Kinematics of interacting galaxies
A 3D-view from the CALIFA survey

ArXiv: 1506.03819

Jorge K. Barrera-Ballesteros
Begoña Garcia-Lorenzo
Jesús Falcón-Barroso
and the CALIFA collaboration

Tenerife - June 2015
Mapping the kinematics in nearby systems

- Detailed analysis of individual systems.
- Most of these studies focus on a particular component of interacting system: stars, ionized, neutral or molecular gas (e.g., Colina+05, Wild +14, Iono+05).
- From rotational patterns to complex velocity fields.
Mapping the kinematics in nearby mergers

- Bellochi+2013: (U)LIRGs at different interacting stages ($N < 60$).
- Velocity field from Hα emission line.
- ~70% of the sample dominated by rotation.
Mapping the kinematics in nearby mergers

- How the internal structure (kinematics) of galaxies is affected as the merger evolves?
- Do the stellar and ionized gas components evolve differentially?
- Quantifying the level of ‘distortions’ produced induced by the interactions using a homogeneous control sample of non-interacting galaxies.
The CALIFA survey

- 937 galaxies from SDSS/DR7 of all Hubble Types.
- Nearby galaxies selected by size (45” < D25 < 80”; 0.005 < z < 0.03).
- PMAS/PPAK-IFU @ CAHA 3.5m.
- Wide range of stellar masses (9.4 < log(M_{star}/M_{☉}) < 11.4).
- > 450 galaxies observed.

http://califa.caha.es/
The CALIFA survey

V_{1200} R_{\sim 1750}

[V_500 R_{\sim 850}]

[OIII] [OII] H_\beta [NII] [SII] [OI]

H_\gamma Ca II Mgb NaD

Ionised gas Kinematics
cross-correlation technique
see García-Lorenzo 2013

Stellar Kinematics
pPXF (Cappellari. 2004)
CALIFA interacting galaxies

103 galaxies at different stages of merger
+ 80 non-interacting galaxies as control sample (Barrera-Ballesteros+2014)
Characterization of Velocity Fields

An “assumption-free” method

Kinematic Centre
(García-Lorenzo+2015)

For a pure-rotational disc, its gradient peak is located at the optical nucleus.
Characterization of Velocity Fields

An “assumption-free” method

Kinematic PA

(García-Lorenzo+2015, Barrera-Ballesteros+2014)
Characterization of Velocity Fields
An “assumption-free” method

Kinematic PA
(García-Lorenzo+2015, Barrera-Ballesteros+2014)
Characterization of Velocity Fields

An “assumption-free” method

Kinematic PA

(García-Lorenzo+2015, Barrera-Ballesteros+2014)
Characterization of Velocity Fields

An “assumption-free” method

Kinematic PA
(García-Lorenzo+2015, Barrera-Ballesteros+2014)
Characterization of Velocity Fields

An “assumption-free” method

Kinematic PA
(García-Lorenzo+2015, Barrera-Ballesteros+2014)
Characterization of Velocity Fields

An “assumption-free” method

Kinematic PA

(García-Lorenzo+2015, Barrera-Ballesteros+2014)
Characterization of Velocity Fields
An “assumption-free” method

Kinematic PA
(García-Lorenzo+2015, Barrera-Ballesteros+2014)

- Average kinematic PA ($PA_{\text{kin}}$).
- Radial deviation of kinematic PA ($\delta PA_{\text{kin}}$).
- Derived for both kinematic sides.
- + Morphological PA (Ellipse fitting)
Morpho-kinematic PA misalignments

\[ \psi_{\text{morph-kin}} = \| \text{PA}_{\text{morph}} - \text{PA}_{\text{kin}} \| \]

<table>
<thead>
<tr>
<th>( \psi_{\text{morph-kin}} ) (deg)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>21 deg &lt; 90% Control</td>
</tr>
<tr>
<td>21-40</td>
<td>90% Interacting</td>
</tr>
<tr>
<td>41-60</td>
<td>22 deg &lt; 90% Control</td>
</tr>
<tr>
<td>61-80</td>
<td>90% Interacting</td>
</tr>
<tr>
<td>81-100</td>
<td>43% of interacting sample with ( \psi_{\text{morph-kin}} &gt; 21 ) degrees.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( \psi_{\text{morph-kin}} ) (deg)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>21 deg &lt; 90% Control</td>
</tr>
<tr>
<td>21-40</td>
<td>90% Interacting</td>
</tr>
<tr>
<td>41-60</td>
<td>22 deg &lt; 90% Control</td>
</tr>
<tr>
<td>61-80</td>
<td>90% Interacting</td>
</tr>
<tr>
<td>81-100</td>
<td>52% of interacting sample with ( \psi_{\text{morph-kin}} &gt; 22 ) degrees.</td>
</tr>
</tbody>
</table>
Morpho-kinematic PA misalignments

\[ \psi_{\text{morph-kin}} = | \text{PA}_{\text{morph}} - \text{PA}_{\text{kin}} | \]

Enhancement of \( \psi_{\text{morph-kin}} \) at the \textbf{merger} stage.
Stellar-Gas Kinematic PA misalignments

\[ \psi_{\text{gas-stars}} = \left| \text{PA}_{\text{gas}} - \text{PA}_{\text{stars}} \right| \]

43% (28/66) of interacting sample with \( \psi_{\text{gas-stars}} > 16 \) degrees.

18% (12/66) of interacting sample with \( \psi_{\text{gas-stars}} > 30 \) degrees.
Stellar-Gas Kinematic PA misalignments

$$\psi_{\text{gas-stars}} = \mid \text{PA}_{\text{gas}} - \text{PA}_{\text{stars}} \mid$$

Large misalignments observed mostly in early-type galaxies, at different stages of interaction.
Stellar-Gas Kinematic PA misalignments

\[ \Psi_{\text{gas-stars}} = | \text{PA}_{\text{gas}} - \text{PA}_{\text{stars}} | \]

Interaction stage
- Pre-merger
- Merger
- Post-merger
- Remnant

\( \Psi_{\text{stars-gas}} \) (deg)

Interaction stage
- Pre-merger
- Merger
- Post-merger
- Remnant

\( \Psi_{\text{stars-gas}} \) (deg)
Summary

• Covering a wide range of environmental and internal parameters, the CALIFA survey allow us to compare the 2D kinematic properties of galaxies at different stages of interaction with non-interacting galaxies.

• We develop an “assumption-free” method to characterize homogeneously the stellar and ionized gas velocity fields from those two samples.

• We trace the impact of interactions in the internal structure of galaxies:
  • Larger morpho-kinematic misalignments comparing to control sample in particular for galaxies with evident signatures of interaction.
  
  • Interacting galaxies show a large impact changing the internal structure of galaxies: 43% (28/66) shows stellar-gas kinematics larger than non-interacting sample.
For more about physical properties of the CALIFA interacting galaxies see the talk:

Central star formation and chemical enrichment in CALIFA interacting galaxies

S8 - 11:45 am