"Present and Future Transient/ Supernovae Studies in the Infrared"

Josh Bloom (UC Berkeley)

SciDAC'10, SLAC, 20 May 2010

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Exploiting the Transient IR Sky

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Overview

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- **Observational Developments**
  - Expanding Zoo of (IR) Transients
  - IR Cosmography Work (Ia; IIP)

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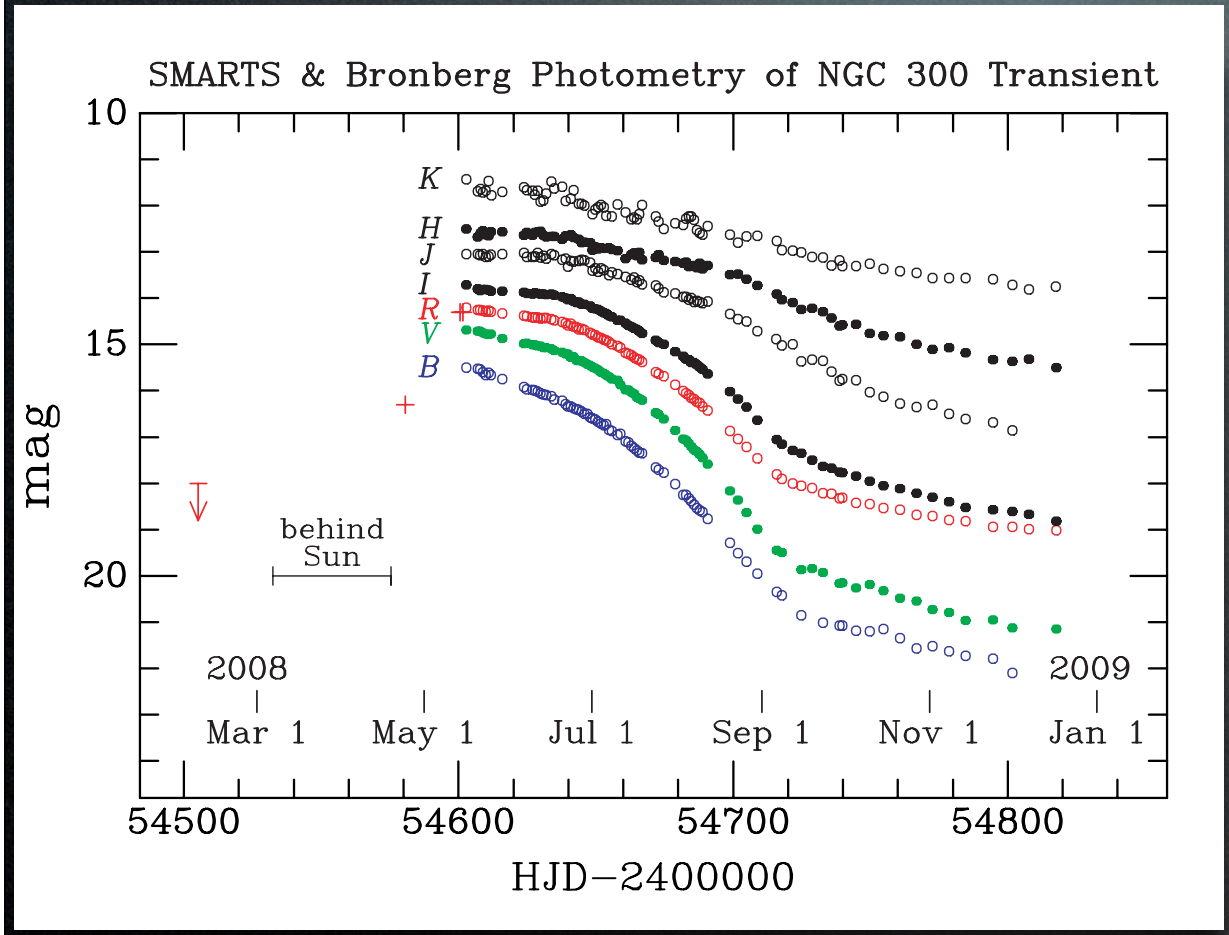
  - IR Cosmography Work (Ia; IIP)
- **Synoptic All-Sky Infrared Imaging Survey (SASIR)**
- **Coupling to New Theory**

Peculiar Red Extragalactic Events



NGC300 OT:

