Kinematics of collisional debris

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What ?

Kinematics of collisional debris

P.-A. Duc / ESO-3D conf-2008

Why ?

- A giant collider to probe the nature and distribution of the various components of galaxies, including dark matter

- A laboratory to probe star-formation in an environment a priori completely different than that of galactic disks

- The nursery of SSCs/GCs, TDGs, UCDs,...

How ?

- A multi-wavelength approach:

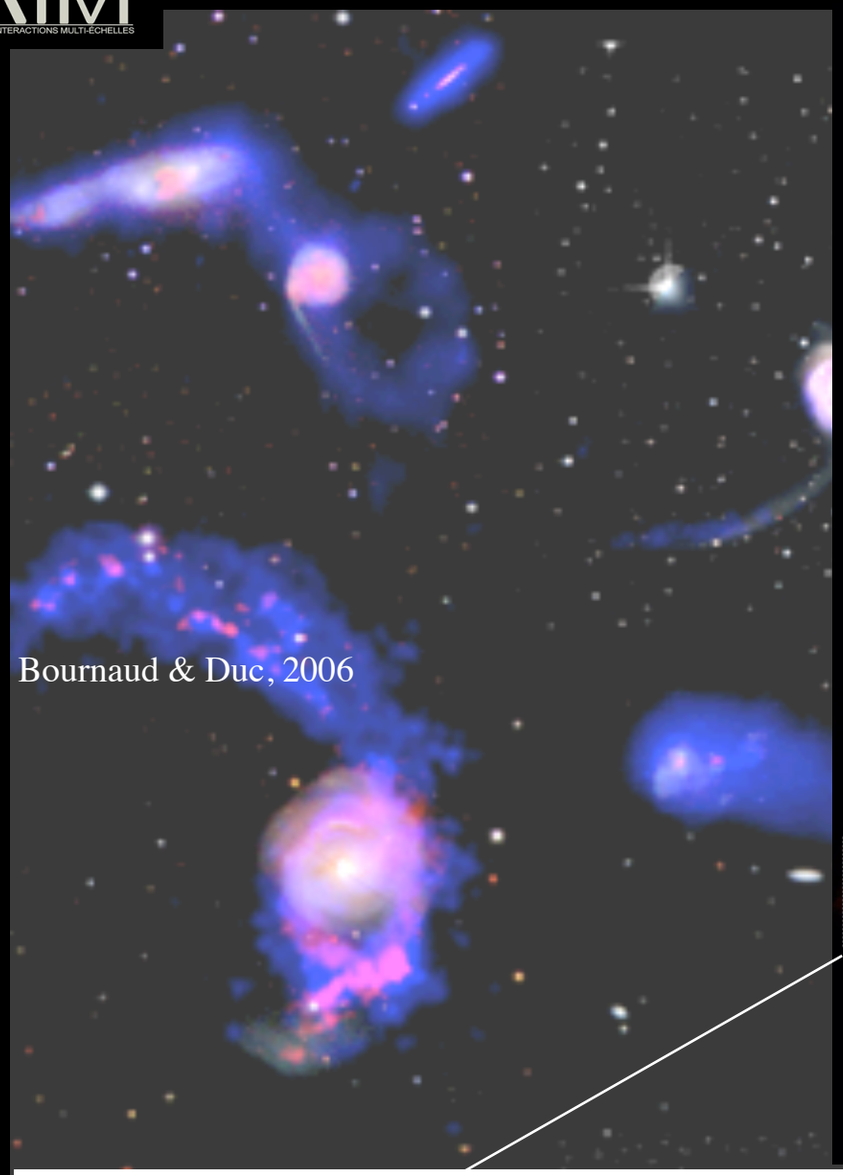
✓UV/GALEX, MIR/Spitzer, broad-band optical/NIR imaging

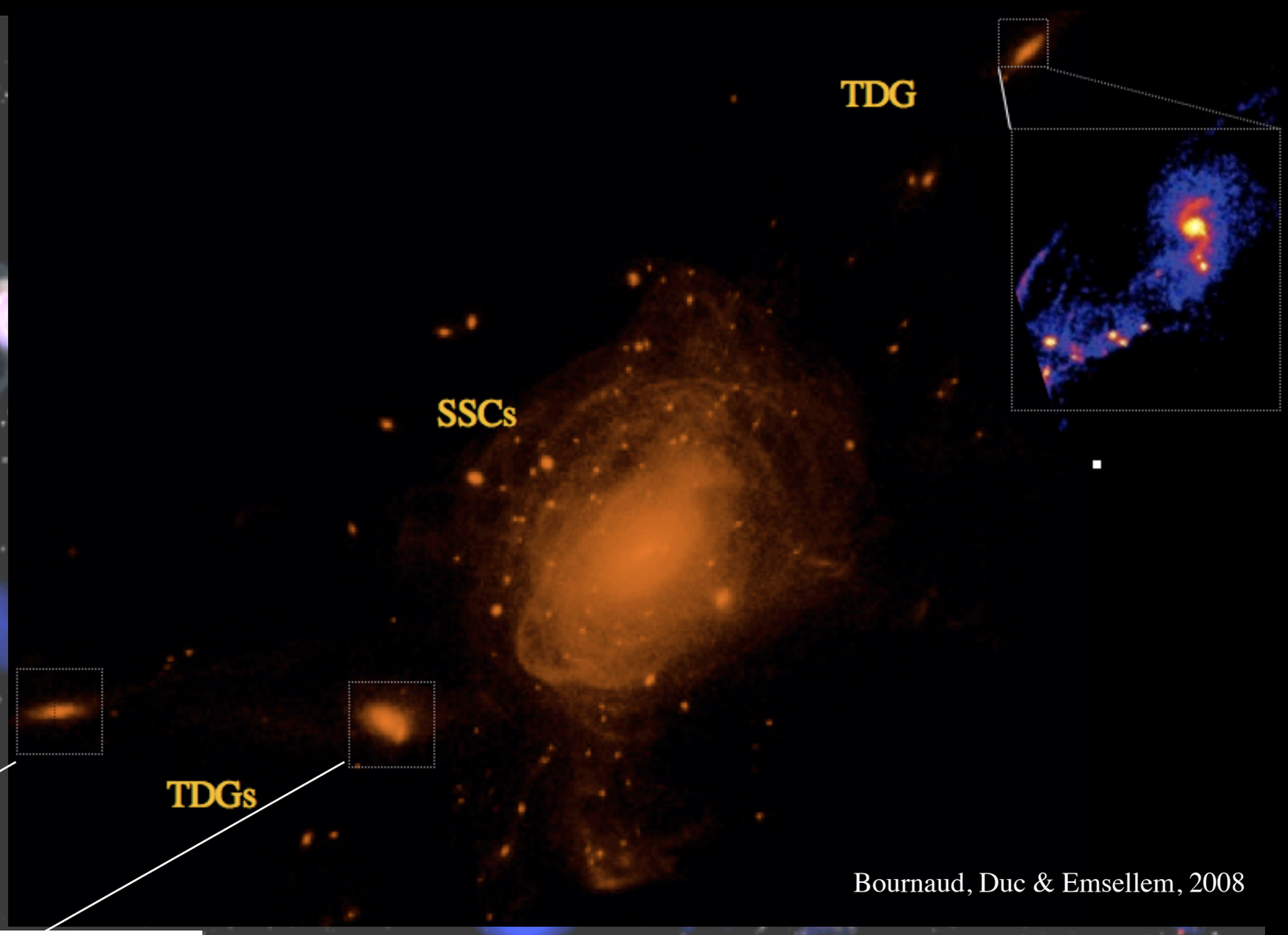
✓3D datacubes: HI/VLA-C+D,B; CO IRAM/OVRO; Halpha CFHT/ESO/FP

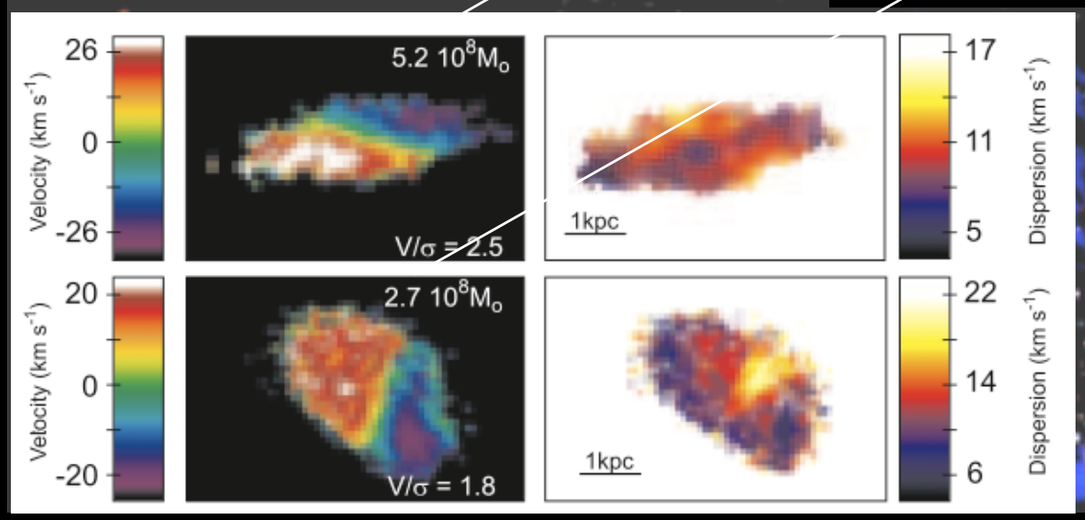
- Detailed kinematical studies: identification of kinematically independent objects

