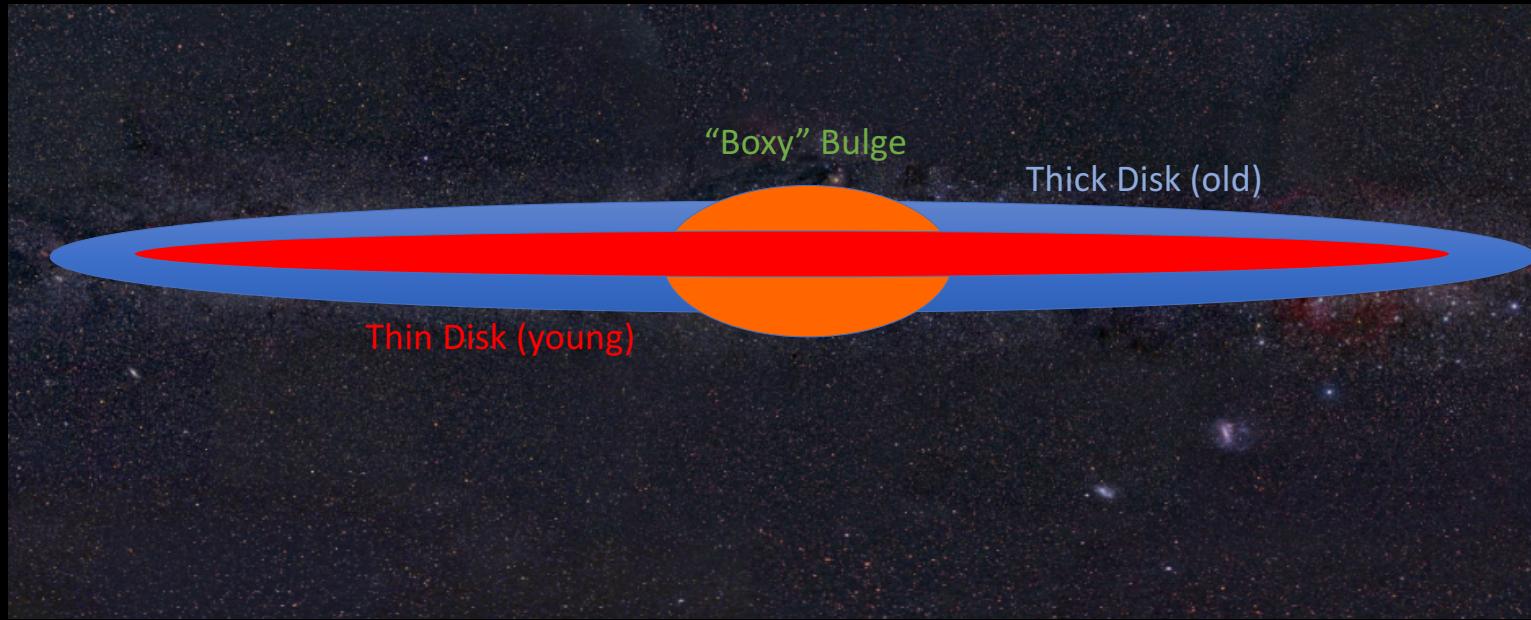


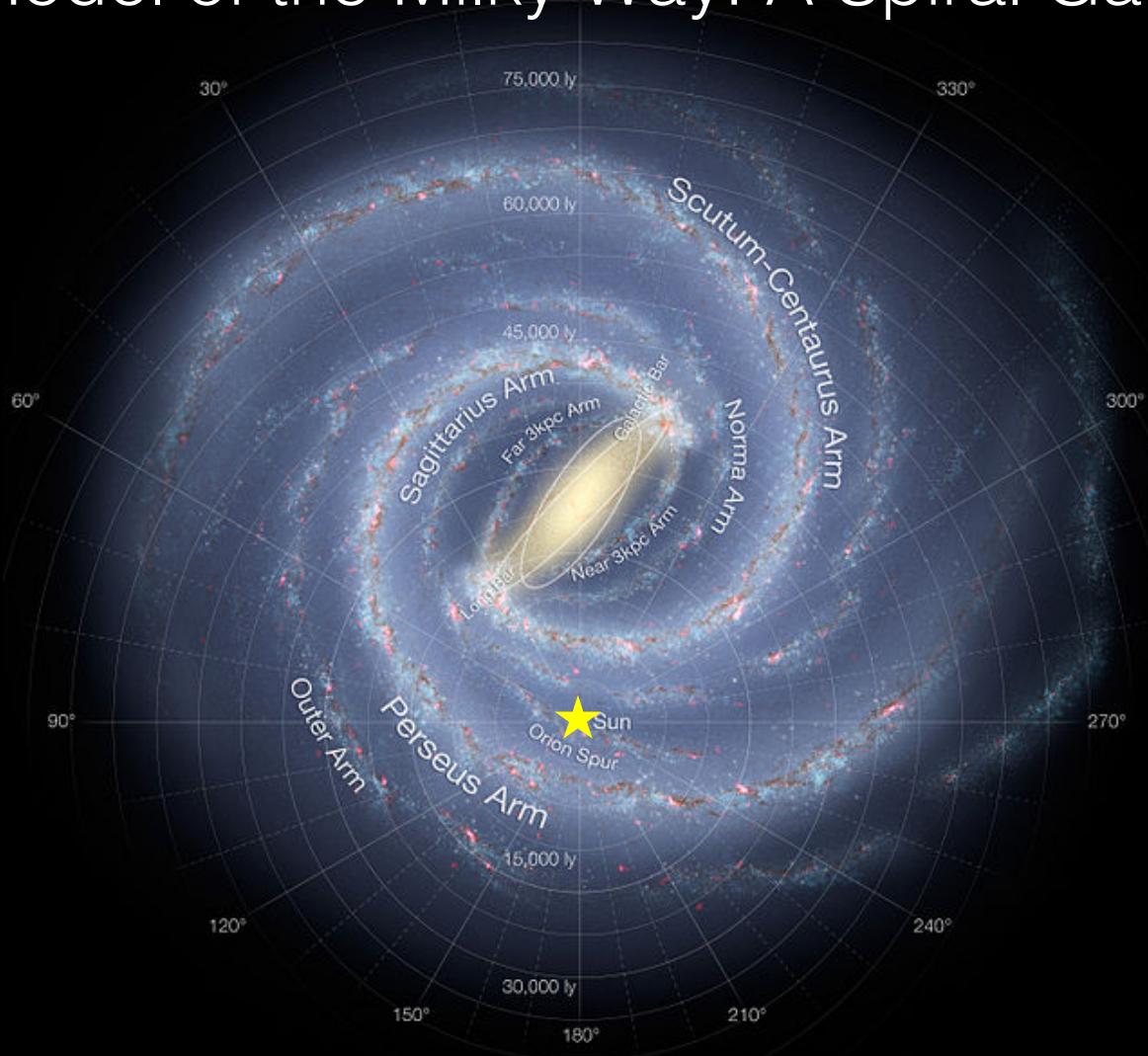
The Structure of our Milky Way Disk:



Diameter \sim 100,000 light years

Mass \sim 60 billion times the mass of the Sun

A Model of the Milky Way: A Spiral Galaxy

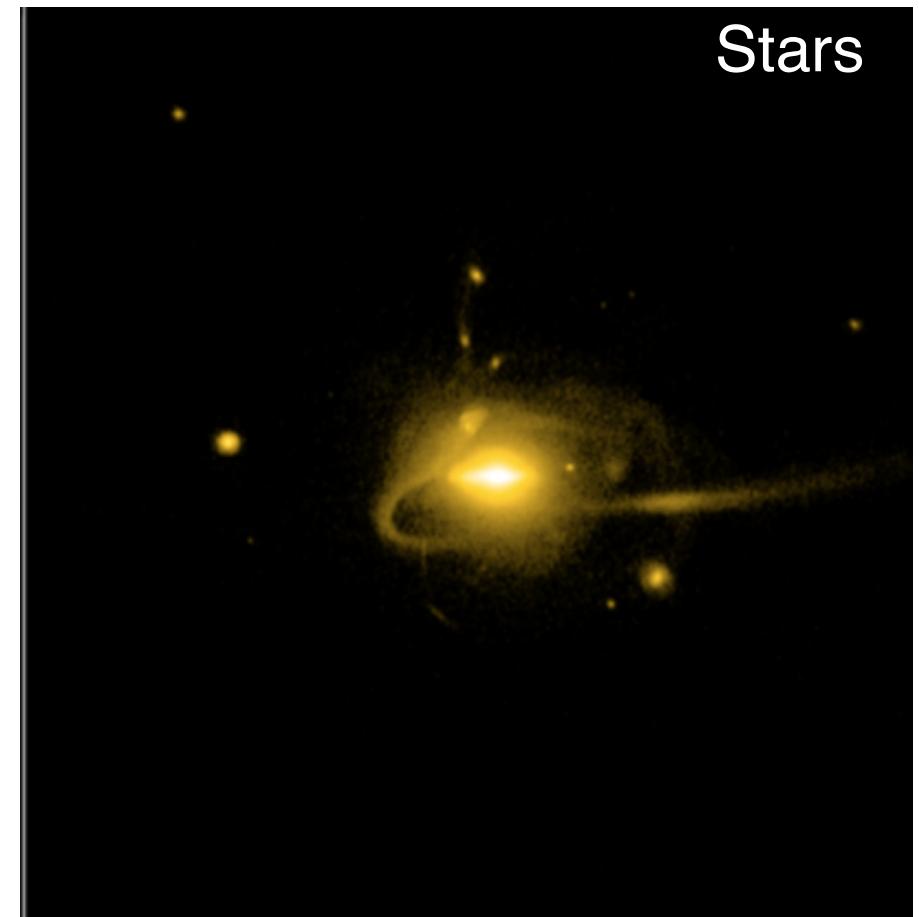




Dark Matter vs. Stars



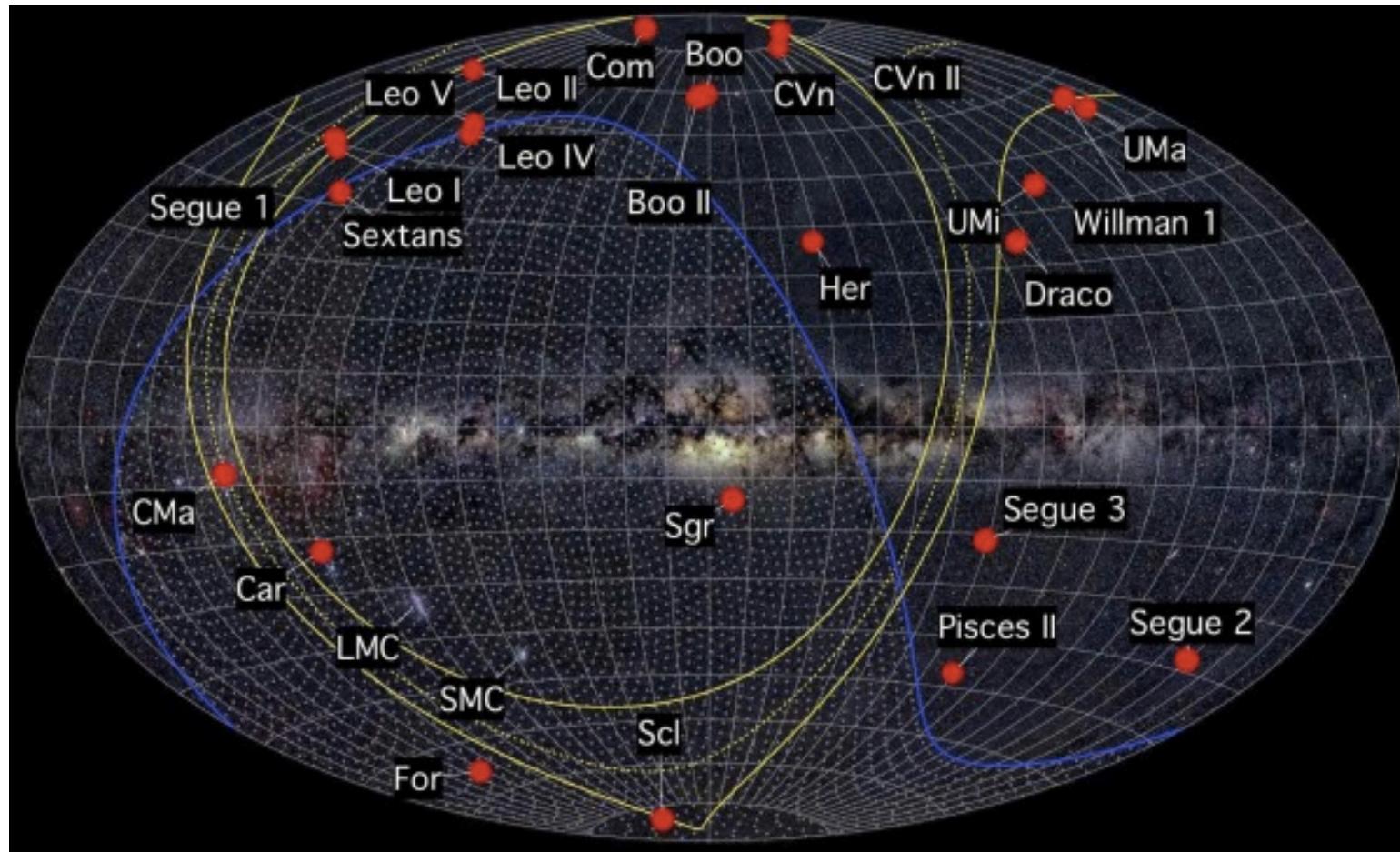
Dark Matter



Stars

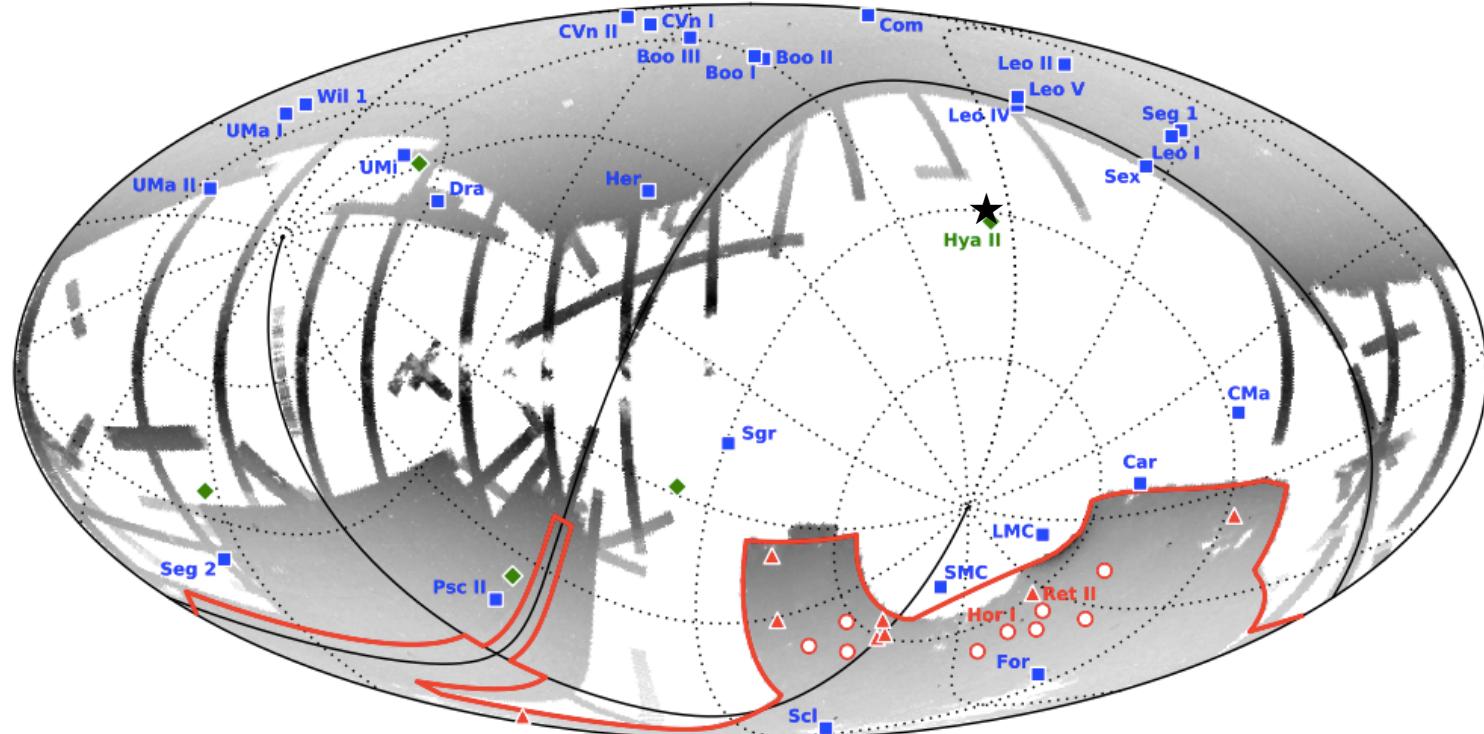
Wetzel+2016

Our Milky Way has many Neighbors



26 Satellites as of Feb 2015

