Kinematics and the ISM phases in II Zw 40

Optical and Infrared IFU spectroscopy

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SUMMARY

I present the results of Integral Field spectroscopy of the prototype HII galaxy II Zw 40 from a combination of two complementary collaborations. Using **Gemini GMOS-IFU** in the red part of the visible spectrum [1]Bordalo, Plana & Telles (2008) derived Hα monochromatic, velocity and dispersion maps on the central star forming knot. We show that II Zw 40 has a kinematic core which is dominated by random motions with a core velocity dispersion of 34 km s^{-1}. It also shows a lower limit supersonic velocity dispersion of 26 km s^{-1}, unaffected by stellar evolution, which permeates the whole star forming region, likely to represent the dispersion associated with gravity. Diagnostic diagrams, such as the Intensity versus σ diagram, are used to identify the kinematic features as shells and filaments due to the stellar driven winds. A single Gaussian fit to the integrated spectrum Hα line over the whole star forming region will measure exactly the same width as a single Gaussian fit to the one pixel core Hα line.

Using **VLT- Sinfoni Integral Field** in the Near-Infrared with adaptive optics on the VLT, [2]Vanzi, Cresci, Telles & Melnick (2008) analyzed the spatial distribution of extinction, ionized Hydrogen, Helium, Fe[II] and molecular hydrogen (H_2) emission and velocity fields. We show that II Zw 40 is solely powered by one super stellar cluster (knot A) producing all the present ionizing radiation. It is also responsible for the photo-excitation of H_2, although this has a peculiar velocity field detached from Bγ and Fe[II].

Both of these studies are in good agreement revealing that the age of the stellar population in the main cluster is such that no supernova (SN) should be present yet so that the gas kinematics must be dominated by the young stars with a dominant turbulent random component in the core. We do not see, in the starbursting region, any geometrical or dynamical structure that can be related to the large scale morphology of the galaxy.