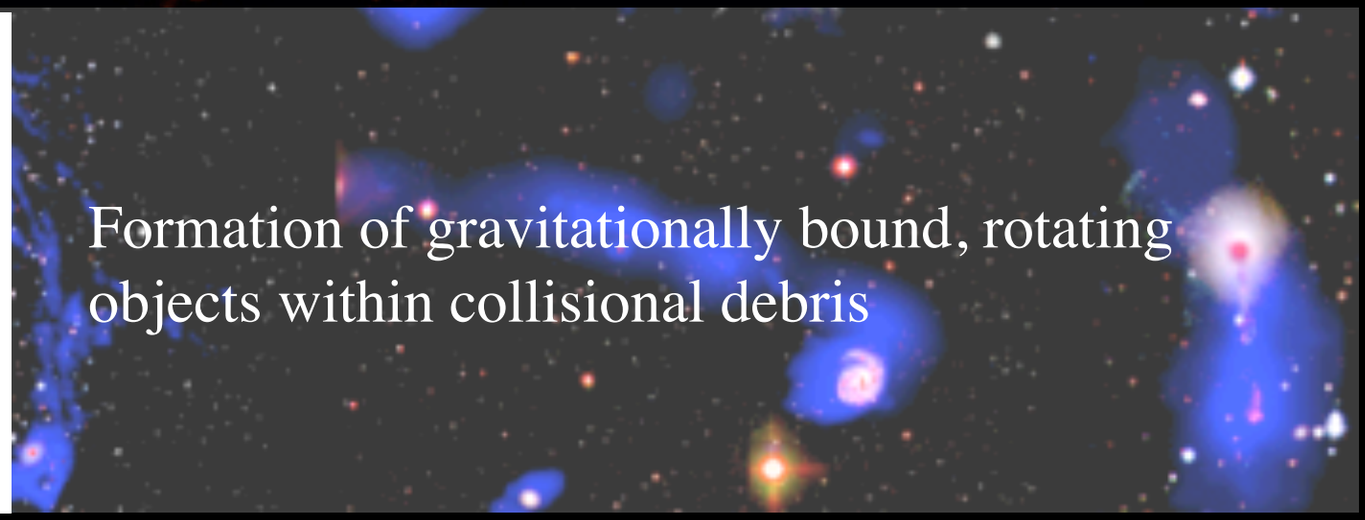
- The support of numerical simulations

Input from numerical simulations

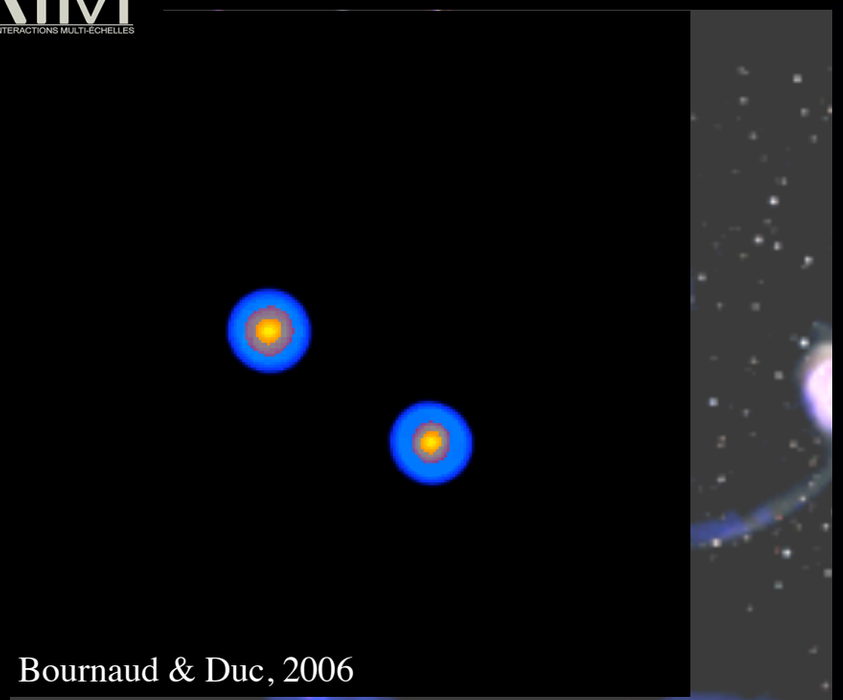




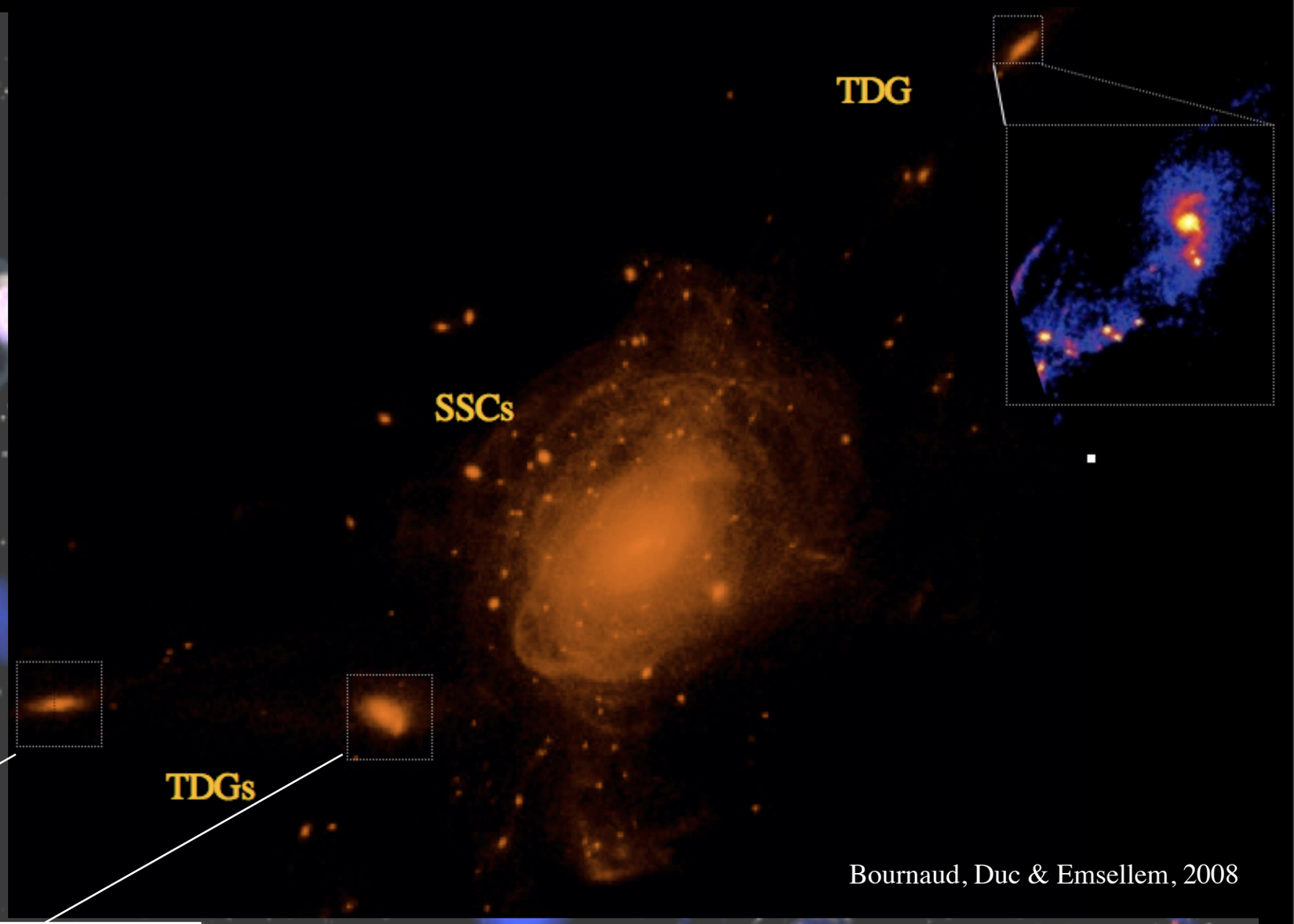




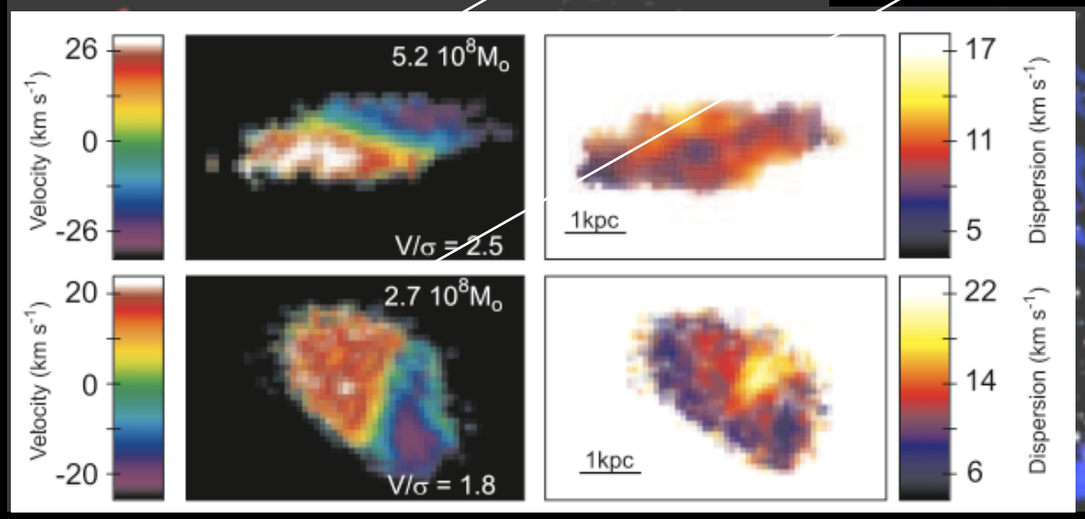
Input from numerical simulations

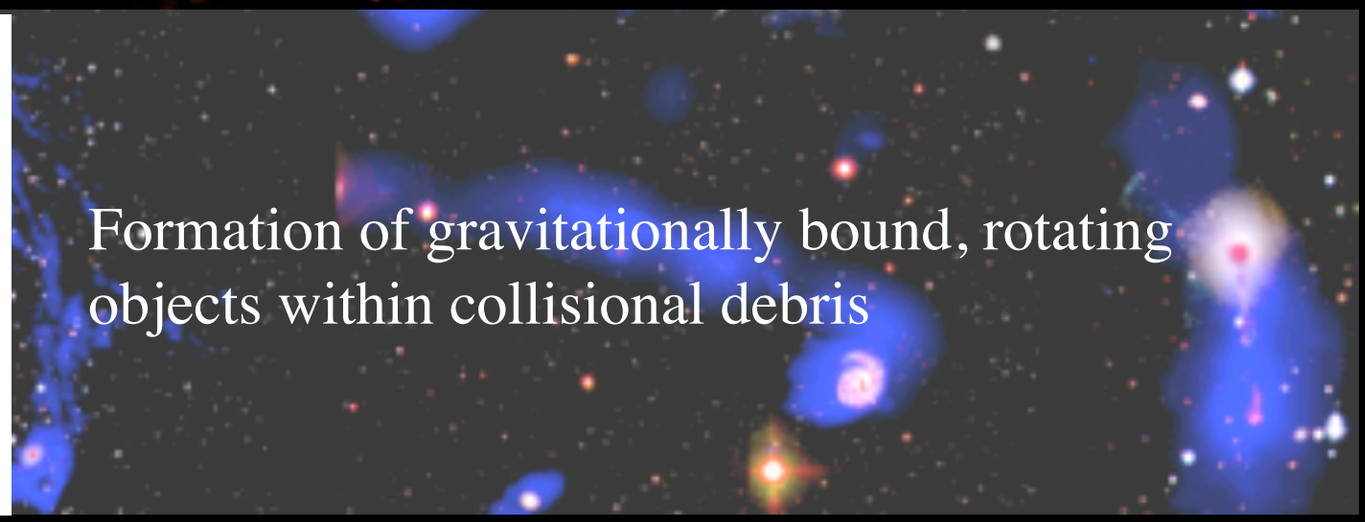


Bournaud & Duc, 2006



Bournaud, Duc & Emsellem, 2008

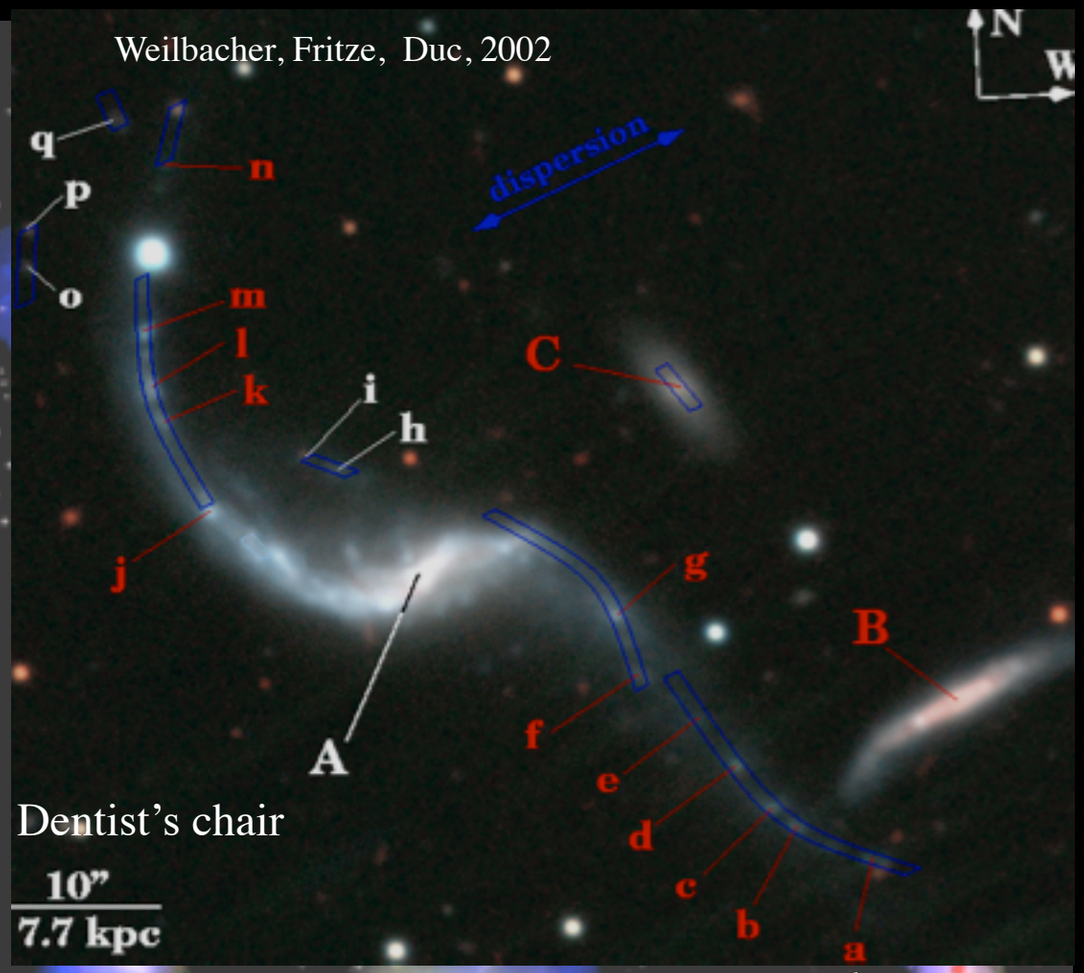


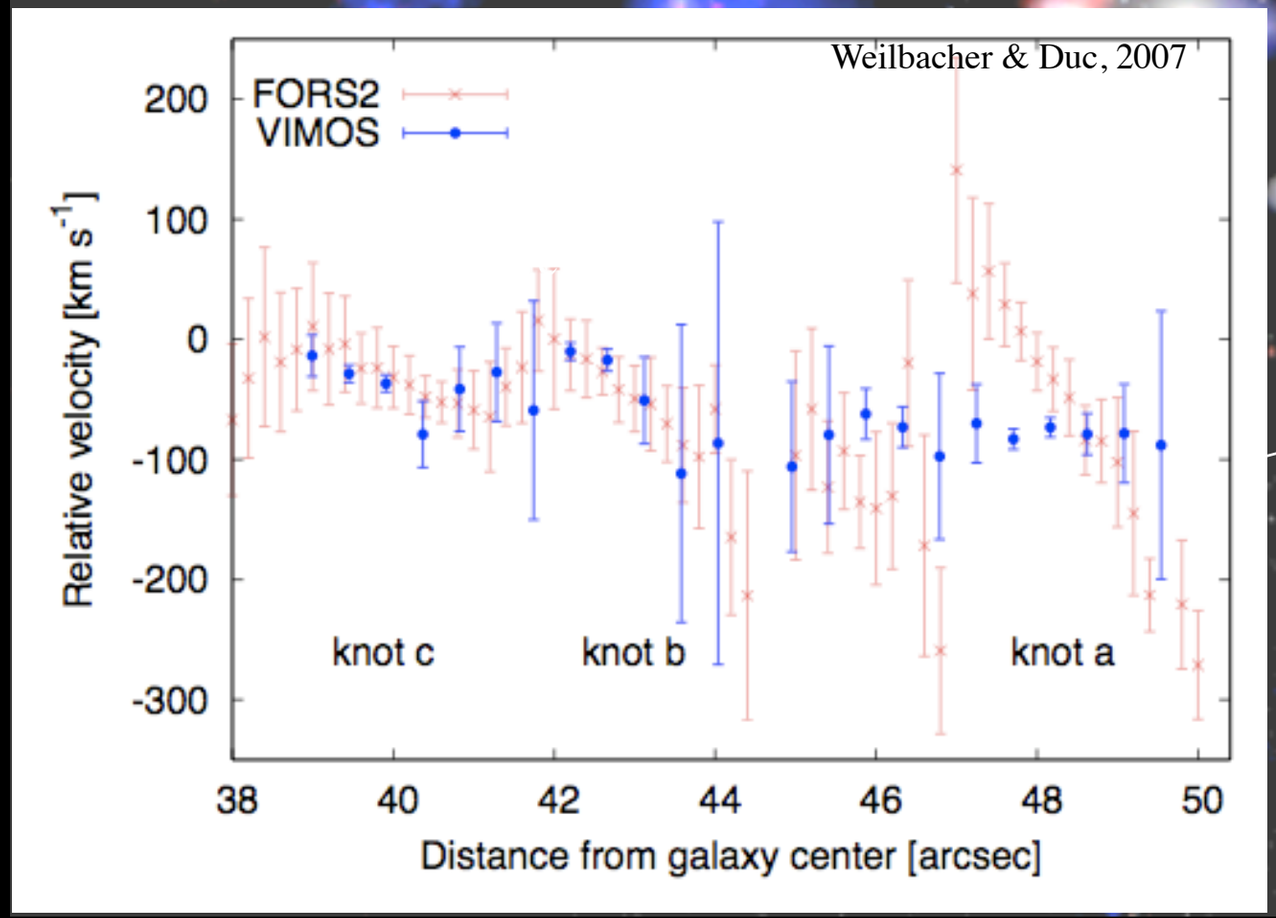


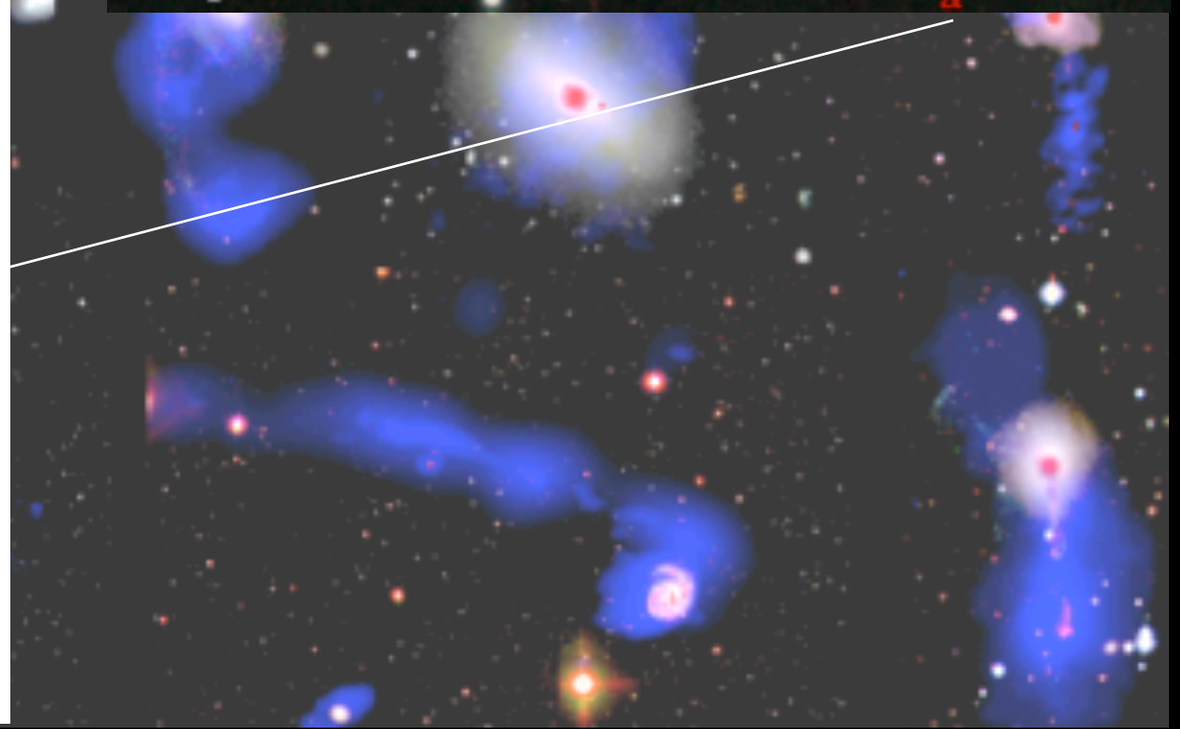
Formation of gravitationally bound, rotating objects within collisional debris

The need for 3D data

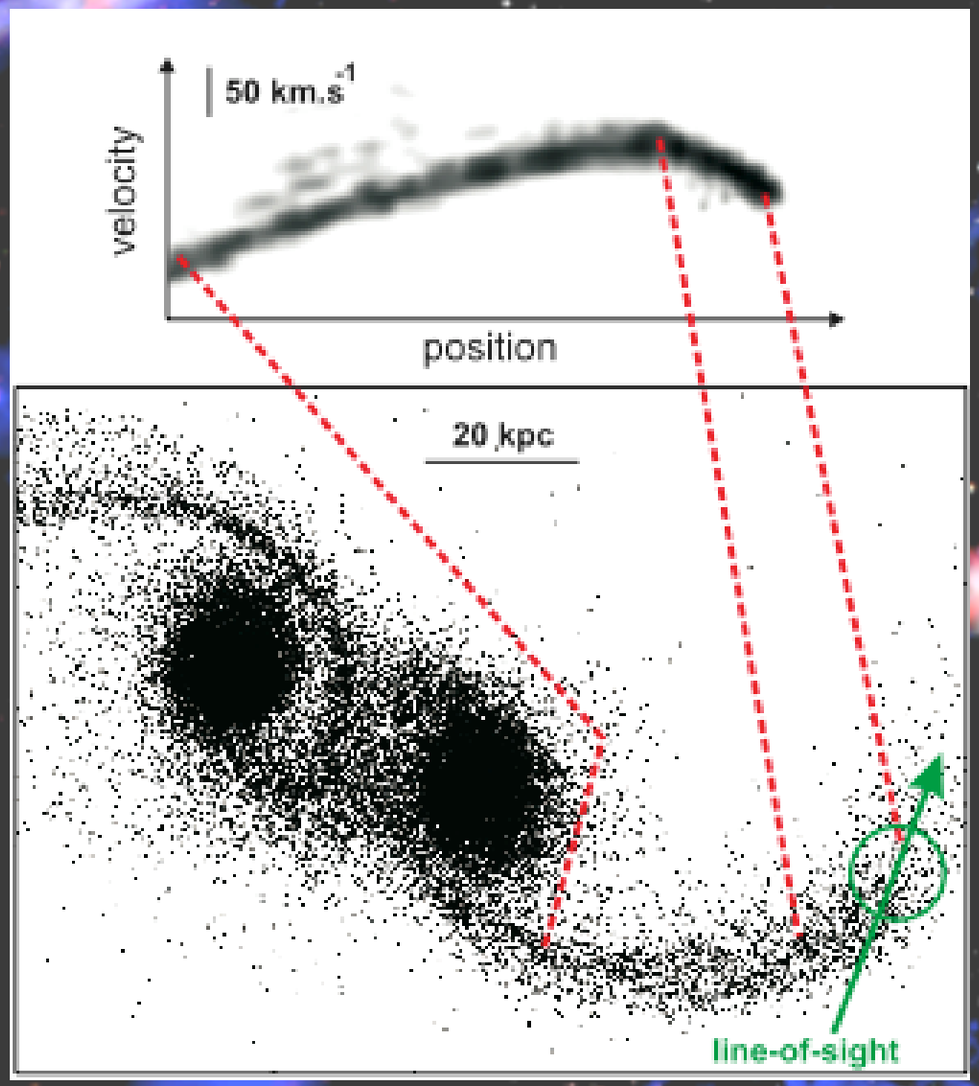
Long slit spectroscopy of tidal tails: fake velocities gradients in tidal condensations







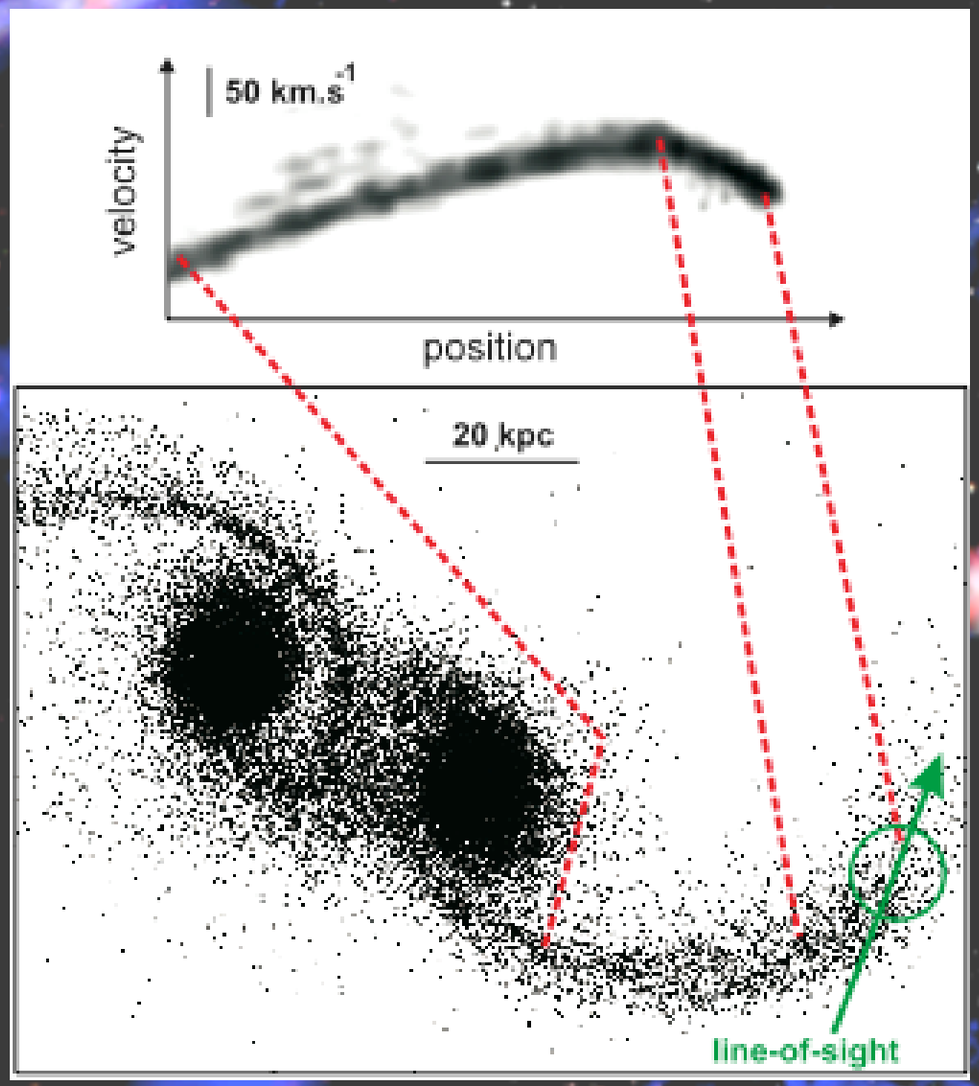
Dealing with projection effects



Disentangling real rotation motions from projected streaming motions along the tails

A change of the velocity gradient before the apparent tip of the tail tells about a projection effect

When projection effects fool even bright scientists....



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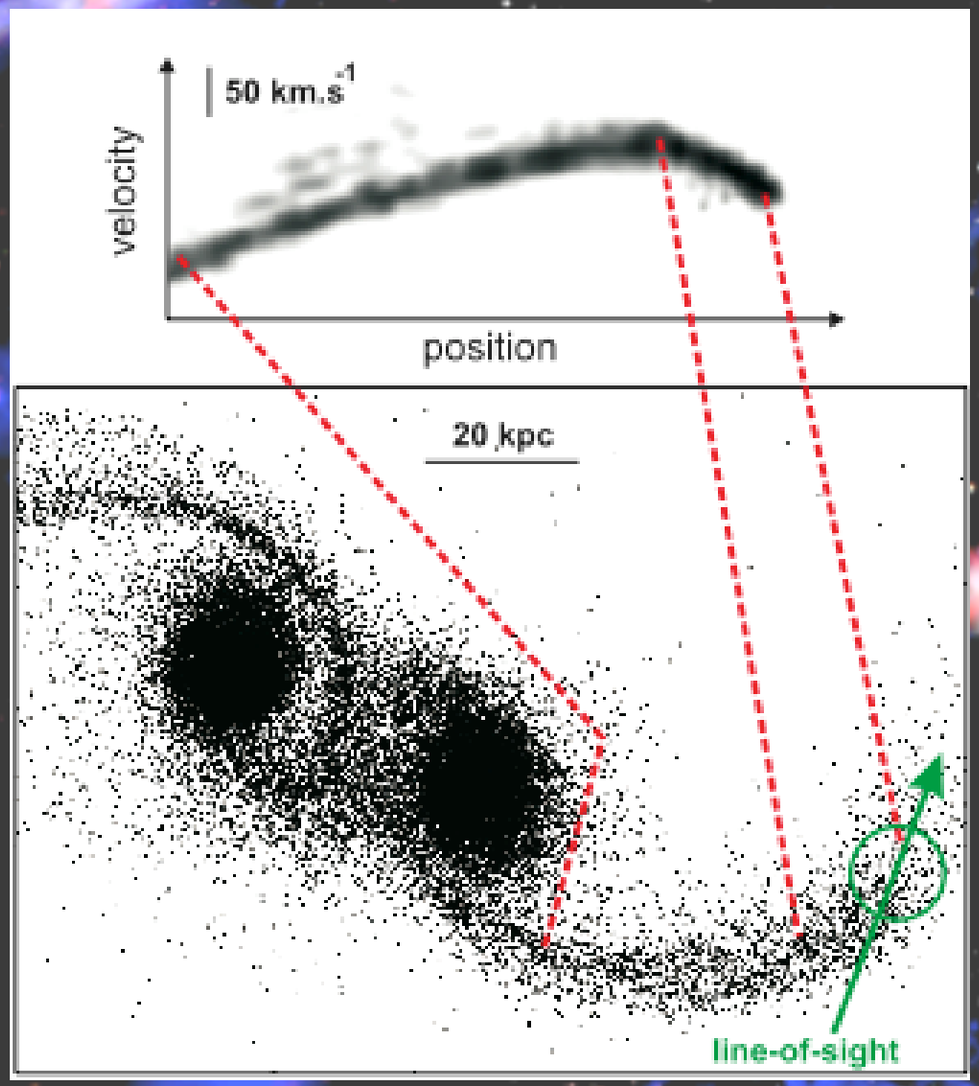

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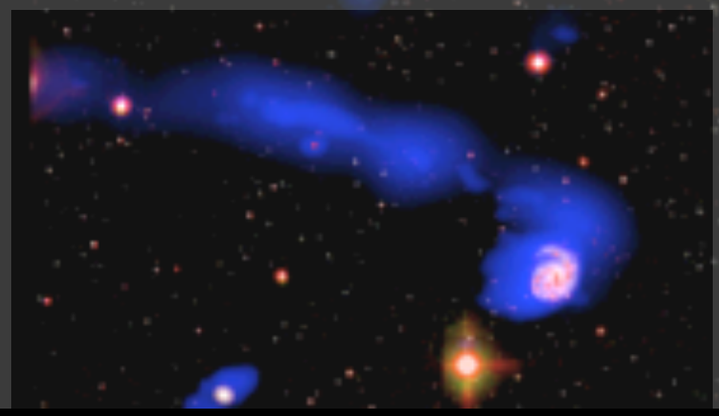

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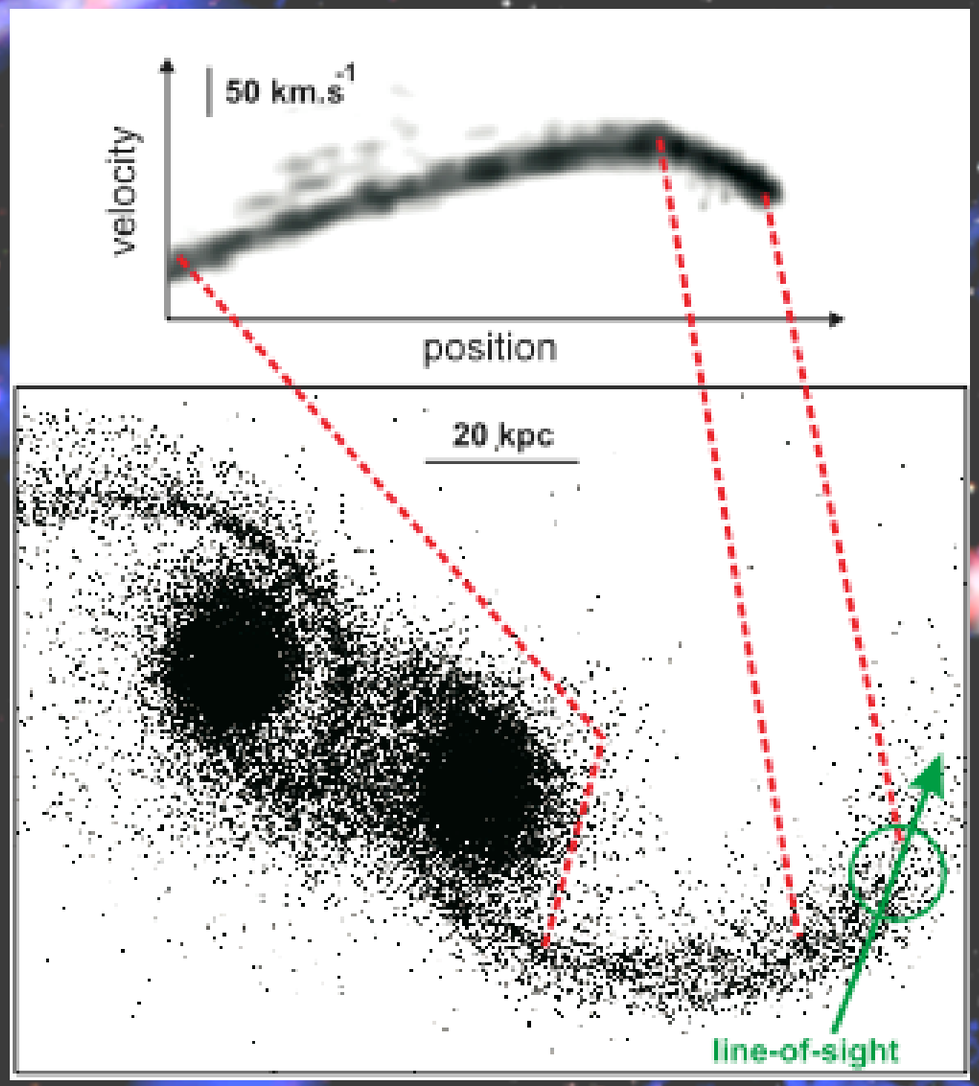

