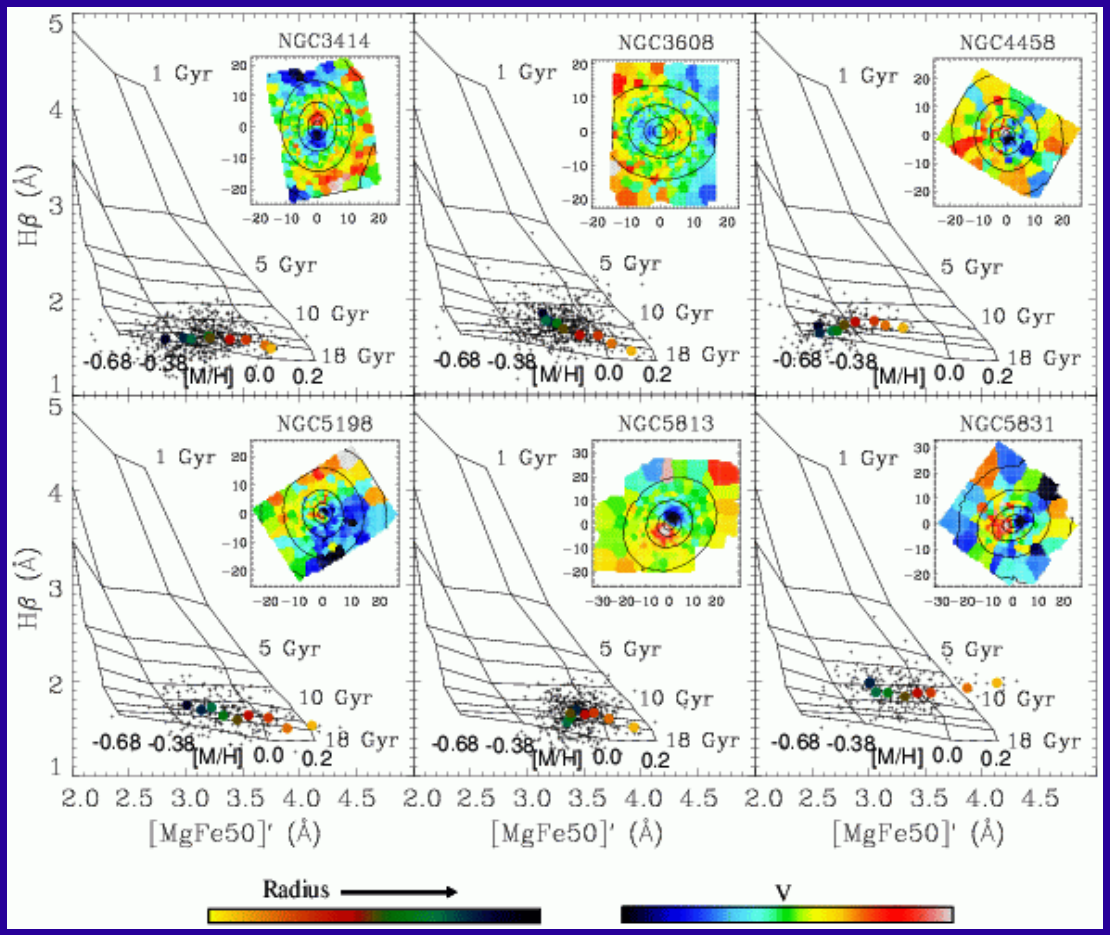
- Isoindices:
  Mg_b isoindex countours
  often flatter than light
  (40%; rotators)



Stellar Pop.: Classic KDCs

(McDermid et al. 06)

SAURON Data:



Classic KDCs:

- Large: kpc' s(0.3-0.4 R_e)
- Massive
- Coeval: homogeneously old
- Non-rotators

Formation:

- Early (dissipative) major merging, then quiescent?
- Recent dissipationless major merging (dry mergers)?

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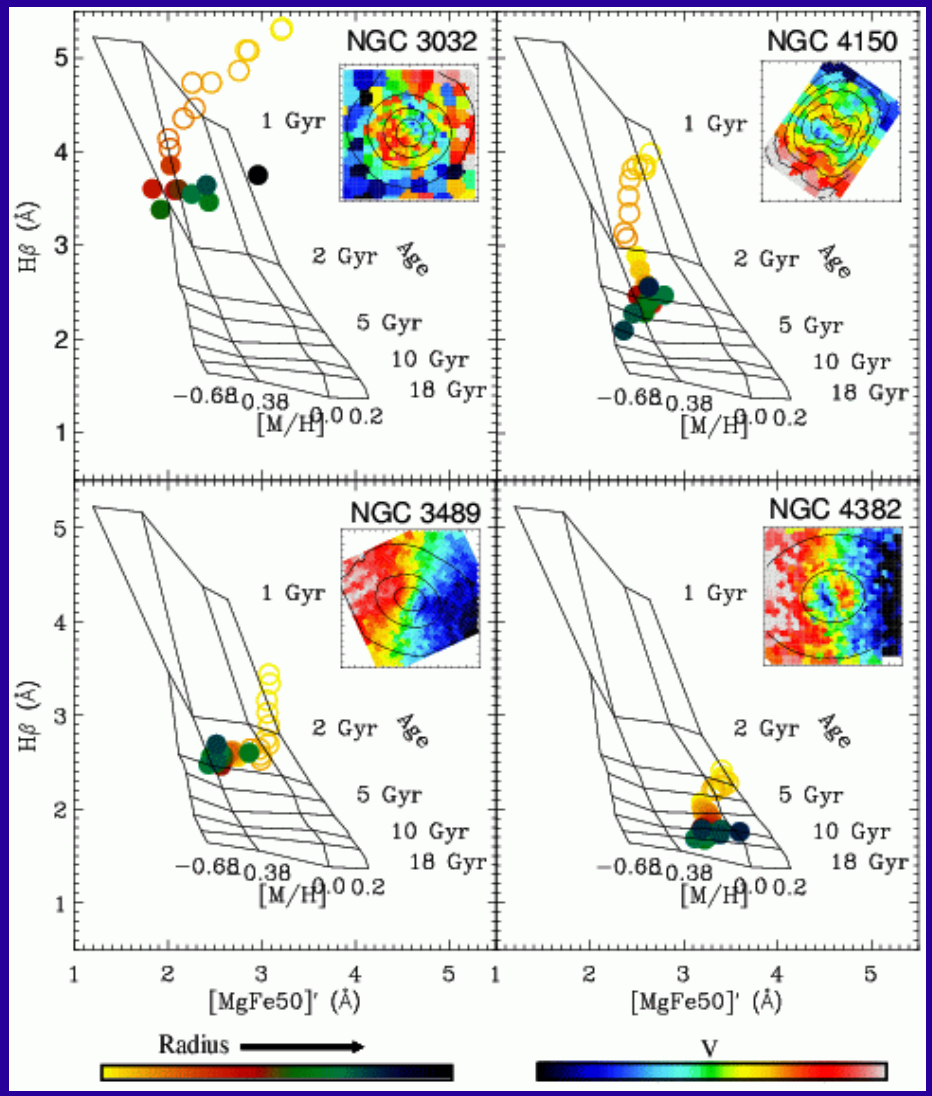
Stellar Pop.: Compact KDCs

(McDermid et al. 06)

SAURON-OASIS Data:



Compact KDCs:

- Small: 100 pc's ($\leq 0.1\ R_e$)
- Lightweight
- Young: distinct, younger toward center
  (contrary to ionized gas)
- Rotators

Formation:

- Recent dissipative minor merging/accretion?

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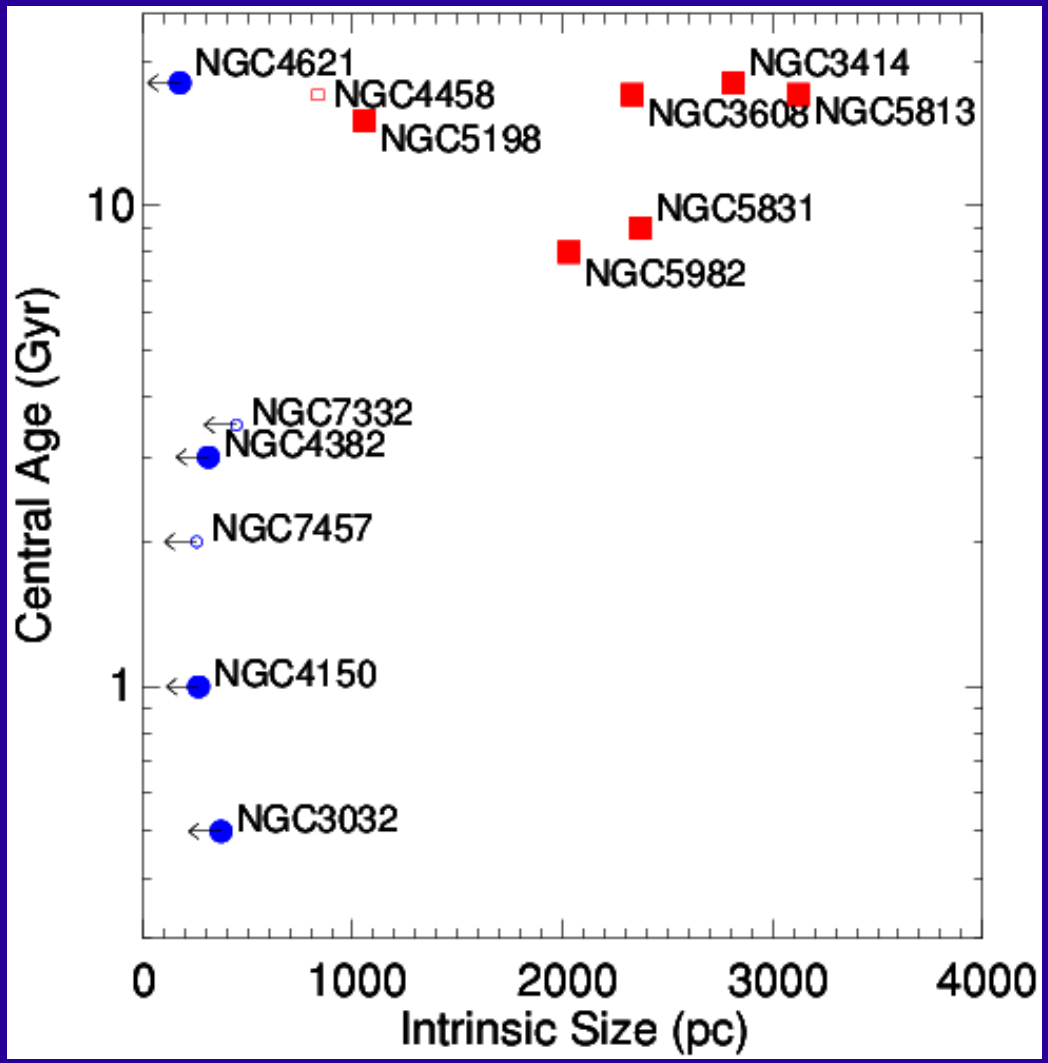
KDCs: Age-Size Dichotomy

(McDermid et al. 06)

SAURON-OASIS Data: Central pixel



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- Lightweight
- Young: distinct, increasingly young toward center
- Rotators

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- Large: kpc's ($0.3\text{-}0.4\ R_e$)
- Massive
- Coeval: homogeneously old
- Non-rotators

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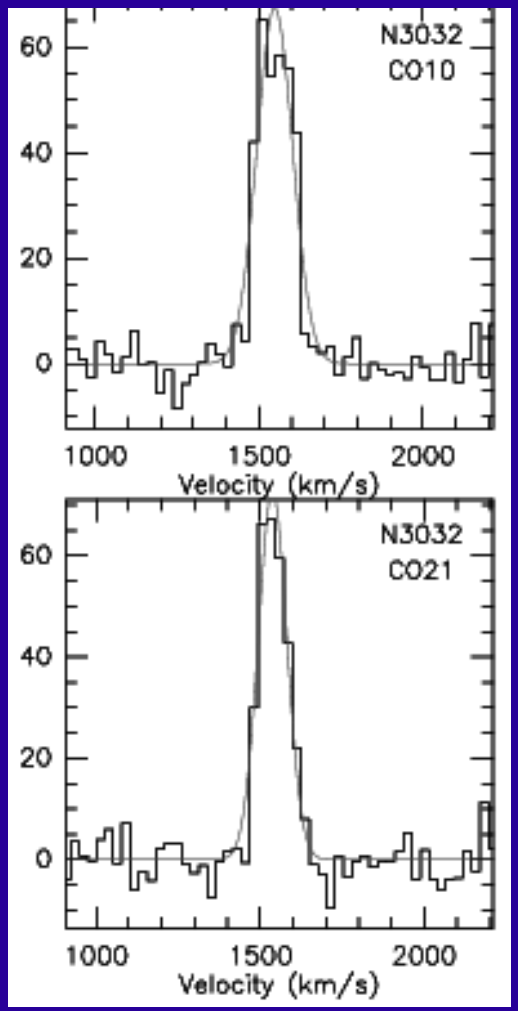
Summary

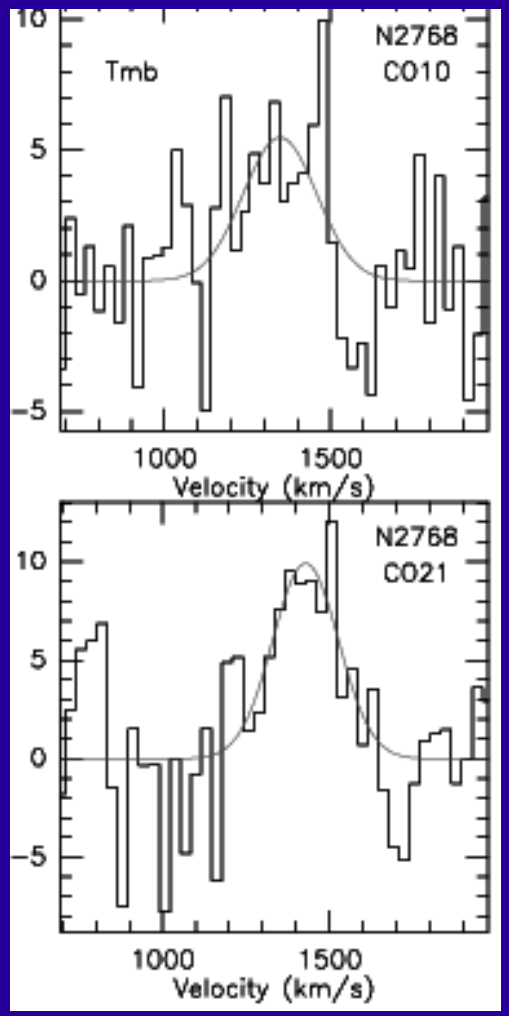
CO: Single-Dish Survey

(Combes, Young & Bureau 07)

High S/N:



Low S/N:



IRAM 30m Survey:

- CO(1-0), 23" FWHM
  (2-1), 12" FWHM
- 39/48 SAURON E/SOs
- Sensitivity: 2-4 mK (30 km s^{-1})
  1-5 x 10^7 $M_\odot$

✗ Literature results

Results:

- 28% detection rate (12/43)
- As expected for L, type
- $\langle CO(2\text{-}1)/CO(1\text{-}0) \rangle \approx 1.4$

