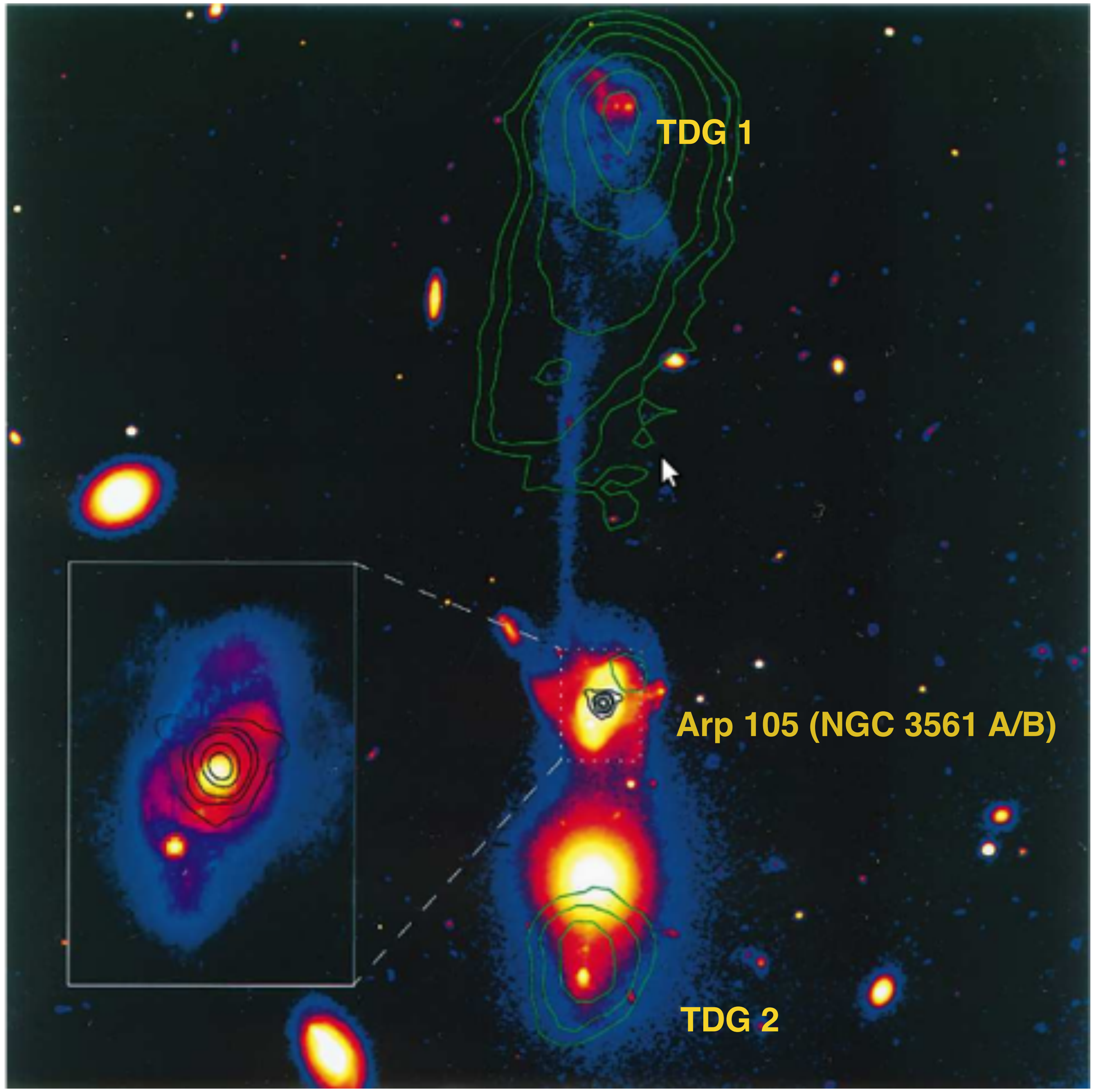
Dark matter in tidal dwarf galaxies

Chandreyee Sengupta

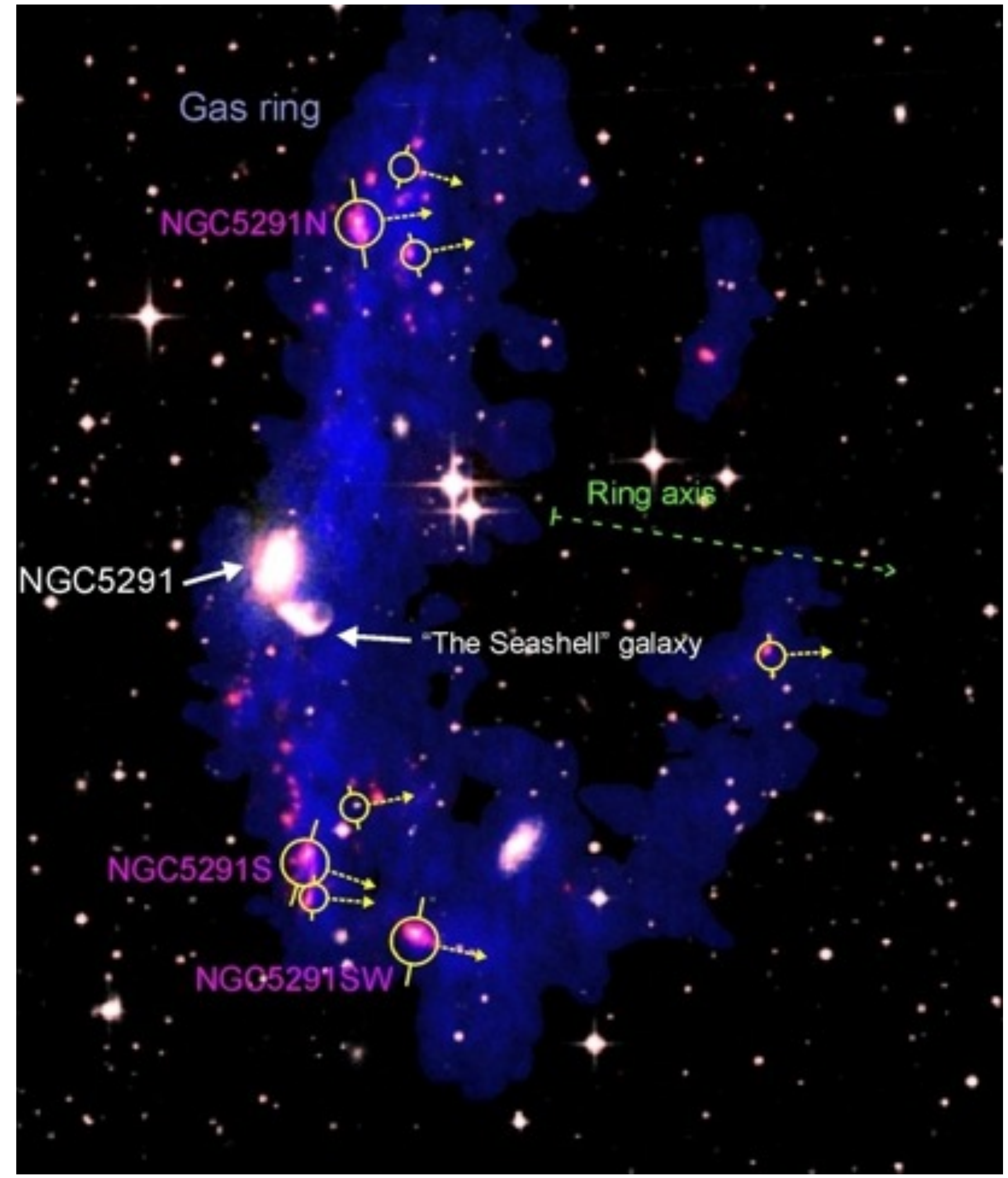
Yonsei University
Observatory, S. Korea

Collaborators:

T. C. Scott (IA, Porto)
R. Sethuram (SHAO)
P. Lagos (IA, Porto)
K. Mishra (ARIES)
D. J. Saikia (NCRA-TIFR)
K. S. Dwarakanath (RRI)
B. W. Sohn (KASI)
D. K. Sahu (IIA)
S. Paudel (KASI)



Duc et al., 1997, A&A, 326, 537



Bournaud et al., 2007, Sci, 316, 1166

TDGs : Dwarf galaxy like structures found in interaction debris

Interesting facts about TDGs.

TDGs are called dwarf galaxies, but are quite different from normal dwarfs.

(1) They are expected to contain little or no dark matter.

Bournaud, F. & Duc, P.-A. 2006, A&A, 456, 481
Wetzstein et al., 2007, MNRAS, 375, 805

(2) Born out of processed material, their metallicities are similar to disk galaxies.

Duc, P.-A. & Mirabel, I. F. 1998, A&A, 333, 813
Weilbacher et al.,. 2003, A&A, 397, 545

(3) They have high probability to be detected in CO lines.

Braine et al., 2001, A&A, 378, 51.

Why study them / What do TDGs tell us ?

1. **Star formation laws** : How stars form outside the main disks of galaxies, do they need certain critical gas densities to form?

2. **Galaxy formation**: How long will the detached dwarfs survive. How many of them are expected to form in an interaction. How do they contribute to dwarf galaxy population

3. **Dark matter effects**: Are TDGs really free of dark matter? Where is the dark matter present in the progenitors? Do they show signs of baryonic dark matter?

Kinematics : Detecting signs of rotation in TDGs

1. Identification of a TDG

TDGs are usually embedded deep inside tidal debris which makes it difficult to establish them as individual galaxies as opposed to large SF regions.

2. Dark matter content

Rotation curves, if detected, can throw light on the dark matter content of TDGs.