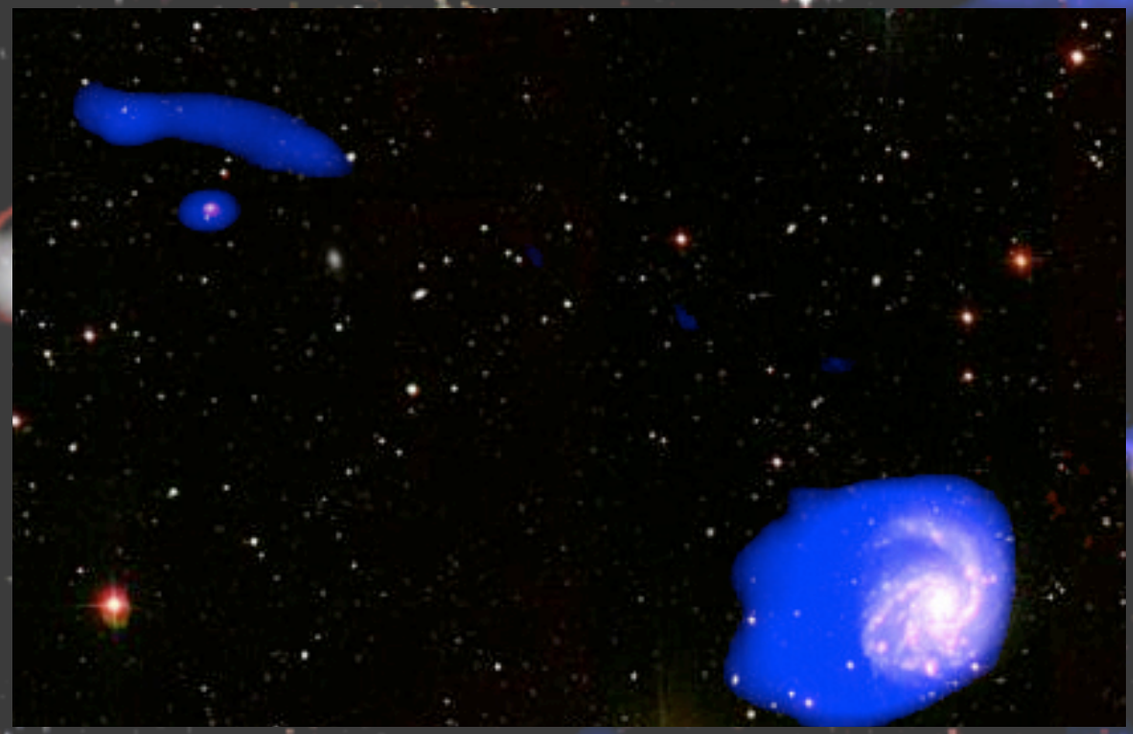

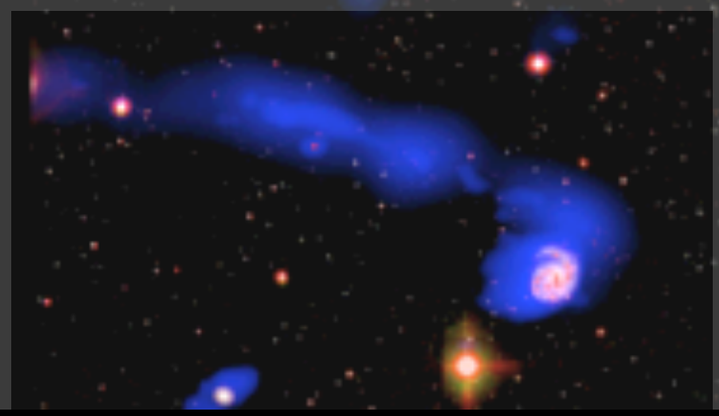

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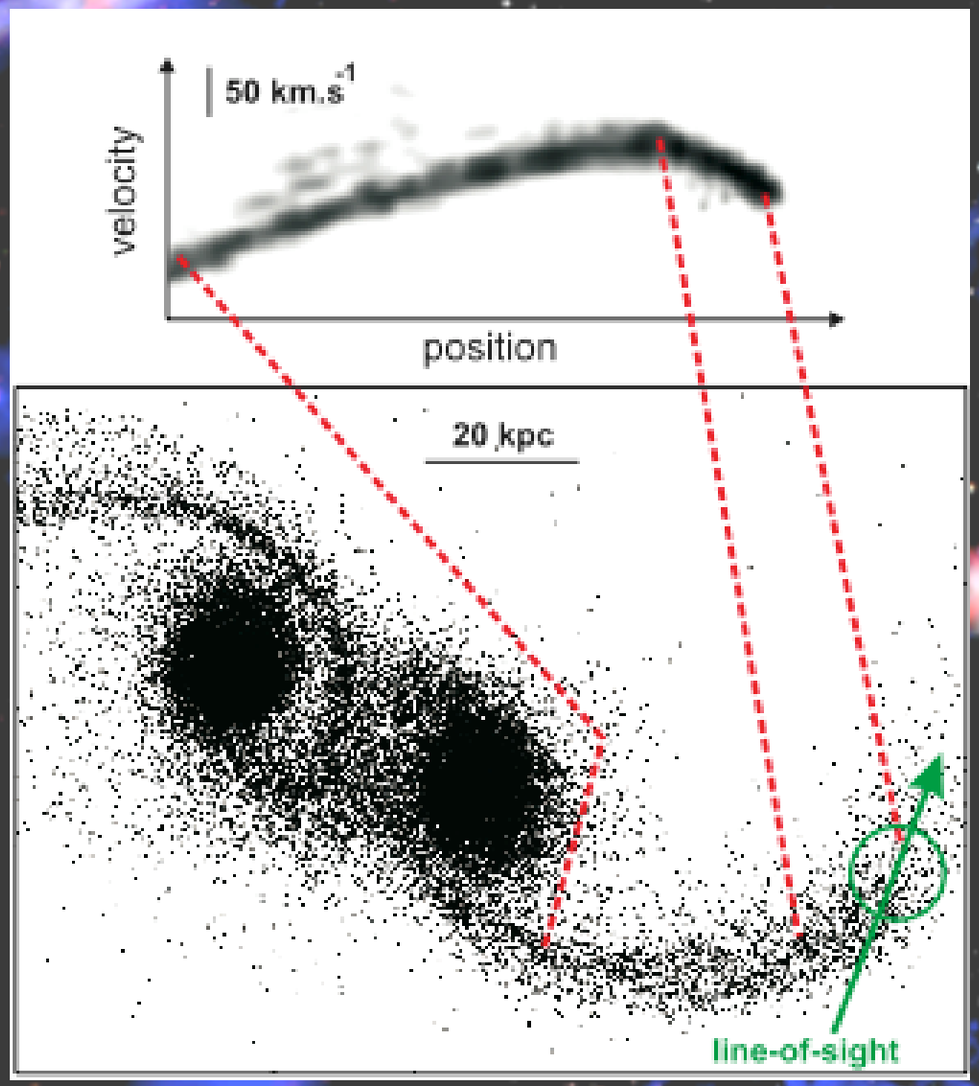
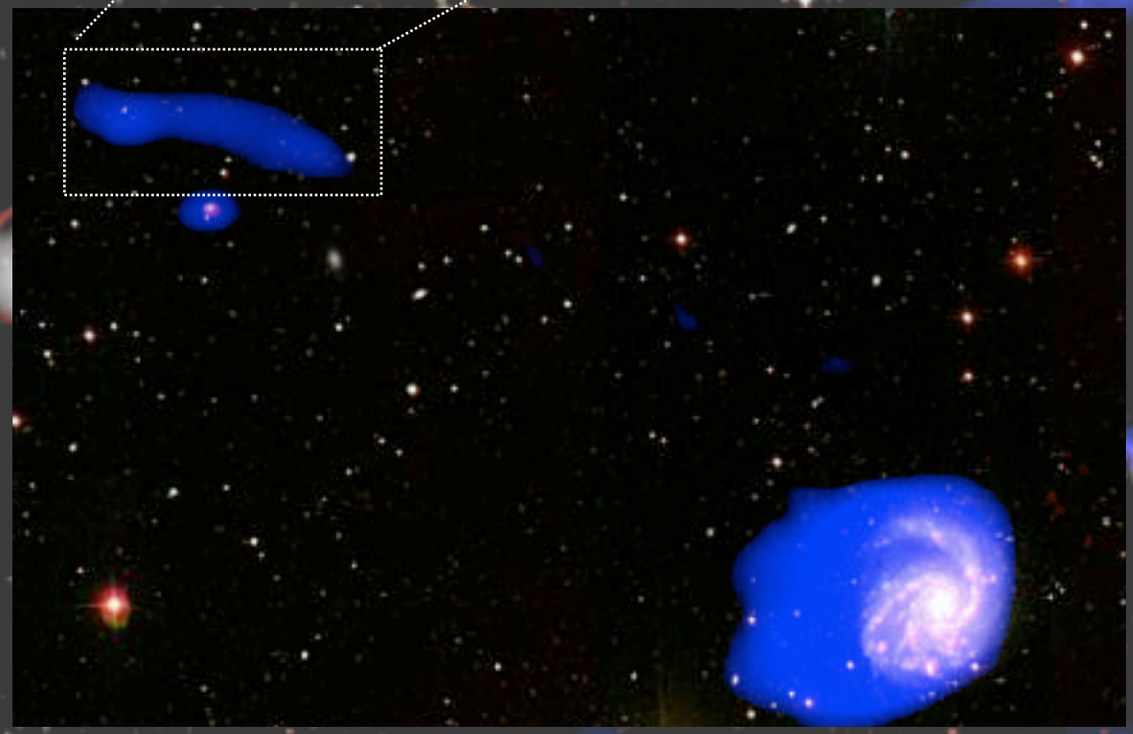
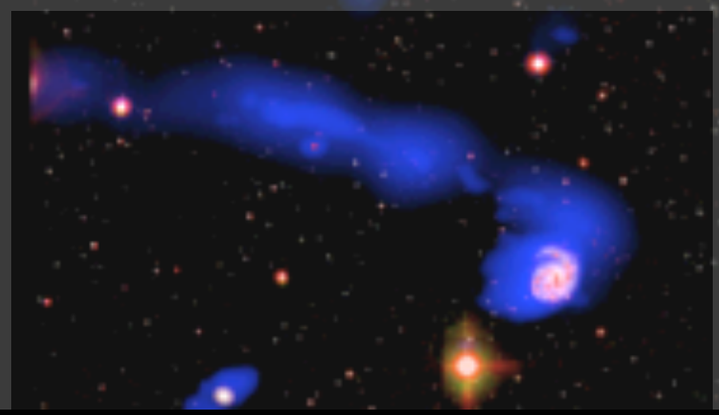


Minchin et al., 2007





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When projection effects fool even bright scientists....

Minchin et al., 2007

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Minchin et al., 2007

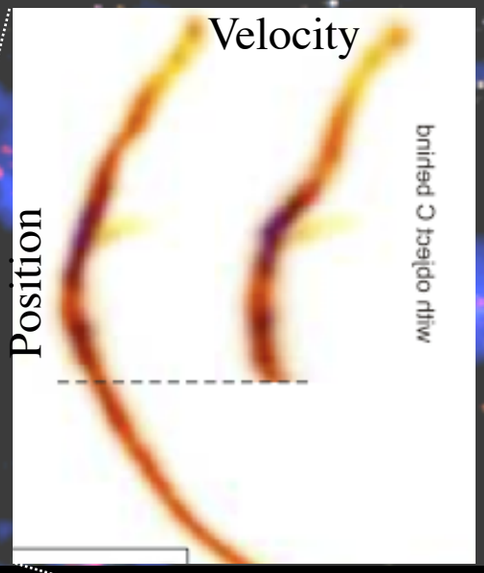
Simulation

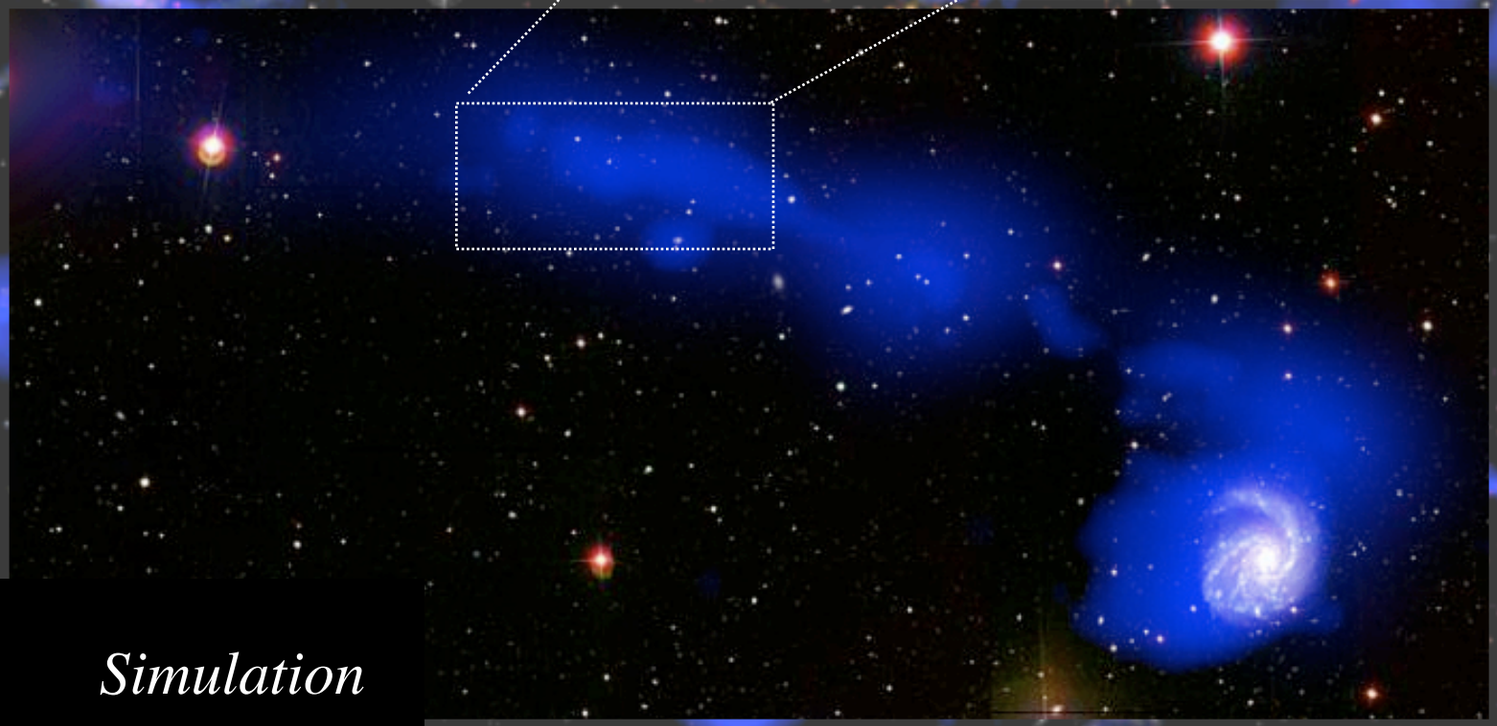
Duc & Bournaud, 2007

When projection effects fool even bright scientists....

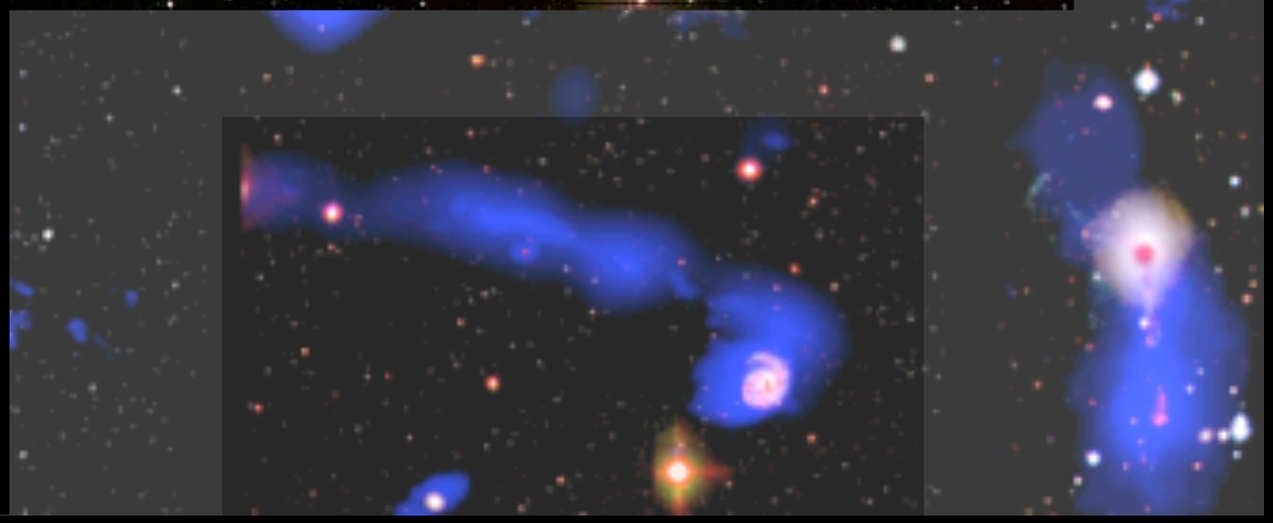
No evidence of a “dark galaxy”!

