Revisiting the local Hubble flow

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Definition

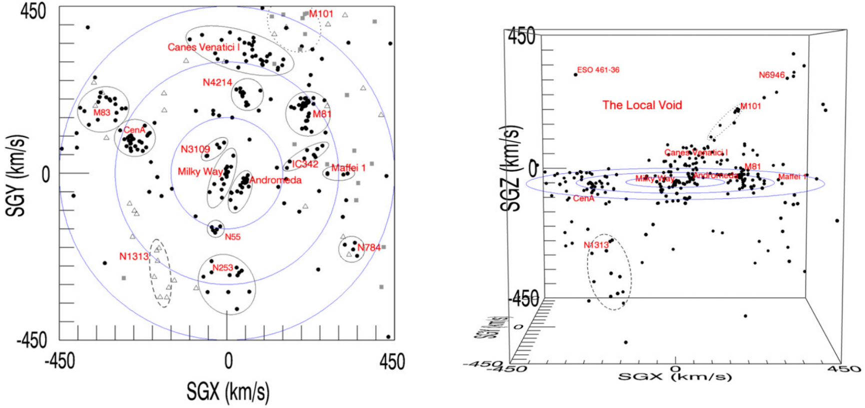
In the ΛCDM model, the Hubble parameter (H_0) determine the expansion rate of the Universe such as :

$$Velocity = H_0 \times Distance$$

Several values depending on the method :
$\rightarrow 67.4 \pm 0.4 km.s^{-1}.Mpc^{-1}$ (Standard candels, Plank coll. 2018)
$\rightarrow 74.03 \pm 1.42 km.s^{-1}.Mpc^{-1}$ (Cepheids HST, Riess et al. 2019)

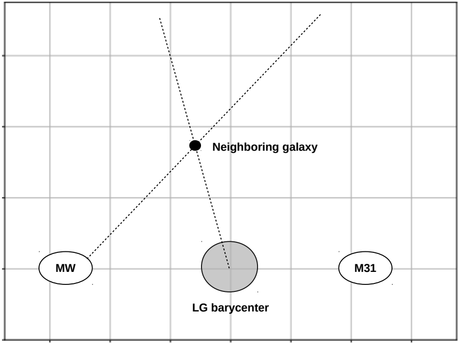
Local Hubble parameter

Different from large-scale value due to **inhomogeneous local structures** (presence of void, sheet, filament ...), creating a anisotropic gravitational potential

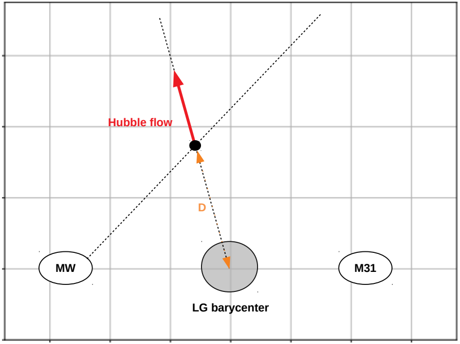


Neighborhood of the Local Group (Courtois et al. 2013)

Presentation of the subject



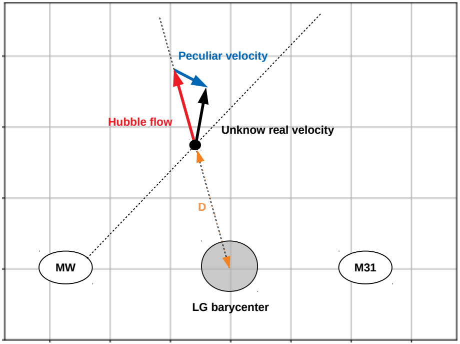
Scheme of the problem
Assuming the position of the Local Group (LG)
according to Karachentsev et al. (2009)



Scheme of the problem
Assuming the position of the Local Group (LG) according to Karachentsev et al. (2009)

Assumption :
The **Hubble velocity** is **radial** in the barycentric referential

$$V_{Hubble} \propto H_0 \times D$$



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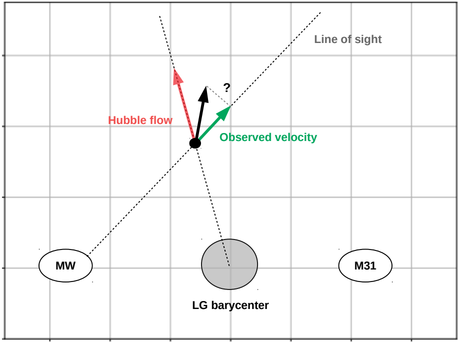
Ascertainment :
The **peculiar velocity shifts the real velocity** of the uniform Hubble flow

$$V_{real}(i) = V_{Hubble} + \Delta V(i)$$



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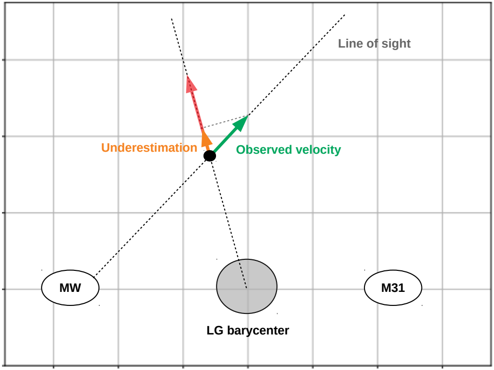
Moreover, the **observed velocity** is a **projection** of the real velocity **on the line of sight**
$\rightarrow$ Lack of information



