ADAS, or SCUDS II: Automated Analysis of Tidal Debris in External Galaxies

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What can we learn from tidal debris?

Johnston et al. (2008)
The State of LSB Tidal Debris Detection/Analysis
Roman (and other upcoming surveys) will provide a wealth of LSB tidal debris substructures, allowing us to study galactic accretion in unprecedented detail.
What do we need in order to determine merger histories from tidal debris substructures?

• **Systematic** surveys: large, statistically robust sample –

• Visual (manual) classification: scalability/consistency

• **Automated** classification/analysis: efficient, consistent, statistical

NGC 474. Image Credit: CFHT, Coelum, MegaCam, J.-C. Cuillandre (CFHT) & G. A. Anselmi (Coelum)
Recent work on detecting & classifying tidal debris

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</thead>
<tbody>
<tr>
<td>Detection of stellar streams</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes*</td>
<td>Yes (CNN)</td>
<td>No</td>
</tr>
<tr>
<td>Classification (morphology)</td>
<td>Visual</td>
<td>SCUDS I - limited</td>
<td>No</td>
<td>Visual/”image matching”</td>
<td>Yes</td>
</tr>
<tr>
<td>Properties (measurements)</td>
<td>Surface brightness</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Efficiency (scalability)</td>
<td>Local only; manual analysis</td>
<td>Yes</td>
<td>Yes</td>
<td>Partly (identification)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*76% completeness, 20% contamination
Summary of ADAS Algorithm
Automated Detection and Analysis of Structure
Step 1: Identify structure with SCUDS II (Hendel & Johnston 2018)

- N-body simulations $\rightarrow$ snapshots
- Mean shift: "Start points" $\rightarrow$ density gradient $\rightarrow$ principal curves
- "Ridge points" & tangent vectors
Step 2: Connect ridge points to form features using proximity + alignment; eliminate “noise”
Step 3: Relate stars to individual structures

Step 1

Step 2

Step 3
Step 4: Classify morphology

- Symmetry
- Orientation
Step 5: Measure length, width, surface brightness of individual features.

Step 1

Step 2

Step 3

Step 4

Width of stars for stream (above) and shell (left).
ADAS Results

- Length/angle subtended: age, orbit, mass
- Dispersion: mass ratio (+ age/orbit dependencies)
- Surface brightness: age, orbit, mass ratio
- Morphology: orbit (+ age for intermediate orbits)
ADAS Results ➞ Merger Histories

Surface brightness ➞ age, orbit, mass ratio

Length ➞ age, mass, orbit

Morphology ➞ orbit
Future Work/Collaborations: Applying ADAS to Real Images

• **Simulated ROMAN background tests**
• HSC LSB image repository
• CNN classification training
Potential Applications for ADAS

• Training for ML algorithms
• Search for gaps in thin streams
• Explore properties of simulation streams (e.g. FIRE)
• Explore whether satellite kinematics are correlated with tidal features
Backup
Requirements for (Limits of by-eye classification methods)

- **Systematic surveys**: large, **statistically robust** sample –
- Visual (manual) classification: scalability/consistency
- **Automated classification/analysis**: efficient, consistent, statistical
Step 1: Detecting Structure with SCUDS II (Hendel & Johnston 2018)

- N-body simulations -> snapshots
- Mean shift process:
  - Starting point grid
  - Converge to “principal curves” by following density gradient
- Obtain
  - Ridge points
  - Tangent vectors
  - (very local) Morphology
Part II: ADAS (Automatic Detection & Analysis of Structure)

1. Connect features using proximity + alignment in ridge points
2. Sort significant features from noise
3. “Assign” particles/stars/pixels to appropriate feature/ridge points
Part II: ADAS (Automatic Detection & Analysis of Structure)

- Step 4: Classify feature morphology
- Step 5: Measure length, dispersion (local & global), surface brightness of individual features
  - Morphology metric: symmetry + “radiality”