Agenda - Day 1 (1 of 2)

Item	Presenter	Time
Introduction	K. Johnston	8:30 – 8:45
Mission Overview		
FAME Science Requirements	K. Seidelmann	8:45 – 9:15
Mission Overview/Timeline	M. Johnson	9:15 – 9:45
Pre-Phase B Status	M. Johnson	9:45 – 10:00
Programmatics		9:45 – 10:15
Top Level Org. Chart	M. Johnson	
FAME Master Schedules	M. Johnson	10:15 – 10:30
Phase B / FY01 Plans	M. Johnson	
Break		10:30 – 10:45
Mission Requirements		
Top Level Requirements (Including Mission Assurance Requirements)	M. Johnson	10:45 – 11:15
Documentation Deliverables	M. Johnson	11:15 – 11:30
Error Budget	K. Johnston	11:30 – 12:15
Lunch		12:15 – 1:15

Agenda - Day 1 (2 of 2)

Item	Presenter	Time
Instrument Description		
Overview (Including Organization Chart)	R. Vassar	1:15 – 1:30
Optics	L. Huff	1:30 – 2:00
CCDs	E. Aamodt	2:00 – 2:15
Structures	P. Dineen / L. Sokolsky	2:15 – 2:45
Thermal	D. Read	2:45 – 3:00
Break		3:00 – 3:15
Electronics	E. Aamodt	3:15 – 3:30
Flight Software / Processing	E. Aamodt	3:30 – 3:45
EGSE	E. Aamodt	3:45 – 3.55
Ground Software	E. Aamodt	3:55 – 4:05
MGSE	P. Dineen	4:05 – 4:15
Building A59 Tour	J. Hauser	4:15 – 5:15
Reception / Quarters A		6:00 – 7:30

Agenda - Day 2 (1 of 2)

Item	Presenter	Time
Spacecraft Bus Description		
Overview (Including Organization Chart)	M. Johnson	8:30 – 8:45
ADCS	P. DeLaHunt / T. Lim	8:45 – 9:15
RCS	M. Osborn	9:15 – 9:30
Structures	R. Mader	9:30 – 9:45
Mechanisms	S. Koss	9:45 – 10:00
Thermal	J. Kim	10:00 – 10:15
MAGE	S. Chappie	10:15 – 10:30
Break		10:30 – 10:45
EPS	R. Ruth	10:45 – 11:00
RF	E. Becker	11:00 – 11:15
CT & DH	K. Clark	11:15 – 11:30
Flight Software	M. Hayden	11:30 – 11:45
EAGE	P. Jaffe	11:45 – 12:00
Ground Software	J. Johnson	12:00 – 12:15
Lunch		12:15 – 1:15

Agenda - Day 2 (2 of 2)

Item	Presenter	Time
Spacecraft Bus to Instrument Interfaces		1:15 – 1:45
Mechanical	R. Mader / P. Dineen	
Thermal	R. Mader / D. Read	
Grounding	C. Garner / E. Aamodt	
Power	C. Garner / E. Aamodt	
Command/Telemetry	C. Garner / E. Aamodt	
Mission Data	C. Garner / S. Horner	
Launch Vehicle (Including Interfaces)	R. Contillo	1:45 – 2:00
Operations		
Mission Operations Overview	P. Klein	2:00 – 2:30
Orbit Determination	A. Hope	2:30 – 2:45
Science Operations (USNO)	R. Gaume	2:45 – 3:00
Science Data Processing	R. Gaume	3:00 – 3:15
Break		3:15 – 3:45
Closing Comments / Action Items	K. Johnston / M. Johnson	3:45 – 4:30

Introduction

Ken Johnston
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USNO
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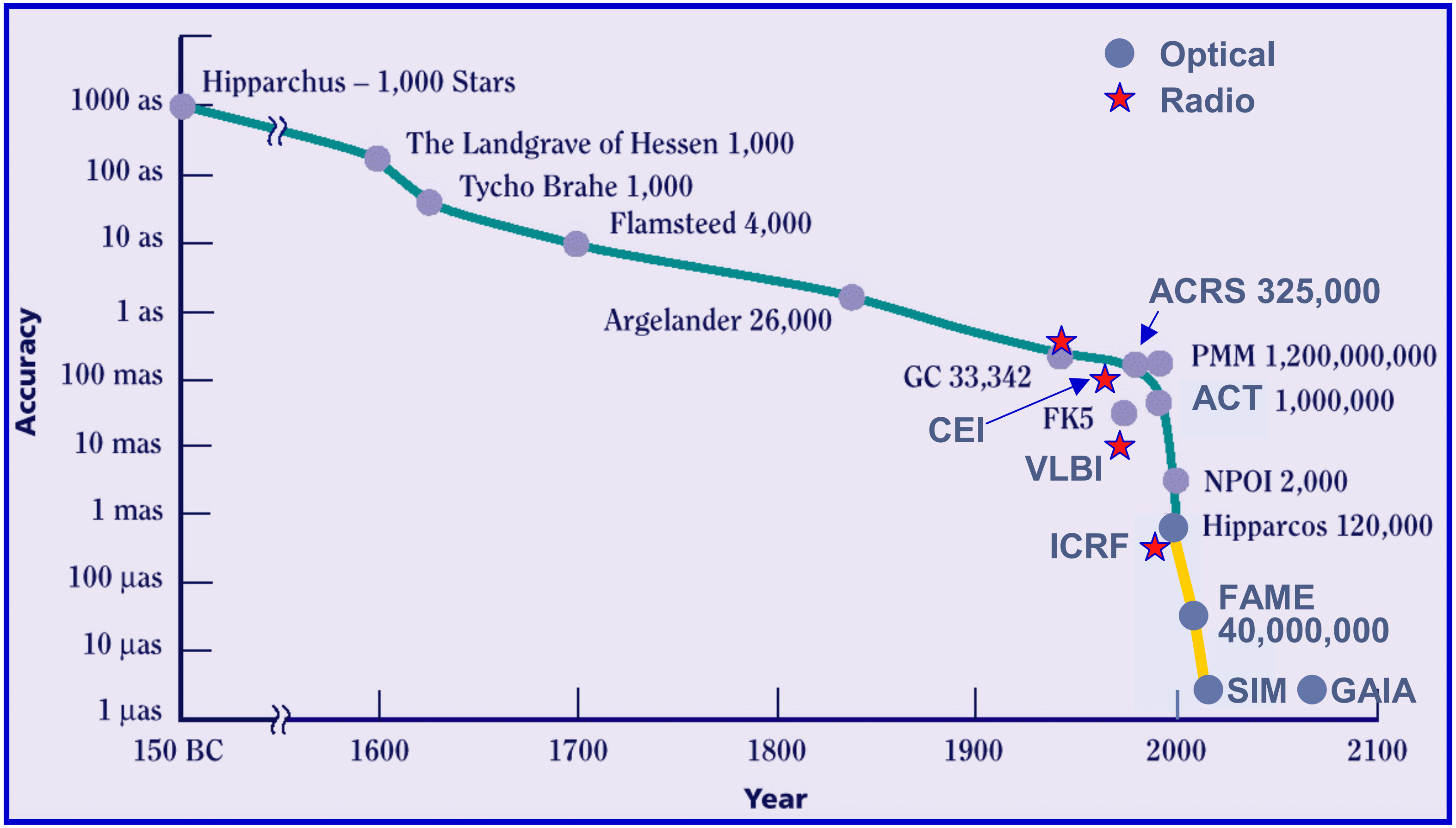
The Golden Age of Astrometry