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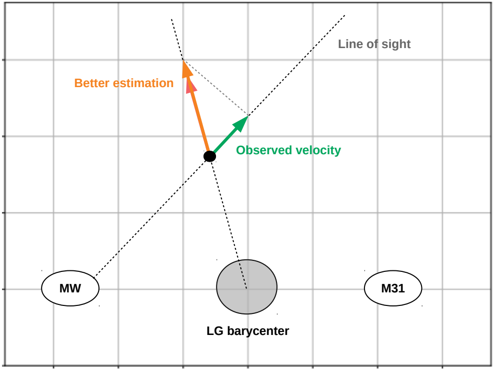
Direct Method :

1. **Changing of referential frame**
2. Radial projection

→ Systematic underestimation of the actual 3D velocity



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Our Method :

1. Reconstruction of the velocity along the barycentric radial axis
2. **Changing of referential frame**
3. The velocity is already radial

→ Better estimation

Method

Estimation of the error related to the new method

Two changing referential frame :

1. Heliocentric to galactocentric
   $\rightarrow$ Position and velocity of the Sun
2. Galactocentric to the barycentric referential frame of the LG
   $\rightarrow$ Position and velocity of M31

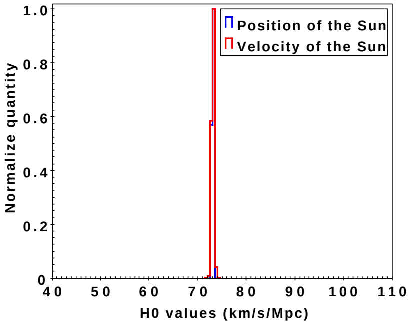
The **uncertainties on this parameters may cause error** during the changing referential

Caracterization of the error

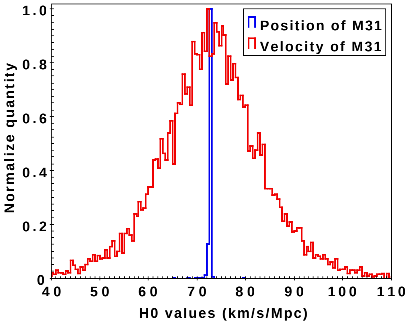
We use **mock data** to **characterize the error** due to uncertainties on the changing frame parameters
$\rightarrow$ Compute the error due to uncertainty on **one parameter** by **freezing all the others**

Mock data created with $H_0^{th} = 73 km.s^{-1}.Mpc^{-1}$

Velocity of M31 according to Salomon et al. (2016)



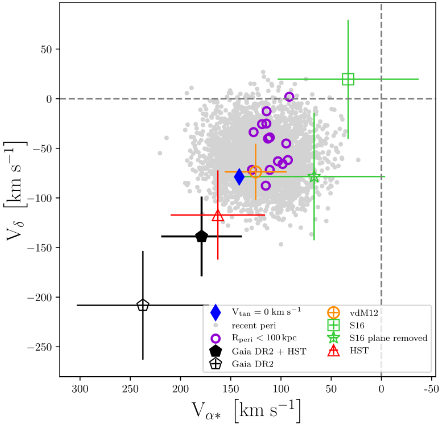
Dispersion of H_0^{th} due to Sun position or velocity



Dispersion of H_0^{th} due to M31 position or velocity

→**Maximum of uncertanity due to M31 velocity**

The tangential velocity of M31 is not consensual

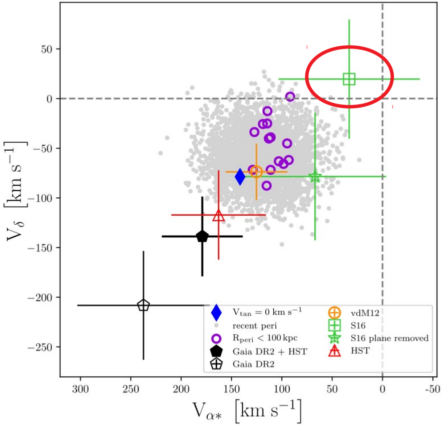


The different tangential velocities of M31 in the heliocentric referential

(van der Marel et al. 2019)

Two approaches :

The tangential velocity of M31 is not consensual



The different tangential velocities of M31 in the heliocentric referential

(van der Marel et al. 2019)

Two approaches :

- **Global measurement of the entire M31 system** (dwarf galaxies)
  Problem : large uncertainties due the sparse number of satellites and possible correlations between them
  $\rightarrow$ **Salomon et al. (2016)**