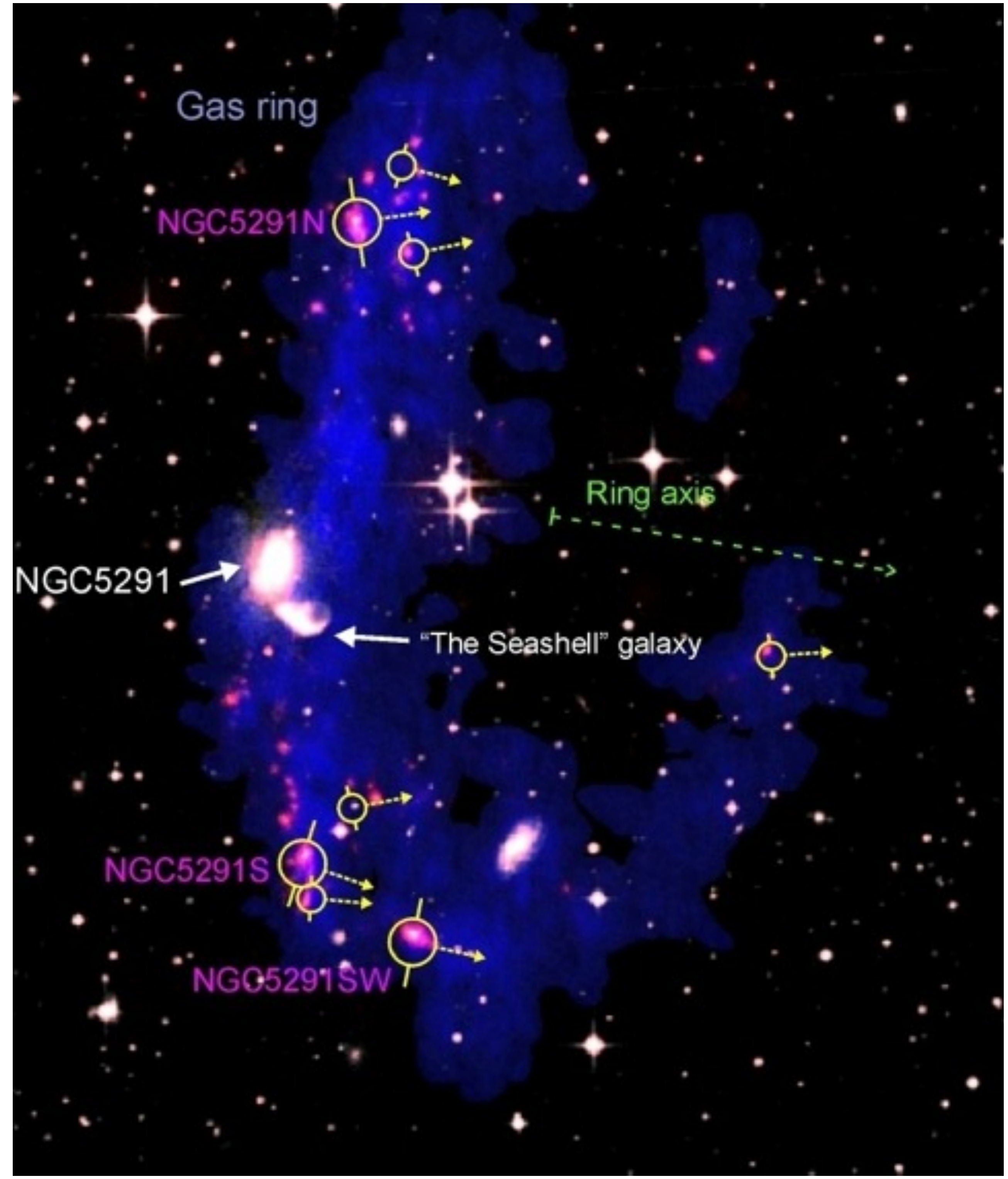
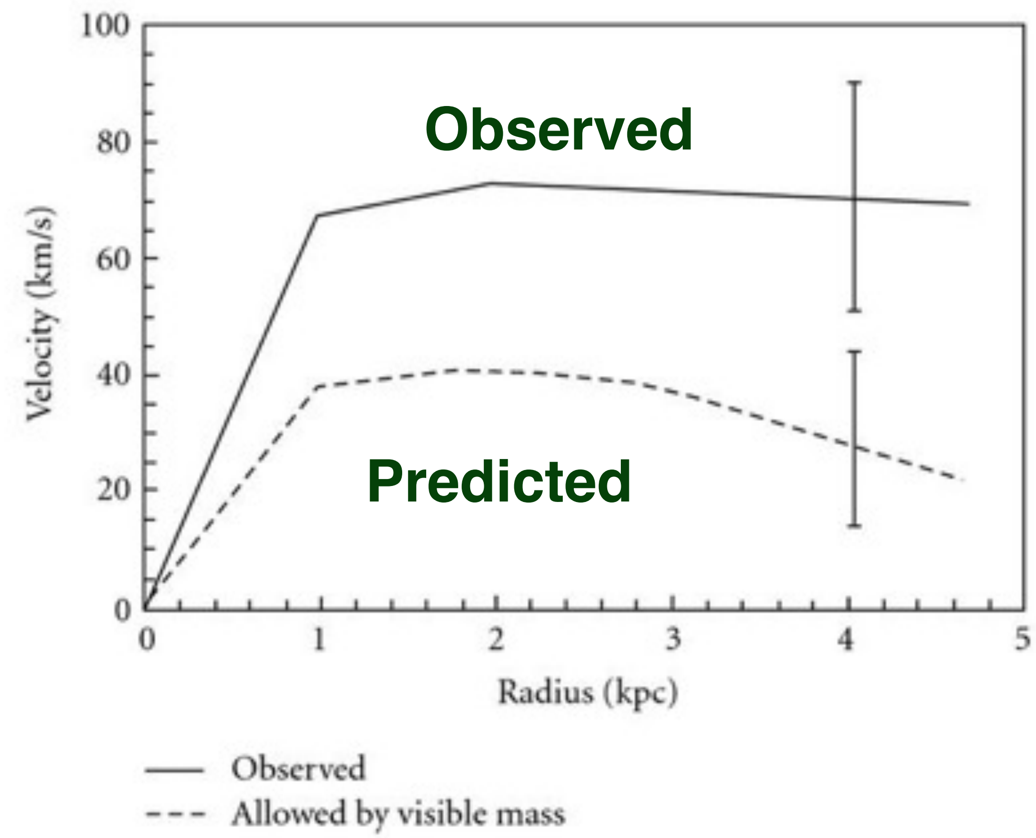
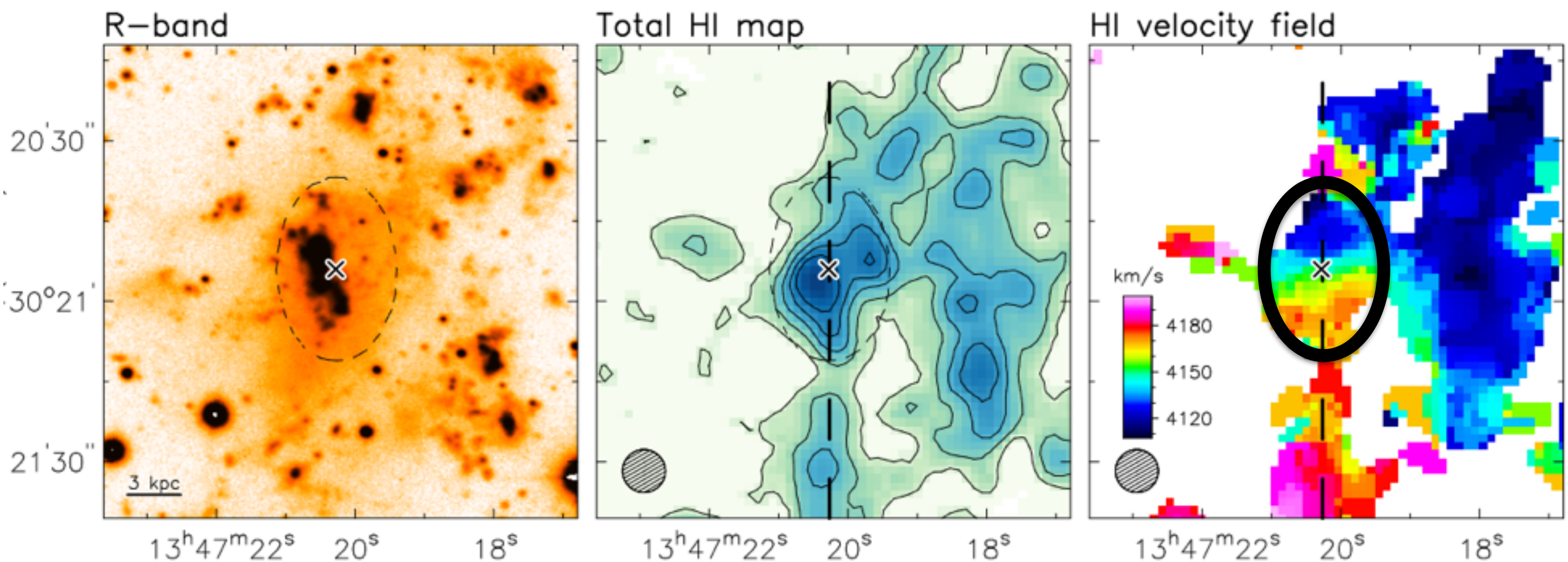


Image credit P. -A. Duc, CEA-CNRS/NRAO/AUI/ NSF/NASA

Detecting rotation curves in these systems is an observational challenge

- **Bournaud et al., 2007, Sci,316,1166 : HI rotation curves for NGC 5291 TDGs**
- Weilbacher et al., 2003, A&A, 397,545 : Halpha velocity gradients.
- Sweet et al., 2016, MNRAS, 455, 2508
- **Lelli et al., 2015, A&A, 584, 113**





Lelli et al., 2015

GMRT HI study of a sample of interacting galaxies

Sample was drawn from

- The Spitzer Spirals, Bridges and Tails Interacting Galaxy Survey
- Spirals, Bridges and Tails: A Galaxy Evolution Explorer Ultraviolet Atlas of Interacting Galaxies.

Smith et al., 2007, AJ, 133, 791
Smith et al., 2010, AJ, 139, 1212

Project Aim is to study the

HI properties of the tidal bridges and debris.
: HI morphology, extent, alignment with optical /IR counterpart.