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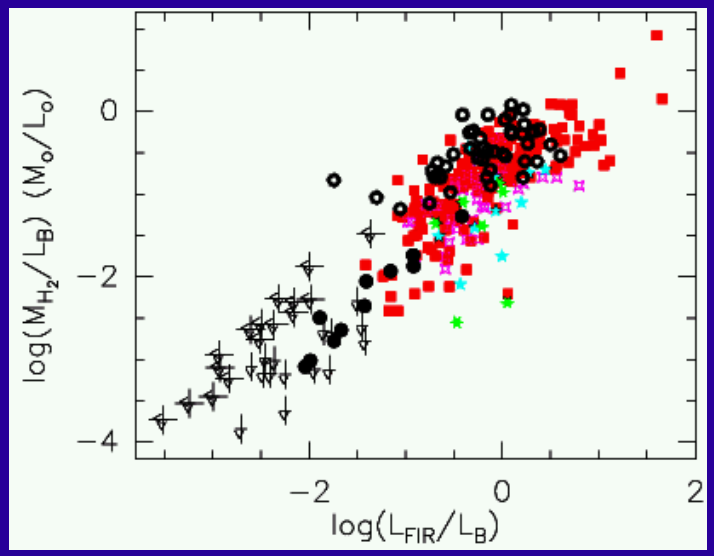
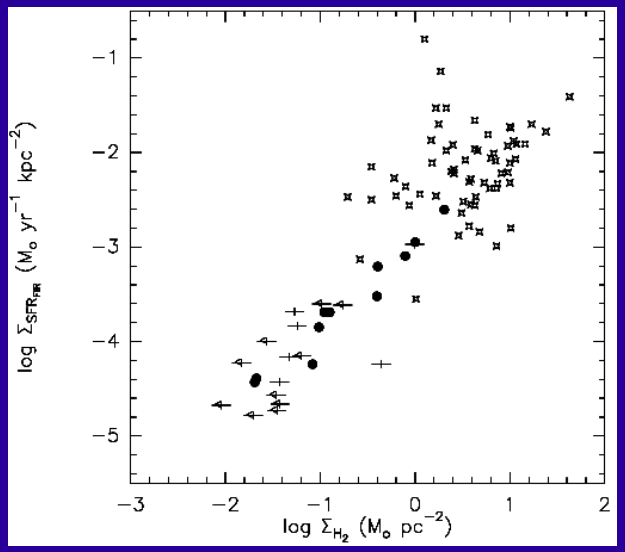
CO: Dust, FIR, SF

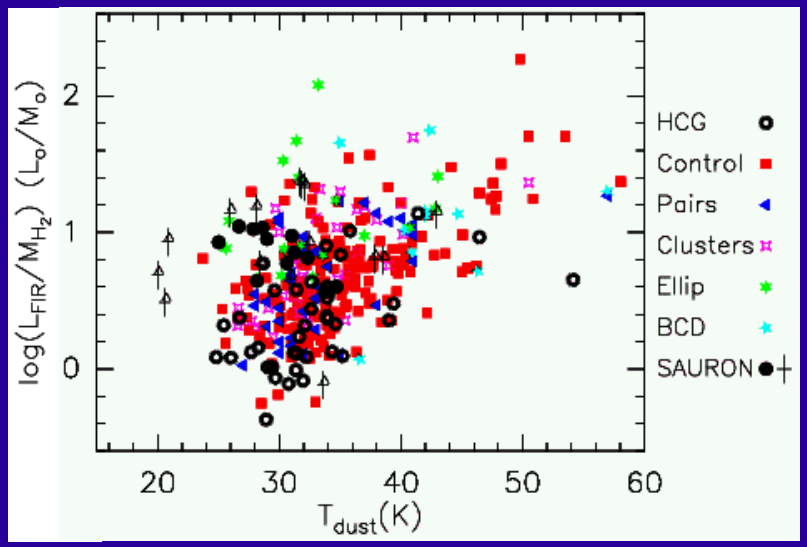
(Combes, Young & Bureau 07)

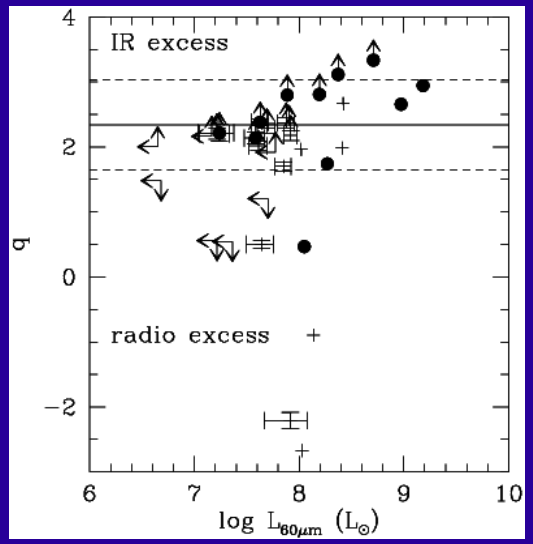




Correlations:

- ✗ More CO for …
  Low L, σ , Fe, Mg,
  B-V, age
  High type, Hβ, Hα





- Extension of:
  M_{H2} – FIR correlation
  Kennicutt - Schmidt relation
- SF:
  High SFE
  IR-excess

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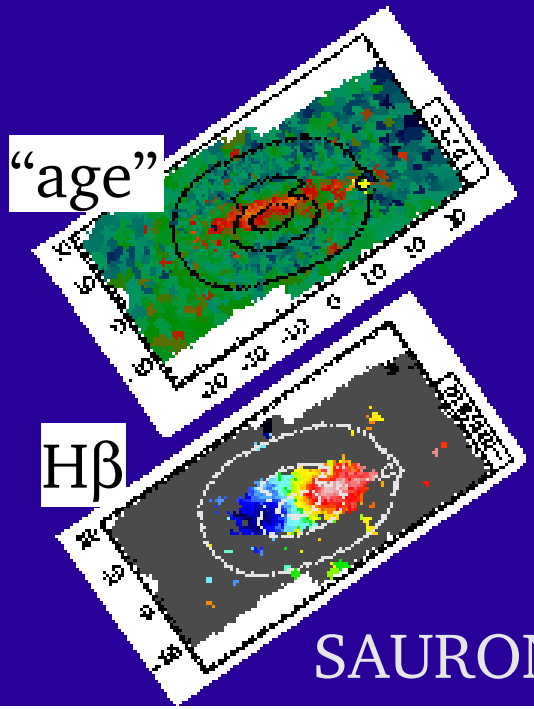
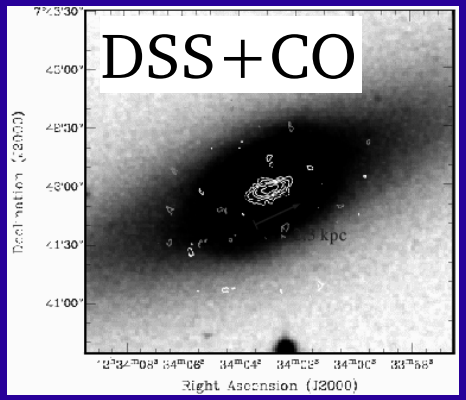
CO: Central Disks

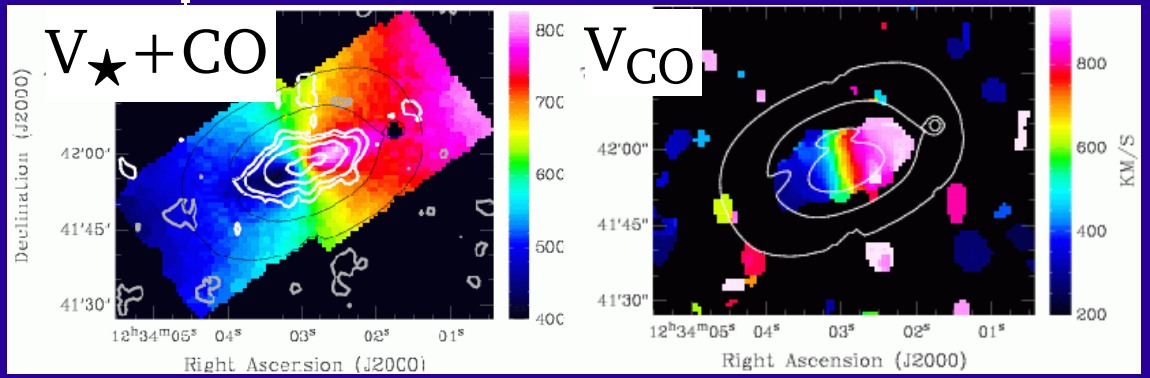
(Young, Bureau & Cappellari 08; Bureau & Young, in prep)

BIMA-SAURON Data: NGC4526





SAURON CO



Central Disks:

- CO cospatial with young stars and central stellar/gas disk
- CO and stars/gas co-rotating

CRs:

- CO roughly cospatial with young stars and CR/gas (generally less extended)
- CO and stars/gas kinematics unrelated ? (triggered SF?)

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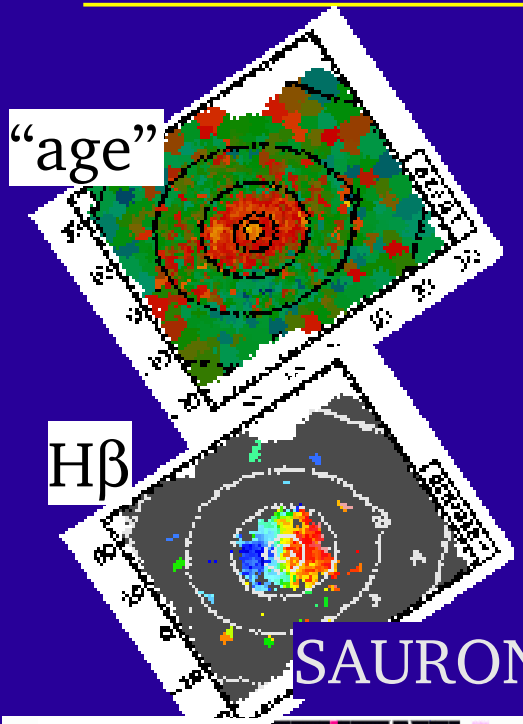
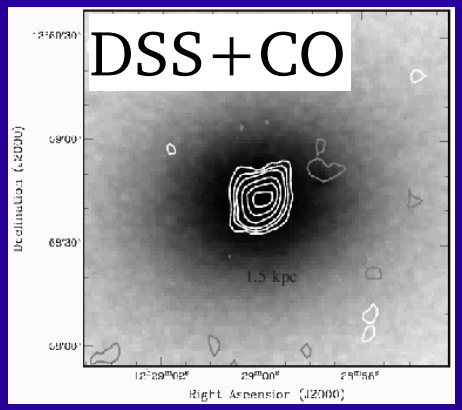
CO: Central Disks

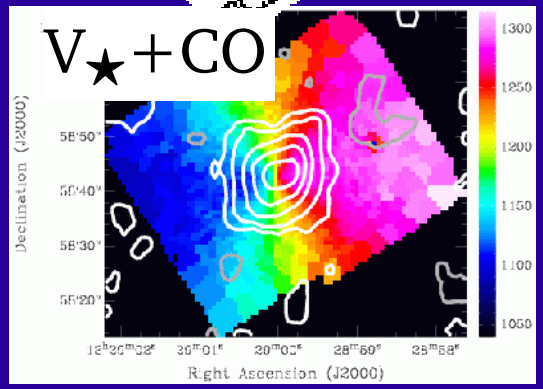
(Young, Bureau & Cappellari 08; Bureau & Young, in prep)

BIMA-SAURON Data: NGC4459

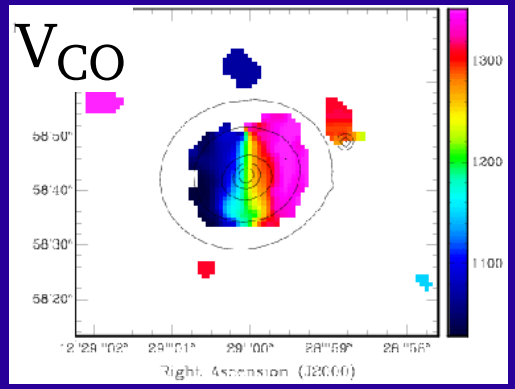




SAURON



CO



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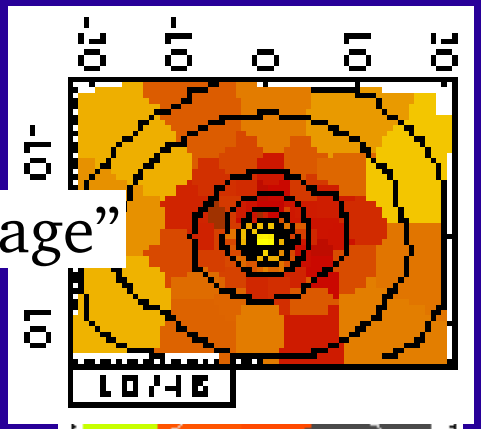
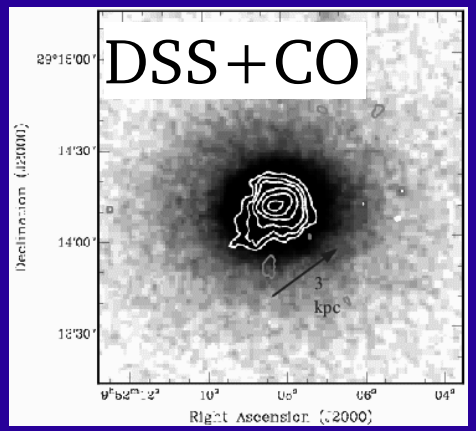
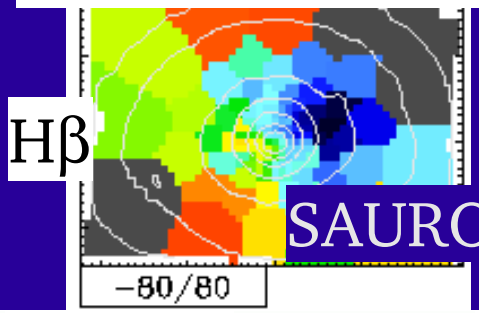
CO: Central Disks

(Young, Bureau & Cappellari 08; Bureau & Young, in prep)

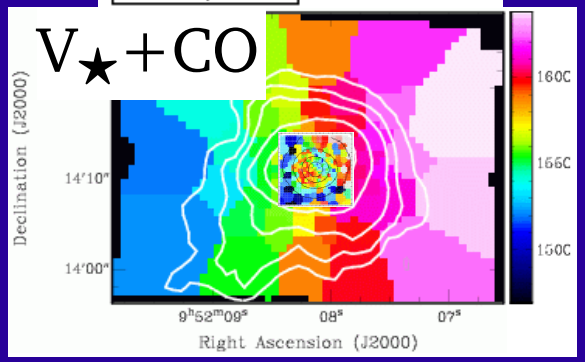
BIMA-SAURON Data: NGC3032

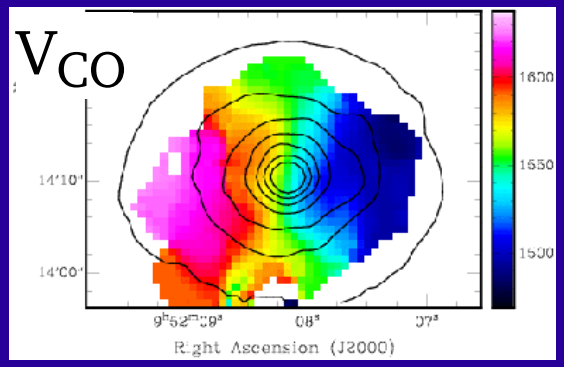






CO





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(Young, Bureau & Cappellari 08; Bureau & Young, in prep)

