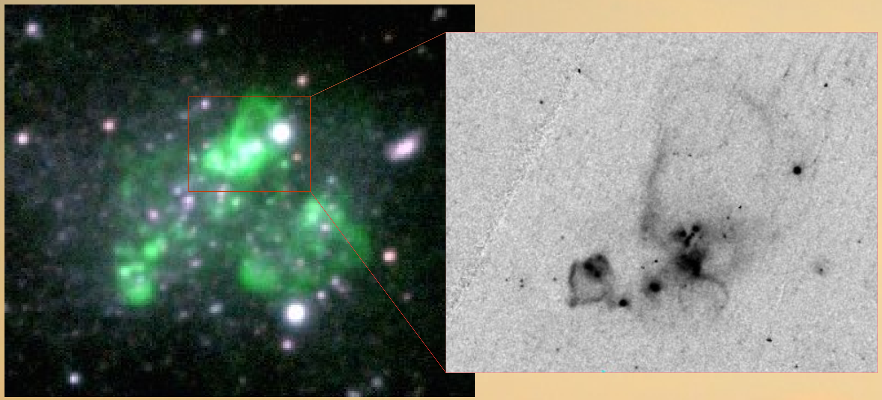

Star formation feedback in dwarf galaxies tracked by 3D spectroscopy with Fabry-Perot interferometers

Alexei Moiseev

Special Astrophysical Observatory, Russian Academy of Sciences

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)

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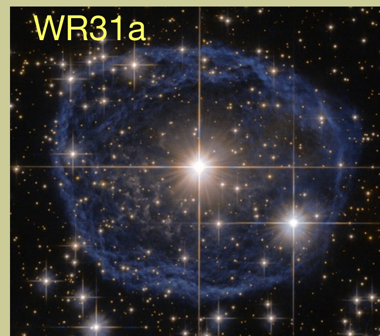
Why observations of of ISM are important:

- Shell parameters are directly related with an energetic output
- Shell ages => age of recent star formation burst
- Origin of the Diffuse Ionized Gas (DIG)

<=Egorov's talk !

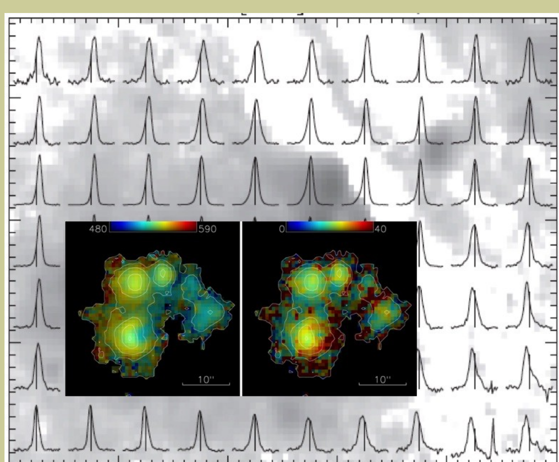
Feedback between massive stars and the interstellar medium

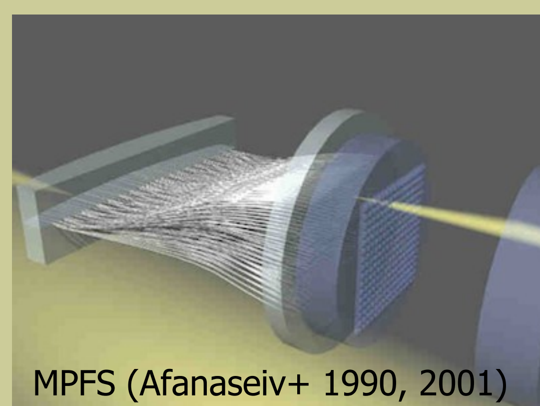
Supernova remnants | WR/Of stars nebulae | Star clusters | Galactic wind



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

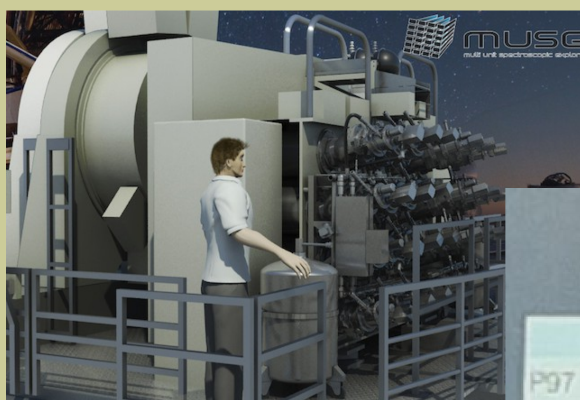
- \- FOV > 1 arcmin
- \- High spectral resolution to resolve 20-30 km/s
  => $\delta\lambda$=0.4-0.7Å => R=$\lambda/\delta\lambda$=9000-16000

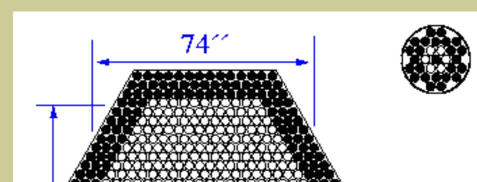


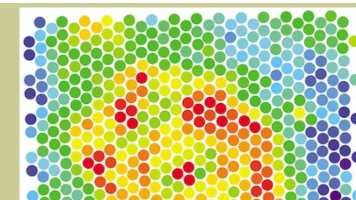

MPFS (Afanaseiv+ 1990, 2001)

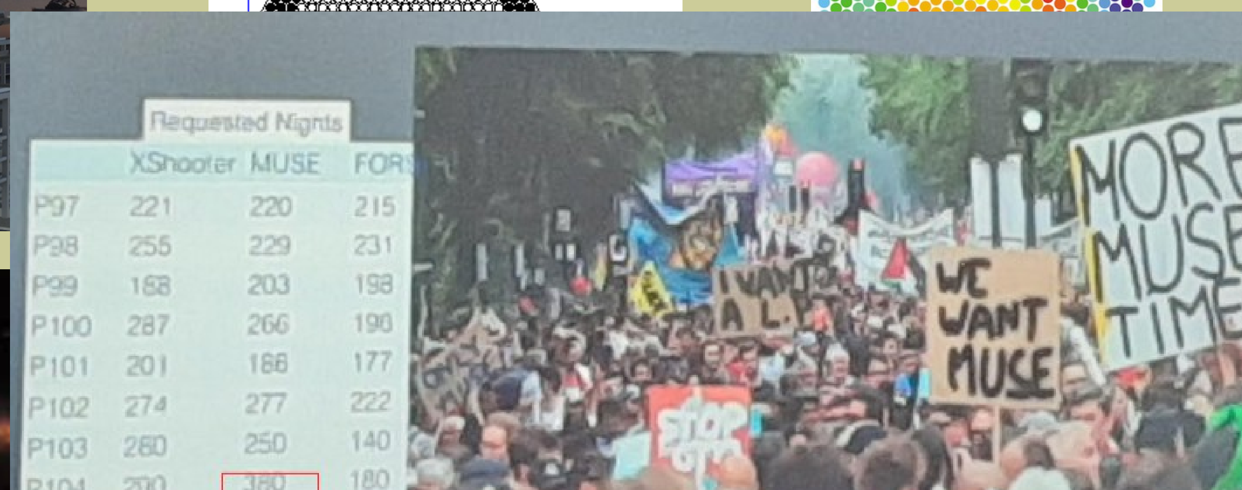
Integral field spectrographs with a largest FOV

	MUSE (8m/VLT) Slicers array	PPAK (3.6mCalarAlto) Fibers array	VIRUS-P/2.7m McDonald
FOV, "	60	74x64	100
Sampling, "	0.2	2.7	4.2
R	2600	850-1650	6500









Requested Nights

	XShooter	MUSE	FORS
P97	221	220	215
P98	255	229	231
P99	168	203	198
P100	287	266	190
P101	201	186	177
P102	274	277	222
P103	260	250	140
P104	200	380	180

Ronald Bacon plenary talk, EWASS-2019

Integral field spectrographs with a largest FOV

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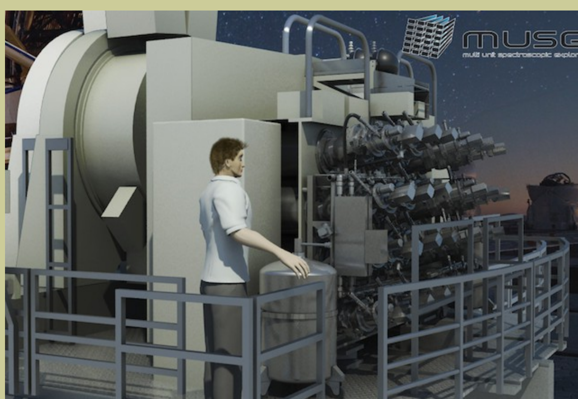
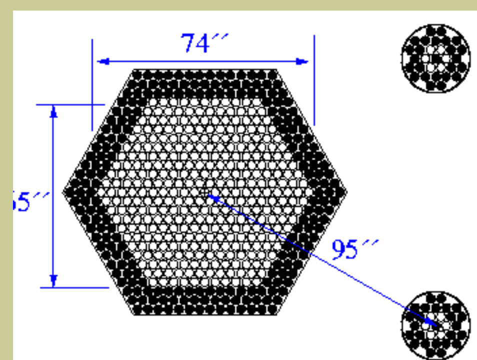
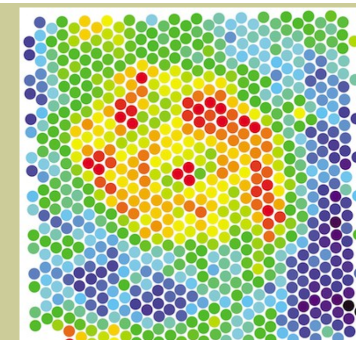
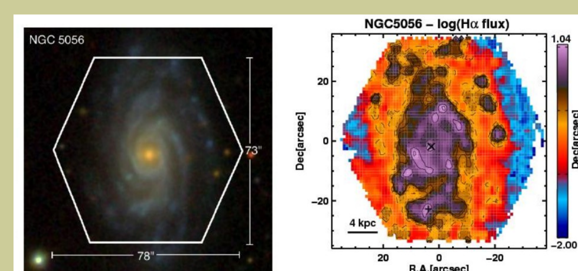






