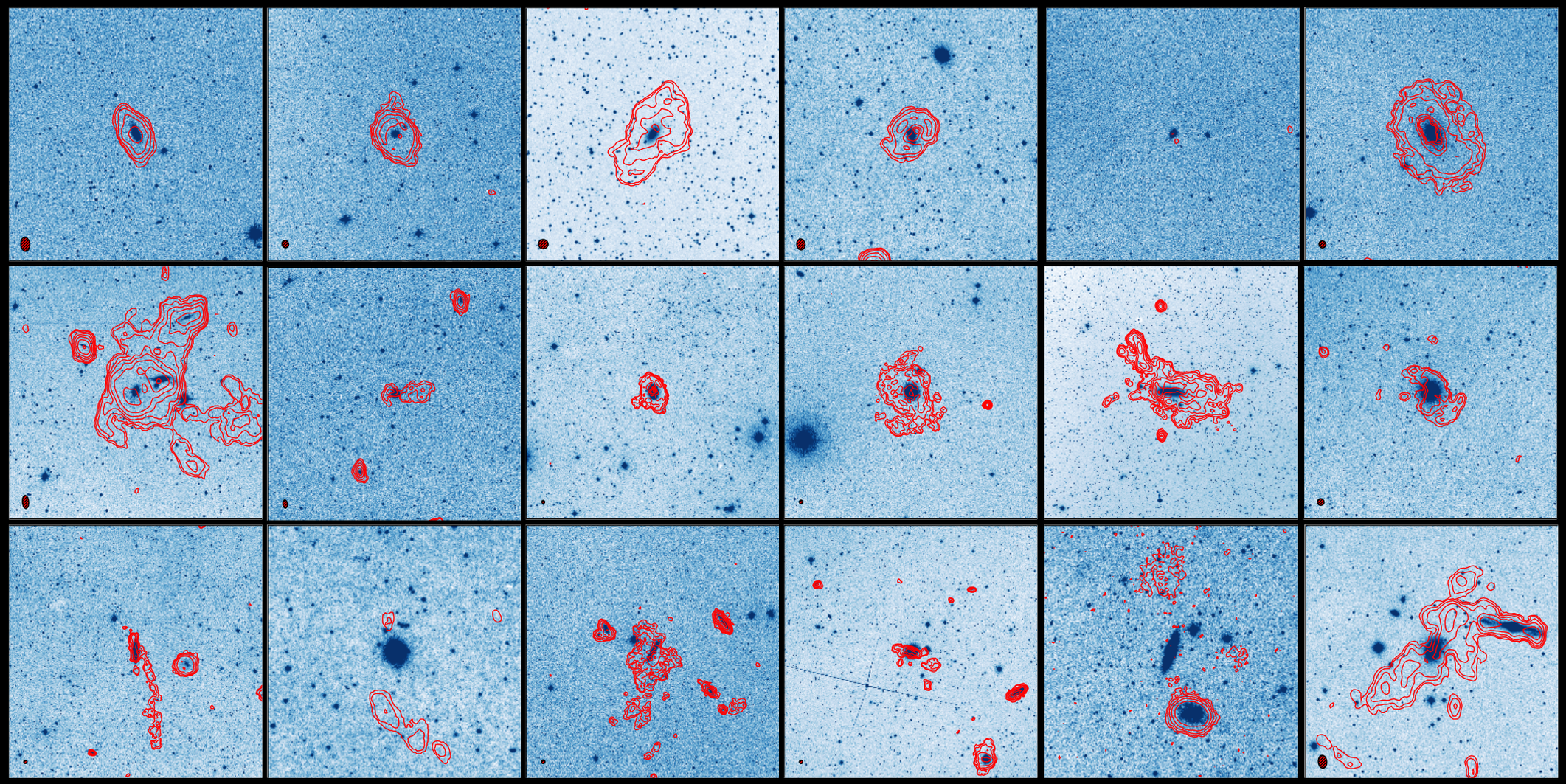
The TF relationship in Early Type Galaxies: results from ATLAS3D



Tom Oosterloo

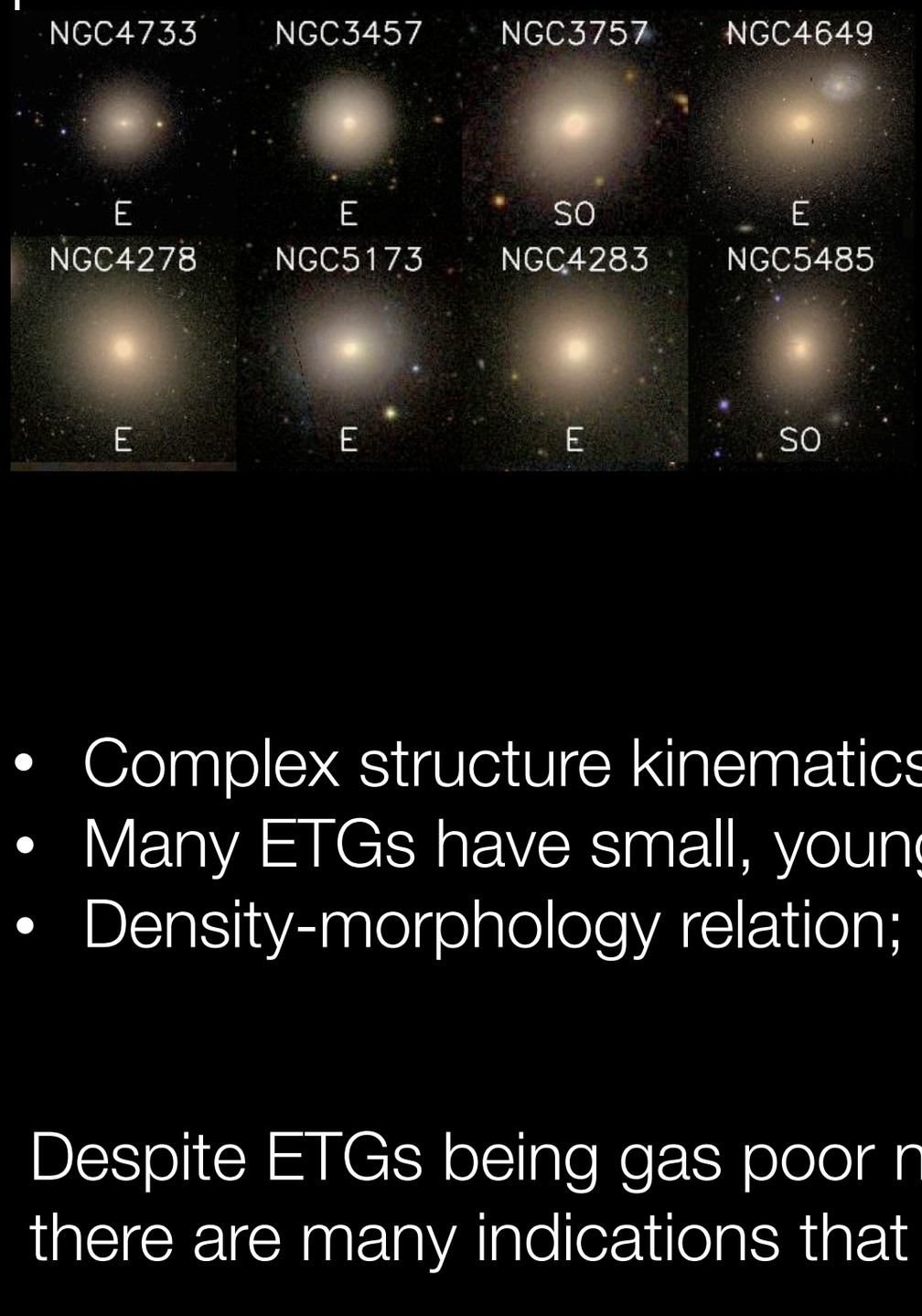
ASTRON & Kapteyn Institute

Raffaella Morganti
Paolo Serra
Milan den Heijer
ATLAS^{3D} collaboration

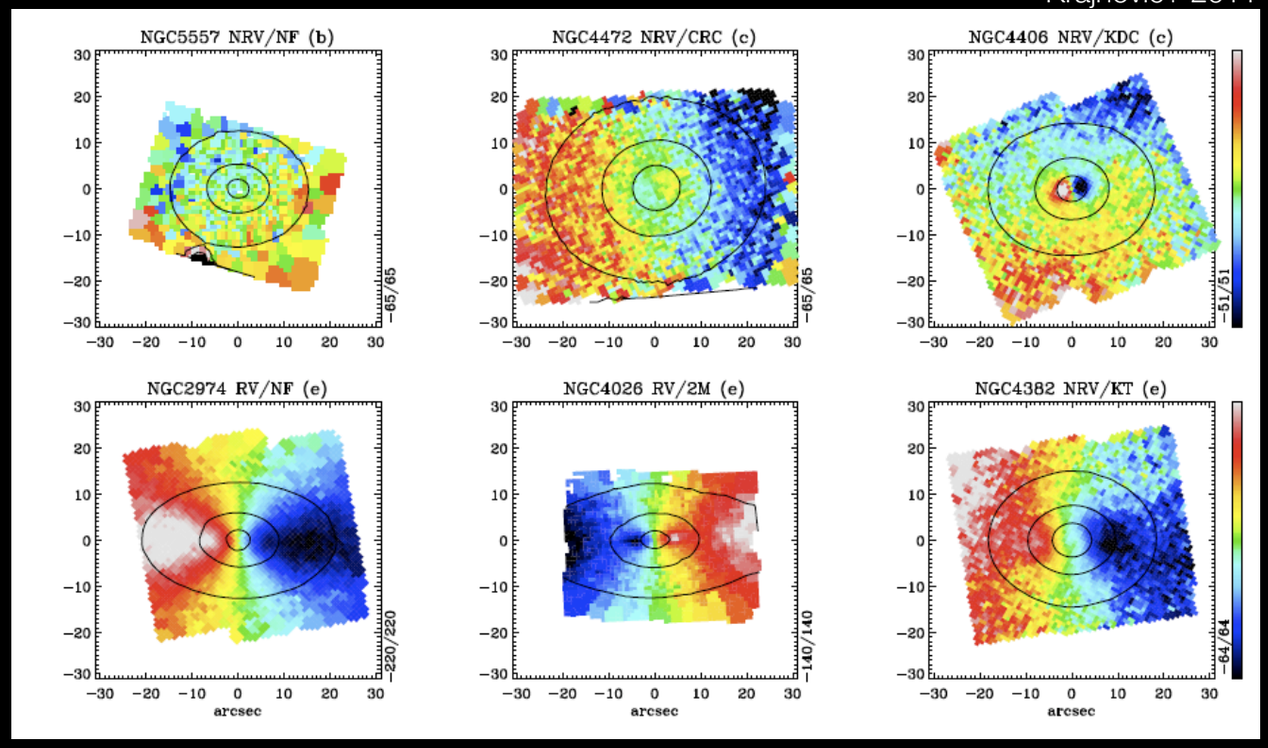
Is there hope for a TFR for early-type galaxies?