$R - K \sim 4 \rightarrow 10$ mag

also, M85-OT, "SN" 2005S, PTF10fqs

progenitors appear to be heavily obscured

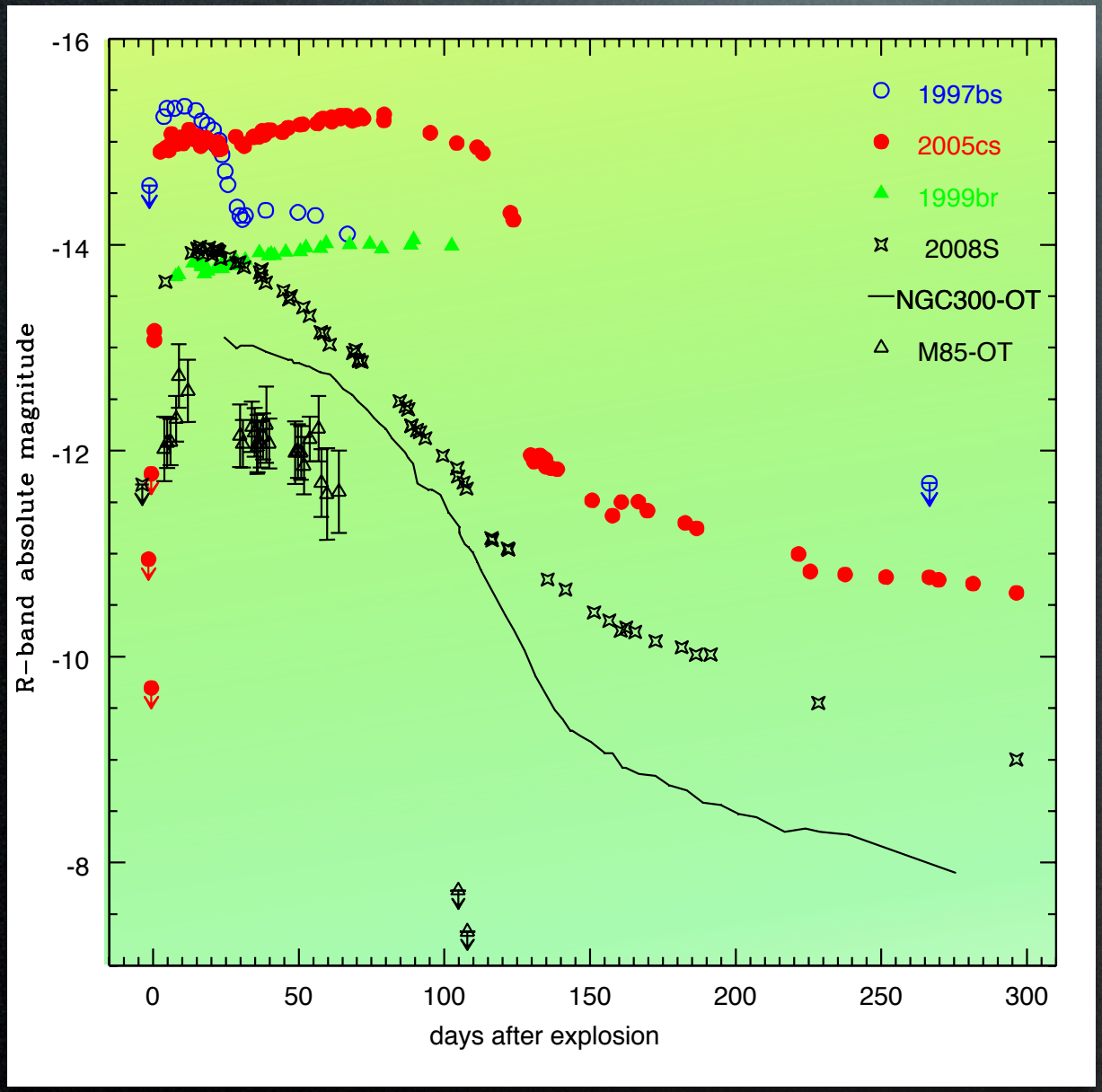
progenitor < 20 M⊙

spectra similar to IIn

Bond+09

Note: all found with <1m telescopes in the optical

Peculiar Red Extragalactic Events



Botticella+10

R Peak: -12 to -14 mag

Models:

- electron-capture SNe of dust-enshrouded AGB star?
- binary accretion (Eta Car-like)
- extreme LBV?
- RSG → BSG transition

Prieto et al. 2008b; Thompson et al. 2008; Botticella et al. 2009, Gogarten+09, Smith et al. 2009

Cool/Red Supergiant Eruptive Outbursts

V838 Mon

M/L-type supergiant
(M_R = -10 mag; ~2000 K)
w/ B-type companion?

- stellar collisions?
- planet cannibalism?
- thermonuclear shell event?
- accretion-induced thermal event?
- ...

