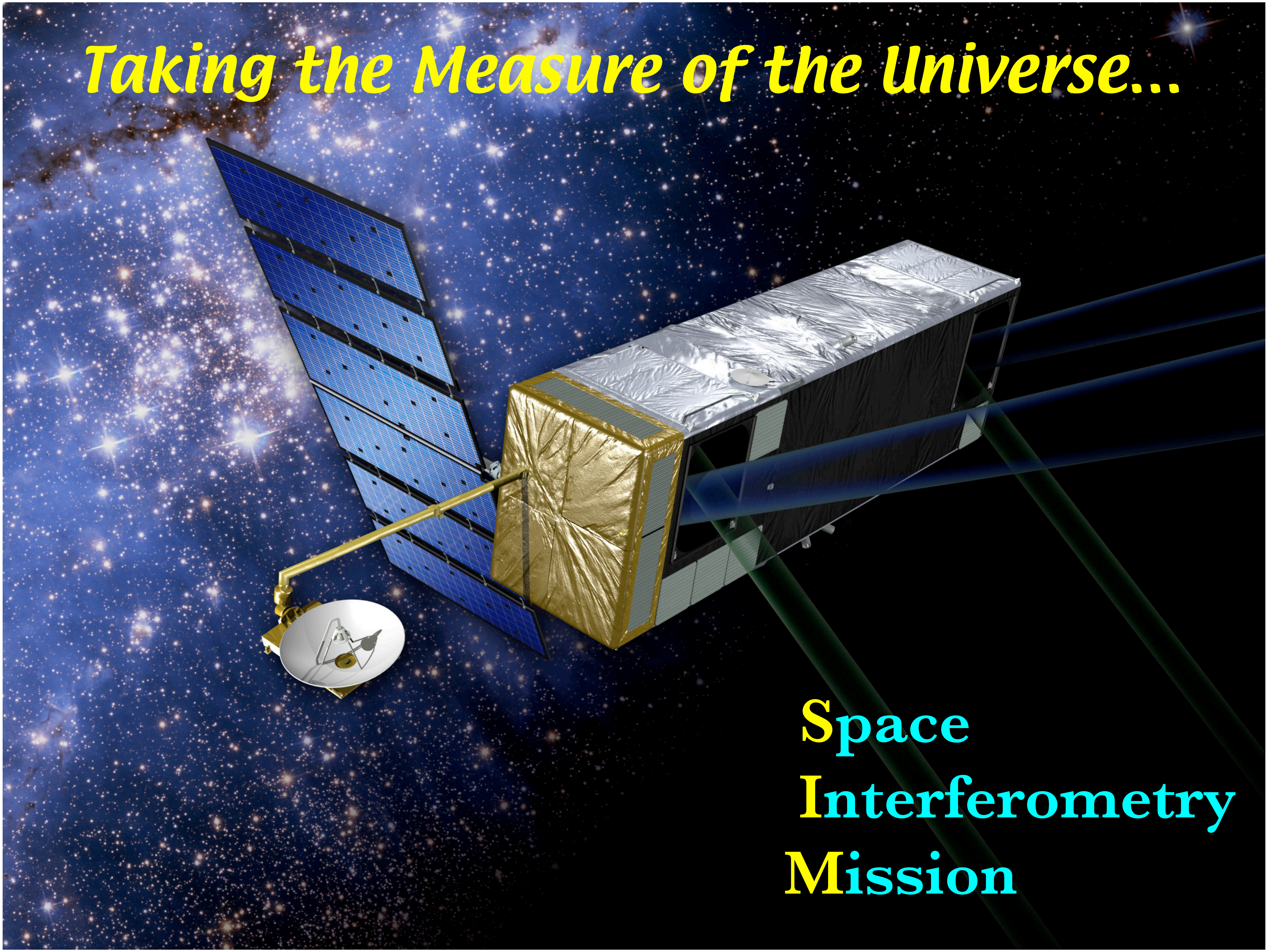

Taking the Measure of the Universe...
Space
Interferometry
Mission

A little history…

- Antiquity $\Rightarrow$ mid 1990’s
  – The “OSI - POINTS” era
- A turning point in 1996
  – The “downselect” problem
  – NASA’s policy choice
- 1996 - 2006
  – A decade of technical development
- The present day
  – Technology is even better now
  – Additional cost savings can be taken

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Interferometry
A Stellar Methodology for Space Astrophysics

AAS #211, Austin, January 2008

Ron Allen, STScI

SIM Synthesis Imaging Scientist

With contributions from Shri Kulkarni, Ed Shaya, Steve Majewski, and the JPL/SIM Project Team

Why interferometry in space?

- Obtaining substantial increases in angular resolution (or smaller Inner Working Angles) with ever-larger filled apertures in space is not sustainable.
- Ground-based radio astronomy confronted the same problem ~50 yrs ago, and moved inexorably to interferometry as the methodology of choice.