Phase A Concept

Full-sky Astrometric Mapping Explorer

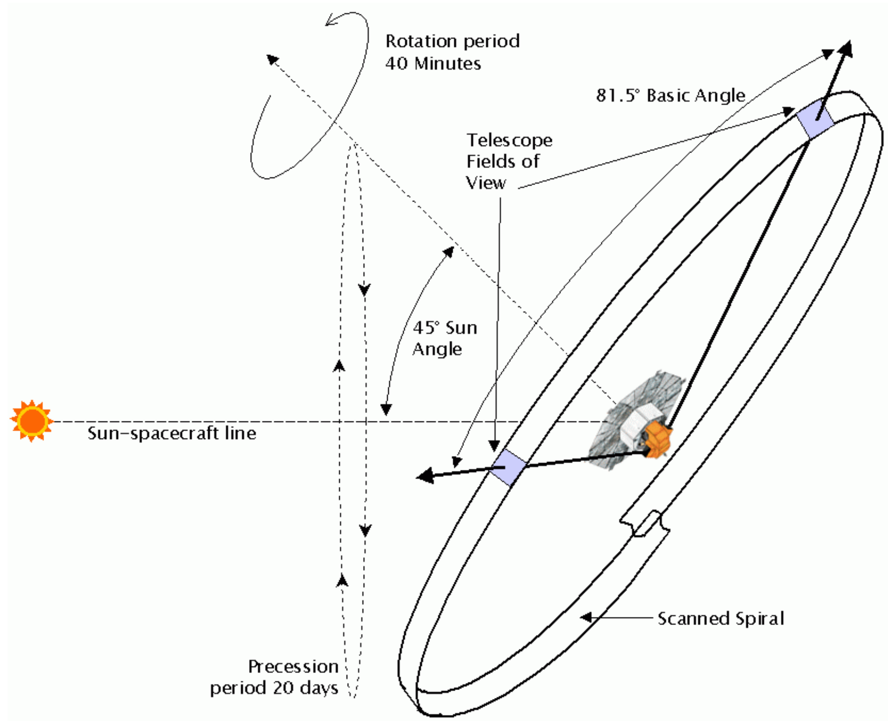
- **United States Naval Observatory**
  - **PI, Oversight of Science and Budget, MO&DA Lead, GDS, MOC, & SOC Development and Implementation, E/PO Lead**
- **Naval Research Laboratory**
  - **PM, System Engineering, S/C Bus Development, Integration, and Test, Comprehensive Testing**
- **Lockheed Martin Missiles and Space**
  - **Instrument Design, Fabrication, Testing, and Support**
- **Smithsonian Astrophysical Observatory**
  - **PS, Synthesis and Verification of Scientific Measurement System, E/PO Support**

Technical Goals and Objectives of FAME

- **FAME Will Perform an All Sky, Astrometric Survey With Unprecedented Accuracy**
  - **Upgrades Existing Star Catalogs by Providing a Precision Catalog of $4x10^7$ Stars**
  - **Provides Positions of Bright Stars (5<mv<9) to <50μas**
  - **Provides Positions of Fainter Stars (9<mv<15) to <500μas**
  - **5 Year Extended Mission Allows for Accurate Measurement of Stellar Parallax, Proper Motions, and Monitoring of Stellar Variability**
  - **Photometric Data in Four Sloan DSS Bands (G', R', I', Z')**

FAME Mission Description

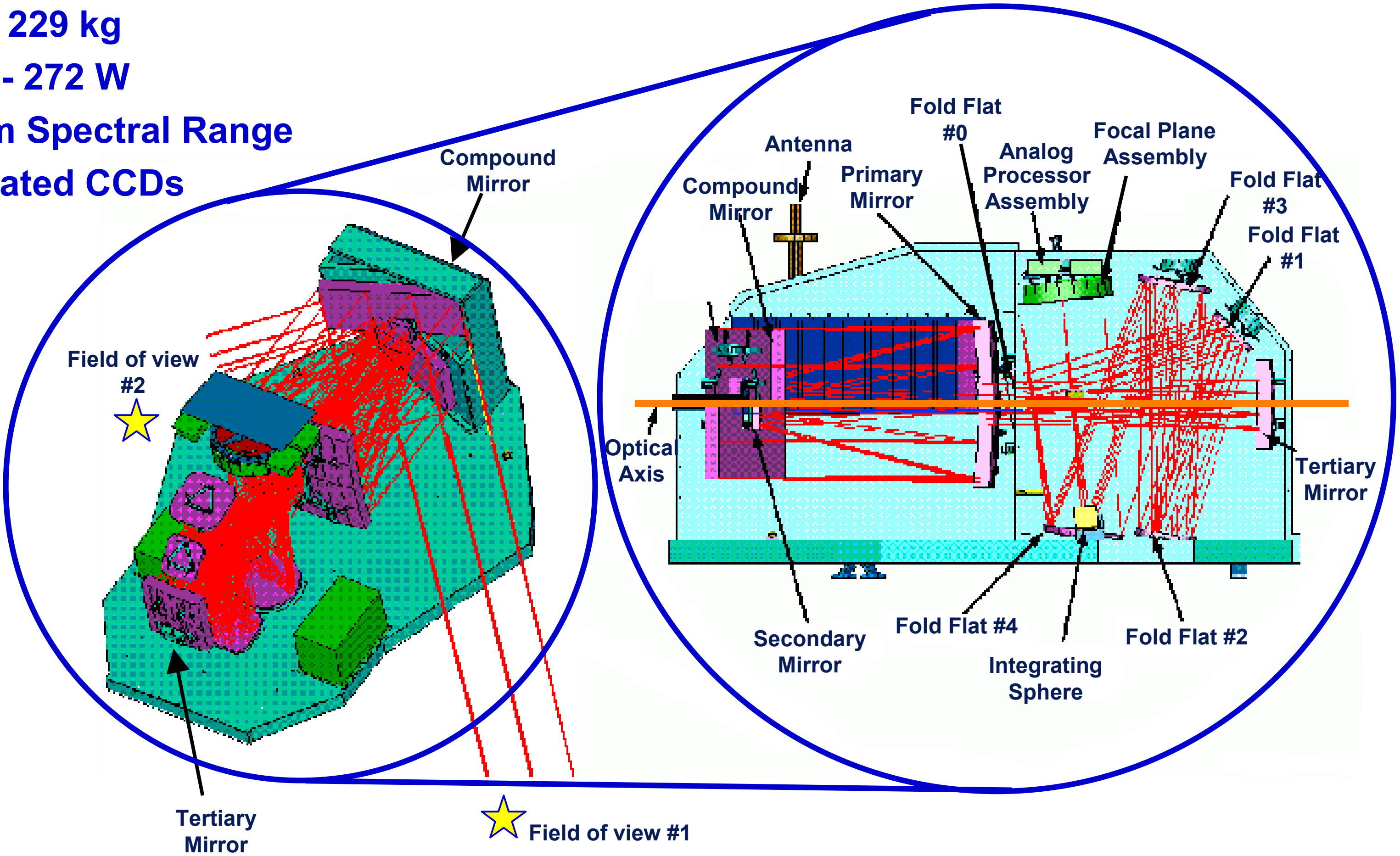
- The Telescope Has Two Fields-of-View Separated by an 81.5° Basic Angle
- The Spacecraft Will Rotate With a 40 Minute Period With the Apertures Sweeping Out a Great Circle on the Sky
- The Spacecraft Rotation Axis Is at a 45° Angle to the Sun
- The Solar Radiation Pressure on the Solar Shield Results in Precession About the Sun-Spacecraft Line With a 20 Day Period
- The Spacecraft Is in Geosychronous Orbit for Continuous Contact