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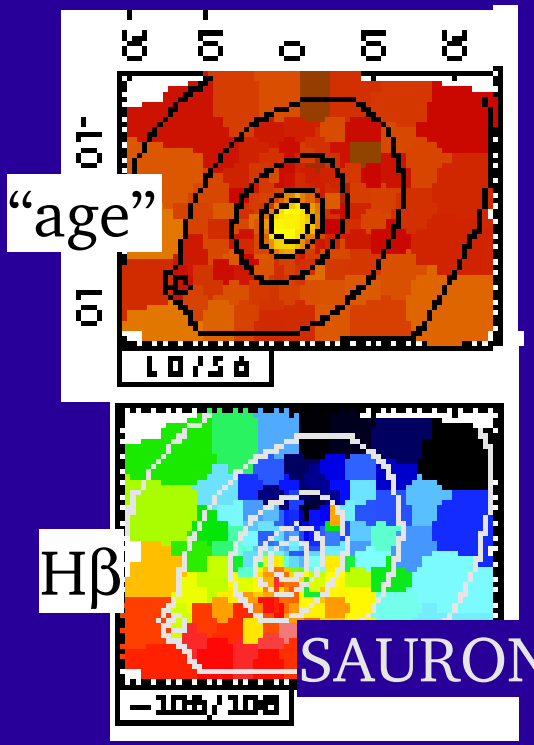

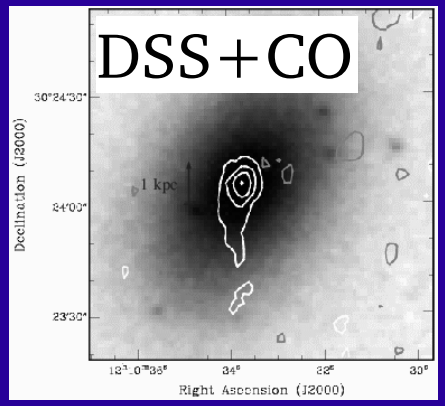

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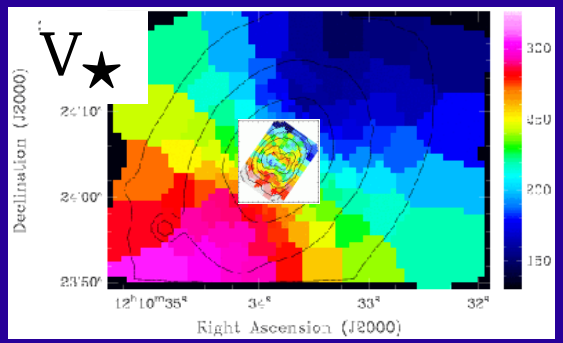

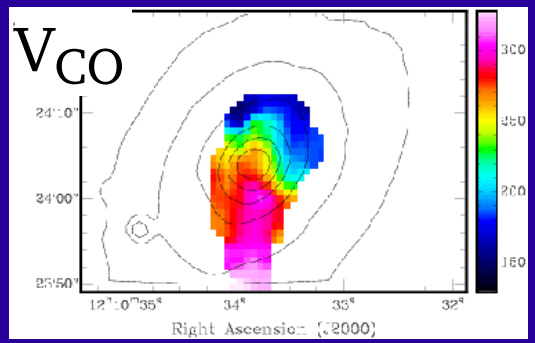

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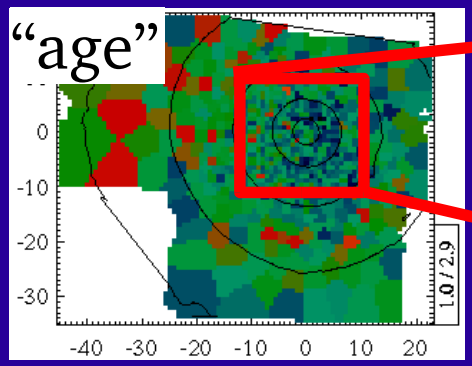
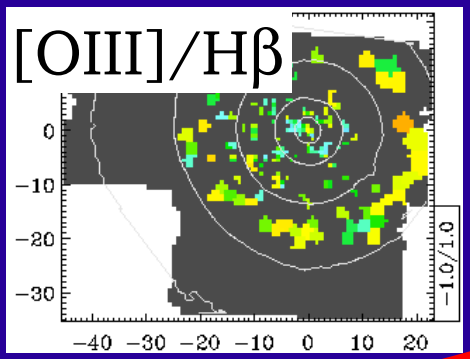
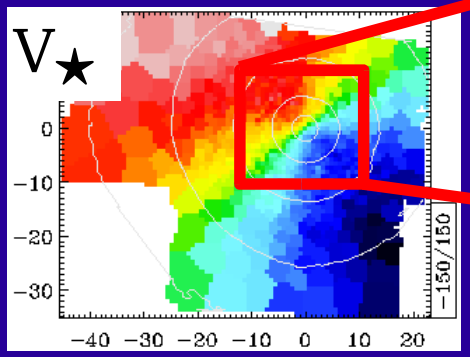
CO: SF Sequence?

(Crocker et al., in prep)

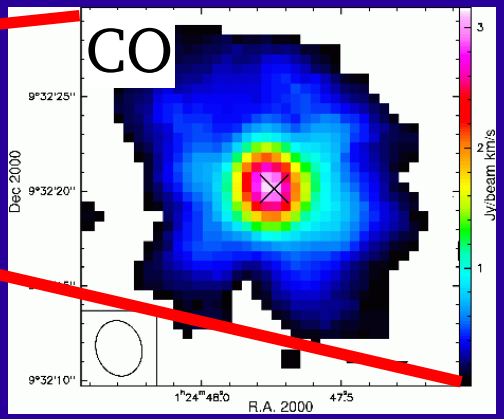
PdBI-SAURON Data: NGC524



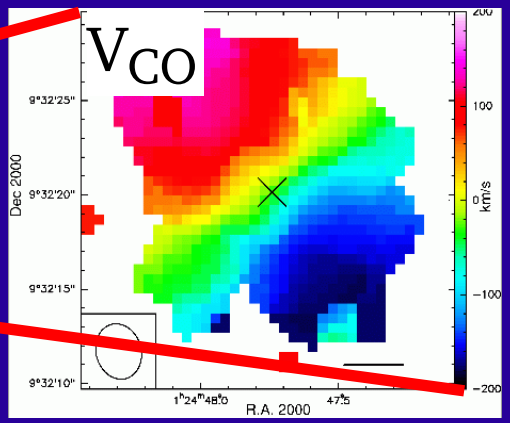




SAURON



CO



SF sequence:

- Current SF
  (low [OIII]/Hβ)
- Recent SF
  (high Hβ linestrength)
- No/weak SF
  (high [OIII]/Hβ, low Hβ)

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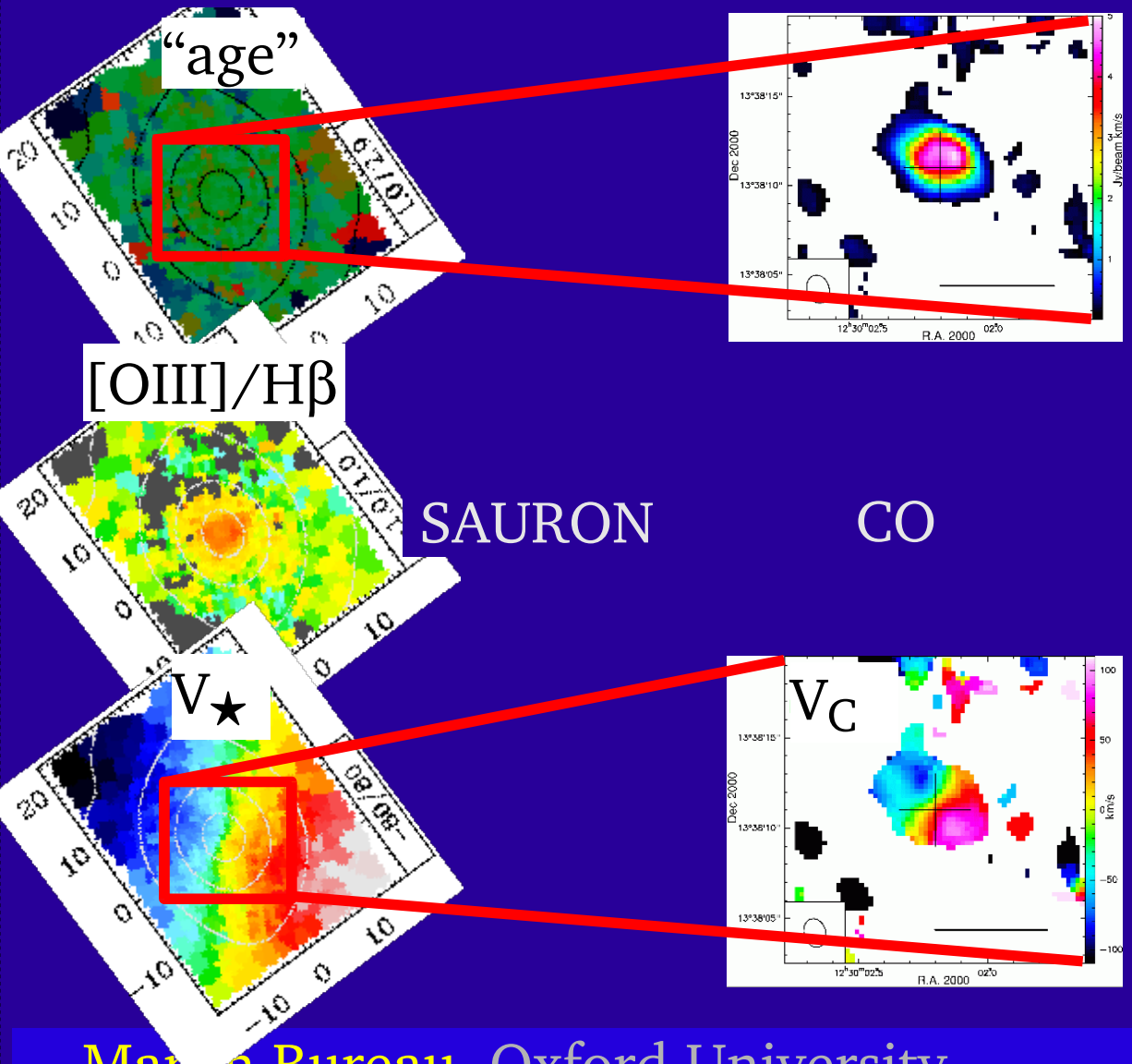
CO: SF Sequence?

(Crocker et al., in prep)

PdBI-SAURON Data: NGC4477



SF sequence:

- Current SF
  (low [OIII]/Hβ)
- Recent SF
  (high Hβ linestrength)
- No/weak SF
  (high [OIII]/Hβ, low Hβ)

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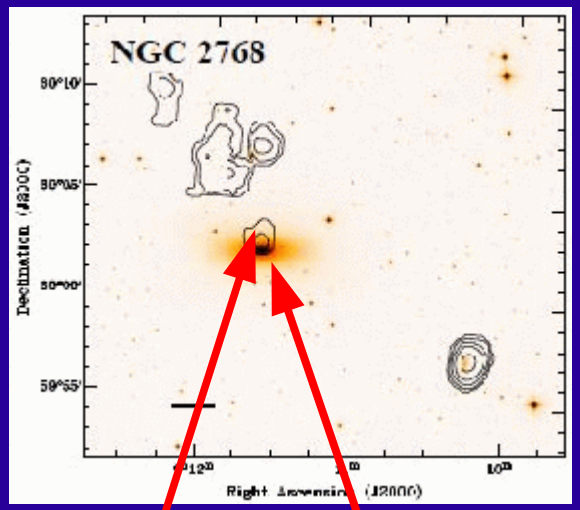
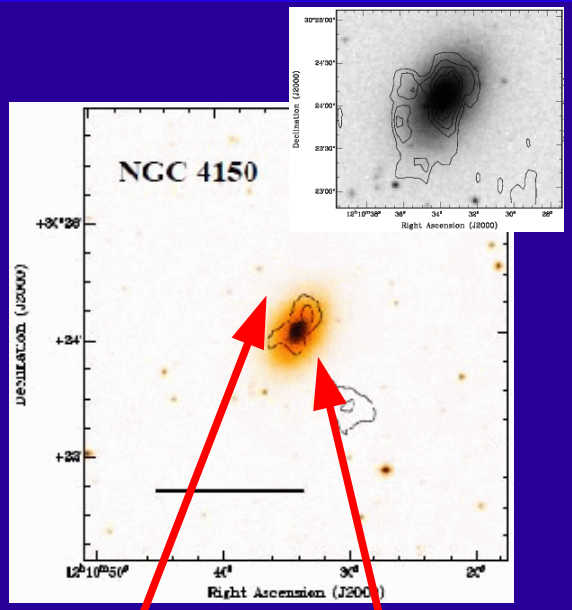
CO: External Accretion

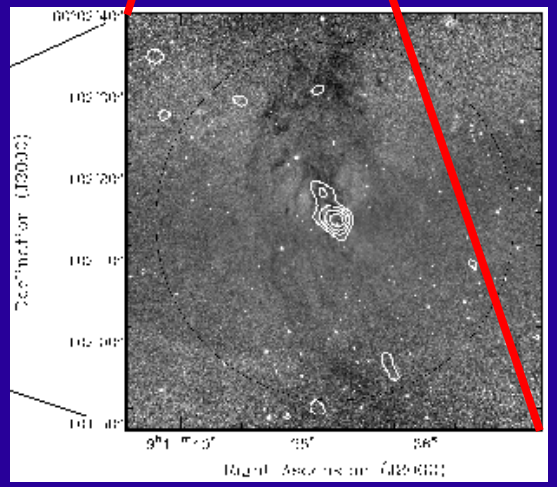
HI:

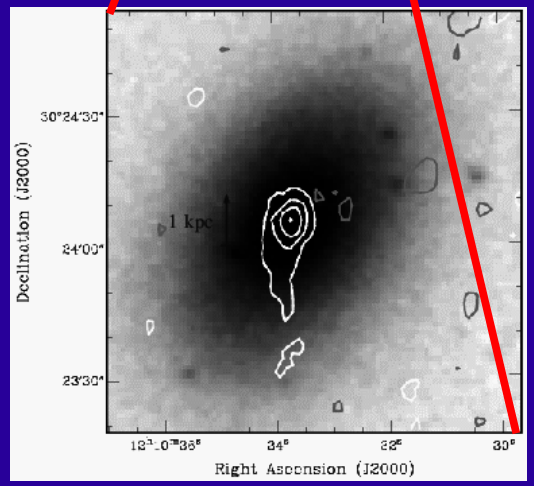




(Morganti et al. 06)

CO:





NGC2685, NGC2768:

- Generic accretion model for polar rings (although likely a polar disk)

Generally:

- Disturbed HI (Morganti et al. 06)
- Lack of strong correlations CO-optical (e.g. scale, L, ...)

