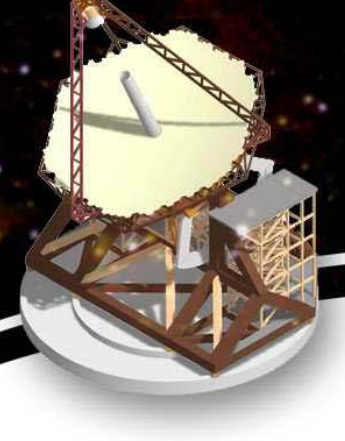

Probing the IMF

AURA NEW INITIATIVES OFFICE

Star Formation in Massive Clusters

Stephen Strom, Knut Olsen and Robert Blum

GSMT SWG
March 17, 2003

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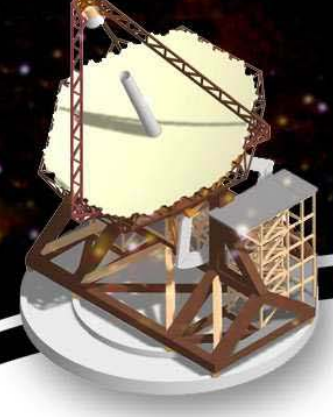

Probing the IMF: Goals

- Quantify the IMF in rich, dense star-forming regions
  - dominant contributor to total stellar content of galaxies
- Understand the relationship between IMF; initial conditions
  - explore linkage to density; thermal + turbulent pressure
    - e.g. Elmegreen and Mohsen (2003)
  - locate the stellar birthline
  - link to mass accretion rate

Critical to modeling star-formation in the early universe

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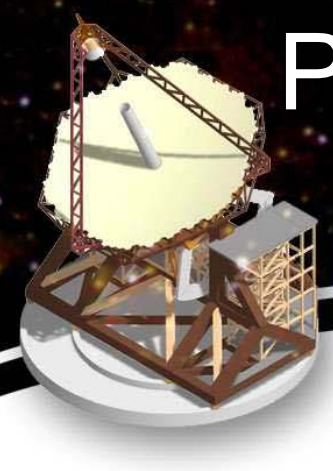
Probing the IMF: Measurements



- JHK photometry
  - MCAO images at high Strehl (~ 0.7 at K-band)
- IFU spectroscopy at R ~ 1000 provides spectral types
- Spectral types + photometry yield:
  - $N(A_v)$
  - statistical model of N(K)
  - N (M) for assumed age