- The FAME Observing Concept
  - The Axis of the FAME Spacecraft Is Pointed 45° From the Sun and Precesses Around the Sun With a 20 Day Period
  - The FAME Spacecraft Rotates With a 40 Minute Period
  - The Two Fields of View Are Normal to the Rotation Axis and Are Separated by an 81.5° Degree Basic Angle

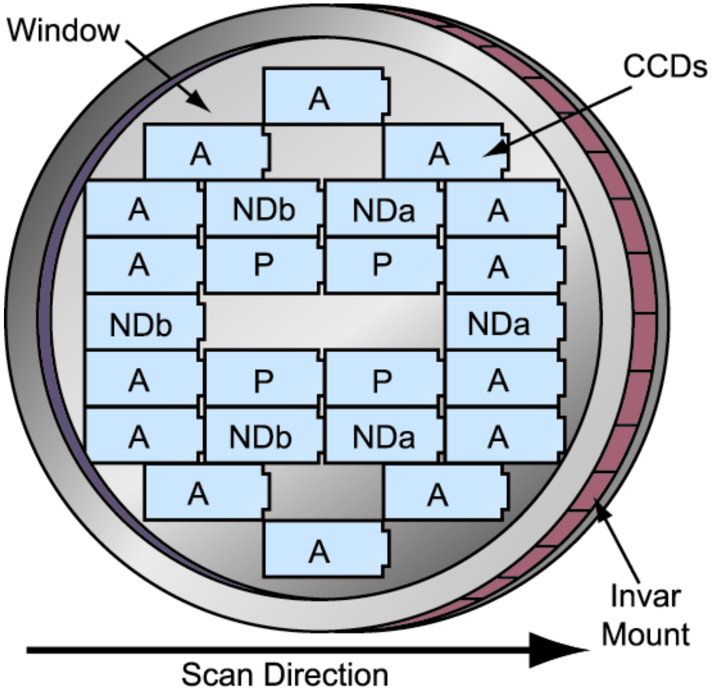
FAME Instrument Description

- Two Input Apertures
- 60×25 cm Aperture Size (Each)
- Total mass - 229 kg
- Total Power - 272 W
- 400 to 900nm Spectral Range
- Back Illuminated CCDs



Instrument developed by Lockheed Martin Missiles and Space ATC

FAME Instrument Description



- The FAME Focal Plane
  - 24 2k·4k CCDs Arranged Around a 1.1° Diameter Field of View
  - Devices Marked With ‘P’ Are the 4 Photometric CCDs and Devices Marked With ‘A’ Are the 20 Astrometric CCDs
  - The 6 Devices Marked With ‘ND’ Have Neutral Density Filters for Astrometry of Brighter Stars

- Telescope Produces Images of Stars Using 24 Large Format CCDs
  - Images of Stars Are Continually Traversing CCD Array As the Spacecraft Rotates
  - CCDs Use Time Delay Integration
  - Synchronization of CCD Clock Rate and Image Motion Is Assured Via Rotation Rate Sensors
  - Star Images Are Time Tagged, Windowed, and Transmitted to Earth
  - 6 CCDs Are Covered by Neutral Density Filters for Astrometry of Bright Stars

Fame Error Sources

- CCD Characteristics
  - Read Noise, QE Variation, etc.
- Instrument Alignment
  - PSF Variations
- Instrument Stability
  - Thermal Effects
- Spacecraft
  - Knowledge of Spacecraft Velocity
- Stellar/External
  - Photon Statistics

FAME Estimated Error Budget

Error Source	Error (μas) a Priori	Error (μas) a Posteriori
Photon Statistics m_V=9 m_V=15	 540 10800	 540 10800
Read Noise ($7e^-$ rms, m_V=9)	6600	6600
QE Variation	560	<10
λ-Dependent Absorption in CCD	300	30
Charge Transfer Effects	800	80
Incorrect Stellar Spectrum Model	4000	50
Undetected Companions	60	60
Onboard Clock Error	<100	<1
Telescope Geometry Variations	100	<10
Optical Distortion	2000	20
Refraction in CCD Window	1	<1
Rotation Rate Changes	10^6	25
Ephemeris (1cm/sec Knowledge)	7	<1

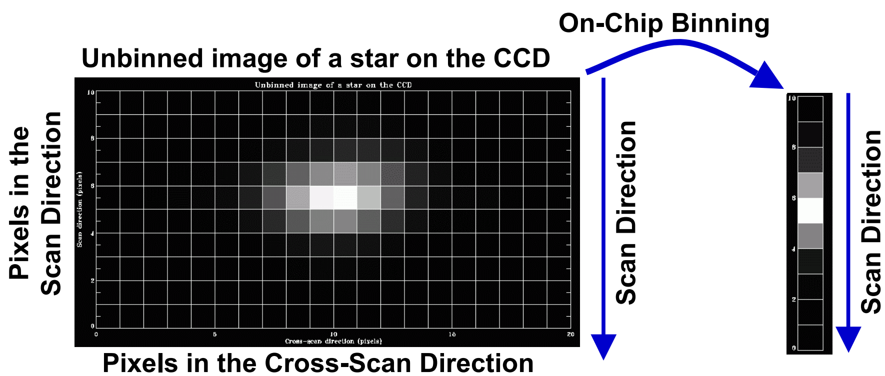
FAME Estimated Error Budget Totals

Visual Magnitude (m_V)	ND Filter Accuracy* (μas)	Gated Array Accuracy* (μas)
5	49	14
7	49	14
9	24	14
11	56	28
13	146	70
15	443	208

*Assumes Systematic Error Contribution Is 10 μas

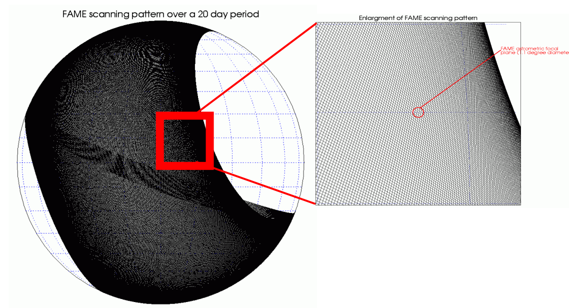
- The FAME Accuracy
  - The Predicted Accuracy of FAME As a Function of Visual Magnitude (Mv)
  - The Second Column Shows the Accuracy If Neutral Density Filters Over 3 of the Astrometric CCDs Are Used for Astrometry of the Brighter Stars (Baseline Design)
  - The Third Column Shows the Accuracy If the CCDs Are Only Integrating During Part of the Time When a Bright Star Is Traversing the Device (Alternate Design)