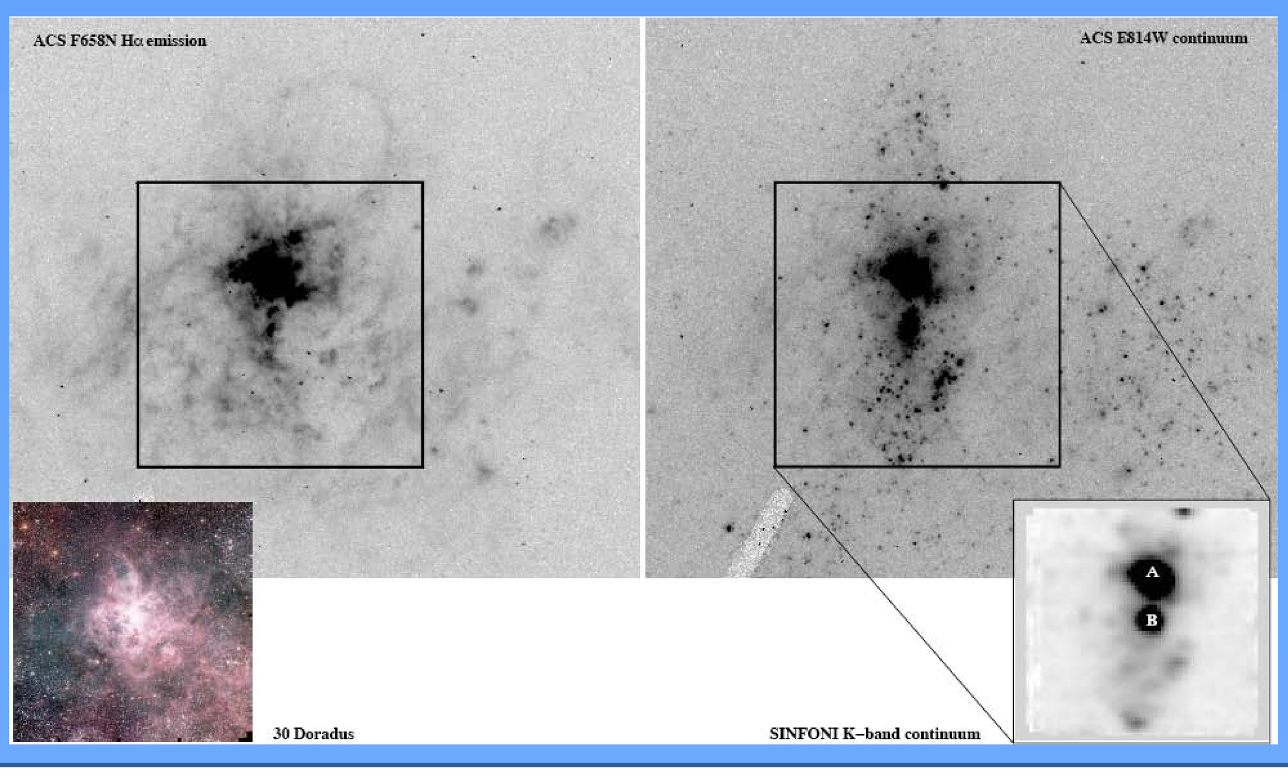

Fig. 1. Archive Hα image of II Zw 40, obtained by ACS on board the HST (left panel). The central box indicates the field covered by our near-IR VLT-SINFONI observations, FOV = 8 00”. The insert in the bottom left shows the 30 Doradus complex, image from WFI at the LaSilla 2.2 m telescope, ESO press photo 14a/02. Archive F814W image of II Zw 40, obtained by ACS on board the HST (right panel). In the lower right insert, continuum image in K band obtained with SINFONI. North is up, east to the left.

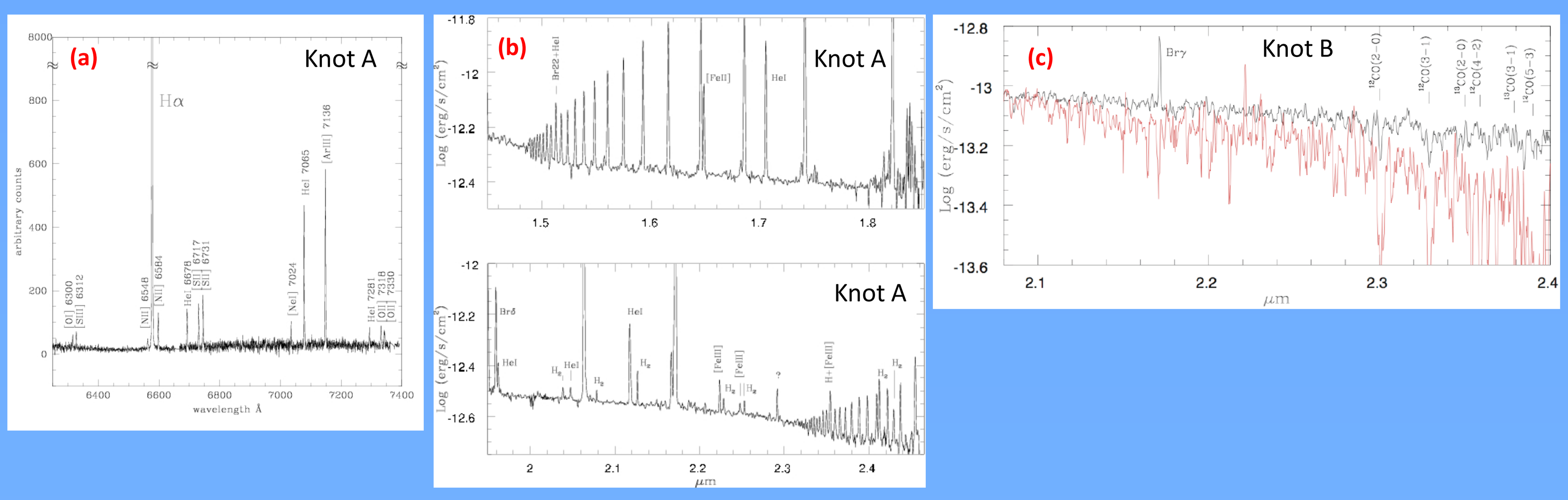

Fig 2. — **(a)** Single pixel GEMINI GMOS-IFU optical spectrum on the bright core centered on knot A. **(b)** Near-infrared VLT-SINFONI spectrum of source A extracted with a circular aperture of 1” radius. Besides a few obvious lines such as Brγ at 2.17 μm or HeI at 2.06 μm, a large number from the Bracket series are detected in the H spectrum, and from the Pfund series beyond 2.3 μm. **(c)** Near-infrared VLT-INFONI spectrum of source B (south of knot A) in the K band dark line. The spectrum was extracted with a circular aperture of 0.75” radius and subtracted from the spectrum of the surrounding area. The CO stellar band head are indicated. The red line shows the combined spectrum of the faint sources in the field of SINFONI: the spectrum is scaled up by a factor of about 10.