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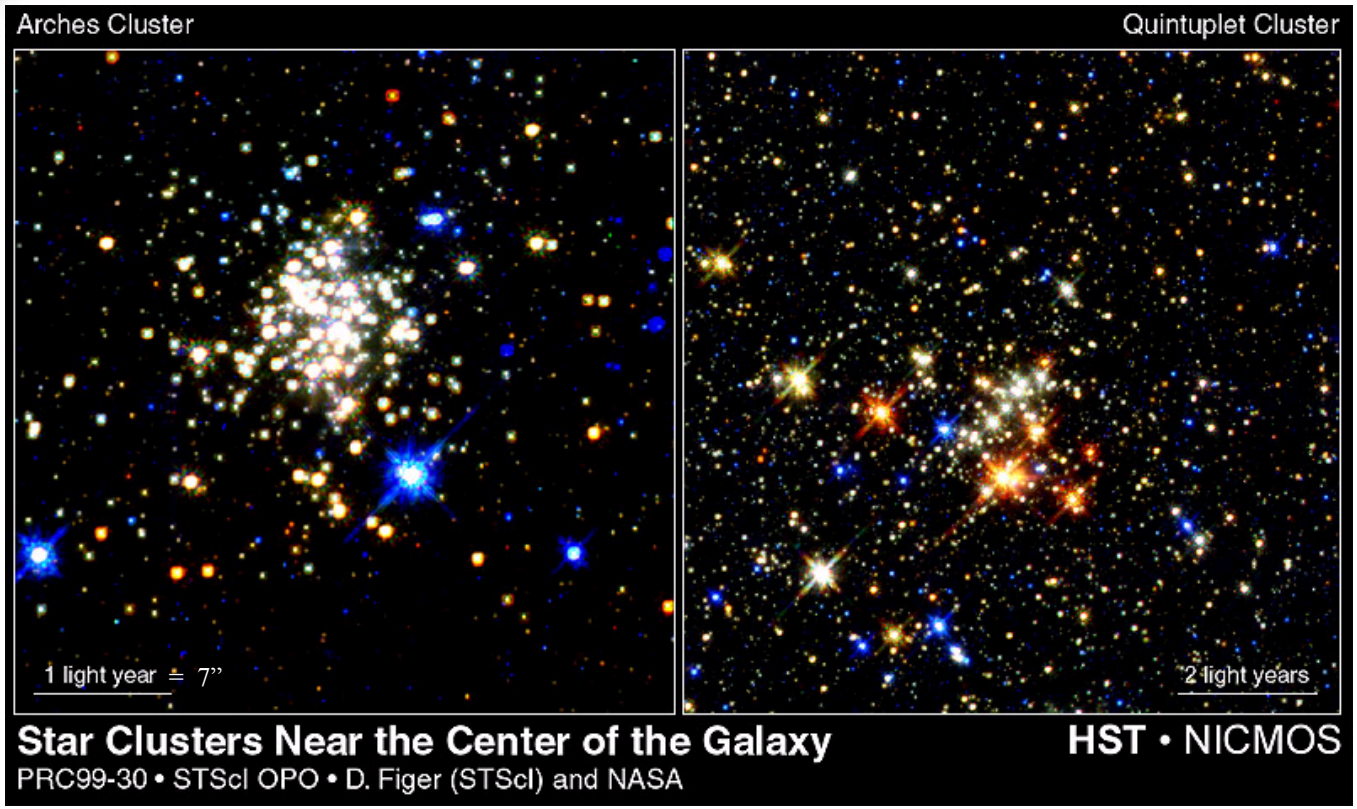
Probing the IMF: Measurements

Galactic Center Superclusters: d = 10 kpc



Stellar density ~ 100x Orion Nebula Cluster

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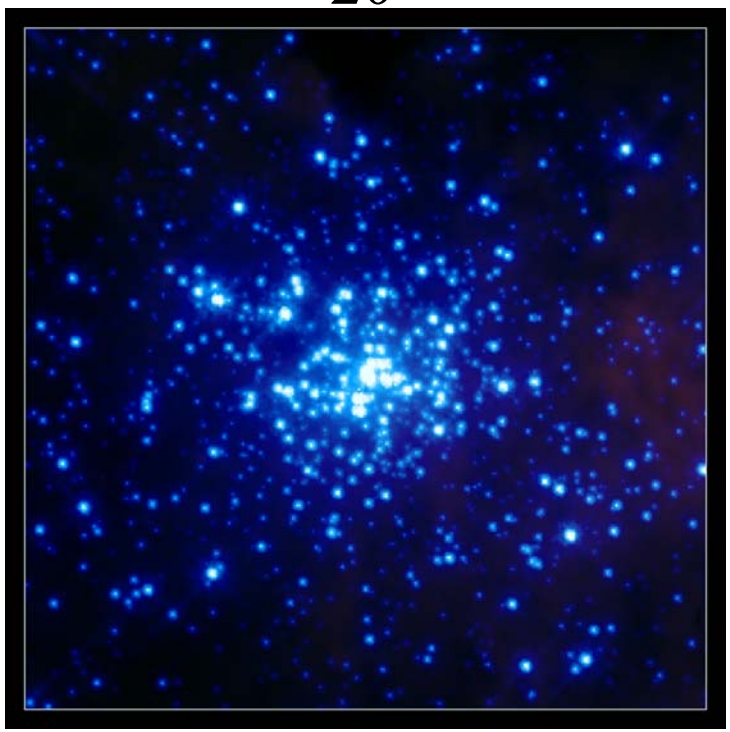
Probing the IMF: Measurements

LMC Massive Cluster: d = 200 kpc

20”