Star formation in tidal debris.
: star formation at the outskirts of the main disk, tidal remnants.

Tidal Dwarf Galaxies.
: galaxy formation from recycled material.

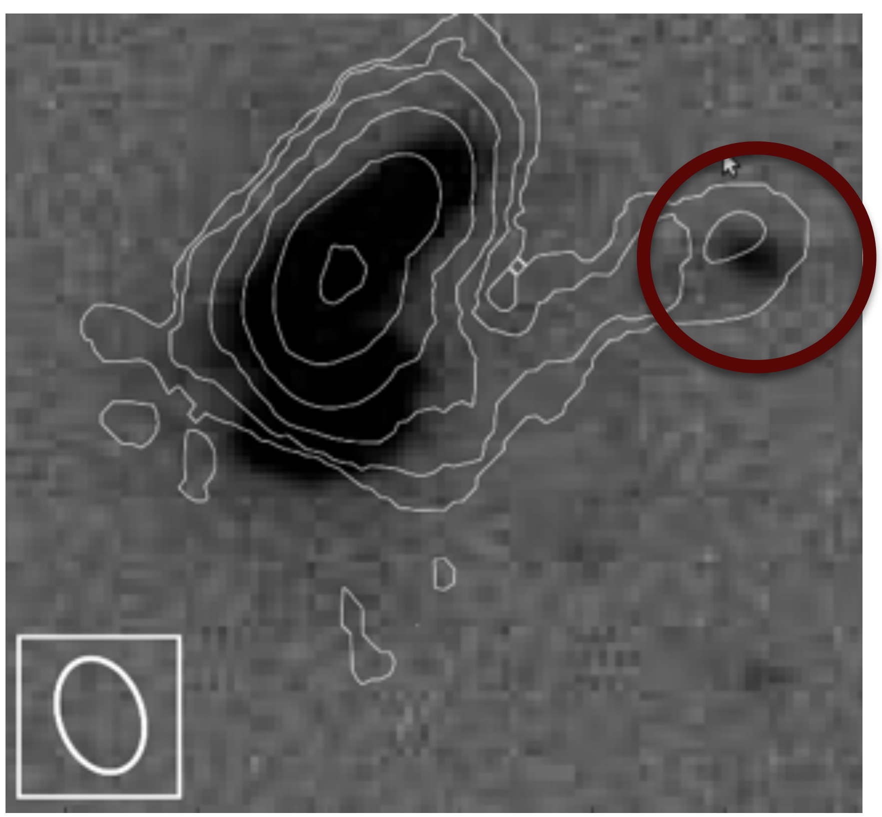
We detected HI in 3 candidate TDGs.

They were considered candidate TDGs based on

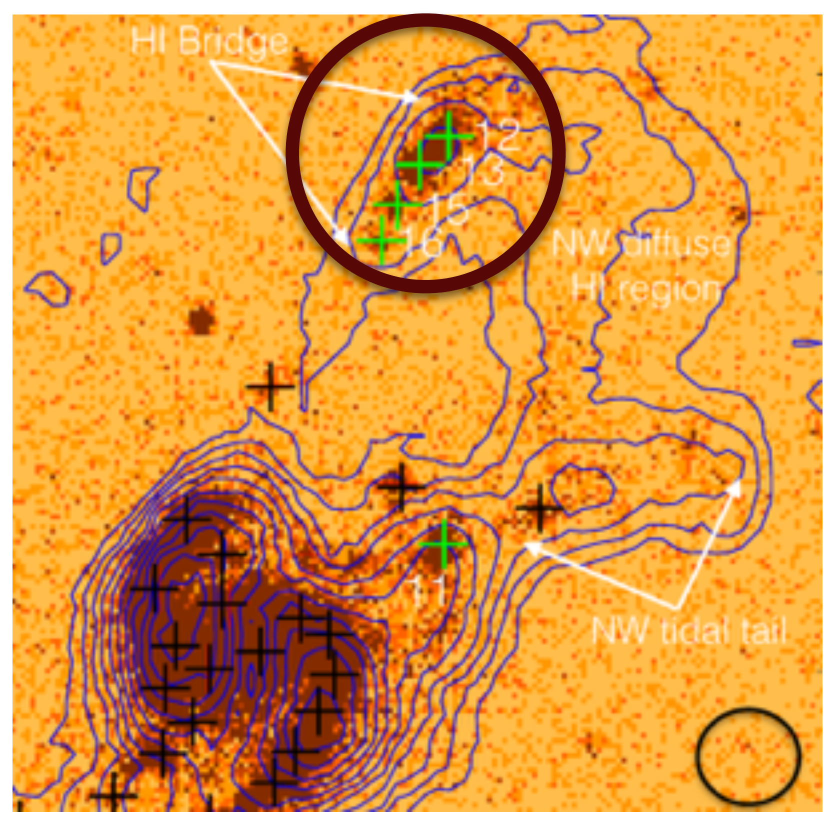
1. Their size, position in a tidal debris (eg. tip of a tidal tail in optical/ UV images)
2. UV brightness (GALEX observations)

HI from GMRT :

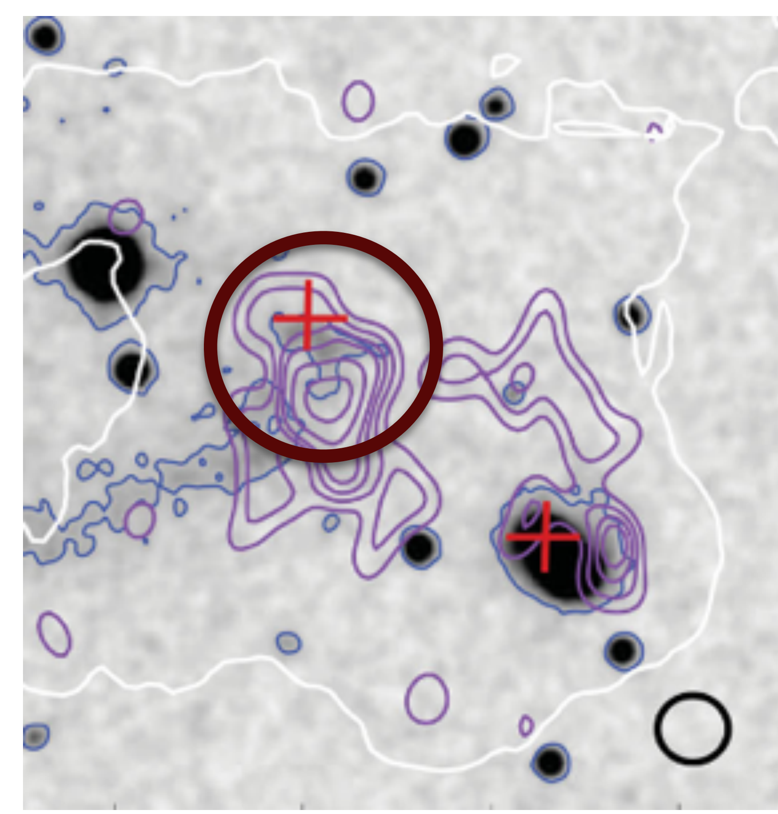
- Established their connection to a parent system through tidal tails
- HI spectra helped to estimate the dynamical mass,
- High resolution data revealed moderate velocity gradient



