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

Martin Bureau, Oxford University

SAURON

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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SAURON: Broad Aims

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)
Main results:

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

- Occasional:
  Young core/body, increasing metallicity

- Isoindices:
  $\text{Mg}_b$ isoindex contours often flatter than light (40%; rotators)
Stellar Pop.: Classic KDCs
(McDermid et al. 06)

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)?
Stellar Pop.: Compact KDCs
(McDermid et al. 06)

Compact KDCs:
- Small: 100 pc’s (≤ 0.1 $R_e$)
- Lightweight
- Young: distinct, younger toward center (contrary to ionized gas)
- Rotators

Formation:
- Recent dissipative minor merging/accretion?

SAURON-OASIS Data:
KDCs: Age-Size Dichotomy
(McDermid et al. 06)

SAURON-OASIS Data:  Central pixel

Compact KDCs:
- Small: 100 pc' $s(\leq 0.1 R_e)$
- Lightweight
- Young: distinct, increasingly young toward center
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Classic KDCs:
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Summary
CO: Single-Dish Survey
(Combes, Young & Bureau 07)

IRAM 30m Survey:
- CO(1-0), 23” FWHM
  CO (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
- \(<\text{CO}(2-1)/\text{CO}(1-0)\> \approx 1.4
**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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Central Disks

CO: Central Disks
(Young, Bureau & Cappellari 08; Bureau & Young, in prep)

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?)
CO: Central Disks
(Young, Bureau & Cappellari 08; Bureau & Young, in prep)

BIMA-SAURON Data: NGC4459

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)
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**BIMA-SAURON Data:**
NGC3032

**“age”**
CO: Central Disks
(Young, Bureau & Cappellari 08; Bureau & Young, in prep)

Central Disks:
• CO cospatial with young stars and central stellar/gas disk
• CO and stars/gas co-rotating

CRs:
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• CO and stars/gas kinematics unrelated? (triggered SF?)

BIMA-SAURON Data: NGC 4150

“age”

Hβ

SAURON

V★

V_co

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CO: SF Sequence?
(Crocker et al., in prep)

PdBI-SAURON Data: NGC524

SF sequence:
• Current SF (low [OIII]/Hβ)
• Recent SF (high Hβ linestrength)
• No/weak SF (high [OIII]/Hβ, low Hβ)
CO: SF Sequence?
(Crocker et al., in prep)

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

PdBI-SAURON Data: NGC4477

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CO: External Accretion

NGC2685, NGC2768:
- Generic accretion model for polar rings (although likely a polar disk)

Generally:
- Disturbed HI
- Lack of strong correlations CO-optical (e.g. scale, L, ...)
- Some galaxies with CO but no HI!
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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Atlas$^3$D:

- Complete volume-limited E/SO sample:
  - 264 E/S0s within $\approx 40$ Mpc, complete WHT/SAURON data
    ($\approx 215$ 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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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
GALEX: Exceptional
(Jeong et al., in prep)

UV Morphologies: Exceptional

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NGC2974: UV Morphology - Kin.
(Jeong et al. 07)

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)
NGC2974: UV Morphology - Kin.  
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Optical-UV Imaging:

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- Young stars and RSF (UV bright and blue) in centre + outer ring
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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:

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GALEX-MDM:

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Other Cases: NGC2273
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**GALEX-MDM:**

![Images of NGC2273 showing various emissions and distributions](Image)

- **I**
- **V**
- **Hβ**
- **VHβ**
- **[OIII]/Hβ**

*Petitpas & Wilson 02*

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Other Cases: NGC4274
(Jeong et al., in prep)

GALEX-MDM:

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Other Cases: NGC4274

(Jeong et al., in prep)

SAURON:

\[ V \star \]

\[ \sigma \star \]

\[ V_{\text{H}\beta} \]

\[ \sigma_{\text{H}\beta} \]

\[ \text{[OIII]/H}\beta \]

\[ (\text{Falcon-Barroso et al. 06}) \]

\[ I_{\text{CO}} \]

\[ V_{\text{CO}} \]

\[ (\text{Koda et al. 05}) \]

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Other Cases: NGC5953

(Jeong et al., in prep)

SAURON:

HI

CO

V_{HI}

V_{CO}

(Falcon-Barroso et al. 06)

(Iono et al. 05)

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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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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)

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Conclusions

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Great synergy
optical IFU – mm interferometry
(and HI, UV, ...)
(do not forget the stars!)

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