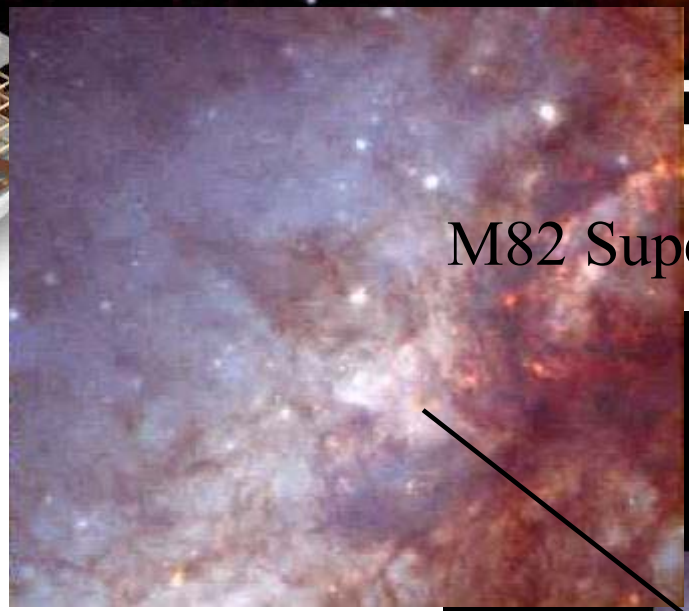


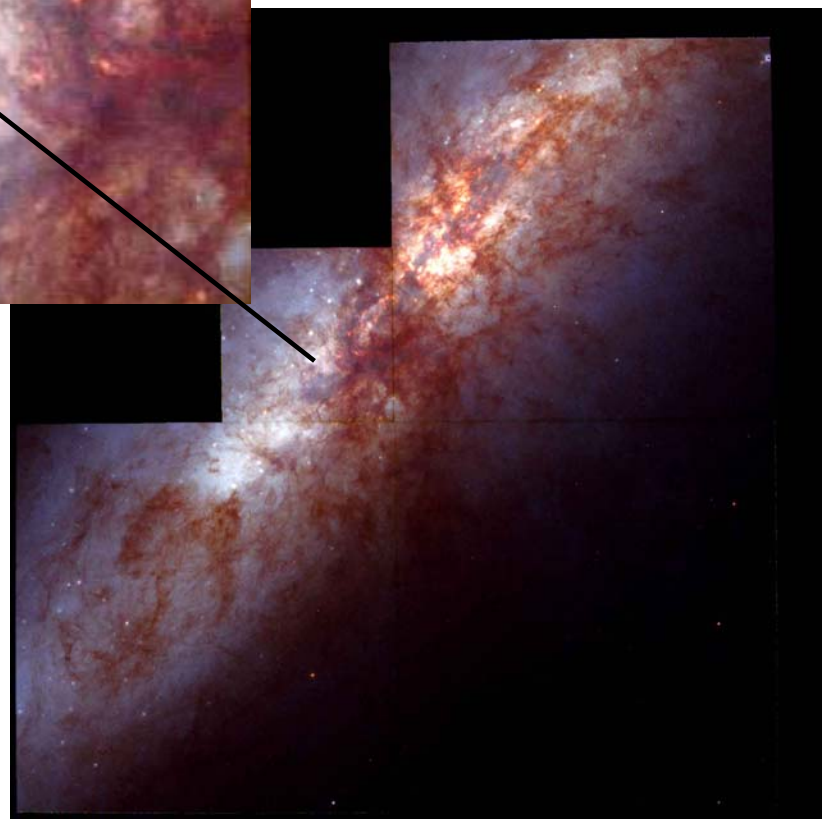
R 136

Stellar density ~ 10x Orion Nebula Cluster

Probing the IMF: Measurements

M82 Superclusters: d = 4 Mpc

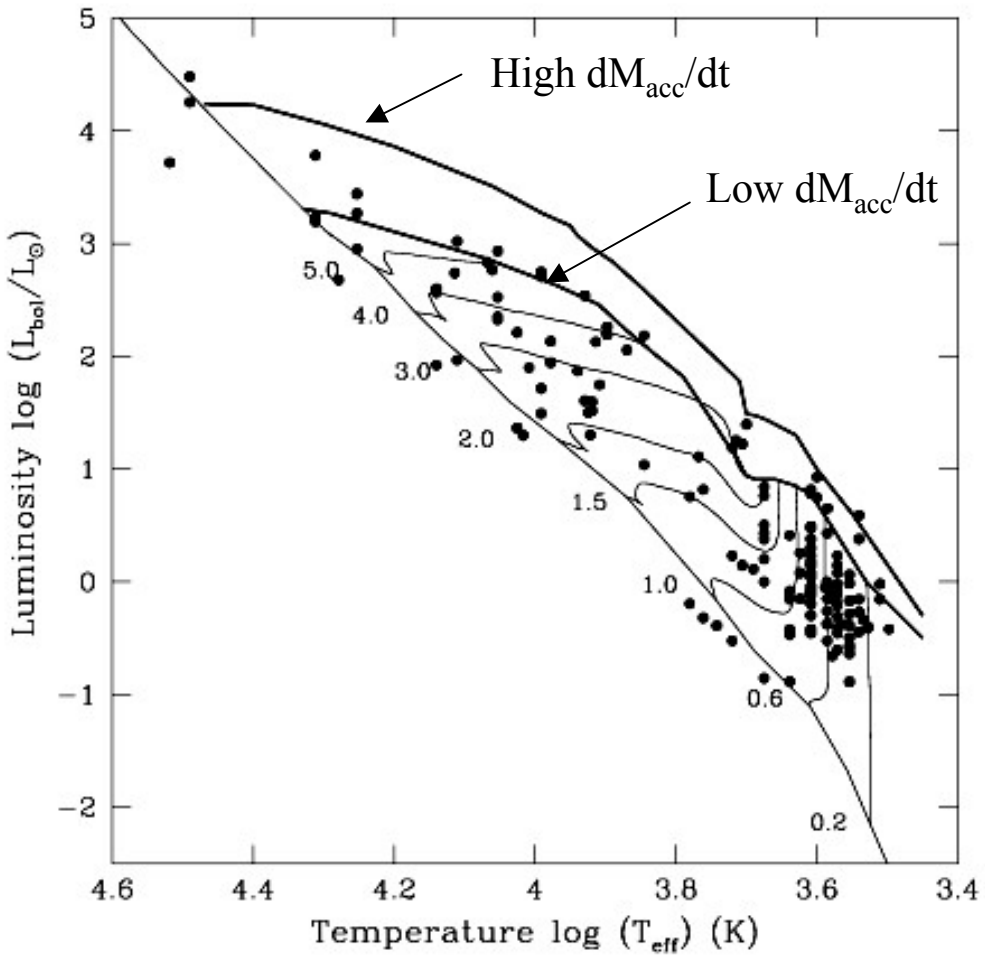




Probing the IMF: Measurements

How is dM_{acc}/dt related to [Fe/H]; stellar density?

Stellar Birthlines for Differing dM_{acc}/dt



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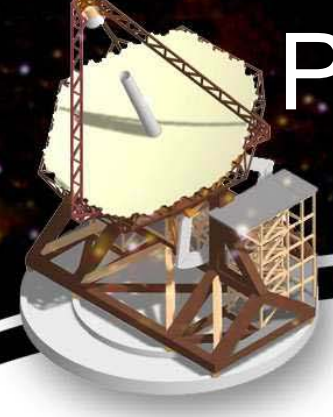
Probing the IMF: Current Status



- Best available data: HST probes of Arches (MWG); R136 (LMC)
  - IMF range limited to $M > 2\ M_{sun}$
- With JWST or MCAO on 8-m telescopes
  - IMF can be probed down to hydrogen-burning limit in MWG
  - Studies in more distant galaxies in Local Group (~1 Mpc) not feasible
    - Crowding limits photometric measurements

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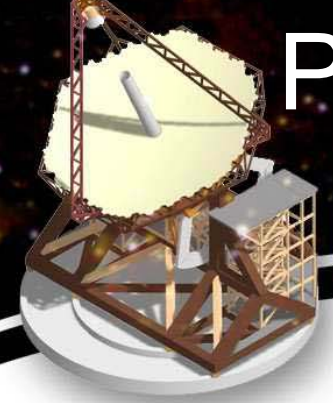
Probing the IMF: Need for GSMT