Minchin et al., 2007



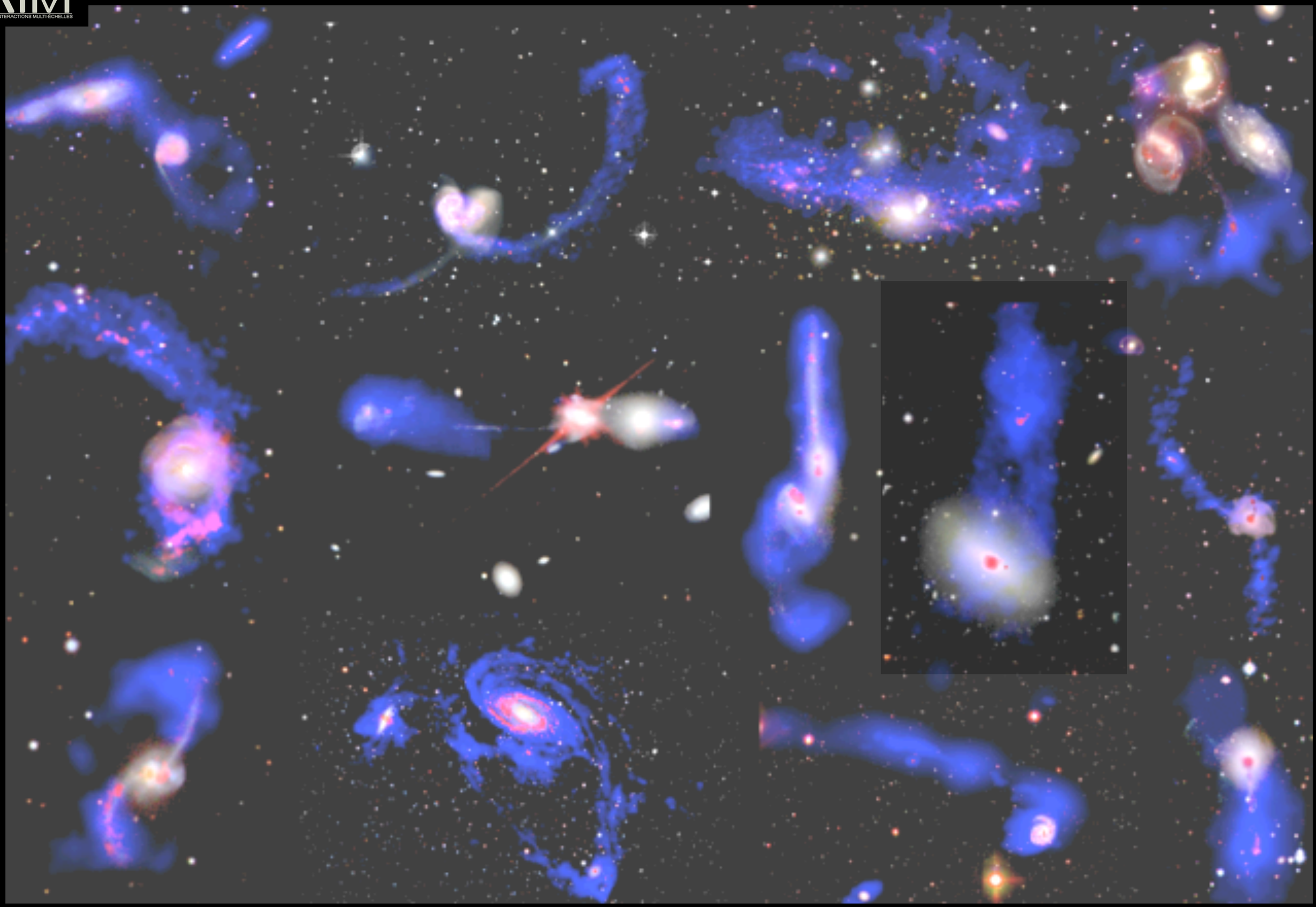


Simulation



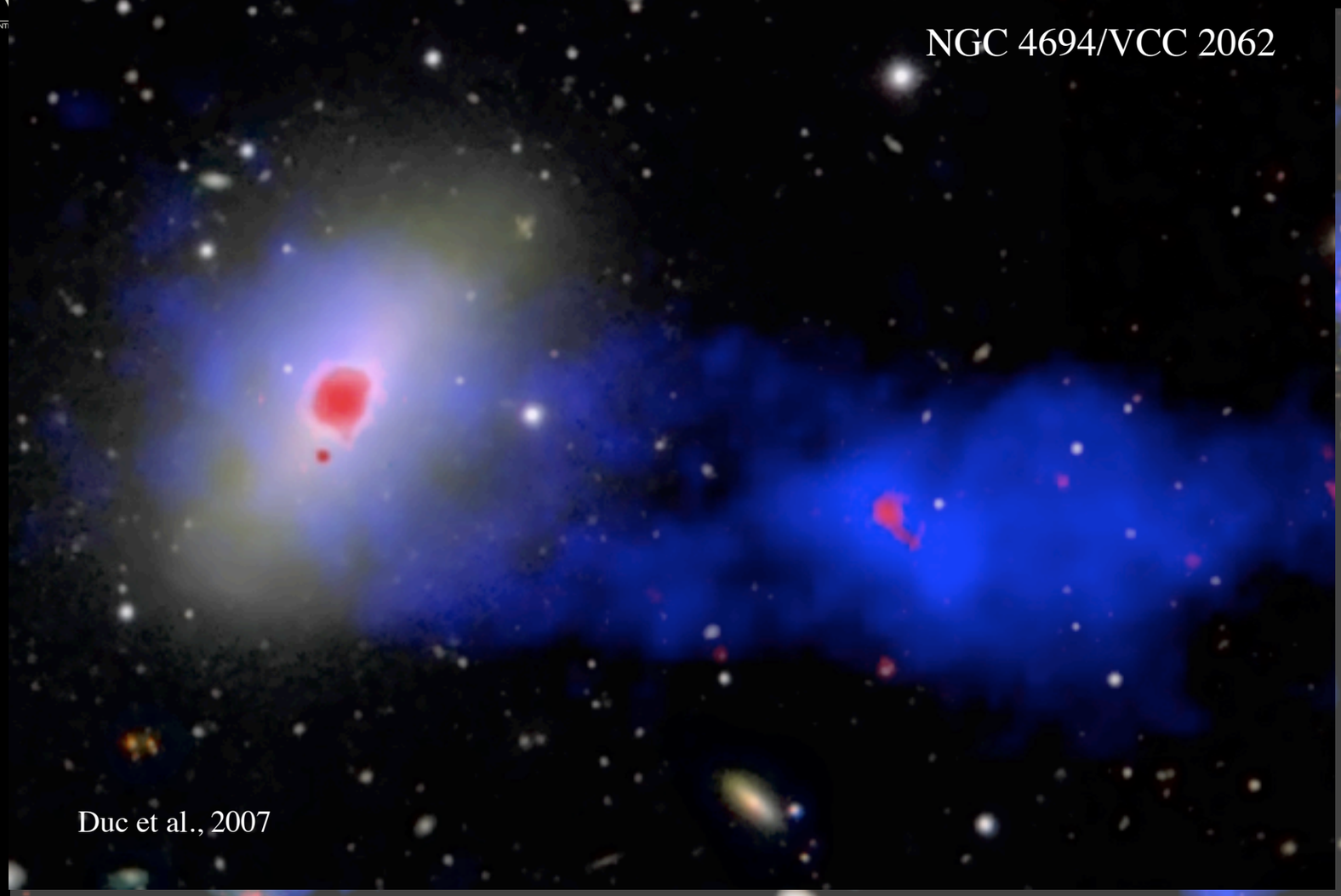
Duc & Bournaud, 2007

(Real) decoupled components in tidal debris

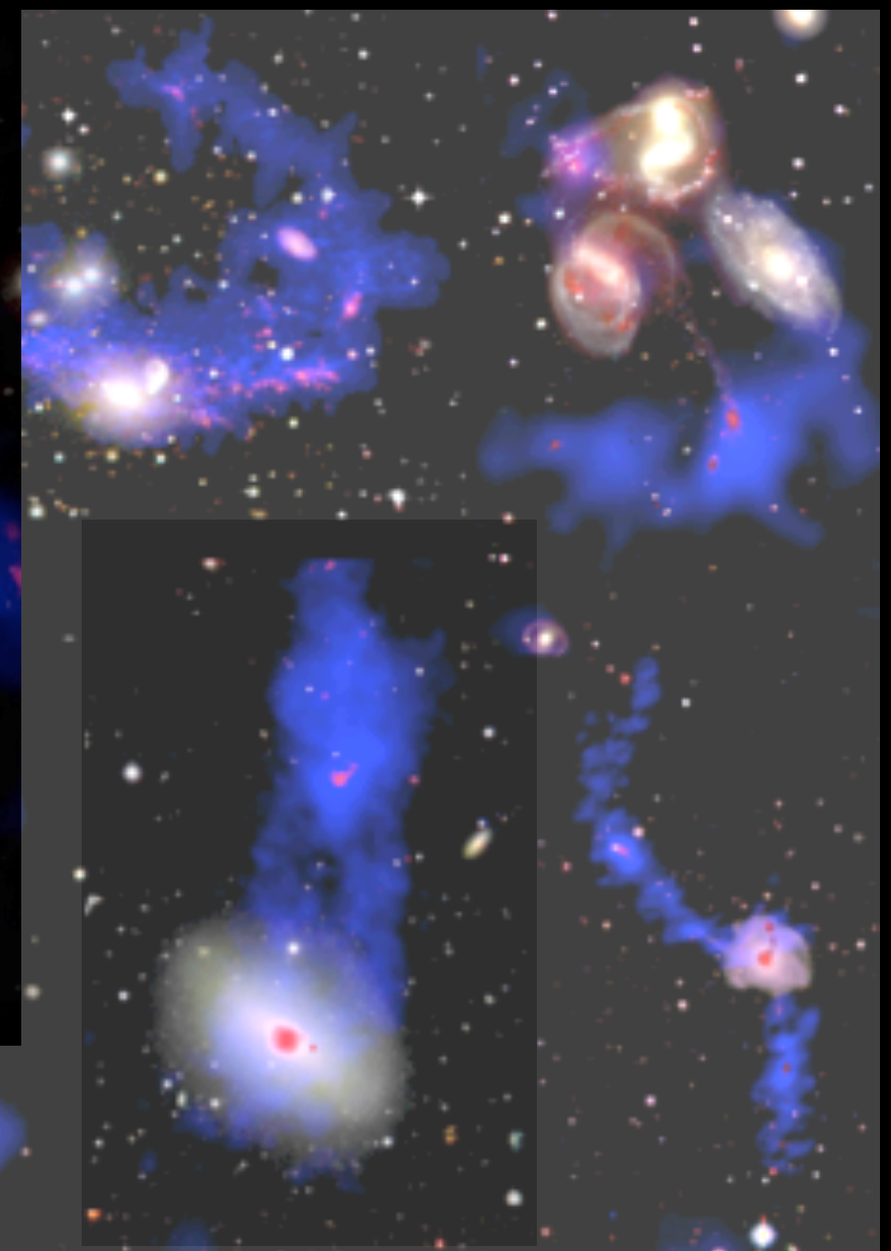


(Real) decoupled components in tidal debris

NGC 4694/VCC 2062

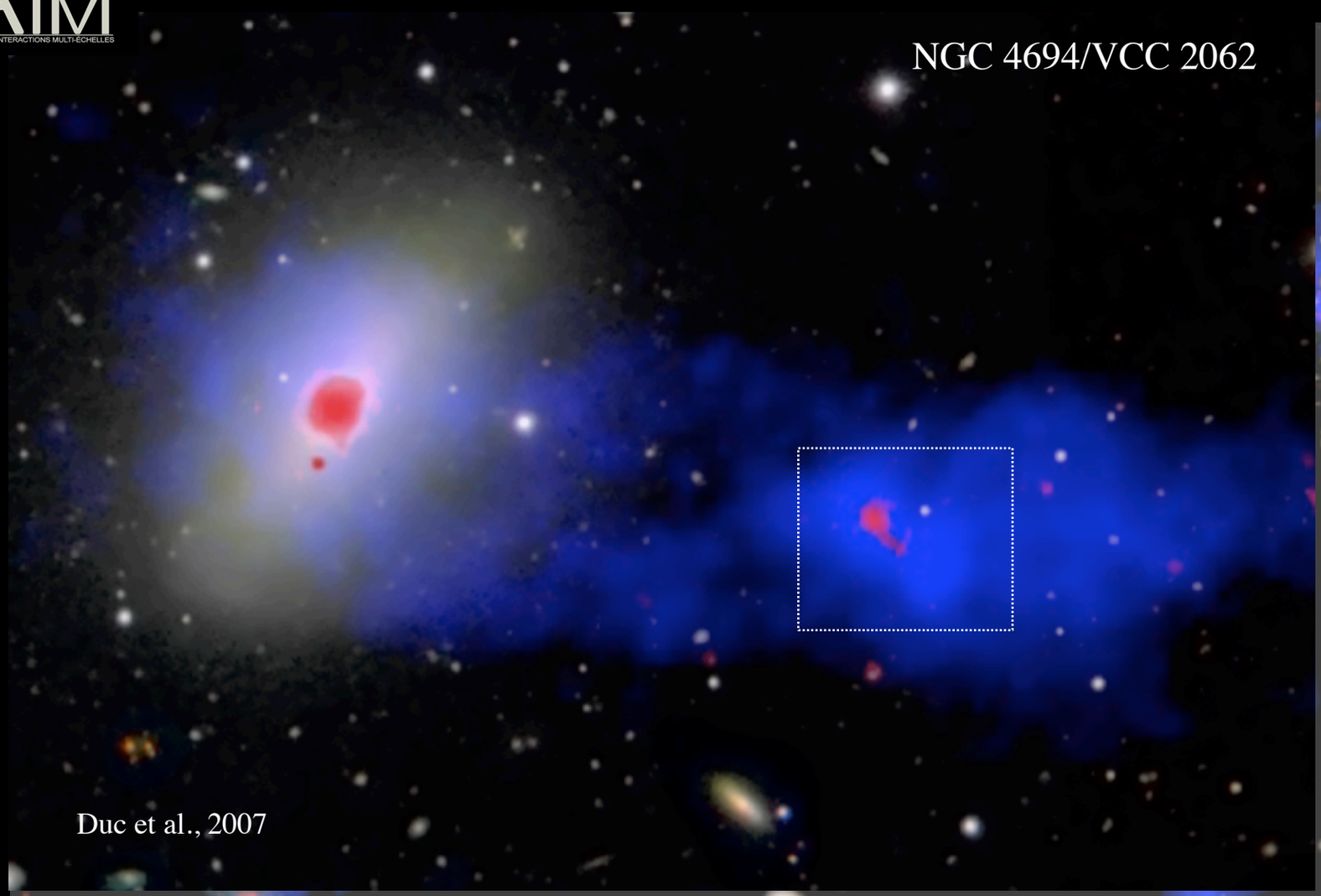


Duc et al., 2007

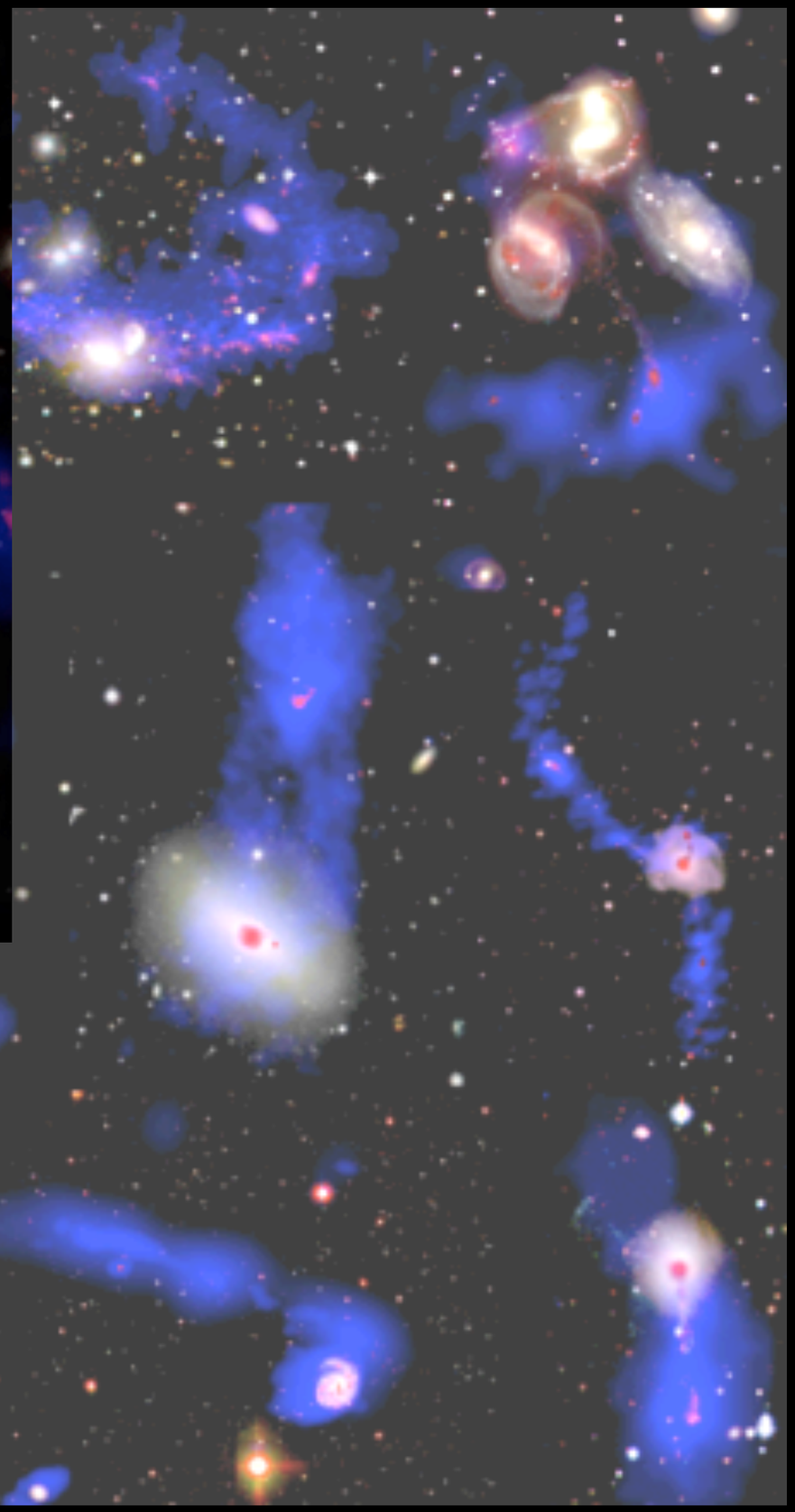


Kinematics and star formation in tidal debris

NGC 4694/VCC 2062



Duc et al., 2007



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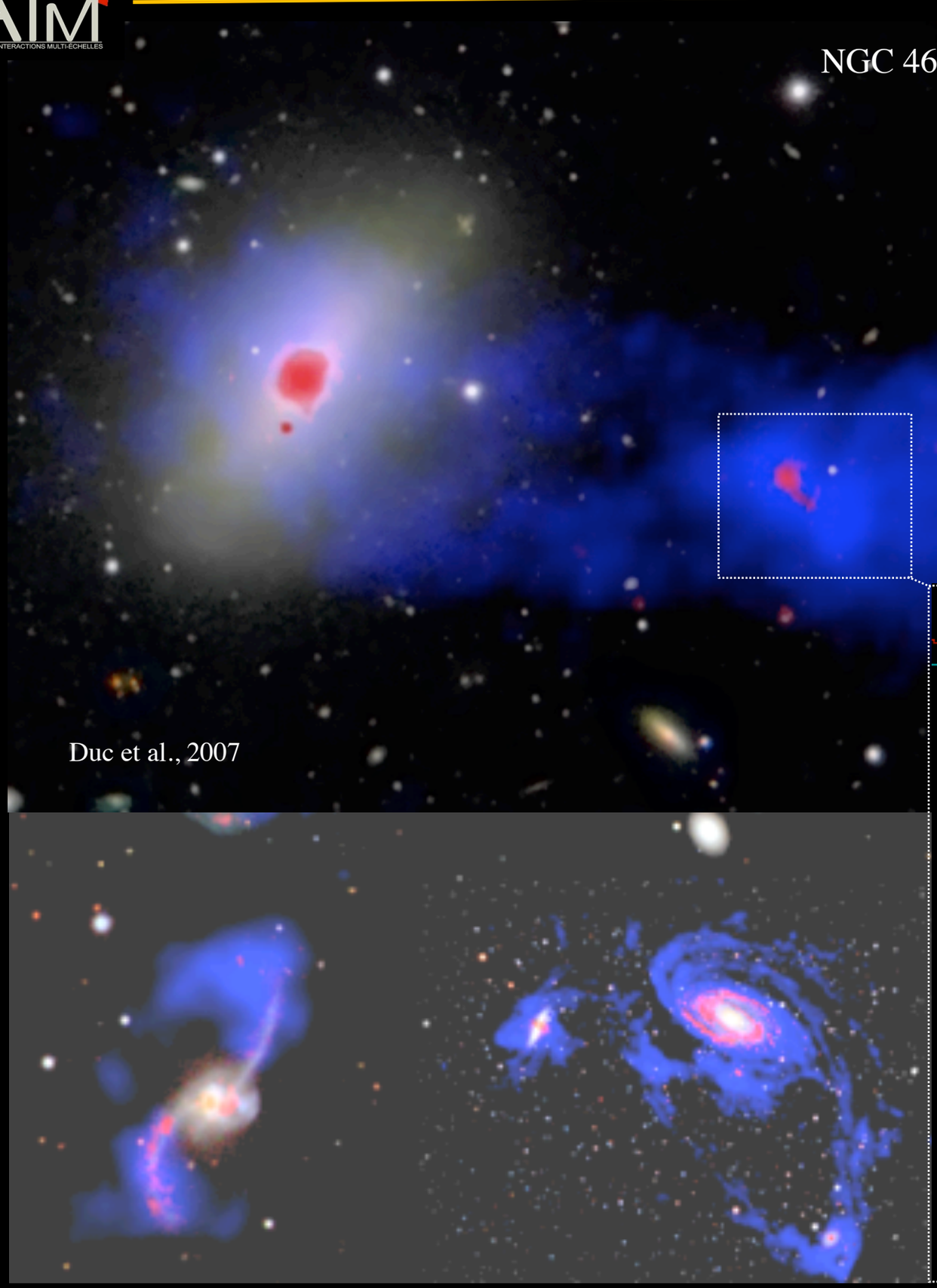
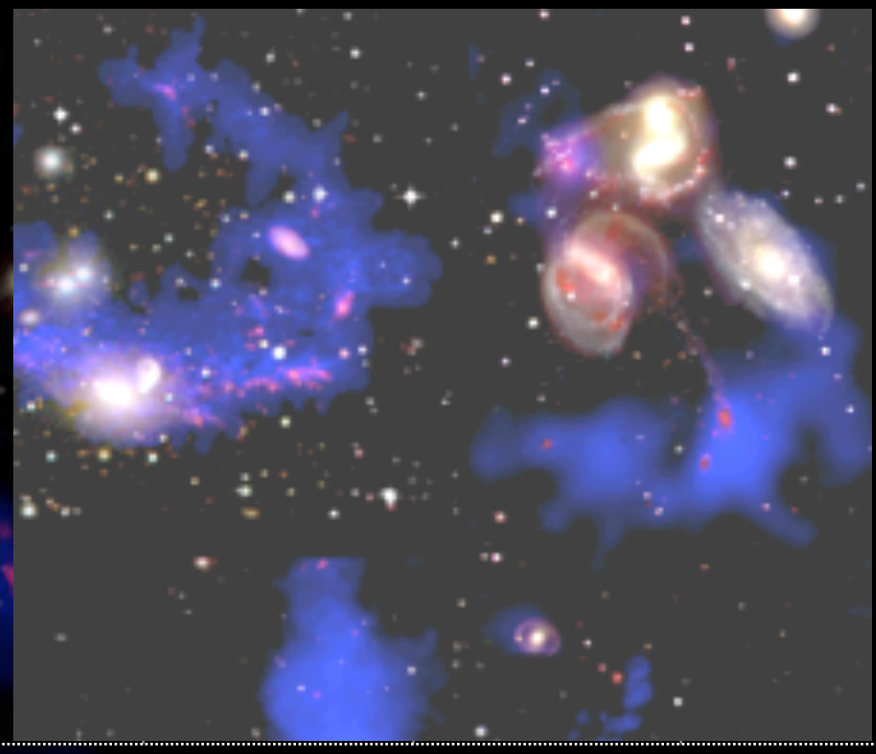
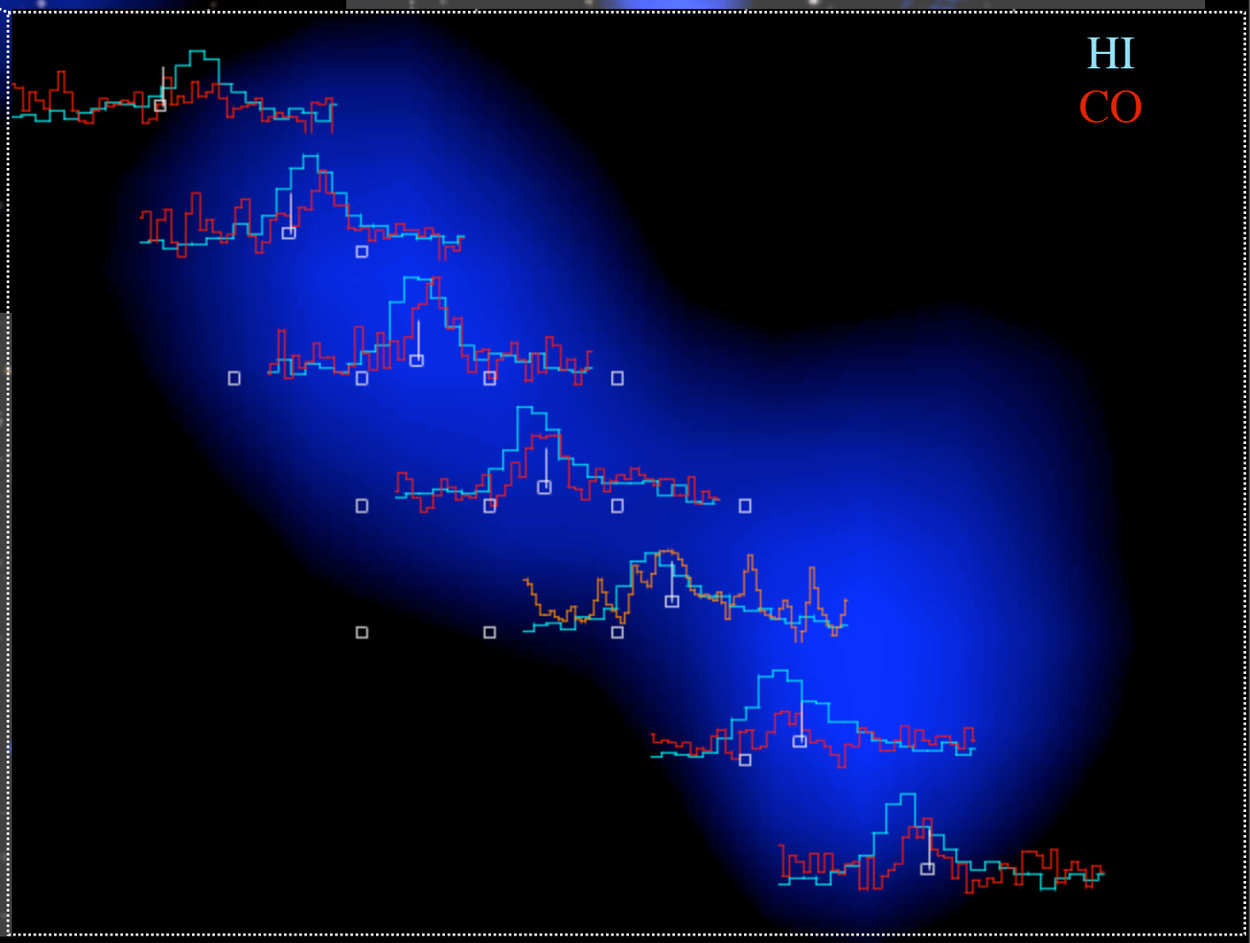