Tylenda, Soker & Szczerba, 2005; Retter & Marom, 2003; van Loon et al., 2004; Lawlor, 2005

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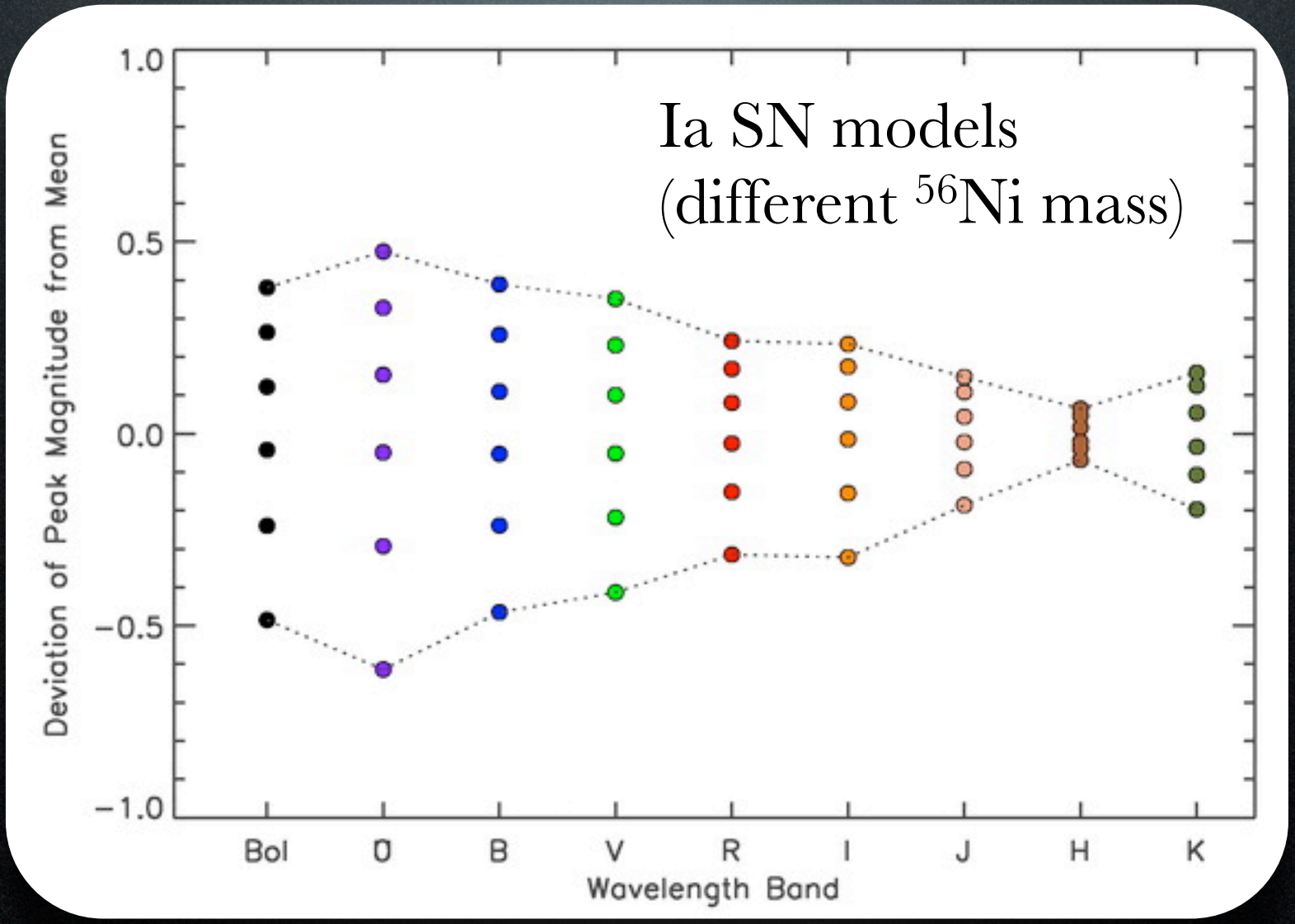
Galactic extension of luminous red novae (e.g. M85OT, NGN300OT, PTF10fqs)?