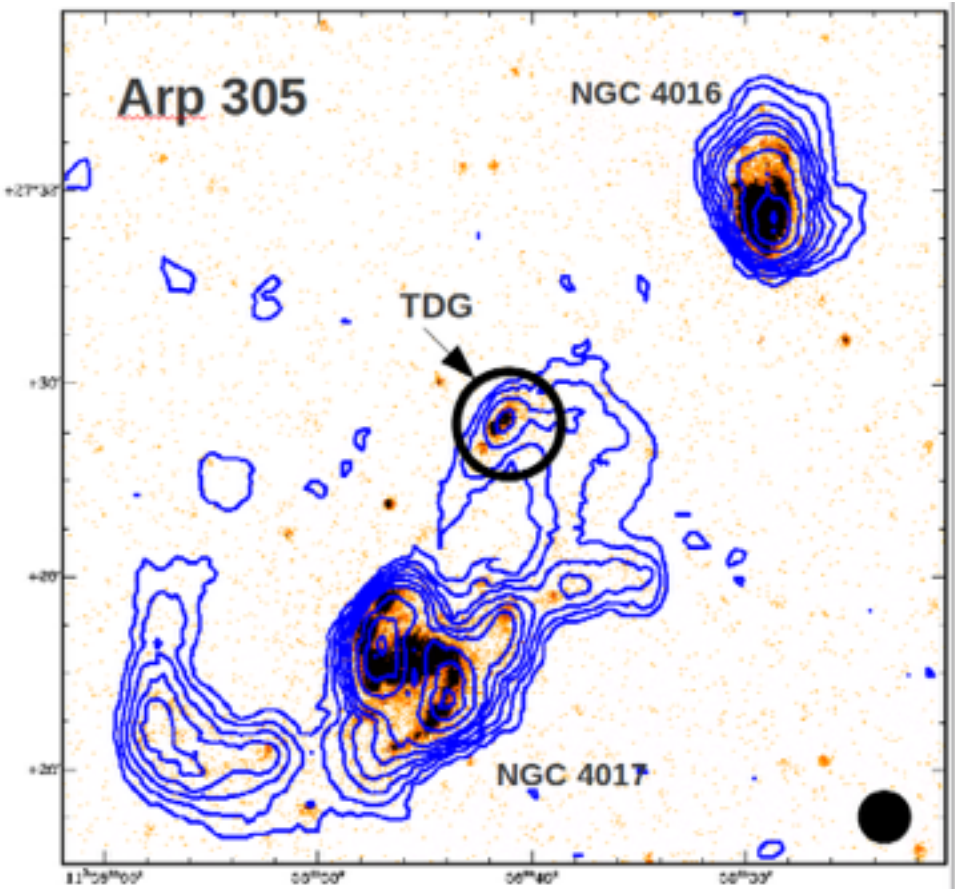
Arp 202

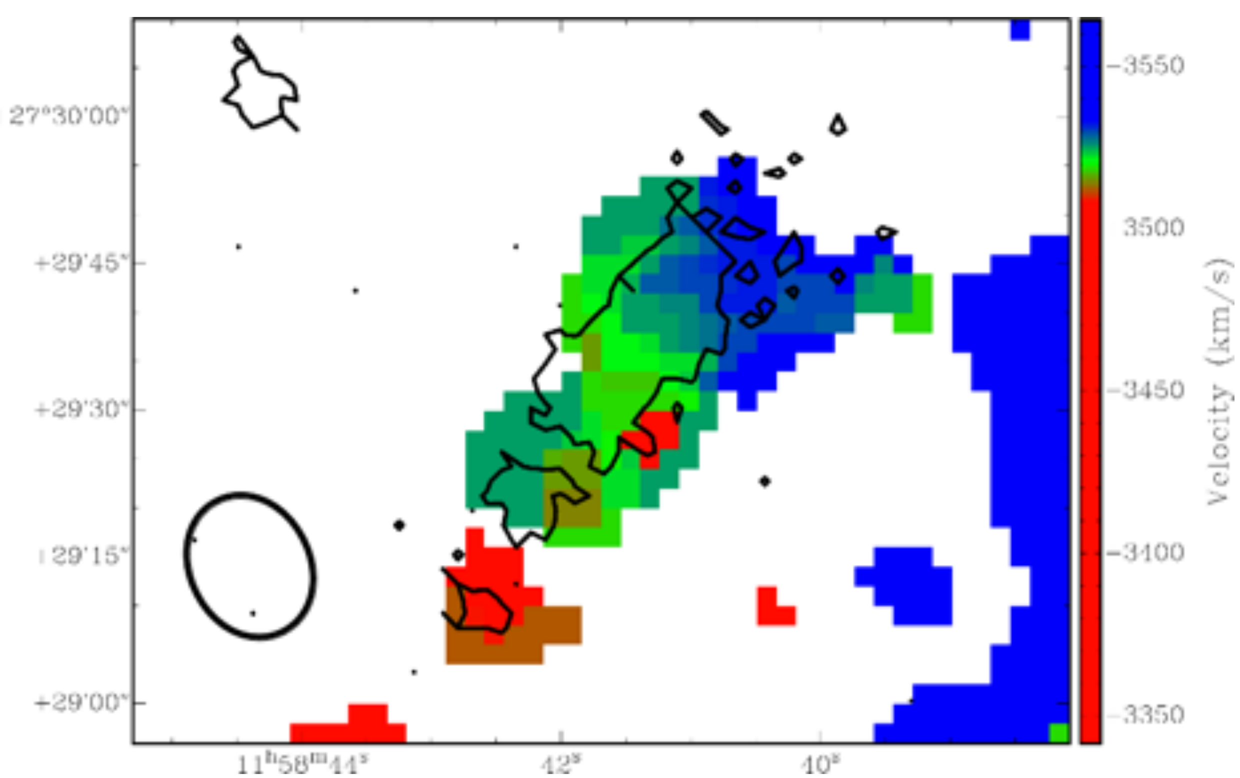


Arp 305



Arp 181





we detected moderate velocity gradient in Arp 305

Properties of the TDG candidate

HR beam ~ 15”X11”, @50 Mpc samples ~3 kpc.
TDG extent ~ 10 kpc
Velocity resolution ~ 7 km/s
Velocity dispersion ~ 11 km/s
Optical mass ~ 7 X 10^6 M_sun
HI mass ~ 6 X 10^8 M_sun
dynamical mass / visible mass ~ 1
Line width ~ 40 km/s

However the TDG is embedded in the debris and kinematically cannot be distinguished from the bridge.