Duc et al., 2007





Kinematics and star formation in tidal debris

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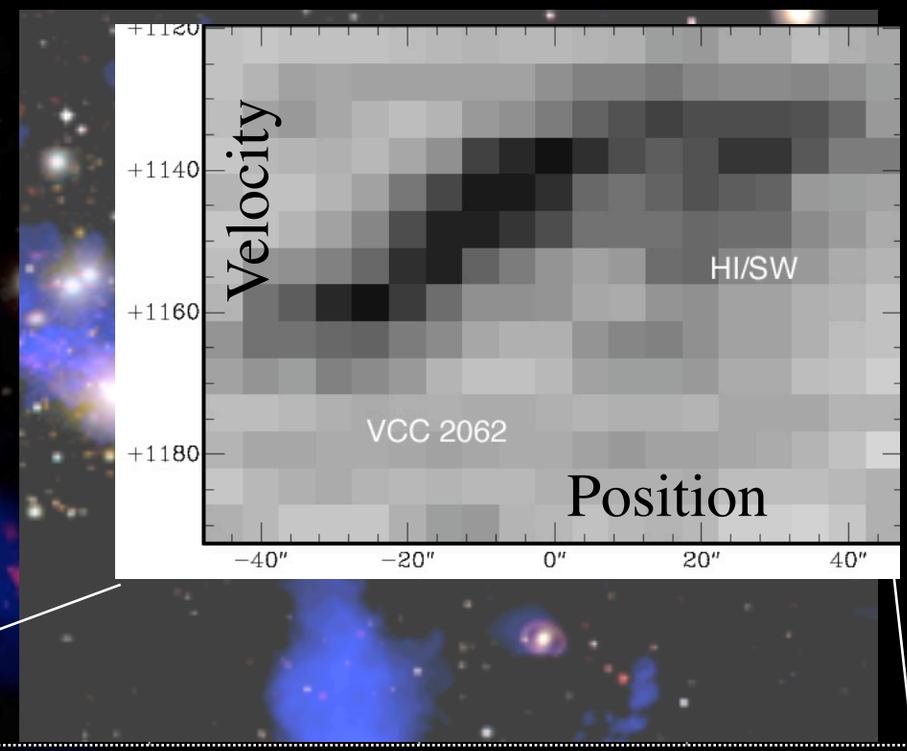
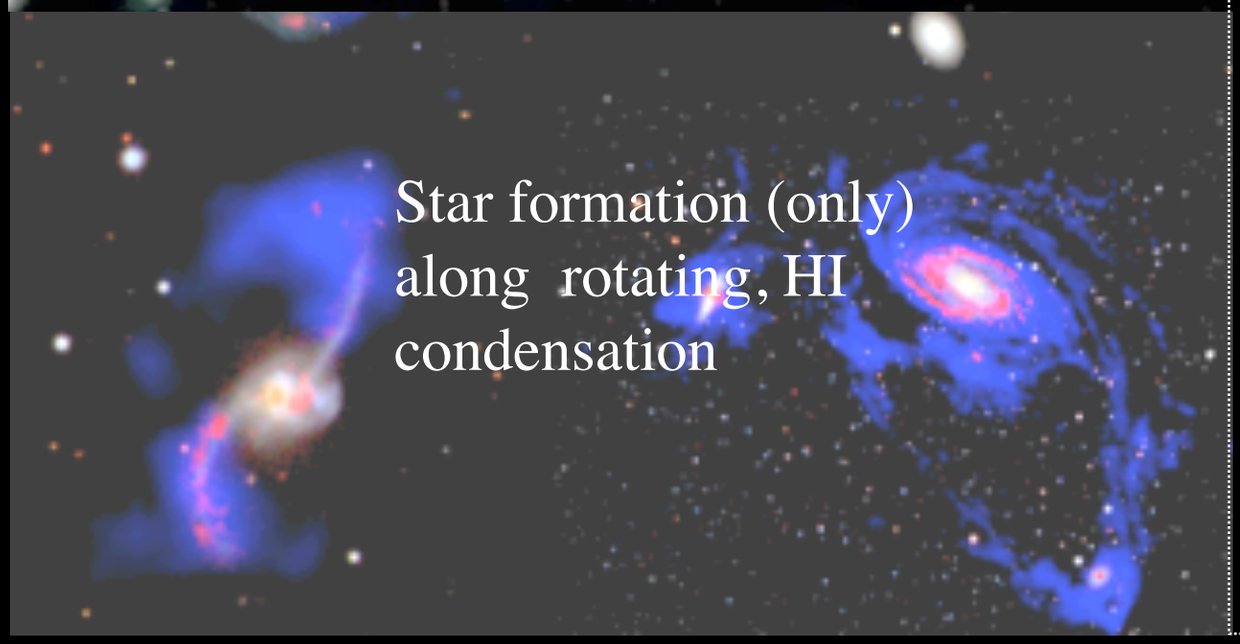
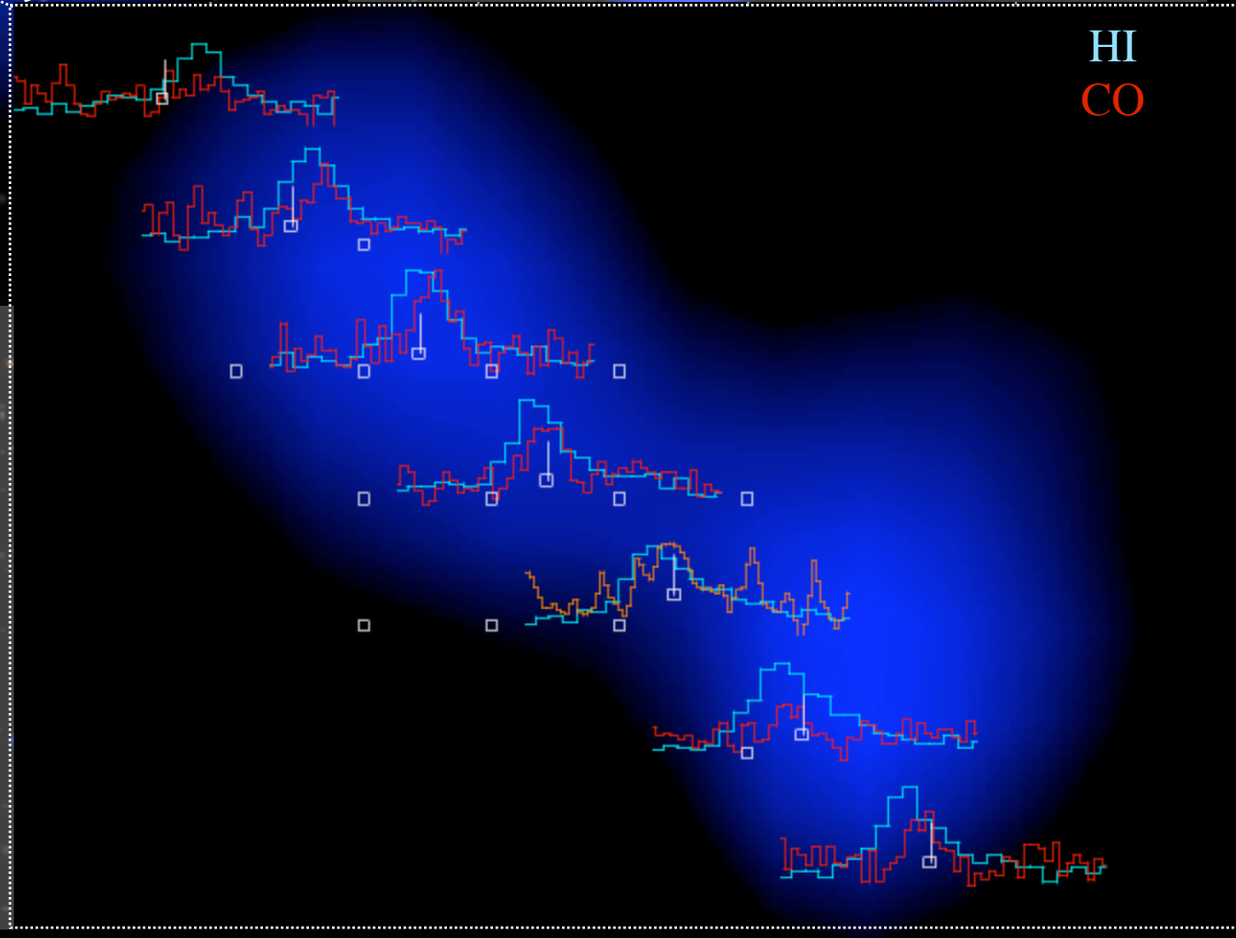


Duc et al., 2007





Probing the distribution of dark matter in and around galaxies with collisional debris

Kinematics of collisional debris

P.-A. Duc / ESO-3D conf-2008

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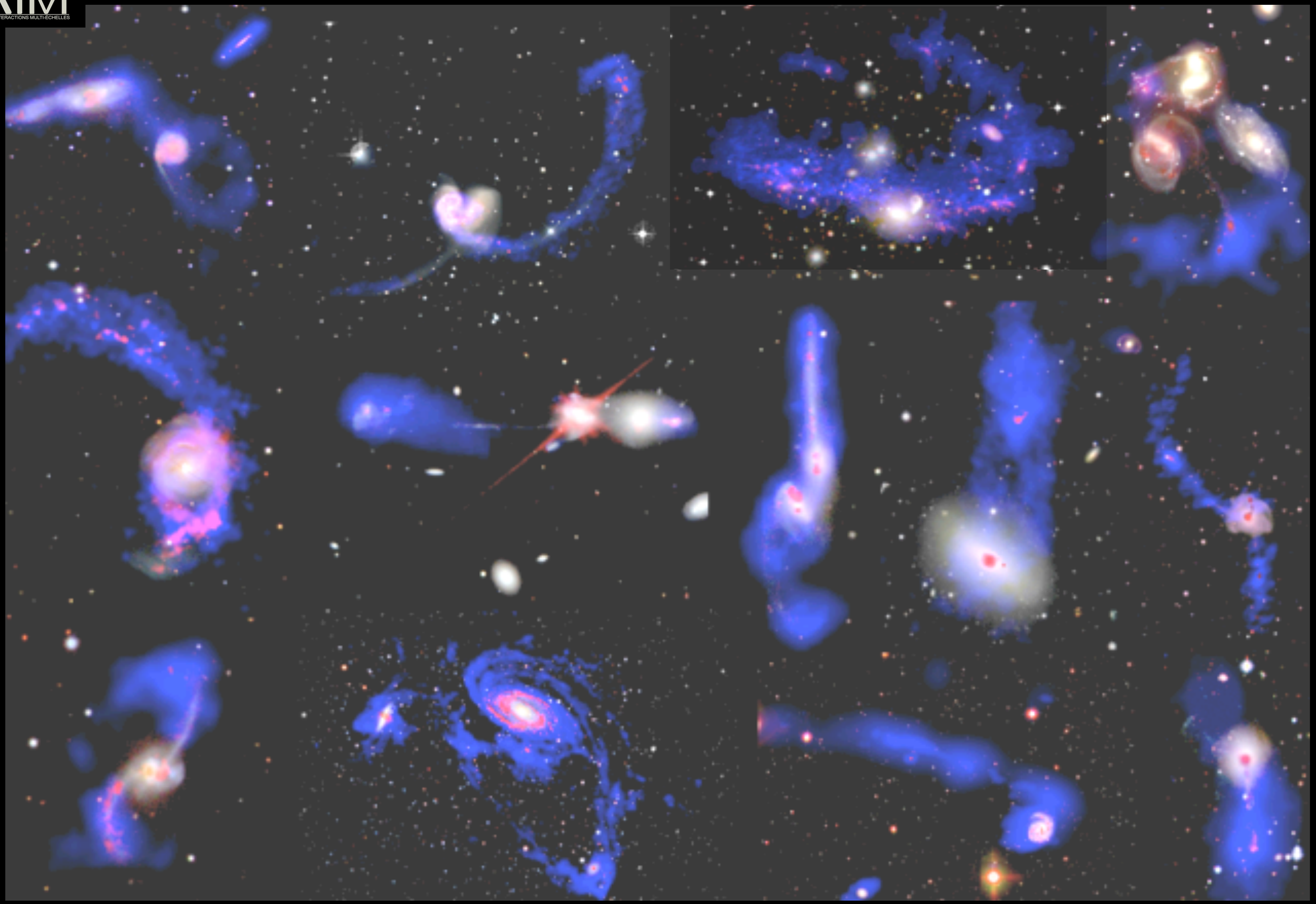
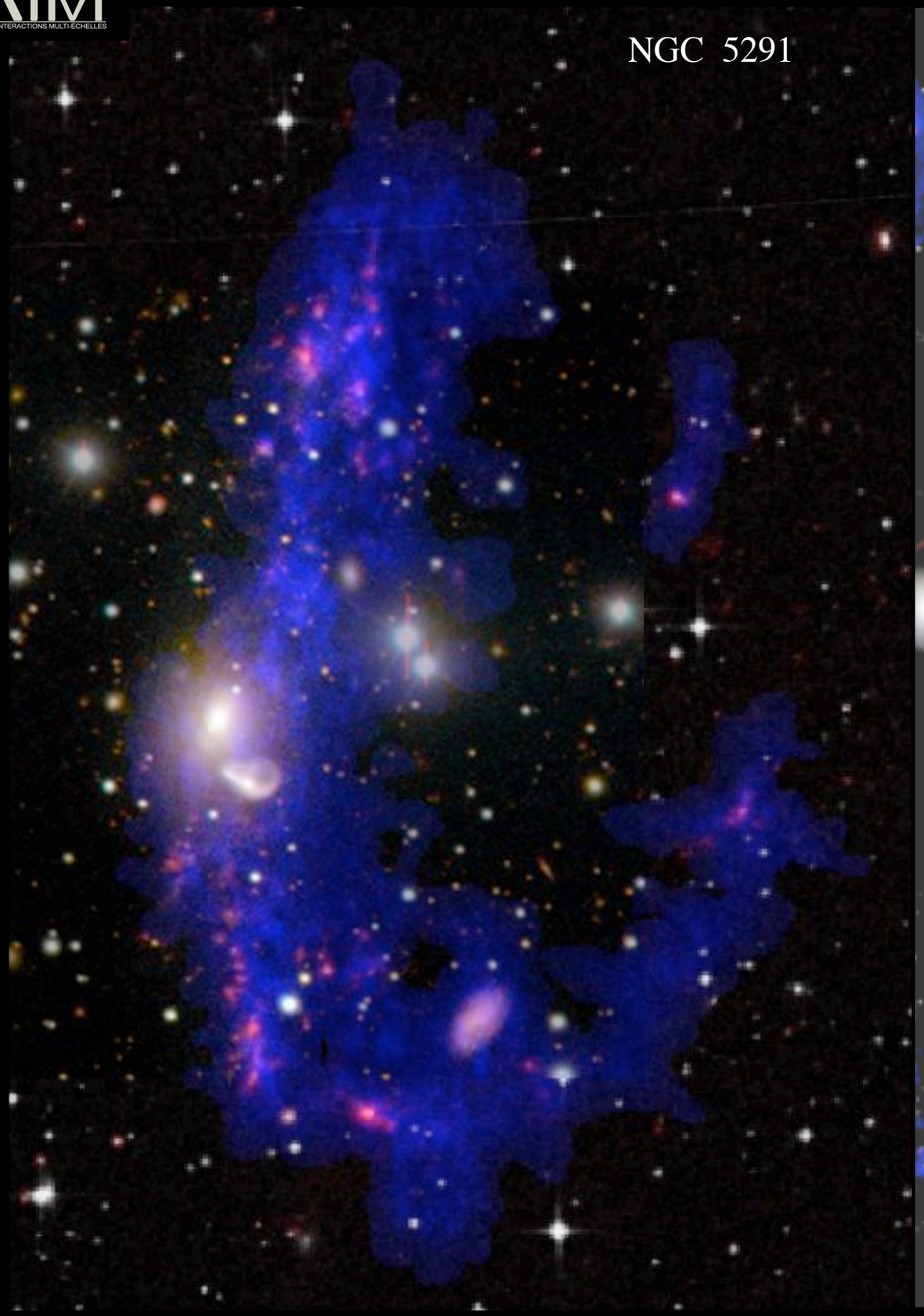
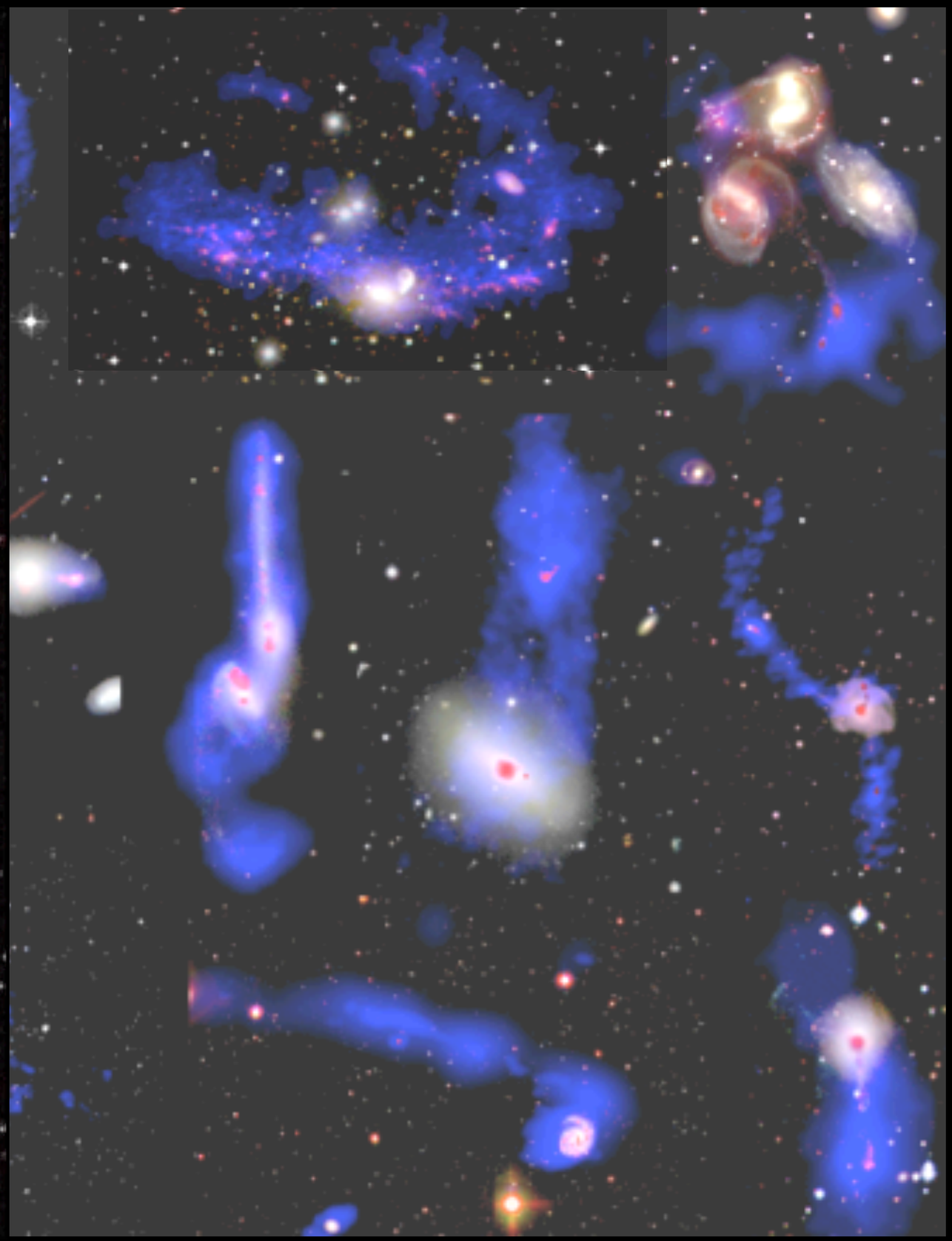


Probing the distribution of dark matter in and around galaxies with collisional debris

NGC 5291





Kinematics of collisional debris

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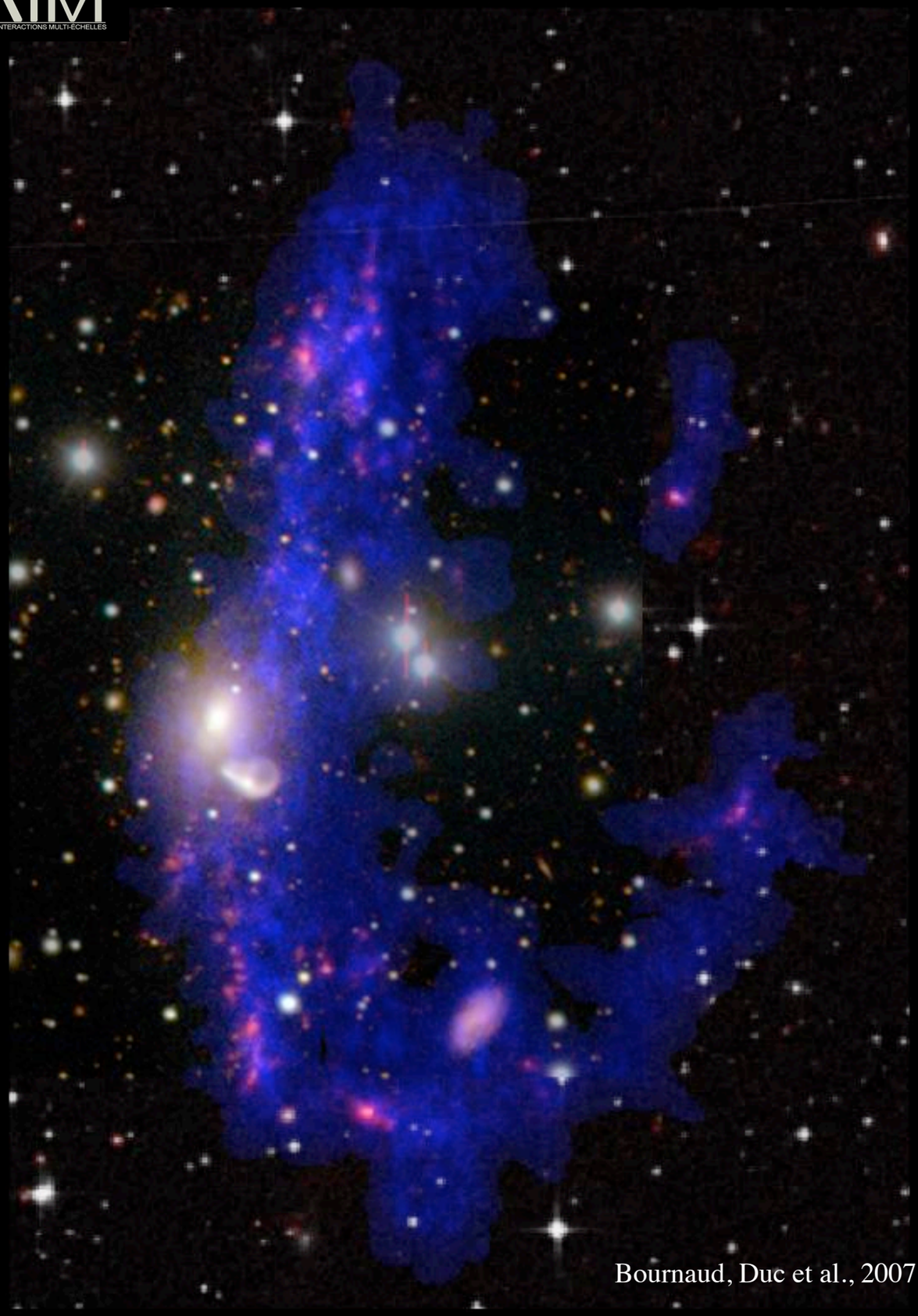