ASTRON

Early-type galaxies are not the boring gas-poor blobs they appear to



Krajnovic+ 2011



- Complex structure kinematics suggests complex evolution, involving gas.
- Many ETGs have small, young(ish) population of stars
- Density-morphology relation; Gas content ⇄ environment

Despite ETGs being gas poor now,
there are many indications that gas played a role in their evolution

Observations

- Different, complementary ways of tackling this problem:
  - single-dish datasets (Knapp, ALFALFA,…)
    - many galaxies, only global information, good for statistics
  - HI imaging (van Gorkom, Schiminovich, …)
    - fewer galaxies, detailed information on structure and kinematics

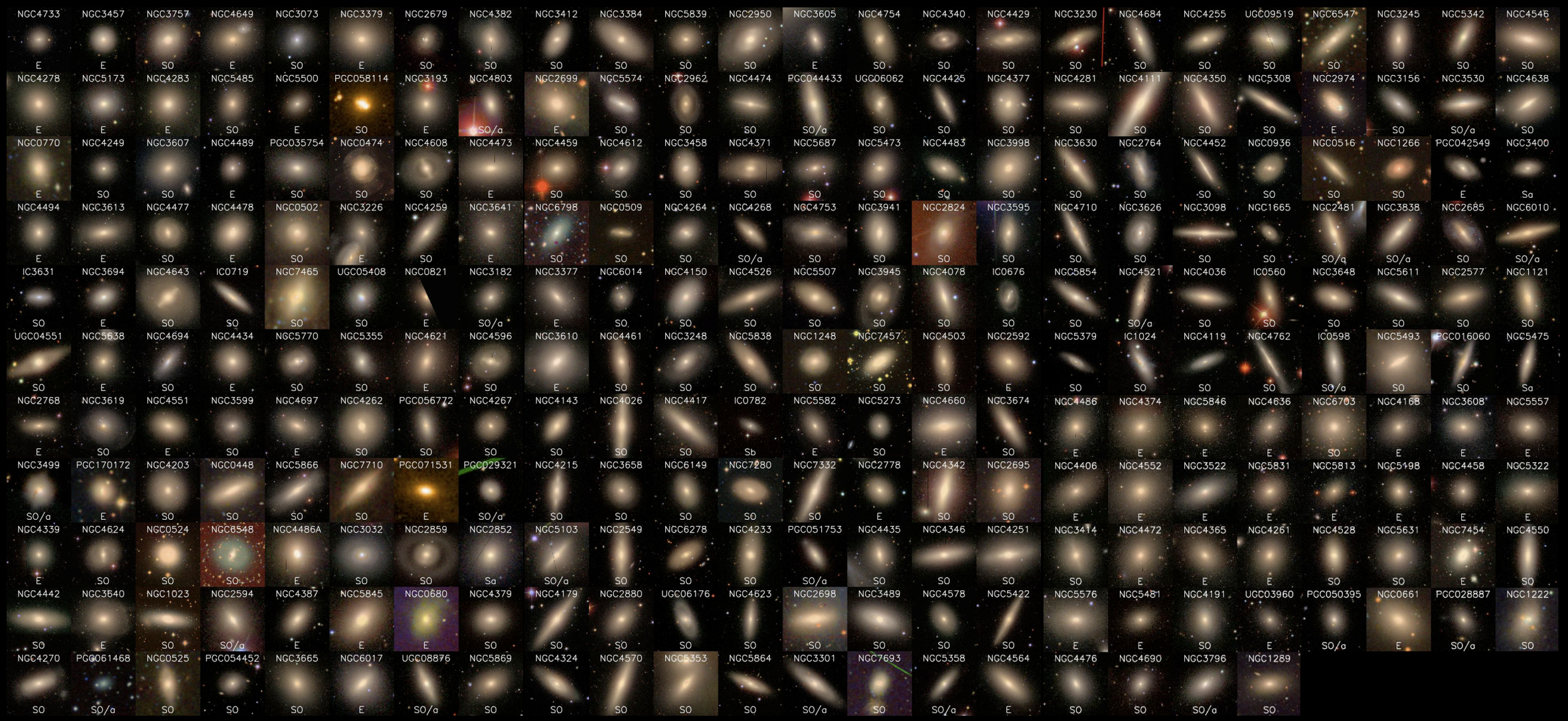
    - HIPASS sample - 54 galaxies, ATCA, limited sensitivity ($10^{8\text{-}9}$ $M_\odot$)
      detection rate 5-10%. Oosterloo+ 2007
    - SAURON - 33 galaxies, WSRT, better sensitivity ($10^{6\text{-}7}$ $M_\odot$).
      detection rate in field 60%. Morganti+ 2006; Oosterloo+ 2010
      lots of complementary data
    - ATLAS3D - Superset of SAURON sample, more distant
      166 galaxies, WSRT, ($10^{6\text{-}7}$ $M_\odot$). Serra+ 2011
      detection rate in field 45%. Deep follow up on subset (*t* x 10)

    - ASKAP, Apertif, MeerKat, EVLA - 100,000+ galaxies, z > 0 2014+

Atlas^{3D} sample: Ellipticals and Lenticulars

- Atlas^{3D} sample: volume limited sample: 260 galaxies < 42 Mpc brighter that M_K -21.5. Main selection criterion: no spiral arms or dust lanes, so includes ellipticals *and* lenticulars. No colour selection.
- Large collaboration; optical (2D spec, imaging), CO, HI, UV, Xray, theory, simulations… PIs: Cappellari, Emsellem, Krajnovic, McDermid.

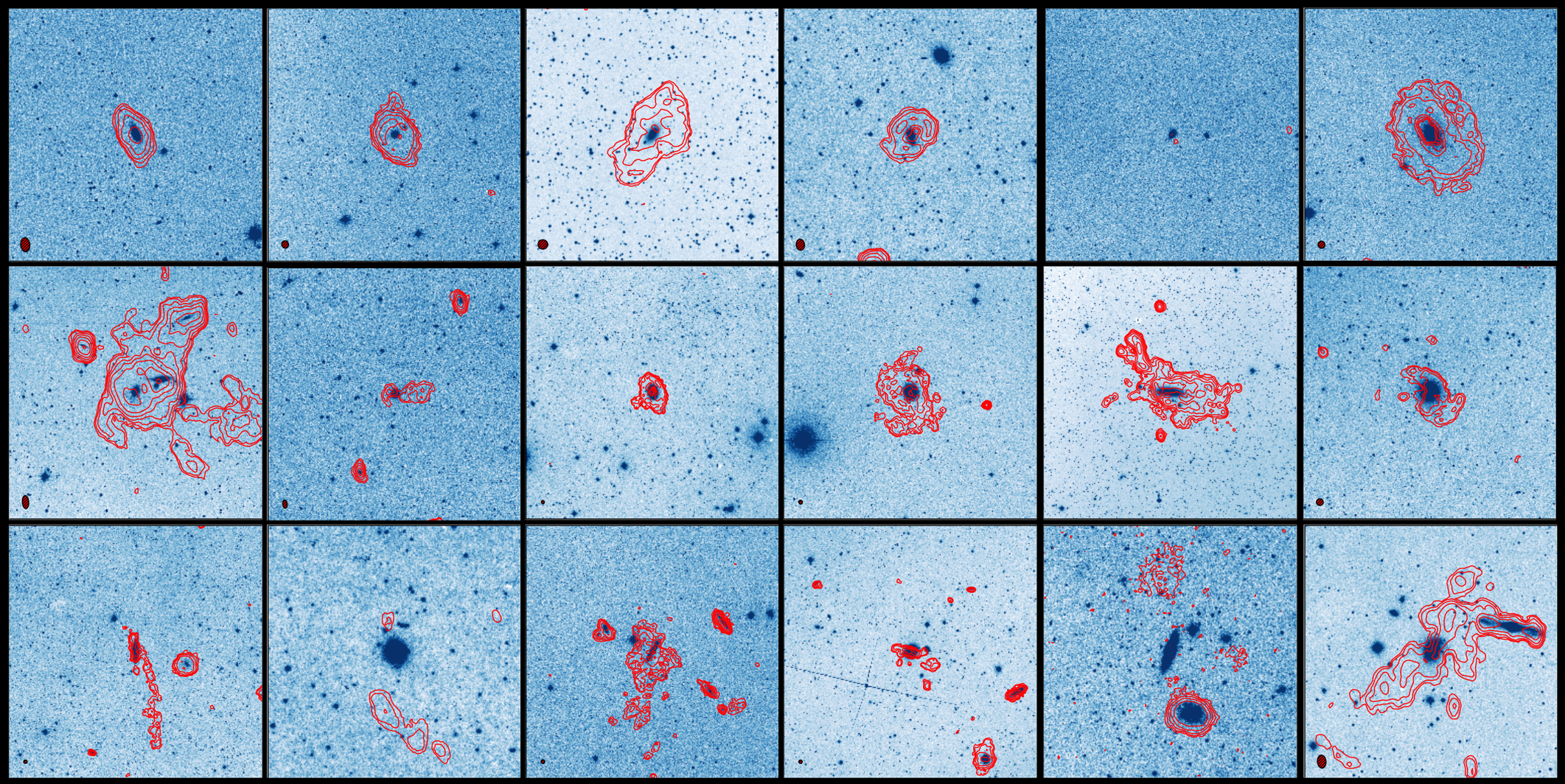
(arXiv:1012.1551, 1102.3801 1102.4444, 1102.4633, 1102.4877, 1104.2326, 1104.3545,1105.5654, 1105.4076,...)