Key issue is crowding (not photon collection):

- See MCAO simulations by K. Olsen (this meeting)

With a 30m GSMT, K-band diffraction limit is 15 mas

- R136-like clusters can be studied throughout the M33 disk
  - Probe birthlines; IMF for wide range of metallicities
- R136-like clusters can be studied out to M82 (upper end of IMF)

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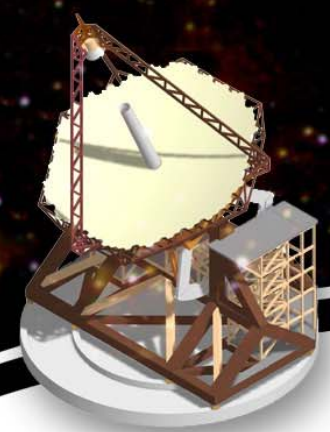
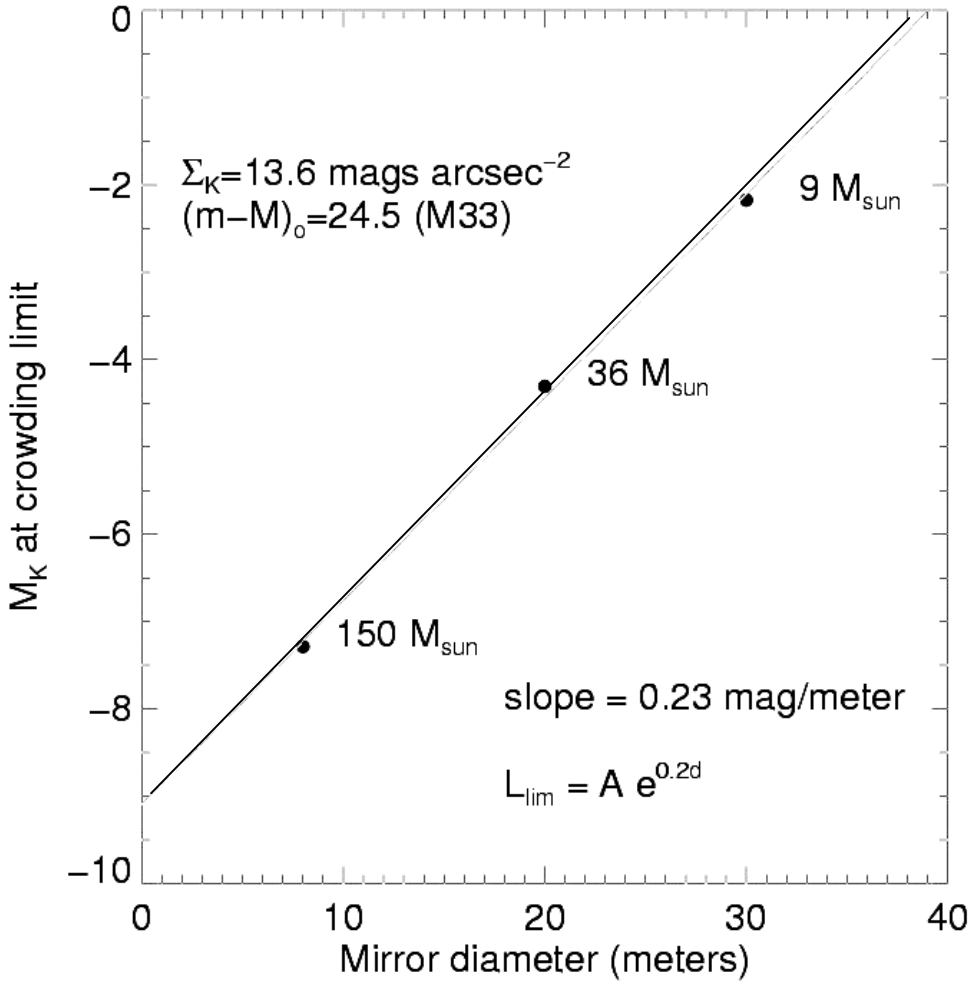