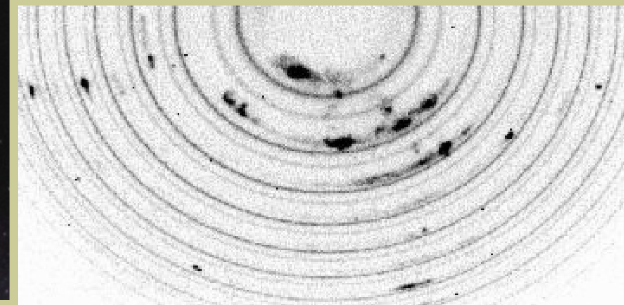


3D spectroscopy with Scanning Fabry-Perot interfereometer

Spectral **C**amera with **O**ptical **R**educer for **P**hotometric and **I**nterferometric **O**bservations

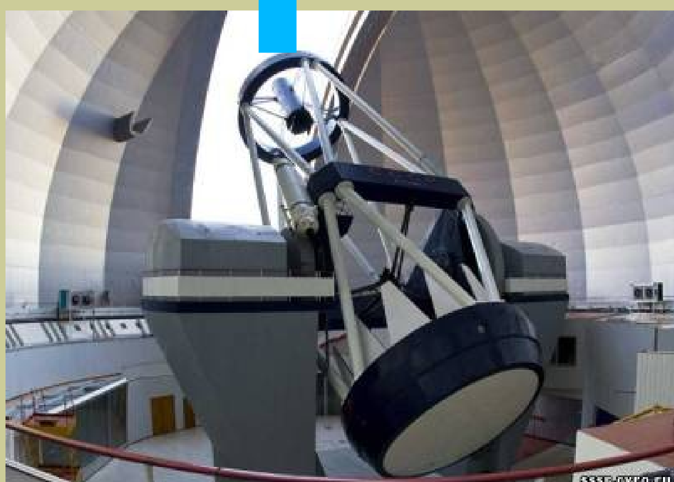
SCORPIO

SCORPIO-2

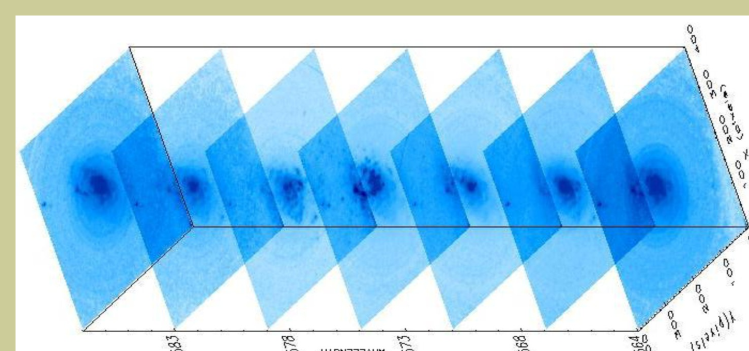


FPI in SCORPIO/SCORPIO-2 (Afanasiev & Moiseev, 2005/2011)
Data reduction: Moiseev & Egorov (2008), Moiseev 2015

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

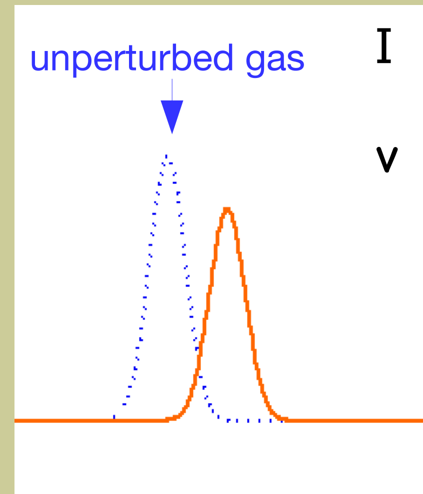


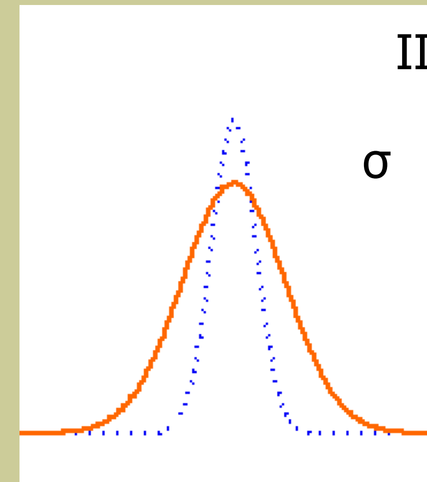
	IFP186	IFP501	IFP751
Order	186	501	751
Interfringe	35 A	13 A	8.7 A
Sp. resolution	1.7 A	0.8A	0.4A



Kinematic feedback: mapping

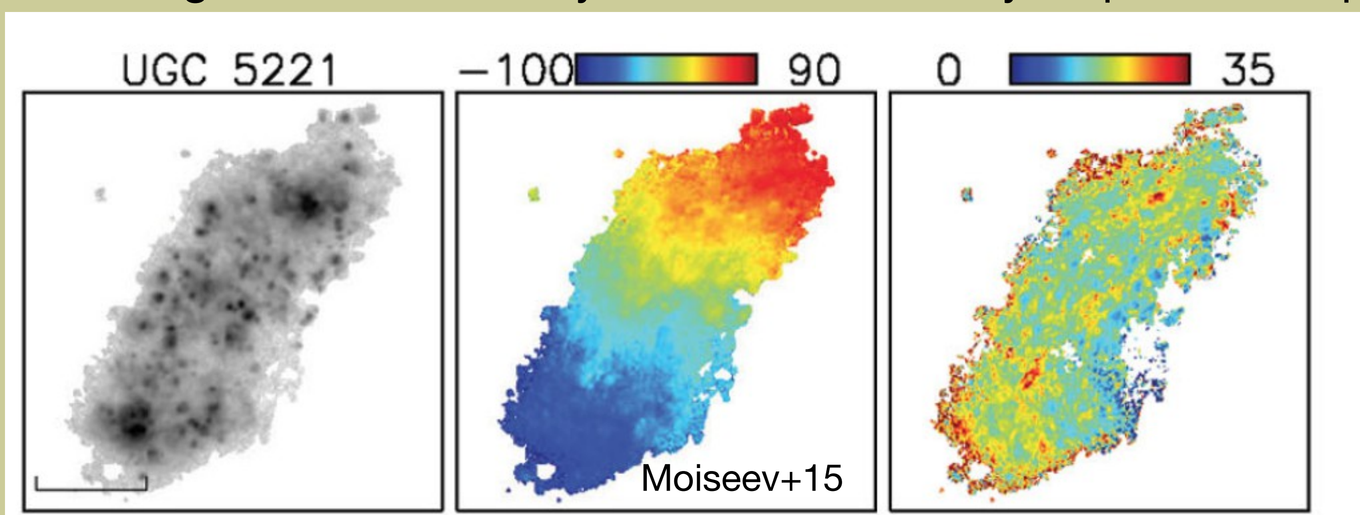
I. Regular motions =>
observed in line-of-sight velocities





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

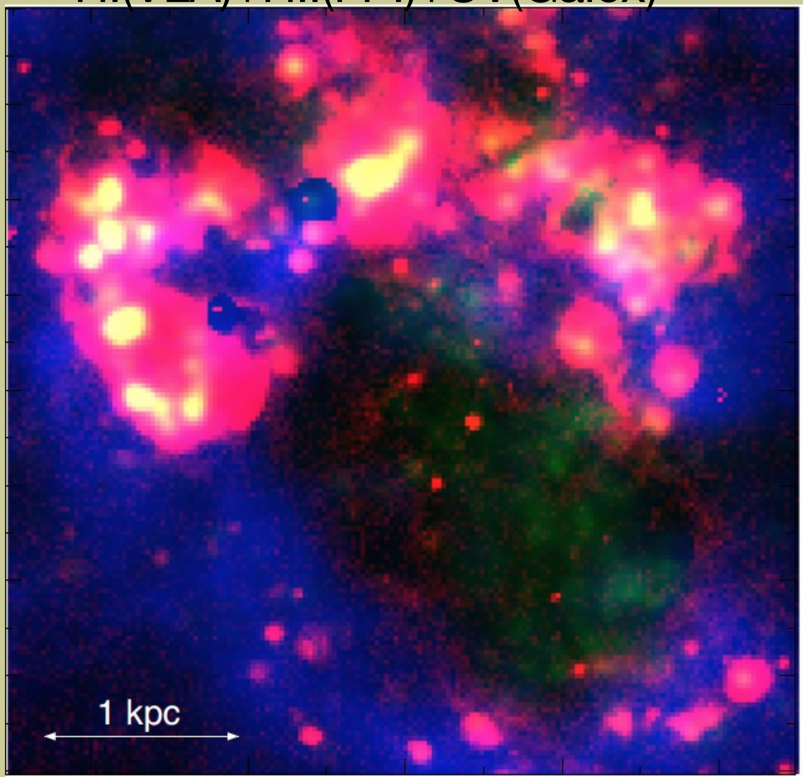
Ha image velocity field velocity dispersion map

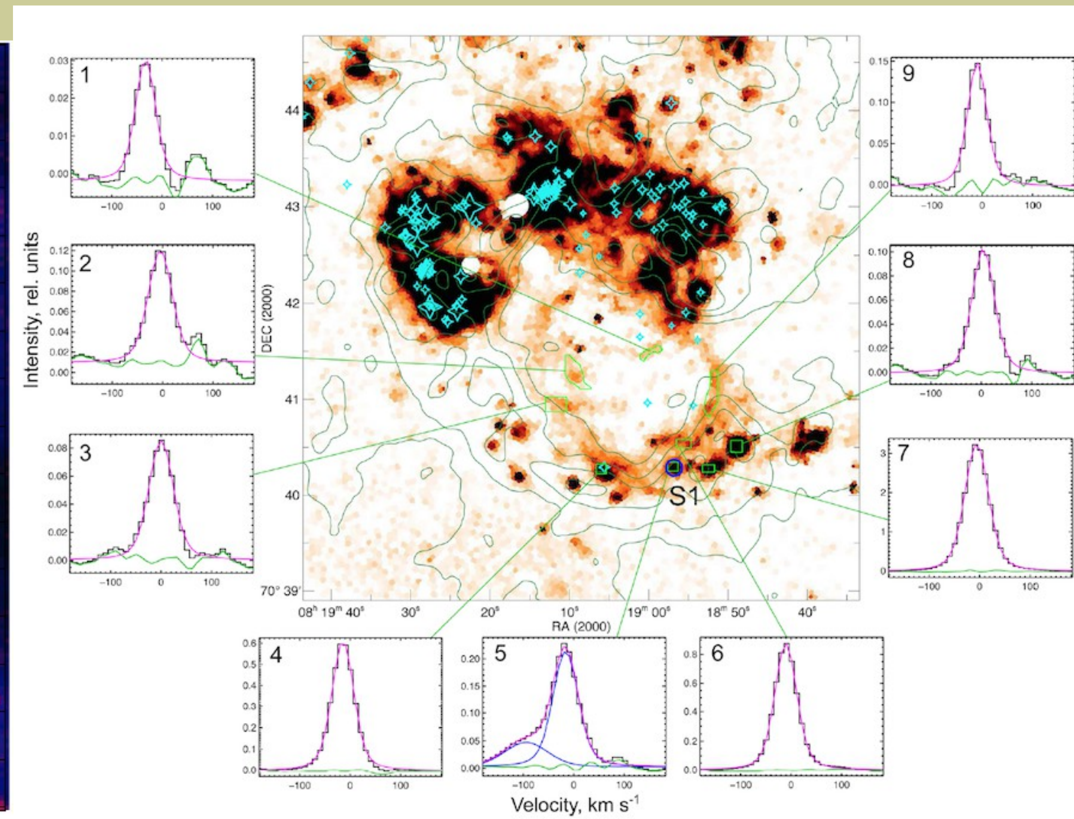


Regular motions: giant shells in Holmberg II

Egorov + 2017a

HI(VLA)+HII(FPI)+UV(Galex)