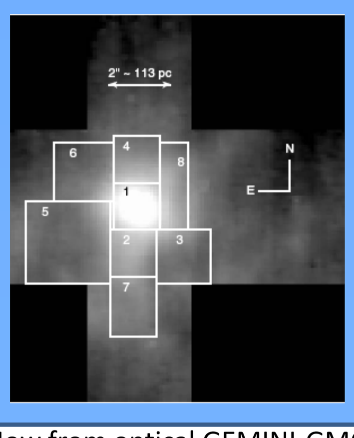

Fig. 5. Now from optical GEMINI-GMOS/IFU. We derived the Hα emission map . Eight individual regions were chosen to dissect the kinematics of the central starburst in II Zw 40, from peculiarities in the monochromatic, velocity and dispersion maps.

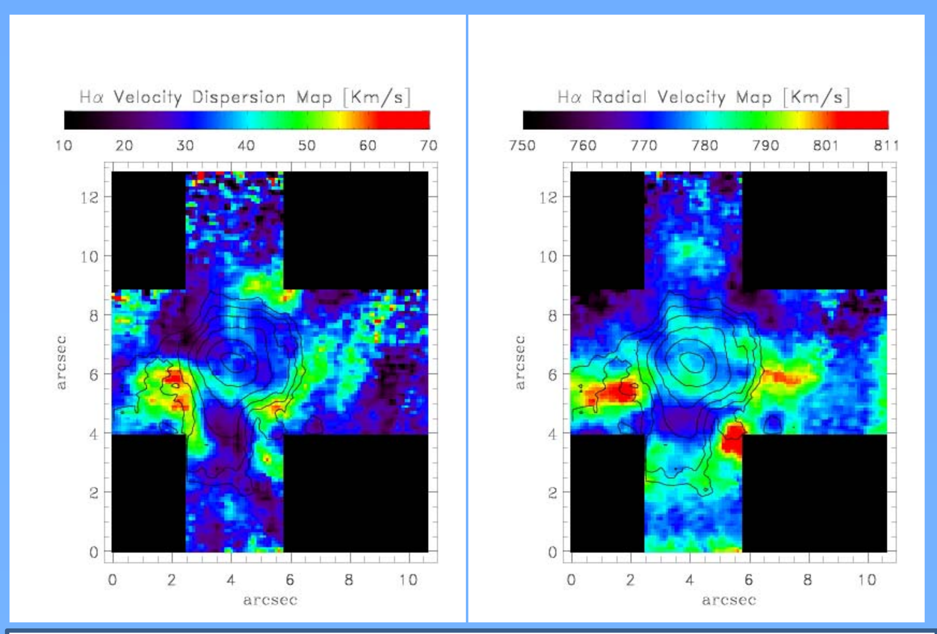

Fig. 6.— **Left Panel:** Hα velocity dispersion map, corrected for instrumental and thermal broadening, of the inner region of II Zw 40. The contours represent Hα line intensity. The S/N_{line} of the faintest contour level is ~ 70. **Right Panel:** Hα radial velocity map. North is up and east is left.