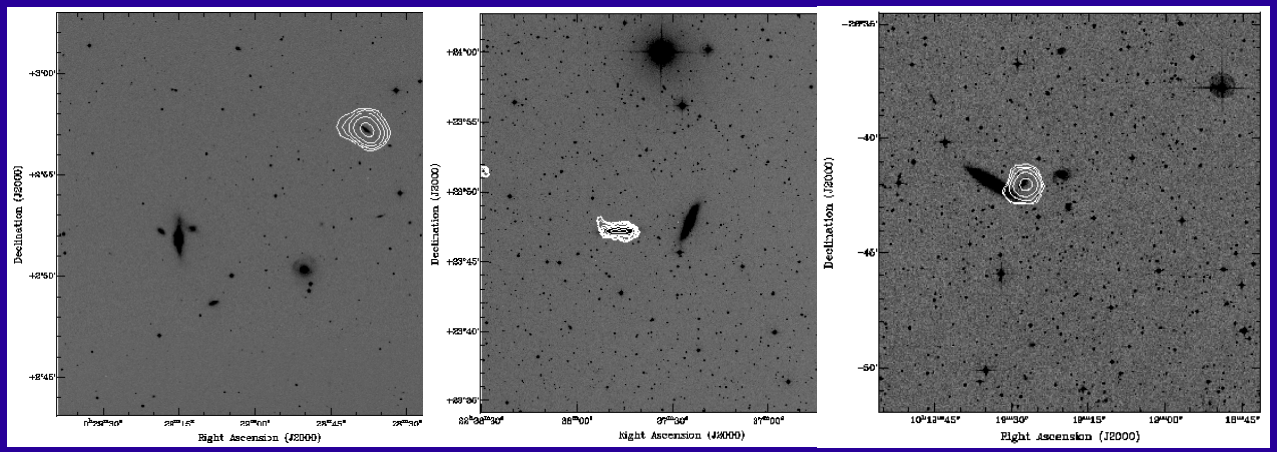
✗ Some galaxies with CO but no HI!

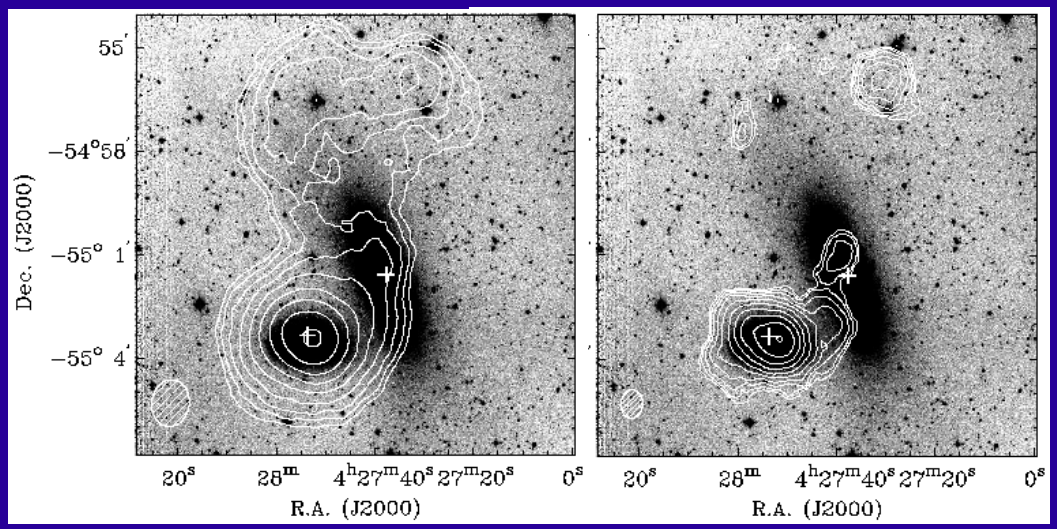
Martin Bureau, Oxford University

HI: NGC128, 3203, 7332, 1596

(Bureau & Chung 06; Chung et al. 06; Chung et al., in prep)

VLA + ATCA:





HI Structure:

- NGC128: Distant HI-rich companion
- NGC7332: Nearby HI-rich companion
- NGC3203: Interacting? HI-rich companion
- NGC1596: Interacting HI-rich companion

⇒ Circumstantial evidence for cold accretion and/or minor mergers

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CO: Future

Atlas^{3D}:

- Complete volume-limited E/SO sample:
  - 264 E/S0s within ≈ 40 Mpc, complete WHT/SAURON data
    (≈ 215 new Northern targets; 38 nights)
  - IRAM 30m CO survey ongoing... 80% complete (213/264)
    (20% detection rate; no significant cluster-field difference)
    (no detection in slow rotators)
  - CARMA CO follow-up ongoing... starts July 2008
    (D array; Berkeley commitment; 130 hours/11 objects this term)

✗ Other diagnostics: multiple transitions, multiple species

✗ Perfect benchmark for ALMA

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The Gas-Star Cycle in Nearby Early-Types: UV, Optical, CO, HI

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SAURON
(R. Bacon, M. Cappellari, R.L. Davies, E. Emsellem, J. Falcon-Barroso, D. Krajnovic, M. Sarzi, H. Kuntschner, R.M. McDermid, R.F. Peletier, G. van de Ven, P.T. de Zeeuw)
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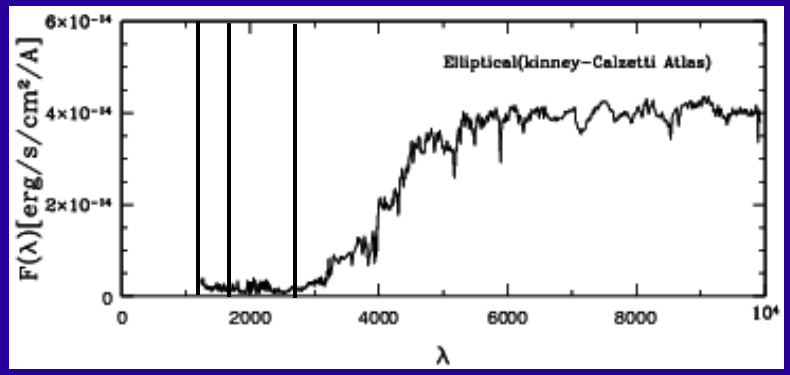
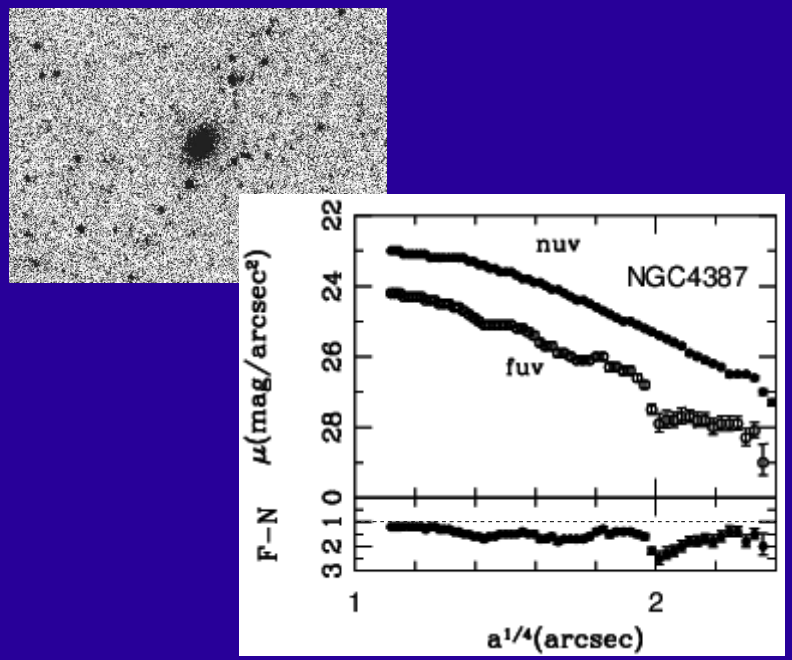
UV/GALEX, HI: Current and recent star formation
Summary

GALEX: UV Emission in E/S0s

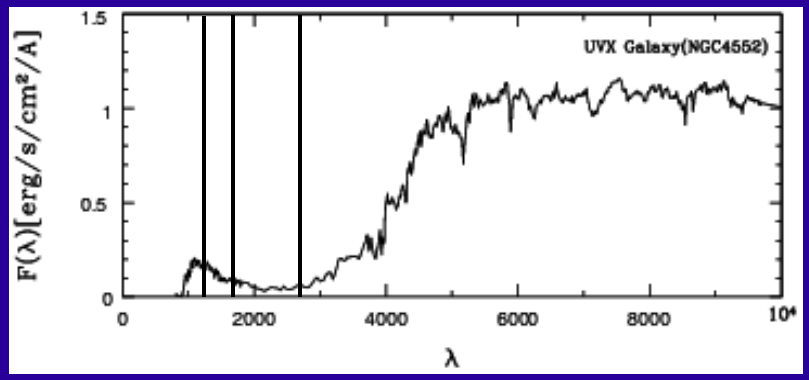
(Jeong et al., in prep)

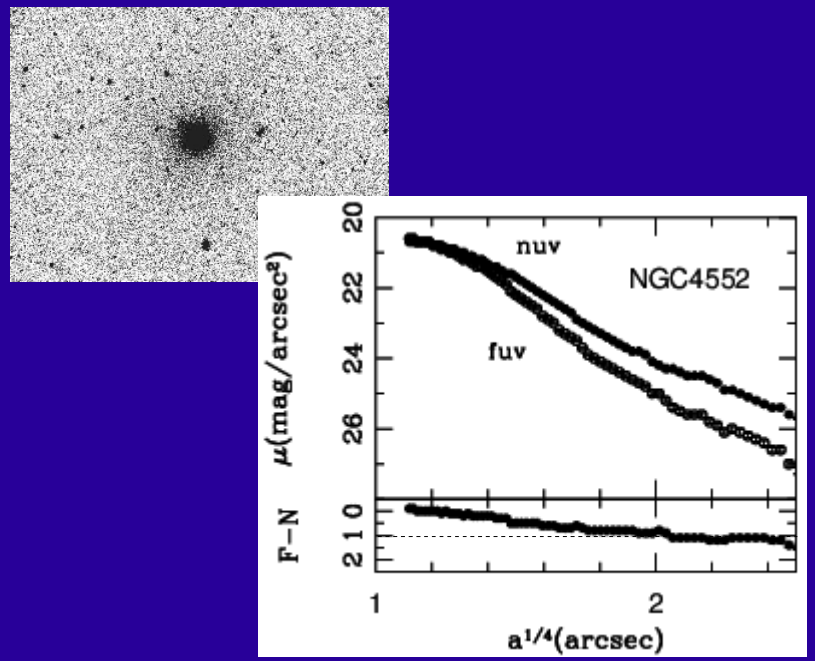
Normal:





UV Upturn:





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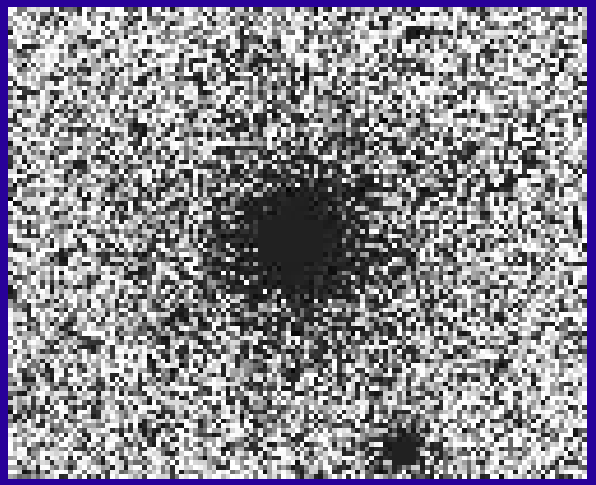
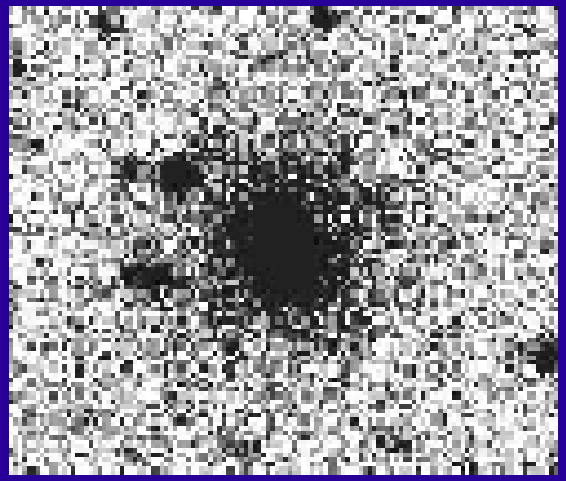
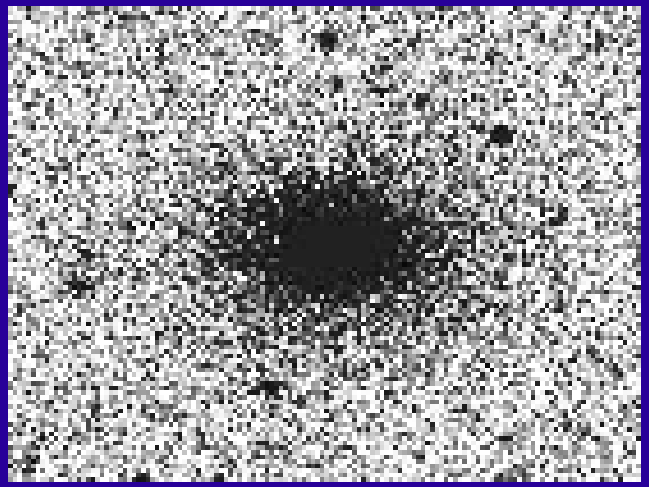
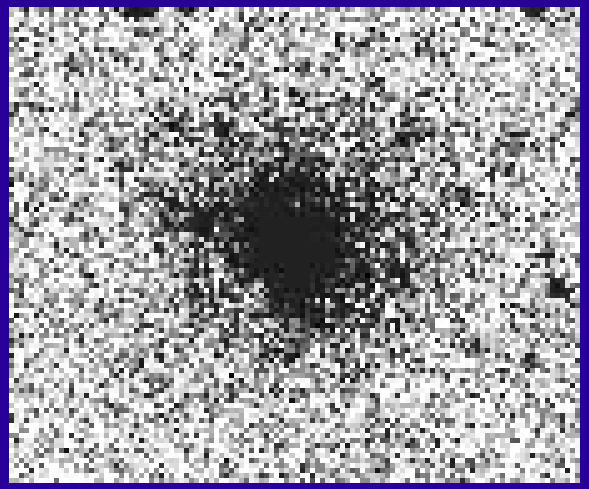
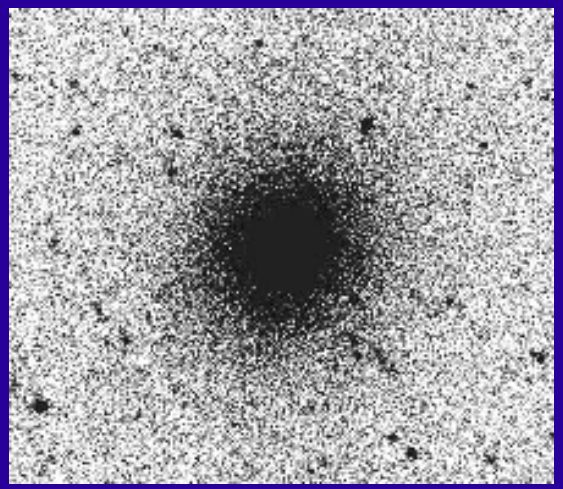
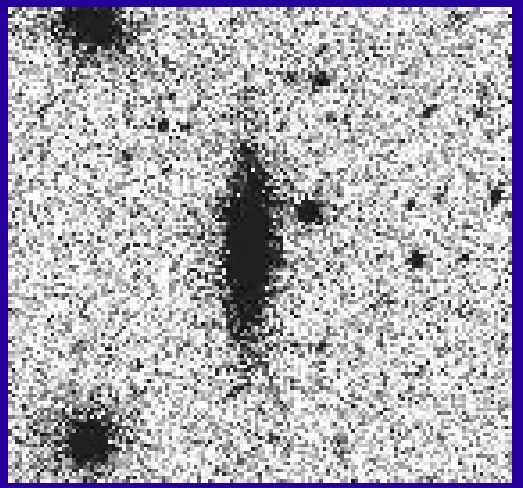
GALEX: Standard