HI observations of Atlas^{3D} sample

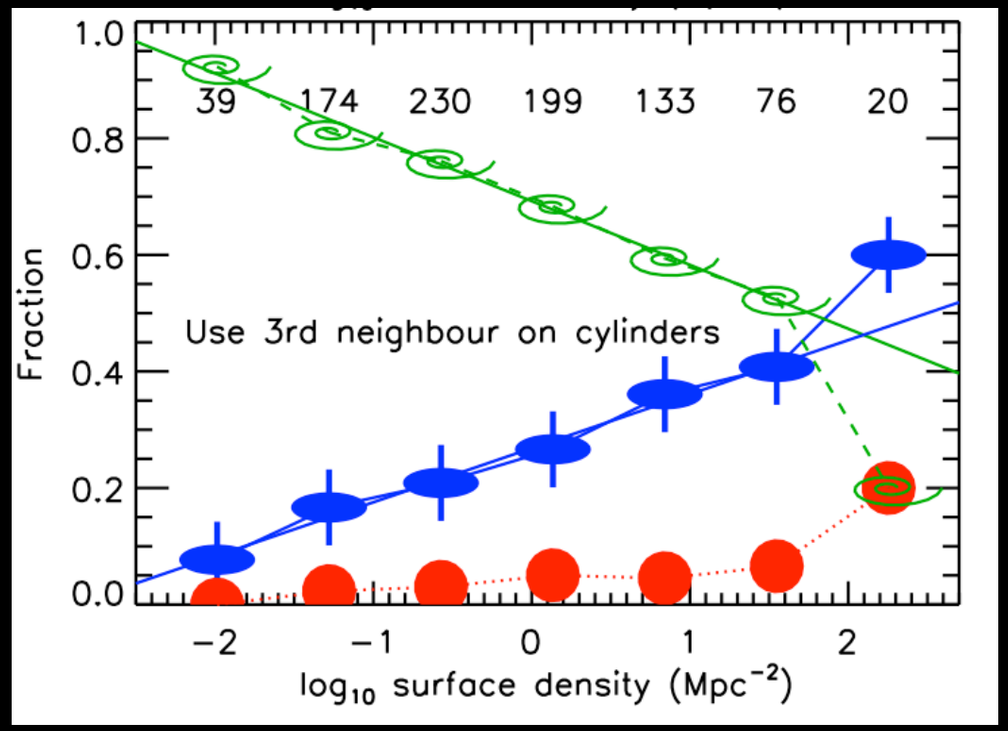
ASTRON

- WSRT observations of those Atlas^{3D} galaxies with δ>20˚ Serra+ arXiv 1111.4241
  - 12 h per galaxy. Detection limit 10^6-10^7 $M_\odot$, $n_{HI,lim}$ 3-5 x 10^{19} cm^{-2}
    deep follow up on subset (10x12h)
  - Detection rate 45% in field, 5% in Virgo. HI is of low column density
  - Large range: many disks/rings, strong warps, polar, tails, clouds.
  - Many signs of ongoing accretion but of small amounts. Interaction, stripping
  - Some correlation between HI kinematics and galaxy type (E vs S0)

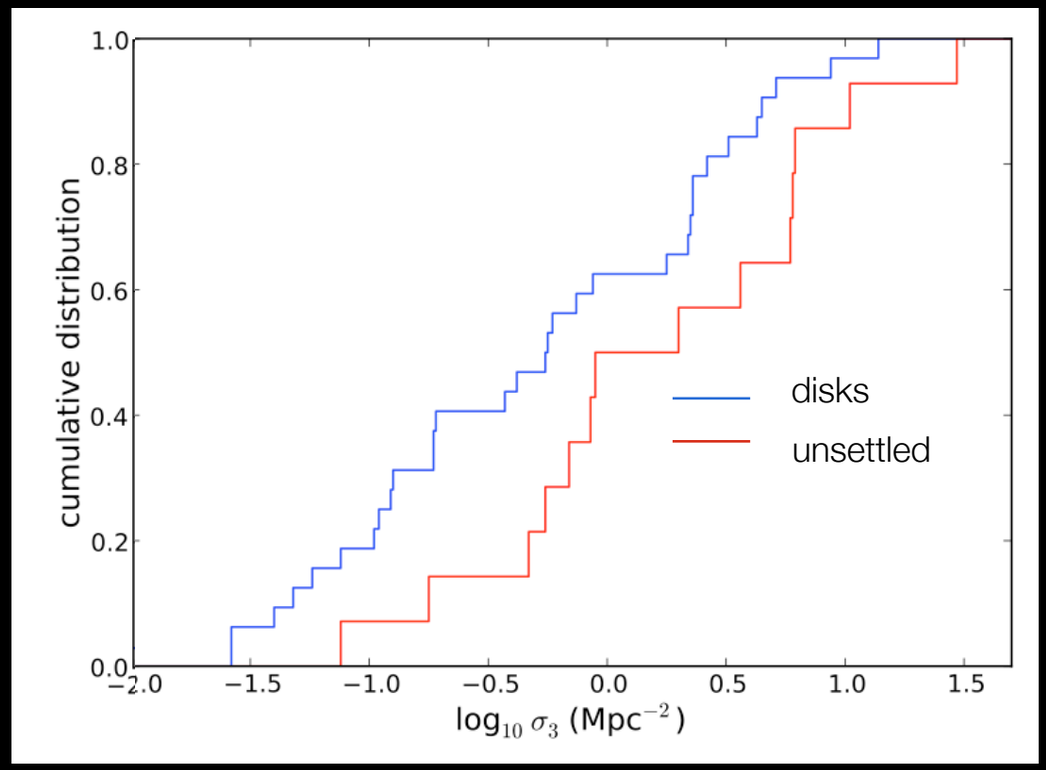


HI morphology depends on small-scale environment

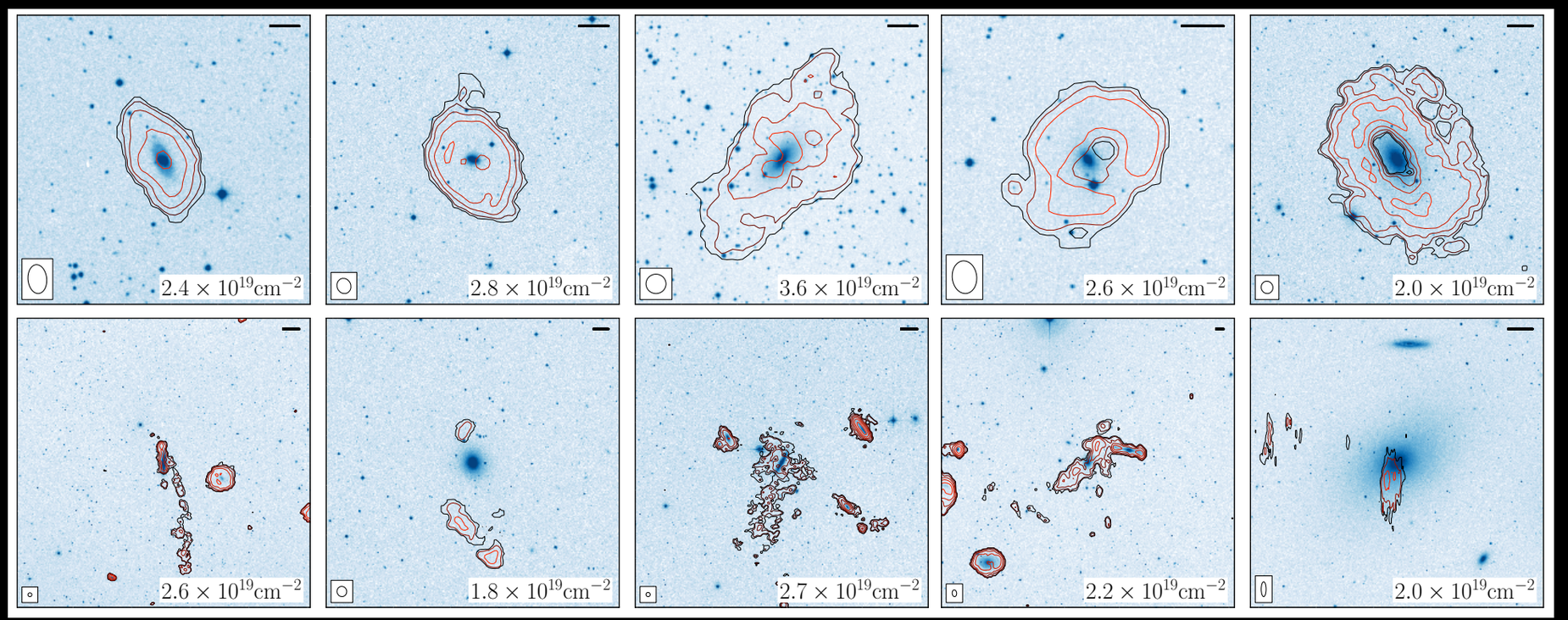
- Related to density-morphology relation?