On-Board Data Processing



- The Data From Most Stars Are Binned by 20 in the Cross-Scan Direction on the CCD Before Being Read-Out

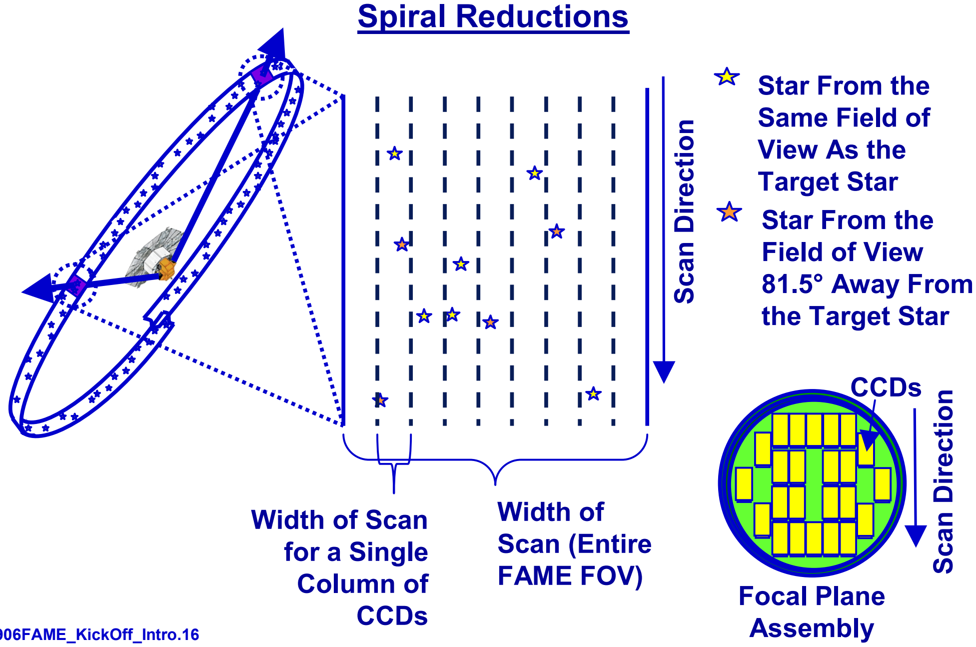
Sphere Reconstruction



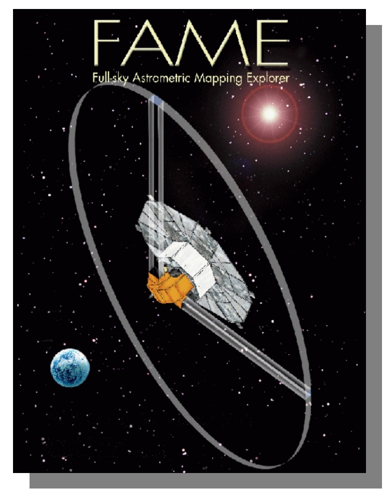
FAME Scan Pattern - The FAME Spacecraft Rotates With a 40 Minute Period Scanning the Two Apertures Across a Great Circle on the Sky. The 20 Day Precession of the Spacecraft About the Sun-spacecraft Line Results in FAME Covering the Entire Sky Except for Exclusion Zones Within 45° of the Sun and the Anti-sun Direction Every 20 Days.

- Use a Subset of the Stars to Globally Tie the Spirals Together Into a Sphere

Spiral Reductions

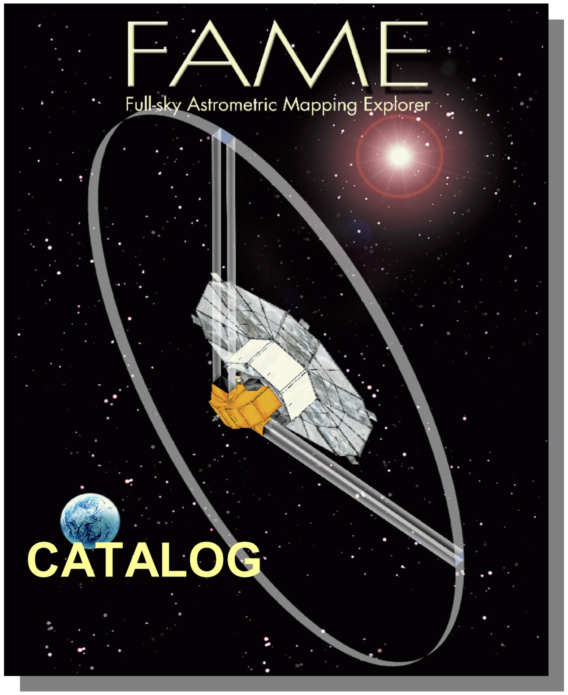


Catalog



FAME Catalog

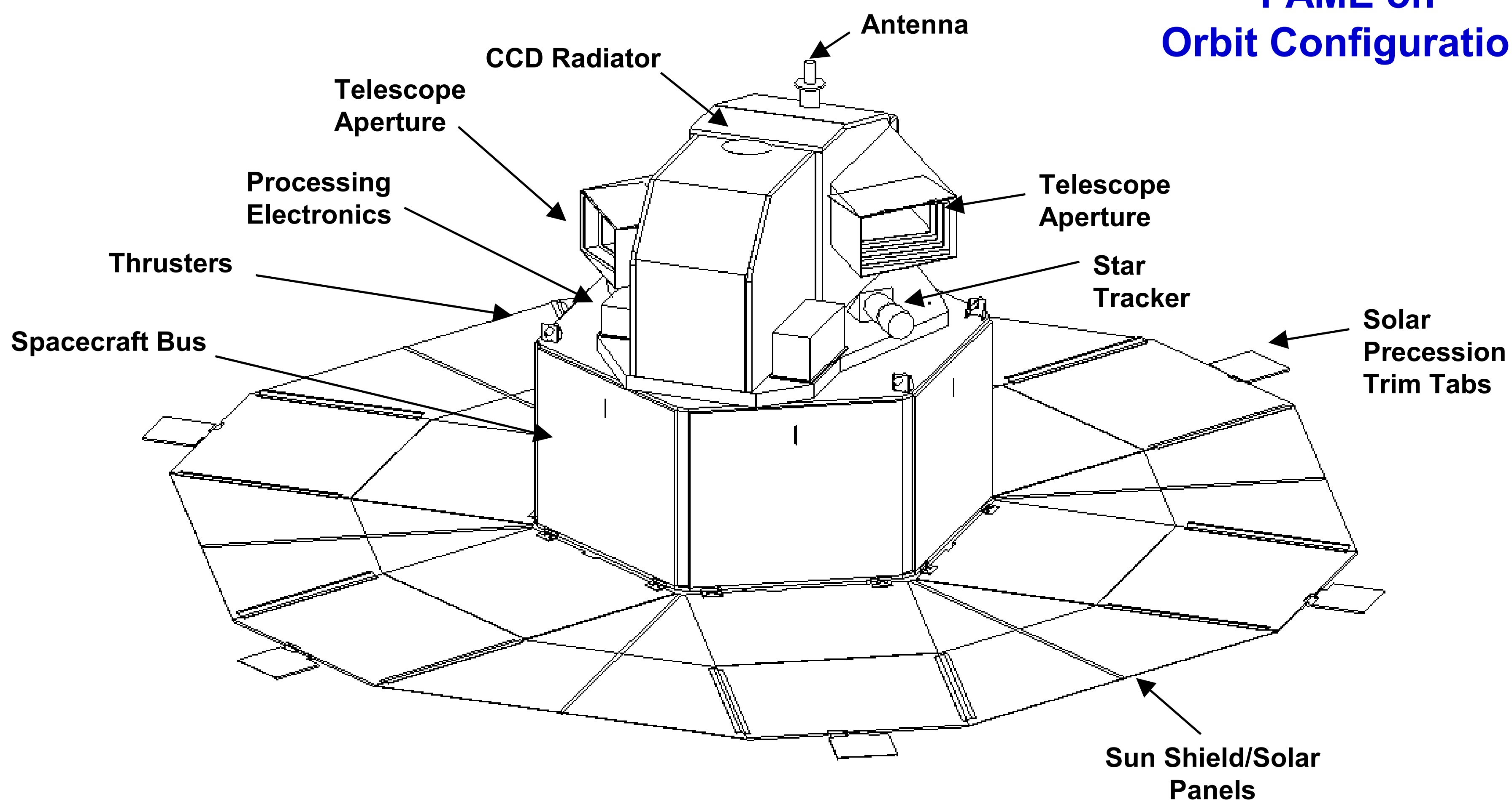
- Catalog Available 3½ Years After Launch
- Complete Catalog From the Extended Mission Available 6 Years After Launch
- 90-95% of FAME Customers Will Want the Complete Catalog With Nominal Positions, Parallaxes, Proper Motions, and Photometry
- The Other 5-10% Will Be Interested in Variations of a Subset of the Catalog Over Time