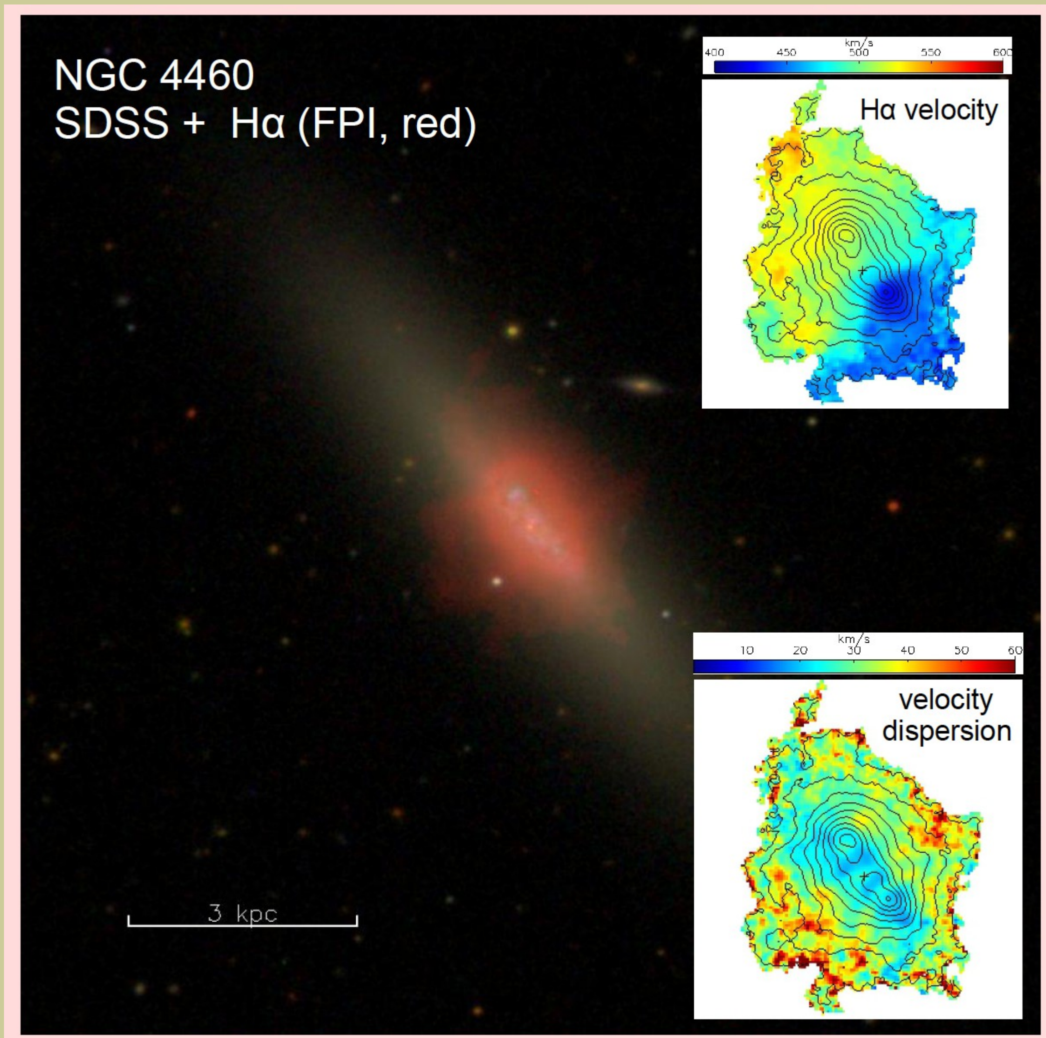


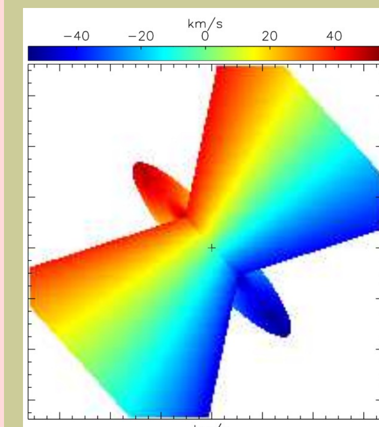


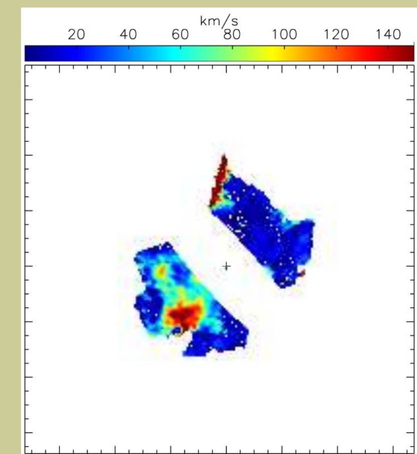
We found 22 H-alpha expanding superbubbles. Significant part of them have no central source of mechanical energy => leakage from HII regions should be important.

<=talk by Oleg Egorov!

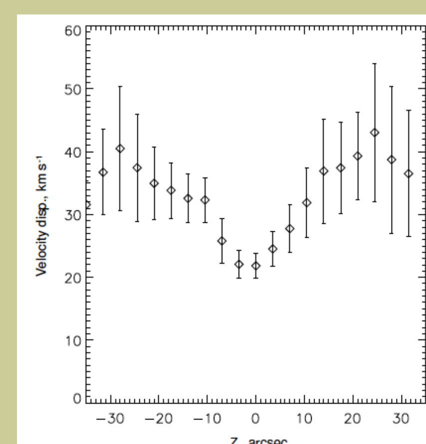
Regular+turbulent motions: galactic wing in NGC 4460





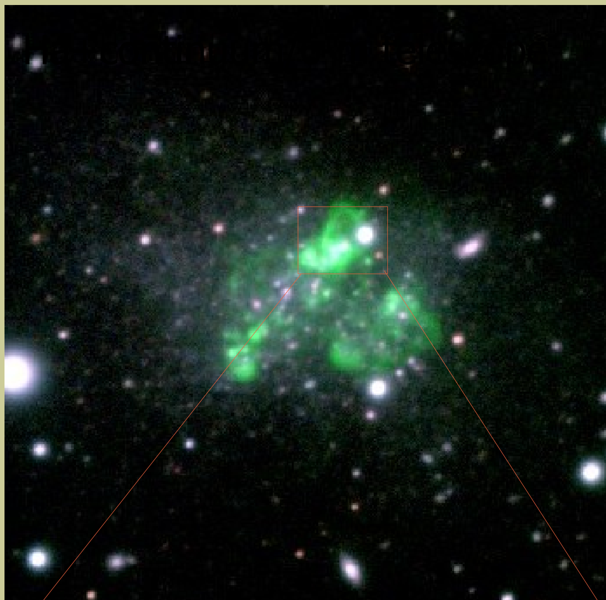


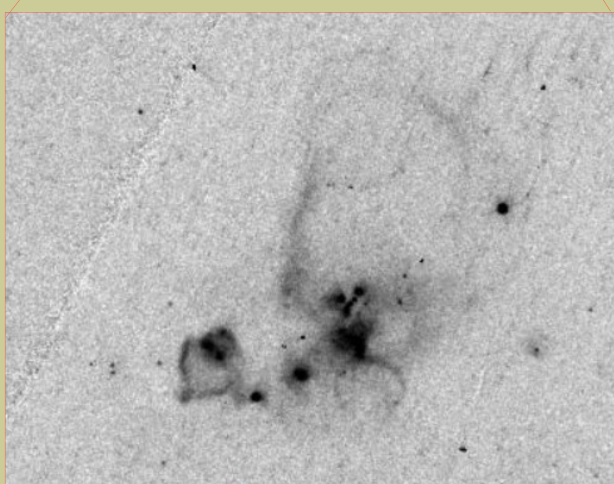
V(outflow)=30-80 km/s
It's comparable to the σ