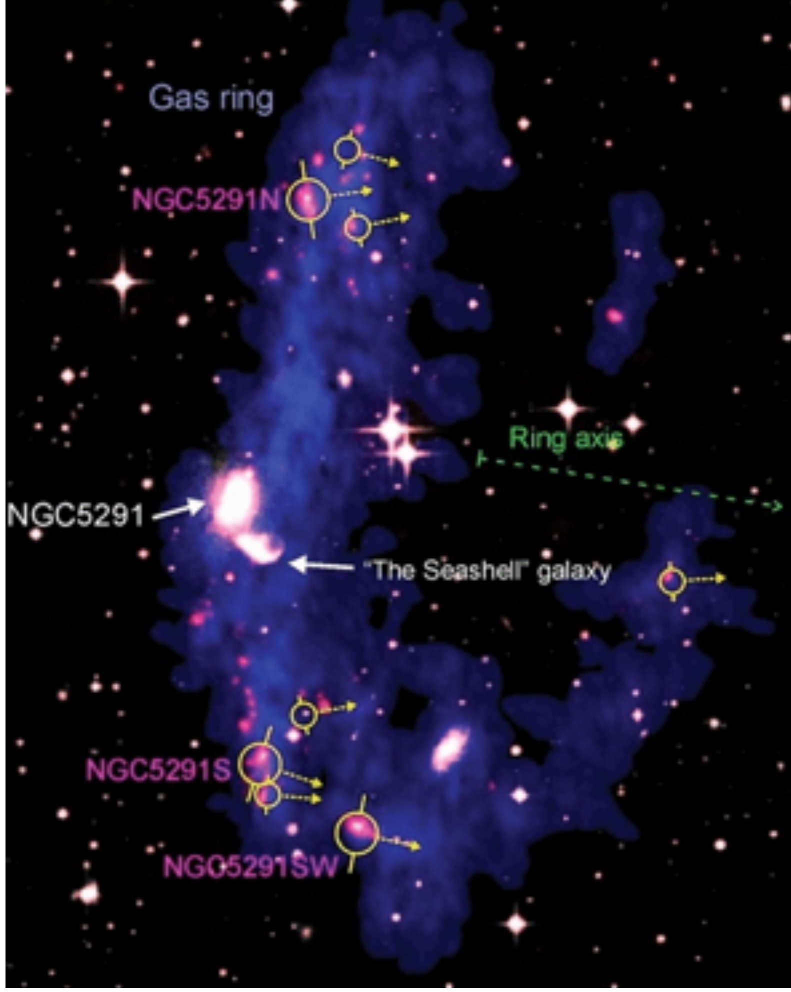
Halpha imaging using the Himalayan Chandra Telescope
+
Spectroscopy using the Gemini telescope

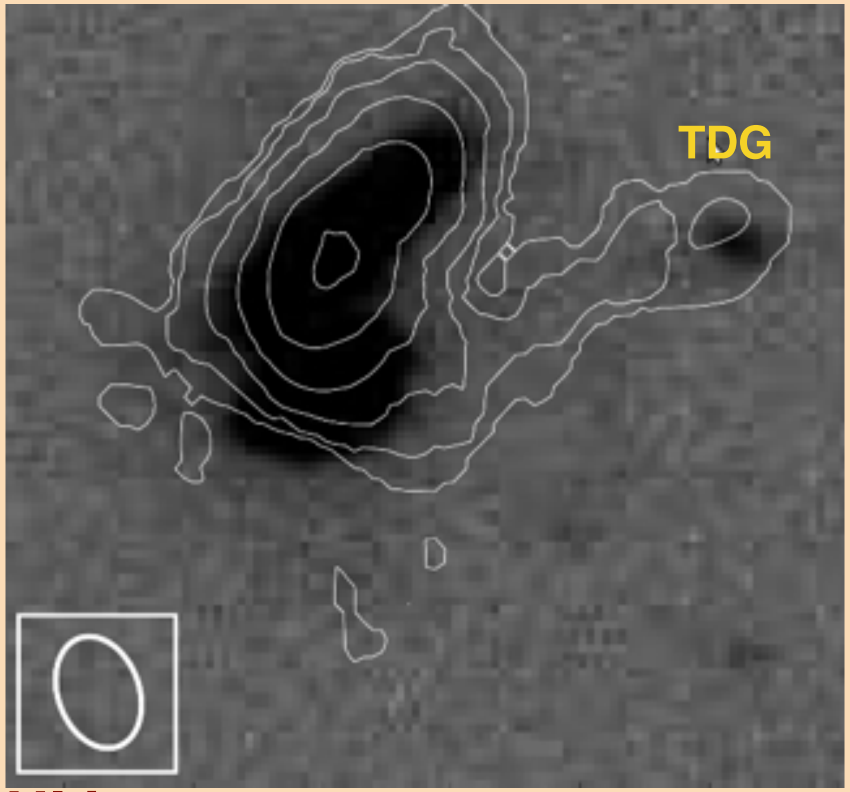
Aims:

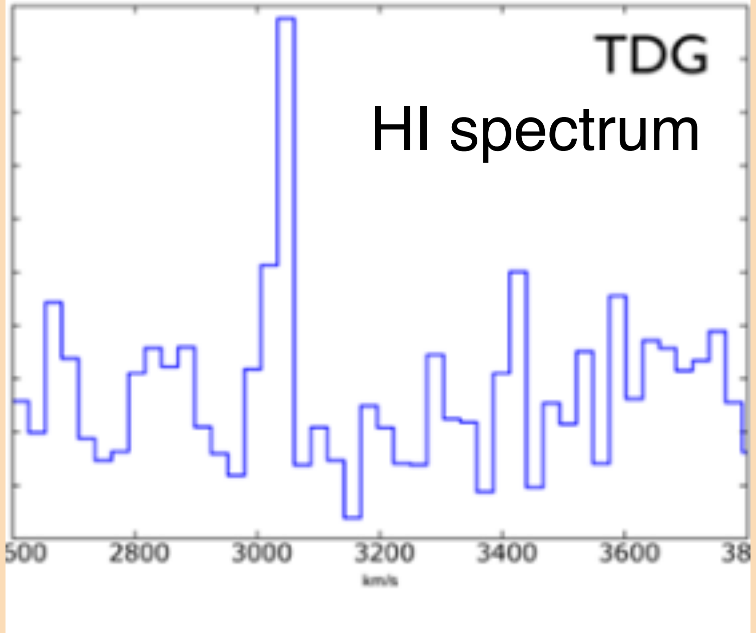
- Halpha extent compared to optical disk and the nature of the emission.
- Spectroscopy to estimate metallicity, velocity gradient
- comparison with other categories of dwarf galaxies
- search for an Halpha disk with extended emission and regular rotation pattern to estimate the dark matter content.