Cappellari et al. paper 7. arXiv: 1104.3545



σ_3 is measure for galaxy density on scales of 1 Mpc



low density

high density but field

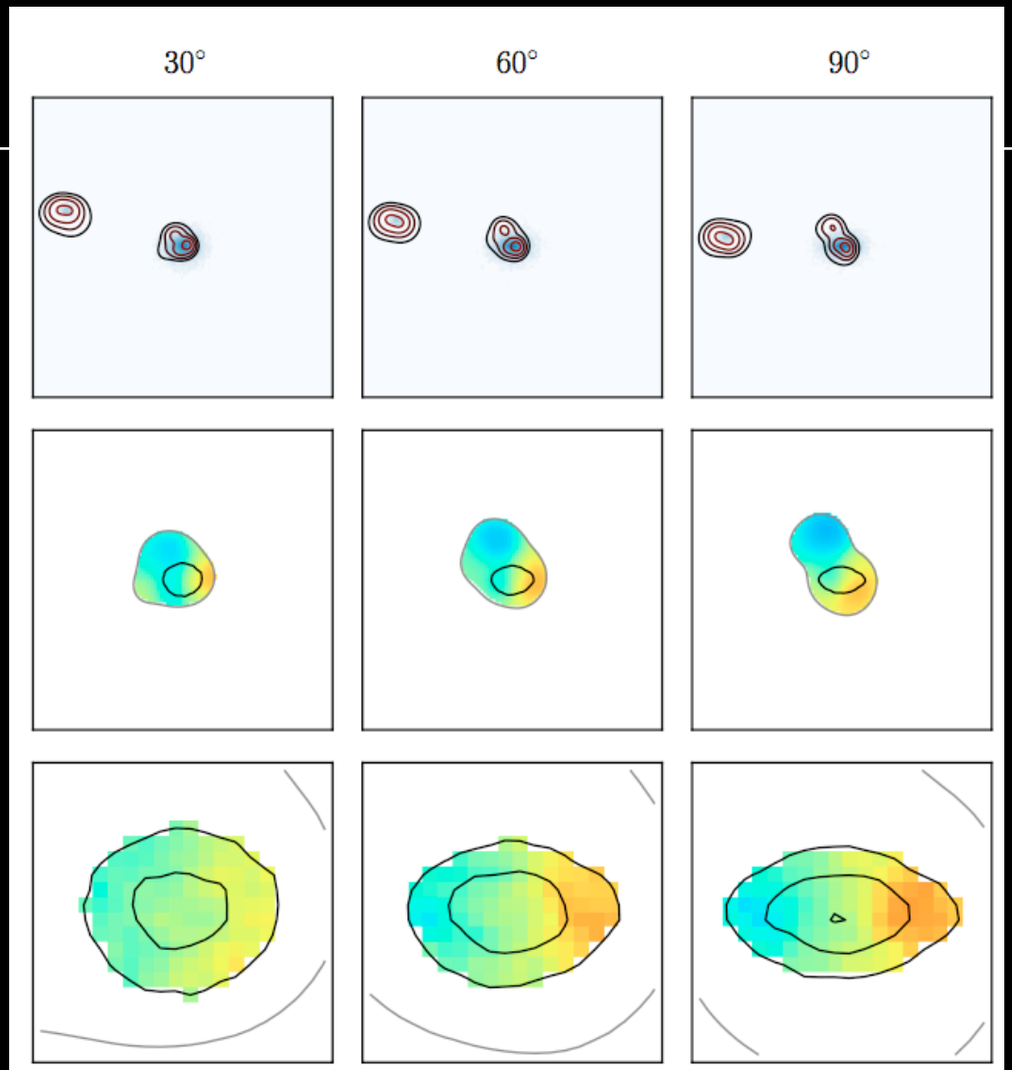
Next step: compare with simulations

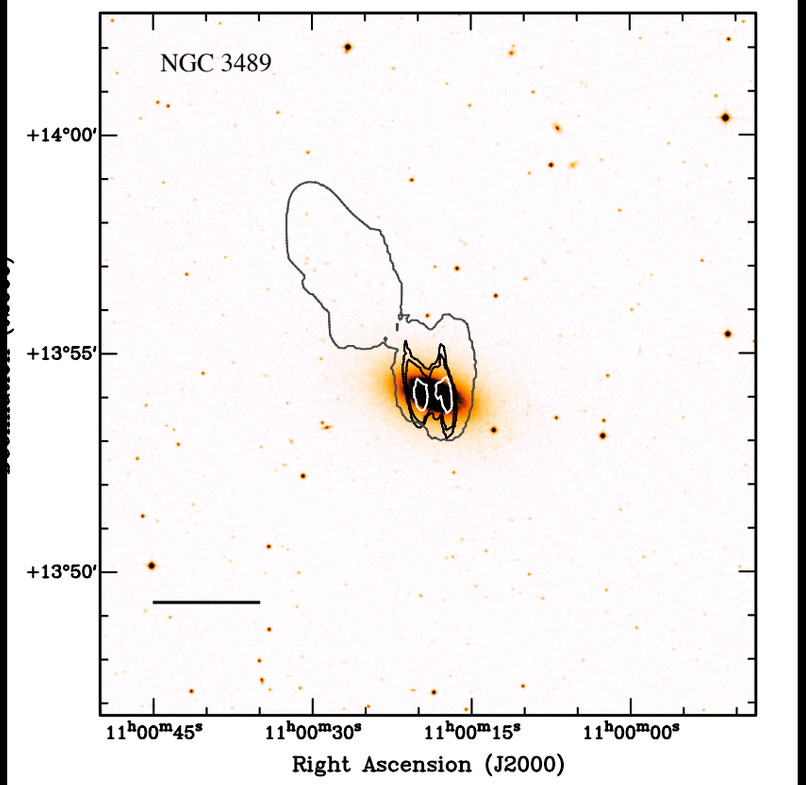
Atlas^{3D} group performing cosmological simulations (Naab+)

See same diversity of HI characteristics in (some) simulations

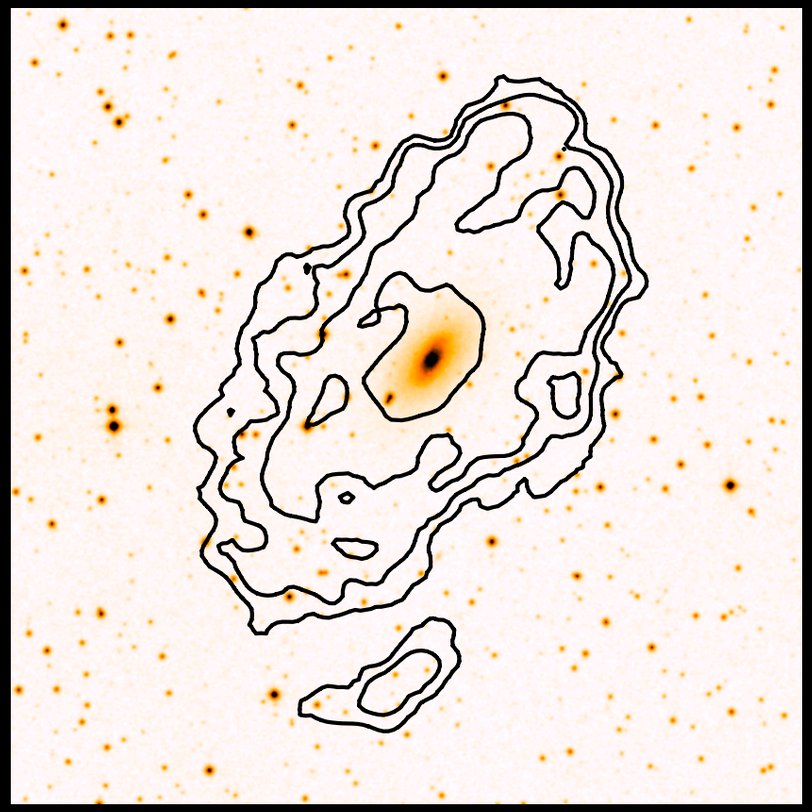
Tracing back the formation of these structures in the simulations will allow us to associate observed HI properties with formation history