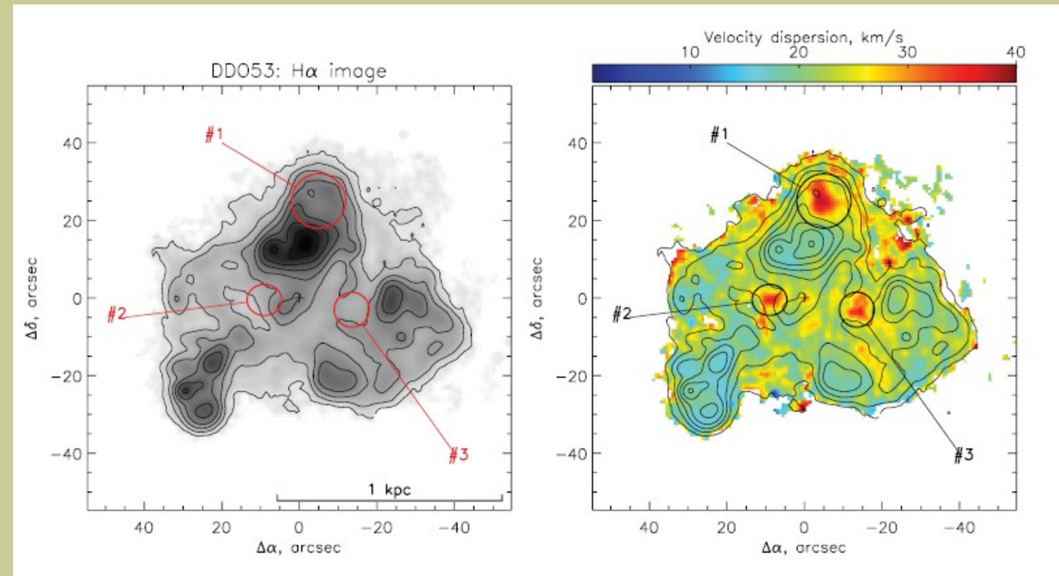
Oparin & AM +15

Turbulent motions: DDO53





HST WFPC2/F656

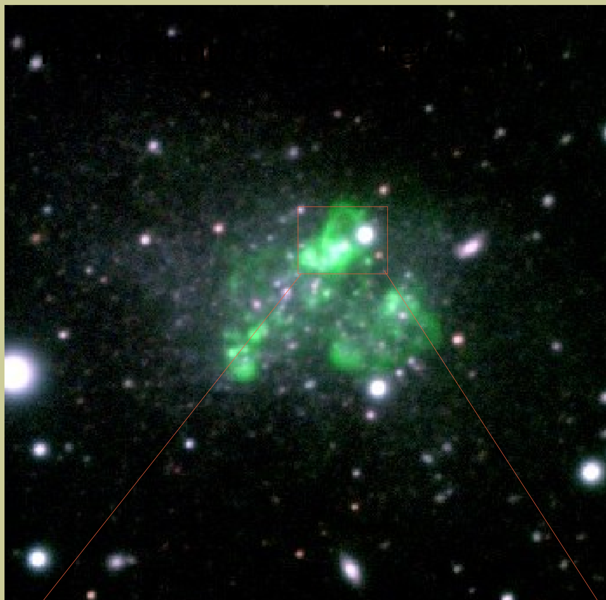


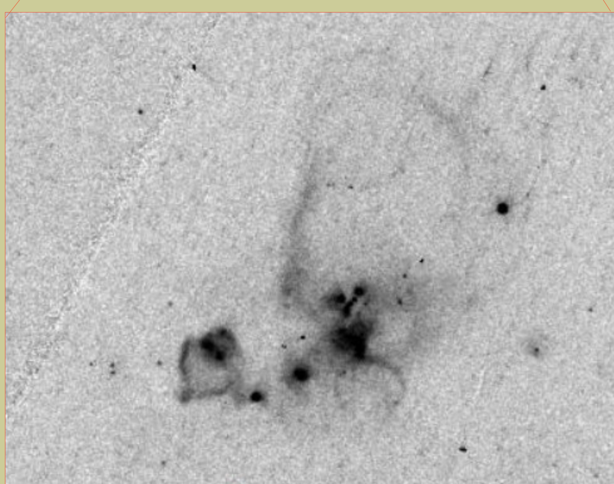
How can we quantify this distribution?

Velocity dispersion increases outside of bright HII regions

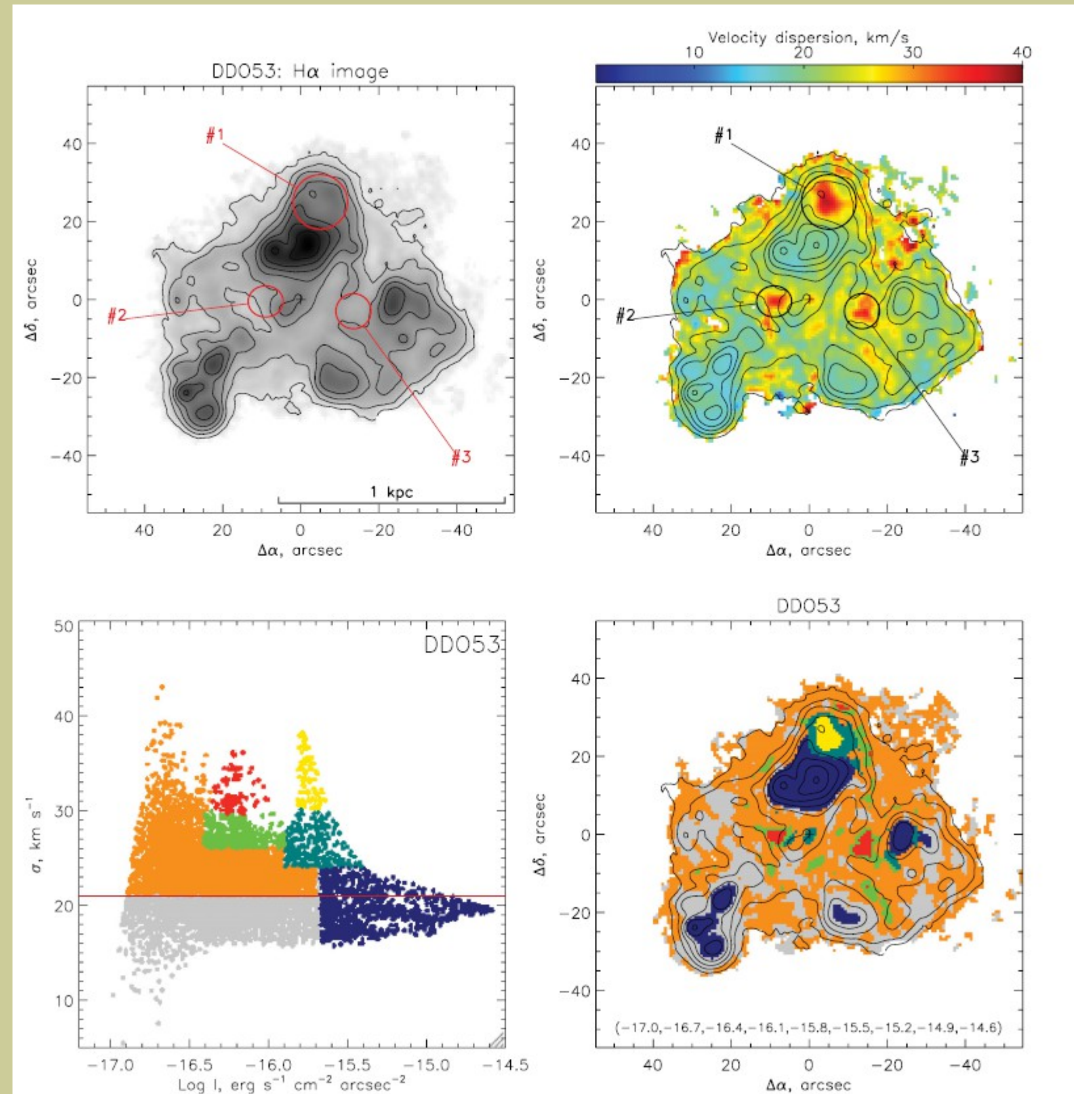
Moiseev & Lozinskaya 2012

Turbulent motions: DDO53





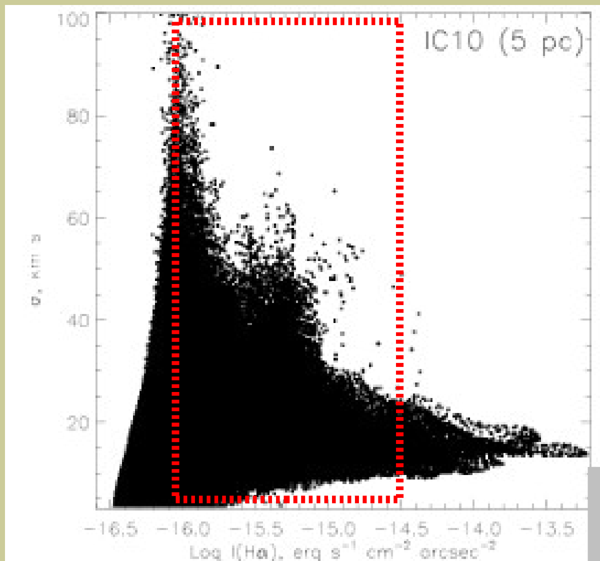
HST WFPC2/F656



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

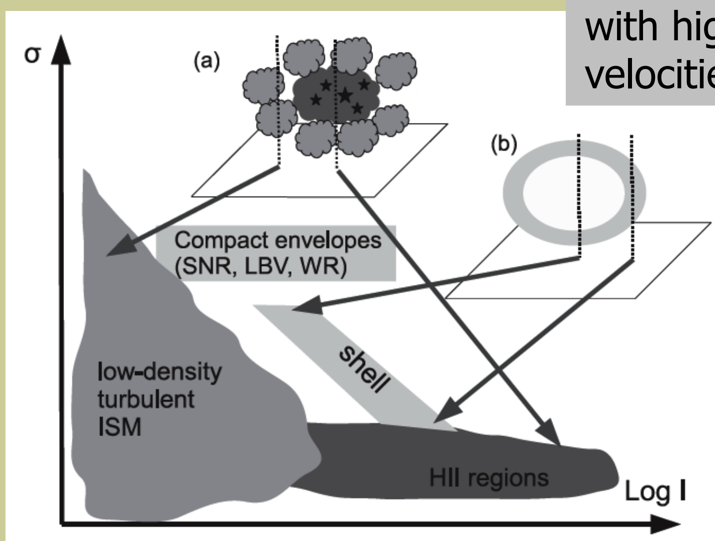


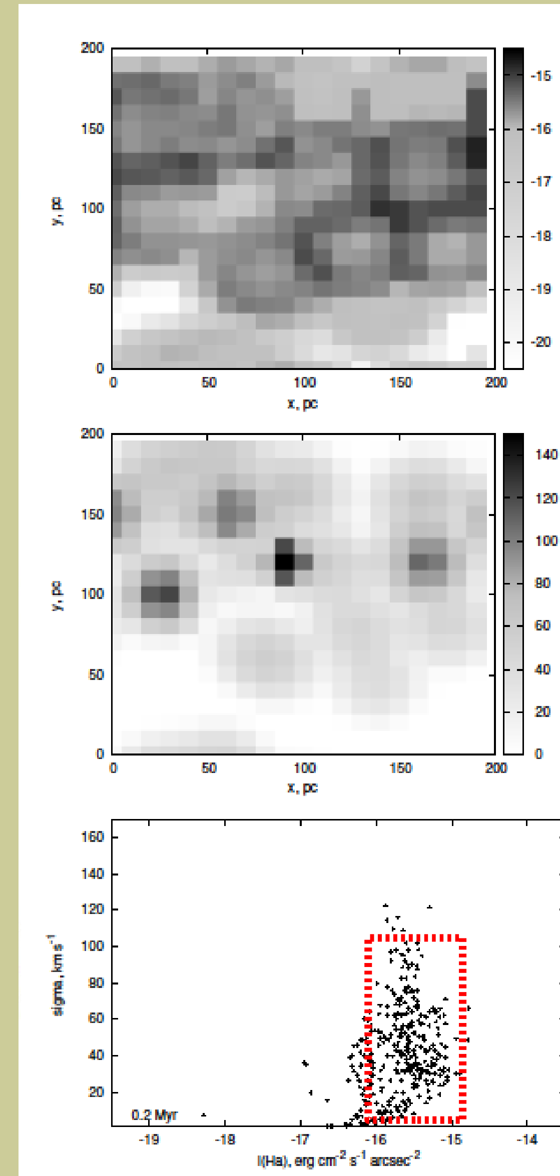
Figure 6. The scheme illustrating the location of points on the $I-\sigma$ diagram. The insets show how we projected on to the sky plane the surface brightness distribution and velocity dispersion (a) from dense H II regions, surrounded by low-density gas with considerable turbulent motions, and (b) from the expanding shell within the model by Muñoz-Tuñón et al. (1996).