(Jeong et al., in prep)

UV Morphologies: Standard

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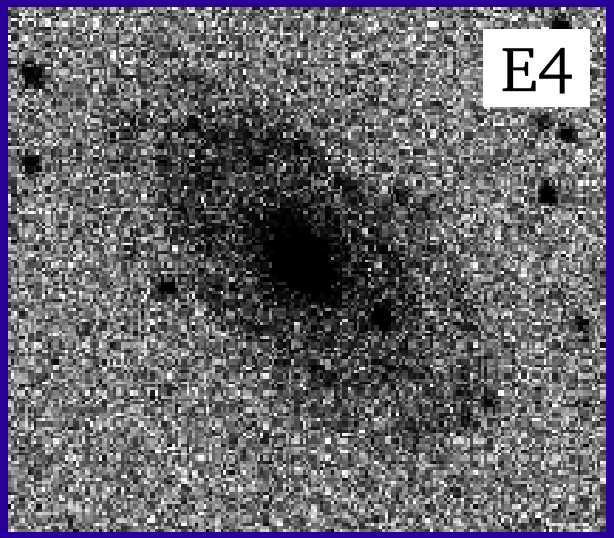
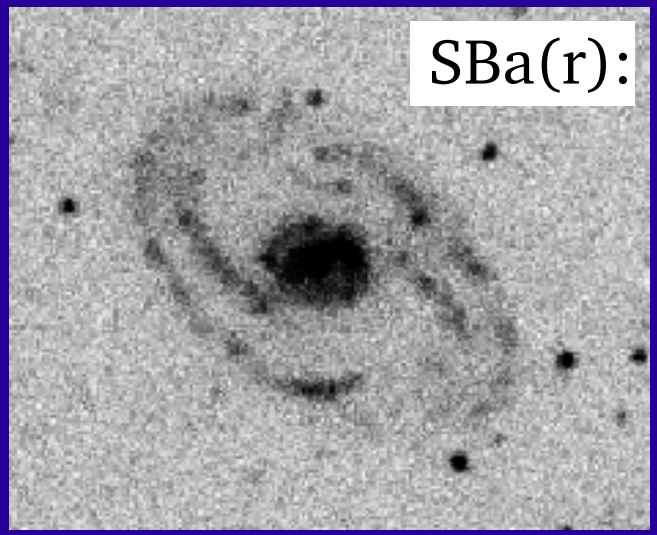
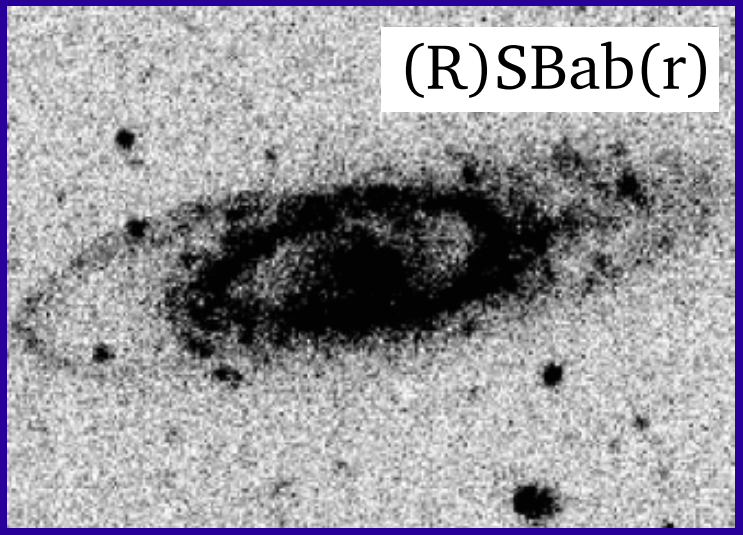
GALEX: Exceptional

(Jeong et al., in prep)

UV Morphologies: Exceptional







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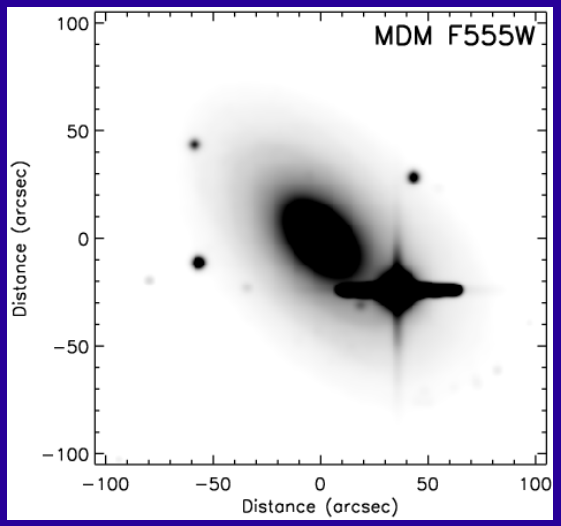
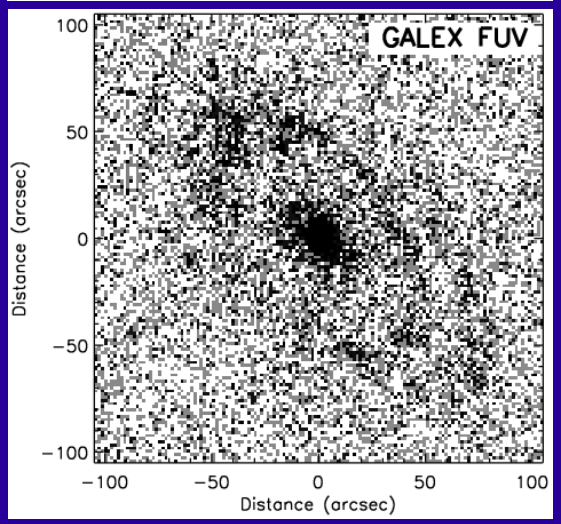
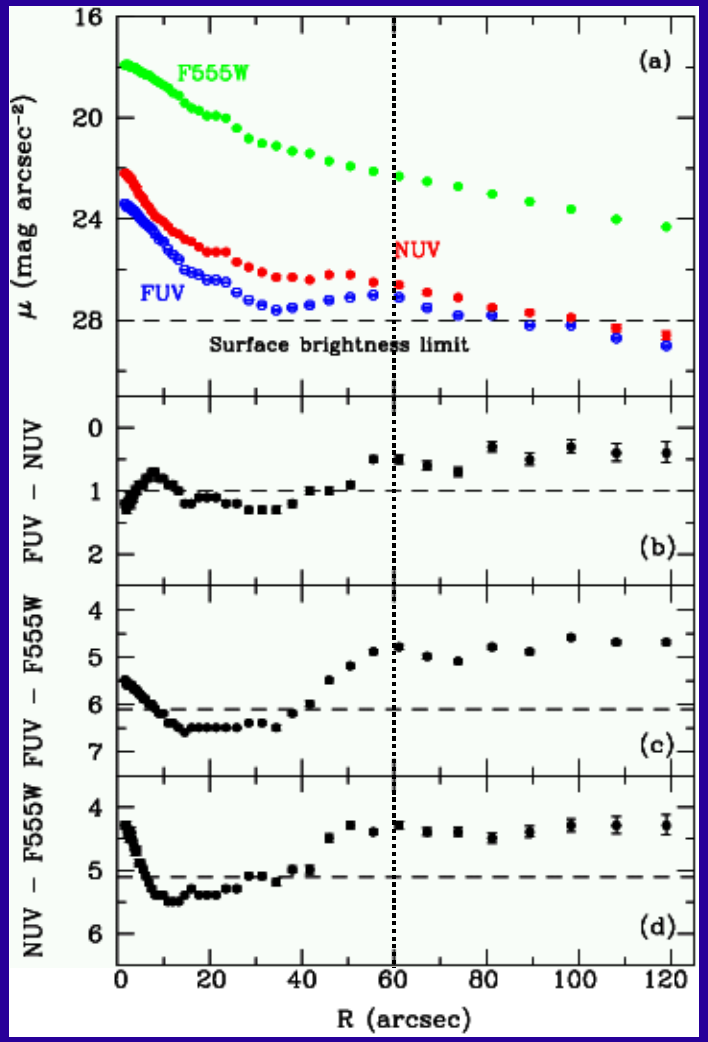
NGC2974: UV Morphology - Kin.

(Jeong et al. 07)

Optical-UV Imaging:







Distribution:

- Young stars and RSF (UV bright and blue) in centre + outer ring
- Possible larger partial ring

Barred Dynamics:

- [OIII] nuclear and inner rings
- Imply unique pattern speed

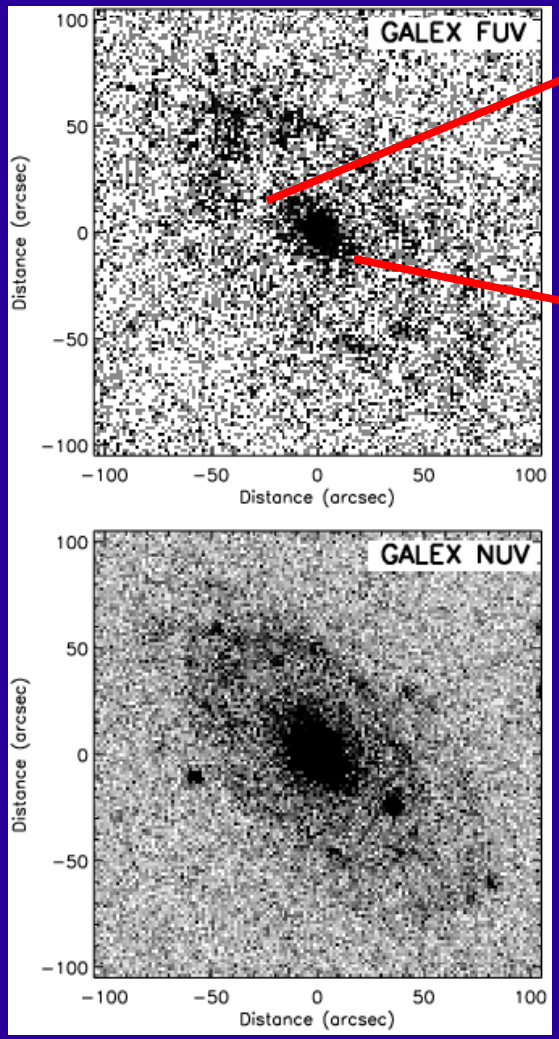
⇒ Bar-driven SF (single pattern speed)

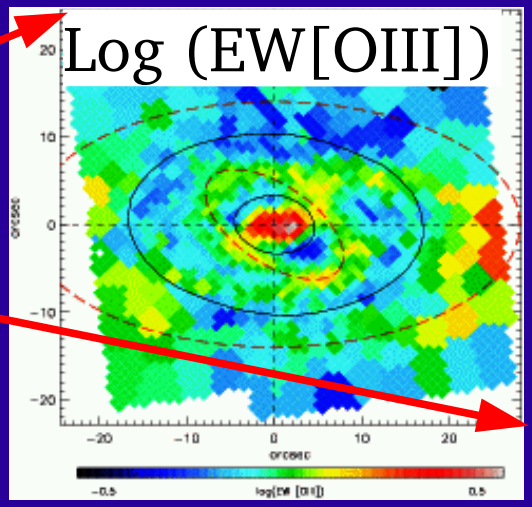
Martin Bureau, Oxford University

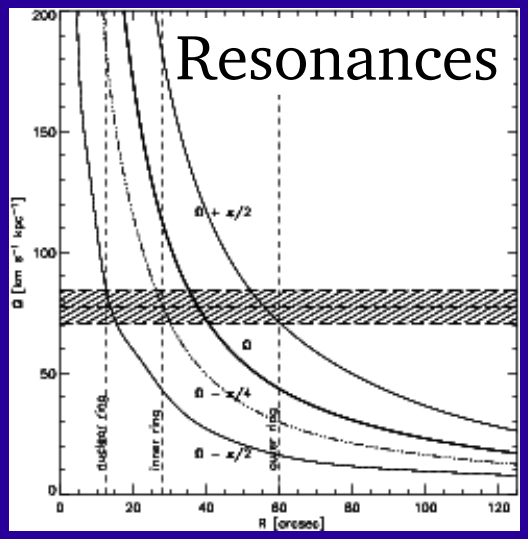
NGC2974: UV Morphology - Kin.