Comparisons

- Ground-based phase-stable radio interferometers currently operate routinely with baselines $>10^5\ \lambda$.
  - Interferometer arrays like the VLA are currently the workhorses of ground-based radio astronomy.
  - Phase stability $\sim\lambda/100$ routine without post-processing.
    - ALMA will provide baselines $>10^6\ \lambda$.
- SIM will demonstrate that we can do this, and even better, at optical wavelengths in space.
  - SIM will provide baselines $> 10 \times 10^6\ \lambda$.
  - Phase stability will be $> \lambda/500$.

What are we waiting for?

- Interferometry is poorly understood.
  - Too few students get the necessary training.
    - Ray-tracing and Snell's law are not enough
    - Familiarity with some Fourier optics is needed
- The scientific return of ground-based O-IR interferometers has been modest.
  - Poor (or no) phase stability.
    - Little impact on current hot astronomy topics
    - Not attractive for young astronomers
- *How do we break out of this?*

A radio astronomy paradigm?

- The development of radio interferometry in the 1950s and 60s was driven by “grand challenge” problems of the time:
  - *Cosmology;* and
  - *The nature of radio galaxies.*
- Only interferometry was capable of providing the necessary angular resolution.
- Major instruments built to attack this problem were used for a wide range of astrophysics.
  - Some became famous in different areas (e.g. WSRT).
    - Filled apertures for surveys and specialized observations.

The new “grand challenges”

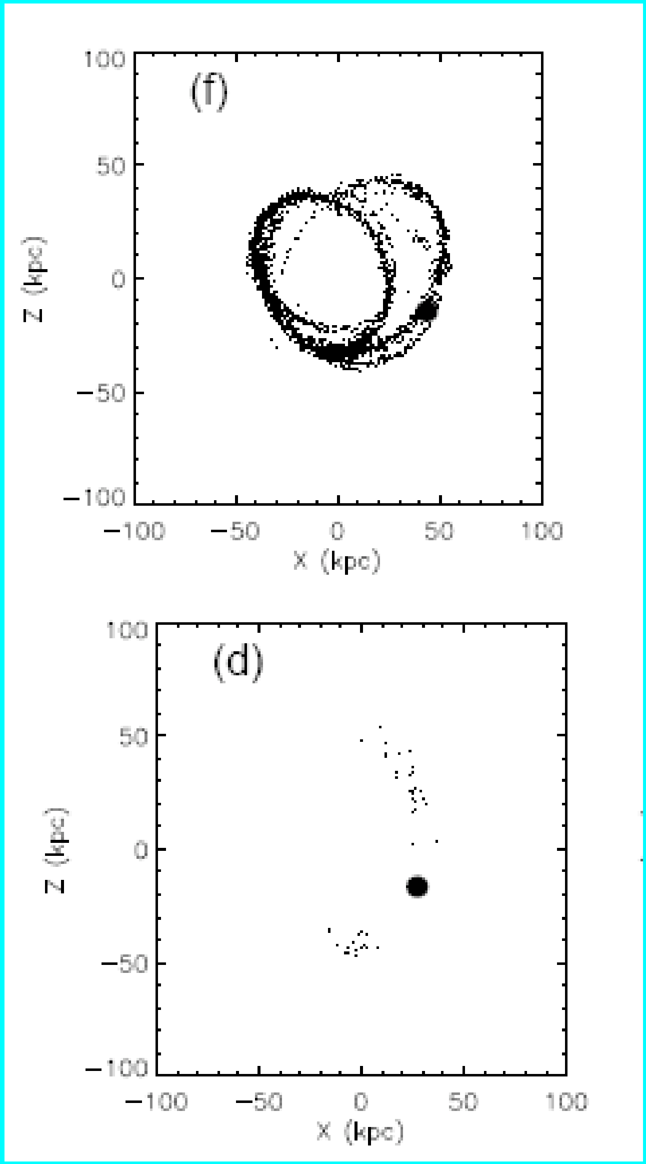
- We presently face new problems in UV-O-IR space astronomy which are arguably in the “grand challenge” class:
  - *Planetology;* and
  - *The nature of Dark Matter.*
- Present instrumentation can not provide either the required precision for astrometry, or the required angular resolution for imaging.
  - *SIM will demonstrate the basic interferometric techniques required to attack these problems at the appropriate wavelengths.*

Taking the measure of the Universe

- A personal favorite: *dark matter*
  - How is it distributed?
    - Measuring the proper motions of Local Group galaxies provides information on the structure of the dark matter on Megaparsec scales.
  - Is it hot, only warm, or is it cold?
    - Measuring the proper motions of stars in a nearby dwarf spheroidal galaxy gives information on the "temperature" of the dark matter.