AM & Lozinskaya +12

I(Hα):

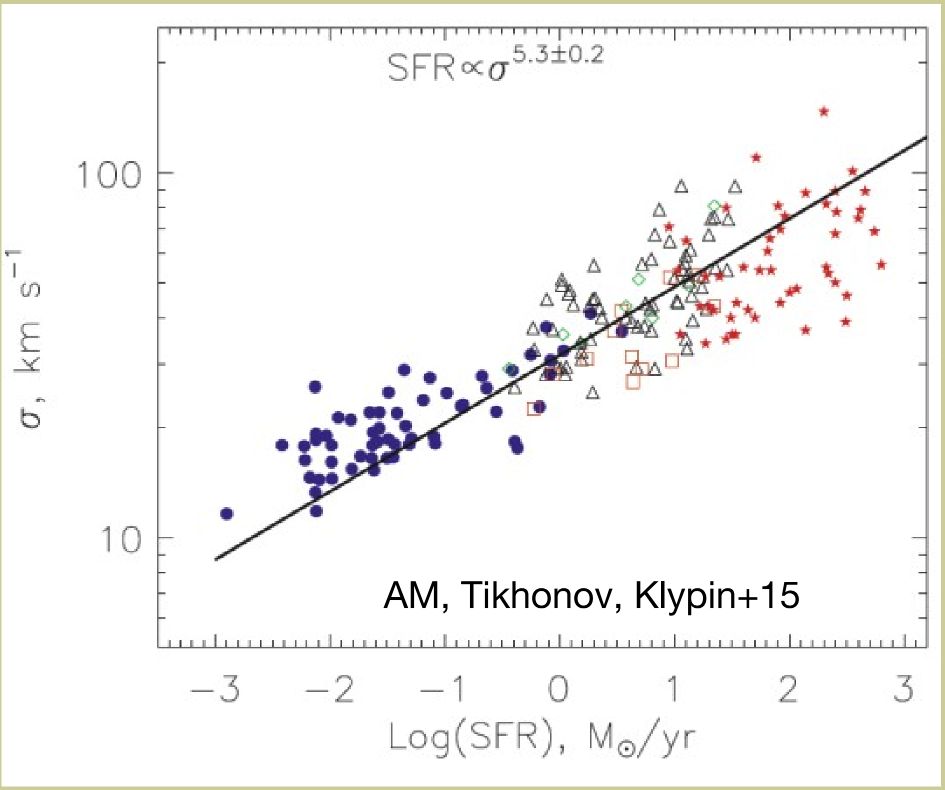
σ:

I-σ:



Vasiliev, AM & Shchekinov +14

H-alpha luminosity (SFR) -σ relation

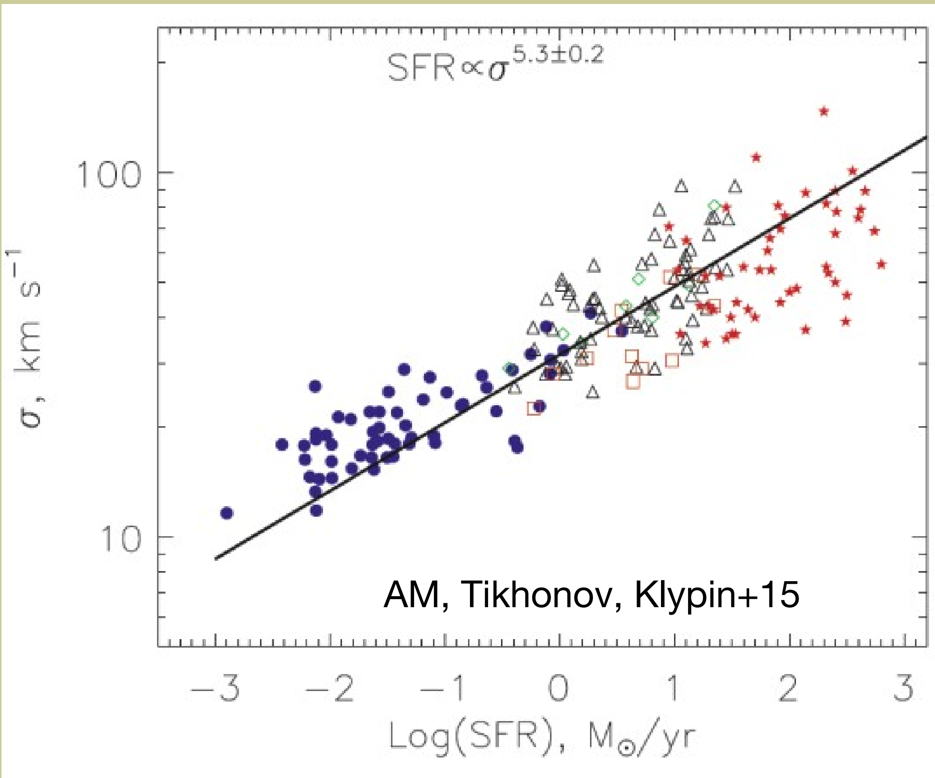


Mean σ, weighted by intensity:

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

We lose information
about spatial distribution.

H-alpha luminosity (SFR) -σ relation



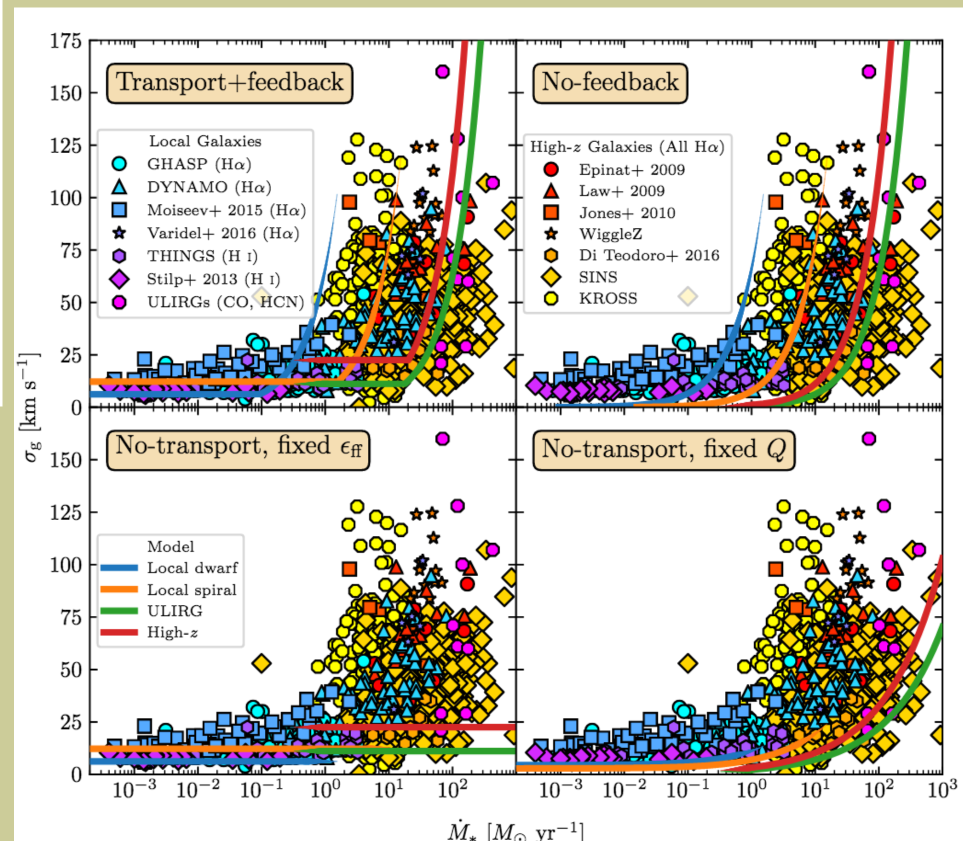
A Unified Model for Galactic Discs: Star Formation, Turbulence Driving, and Mass Transport

Mark R. Krumholz[1*], Blakesley Burkhart[2], John C. Forbes[2], and Roland M. Crocker[1]

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

Mean σ, weighted by intensity:

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

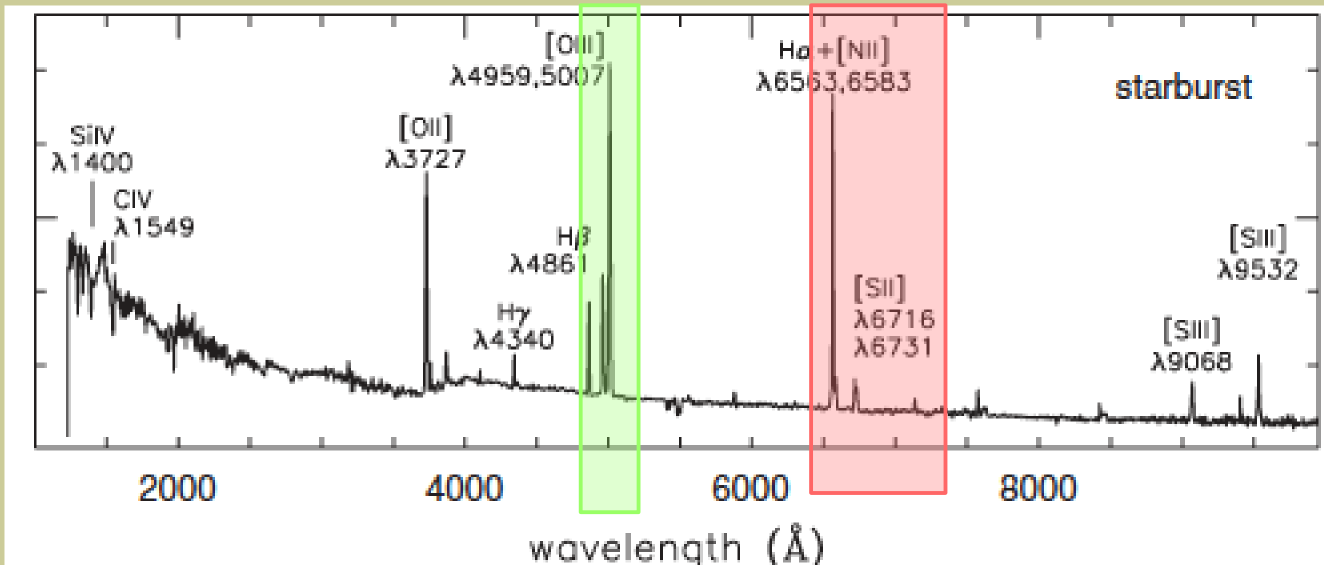


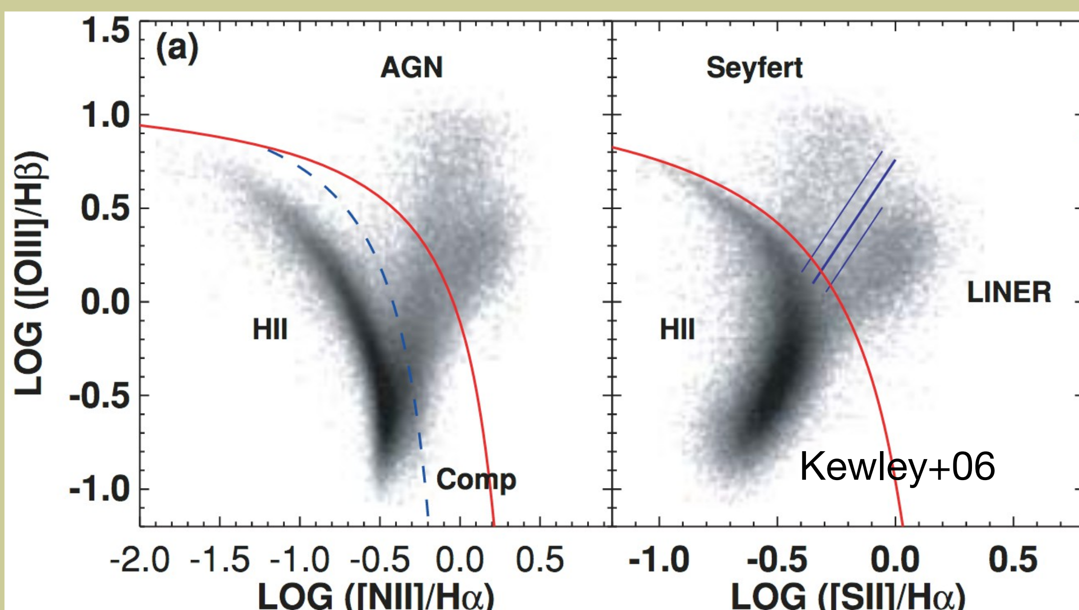
We lose information about spatial distribution.

Krumholz +18

Feedback in ionization properties

Seagull-diagram :)





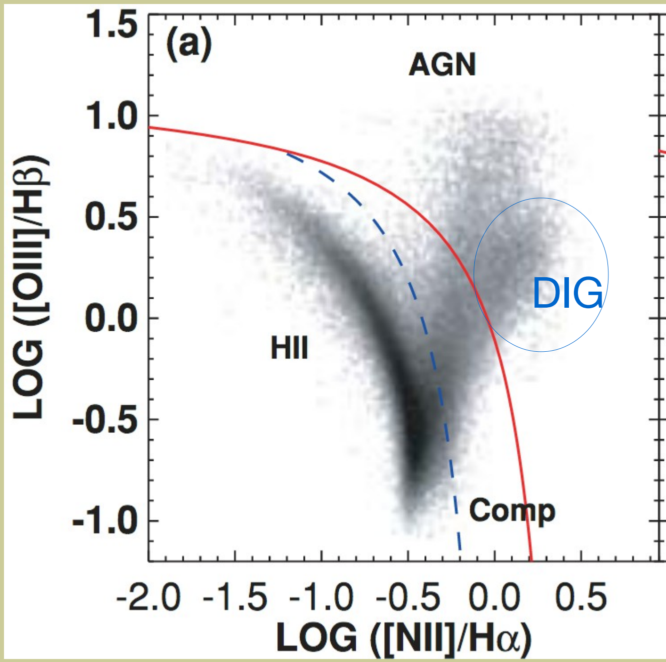
- brightest lines
- extinction-independent ratio

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

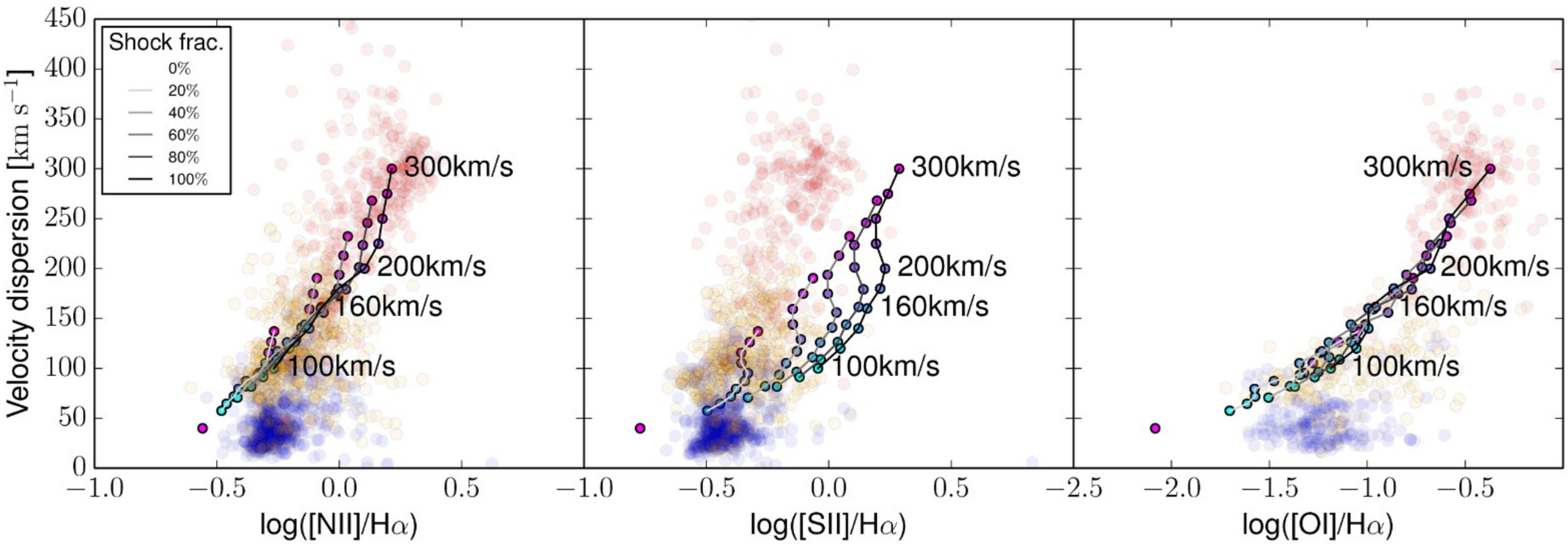
3) Old stellar population: AGB, etc.

Hight velocity dispersion means turbulent motions powered by stellar feedback

→ "BPT-sigma relation"

BPT-sigma in luminous galaxies

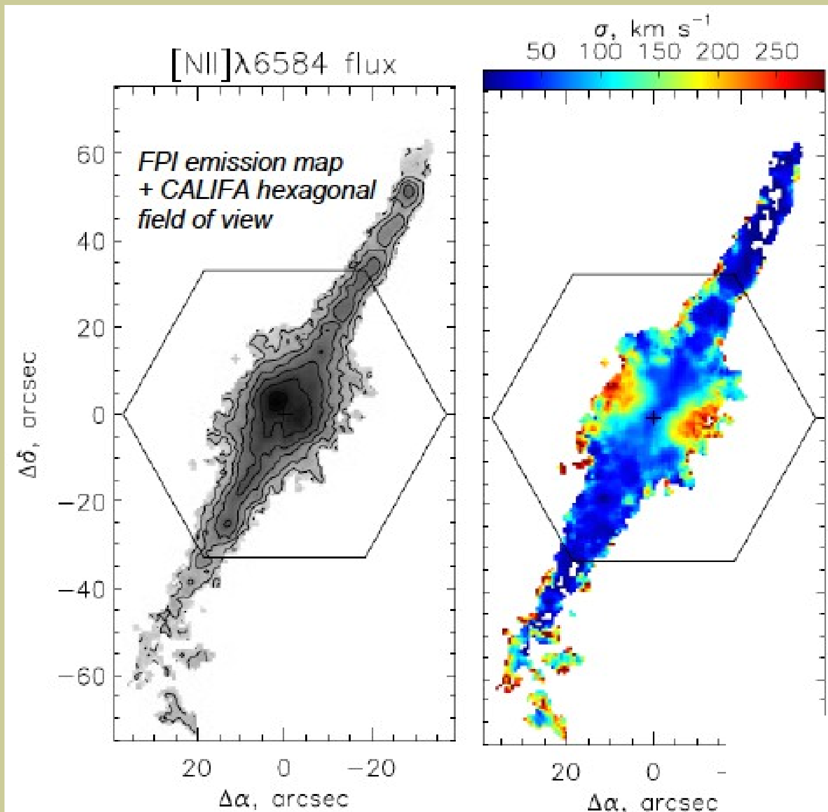
SAMI survey Ho+2014

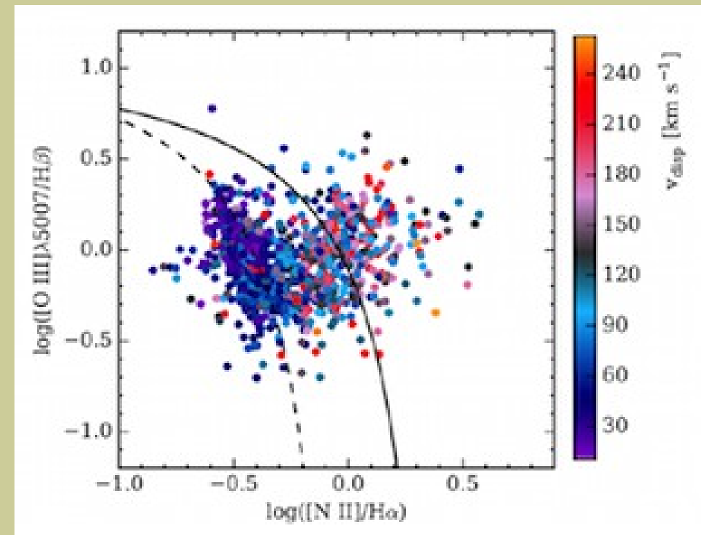


What about local dwarf galaxies? We need higher velocity resolution (σ<45 km/s)