The Study of Fundamental Properties of a Large Sample of Stars Is Needed to Answer Many Key Astrophysical Questions

FAME Spacecraft

FAME on Orbit Configuration



Spacecraft Design Uses Component Heritage From *Clementine*

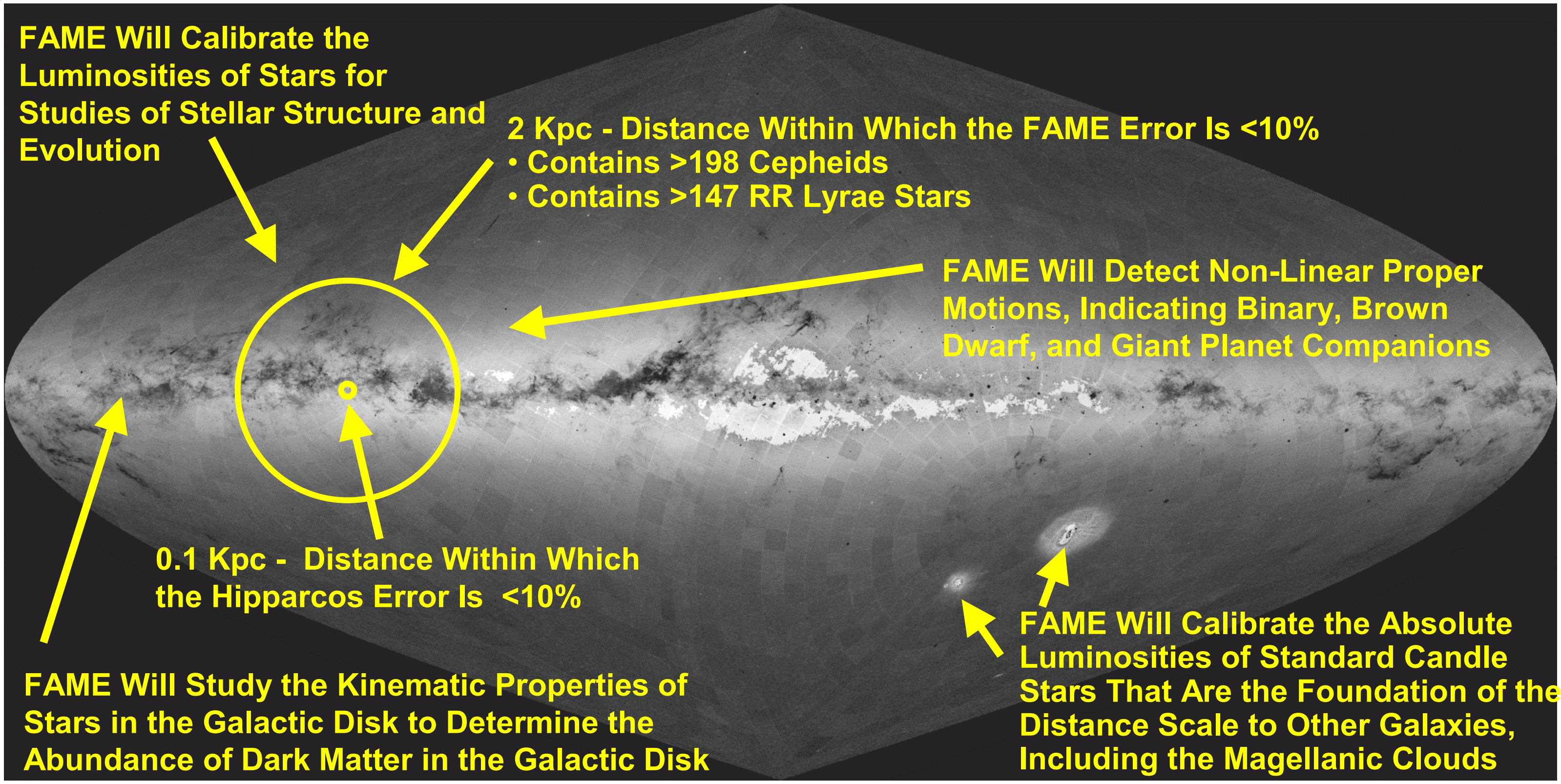
FAME Schedule

- Phase A Concept Study
  - February - June 1999
- Phase B
  - September 2000 - June 2001
- Phase C
  - July 2001 - March 2002
- Phase D
  - April 2002 - June 2004
- Launch
  - June 2004
- Phase E
  - July 2004 - January 2008
- DoD Extended Mission
  - January 2007 - July 2010

Most Important Science Result

- FAME Opens up a New Dimension in Stellar Astrophysics
- Stellar Evolution and Structure
  - Calibration of Absolute Luminosities
- Extragalactic Distance Scale:
  - Determine Distances to "Standard Candle" Stars Which Are Fundamental in Defining Distance Scales
- Measure the Distance to the Magellanic Clouds to 2% Accuracy
- Determine the Abundance of Dark Matter in the Galactic Disk
- Discover Brown Dwarfs and Giant Planet Companions
- Statistically Determine the Level of Optical Variations in Solar Type Stars