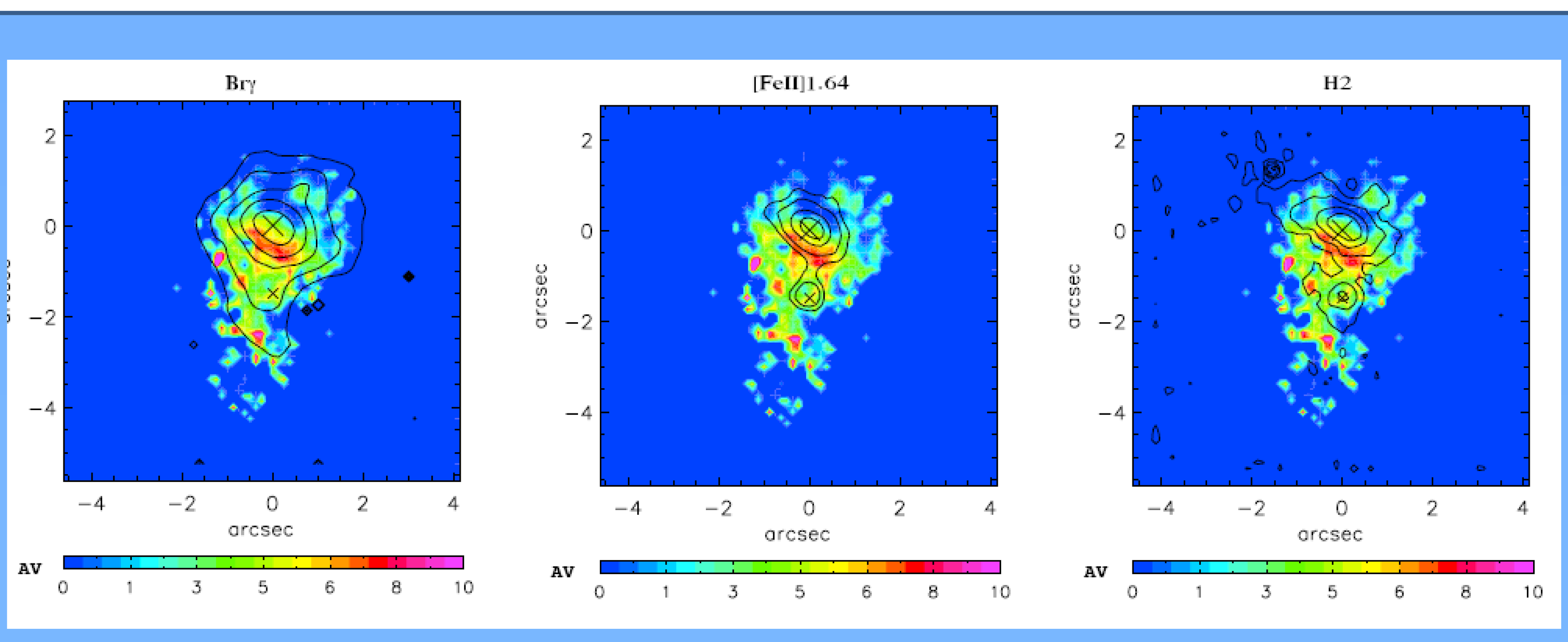

Fig. 3. Comparison of the geometry of the emission lines (contours) and the spatial distribution of the extinction, derived from the Brγ / Br11 ratio (colorscale). The contours of Brγ, [FeII]1.64, and H_2 are plotted on the left, central, and right panel respectively. The positions of the brightest continuum sources A and B are indicated by crosses.