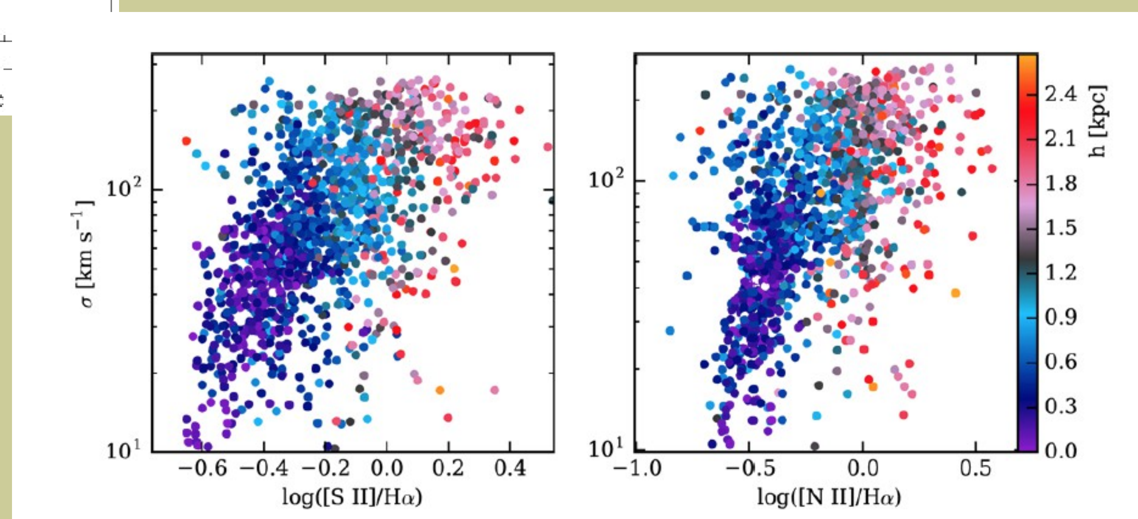
Combination of high-resolution FPI maps with 3D spectrophotometric data!

Wind in UGC 10043: CALIFA + FPI



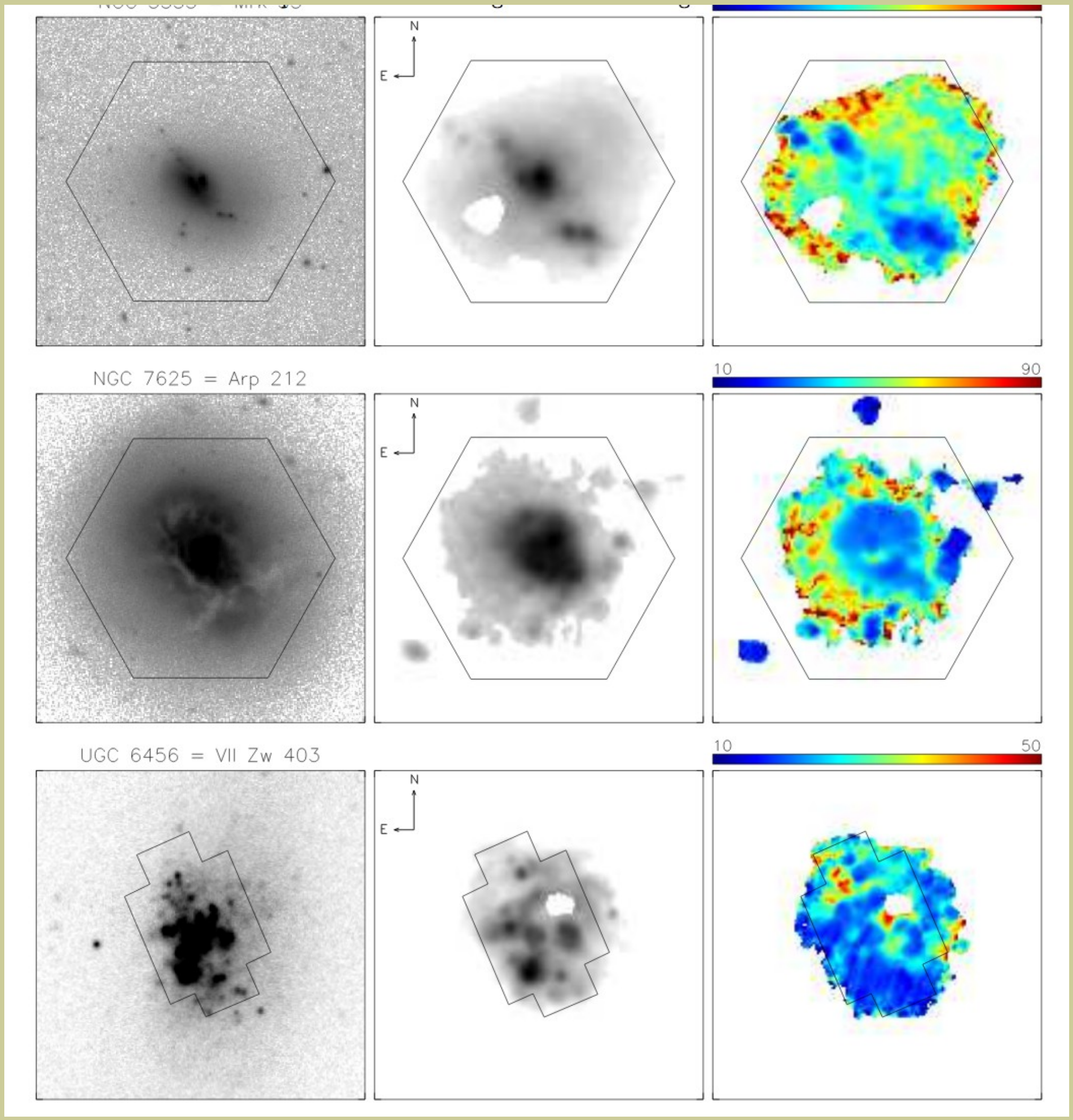


An agreement between the line ratios and kinematics



Lopez-Coba+15

BPT-sigma relation on dwarf galaxies: it works



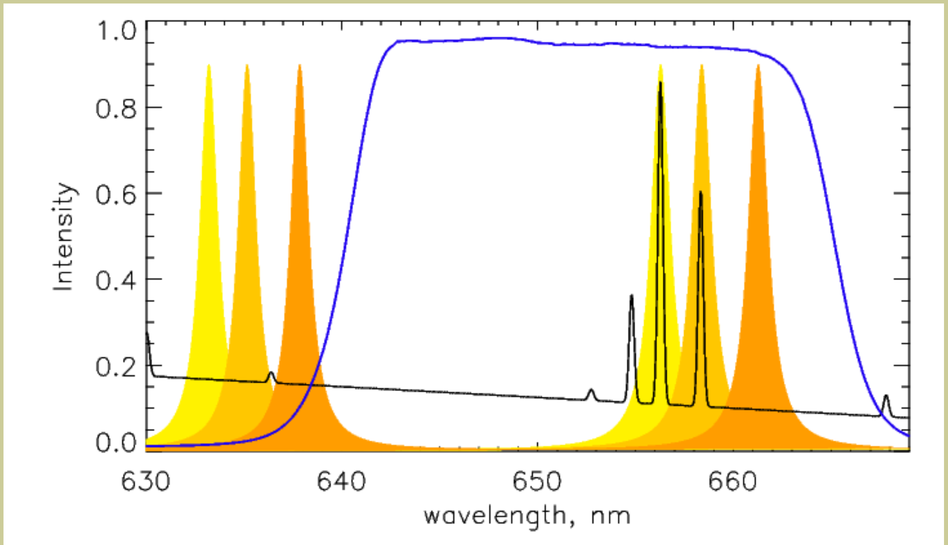
Dmitry Oparin's talk !

6-m telescope FPI maps
+
Archival integral-field data

MaN**G**a**L**=**Ma**pper of **N**arrow **G**alaxy **L**ines

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

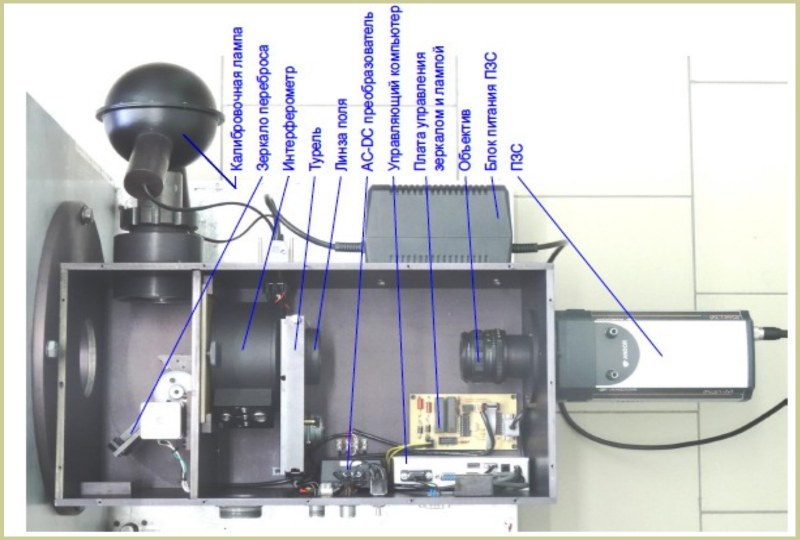
Low order Fabry-Perot interferometer = tunable filter