FAME Coverage of the Milky Way



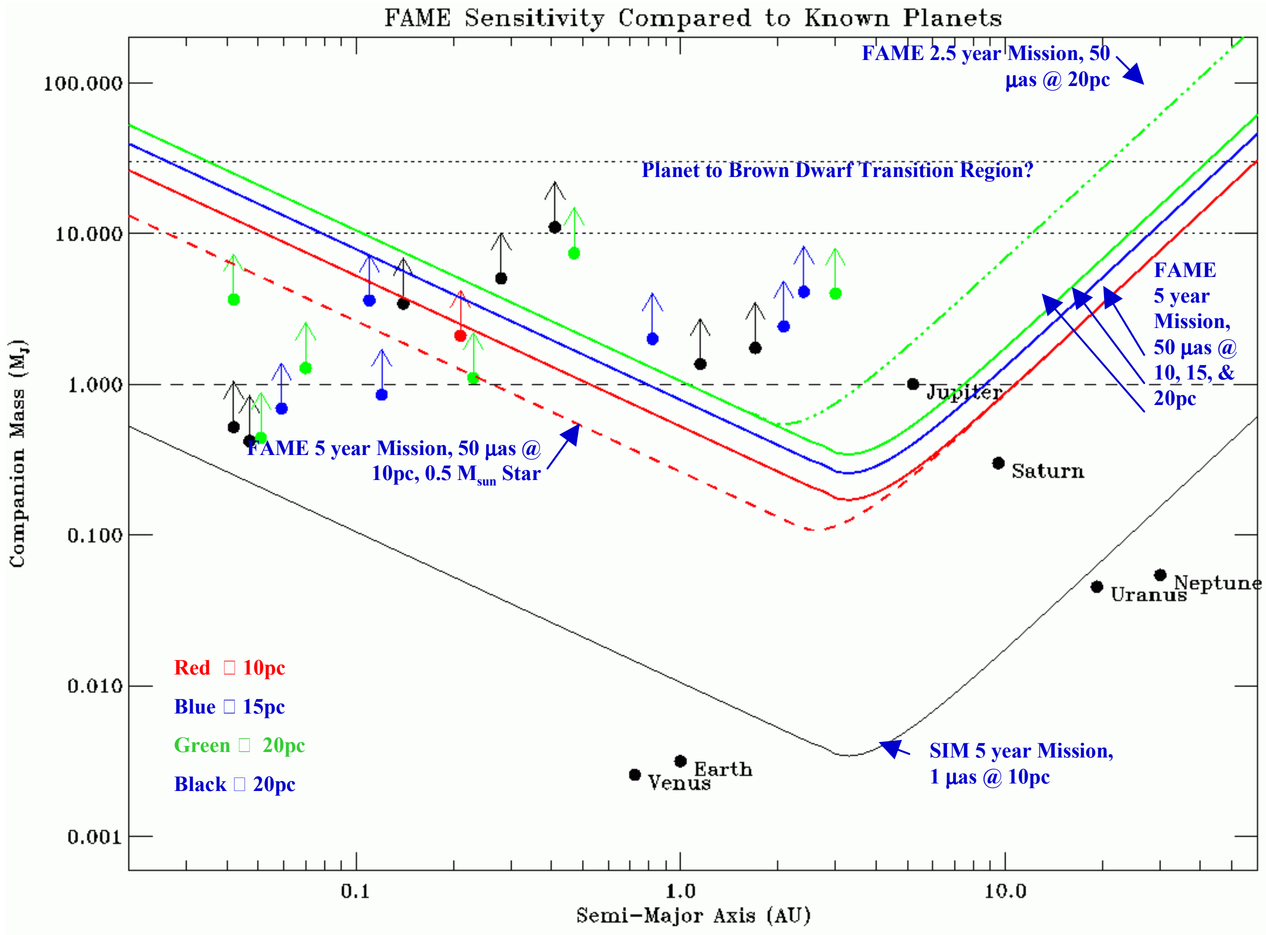
- **FAME Science**
  - FAME Will Map Our Quadrant of the Galaxy Out to 2 Kpc From the Sun Providing the Information Needed to Calibrate the Standard Candles That Define the Extragalactic Distance Scale, Calibrate the Absolute Luminosities of Stars of All Spectral Types for Studies of Stellar Structure and Evolution, and Detect Orbital Motions Caused by Brown Dwarfs and Giant Planets
  - FAME Will Not Only Improve on the Accuracies of Star Positions Determined by Hipparcos but Also Expand the Volume of Space for Which Accurate Positions Are Known by a Factor of 8,000

Astronomical Search for Origins and Planetary Systems (ASO)

- **Detect Hundreds of Sub-Stellar Companions of Solar Type Stars**
- **Determine the Inclinations and Thus the Masses of Known Exoplanets Detected by Radial Velocity Techniques**
- **Determine the Frequency of Solar-Type Stars Orbited by Brown Dwarf Companions in the Mass Range of 10 to 80 M_{jup} With Orbital Periods up to Twice the Duration of the FAME Mission**
- **Explore the Transition Region Between Brown Dwarfs and Giant Planets, Which Appears to Be in the Range of 10 to 30 M_{jup}**
- **Identify Interesting Targets for SIM and TPF**

