The vast, thin plane of corotating dwarf galaxies, orbiting Andromeda

Ibata+, 2013, Nature, 493, 62 (Conn+ 13)

• Accurate, **homogeneous distances** to **27 M31 dwarf galaxies**, providing the 3-dimensional positions on the sky

• Radial velocity measurements using Keck/Deimos data



## **Radial velocity measurements**

- 13/15 are corotating
- Significance: 99.998%





Similar flattened structures of gas-deficient satellite systems have been discovered elsewhere (Milky Way, Cen A, M81)

## **Formation Scenarios**

- Accretion of groups of satellites (d'Onghia & Like 08; Li & Helmi 08)
  - \* Too many satellites observed in the plane
  - \* No marked chemical distinctions between disk and non-disk members
  - \* How could such an extended structure form?
- **Tidal dwarf galaxies**, generated by a major merger with a gas-rich galaxy (Wetzstein+ 07, Bournaud+ 08, Pawlowski+ 11, Hammer+ 13)
  - \* Dwarfs appear to be strongly dark matter dominated
  - \* Stellar populations are old (5-9 Gyrs)

## What's about cosmological simulations?

(Metz+08; Lovell+11; Starkenberg+11; Keller+12, see however Pawlowski+12)

Moore et al. 1999



Which of these galaxies are visible?

0.4

0.3

## The co-planarity of satellite galaxies: evidence for cold stream accretion (Dekel+09)?

(Goerdt & Burkert, astroph/1307.2102)



(Ceverino, Dekel & Bournaud 10)

MareNostrum (Ocvirk, Pichon & Teyssier 08)

#### The probability to have n of m streams at angle 3.6 degrees



• Finite impact parameters lead naturally to coherent rotation

## Cold streams might naturally explain the origin of flattened, corotating structures in galaxy halos

### **Questions:**

- How likely are cold stream phases and how long do they last?
- How curved are cold streams, i.e. how does their direction change with time?
- Where are all the satellites, predicted by CDM cosmology?

# Are cold stream satellites the visible substructures of galaxies?



## But there is more: Satellite positions, viewed from M31



• Milky Way is part of this disk of satellites.

• The Milky Way disk is perpendicular to the satellite disk

• 13/15 are corotating

• 12/13 of these satellites are on the Milky Way side