For the pilot run with HCT and Gemini, we chose a TDG candidate well separated from the tidal debris — Arp 202.

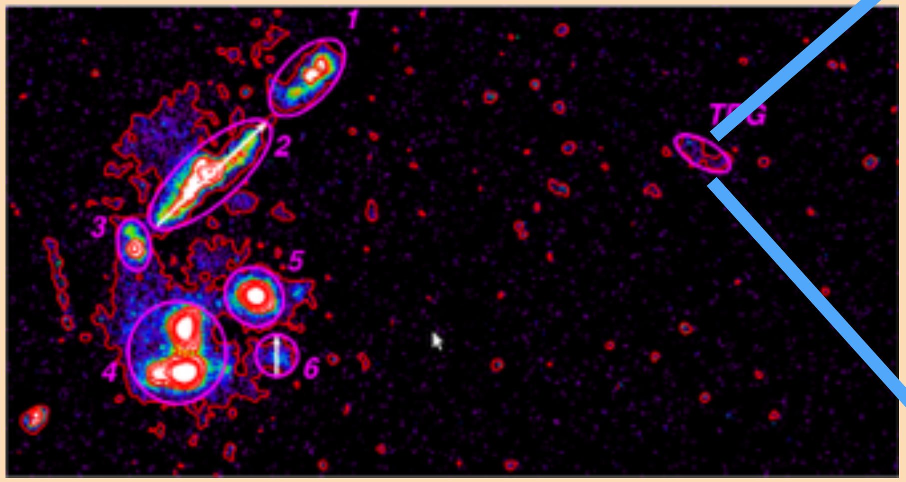
data reduction and analysis: Ramya Sethuram