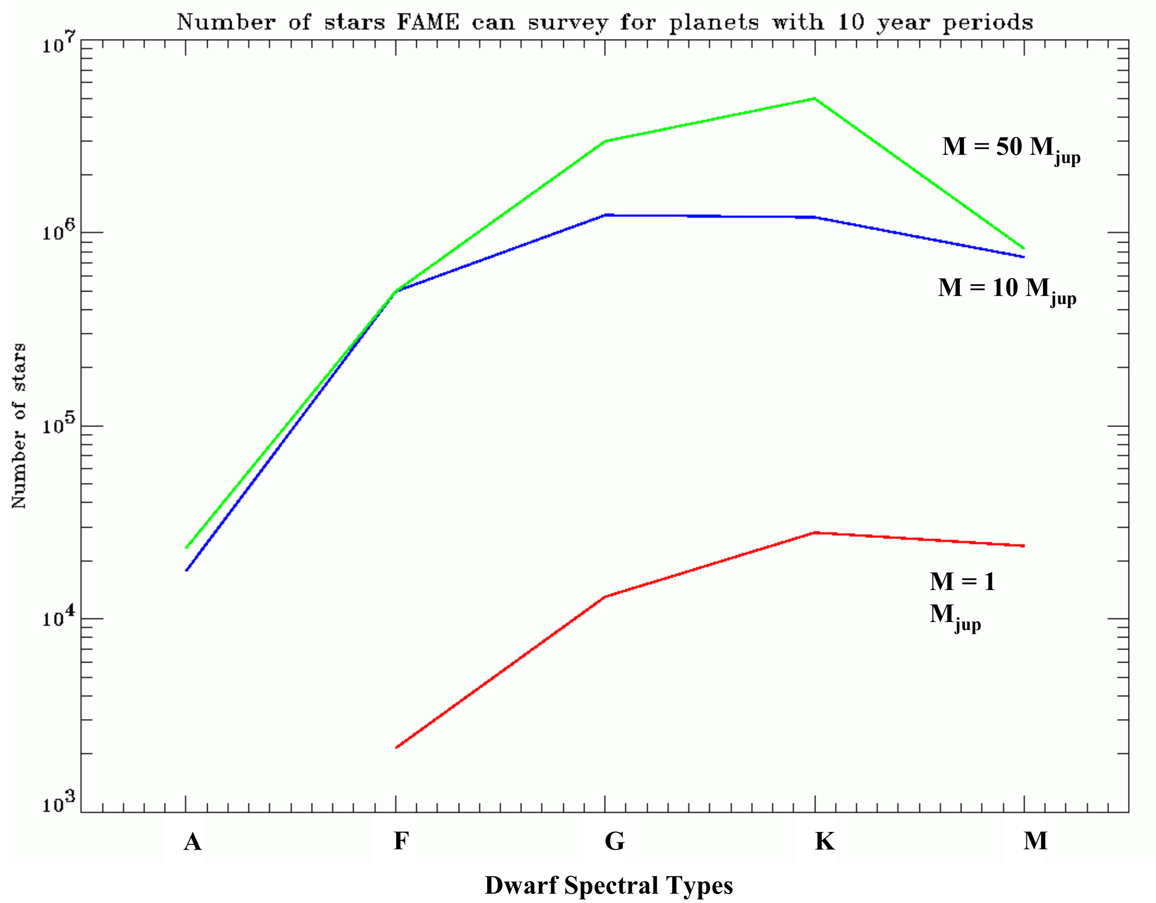
FAME Planet Detection Sensitivity

- **FAME Planet Detection Sensitivity**
  - The Precision of FAME Is Compared to the Known Exoplanets and the SIM Predicted Precision
  - The Masses of the Known Planets Are Minimums Because the Inclination of the Systems Are Unknown
  - The Points and Arrows Are Color Coded to Indicate the Approximate Distance of the System
  - The FAME Sensitivities Are Plotted for Stars at 10 (Red), 15 (Blue), and 20 Parsecs (Green) for a Host Star Mass of 1.0 Msun
  - The Dash-Dot Green Line Is for the Case of a 2.5 Year FAME Mission, and the Dashed Red Line Is for a Host Star Mass of 0.5 Msun



FAME Planet Survey

- **FAME Planet Survey**
  - **FAME Will Survey a Substantial Number of Stars for Giant Planets, Giving a Statistically Significant Sample of Giant Planet Masses and Frequency of Planet Formation**
  - **This Figure Shows the Number of Stars Within the Precision Range of FAME That Can Be Sampled for the Given Main Sequence Spectral Types**
  - **This Figure Assumes a 10 Year Orbital Period for the Planet**



Stellar Evolution

- Calibrate the Absolute Luminosities of Solar Neighborhood Stars
  - Population I
  - Population II
- Enable Diverse Studies of Stellar and Galactic Evolution
- Determine Distances and Ages of Galactic Open and Globular Clusters Using the Determined Absolute Luminosities
- Resolve the Discrepancy in Distances to the Pleiades and Other Open Clusters

Open Clusters Are Key to Testing Stellar Theory

- Theorists Estimate Their Models Are Uncertain at the 0.02 Mag. Level, but Disagree With One Another at the 0.04 Mag. Level
- FAME Will Determine the Distances to All Clusters Within 200pc to 1% or Better
  - Nearby Clusters - FAME Will Measure Distances to Individual Stars to Take Out Depth Effects
  - More Distant Clusters - FAME Will Determine Relative Depths of Stars From Differences in Proper Motions

Cluster	~Distance, d (pc)	Transverse Velocity, V_t (km/s)	Velocity Dispersion, V_d (m/s)	Radius (Degrees)	$\frac{Vd}{Vt}$	$\frac{300\ \mu as/yr}{Vt/d}$
Hyades	46	25	330	2	1.3%	0.3%
Pleiades	130	30	700	2	2.3%	0.6%
α Per	180	35		2		0.7%
Preasepe	180	33	600?	4	1.8%	0.8%
Coma	80	6	300	3	5.0%	1.9%
Ursa Major	20	11		20		0.3%
IC 2391	145					
IC 2602	145					

The Sun-Earth Connection (SEC)

- By Monitoring ~40,000 Solar-Type Stars for 5 Years, FAME Can Dramatically Increase the Number of Solar-Type Stars Available for Accurate Variability Studies by a Factor of 100, FAME Can:
  - Sample Long-Term Behavior of Solar-Type Stars, With Possible Implications for Climate Changes or Conditions Inimical to Life
  - Search for Evidence of Magnetic Activity Cycles Analogous to the 11 Year Solar Activity Cycle
- Sample the Activity Cycles of Other Solar-Type Stars So We Can Put the Sun's Activity Level in the Context of Other, Similar Stars
- Identify and Categorize a Large Number of Variable Stars

Precise Photometric Survey for Magnetic Cycle Variability

Expected Photometric Uncertainty (Single Observation)

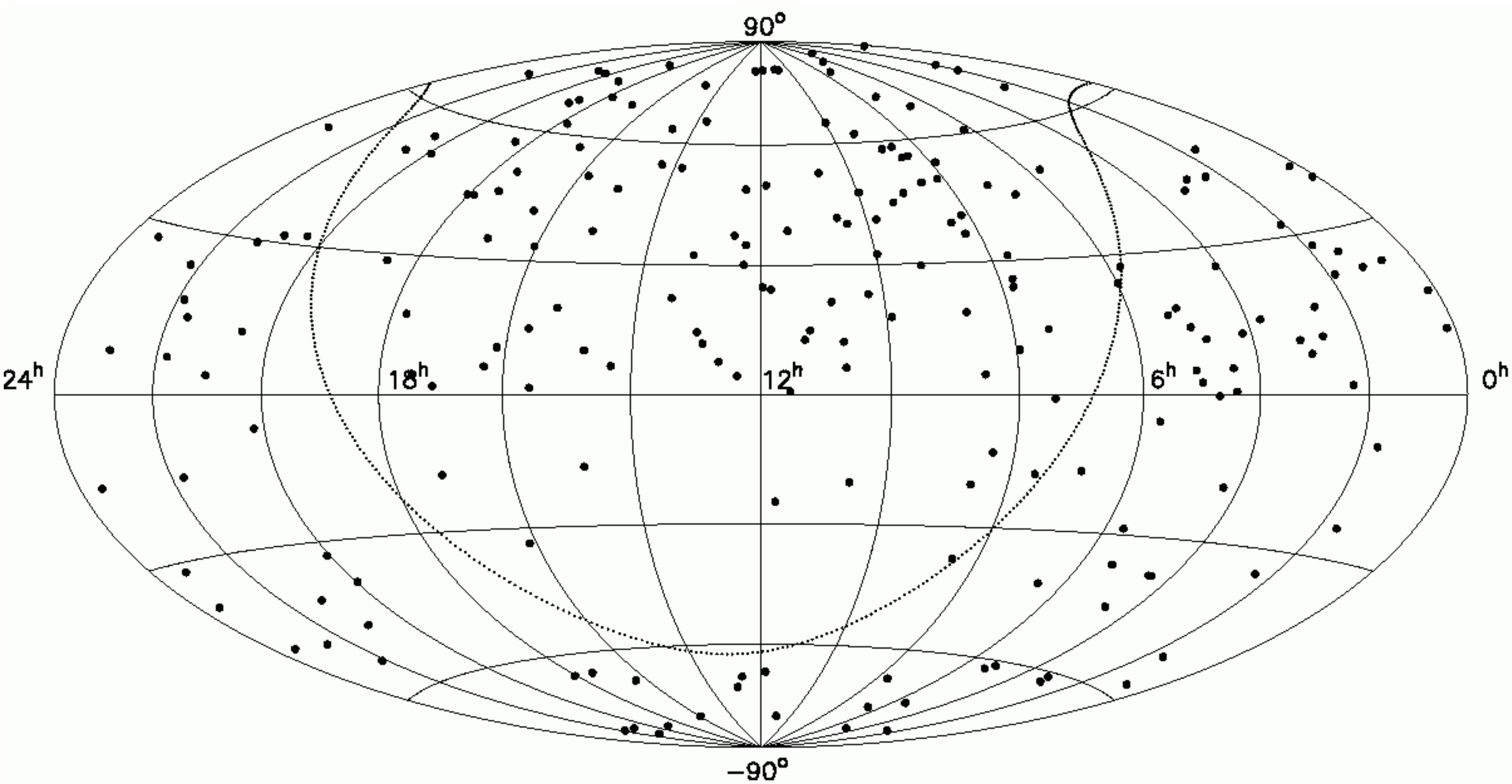
Magnitude	Astrometric Filter	g', r', i' Filters	Hipparcos H_p
8	0.0010	0.0016	0.011
9	0.0016	0.0025	0.015
11	0.004	0.006	0.033
13	0.010	0.016	
15	0.025	0.040	