Possible New Dwarfs found by DES Survey +PANSTARRS +SMASH survey = **~ 50 ?**



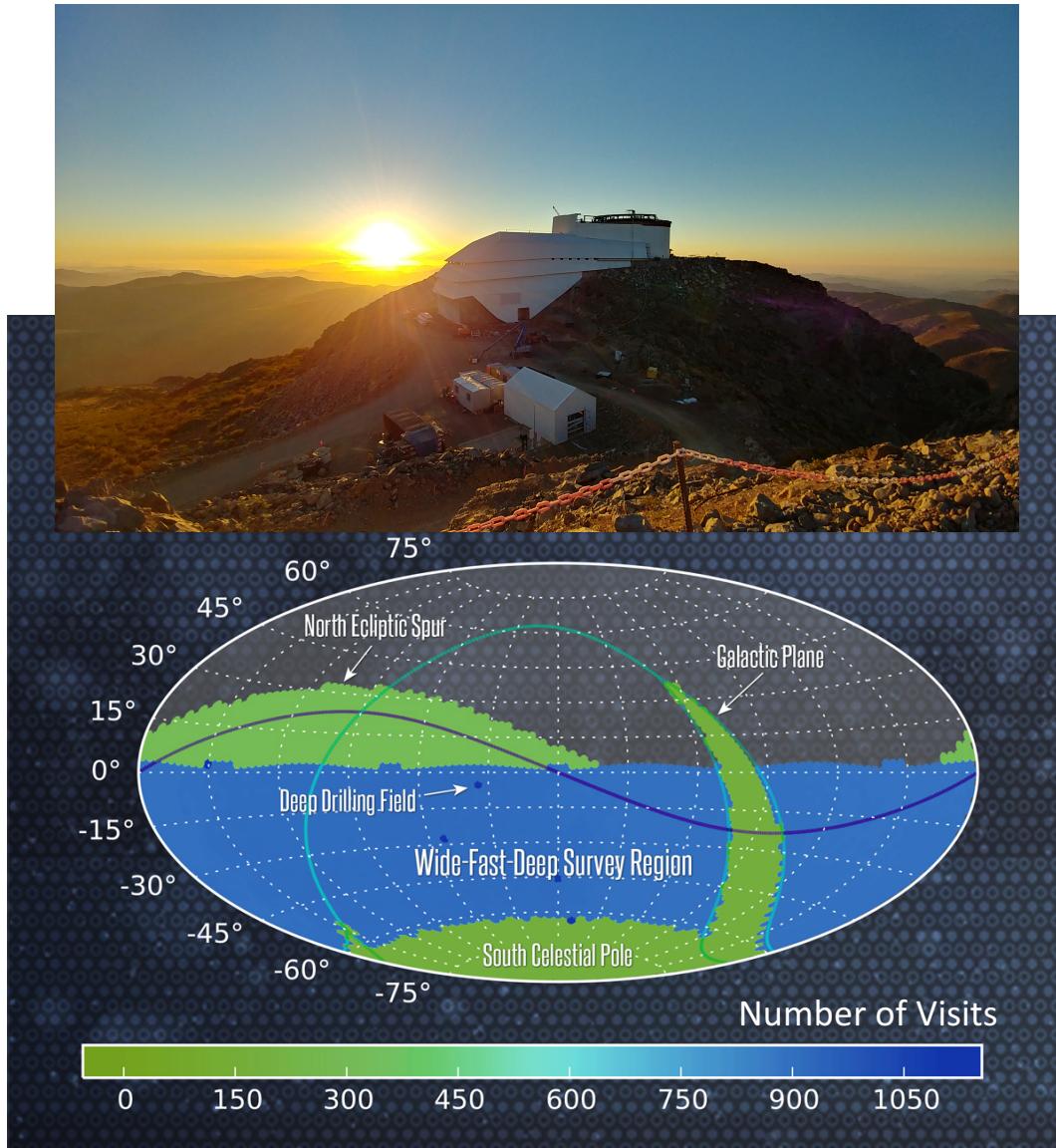
Bechtol + 2015 (DES); Koposov+2015; Laevens +2015;
Martin, Nidever, Besla+ 2015 (SMASH), Drlica-Wagner+2015
(DES), Homma+2016 ... more to come with LSST!

LSST:

The structure and evolutionary history of the Milky Way
Constrain Dark Energy & Dark Matter

This telescope will produce the deepest, widest, image of the Universe:

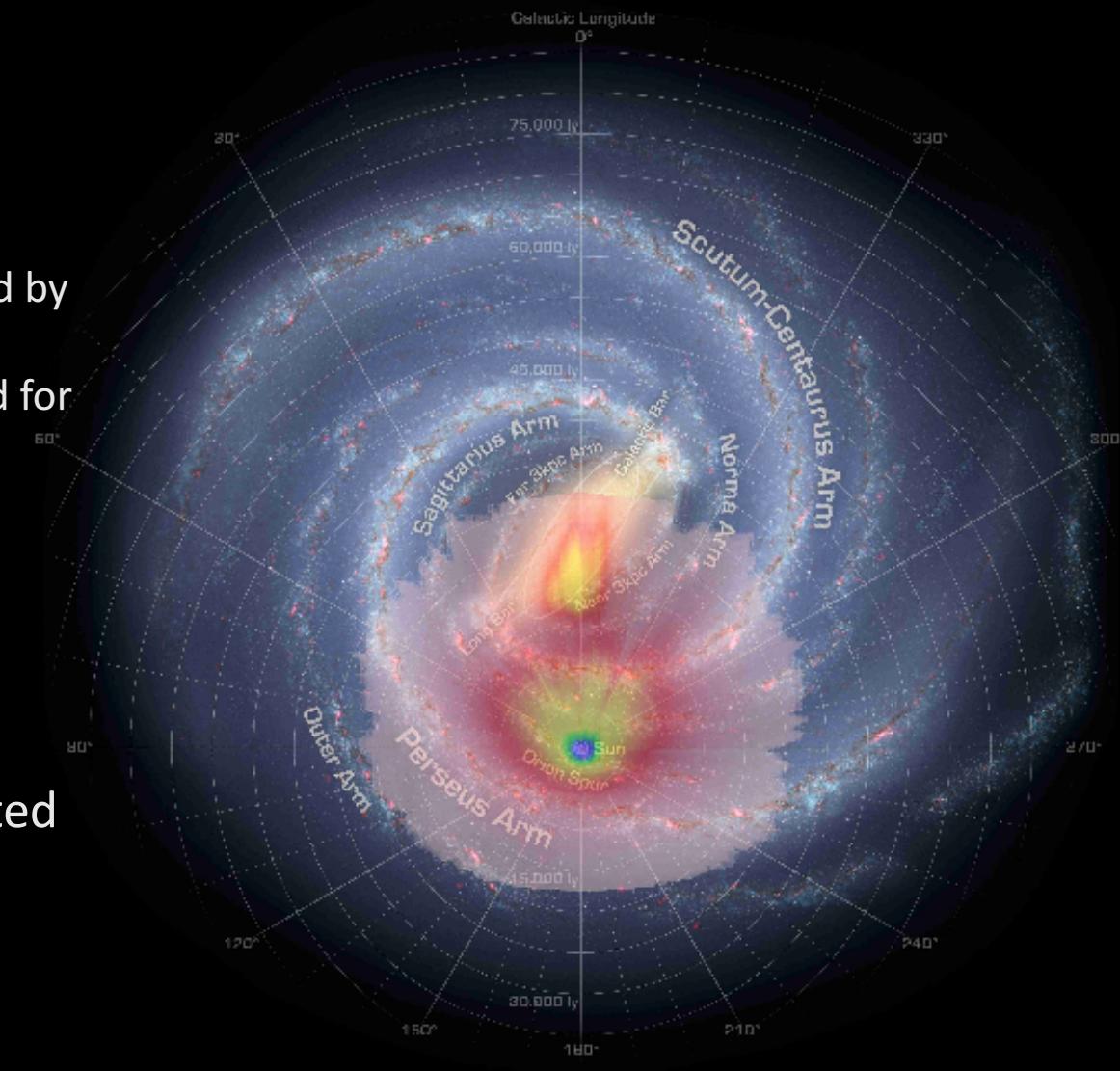
- 27-ft (8.4-m) mirror, the width of a singles tennis court
- 3200 megapixel camera
- Each image the size of 40 full moons (Wide field!)
- 37 billion stars and galaxies
- 10 year survey of the sky: starting 2022
- 10 million alerts, 1000 pairs of exposures, 15 Terabytes of data .. every night!



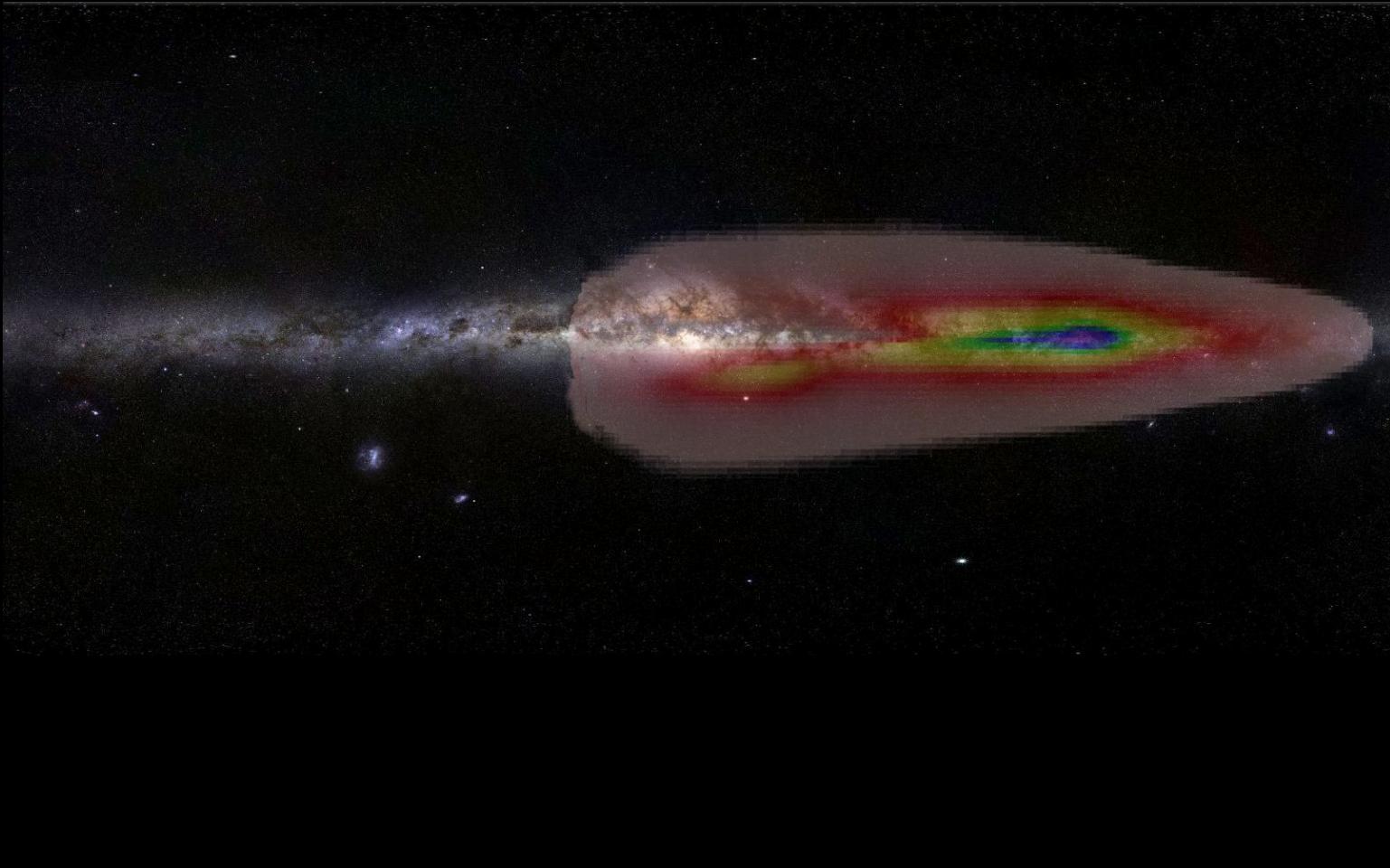
GAIA

Gaia is a space observatory operated by the European Space Agency. It is designed for astrometry.

ASTROMETRY:
measuring the
positions and
distances of stars
with unprecedented
precision.