(Jeong et al. 07)

Optical-UV Imaging:







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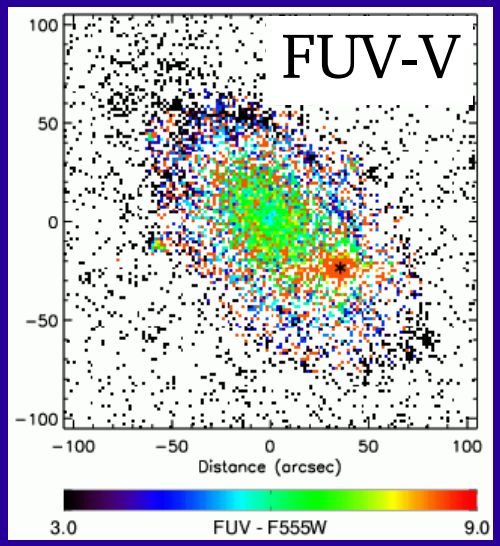
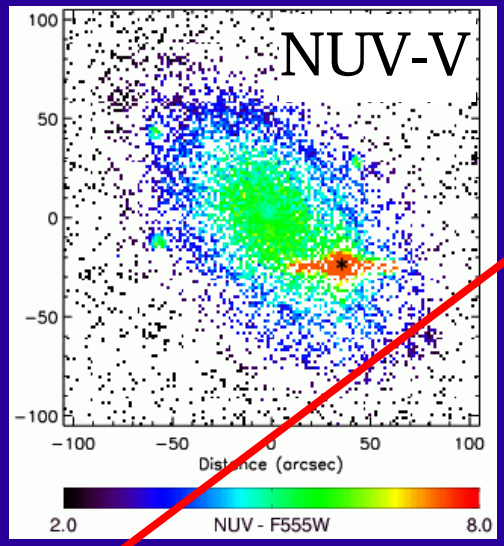
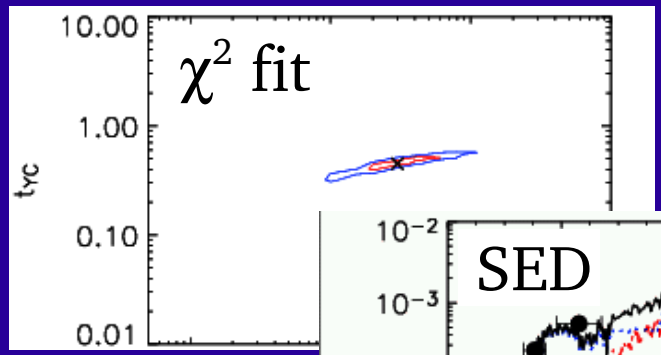
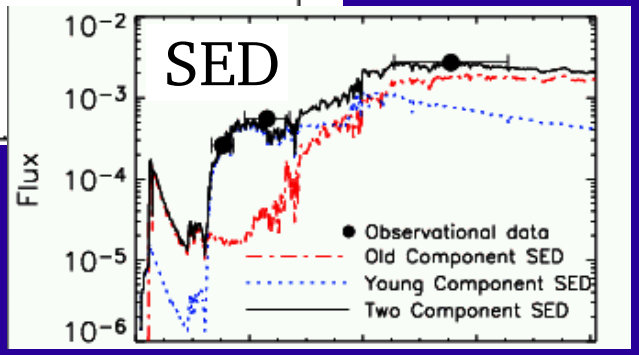
NGC2974: Stellar Pop. Modeling

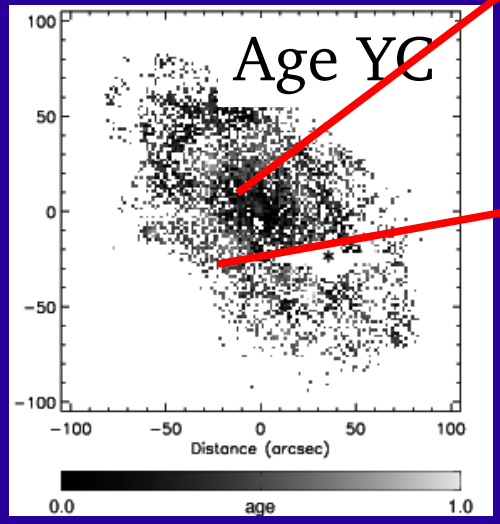
(Jeong et al. 07)

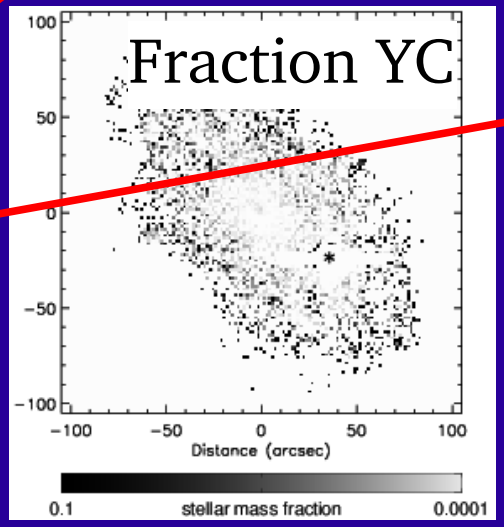


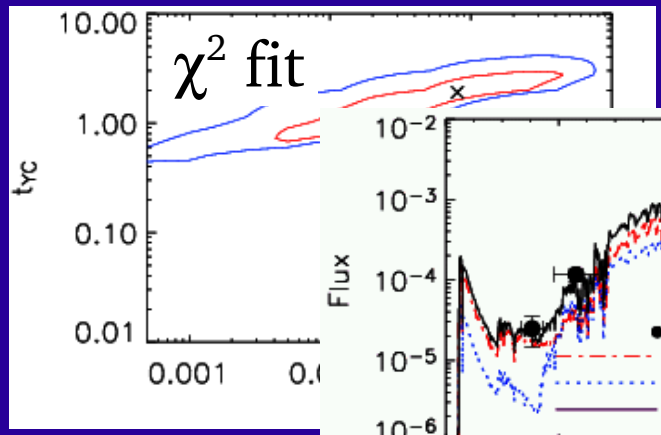


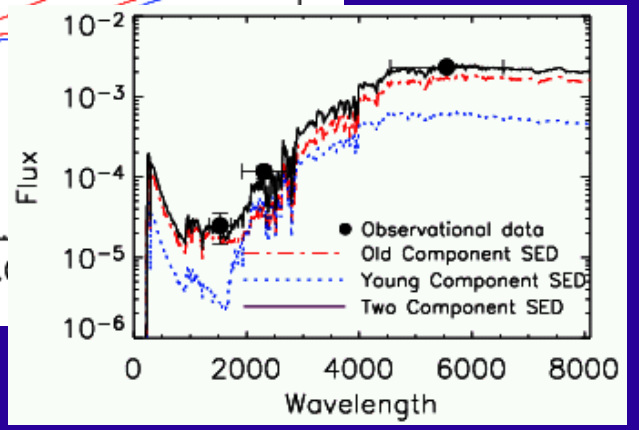












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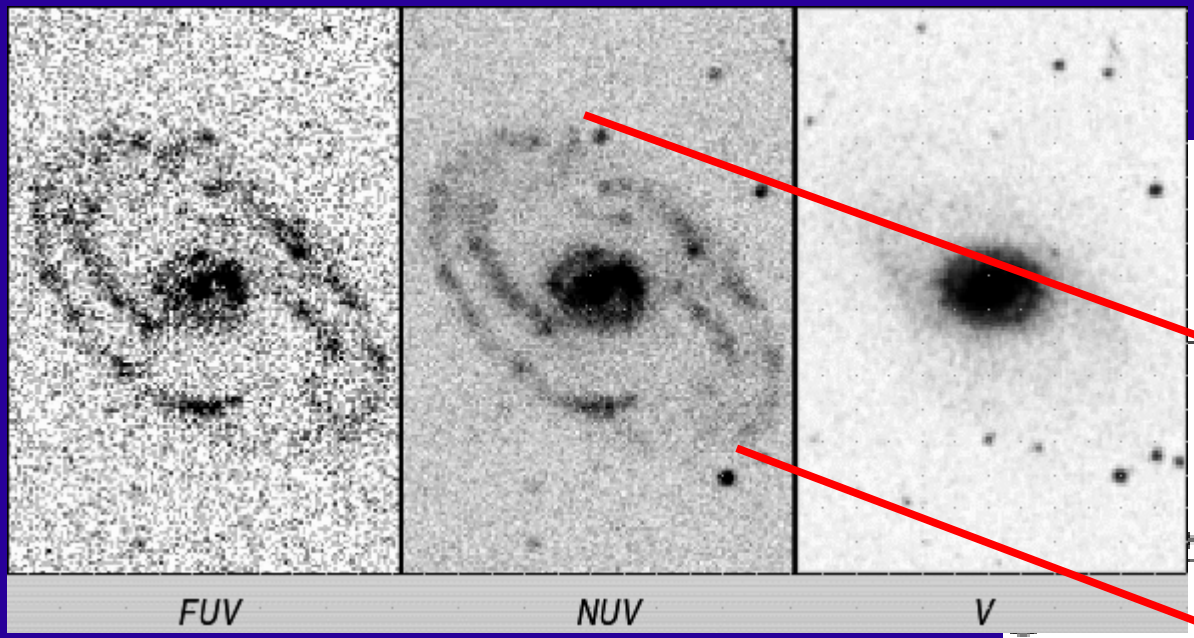
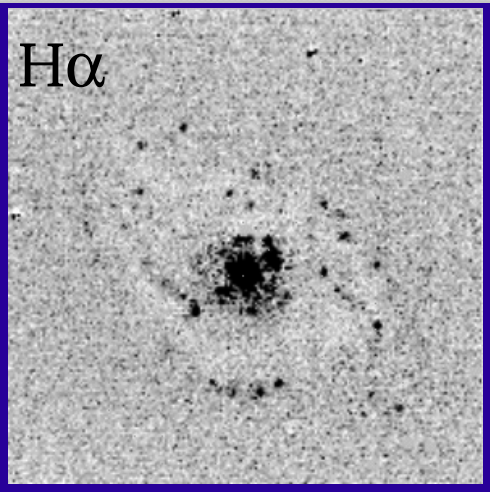
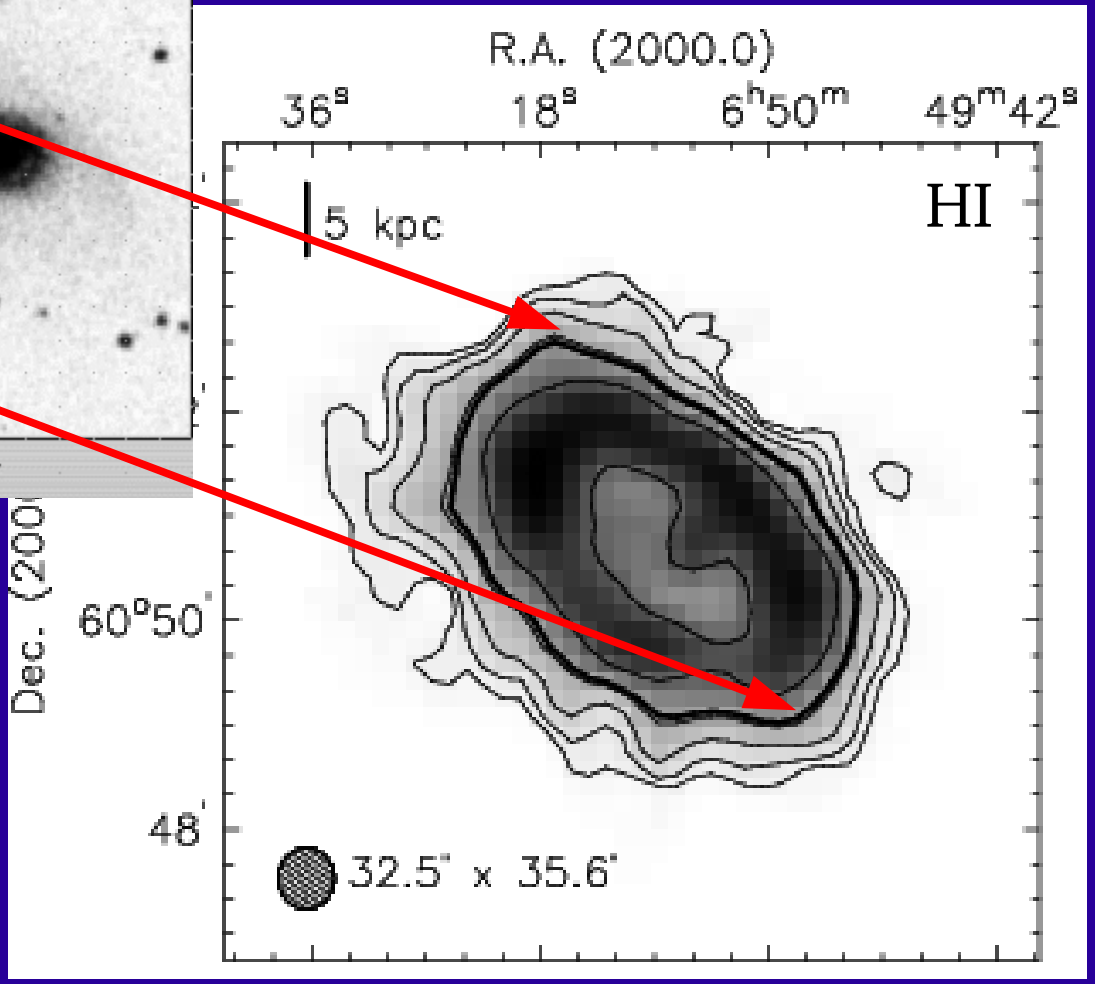
Other Cases: NGC2273

(Jeong et al., in prep)

GALEX-MDM:





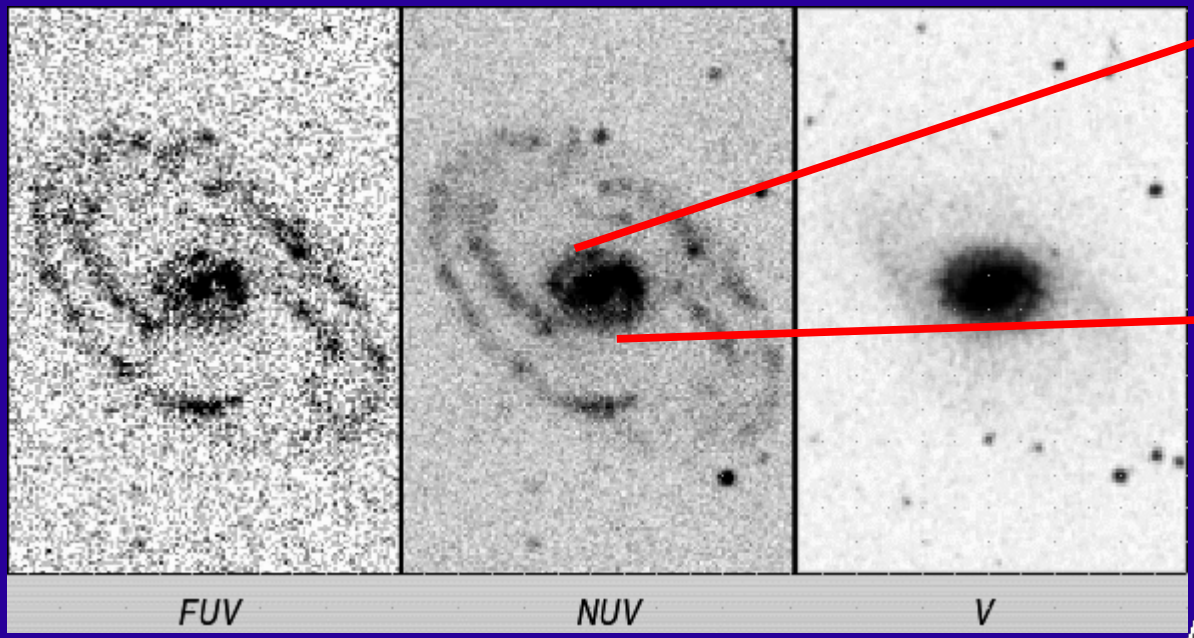


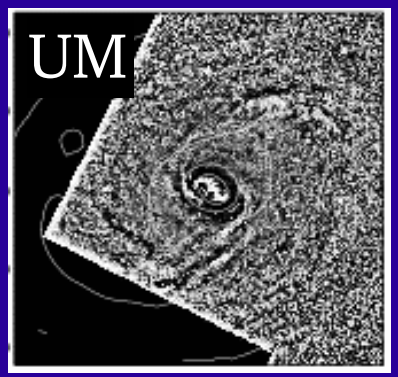
Martin Bureau, Oxford University

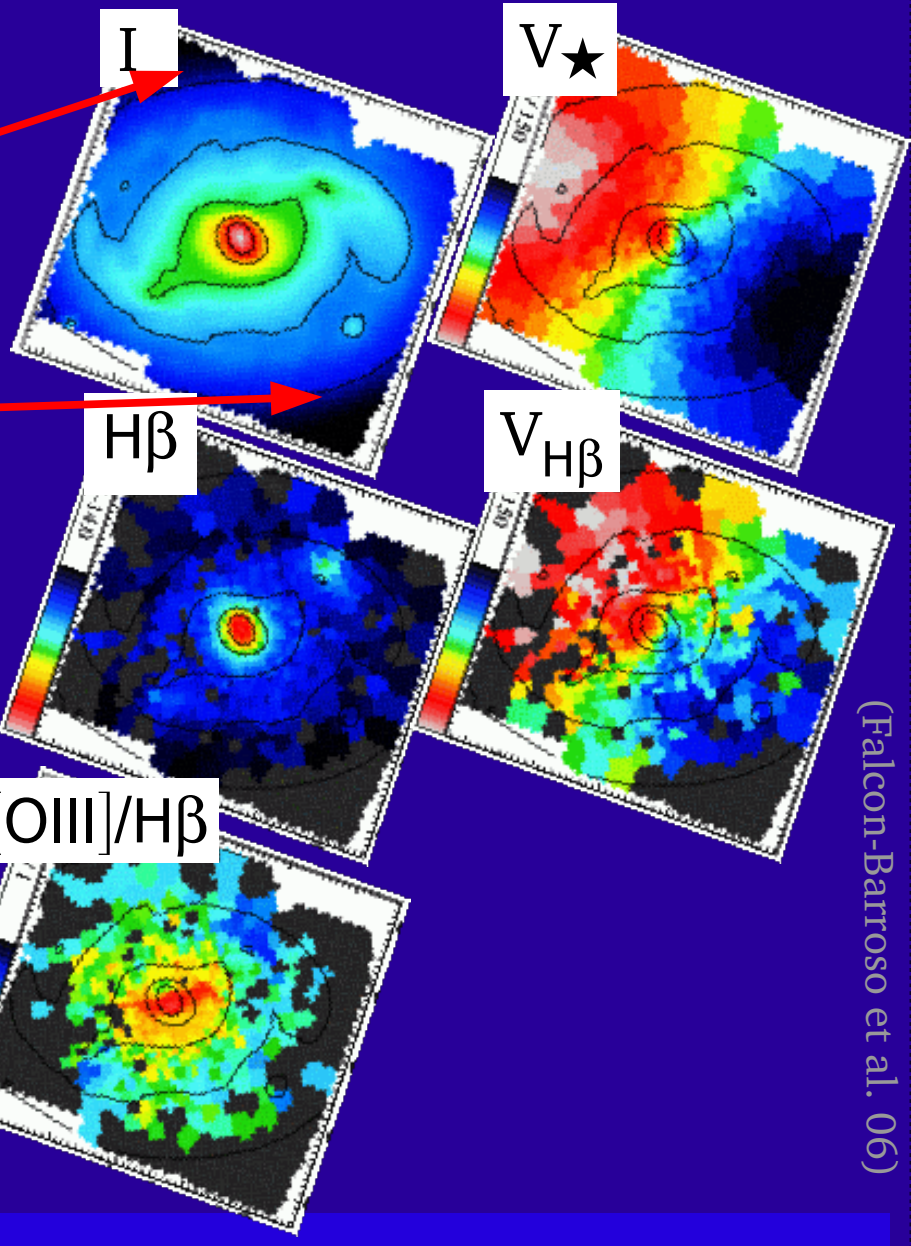
Other Cases: NGC2273

(Jeong et al., in prep)

GALEX-MDM:







(Falcon-Barroso et al. 06)

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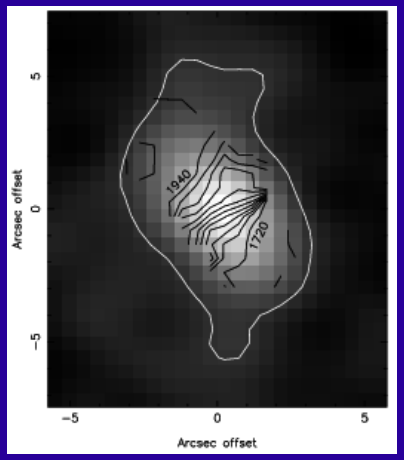
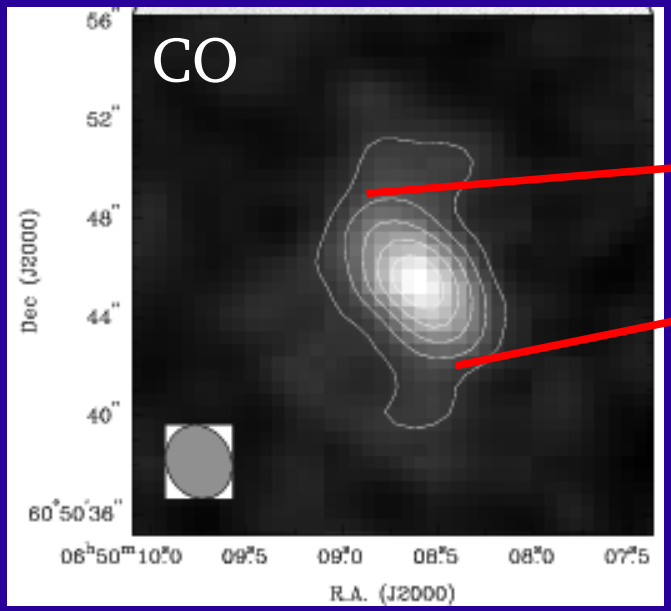
Other Cases: NGC2273

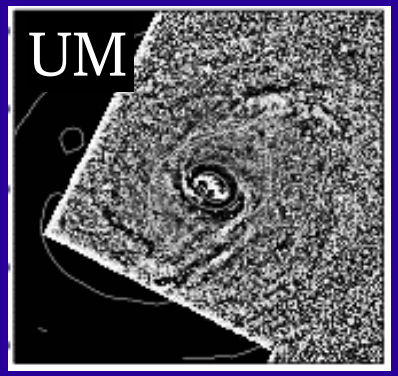
(Jeong et al., in prep)

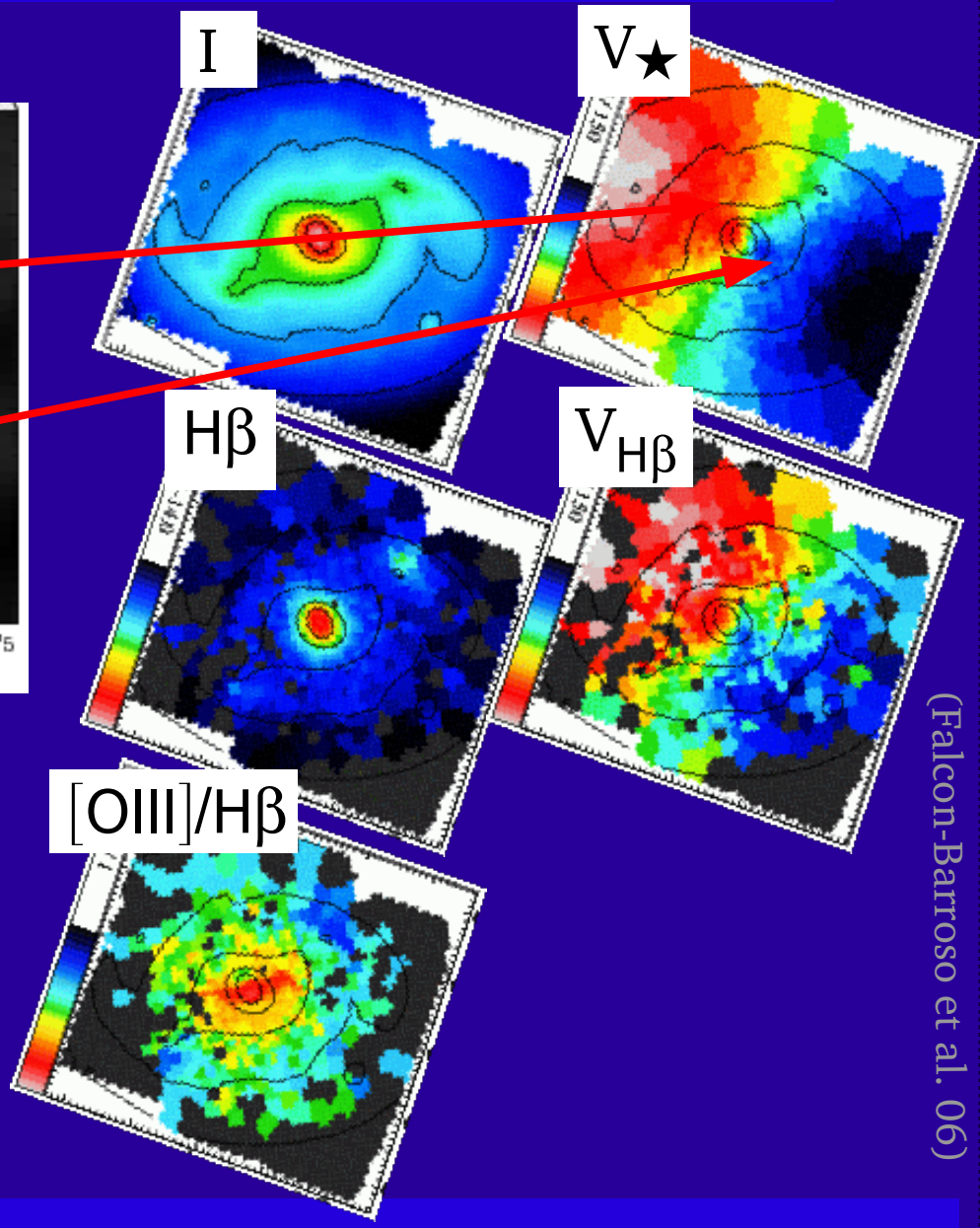
GALEX-MDM:



(Petitpas & Wilson 02)







(Falcon-Barroso et al. 06)

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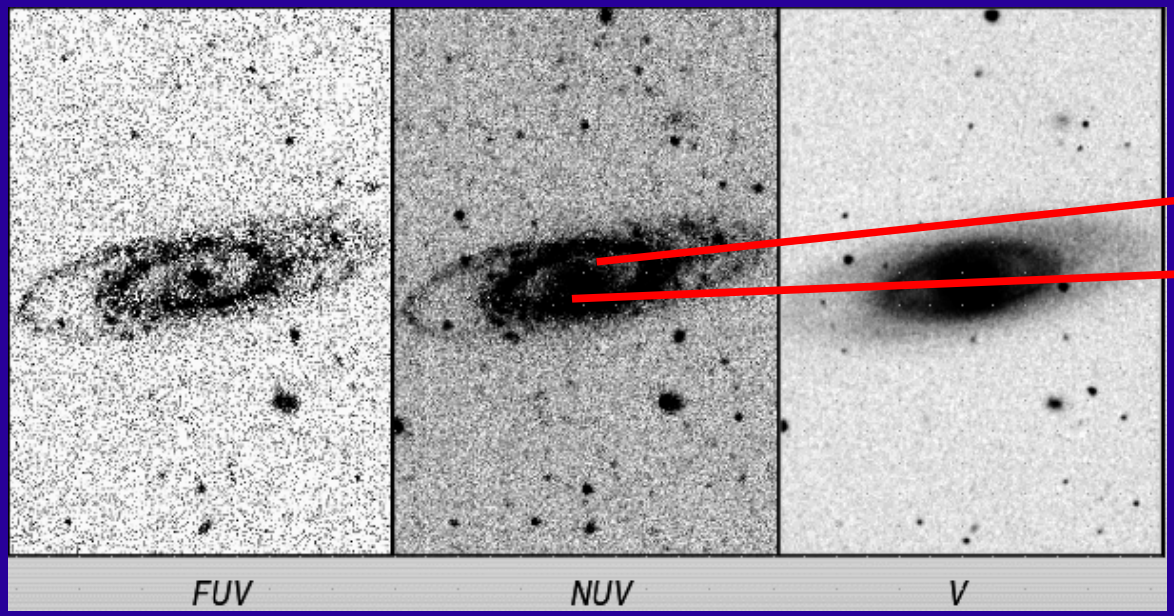
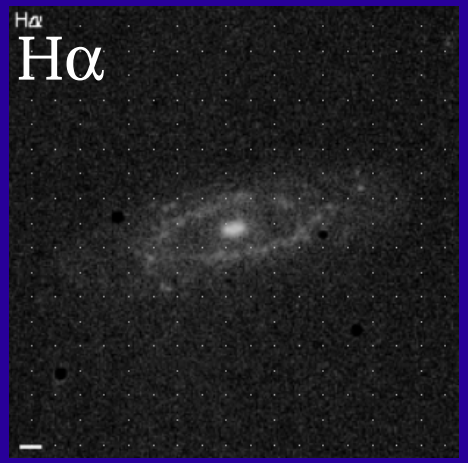
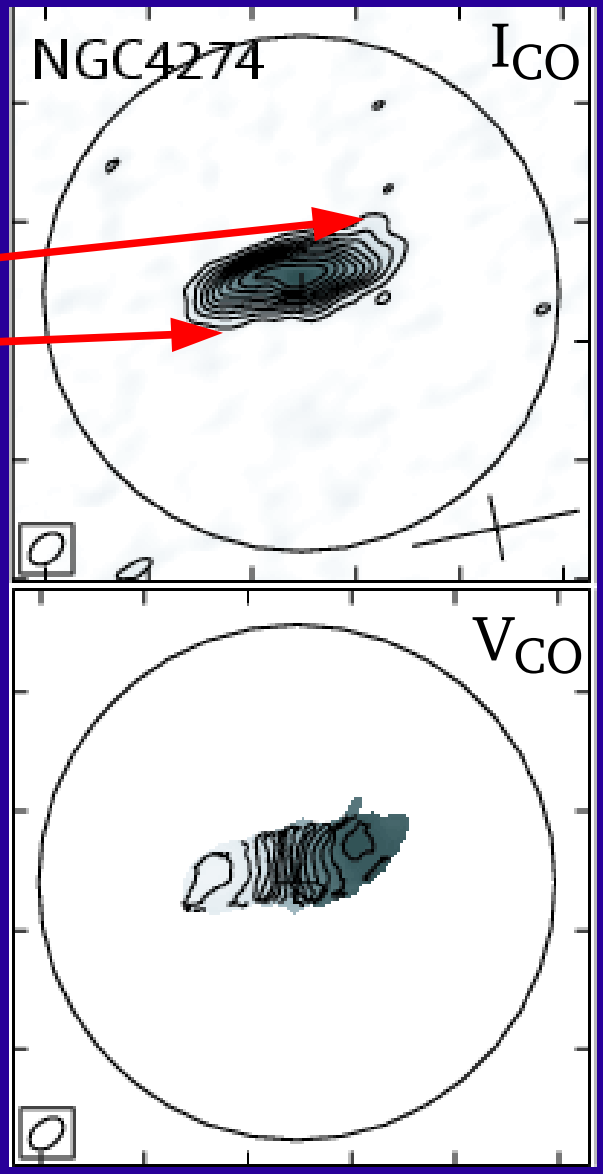
Other Cases: NGC4274

