

Constraint of Star Formation Rates in Post-starburst Galaxies

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What are Post-Starburst Galaxies (PSGs)?

- ▶ Rare objects in the **green valley** of the galaxy colour-magnitude diagram
- ▶ Optical spectra dominated by **A-type stars**
- ▶ **No nebular emission** from ongoing star formation

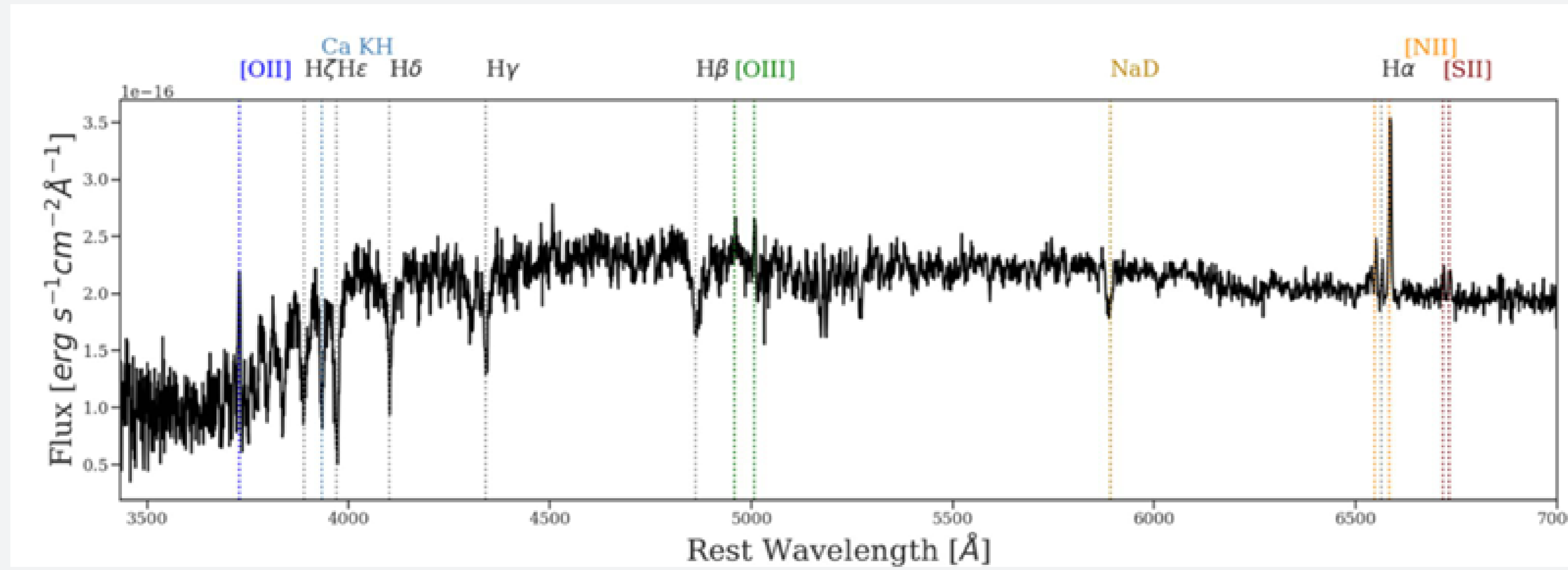


Figure: Example optical spectrum of a post-starburst galaxy showing A-type star absorption features and absence of emission lines.

Key Questions

- ▶ Is there any residual star formation in PSGs?
- ▶ Could star formation be **heavily obscured** by dust?
- ▶ Do PSGs represent a truly **quenched** population?
- ▶ Why is molecular gas present but not forming stars?

Previous Constraints

- ▶ **Radio observations (1.4 GHz):** Nielsen et al. (2012) find average SFR $< 1.6 M_{\odot} \text{ yr}^{-1}$
- ▶ Most radio flux likely comes from **weak AGNs**
- ▶ Optical colours exclude current star formation
- ▶ Molecular gas detected in many PSGs (French et al. 2015; Rowlands et al. 2015)

Key References

Alatalo et al. (2016) ApJS, 224, 38 French et al. (2015) ApJ, 801, 1 Goto (2007) MNRAS, 381, 187
Melnick & De Propris (2013) MNRAS, 431, 2034 Nielsen et al. (2012) ApJ, 761, L16
Wild et al. (2009) MNRAS, 395, 144

Why Use Type II Supernovae?

- ▶ Type II SNe come from **massive stars** ($> 8 M_{\odot}$)
- ▶ Short progenitor lifetimes \rightarrow trace SFR over last $\sim 50 \text{ Myr}$
- ▶ **Not affected** by dust extinction
- ▶ Provide **direct** measurement of recent massive star formation
- ▶ Complementary to radio/far-IR indicators

Galaxy Samples & Observations

- ▶ **Melnick & De Propris (2013):** 65 classical E+A galaxies
- ▶ **Alatalo et al. (2016):** 246 'shocked' PSGs
- ▶ SDSS galaxies with ZTF Bright Transient Survey (7 years)
- ▶ Complete for Type II SNe to $z = 0.05$

ZERO SUPERNOVAE DETECTED

0 in 65 galaxies 0 in 246 galaxies

Statistical Upper Limits (95% Confidence)

From binomial distribution:

SN fraction limits:

- ▶ Melnick & De Propris: < 0.04
- ▶ Alatalo et al.: < 0.01

Star Formation Rates:

$$SFR_{M+13} < 0.06 M_{\odot} \text{ yr}^{-1} \text{ Mpc}^{-3}$$

$$SFR_{A+16} < 0.02 M_{\odot} \text{ yr}^{-1} \text{ Mpc}^{-3}$$

Per galaxy equivalent:

$$< 0.8 M_{\odot} \text{ yr}^{-1} (M + 13)$$

$$< 0.3 M_{\odot} \text{ yr}^{-1} (A + 16)$$

Consistent with radio limits from Nielsen et al. (2012)

Volumetric Supernova Rates

SNum (SN units):

- ▶ Melnick & De Propris: < 0.008
 - ▶ Alatalo et al.: < 0.0004
- Units: $\text{SN} (100 \text{ yr})^{-1} (10^{10} M_{\odot})^{-1}$

Comparable to elliptical galaxy upper limits

Conclusions

- ▶ **Star formation has completely ceased** in PSGs
- ▶ No evidence for obscured star formation
- ▶ Residual radio emission likely from **weak AGNs**
- ▶ Molecular gas present but **not forming stars**
- ▶ PSGs are truly **quenched** populations