Estimating GSMT Performance

- Assume MCAO system that delivers Strehl of 0.7 at K
- Use as input a composite K-band luminosity function
  - Arches IMF from Blum et al. (2002) [upper end]
  - Orion IMF from Hillenbrand & Carpenter (2000) [lower end]
- Derive crowding from observed central surface densities
  - Arches cluster
  - R136
- Estimate crowding limit ($\sigma_K < 0.1$ m) for $R/R_{1/2}$ = 0.5, 1, 2, 5
- Convert K-limit to mass limit using t = 1 Myr isochrone

Lower Mass Limit for IMF Studies: Arches-Like Cluster in M33



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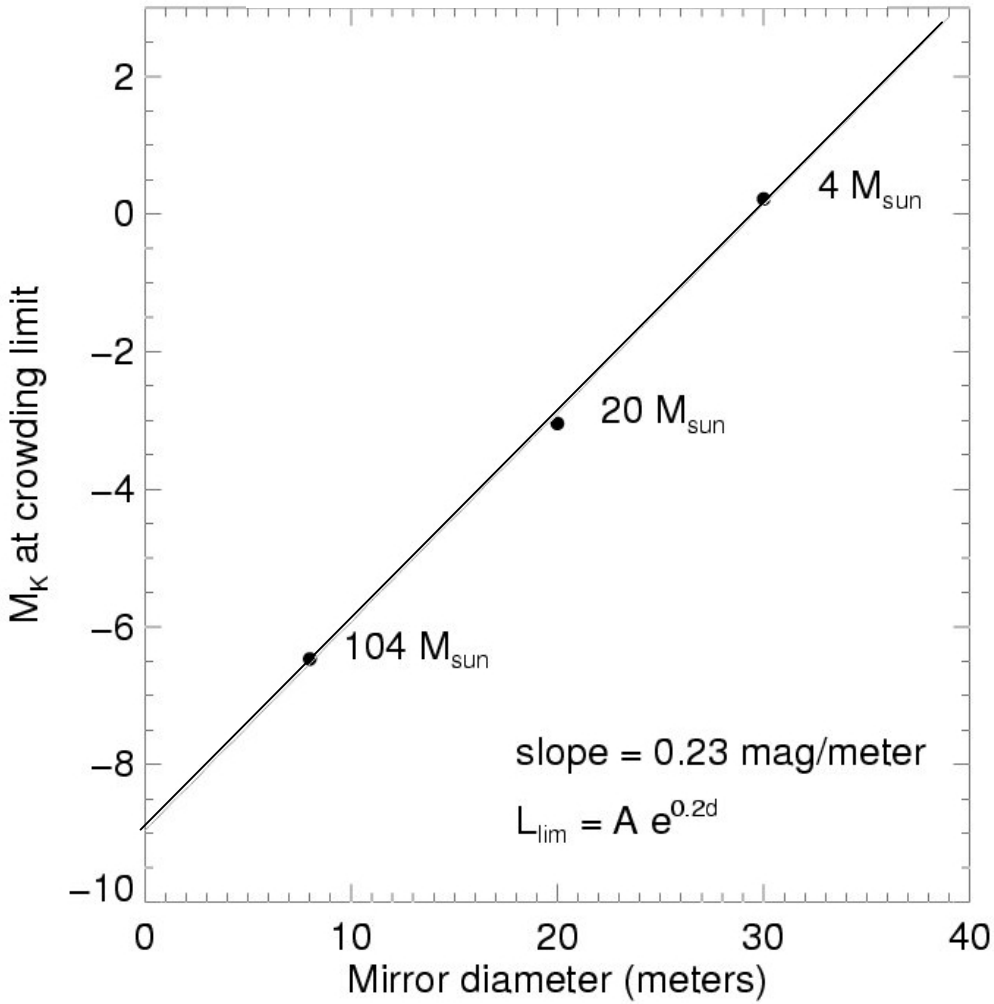
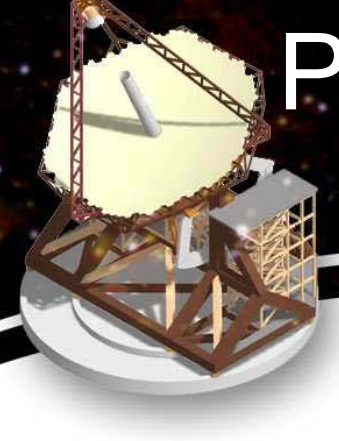
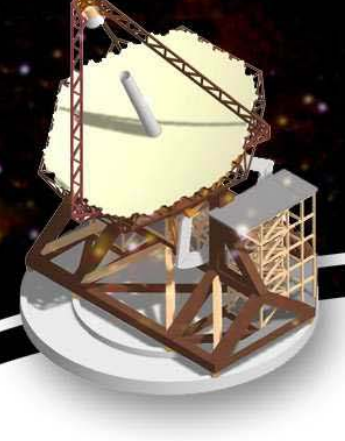
Lower Mass Limit for IMF Studies: R136-Like Cluster in M33