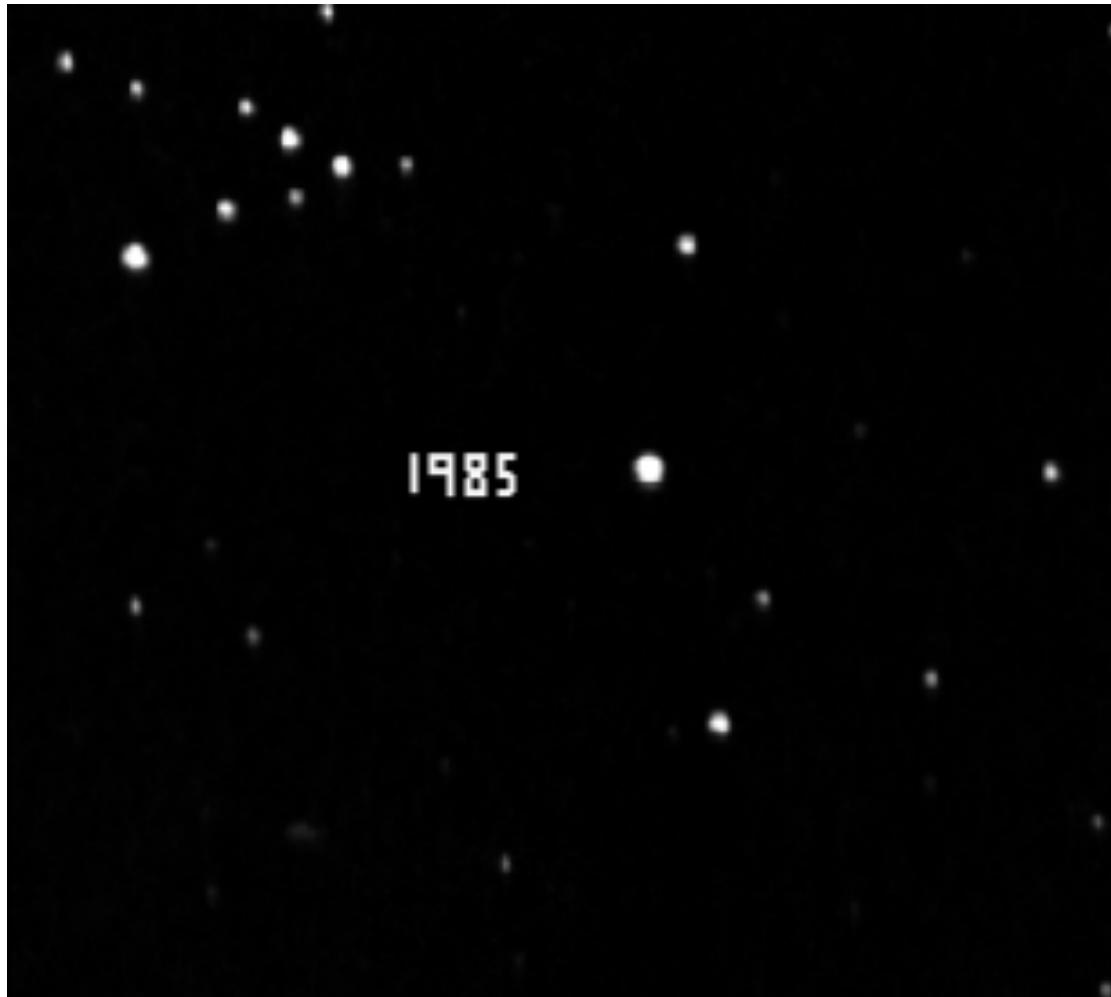


GAIA



Proper Motions

Barnard's Star



GAIA



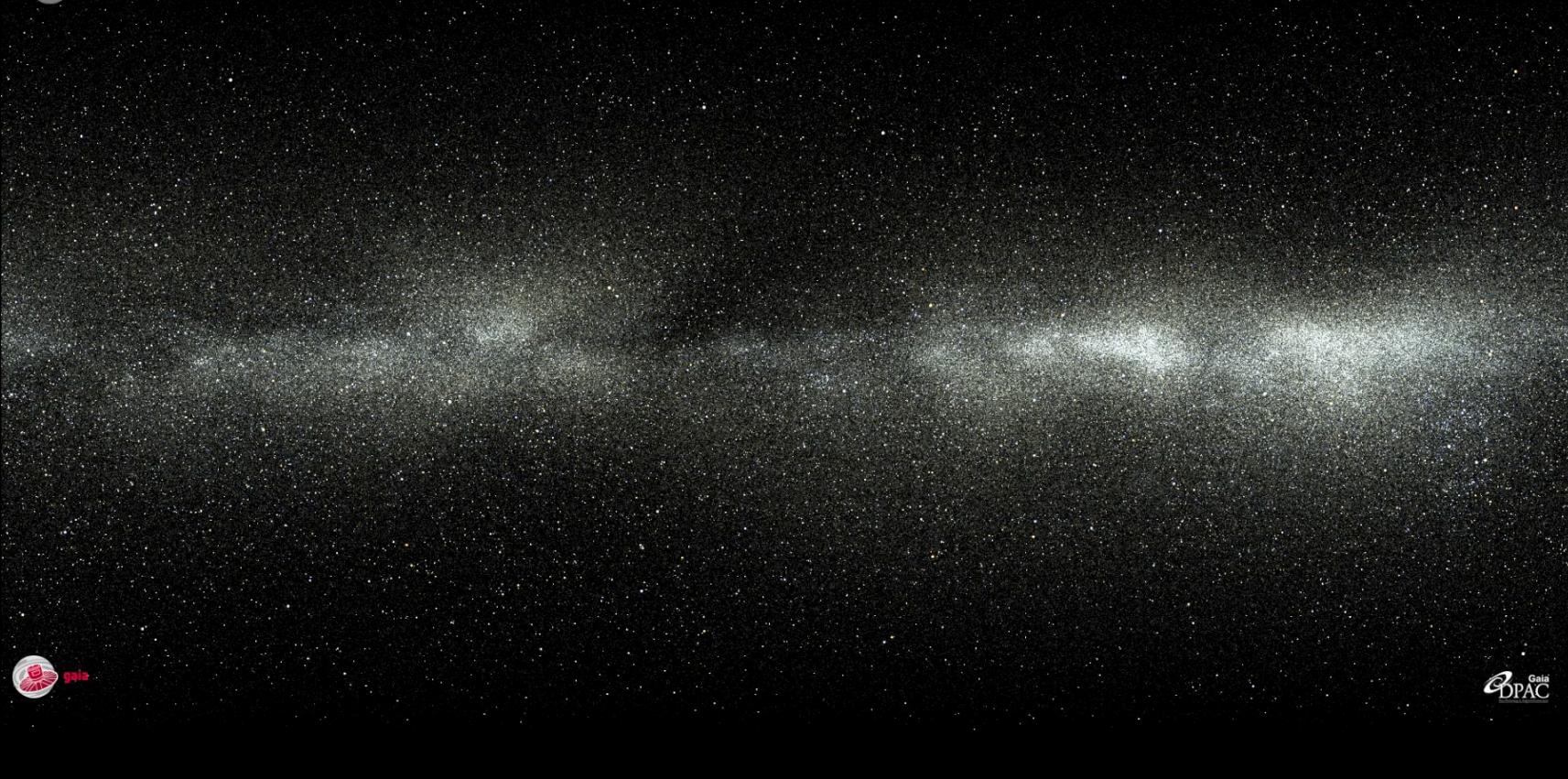
Data Release 1: Sep. 2016

Data Release 2 : April 2018 – during this semester!!