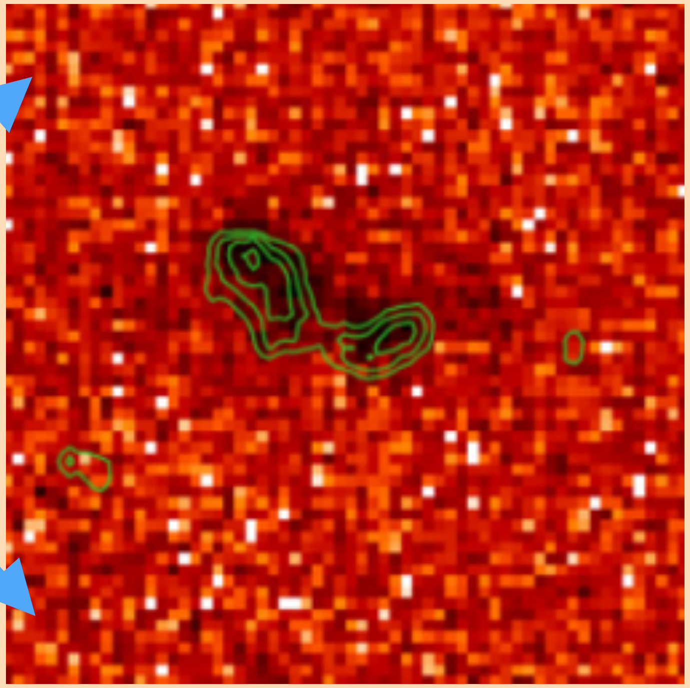






HI image





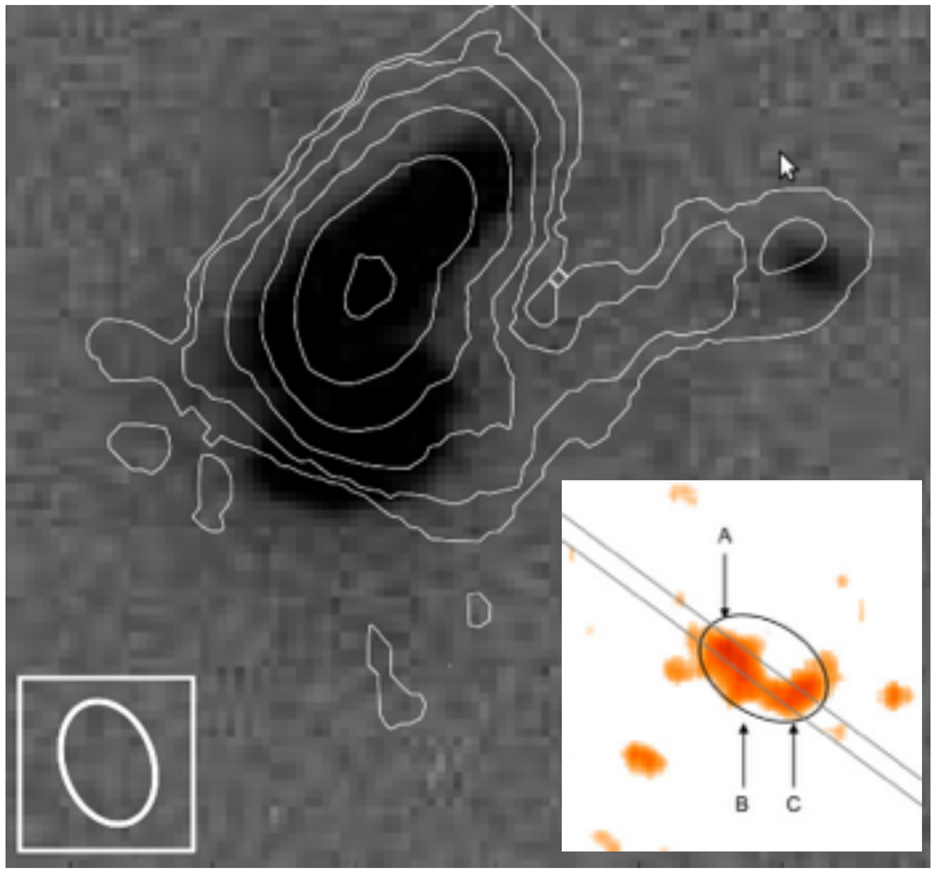
Halpha image

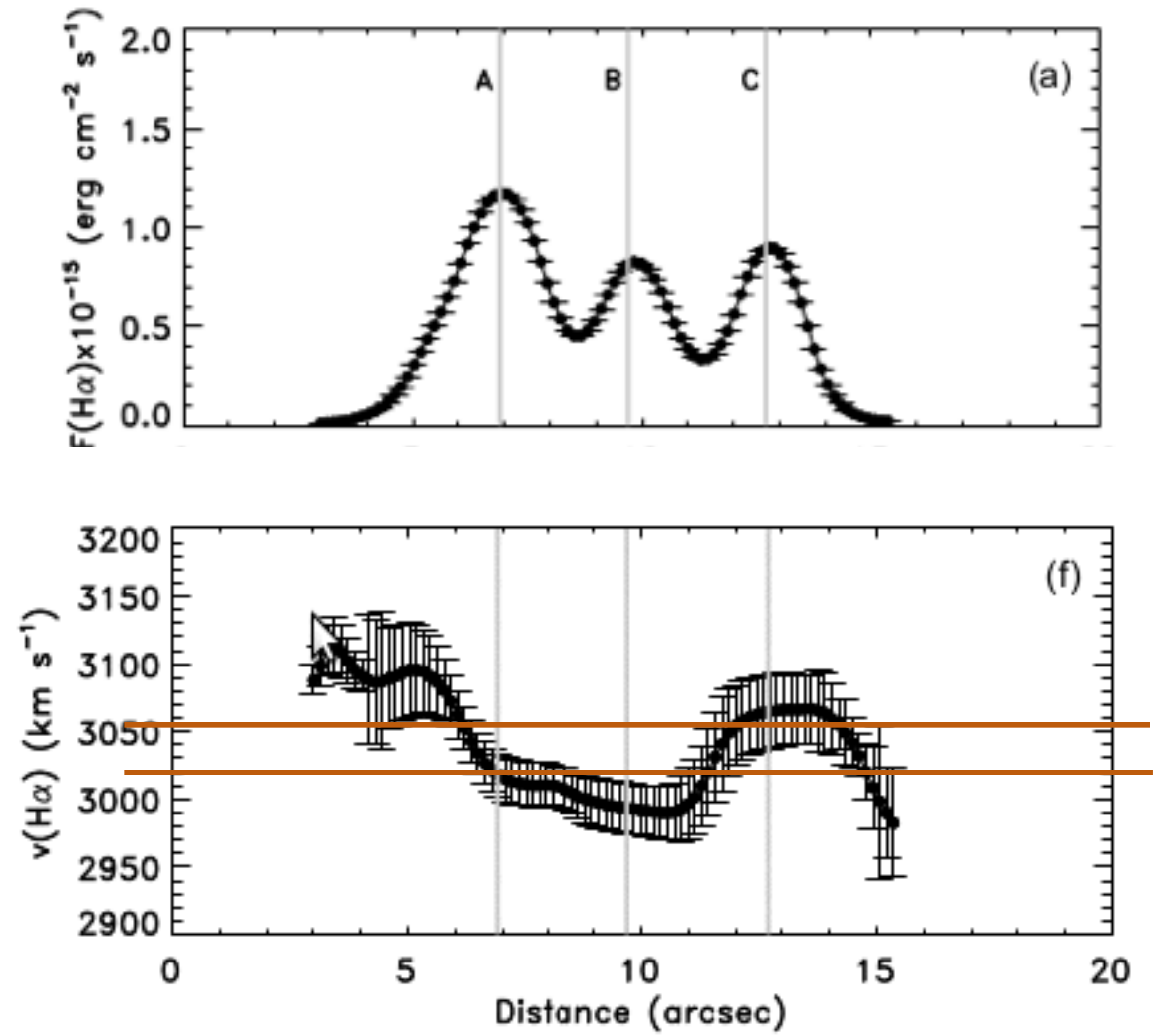
Main Results:

- TDG detected in Halpha, emission extent ~ 3 kpc
- The emission is clumpy, we detect three main SF regions.
- Halpha luminosity ~ 4 X 10^{38} erg/s

Gemini long slit spectroscopy on the TDG: results from the pilot observations.

data reduction and analysis: Patricio Lagos



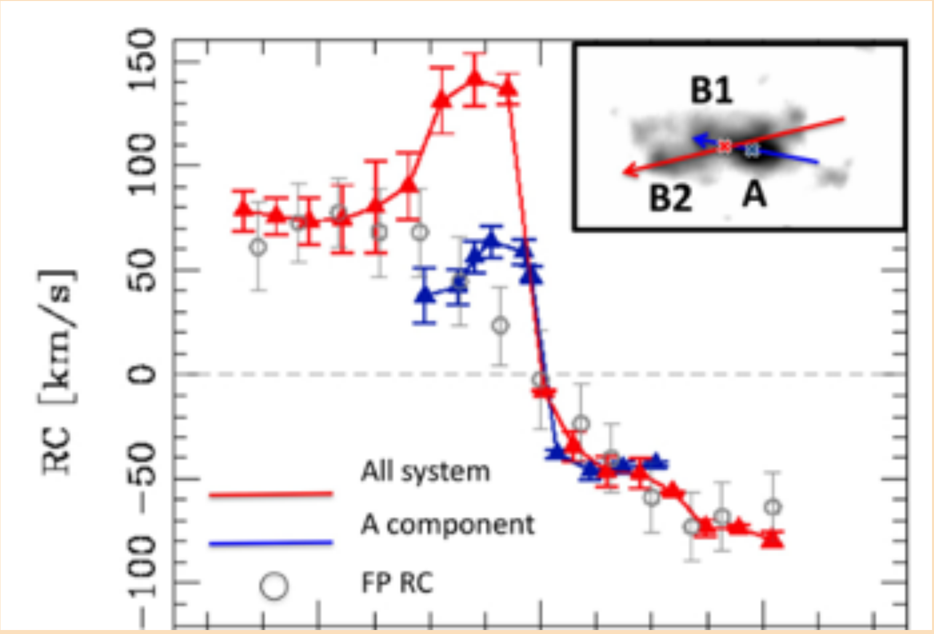


Main results :

- Metallicity (12+log(O/H)) ~ 8.10, lower compared to TDGs; but similar to parent galaxy outer disk
- TDG dominated by young stars; bright in GALEX, Halpha and not detected in Spitzer
- Three Halpha peaks, significantly scattered in velocity range (80 km/s) with no regular gradient along the slit.

Except NGC 5291N, all four TDGs in the literature, with high resolution HI and Halpha observations, show regular HI velocity gradient and chaotic Halpha disk.

Lelli et al., 2015, A&A, 584, 113



Flores et al., 2016, MNRAS, 457, 14

Future work plan: HI and Halpha observations of a sample of TDGs

- ***HI observations :*** tidal tails/debris which connect the TDG candidate to its parent system, HI velocity gradient, dynamical mass estimate.
- ***Halpha imaging observations:*** may help to isolate the TDG from the tidal tail, will reveal the extent of the Halpha disks compared to optical/ HI disk and nature of the emission.
- ***Spectroscopy:*** estimate the metallicities, for disks with extended Hα emission, an effort to estimate velocity gradients, understand gas kinematics.

Combining HI and Halpha data can reveal a clearer idea about the gas -star relation in the disks of TDGs, and in some cases may also also its dark matter content.