Star formation feedback in dwarf galaxies tracked by 3D spectroscopy with Fabry-Perot interferometers

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Feedback between massive stars and the interstellar medium

- Supernova remnants
- WR/Of stars nebulae
- Star clusters
- Galactic wind

Dwarf galaxies are very usable to feedback process in ISM:

- **Slow solid-body rotation and lack of strong spiral waves** -> shells and other structures are not destroyed by galaxy rotation
- **“Weak” potential well** -> HI discs are relatively thick
- Numerous local star forming dwarf galaxies -> a good spatial resolution (~10 pc)
Dwarf galaxies are very usable to feedback process in ISM:

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**Why observations of ISM are important:**

- Shell parameters are directly related with an energetic output
- Shell ages => age of recent star formation burst
- Origin of the Diffuse Ionized Gas (DIG)
Feedback between massive stars and the interstellar medium

Supernova remnants  WR/Of stars nebulae  Star clusters  Galactic wind

| G299.2-2.9 | WR31a | R136 | M82 |

3D spectroscopy is necessary for warm (ionized) ISM study. Also we need:

- FOV > 1 arcmin
- High spectral resolution to resolve 20-30 km/s

=> \[ \delta \lambda = 0.4-0.7 \text{Å} \] => \[ R = \frac{\lambda}{\delta \lambda} = 9000-16000 \]

MPFS (Afanaseiv+ 1990, 2001)
Integral field spectrographs with a largest FOV

<table>
<thead>
<tr>
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<th>MUSE (8m/VLT) Slicers array</th>
<th>PPAK (3.6mCalarAlto) Fibers array</th>
<th>VIRUS-P/2.7m McDonald</th>
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<td>60</td>
<td>74×64</td>
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Ronald Bacon plenary talk, EWASS-2019
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3D spectroscopy with Scanning Fabry-Perot interferometer

Spectral Camera with Optical Reducer for Photometric and Interferometric Observations

FPI in SCORPIO/SCORPIO-2 (Afanasiev & Moiseev, 2005/2011)
Data reduction: Moiseev & Egorov (2008), Moiseev 2015

Field of view: 6.1 x 6.1 arcmin
Spectral range: Hα, [SII], [OIII] lines
Spatial sampling: 0.35-0.70 "/px
Spectral resolution: R=4000-16000

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<th>IFP186</th>
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<th>IFP751</th>
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<td>Order</td>
<td>186</td>
<td>501</td>
</tr>
<tr>
<td>Interfringe</td>
<td>35 A</td>
<td>13 A</td>
</tr>
<tr>
<td>Sp. resolution</td>
<td>1.7 A</td>
<td>0.8 A</td>
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Kinematic feedback: mapping

I. Regular motions =>
observed in line-of-sight velocities

II. Turbulent motions =>
observed in velocity dispersion (σ)

Ha image       velocity field      velocity dispersion map

UGC 5221       -100               0

Moiseev+15
We found 22 H-alpha expanding superbubbles. Significant part of them have no central source of mechanical energy => leakage from HII regions should be important.

<=talk by Oleg Egorov!
Regular+turbulent motions: galactic wing in NGC 4460

V(outflow)=30-80 km/s
It's comparable to the $\sigma$

Oparin & AM +15
Turbulent motions: DDO53

How can we quantify this distribution?

Velocity dispersion increases outside of bright HII regions

Moiseev & Lozinskaya 2012
Turbulent motions: DDO53

Velocity dispersion increases outside of bright HII regions

Moiseev & Lozinskaya 2012
I-σ diagrams in dwarf galaxies

Munoz-Tunon + 96
Martinez-Delgado + 07
Maiara & Plana + 18

'Coronae' of perturbed low density gas (DIG) with high turbulent velocities

Munoz-Tunon + 96
Martinez-Delgado + 07
Maiara & Plana + 18

Vasiliev, AM & Shchekinov + 14

AM & Lozinskaya + 12
H-alpha luminosity (SFR) - $\sigma$ relation

Mean $\sigma$, weighted by intensity:

$$\sigma = \frac{\sum \sigma_i I_i}{\sum I_i}$$

We lose information about spatial distribution.
H-alpha luminosity (SFR) - $\sigma$ relation

**Mean $\sigma$, weighted by intensity:**

$$\sigma = \frac{\sum \sigma_i I_i}{\sum I_i}$$

We lose information about spatial distribution.

*it predicts a transition from mostly gravity-driven turbulence at high redshift to star-formation-driven turbulence at low redshift.*

Krumholz + 18
Feedback in ionization properties

- brightest lines
- extinction-independent ratio

BPT
(Baldwin, Phillips & Terlevich 1981)

Mixing of shock and photoionization sequences
Diffuse ionized gas (DIG)

DIG line ratios cannot be explained by models of HII regions (Binette + 94, Zhang+18)

1) Young stellar population: shock waves powered by winds and SNe

2) Young stellar population: leaking Lyman continuum

3) Old stellar population: AGB, etc.

High velocity dispersion means turbulent motions powered by stellar feedback

"BPT-sigma relation"
What about local dwarf galaxies? We need higher velocity resolution ($\sigma<45$ km/s)

Combination of high-resolution FPI maps with 3D spectrophotometric data!
Wind in UGC 10043: CALIFA + FPI

An agreement between the line ratios and kinematics.

Lopez-Coba+15
BPT-sigma relation on dwarf galaxies: it works

Dmitry Oparin's talk!

6-m telescope FPI maps
+ Archival integral-field data
MaNGaL=Mapper of Narrow Galaxy Lines

- 1m SAO : 0.51 "/px, FOV 8.7'
- 2.5-m SAI : 0.33 "/px, FOV 5.6'

Low order Fabry-Perot interferometer = tunable filter

Spectral range: 4600-7500 Å

FWHM:
δλ =15-25 Å (FPI gap =5-14 μm)

*`Mangal' is a Caucasian and Middle Eastern barbeque.
The first light at 2.5m telescope: NGC 1569

BTA: Ha+[NII], Texp=1200 s
Karachentsev & Kaisin 2010.
NGC 3077: shells and PNe in M81 group dwarf galaxy

Oparin, Egorov, Moiseev, in prep

PNe candidates in N3077 (poster by Sypkova)

Talk by Oparin
Summary

• We can create high-quality maps of ionized gas velocity dispersion. More ideas to analysis and interpretations are welcome: I-σ, L-σ, BPT-σ, what else?

• BPT-sigma relations is a way to understand the origin of gas ionization in star forming galaxies (dwarf and giant)
Summary

- We can create high-quality maps of ionized gas velocity dispersion. More ideas to analysis and interpretations are welcome: I-σ, L-σ, BPT-σ, what else?

- BPT-sigma relations is a way to understand the origin of gas ionization in star forming galaxies (dwarf and giant)

Many thanks to the telescope and to the scientific and technical staff of the SAO RAS!