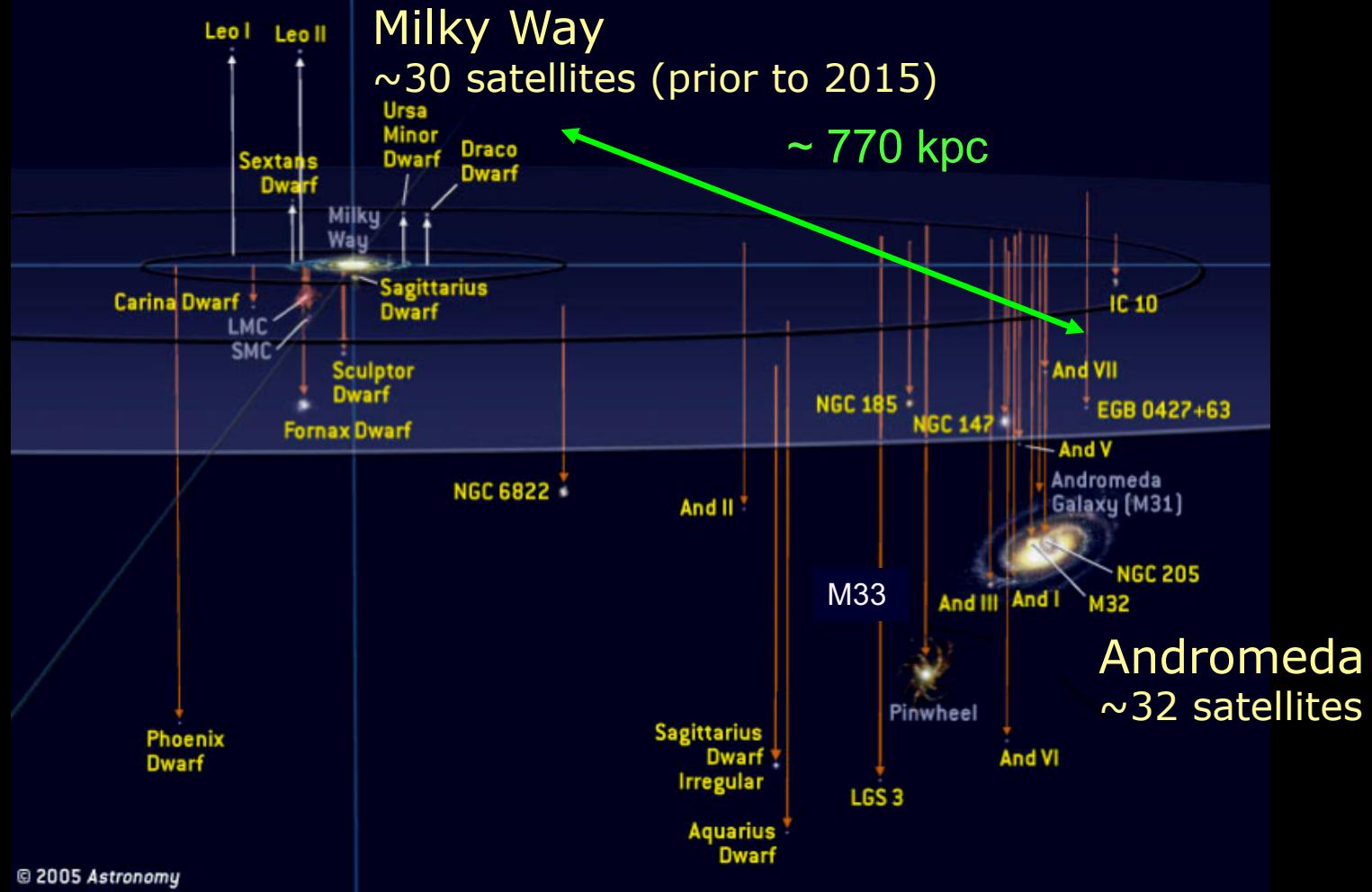
Data Release 3: Mid to late 2020 -- during your grad careers!

Mission Duration: Until 2022

Years from now: 3,363,750



Our Local Group of Galaxies



HSTPROMO

The HST Proper Motion Collaboration

(<http://www.stsci.edu/~marel/hstpromo.html>)

- Characteristic velocity accuracy necessary
~10 km/s at 70 kpc (Milky Way halo/satellite dynamics)

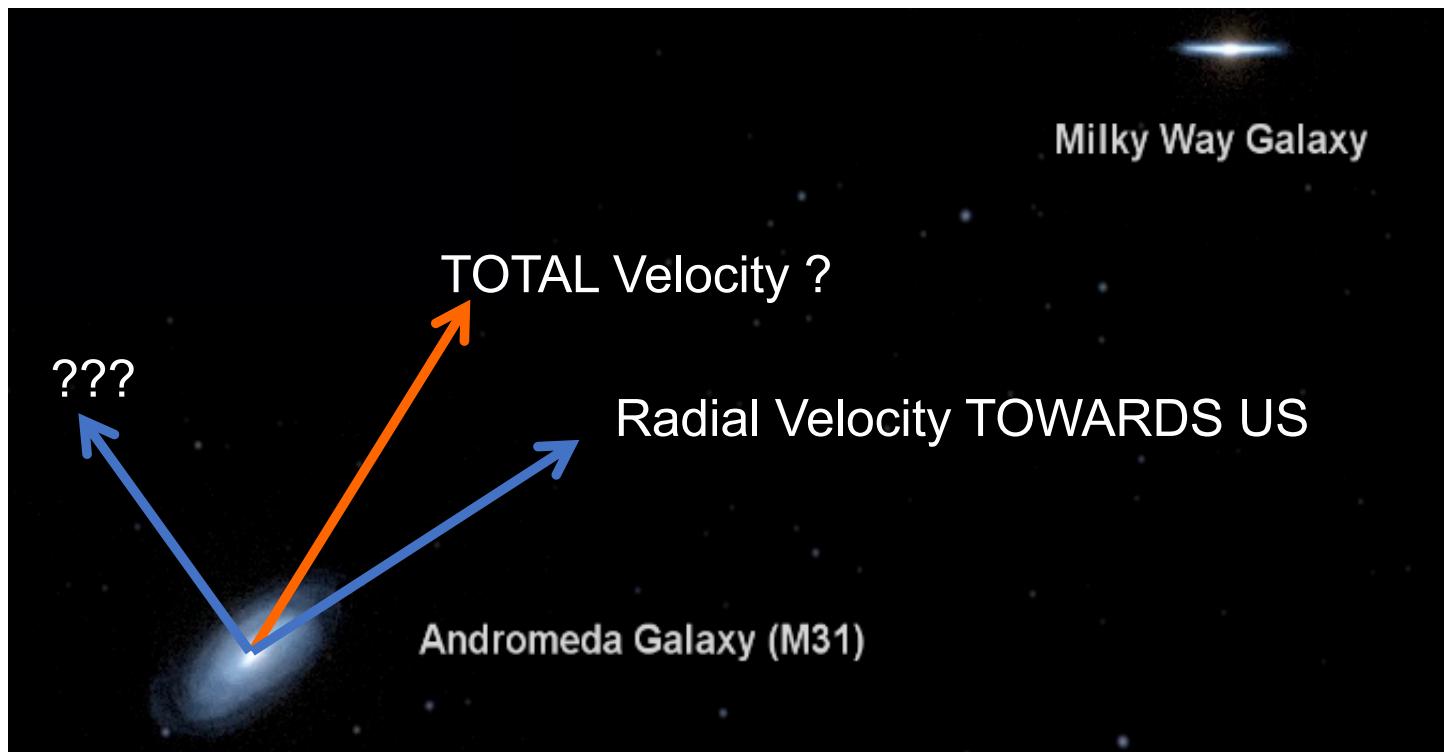
- Corresponding PM accuracy
~ 30 μ as / yr

(~ speed of human hair growth
at distance of the Moon)

With HST we can measure a
change of 0.006 ACS/WFC pixels
over a 10 yr baseline



What is the 3D velocity of M31?