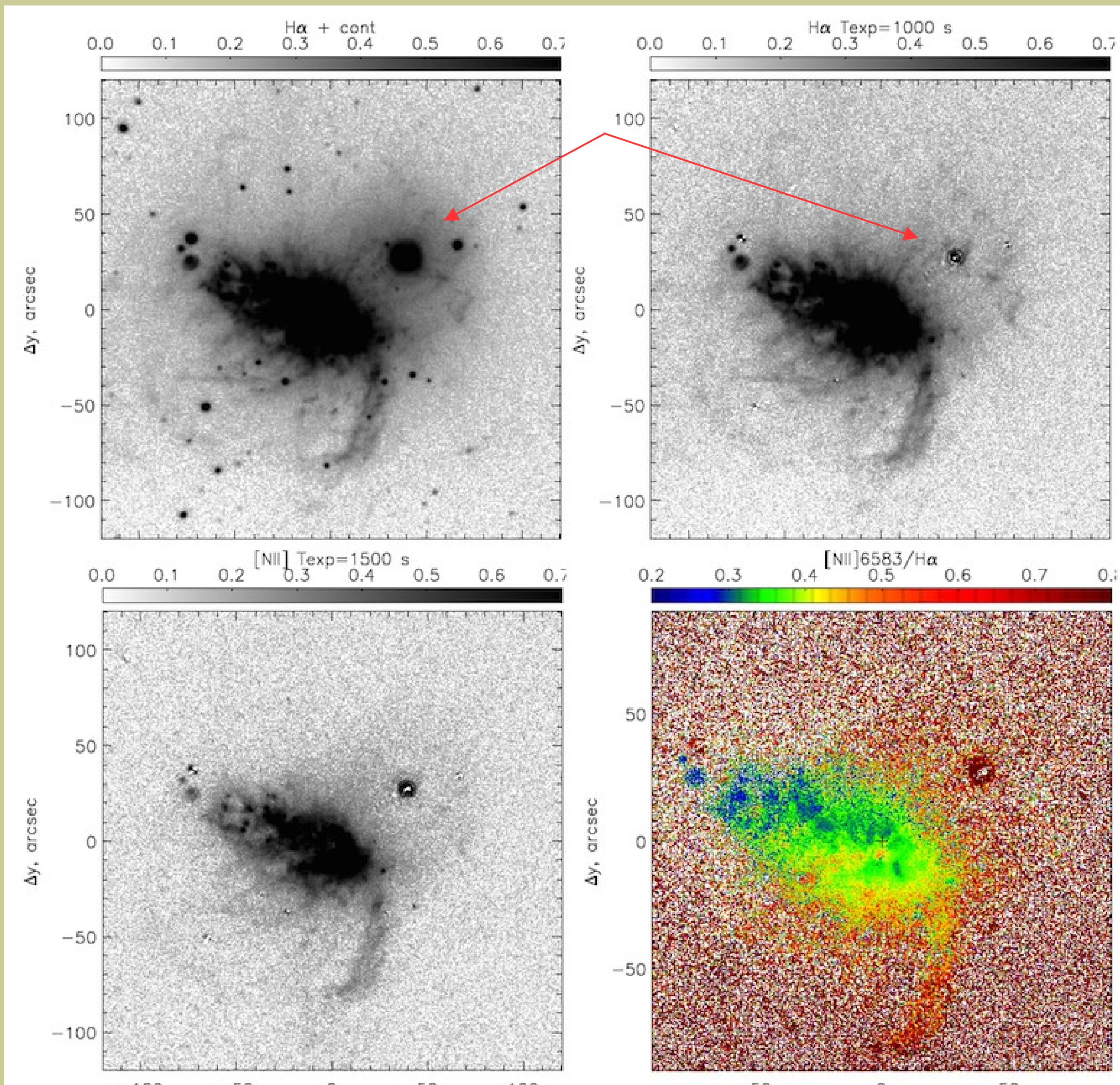
Spectral range: 4600-7500 Å

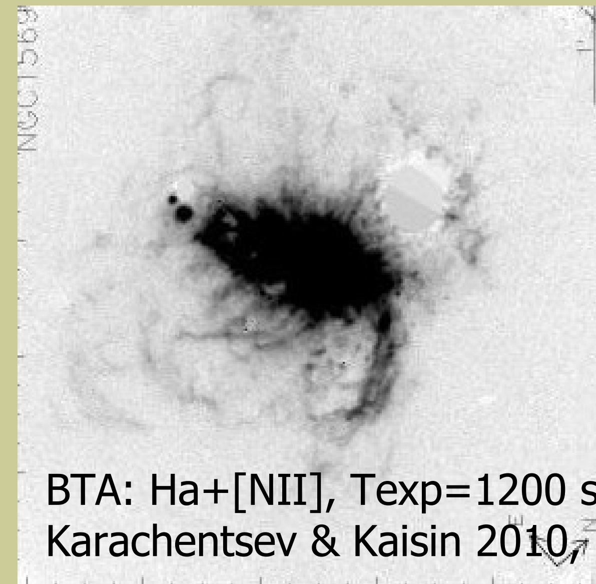
FWHM:
δλ =15-25 Å (FPI gap =5-14 μm)

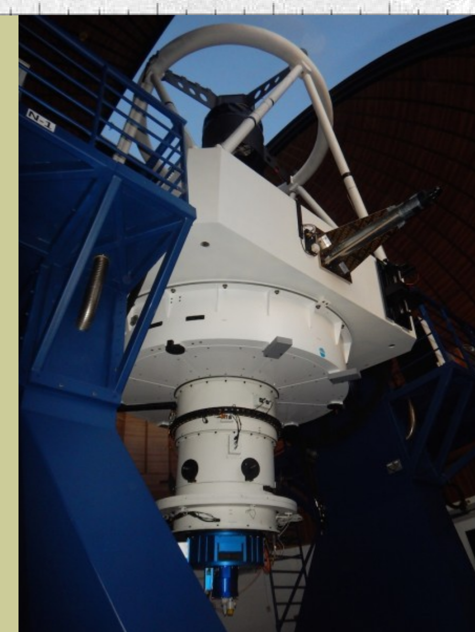
*`Mangal' is a Caucassian and Middle Eastern barbeque.



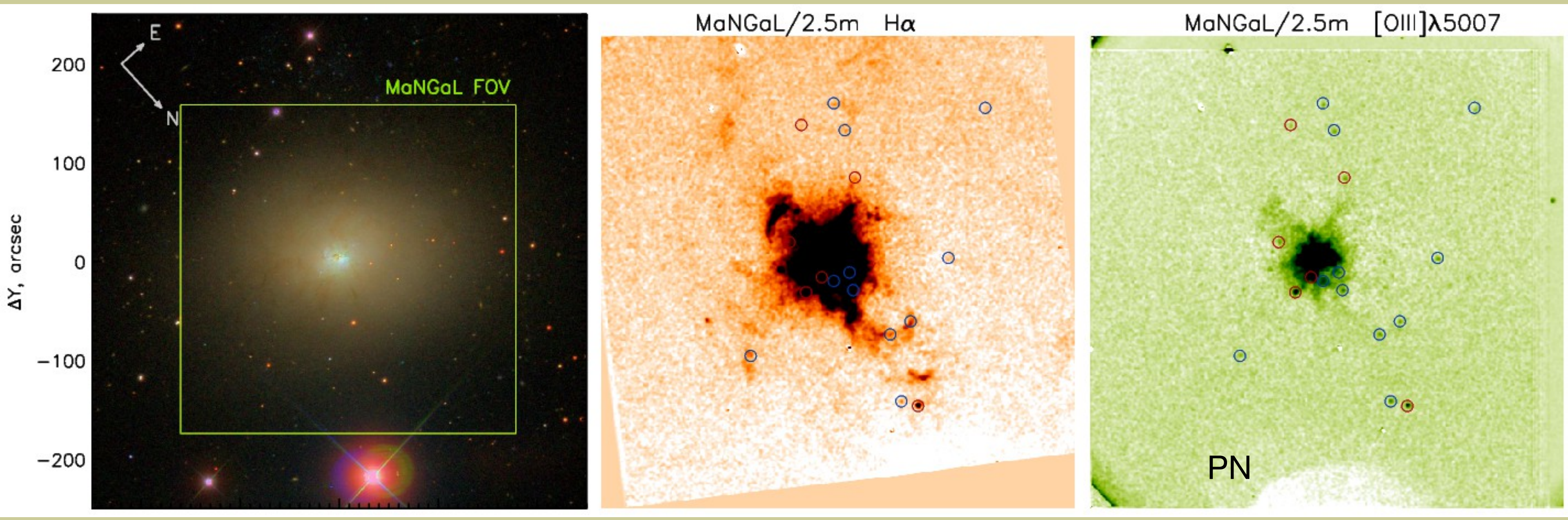
The first light at 2.5m telescope: NGC 1569

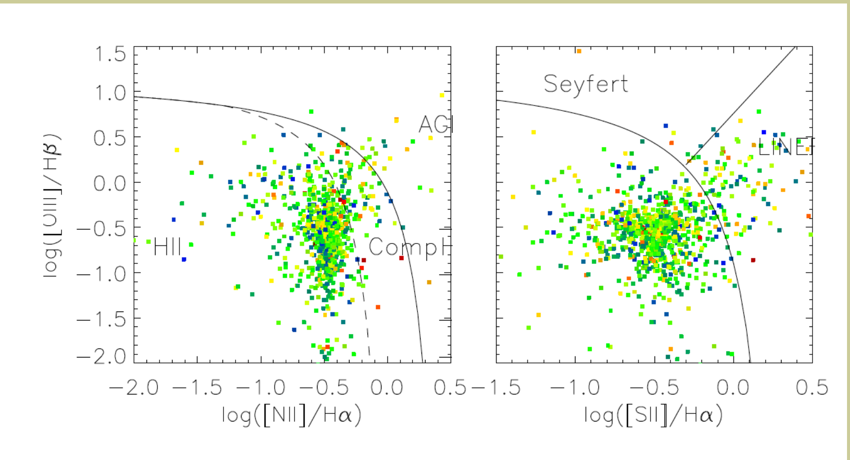


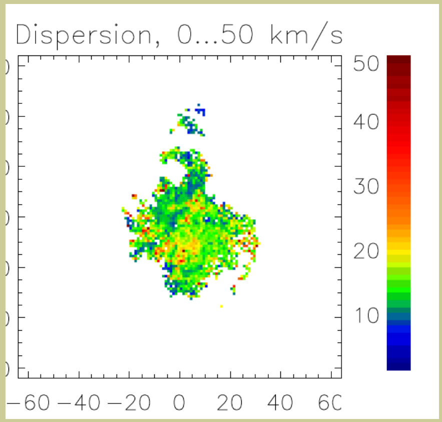




NGC 3077: shells and PNe in M81 group dwarf galaxy







PNe candidates in N3077 (poster by Sypkova)

Talk by Oparin

Oparin, Egorov, Moiseev, in prep

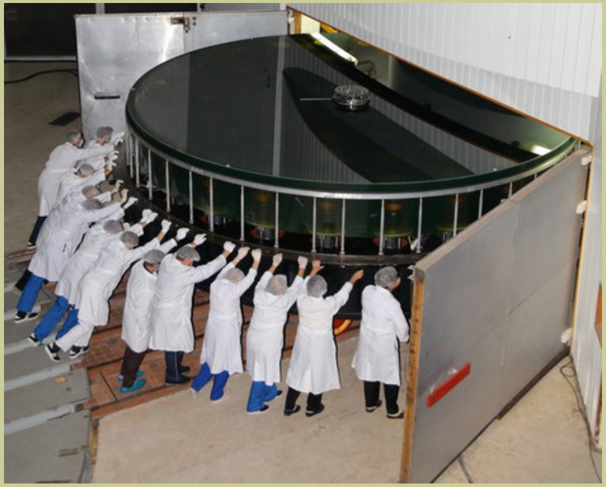
Summary

- 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!