example: small inner disks form from accretion of small companion

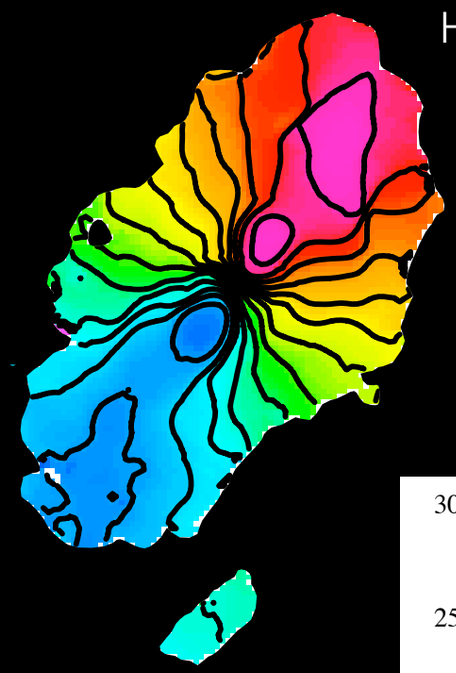




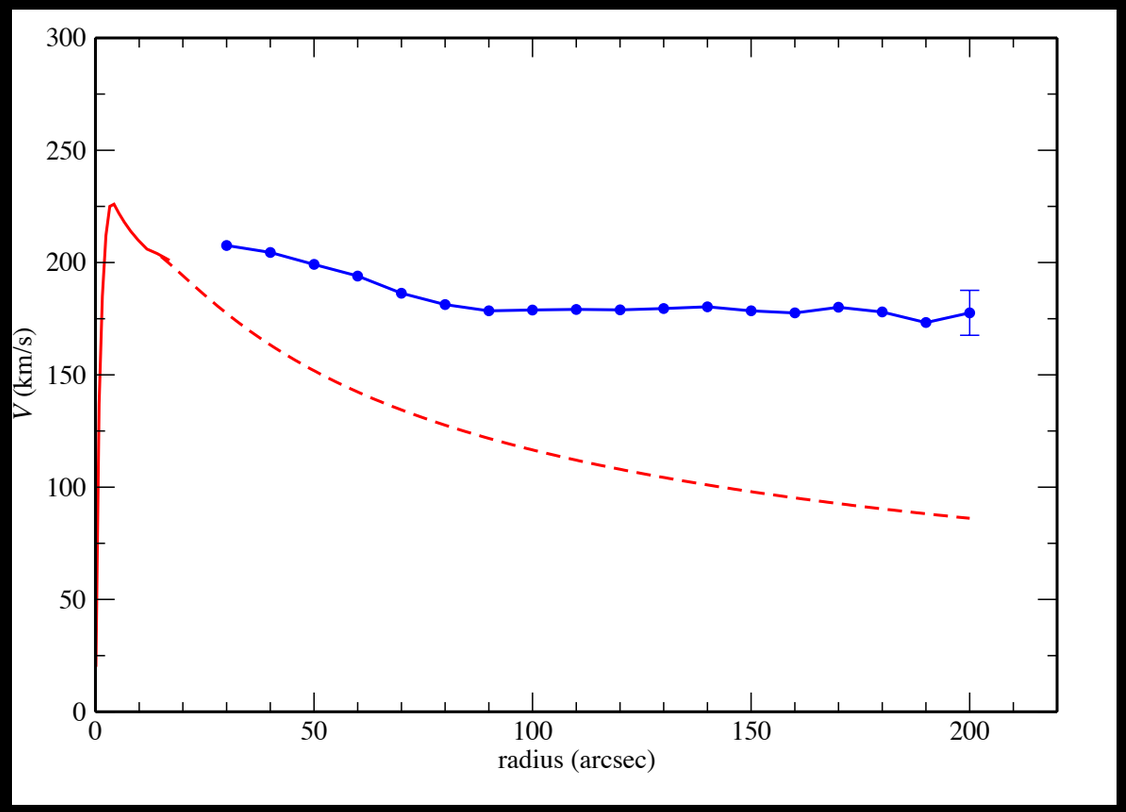
Many large, regular disks



NGC 6798



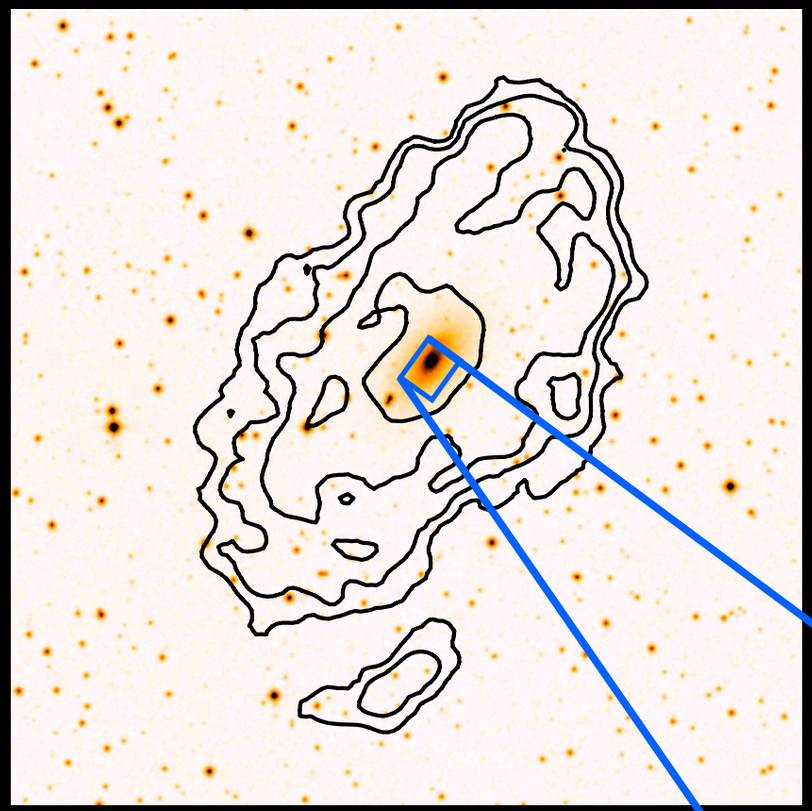
HI velocity field



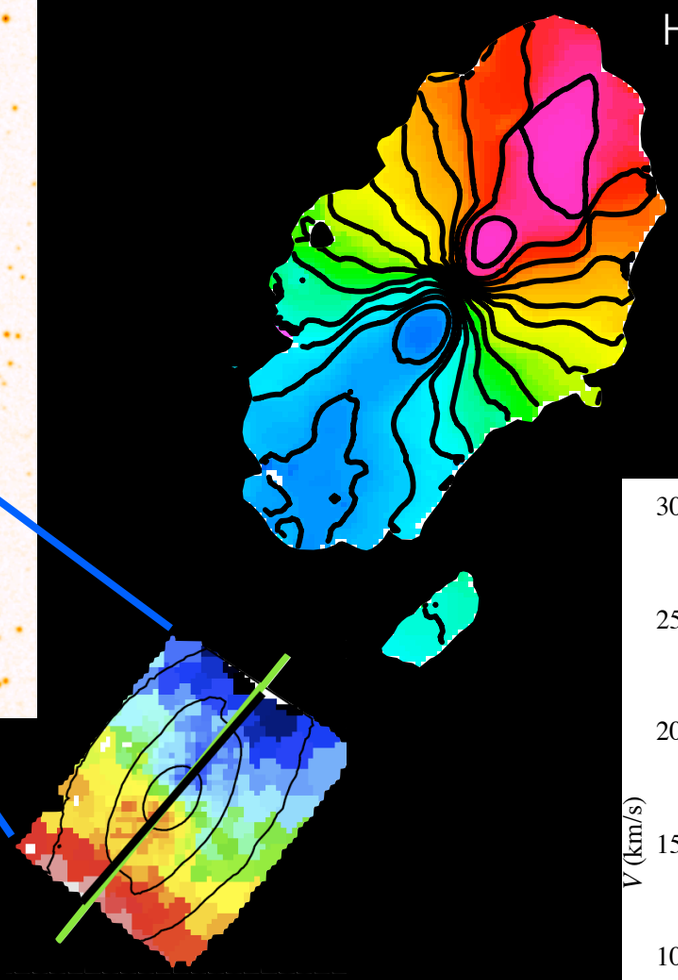
Regular disk, 90 kpc diameter.
Low column density, ‘no’ star formation.
Large, old HI reservoir with no star formation.

‘flat’ rotation out to 12 Reff

Large, regular disks

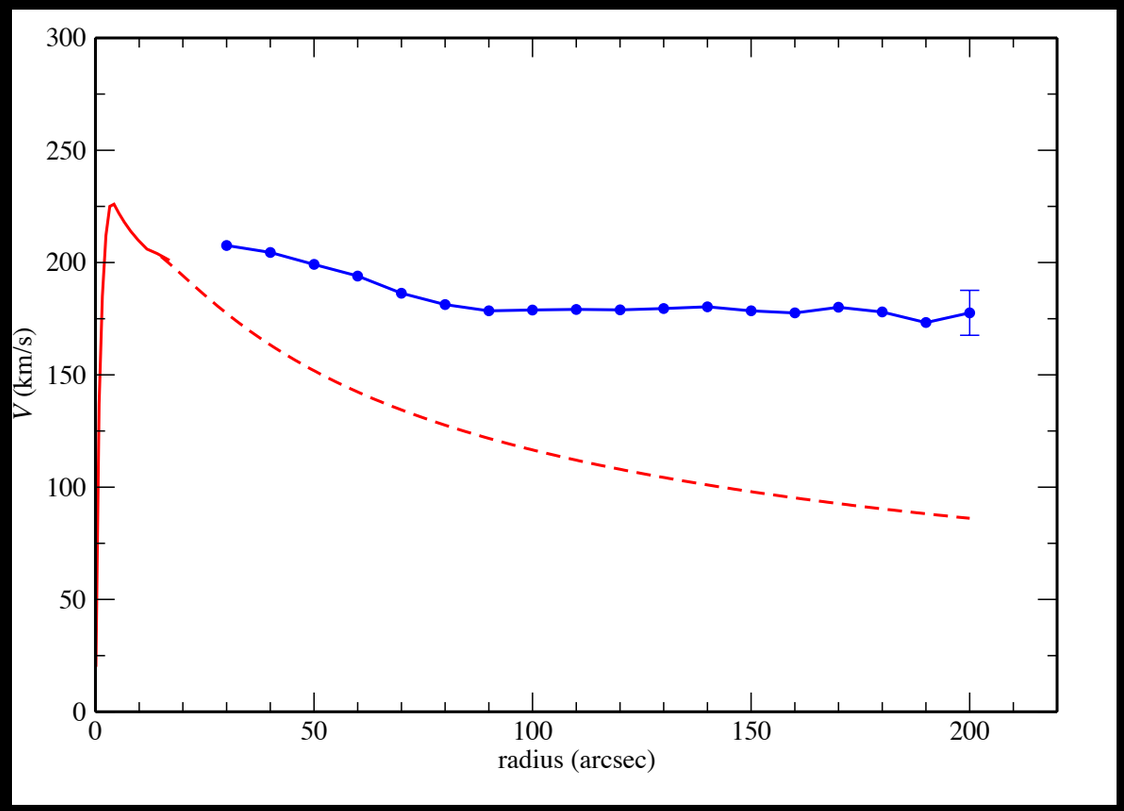


NGC 6798



HI velocity field

stellar velocity field



‘flat’ rotation out to 12 Reff

Regular disk, 90 kpc diameter.
Low column density.
Large, old HI reservoir with no star formation.
Counterrotating. Find several of such disks

CO

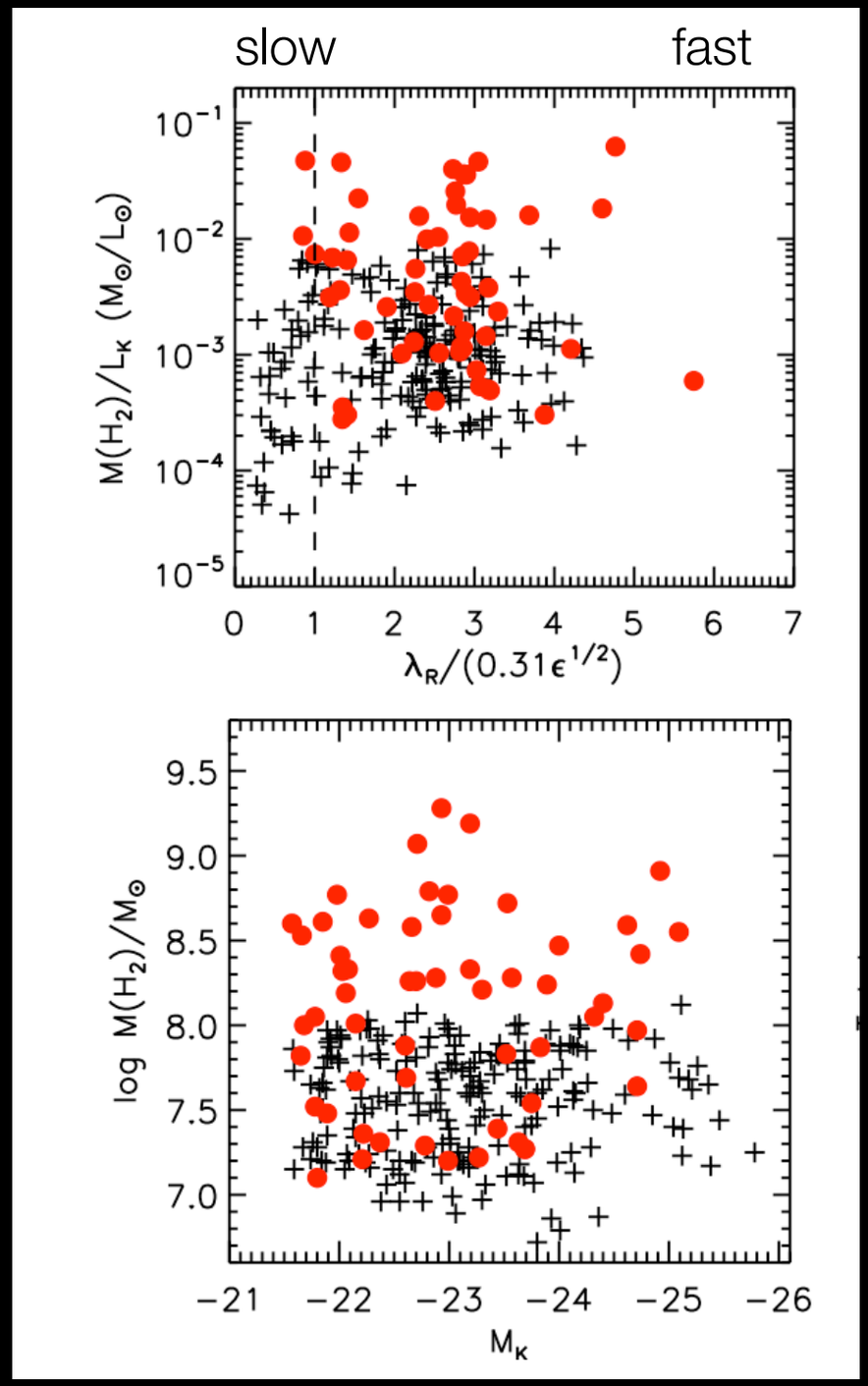
Many ETGs also have CO (Young+ 2011)

detection rate 22% for M_{lim} ~ 10^7- 10^8 $M_\odot$

CO independent of stellar mass (like HI), correlates with dynamics

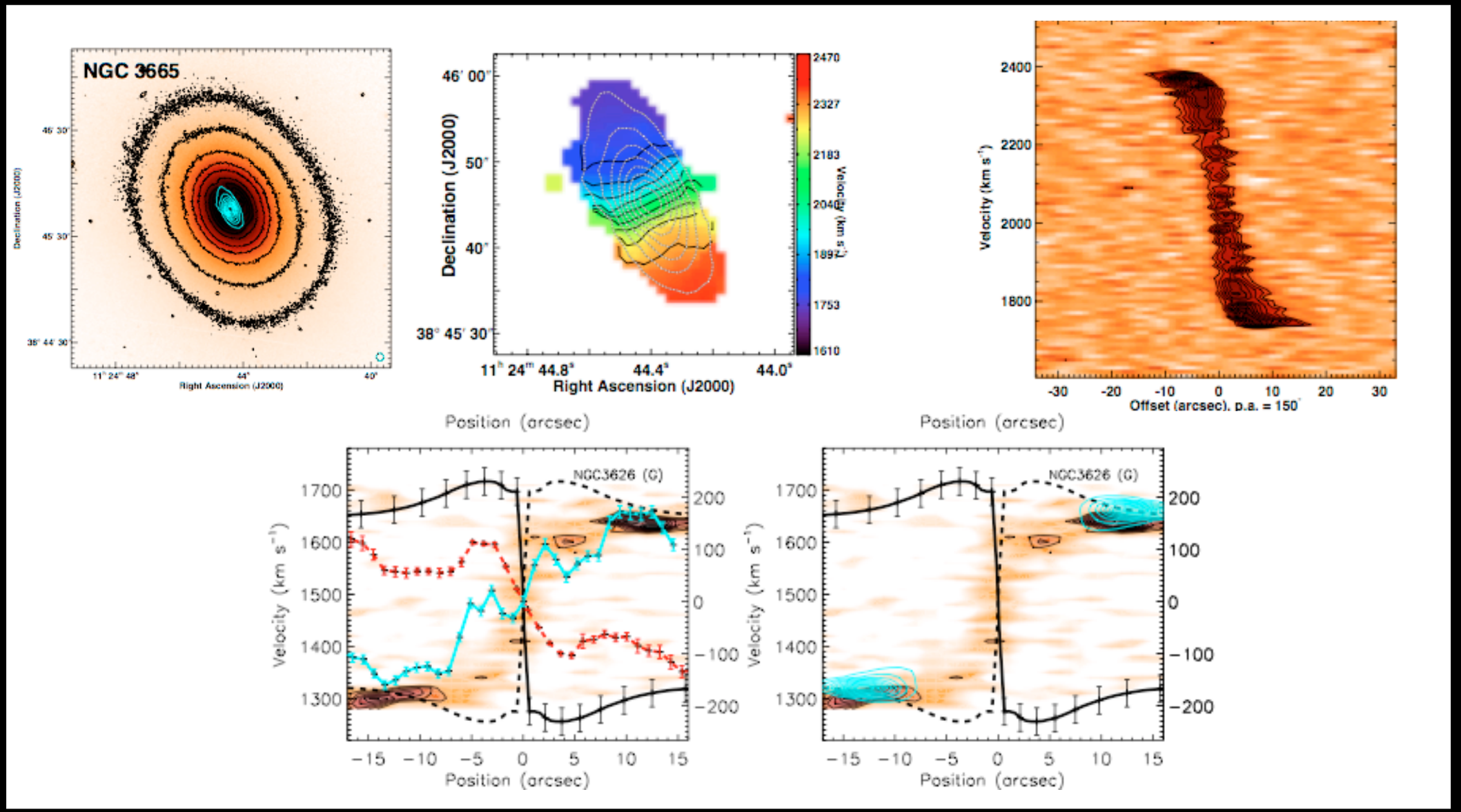
Much less dependent on environment, but H_2 richest systems are in field

