Molecular gas and star formation in early-type galaxies

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Two main questions

- What is the molecular gas in early-type galaxies doing?
  - Distribution, comparison with ionised gas and stellar populations

- Do early-type galaxies follow the same SF laws and correlations as spirals/starbursts?
Sample:

**Molecular gas**: interferometric CO maps

**Star formation**: IFU maps, also literature FIR and radio

- 48 galaxies part of the SAURON E/S0 sample
  - 11 have CO
    - 4 observed with BIMA
    - 5 observed with PdB
  - 26 observed with PPAK
- 12 E/S0s with CO maps in the literature
  - 6 observed with PPAK
  - 2 observed with SAURON

17 E/S0s currently with IFU data **and** CO maps!
Molecular gas distributions

- Central (except merger remnants)
- Disk or ring (one spiral)

Disk in NGC 524

Ring in NGC 4477

Spiral in NGC 3489
Molecular gas distributions

- Central (except merger remnants)
- Disk or ring
- Radial extent depends on mass → relatively constant average surface density

\[
\log(H_2 \text{ mass}/M_{\odot}) \quad \log(H_2 \text{ radius}/\text{kpc}) \\
\log(density) \quad \log(density)
\]
Molecular and ionized gas

IFU maps of $\text{OIII}/\text{H}\beta$ emission-line ratio. Use this ratio to diagnose star formation:

- $\log(\text{OIII}/\text{H}\beta) < -0.2 \rightarrow$ ionisation attributable to star formation
- $\log(\text{OIII}/\text{H}\beta) > -0.2 \rightarrow$ ionisation dominated by other source

4 star forming galaxies:

4 not star formation dominated galaxies:
Molecular gas and stellar populations

- 3 diagnostics: optical color, NUV-V color and absorption linestrengths
- 1) Optical color:

8/17 galaxies to the blue side of the red sequence → must have young stellar populations

![Diagram](image.png)

- E/S0 galaxies w/ CO
- E/S0 galaxies w/o CO
Molecular gas and stellar populations

- 3 diagnostics: optical color, NUV-V color and absorption linestrengths
  - 1) Optical color
  - 2) NUV-V color:

Reveals central young pop in 2 optically red galaxies.

BUT- 3 other E/S0s with molecular gas show no young stars in UV....
Molecular gas and stellar populations

- 3) Absorption linestrength $\rightarrow$ stellar population ages via SSP models

Locally young

Globally young

Old

0.4 Gyr

18 Gyr
Different stages of evolution

- 3 types:
  - Definitely star forming: star-forming ionisation - young stars
  - Post-starburst: other ionisation - young stars dominate
  - Not star forming: other ionisation - old stars
SF tracers in E/S0s

- Goal: test if star formation follows same correlations/laws as in spirals/starbursts
- Problem: SF tracers may be significantly contaminated

Radio
- contribution from AGN
- magnetic field in E/S0s different than spirals?

FIR
- contribution from other heating sources (AGN, pAGB stars)
- different dust content?

Hβ emission line
- contribution from other ionising sources (AGN, pAGB stars)
- unknown extinction
SF Correlations

• 1) Radio vs. FIR

- 2 radio excess galaxies → identifiable as AGN

- 3 FIR excess galaxies → ?

- E/S0s tend to lie to the FIR excess (or radio deficient) side of the relation (other than AGN)
SF Correlations

- no true H\(\beta\) excess galaxies
-4 FIR excess galaxies \(\rightarrow\) ?
-mostly lie to the FIR excess/H\(\beta\) deficient side of the relation
SF Correlations

3) Hβ vs. radio

- no true Hβ excess galaxies
- 2 AGN are radio-excess
-2 others Hβ deficient
- most lie to the FIR excess/Hβ deficient side of the relation
SF laws

1) FIR-based

- Very good FIR-\(H_2\) mass correlation, but slope < 1
- Almost all galaxies within KS law bounds
SF laws

• 2) $H\beta$-based

-SFRs far too low $\rightarrow$ significant extinction
SF laws

- 3) Radio-based

- Decent radio-\( \text{H}_2 \) mass correlation, despite radio AGN
- Galaxies mostly within KS law bounds
Conclusions

- Despite many potential contaminants, early-type galaxies roughly follow SF correlations and laws
  - Hβ too weak
  - FIR excess galaxies
  - Can other ionisation sources act like star formation?

- Three types of E/S0s with molecular gas:
  - Star forming
  - Post-starburst
  - Not or inefficiently star forming