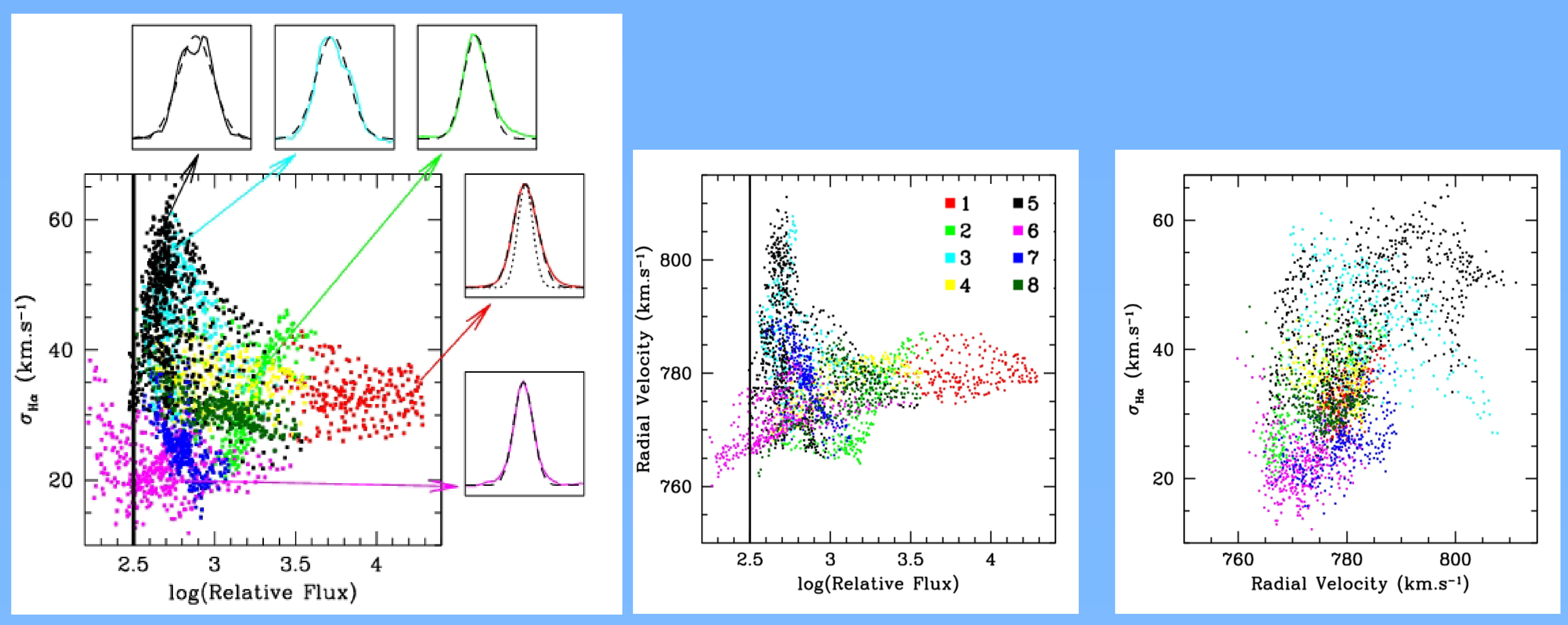

Fig. 7.— Kinematics Diagnostic Diagrams (see Muñoz-Tuñón etal 1996, Yang etal 1996). I-σ (left), I-V (center) and V -σ (right) plots for the whole field observed in II Zw 40. Color coded pixels indicate the individual regions as shown in figure 5. Characteristic individual pixel line profiles are shown in different inserts. Dashed lines represent the single Gaussian fits and the dotted line under the red profile is the instrumental profile. The vertical solid line at log(Relative Flux) = 2.5 represent our confidence level (S/N_{line}~40). Inclined bands in the I-σ (left) indicate the presence of shells in regions 3 (cyan) and 5 (black). Region 6 (magenta) seems to be unaffected by stellar evolution and that may still keep the kinematic signature of the proto-cloud that gave rise to the present starburst. It also sets a lower limit of ~23 kms-1 to $\sigma_{grav.}$ Region 1 (red, on knot 1) seems to be kinematically very young and is dominated by random motions, not due to shells or radial velocity, likely to be associated with gravity. Results are consistent in the light of the Cometary Stirring Model of cluster formation (Tenorio-Tagle etal 1993).