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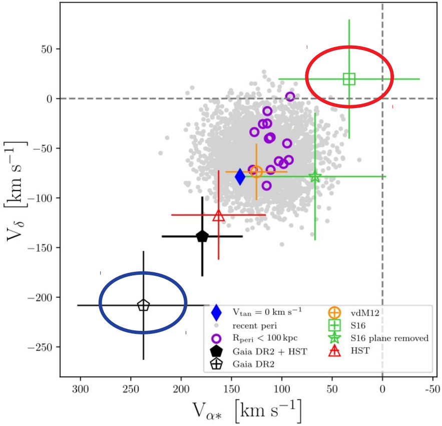

The different tangential velocities of M31 in the heliocentric referential

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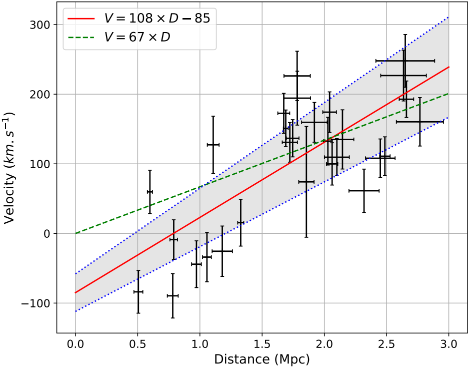
Two approaches :

- **Global measurement of the entire M31 system** (dwarf galaxies)
  Problem : large uncertainties due the sparse number of satellites and possible correlations between them
  → **Salomon et al. (2016)**
- **Targetting individual stars of M31** (highly model dependant)
  → **Gaia, van der Marel et al. (2019)**

Estimation of the **local Hubble parameter**, via a linear fit of the velocities of the galaxies in the **barycentric referential frame**, with a **M31 velocity according to Salomon et al. (2016)**



McConnachie (2012) galaxy compilation transformed into barycentric radial velocities

Linear fit of the velocities :

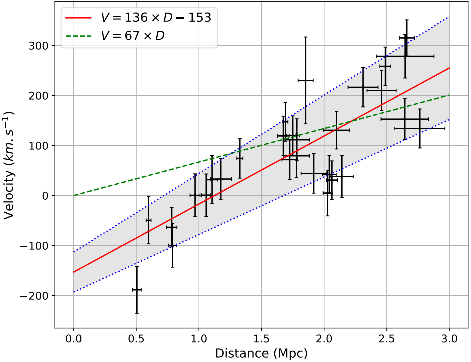
$$V = H_0 \times D + V_0$$

Zero-velocity surface parameter :

$$R_0 = \frac{V_0}{H_0}$$

- $H_0 = 108 \pm 15 km.s^{-1}.Mpc^{-1}$
- $V_0 = -85 \pm 27 km.s^{-1}$
- $R_0 \approx 780 kpc$

Estimation of the **local Hubble parameter**, via a linear fit of the velocities of the galaxies in the **barycentric referential**, with a **M31 velocity according to van der Marel et al. (2019)**



McConnachie (2012) galaxy compilation transformed into barycentric radial velocities

Linear fit of the velocities :

$$V = H_0 \times D + V_0$$

Radius of the Zero-velocity surface sphere :

$$R_0 = \frac{V_0}{H_0}$$

- $H_0 = 136 \pm 21 km.s^{-1}.Mpc^{-1}$
- $V_0 = -153 \pm 40 km.s^{-1}$
- $R_0 \approx 1120 kpc$

Limitations

- **Simplification of the velocity** configuration :
  $\rightarrow V_{galaxy} = V_{Hubble} + V_{peculiar}$
- **Uniform spatial distribution** of the peculiar velocities
  → Insufficient statistics for this assumption ?
  → Potential dynamical bias due to groups of galaxies (binarity ...)
- **Reconstruction** of the **observed velocities** on the barycentric radial axis
  → Still unaccurate
- **Approximation of the LG barycenter position** assuming only the mass of MW and M31
  → Magellan clouds and M33 can contribute up to 1/5 of the mass of the LG and thus change the position of its barycenter (Gomez et al. 2015)
- Data limited to 3Mpc

Prospects

- **Relax the contraints** on the position and velocity of the **barycenter**
- We have an opportunity to **limit the uncertainty on the mass** of the LG
- Study the presence of a **potential velocity flow** in the neighborhood that would influence the value of the local Hubble parameter

Conclusion

- The **new referential changing method** alow us to do a **new estimation of the local Hubble parameter**.
- We produce **two estimations of this local Hubble parameter** corresponding to the two extreme values of the tangential velocity of M31 :
  - $H_0 = 108 \pm 15 km.s^{-1}.Mpc^{-1}$ (using M31 velocity of S+16)
  - $R_0 \approx 780 kpc$
  - $H_0 = 136 \pm 21 km.s^{-1}.Mpc^{-1}$ (using M31 velocity of vdM+19)
  - $R_0 \approx 1120 kpc$
- The large difference between the estimation of the local value and the large-scale value of the Hubble parameter require **complementary studies**

Thank you for your attention