Probing the IMF: Requirements

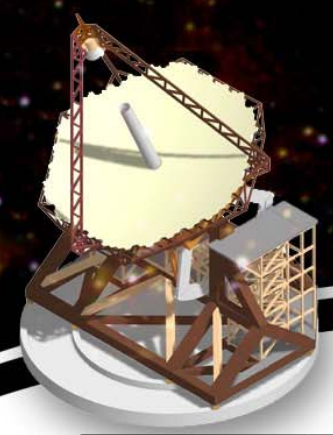


- MCAO-fed near IR imager with ~0.5’ -1’ FOV
  - Deliver Strehl ~ 0.7 at K-band
- MCAO-fed IFU spectrograph with R ~ 3000



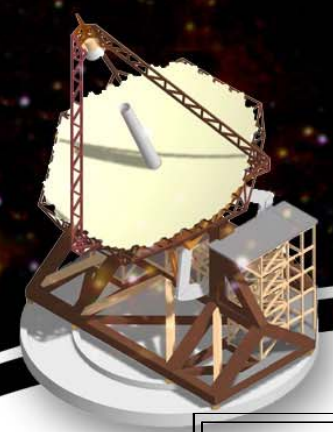
Probing the IMF: Trades

- Ability to probe IMF to larger distances; lower masses increases as (aperture)^2
  - Directly linked to reduced crowding
- Adequate sampling of IMF requires MCAO field r ~ 15”



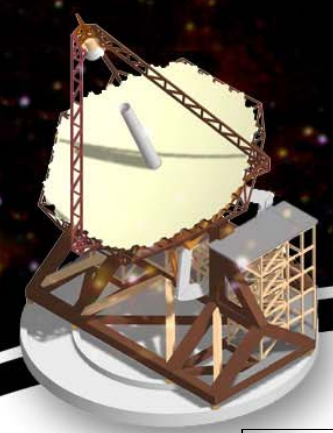
Results: 30-m GSMT

	Limiting M_K			Limiting mass			Exposure time		
	LMC	M33	M82	LMC	M33	M82	LMC	M33	M82
$0.5R_{1/2}$	>9.0	-7.5	<-8.0	~0.01	~150	>150	10000	0.01	<0.2
$R_{1/2}$	>9.0	-5.6	<-8.0	~0.01	83	>150	10000	0.08	<0.2
$2R_{1/2}$	>9.0	-2.2	-7.8	~0.01	9.4	>150	10000	2.2	0.2
$5R_{1/2}$	>9.0	3.0	-3.9	~0.01	0.4	28	10000	10000	16.6



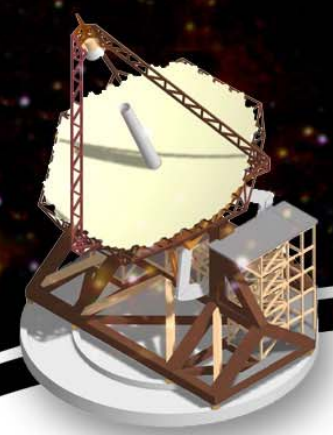
Results: 20-m

	Limiting M_K			Limiting mass			Exposure time		
	LMC	M33	M82	LMC	M33	M82	LMC	M33	M82
$0.5R_{1/2}$	8.1	<-8.0	<-8.0	~0.02	>150	>150	10000	0.02	<0.4
$R_{1/2}$	8.1	-6.9	<-8.0	~0.02	>150	>150	10000	0.05	<0.4
$2R_{1/2}$	8.1	-4.3	<-8.0	~0.02	36	>150	10000	0.6	<0.4
$5R_{1/2}$	8.1	2.1	-5.6	~0.02	0.6	80	10000	10000	6