Bournaud, Duc et al., 2007

Probing the distribution of dark matter in and around galaxies with collisional debris

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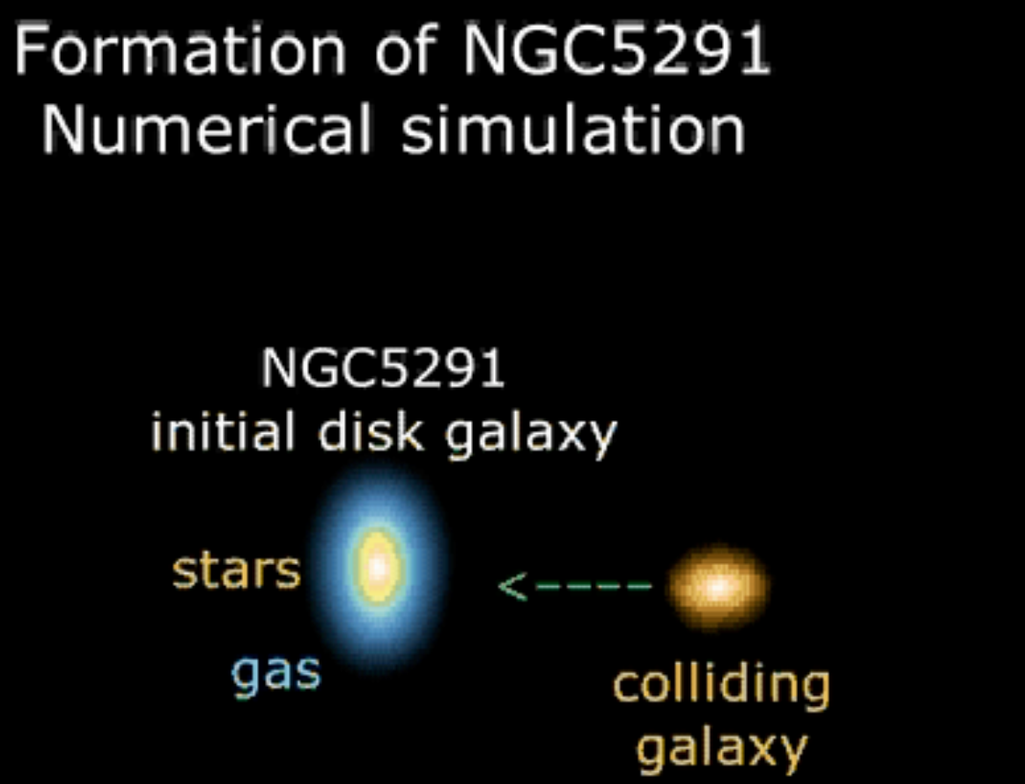
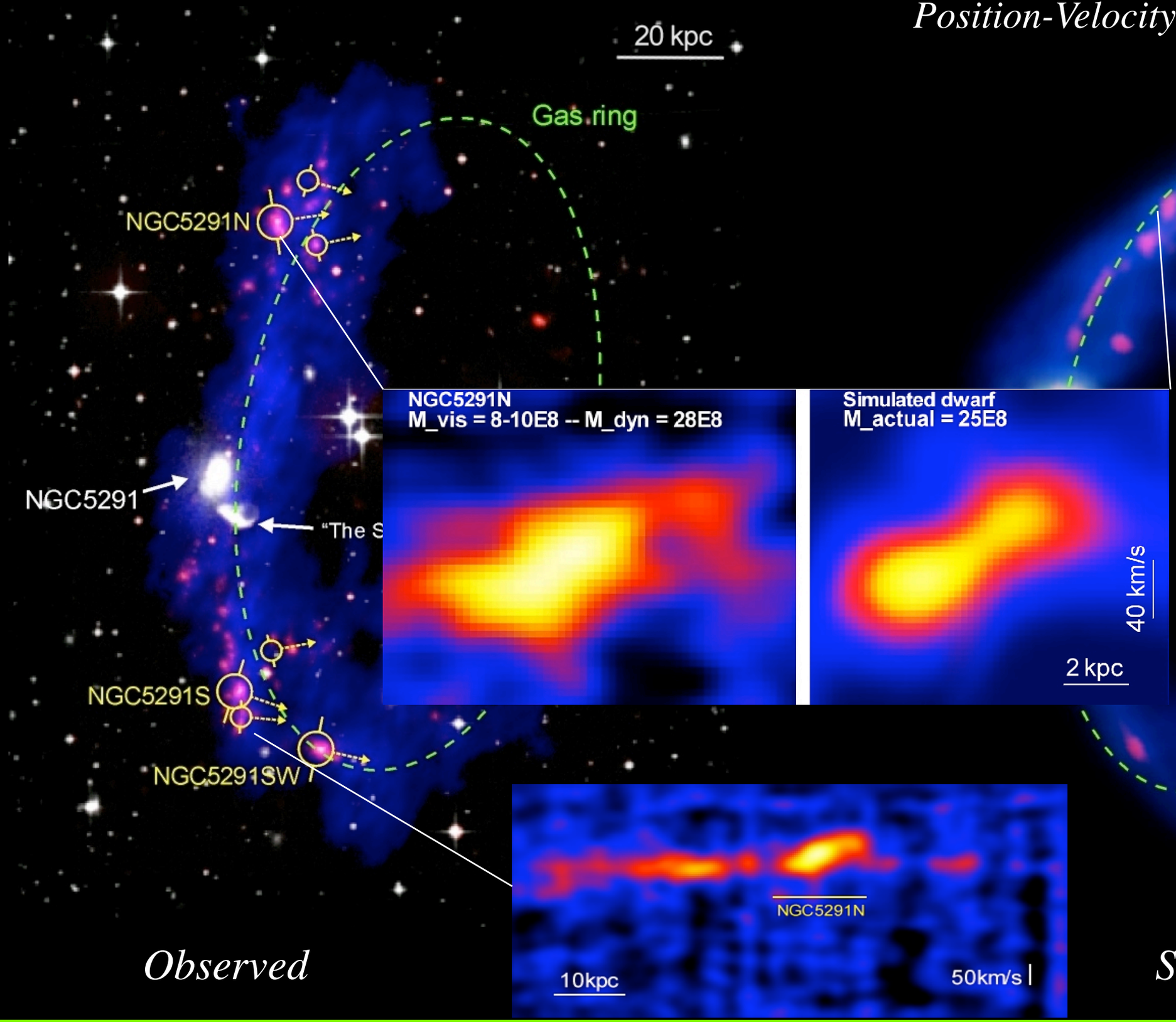


Probing the distribution of dark matter in and around galaxies with collisional debris

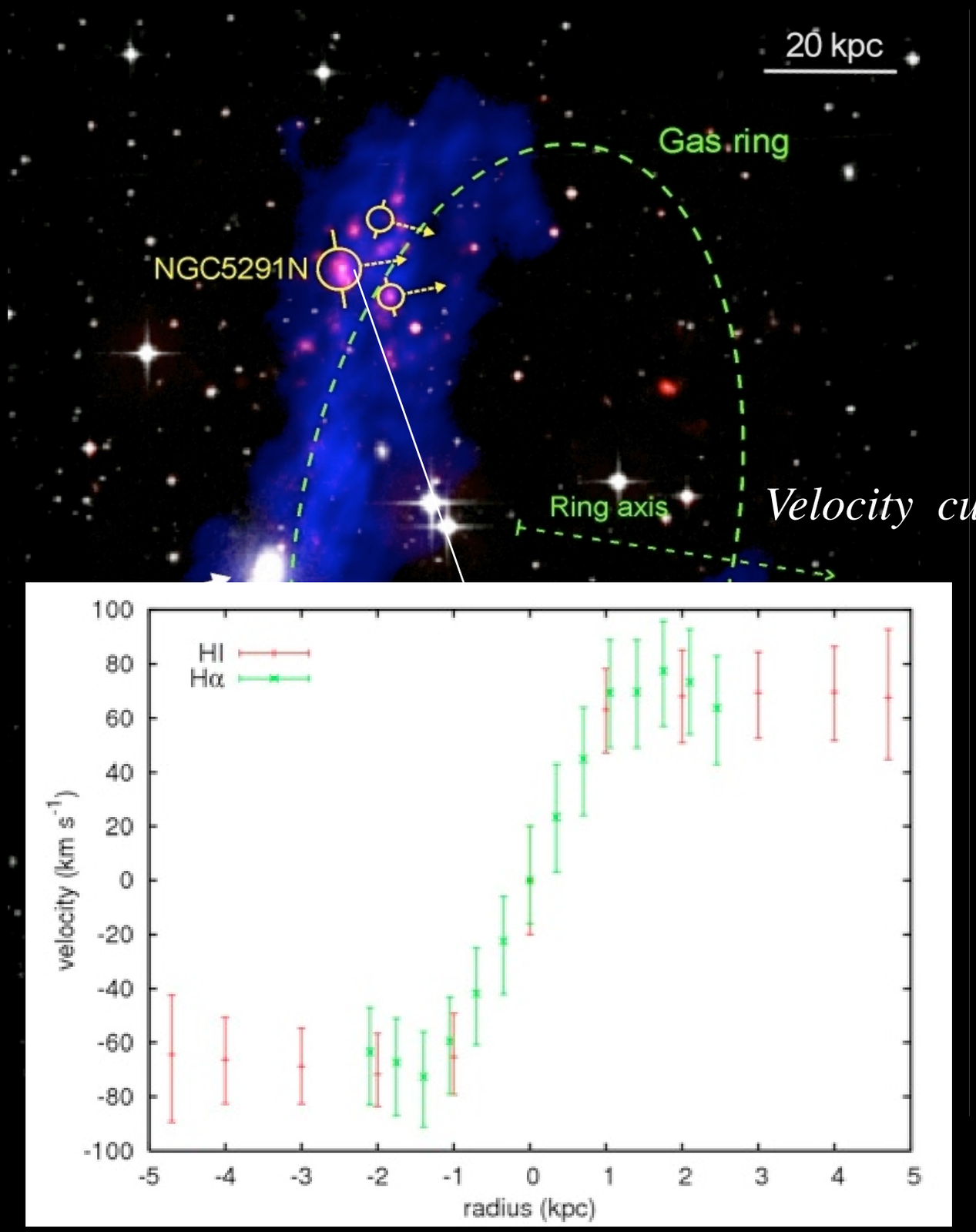
Position-Velocity diagrams



Bournaud et al., 2007

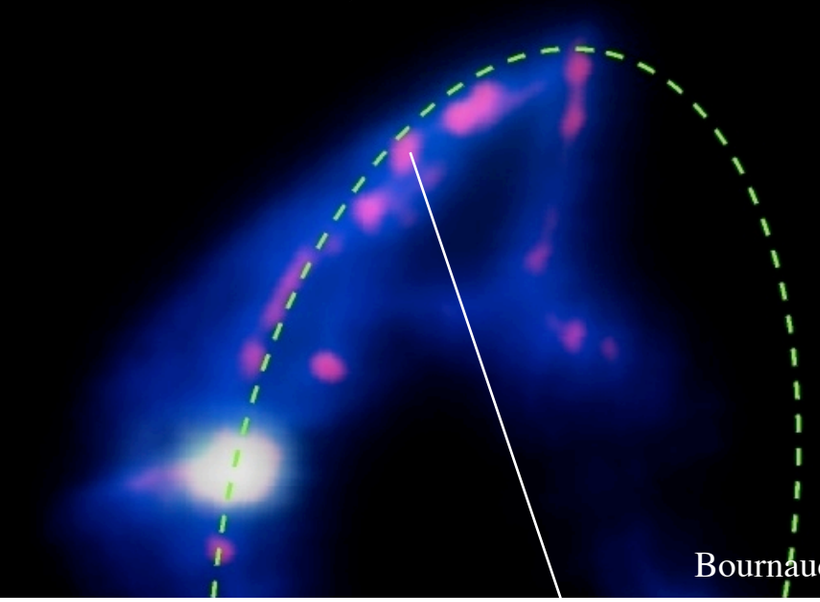
Observed *Simulated*

Probing the distribution of dark matter in and around galaxies with collisional debris

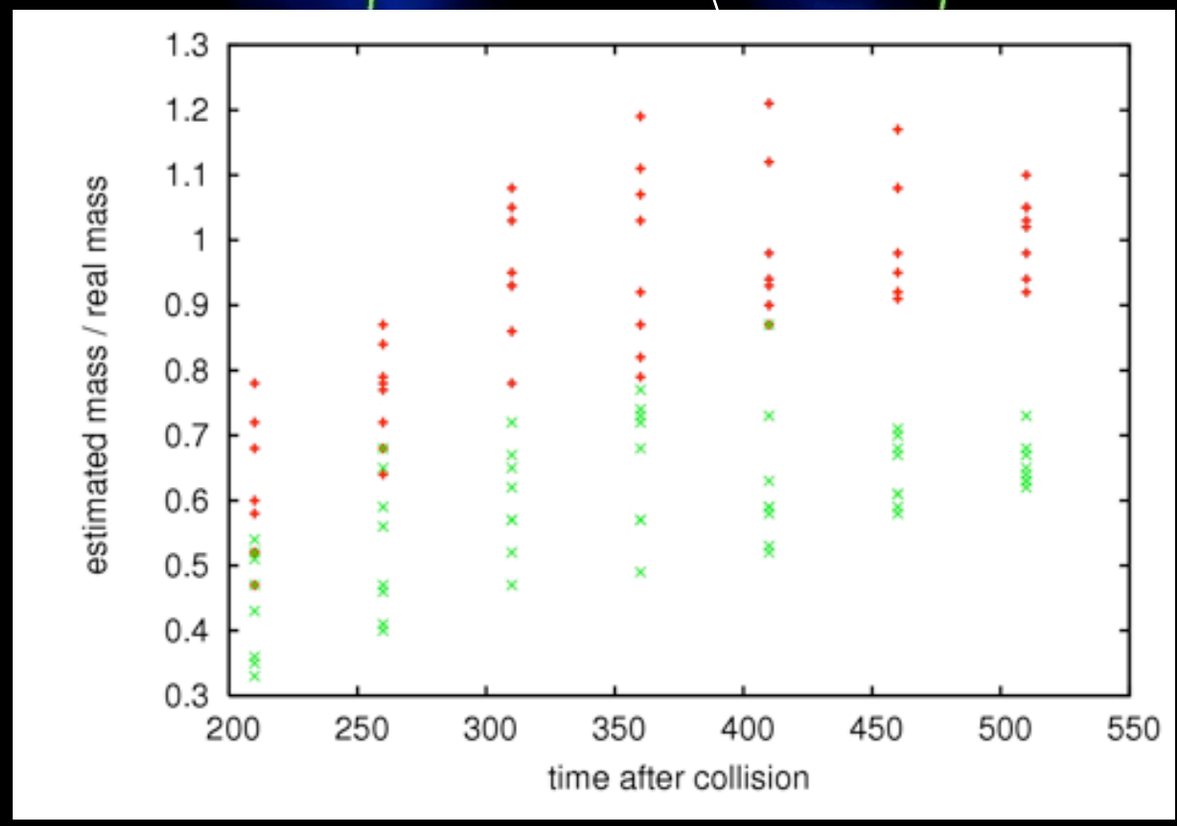


Velocity curves

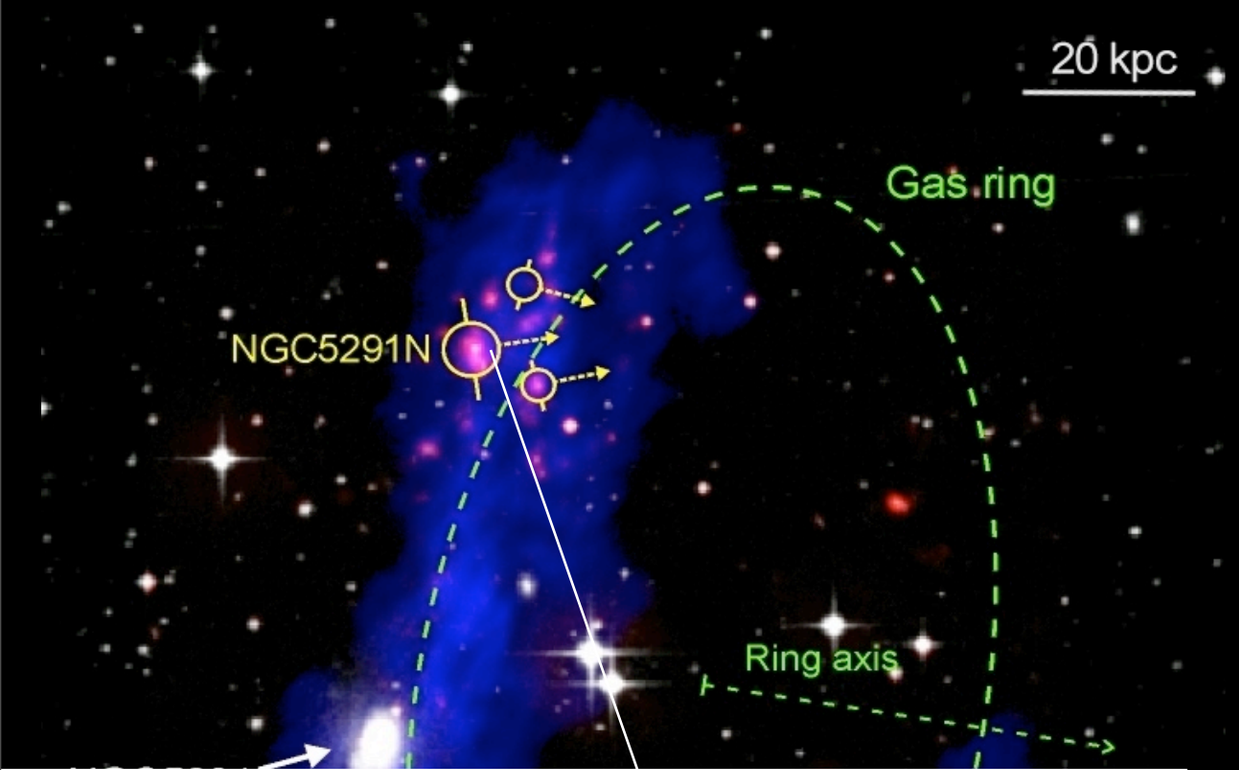
Errors of the method checked with the simulations (systematics, inclination)



Bournaud et al., 2007



Probing the internal kinematics of debris: revealing an unexpected missing mass



$M_{lum} = M_{HI} + M_{H2/CO} + M_{stars}$

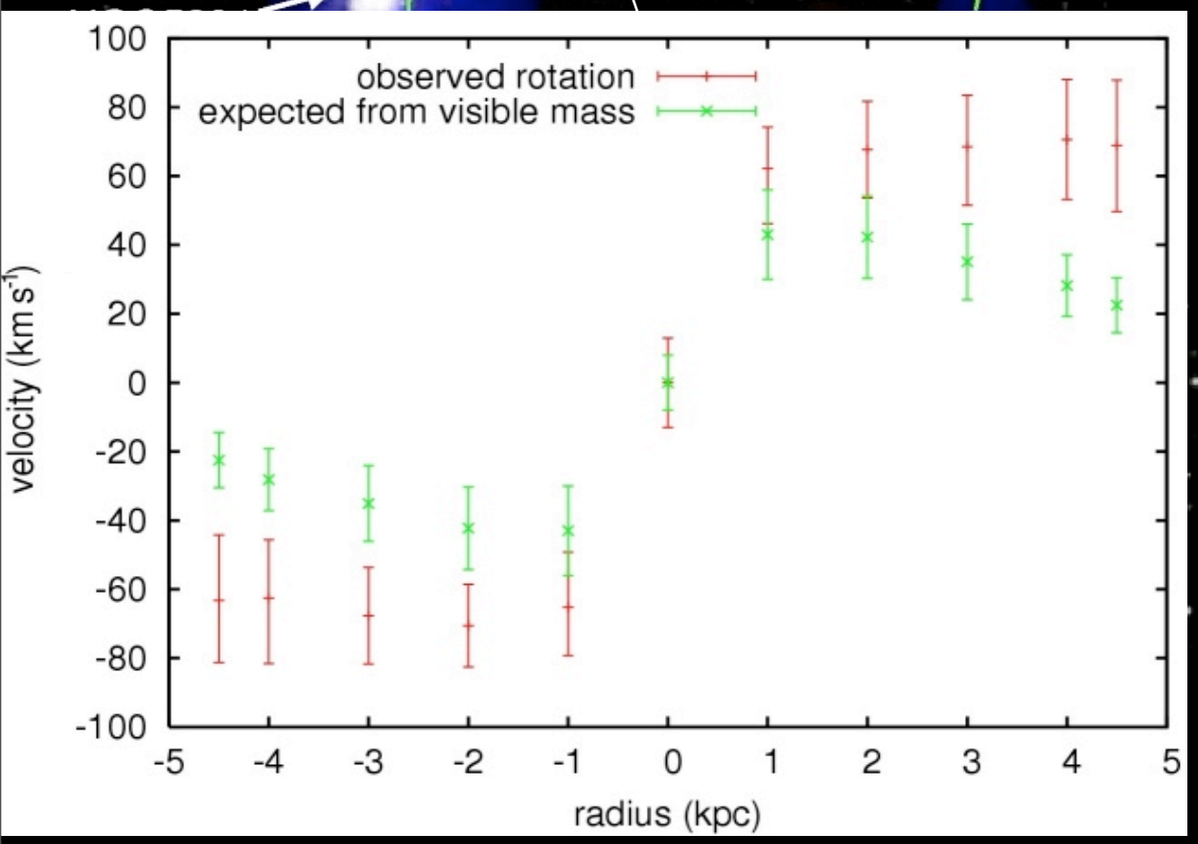
$8.8 \times 10^8 = 5.7 \times 10^8 + 2 \times 10^8 + 1.1 \times 10^8$

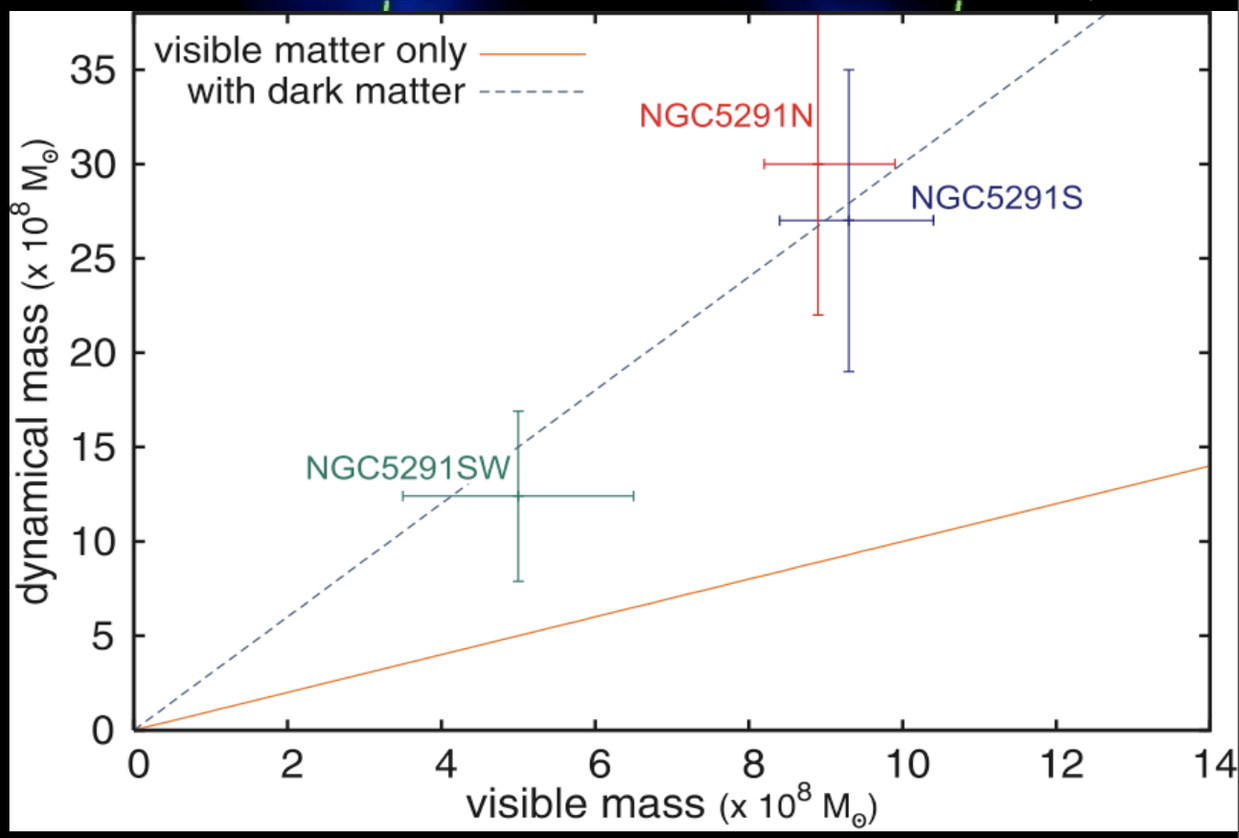
$M_{dyn} = 3 \times M_{lum}$

(for 3 objects)

M(H2/CO) wrong by a factor of at least 10 despite a relatively high metallicity?