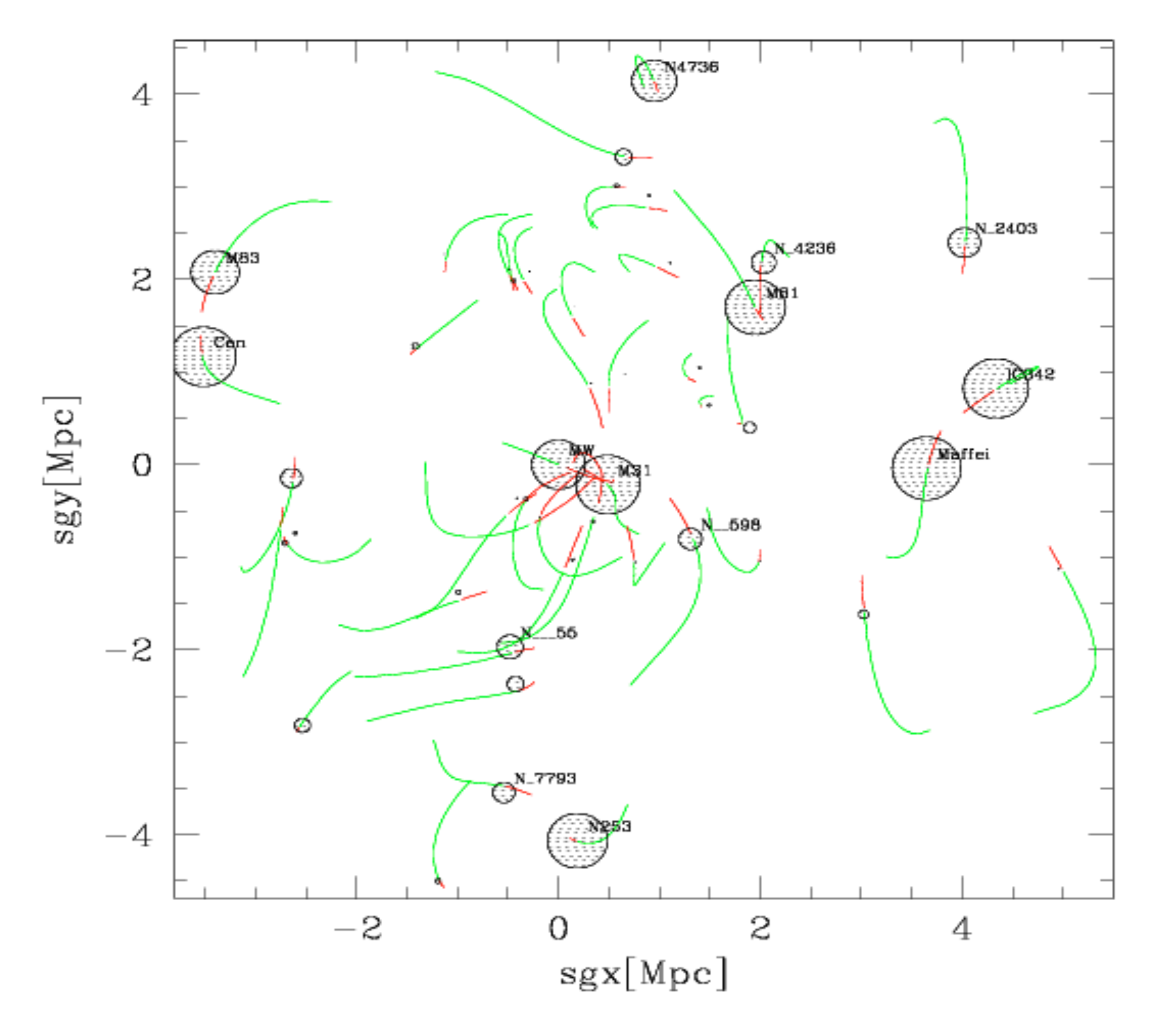
Dark Matter in the Galaxy

- Tidal Tails (smooth streams of stars)
  - Measure: **distances**, **proper motions**, radial velocities, and positions.
    - Sgr needs 100 μas/yr, but others need 10.
  - Calculate orbits with constraint that all of the stars started as a single system.
  - Detemine mass and moments of mass of Galaxy. 1% error on circular speed at Solar Circle. Flattening of Dark Matter halo. Determine substructure in the halo.
  - 2 GCs (Pal 5 and NGC 5466) and several dSph have tidal tails.



Nearby galaxy trajectories

- Measure proper motions of nearby LG galaxies over mission lifetime.
- Develop consistent model of the total mass distribution.
- Obtain total mass, total M/L ratio, constraints on hot dark matter density, and history of group formation.



DM in Dwarf Spheroidals

- Constrain dark matter particle mass.
  - Cold/massive particles create matter cusp.
  - Warm/lighter particles create matter core.
- To determine slope of dark matter density profile, we need to measure velocity anisotropy of stars.
  - Require p.m. error of 7 km/s on 200 stars/galaxy to reach 0.1 error on profile log-slope.
  - Roughly 15 μas/yr measurements at 19th mag.
  - Candidates: Sculptor (too close?), Draco, Ursa Minor, Sextans and Bootes

In conclusion …

- Addressing current “grand challenge” problems in UV-O-IR space astrophysics requires the development of phase-stable, scaleable, precision interferometry.
  - Future imagers will be constellations of collectors arranged into arrays of such interferometers.
- SIM is just such an interferometer.
- *SIM will demonstrate routine, long-term operation of the required technology in space.*

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  - Future imagers will be constellations of collectors arranged into arrays of such interferometers.
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- *SIM will demonstrate routine, long-term operation of the required technology in space.*
- **SIM will change the paradigm.**