Ionised winds in normal star-forming galaxies in 3D

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\[ \phi(L) \]

**Galaxy luminosity**

**theory (CDM-motivated)**

\[ L^* \sim 3 \times 10^{10} L_\odot \]

**SN**

**observations**

**AGN**
Winds in main-sequence galaxies?

Na D winds in stacked SDSS spectra

- At $z \sim 0$, normal star-forming galaxies could also host winds
- Detected in NaD5890,5896 with stacked SDSS spectra
- Problems:
  - $\text{EW(NaD)}$ gets smaller when there is less dust ($\text{Na} \rightarrow \text{Na}^+$)
  - Individual detection requires good sensitivity & right galaxy inclination

$\Sigma_{\text{SFR}}$ increase

$\text{red} \rightarrow \text{black}$

Chen et al. (2010)
Winds in main-sequence galaxies?

- \( \log(M^*/M_\odot) \)
- SFR \([M_\odot \text{ yr}^{-1}]\)

Classical starburst winds

- SDSS
- M82
- NGC1482
- NGC3079
- NGC253
- MW
- Arp220
- M82
- NGC1482
- NGC3079

\( z \approx 0 \) SDSS main sequence

- Elbaz et al. (2007)
- \( z < 0.2 \) (UL)IRGs NaID winds
- Rupke et al. (2005)
The SAMI galaxy survey

- Local IFS survey (z~0.05) w/ 3.9-m Anglo-Australian Telescope
- 13 fiber bundles in 1 deg FOV
- Target sample size: 3,400 galaxies (currently >2,000)
- Early data release (Allen et al. 2015; N=107)
- First data release Aug. 2017, including value added catalog (N~800; Green et al. 2017)
Galaxy main-sequence in 3D

log(SFR) vs log(M*)

courtesy of Scott Croom
Galaxy main-sequence in 3D

courtesy of Scott Croom
• 40 edge-on (i>80 deg), non-AGN (optical line ratios), non-interacting normal star-forming galaxies

• Extra-planar line emission detected in SAMI
Ho et al. (2016)
See also Ho et al. (2014)
Leslie et al. (2017)
Tescari et al. (2017)
Extraplanar line-emitting gas

- Strong disk-halo interaction
- Galactic winds
- Bipolar outflows in cone-like structures
- Shock excited

- Weak disk-halo interaction
- Extended diffuse ionised gas (eDIG)
- Co-rotating with disk
- Photoionisation + extra heating (shock or turbulent)

M82

NGC891 (Hα narrow band)

Hα + [NII]

eDIG

Pildis et al. (1994)
Kinematic asymmetry

Galactic wind

\[ V_{\text{gas}} \]

\[ V_{\text{gas,flipped}} \]

\[ V_{\text{gas}} - V_{\text{gas,flipped}} \]

\[ V_{\text{gas}} \]

\[ V_{\text{gas,flipped}} \]

\[ V_{\text{gas}} - V_{\text{gas,flipped}} \]

SDSS

\[ \text{log}(\text{[NII]/H} \alpha) \]

\[ \text{log}(\text{[SII]/H} \alpha) \]

\[ \text{log}(\text{[OI]/H} \alpha) \]

\[ \delta \text{ Dec. [arcsec]} \]

\[ \delta \text{ R.A. [arcsec]} \]

Galactic wind and eDIG kinematic asymmetry maps.
Extrapolated velocity dispersion

Galactic wind
$\sigma_{\text{gas}}$ [km/s]

$\eta_{50}$: 0.49

eDIG
$\sigma_{\text{gas}}$ [km/s]

$\eta_{50}$: 0.34
Wind in normal galaxies at z=0

Ho et al. (2016)
See also Leslie et al. (2017)
Why some are wind-dominated?

✓ High star formation per surface area

Red: wind-dominated
Blue: not wind-dominated

Ho et al. (2016)
Why some are wind-dominated?

✓ Bursty star formation history

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Blue: not wind-dominated

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Ho et al. (2016)
Bursty star formation drives winds in FIRE

FIRE simulation

Muratov et al. 2015
Bigiel, Blanc, Emsellem, Escala, Groves, Hughes, Kreckel, Kruijssen, Leroy, Perez, Meidt, Pety, Rosolowsky, Sanchez-Plasquez, Sandstrom, Schinnerer, Schruba, Usero Chevance, Guzman, Herrera, Ho, Hygate, Johnson, Lang, Liu, McElroy, Querejeta, Razza, Rebolledo, Saito, Sliwa, Sun, Utreras, Ward
NGC628 w/ PHANGS collaboration

MUSE Hα $10^4$ K(PI: Kreckel; Blanc)

ALMA CO(2-1) 10 - 100K

MUSE 6-point mosaic

resolution 1 arcsec = 50pc
NGC628 w/ PHANGS collaboration

MUSE Hα 10^4 K (PI: Kreckel; Blanc)

ALMA CO(2-1) 10 - 100K

rest wavelength (Å)

Hα line profile examples

blue wing
red wing

MUSE 6-point mosaic

1 arcsec = 50pc
Summary

- Ionised winds commonly seen in normal, present-day main-sequence galaxies

- Even when $\Sigma_{\text{SFR}}$ is below $0.1 \text{M}_\odot/\text{yr}/\text{kpc}^2$

- High $\Sigma_{\text{SFR}}$ and bursty star formation drive “starburst-driven winds”

- Concentration and short timescale of star forming activities are the keys to driving ionised winds