Number of Stars to Be Surveyed by FAME (50μas at mag. = 10.0) Total = 500,000

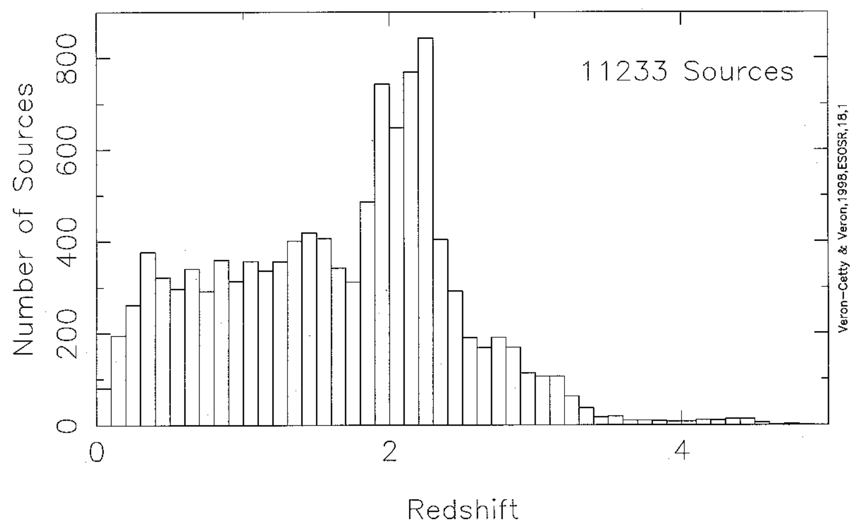
Luminosity Class	O	B	A	F	G	K	M0
I, II, III				3700	30000	50000	20000
V	45	130000	50000	130000	40000	9000	1170
White Dwarf		25	10				

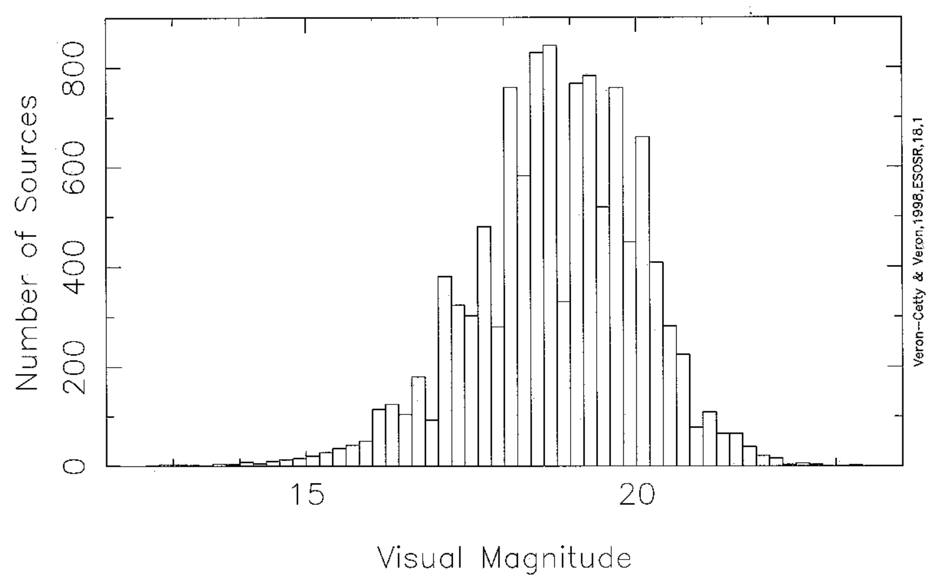
Radio Reference Frame

- ICRF Adopted in 1998
- Individual Source Positions to 300 μas



Quasars and BL Lac Objects





Timeliness of FAME

- A Major Catalog of Accurate Fundamental Stellar Properties Will Enable Advances Across Numerous Branches of Astrophysics
- FAME Will Define a Reference Grid That Can Be Used for SIM, TPF, and Space Navigation
- FAME Will Identify Interesting Targets for SIM and TPF, Increasing Their Scientific Return
- FAME Is an Appropriate Stepping Stone Between Hipparcos and GAIA
- Large CCD Array Cameras Are Now Routinely Built for Ground Applications and Are Ready for Space

FAME Summary

- Calibrate the Zero Point of the Extragalactic Distance Scale to 1%
- Determine Absolute Luminosities of a Wide Range of Spectral Types
- Detect a Meaningful Statistical Sample of Companion Stars, Brown Dwarfs, and Giant Planets
- Enable Studies of the Kinematics of Our Galaxy, Including the Effect of Dark Matter in the Disk
- Characterize Stellar Variability of a Large Sample of Stars at the 0.1% Level
- Define an Optical Reference Frame for Future Scientific Endeavors

FAME Science Team

- Dr. John Bahcall, Princeton
- Dr. Charles Beichman, Caltech
- Dr. Alan Boss, Carnegie Inst. Washington
- Dr. Christian DeVegt, U. Hamburg
- Dr. George Gatewood, U. Pittsburg
- Dr. Marvin Germain, USNO
- Dr. Andrew Gould, Ohio State
- Dr. Thomas P. Greene, NASA Ames
- Dr. Scott Horner, USNO
- Dr. John Huchra, CfA
- Dr. William H. Jefferys, U. Texas
- Dr. Kenneth Johnston, USNO
- Dr. David Latham, CfA
- Dr. David Monet, USNO
- Dr. Marc Murison, USNO
- Dr. James Phillips, SAO
- Dr. Robert Reasenberg, SAO
- Dr. Siegfried Röser, Astronomisches Rechen-Institut
- Dr. Allan Sandage, Carnegie Obs.
- Dr. P. Kenneth Seidelmann, USNO
- Dr. Mike Shao, JPL
- Dr. Irwin I. Shapiro, CfA
- Mr. Sean Urban, USNO
- Dr. William Van Altena, Yale
- Dr. Donald York, U. Chicago