Results: 8-m

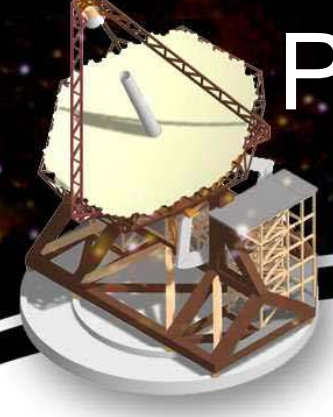
	Limiting M_K			Limiting mass			Exposure time		
	LMC	M33	M82	LMC	M33	M82	LMC	M33	M82
$0.5R_{1/2}$	-2.2	<-8.0	<-8.0	9.5	>150	>150	0.1	0.1	<3
$R_{1/2}$	6.1	<-8.0	<-8.0	~0.05	>150	>150	10000	0.1	<3
$2R_{1/2}$	6.1	-7.3	<-8.0	~0.05	>150	>150	10000	0.2	<3
$5R_{1/2}$	6.1	-3.0	<-8.0	~0.05	>150	>150	10000	36.6	<3



Example Program

- Milky Way
  - Observe rich clusters from galactic center to Perseus arm
    - Probe N(M) down to hydrogen-burning limit
    - Define role of metallicity on birthline; IMF
- LMC & SMC
  - Extend understanding to lower metallicities
- M33
  - Probe N(M) for M > 4 M_{sun} for super-rich clusters across the galactic disk
- Total time to complete program ~ 10s of nights

Probing the IMF: Ancillary Science



- Quantify the spatial distribution for stars of different masses & ages
  - Do massive stars form preferentially near the cluster center?
  - If so, does this imply a different formation mechanism?
    - e.g, mergers in dense cluster core
- Quantify stellar multiplicity in dense clusters
  - How do dynamical interactions influence multiplicity?
  - What are the relevant timescales and environmental conditions?

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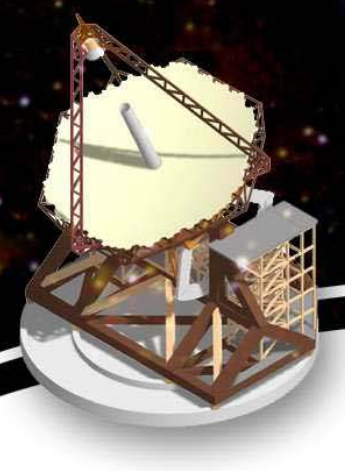

Probing the IMF: Additional Simulations Needed

- Simulate variable extinction & nebular background
- Understand Strehl vs photometric precision trade
- Understand IFU spectrograph performance requirements
- Understand spectroscopic sample needed to derive $N(A_v)$

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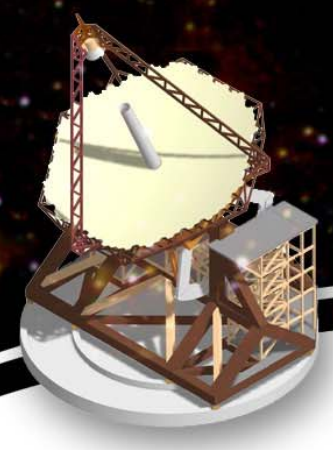

Conclusions

- GSMT can establish the link between emerging stellar populations and initial conditions in star-forming regions
  - Fundamental to understanding star-formation process
  - Essential to undertanding galactic evolution

- Size matters!
  - Crowding limits phometric accuracy
  - Crowding limit scales as d^2
  - Telescope diameters of 30m or greater are needed

- The IMF example is representative of a large class of problems that require superb image quality over ~1’ FOV