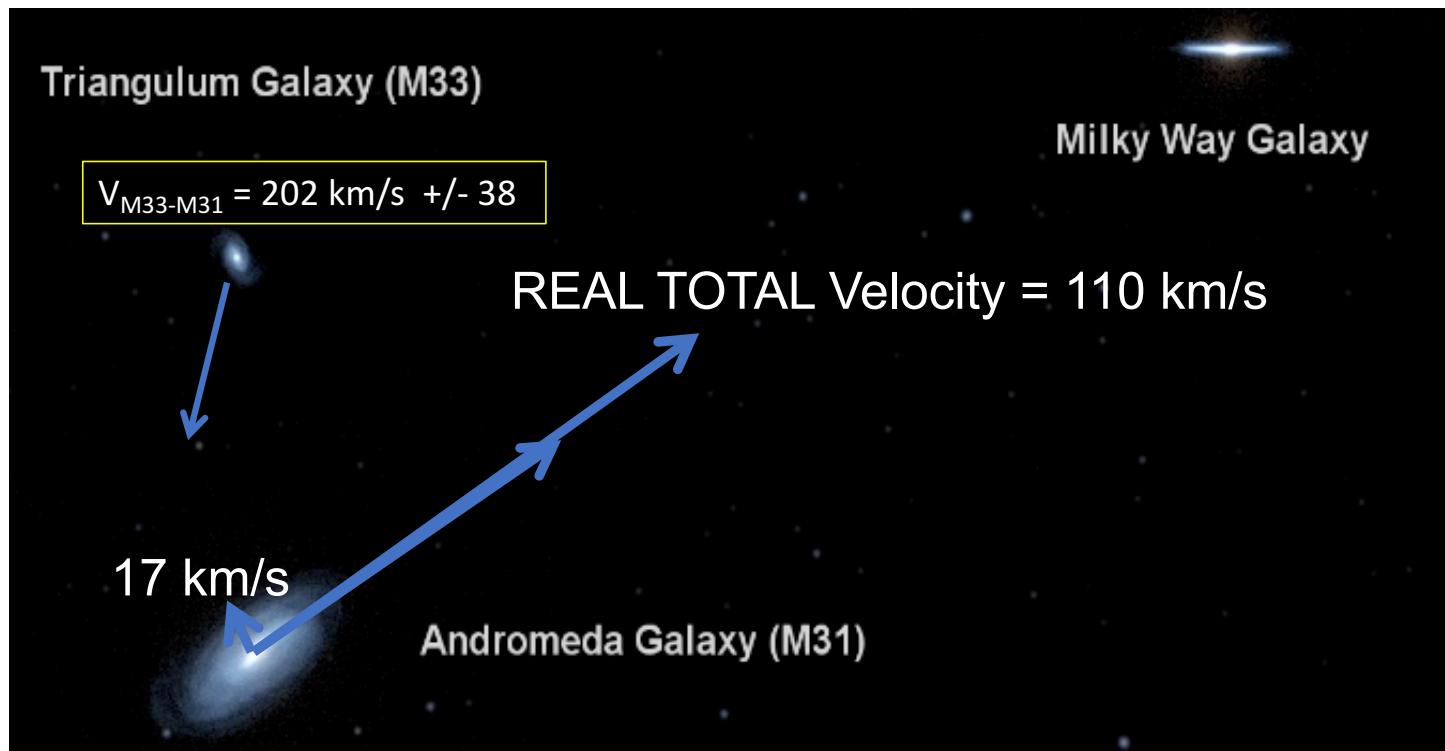


HSTPROMO: The First Direct Proper Motion Measurement of M31

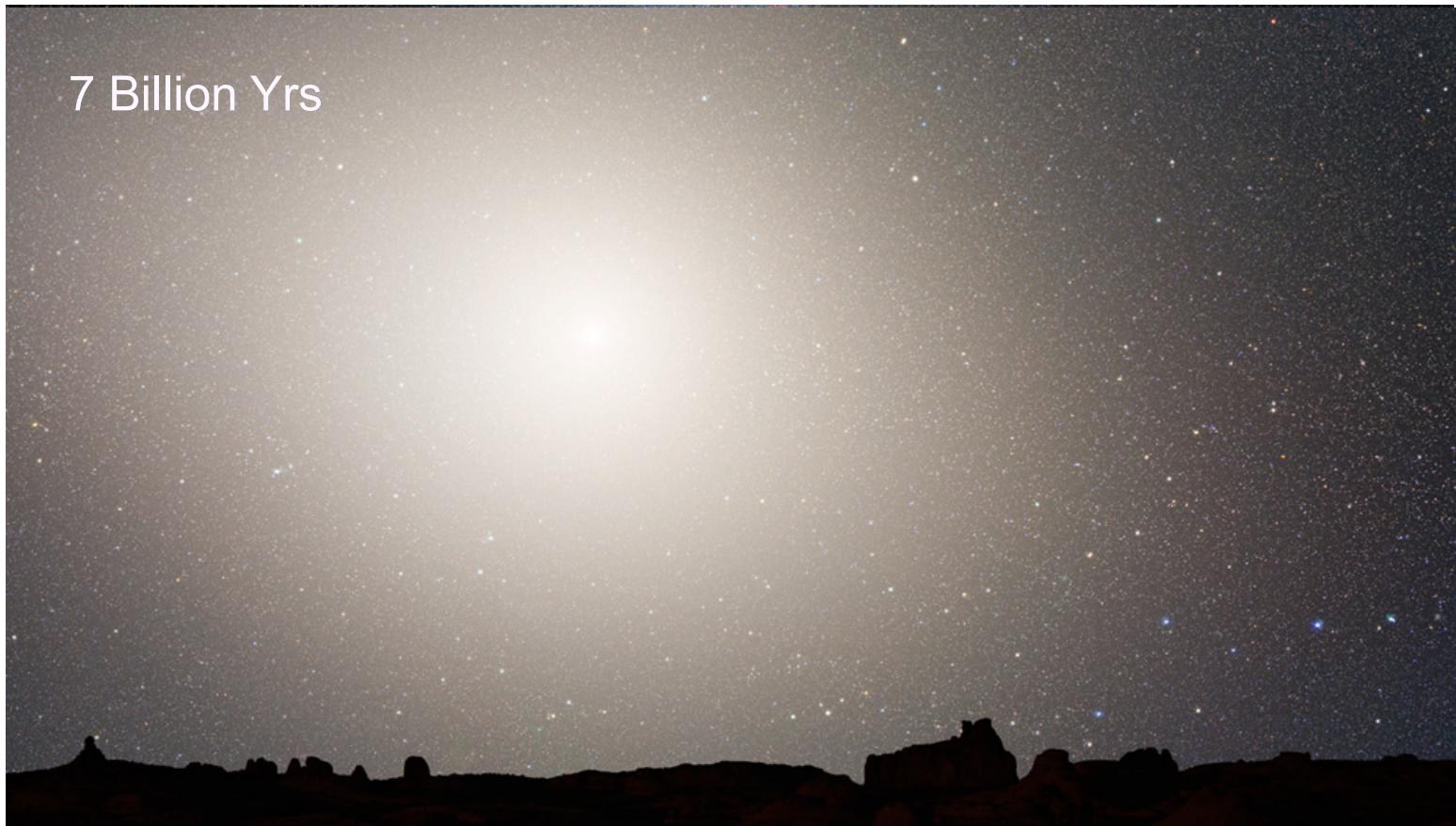


Sohn + 2012 (12 μ as accuracy) - M31 is coming straight at us!

Andromeda is heading DIRECTLY towards us!