(Jeong et al., in prep)

GALEX-MDM:







(Koda et al. 05)

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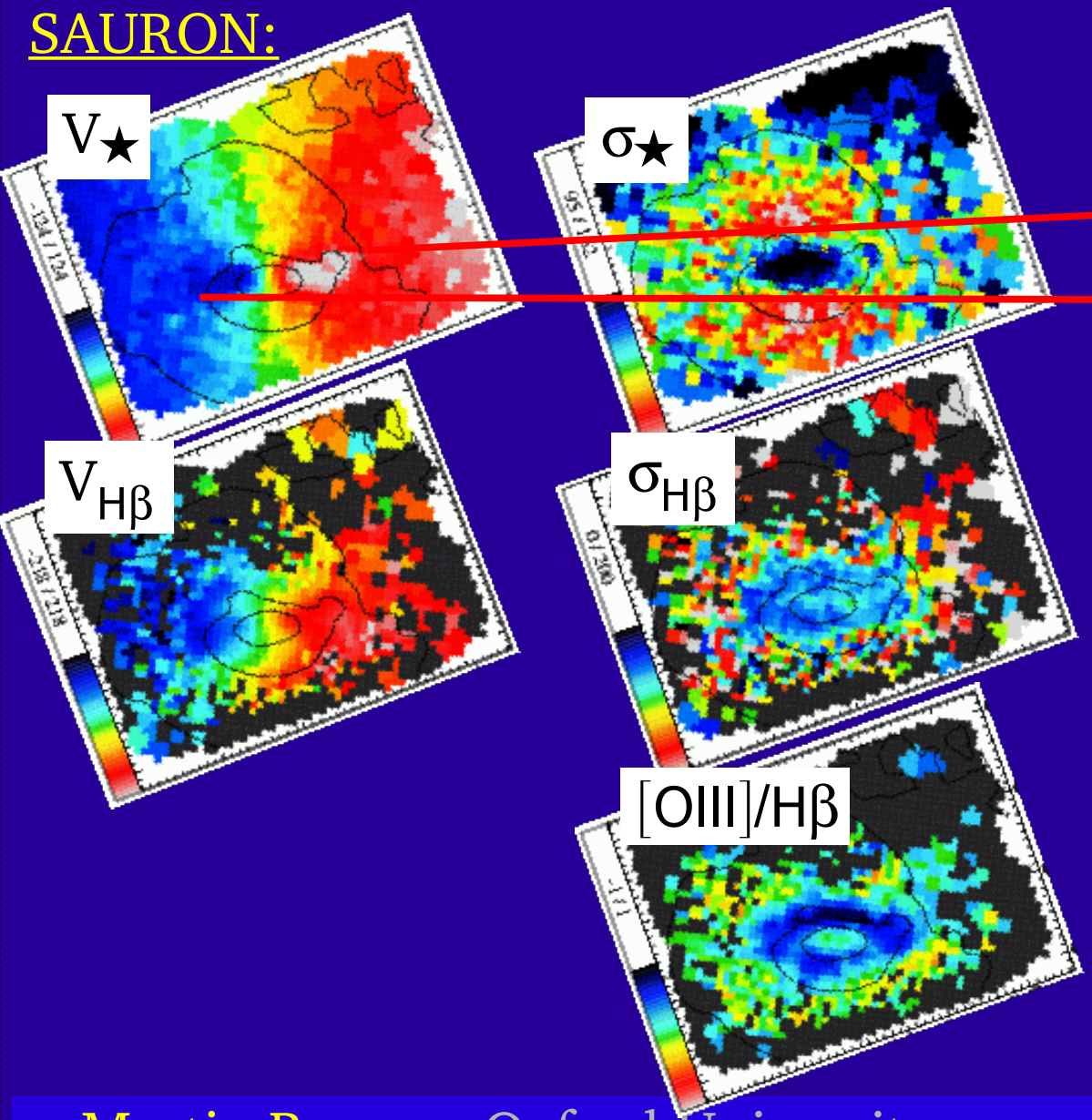
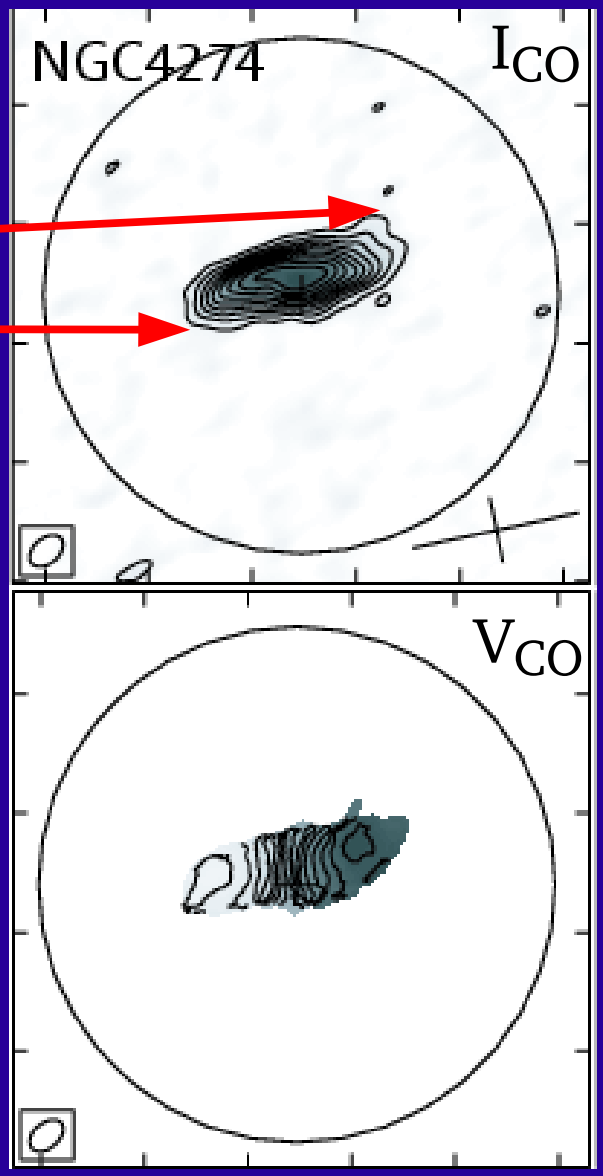
Other Cases: NGC4274

(Jeong et al., in prep)

SAURON:



(Falcon-Barroso et al. 06)



(Koda et al. 05)

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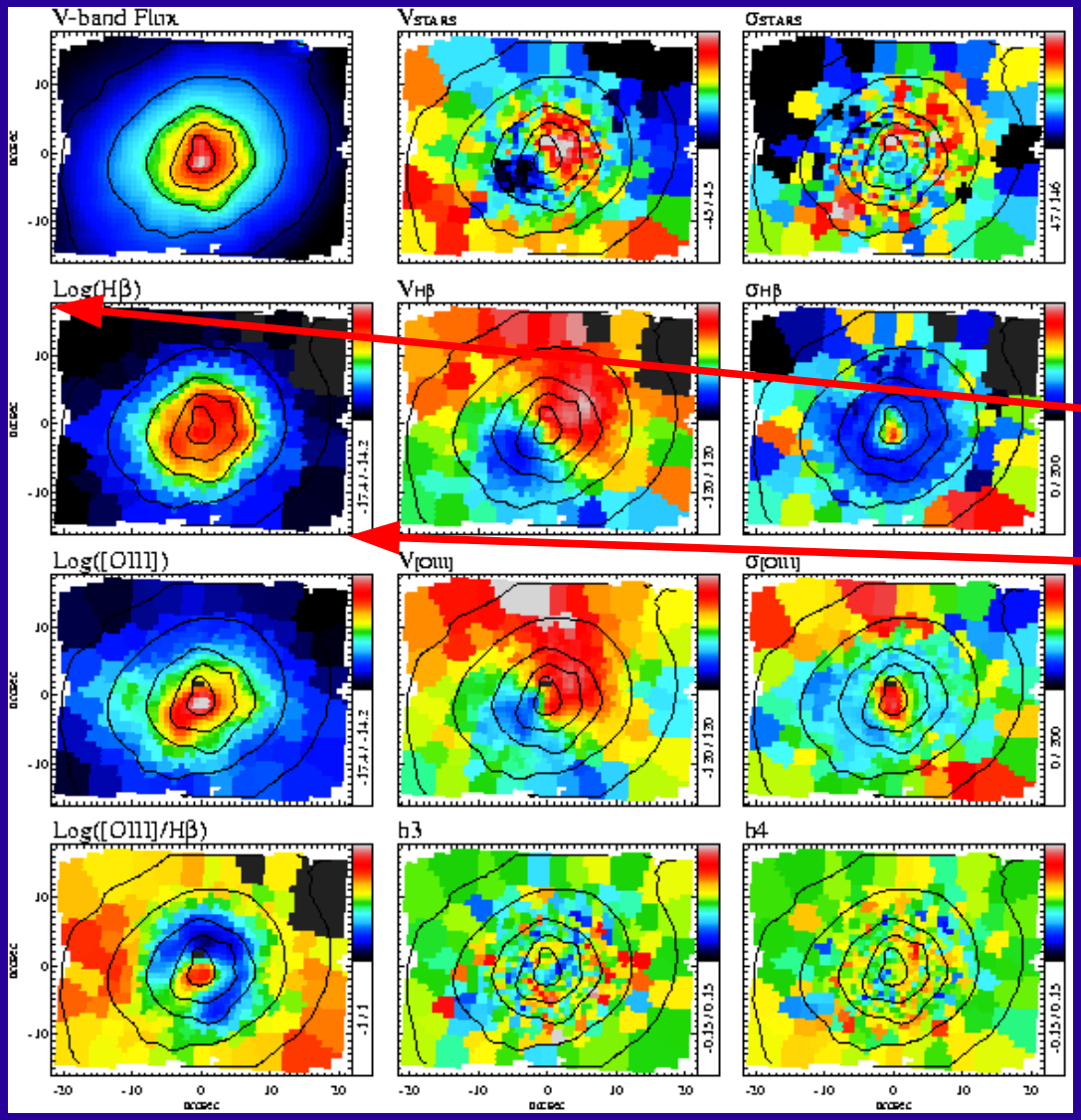
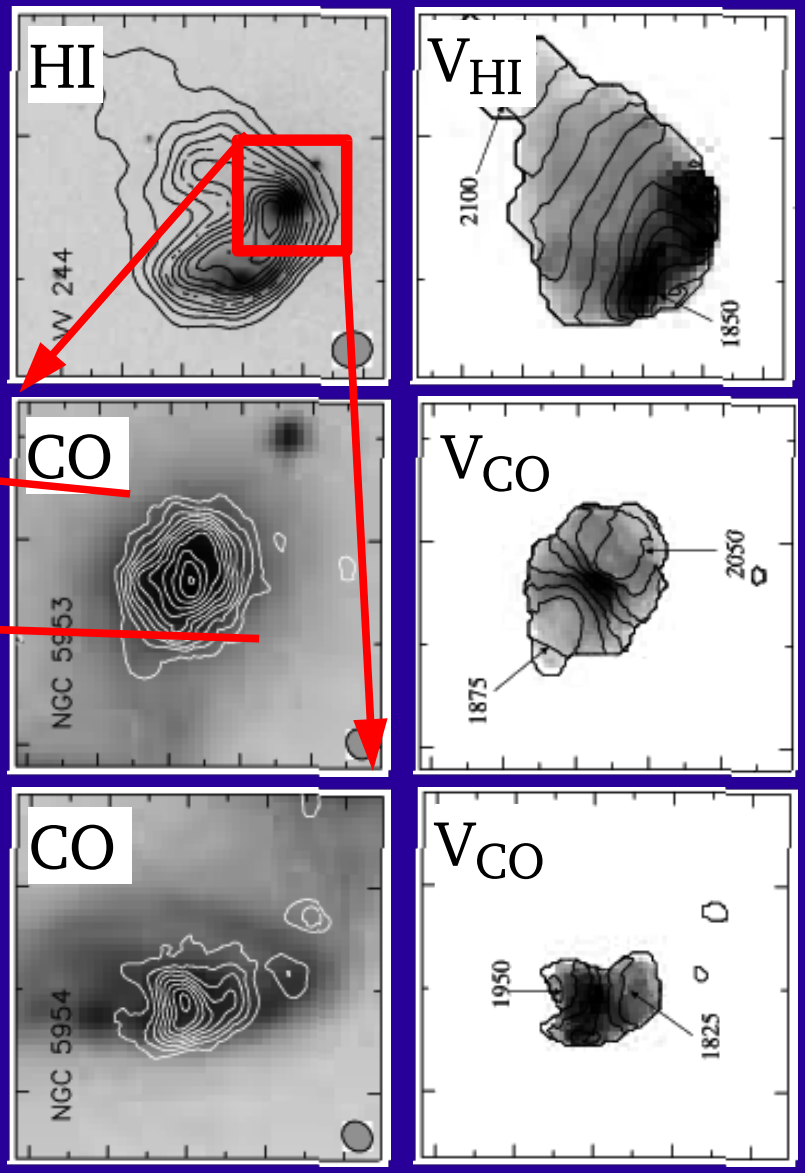
Other Cases: NGC5953

(Jeong et al., in prep)

SAURON:





(Iono et al. 05)

(Falcon-Barroso et al. 06)

Martin Bureau, Oxford University

The Gas-Star Cycle in Nearby Early-Types: UV, Optical, CO, HI

Martin Bureau, Oxford University

SAURON
(R. Bacon, M. Cappellari, R.L. Davies, E. Emsellem, J. Falcon-Barroso, D. Krajnovic, M. Sarzi, H. Kuntschner, R.M. McDermid, R.F. Peletier, G. van de Ven, P.T. de Zeeuw)
CO
(F. Combes, A. Crocker, L.M. Young)
GALEX
(H. Jeong, Y-K. Sheen, S.K. Yi)

Plans: Optical/SAURON: Stellar populations in E/S0s and KDCs
CO/BIMA, HI: Star formation fuel, gas accretion
UV/GALEX, HI: Current and recent star formation
Summary

(Preliminary) Conclusions

- KDCs: - Classic KDCs: Large, massive, homogeneously old, non-rotator
  (early dissipational/late dissipationless major merger)
  - Compact KDCs: Small, lightweight, young, rotator
  (minor merger/gas accretion)
- CO: - Central disks: CO cospatial/corotating with gas/young stars
  - Central CRs: CO roughly cospatial with gas/young stars
  (generally less extended), unrelated to CRs ?
  - SF sequence? Current, recent, no/weak SF...
  ✗ Still in exploratory phase, building up sample...
- UV: - Resolved UV-optical colors: Constraints on age, mass fraction,
  and surface density of young stars
  - Recent SF correlated with stellar/ionised-gas/CO dynamics
  (disk formation ?) (both secular and externally-triggered SF)

Martin Bureau, Oxford University

(Preliminary) Conclusions

- KDCs: - Classic KDCs: Large, massive, homogeneously old, non-rotator
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- C… stars
  …s
  …Rs ?

- U… raction,
  and surface density of young stars
  - Recent SF correlated with stellar/ionised-gas/CO dynamics
  (disk formation ?) (both secular and externally-triggered SF)

Great synergy
optical IFU – mm interferometry

(and HI, UV, ...)
(do not forget the stars!)

Martin Bureau, Oxford University