In cluster much more often aligned with stars



ETGs also have CO disks

- CARMA observations (Davis+)
- Small disks, give information on inner regions.
  Often reaching the peak of the rotation curve
- Most cold gas in inner regions is molecular: M_{H2}/M_{HI} ~ 10

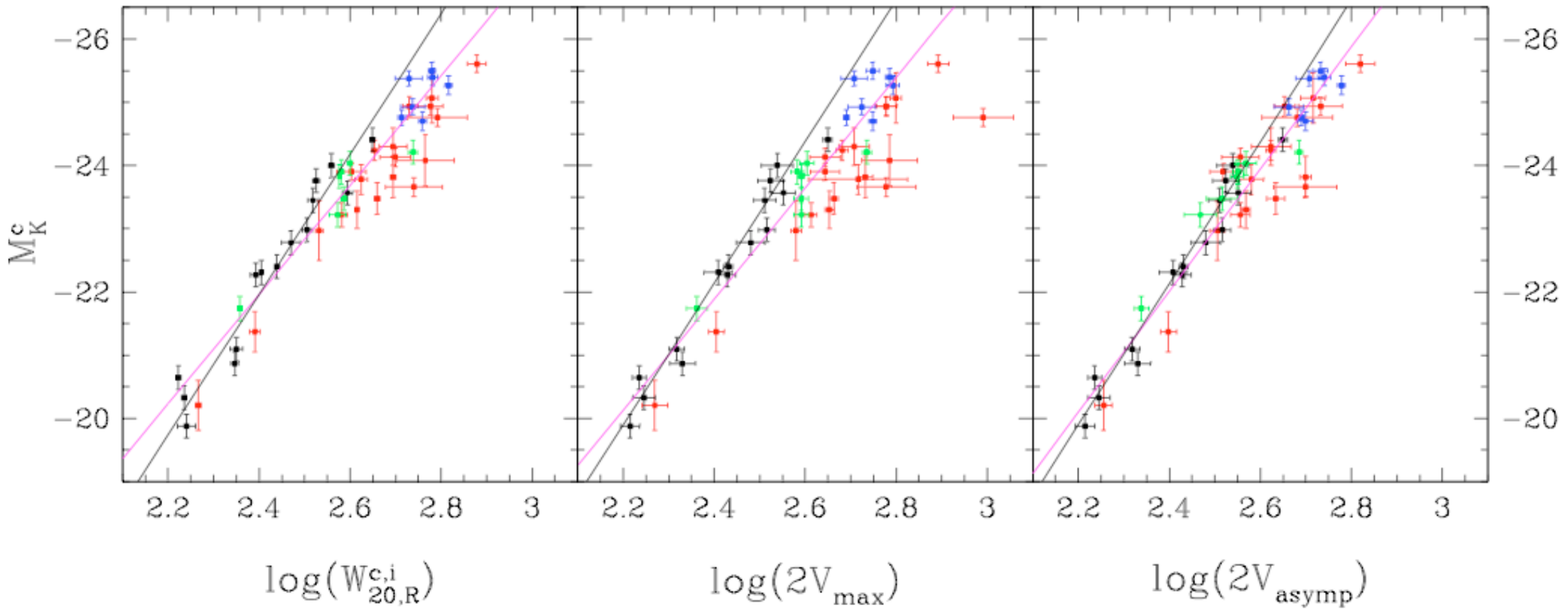


ETGs have gas disks: can make TFR

ASTRON

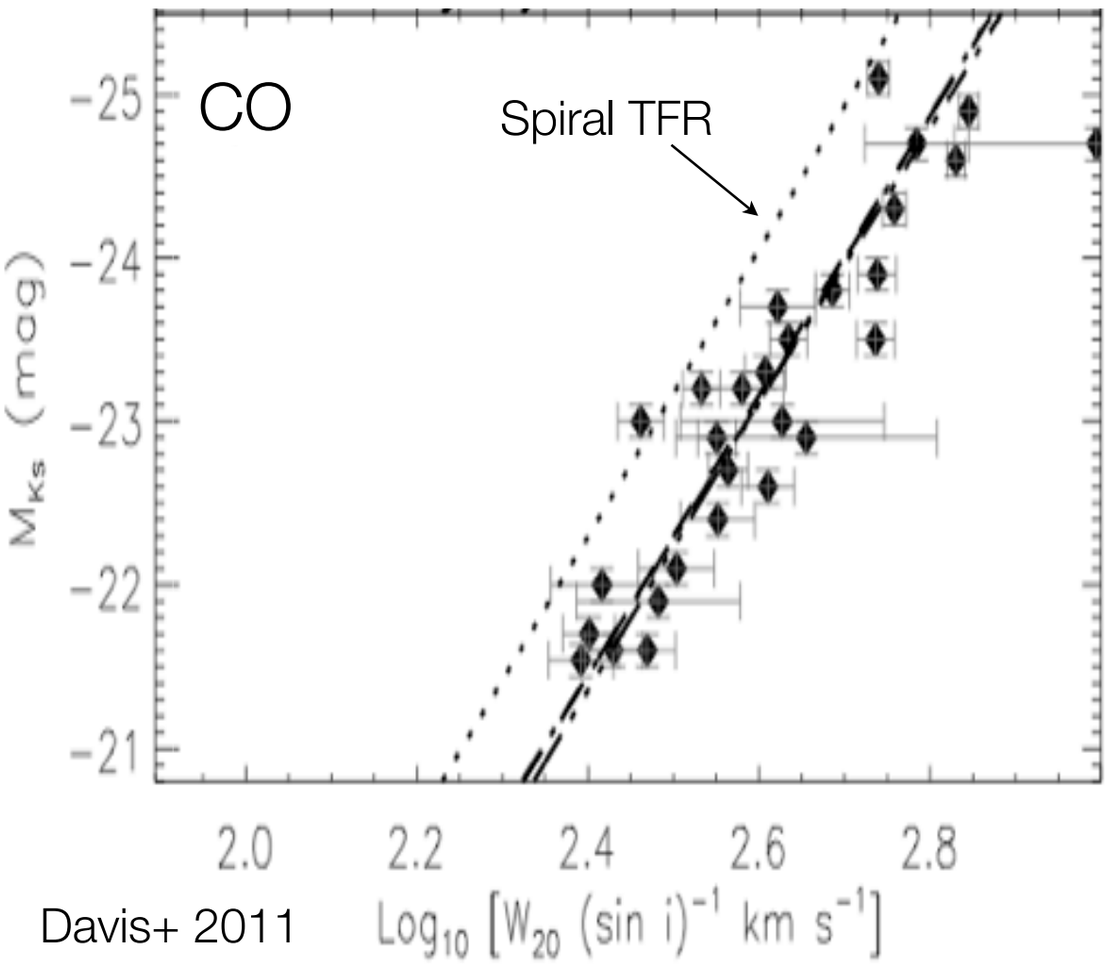
- Comparing TFR for different types of galaxies can give clues on luminosity evolution (fading of stellar populations) and on difference in structure (different size for given mass, different mass distribution)
- Evidence for a systematic offset of the S0 TFR from that of later-type spirals
  - offset seems to be small (Williams+ 2010, Davis+ 2011)
    - corresponds to 1-2 Gyr after star formation stops. Is short…
    - Sa-S0's are smaller for the same mass than later-types?
- Larger offset for massive galaxies? (Noordermeer & Verheijen). Differences in shape of rotation curve!
- Complication: be sure you use the same measure of rotation

ETGs have gas disks: can make TFR



- Larger offset for massive galaxies? (Noordermeer & Verheijen). Differences in shape of rotation curve!
- Complication: be sure you use the same measure of rotation