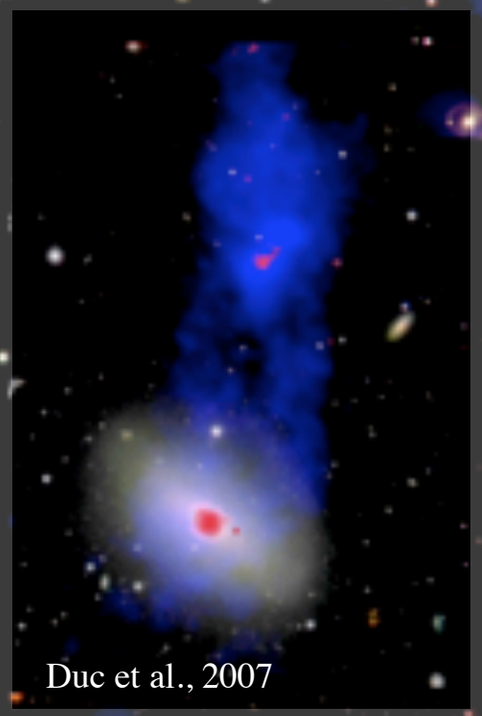
Bournaud et al., 2007





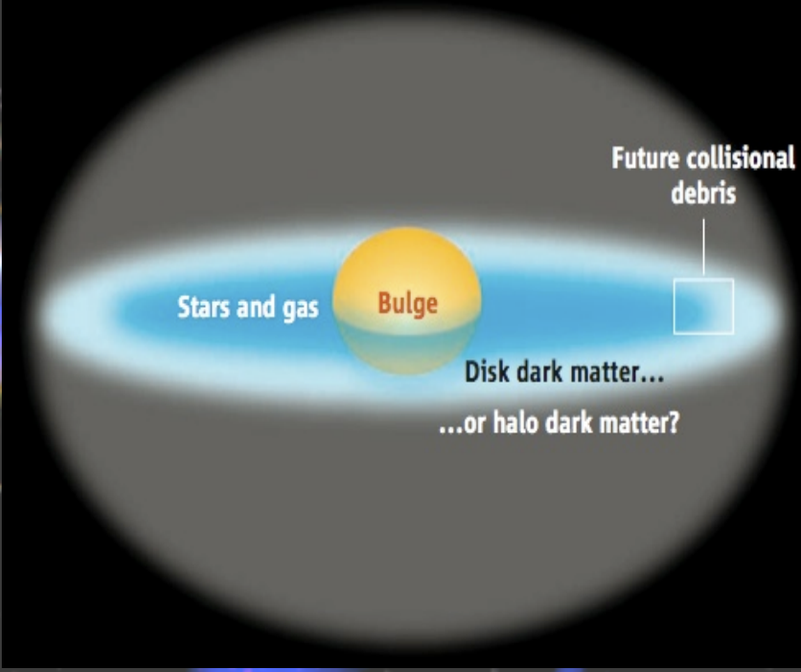
Missing mass found in other interacting systems


Saviane et al., 2008


Duc et al., 2007

Origin of the missing mass

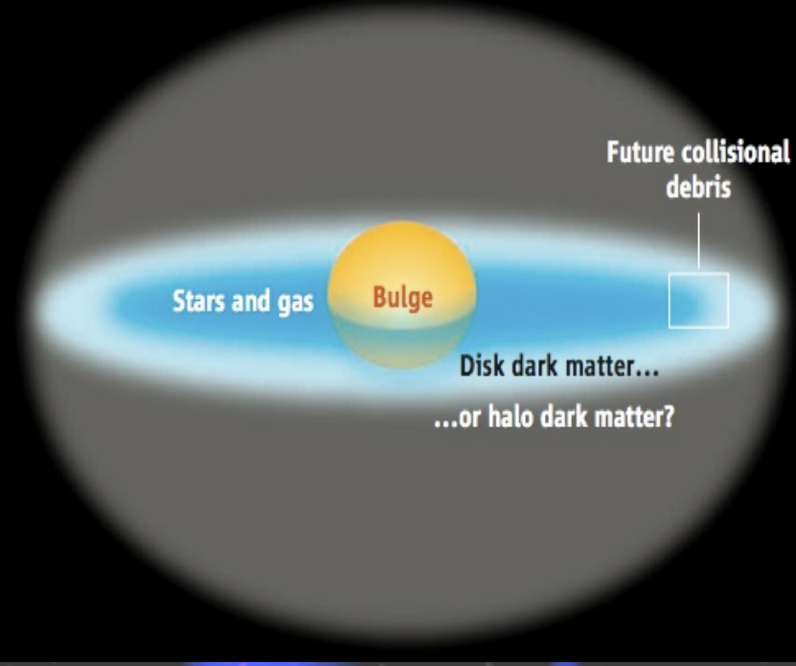
In spiral disks! Less than 10% comes from the cosmological halo: not conventional DM



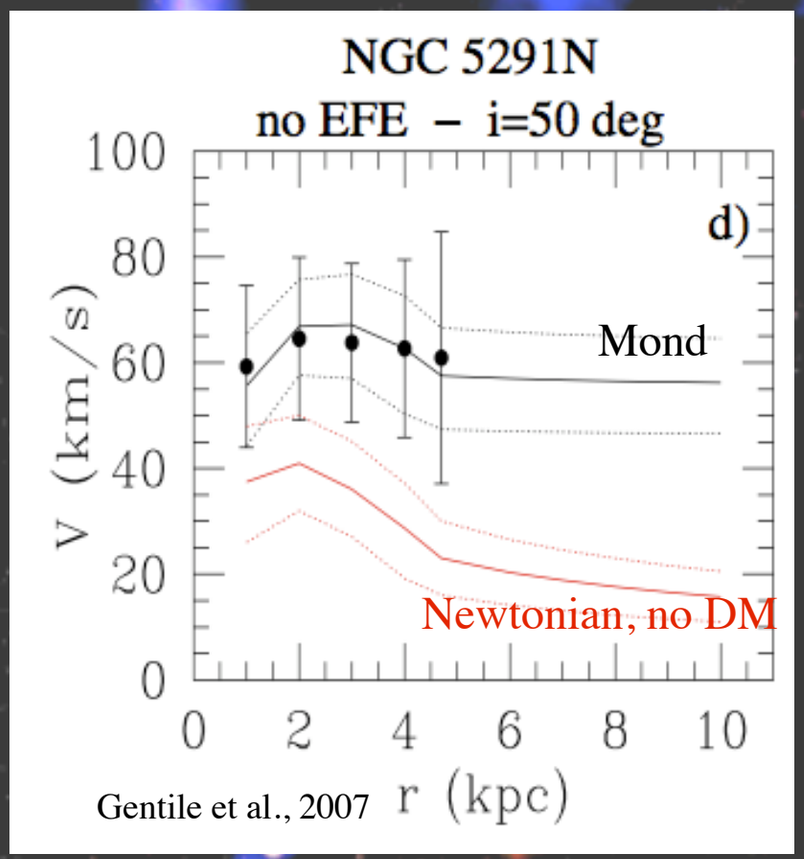
Gentile et al., 2007

Origin of the missing mass

✓ In <u>spiral disks</u>! Less than 10% comes from the cosmological halo: not conventional DM



✓<u>Alternative theories</u>: MOND may reproduce the formation of TDGs and their internal kinematics: Milgrom (2007), Gentile at al. (2007)



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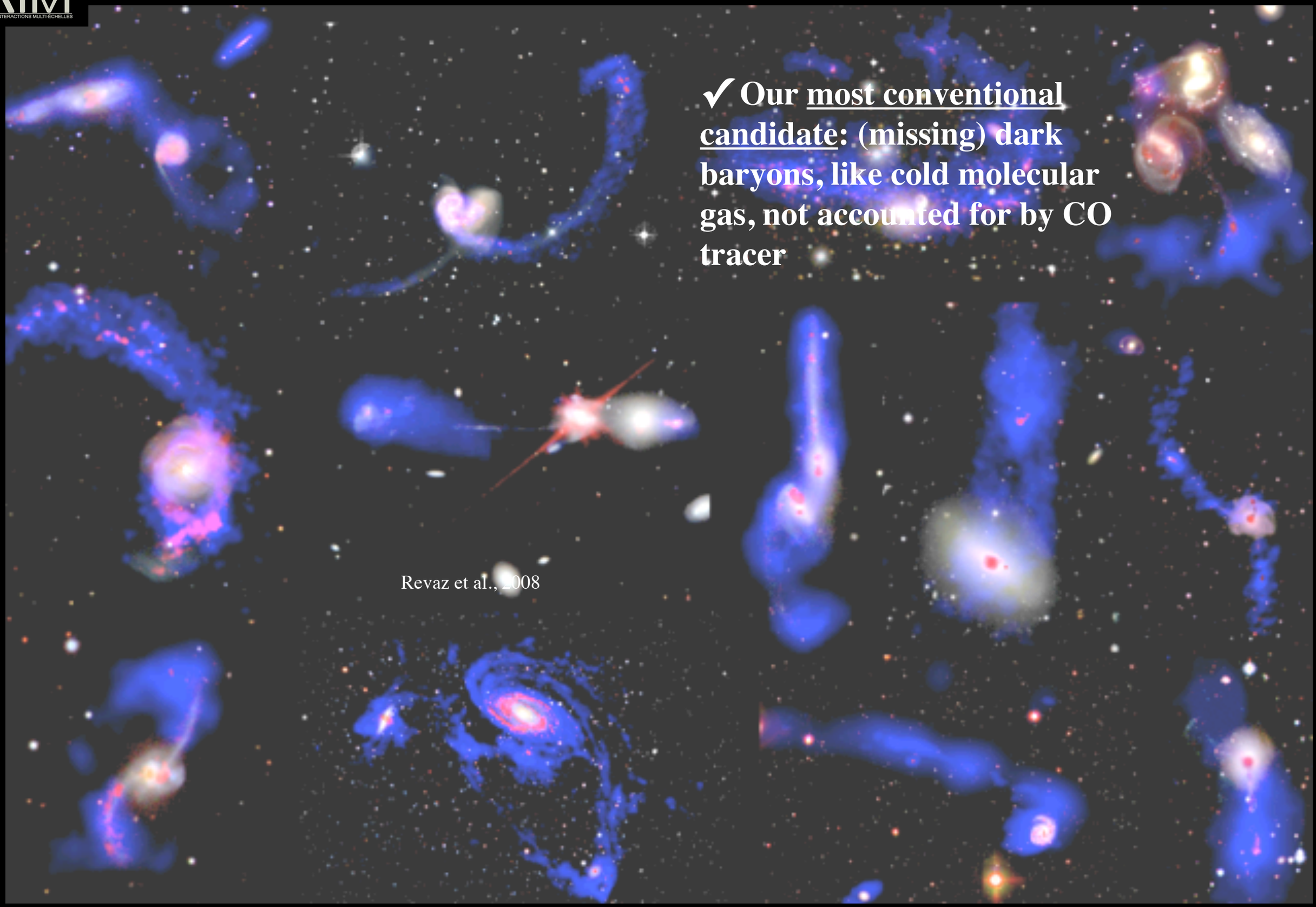
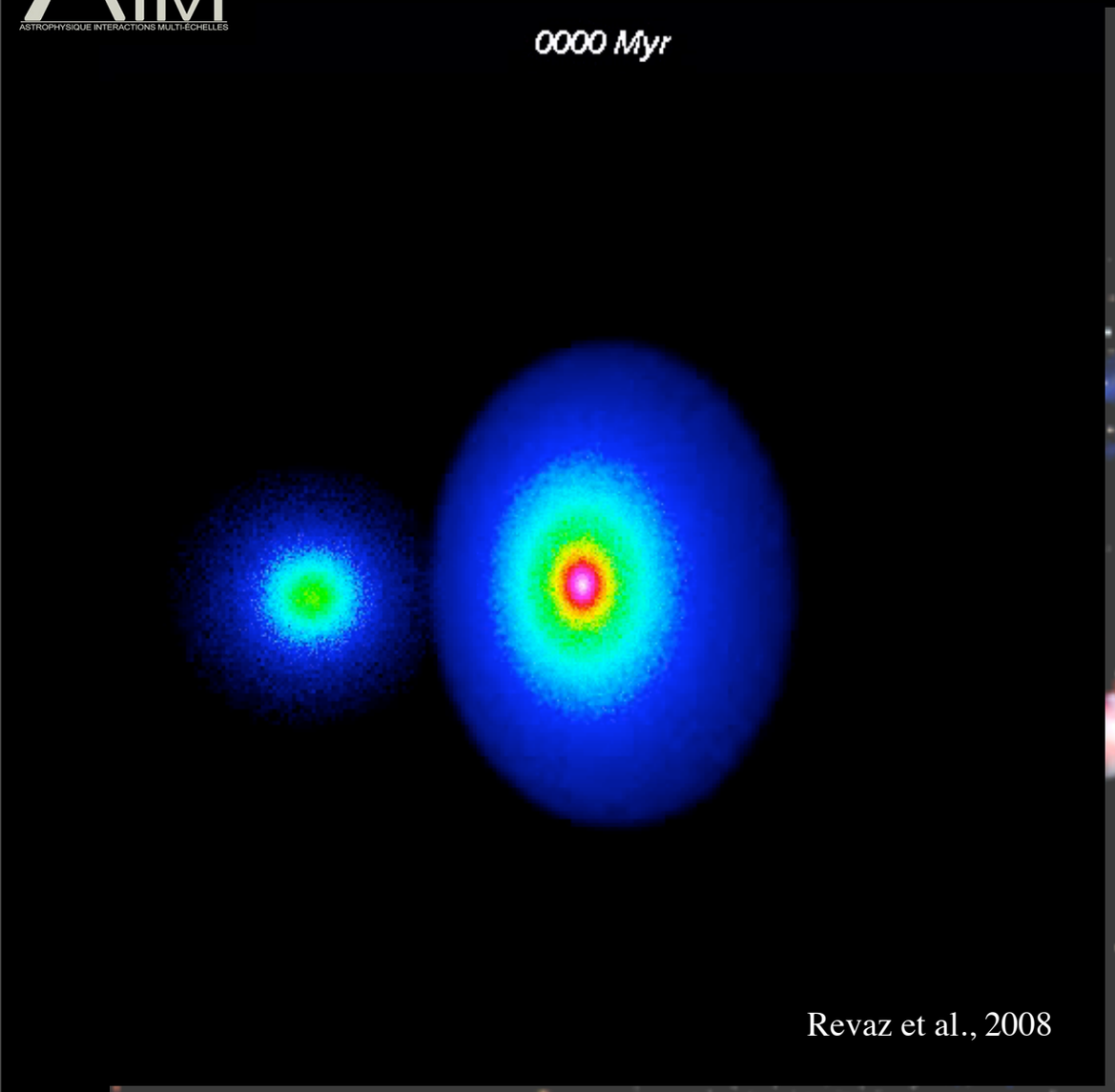


✓ Our <u>most conventional candidate</u>: (missing) dark baryons, like cold molecular gas, not accounted for by CO tracer

Revaz et al., 2008

Origin of the missing mass



Revaz et al., 2008

✓Our most conventional candidate: (missing) dark baryons, like cold molecular gas, not accounted for by CO tracer

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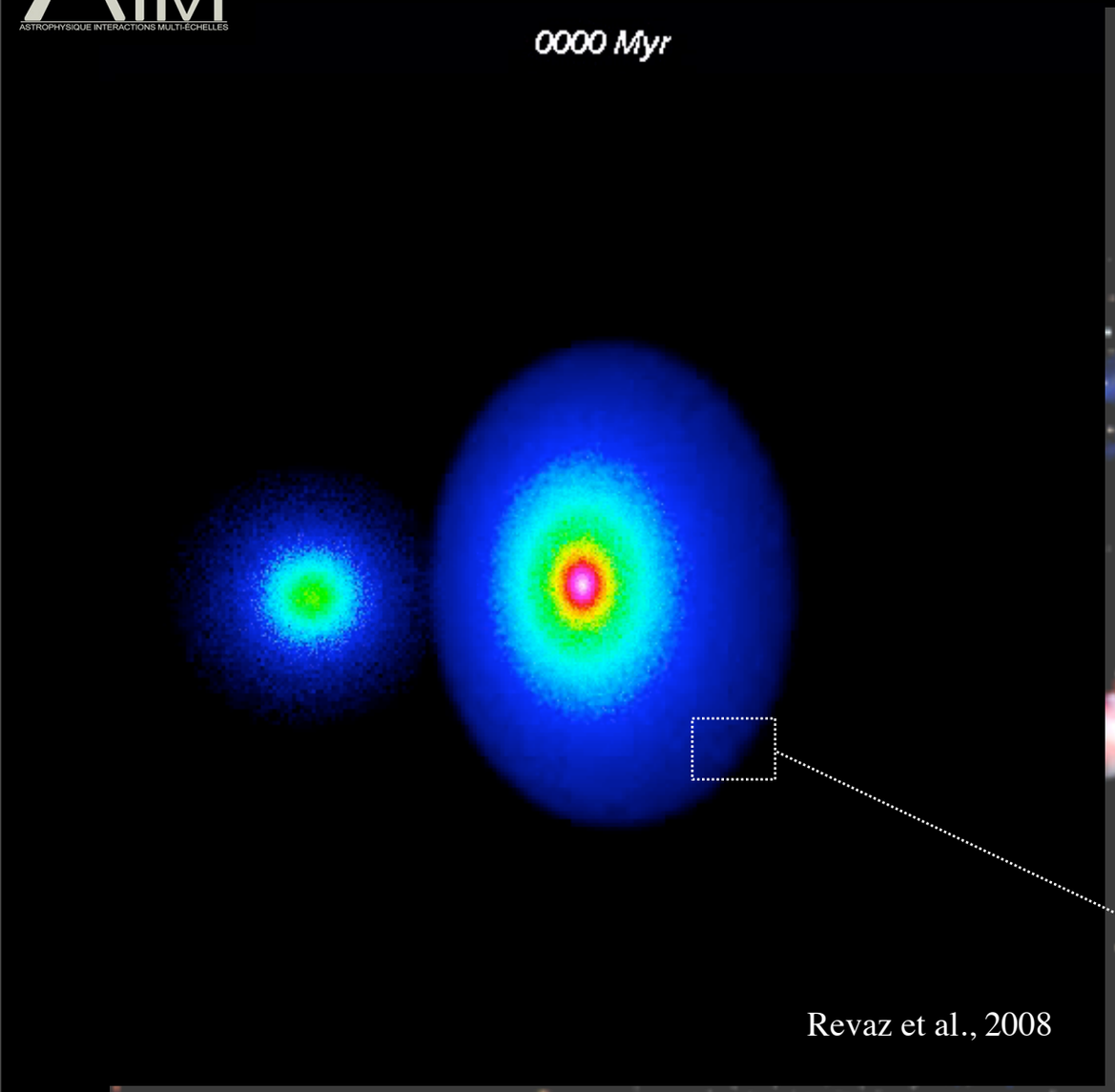