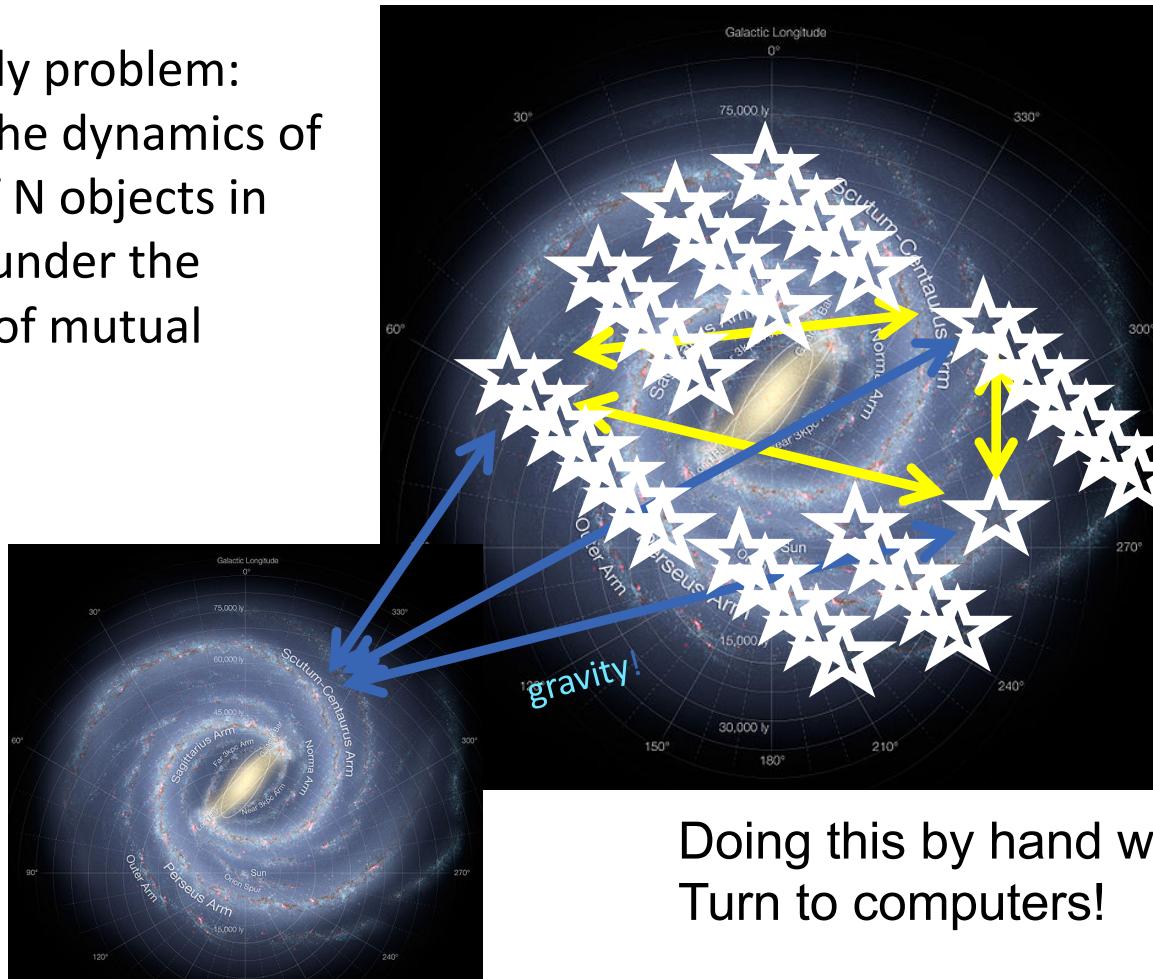
With the new M31 proper motion measurement we can predict the timing of the collision between the MW & M31: **$3.87^{+0.42}_{-0.32}$ Gyr** van der Marel,Besla+2012



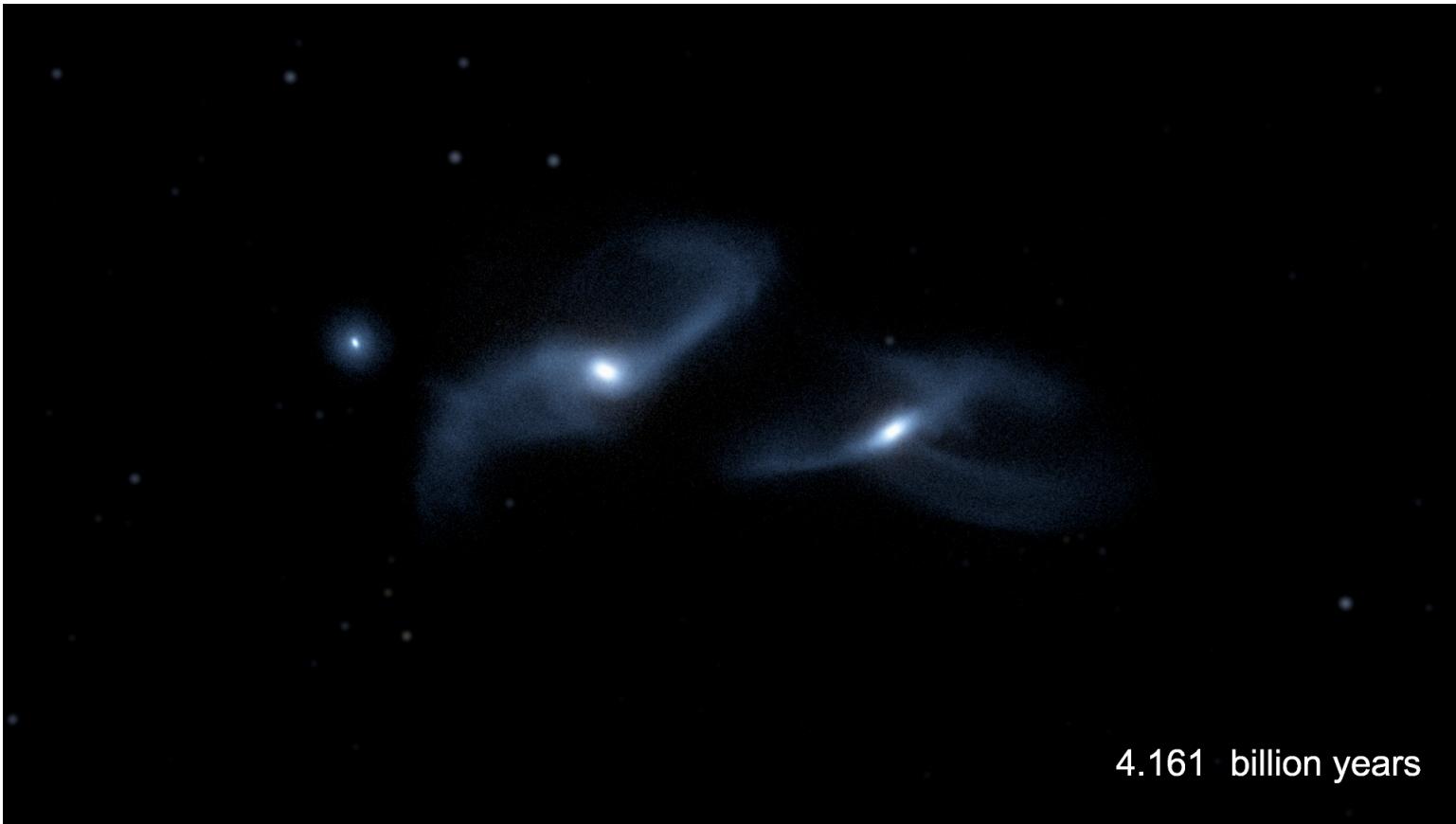
Artistic License: Z. Levay and R. van der Marel (STScI), T.Hallas, and A. Mellinger

Simulating a Galaxy Collision

The N-body problem:
solve for the dynamics of
a group of N objects in
3D space under the
influence of mutual
gravity.



Doing this by hand would suck!
Turn to computers!



4.161 billion years

Credit: Besla, Frank Summers