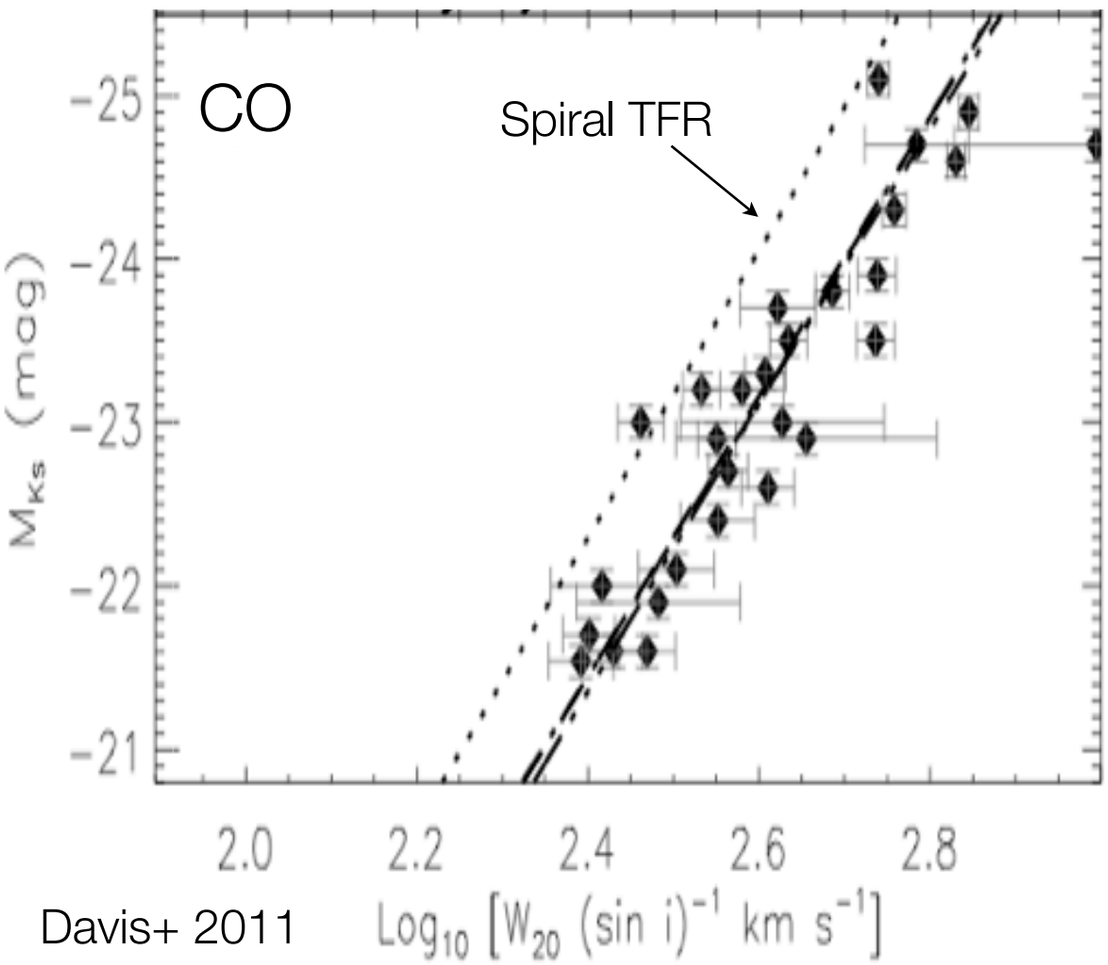
Tully-Fisher relation



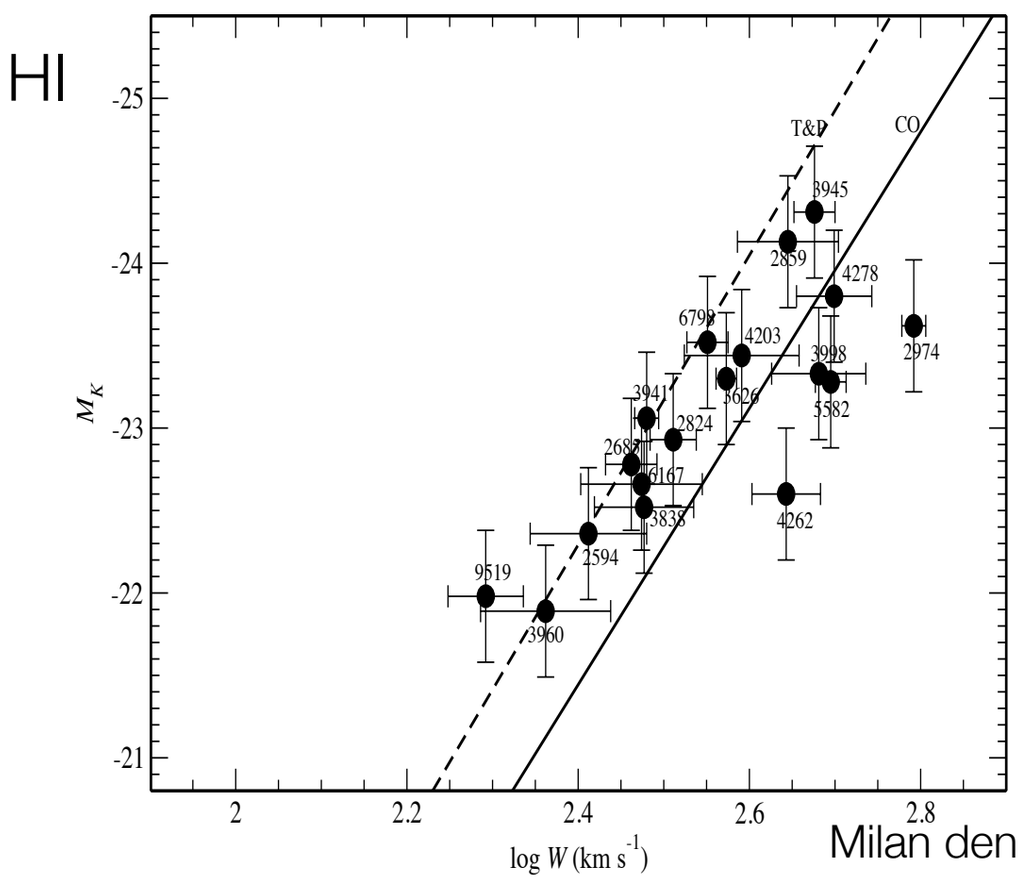
Davis+ 2011

- CO TFR of ETGs offset from spirals (Tully+Pierce 2000). But: CO traces inner regions