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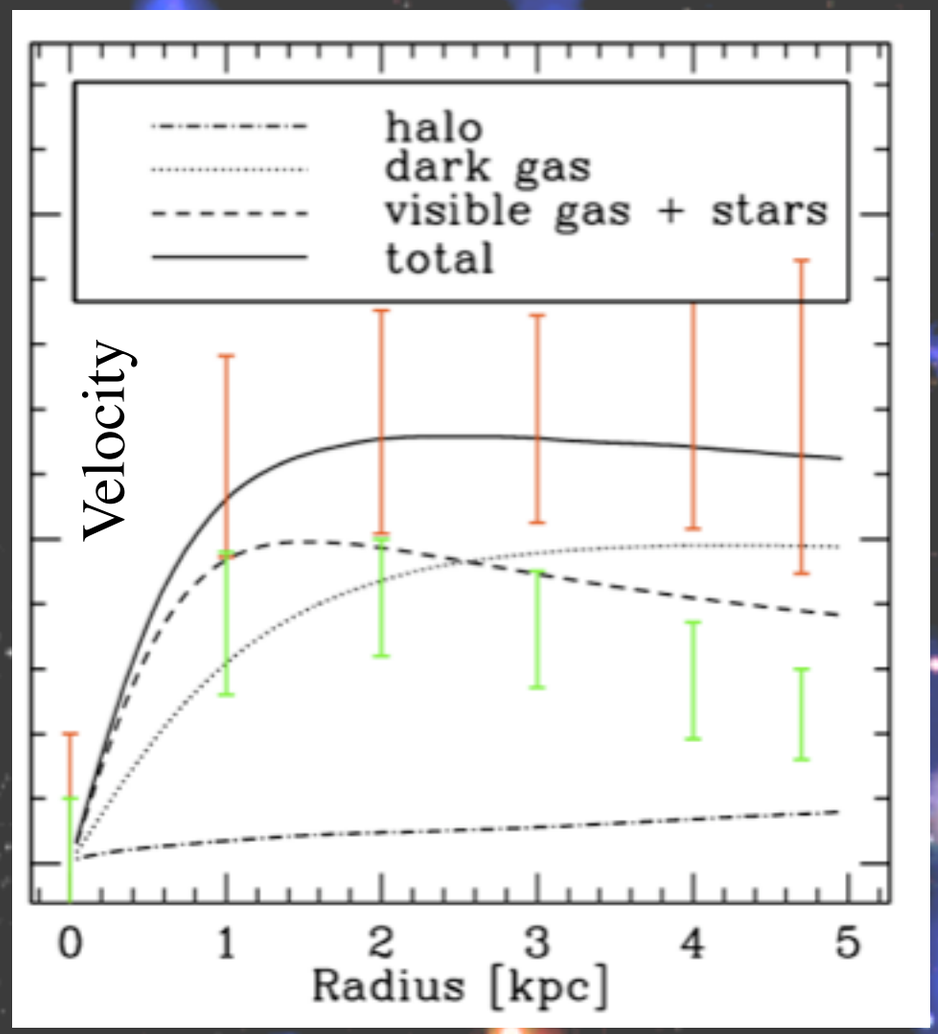


Summary

A study of star formation in an unusual environment:

Star-formation associated with kinematically decoupled components in the tidal debris (not necessary at local HI peak)

A study of structure formation:

SSCs/GCs, TDGs

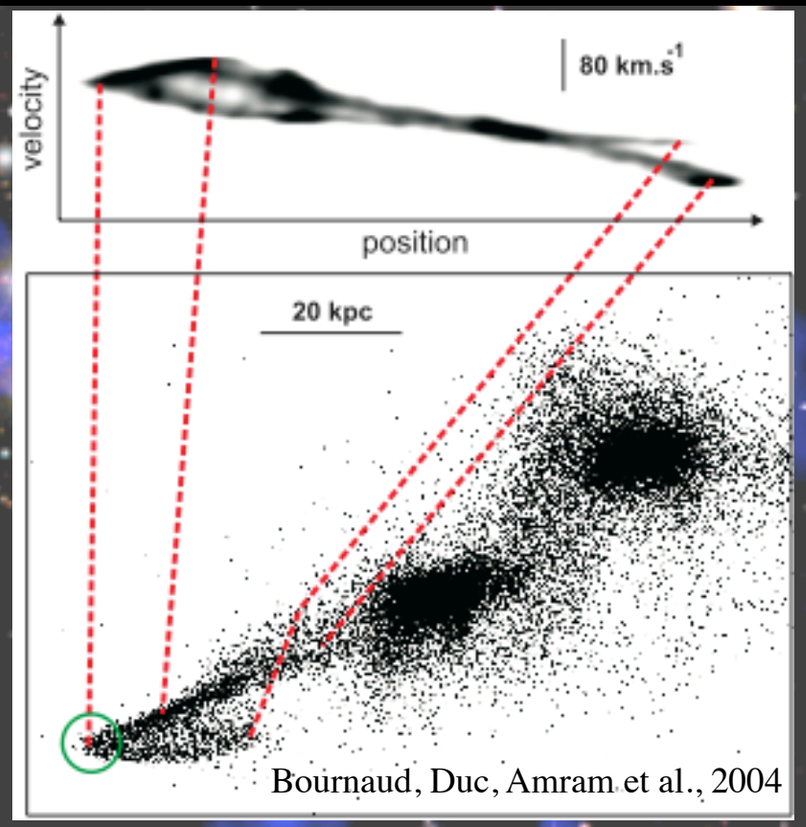
A cosmological test:

(An extended cosmological-like Dark Matter halo required to form TDGs)

The unexpected fraction of missing mass in collisional debris reveal the presence of "dark baryons" in spiral disks .... or is a challenge to CDM

Dealing with projection effects

Disentangling real rotation curves from projected streaming motions along the tails



Arp 105

NGC 2992

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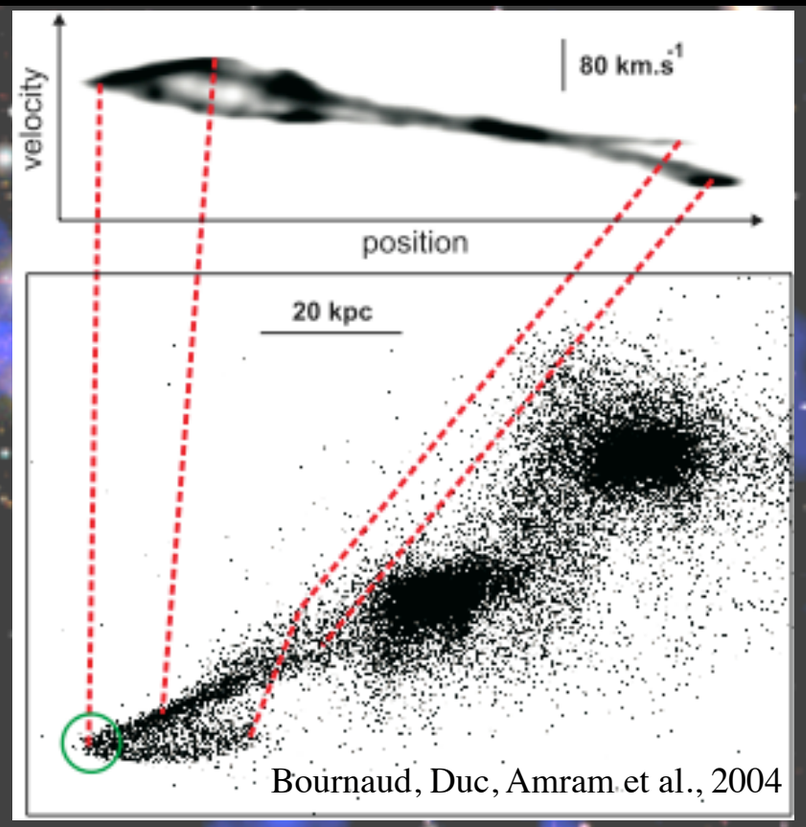

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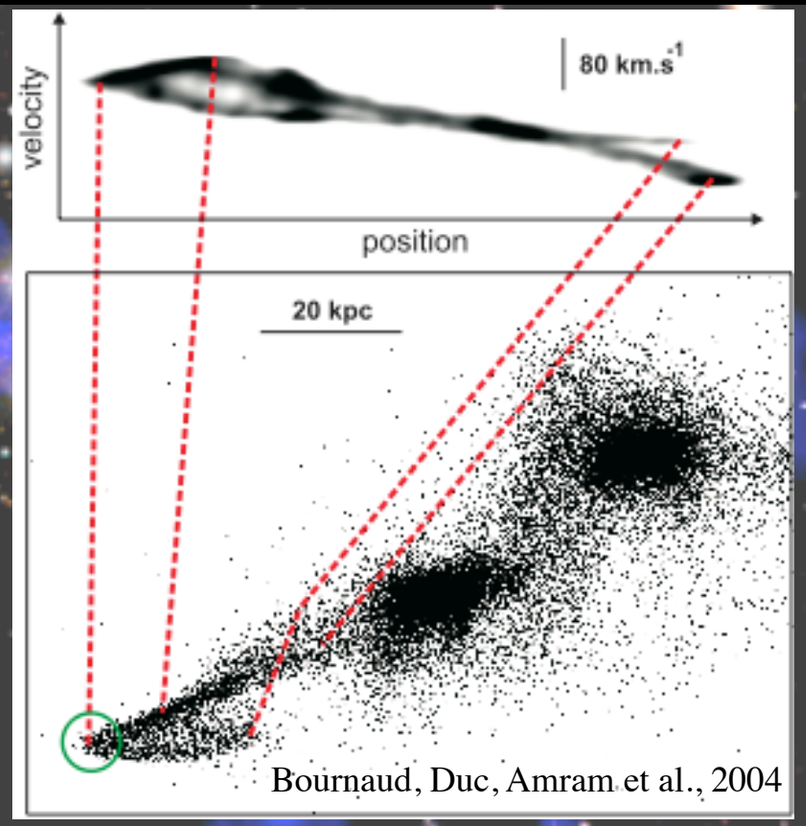
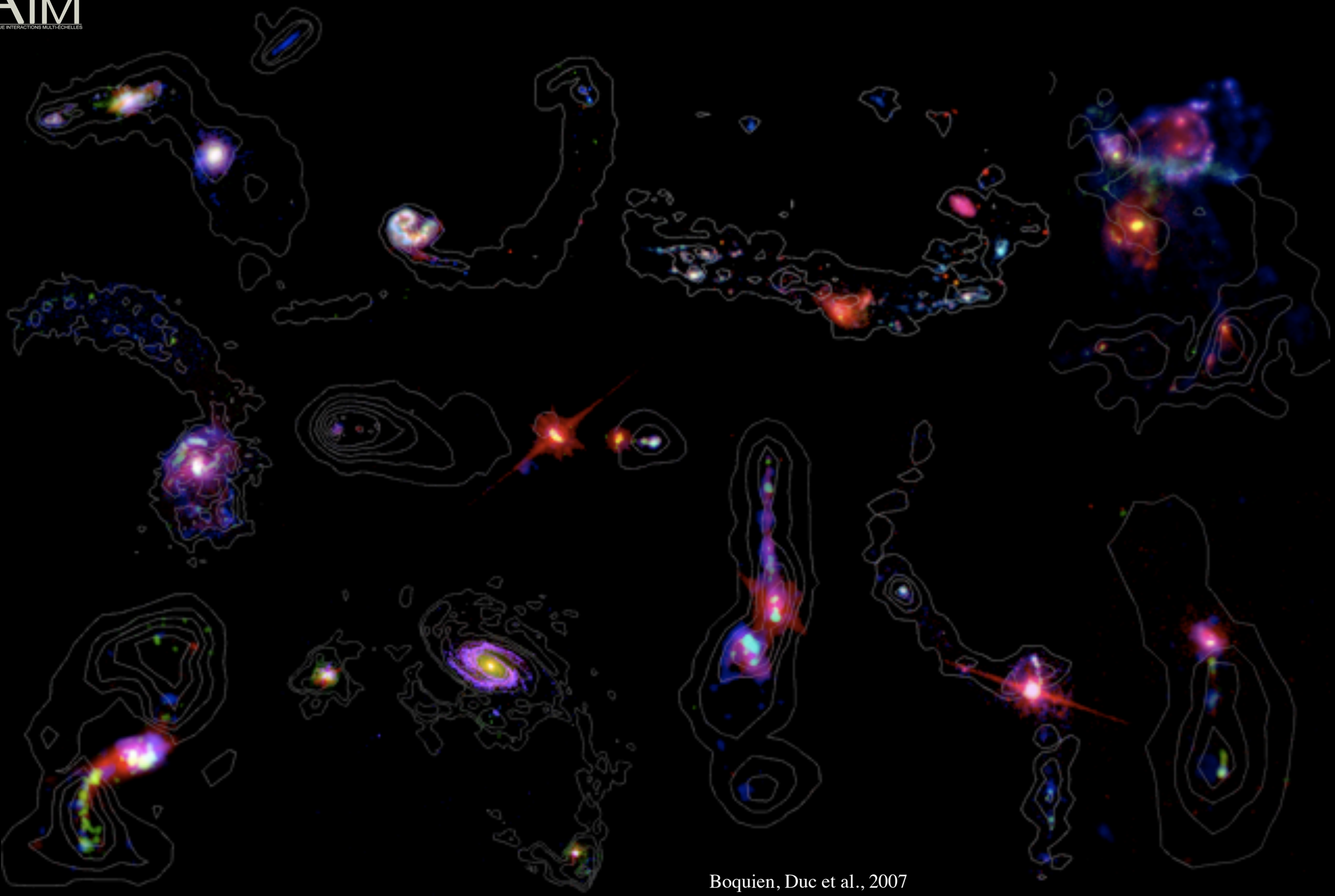


NGC 2992

Kinematics and star formation in tidal debris



Boquien, Duc et al., 2007

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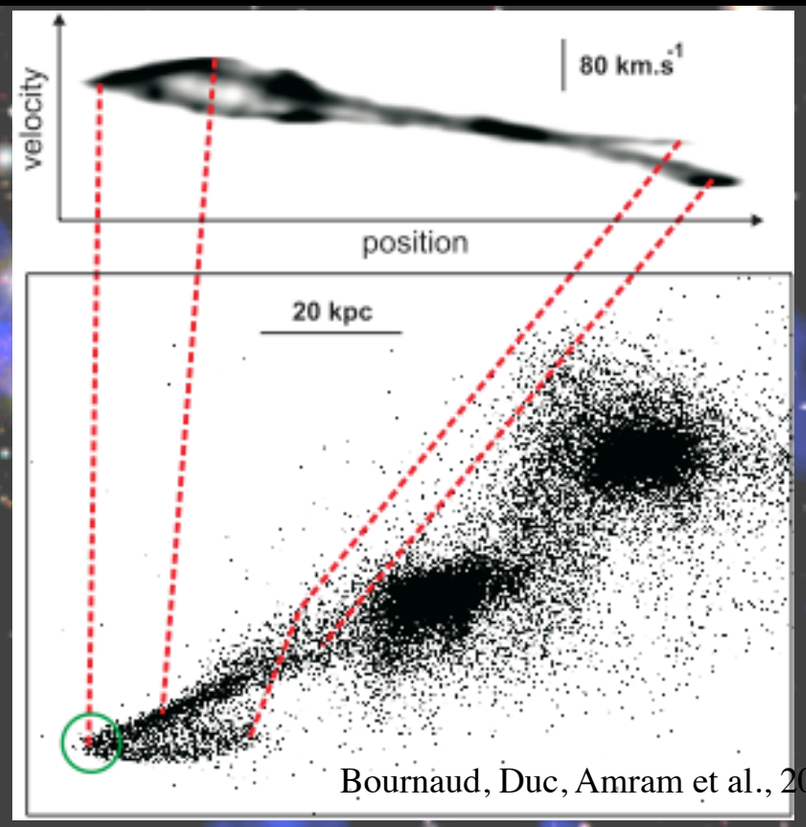

Bournaud, Duc, Amram et al., 200

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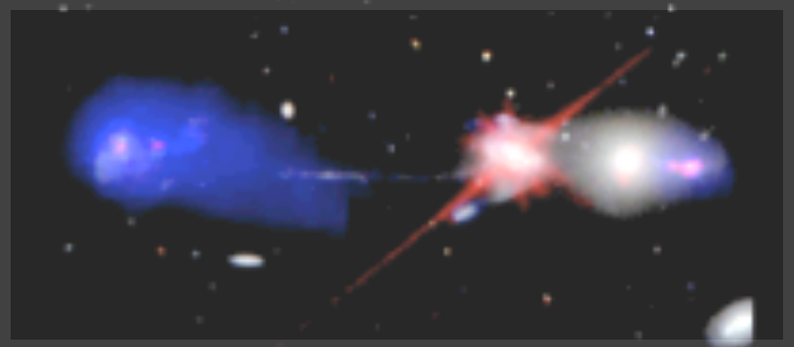

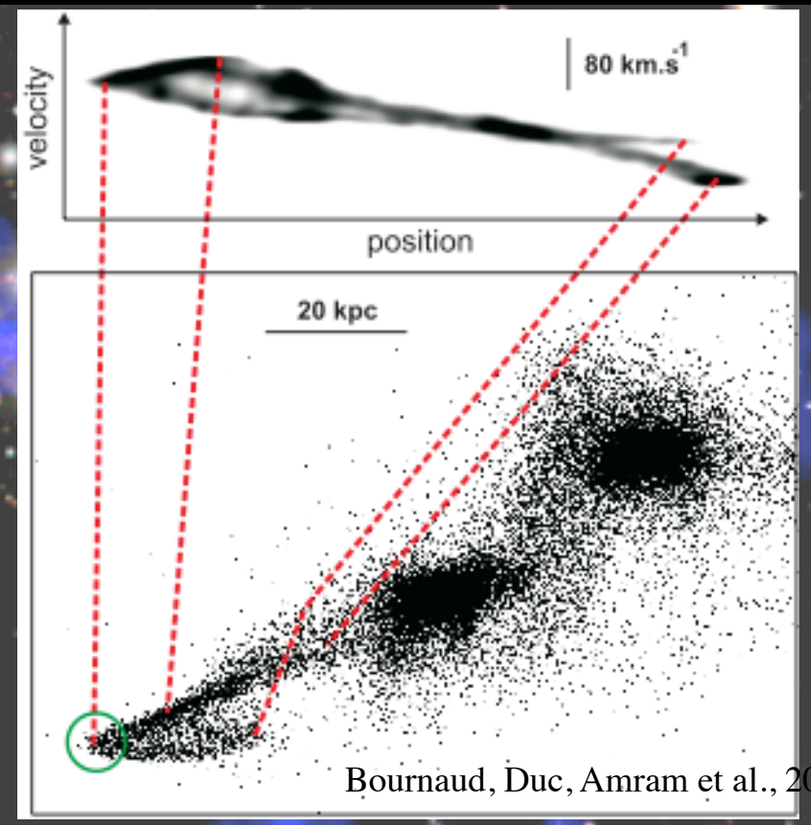

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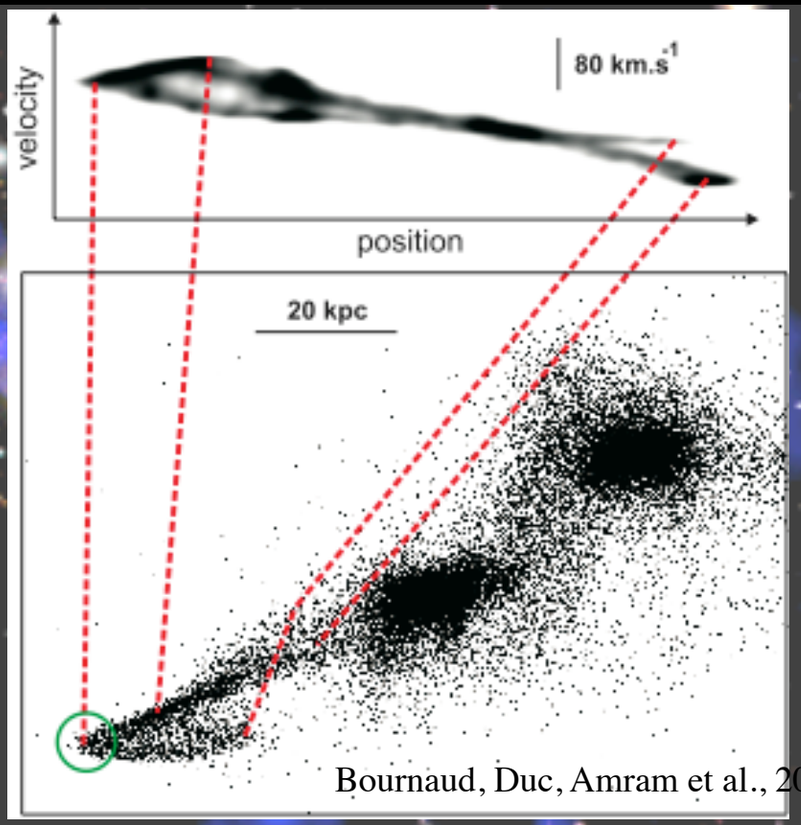

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Arp 105

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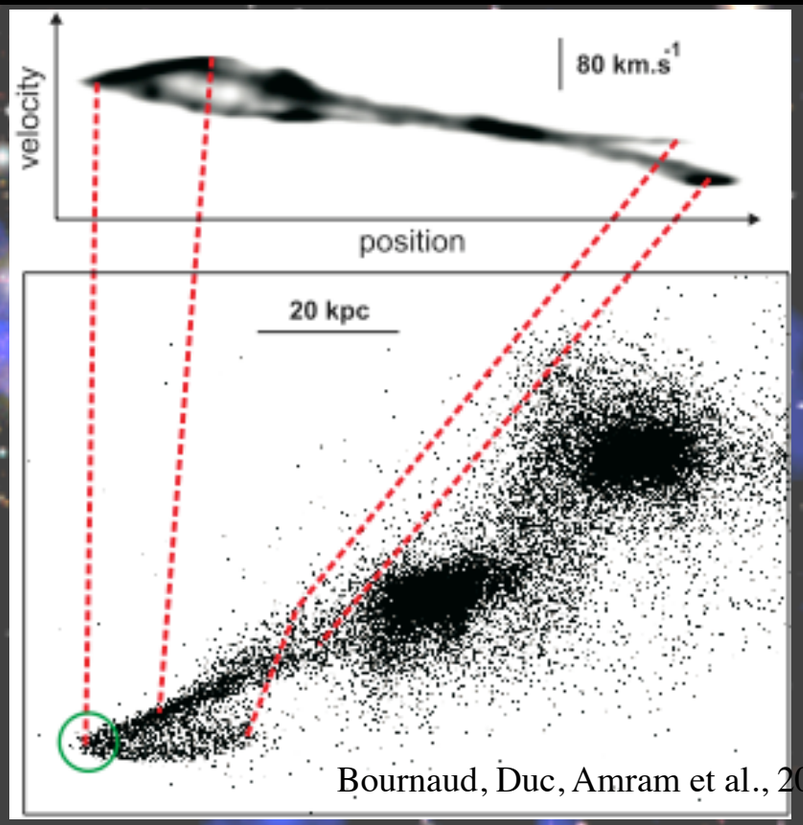
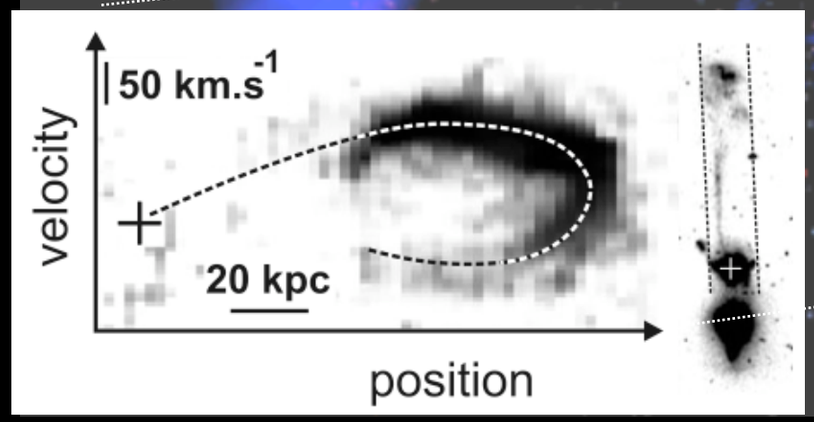


Bournaud, Duc, Amram et al., 200



Arp 105