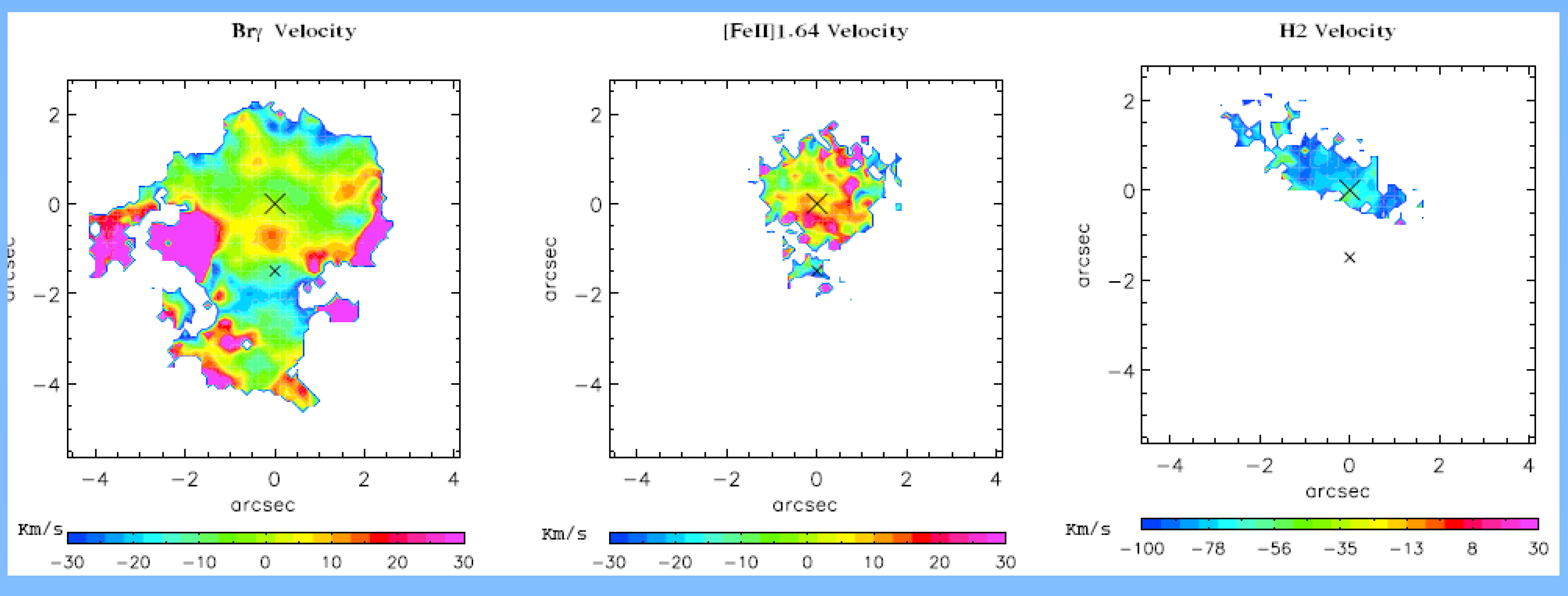

Fig. 4. Radial velocity maps of Brγ (left), [FeII]1.64 (center) and H_2 (right). The positions of the brightest continuum sources A and B are marked by crosses. The zero point of the velocity refers to the Brγ emission on source A. The H_2 cloud shows an average offset of about 90 km/s with respect to the other components.

SOME KINEMATIC CONCLUSIONS:

• The kinematic features in II Zw 40 are all remarkably similar to the ones found in supersonic GHIIRs in irregular and other star forming galaxies, powered by massive star and stellar cluster formation and evolution.

• The diagnostic diagrams of I versus σ, I versus V, and additionally σ versus V are powerful tools to identify the sources of internal motions such as shells, filaments or outflows from the presence of stellar driven winds and/or SN. These motions will cause the presence of wings and have little effect on the narrow emission line width of the integrated spectrum.

•The single Gaussian fit to the narrow component of an integrated emission line which encompasses the brightest knot will always measure the core line width dominated by random motions. This core supersonic σ is the one producing the Luminosity-σ relation (Melnick etal 1988) observed in GIIRs and HII galaxies, and it is likely to be due mostly to gravity.

•However, we must further investigate how these derived motions precisely relate to the underlying mass distribution before we can derive absolute total galactic masses. We must also investigate, with a statistically significant sample, the possible evolutionary effects of the starburst on the observed Luminosity-σ relation and how they can be parametrized for the use as a powerful extragalactic distance estimator applied to high redshifts.

INTERSTELLAR MEDIUM CONCLUSIONS:

• II Zw 40 was shown to be dominated by one giant HII region powered by a single young super-massive cluster with a mass of $1.7 \times 10^6 M_\odot$ and an age of 3 Myr at most, as derived from the Brγ luminosity and equivalent width, respectively. All other compact sources detected are less massive and older. The starbursting region of II Zw 40 could be regarded as a scaled up version of 30 Dor.

• The ISM is mostly photo-excited. Lines of H_2 and [FeII] do not show signs of shocks. Consistent with the very young age and with kinematic results, there must be very few, if any, SN in the star-forming region, and certainly none would be present in the main cluster.

• We detected a giant cloud of H_2, which is not related to the giant HII region, having a different morphology and dynamics, but that is still photo-excited by the radiation field emanating from the main cluster.

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