Tully-Fisher relation



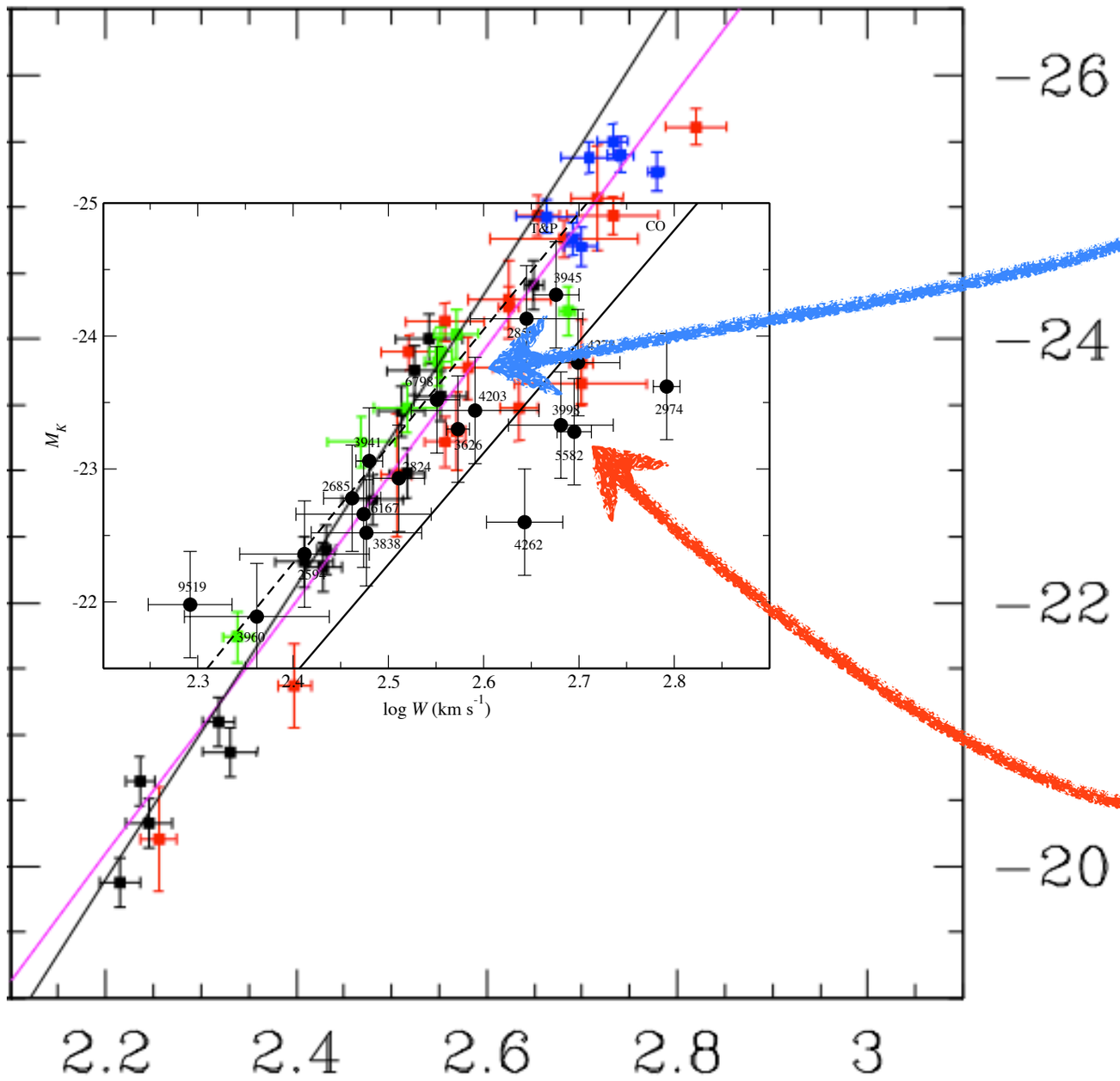
Davis+ 2011

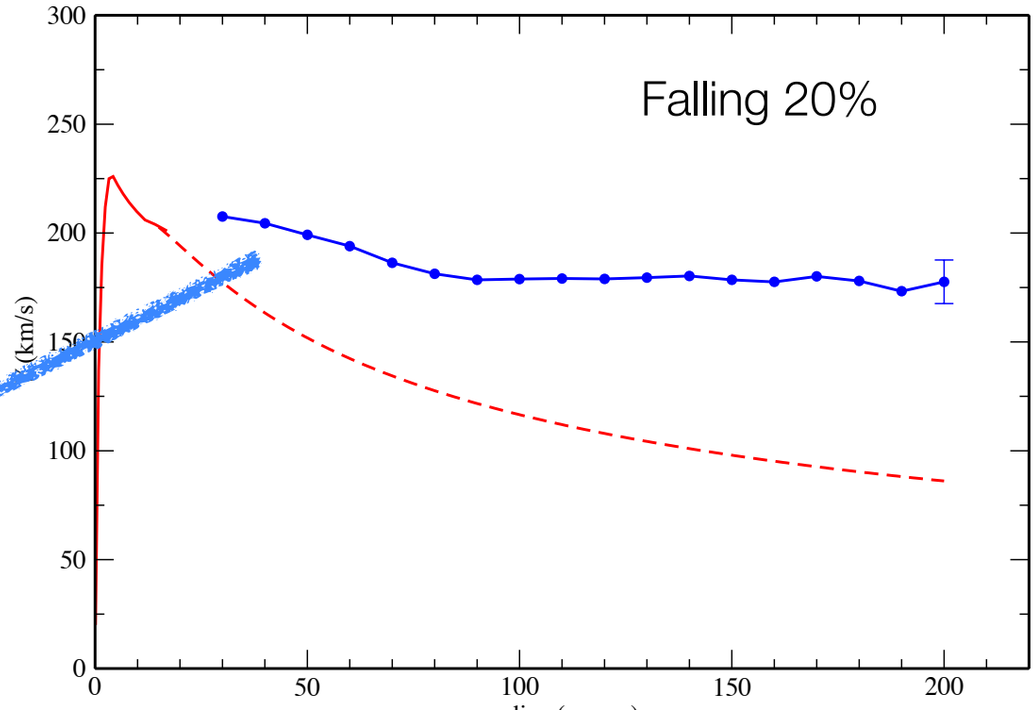


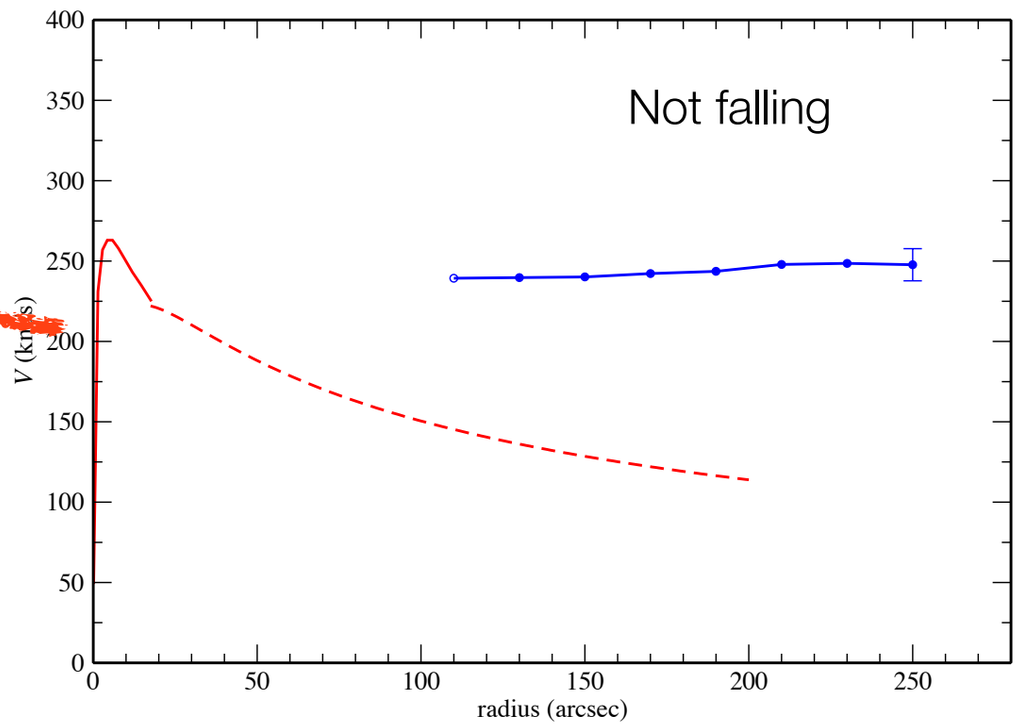
Milan den Heijer, Bonn

- CO TFR of ETGs offset from spirals (Tully+Pierce 2000). But: CO traces inner regions
- Smaller HI offset due to drop of rotation velocity. Not all galaxies.
  - Important for high z (ALMA)
- Population effect is small. These galaxies have gas!
- Not a very tight HI TFR, large offsets/scatter for more massive galaxies. Why?

Large offsets are for flat flat rotation curves

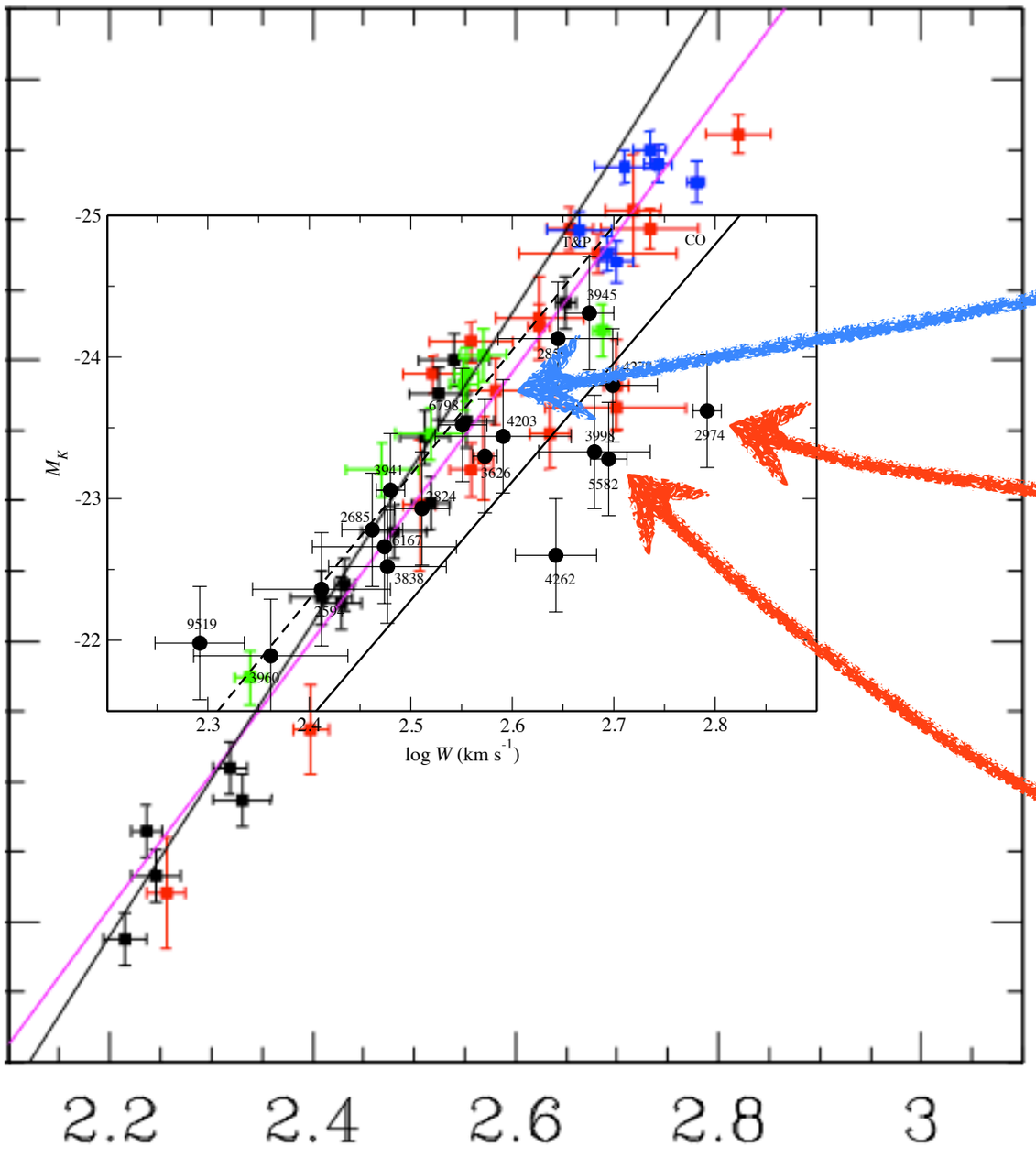


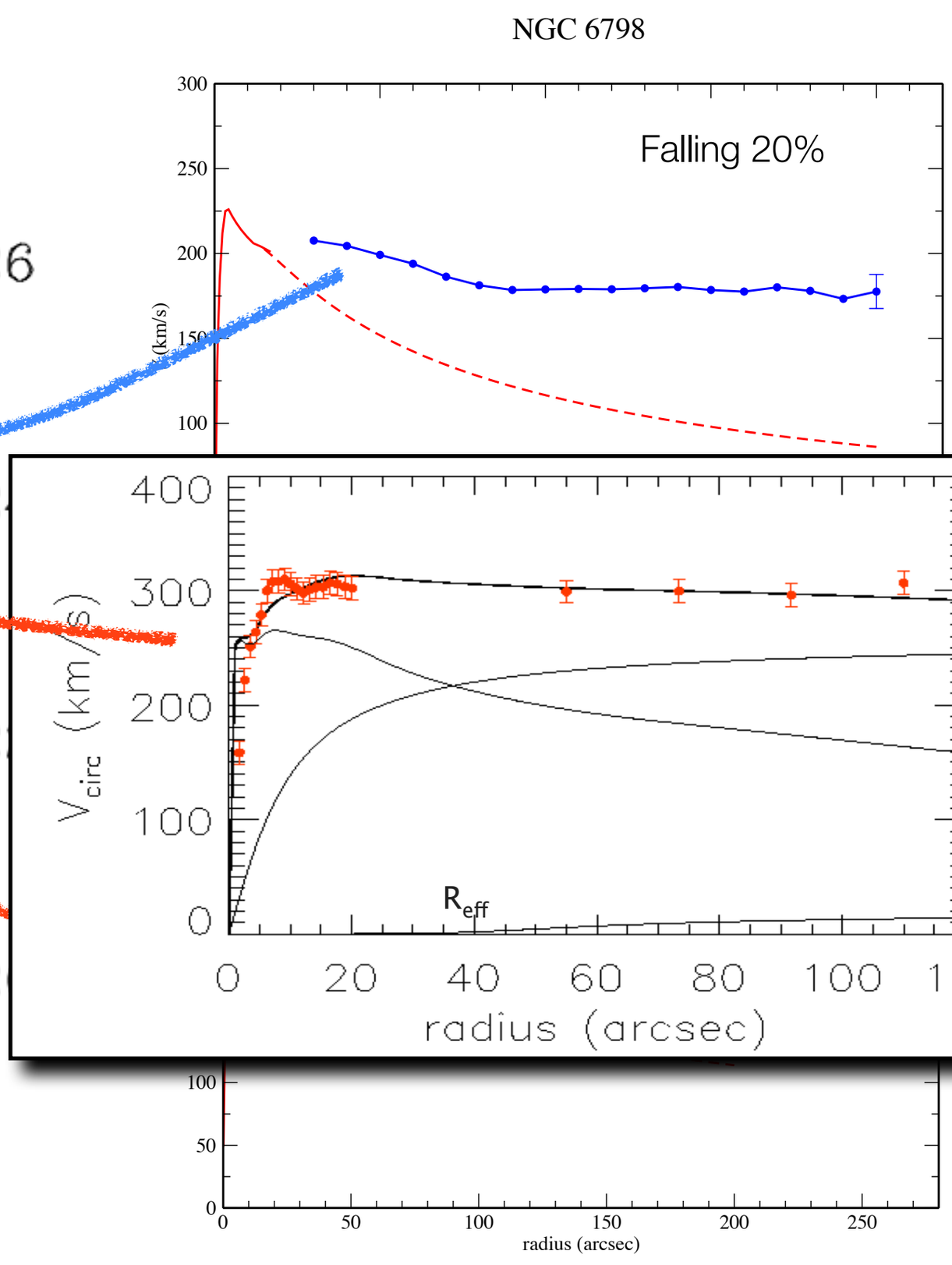




Large offsets are for flat flat rotation curves

ASTRON





TFR in early-type galaxies

ASTRON

- ~20% of field early-type galaxies have regular HI disks of low column density, sometimes very large. Many are polar, 90° warps, counter rotating
- 10-15% of all early-type galaxies have regular CO disks
- Combine with simulations so gas can serve to reconstruct evolution

- Can construct TFR for early-type galaxies.

- Difference of TFR for between CO and HI: declining rotation curve.
  Important for high-z studies.
  Most galaxies: small offset from spiral TFR

- Some massive galaxies have large offsets: rotation curve not declining
  - check in simulations; different evolution?