SN IR Cosmography



Kasen 06

PAIRITEL SUPERNOVA PROJECT DATA CENSUS

Last Updated 10/17/07

Only includes data with at least 4 epochs

2004-05 mosaics on disk

SN.ID	Name	SNTEMP. ID	J	H	K	Temp
147	n4012		16	16	16	
148	05m		8	8	8	
1	05am	9	**16**	**17**	**17**	3*
##			**2**	**3**	**4**	
2	04gq	2	3	3	3	4-5*
##			8	8	8	
##			1	1	1	
3	04gt	4	25	25	25	3*
##			0	0	0	
4	04gk	5	45	45	45	1*
##			71	68	72	
5	05ao	10	**16**	**19**	**19**	11
##			**1**	**1**	**1**	
6	05ak	11	**35**	**36**	**36**	11
8	05ay	13	12	12	12	5*
10	05bl	14	**20**	**20**	**20**	5*
11	05bf	3	33	33	33	5
12	05bo	15	**17**	**17**	**17**	4*
13	05az	16	22	22	22	5*
14	05cc	17	**26**	**26**	**26**	10
15	05cf	18	**26**	**27**	**27**	13
16	05ch	19	**12**	**12**	**12**	6
17	05cs	20	7	7	7	3

2005-06 mosaics on disk

SN.ID	Name	SNTEMP. ID	J	H	K	Temp
18	05el	24	**38**	**40**	**40**	4
21	05ek	21	23	23	23	1-2
24	05eo	22	31	31	20	6
25	05M006	8	**40**	**40**	**40**	1*
26	05eq	25	**27**	**28**	**27**	3-4
27	05eu	37	**35**	**35**	**35**	5
28	05hf	34	**31**	**31**	**31**	8-9
29	05hg	6	40	40	34	5-6
30	05hk	36	**30**	**30**	**30**	5
31	05iq	38	**16**	**16**	**16**	5
32	05ke	26	**36**	**35**	**36**	6
33	05kl	30	25	24	22	4
35	05ls	28	**27**	**28**	**29**	2
36	05mf	7	13	13	11	5
37	05mc	29	**48**	**48**	**47**	10
38	05na	40	**#**	**#**	**#**	1
39	06D	32	**30**	**30**	**30**	4
40	06E	33	**33**	**33**	**33**	6
41	06N	31	**31**	**31**	**31**	6-7
42	06X	42	**77**	**76**	**78**	3
43	06ac	35	**41**	**42**	**42**	4~/5$
44	06aj	39	8	8	8	3
45	06ax	43	**18**	**18**	**18**	1-2
46	06az	44	**24**	**24**	**24**	4
48	06bq	41	**17**	**18**	**18**	2
49	06cp	45	**5**	**5**	**5**	6
50	06cz	46	**4**	**4**	**4**	4

2006-07 mosaics on disk

SN.ID	Name	SNTEMP. ID	J	H	K	Temp
53	06gr	59	**5**	**5**	**5**	2
54	06fo	47	26	25	26	1
55	06is	48	**52**	**52**	**52**	2
56	06jc	62	**91**	**91**	**91**	active
57	06lc	54	22	22	22	1 up
58	06ld	55	19	19	19	1 up
59	06le	49	**50**	**49**	**50**	4
60	06lf	50	**47**	**48**	**47**	2
61	06mq	SN	21	21	22	Nov
62	07C	56	24	24	23	Jan
63	07D	57	3	3	4	up-Mar
64	07I	58	30	30	28	Dec
65	07S	SN	23	23	23	Oct/Nov
66	07aa	51	28	29	28	Dec
67	07af	52	36	37	37	Jan
68	07ag	SN	14	13	14	Oct/Nov
69	07av	SN	10	10	9	Oct/Nov
70	07bj	53	**41**	**41**	**39**	1 Feb
72	07bz	SN	15	15	15	Dec
73	07ca	SN	14	14	14	Dec/Jan
74	07ce	SN	4	4	4	Nov
76	07co	60	11	11	11	1
77	07cq	61	5	5	6	2

2007-08 mosaics on disk

SN.ID	Name	SNTEMP. ID	J	H	K	Temp
79	07fb	SN	**14**	**14**	**15**	SN
81	07gr	SN	**15**	**17**	**17**	SN
82	07hj	SN	**7**	**7**	**7**	SN
83	07if	SN	**9**	**9**	**9**	SN
84	07hu	SN	**1**	**1**	**1**	SN
87	07ir	SN	**10**	**10**	**9**	SN
93	07kk	SN	**7**	**6**	**7**	SN
95	07le	SN	**2**	**2**	**2**	SN

	04-05	05-06	06-07	07-08	Tot	
Ia	9	20	12	6	47	64%
Ib/Ic	5	6	9	1	21	28%
II	3	0	2	0	5	7%
???	0	1	0	0	1	1%
	17	27	23	7	74	100%
Temp.	15	27	10	0	52	
% temp.	88%	100%	43%	0%	70%	

SN Type Color Codes

Ia | Ib/Ic | II | ???

SN.ID - some SNe have multiple ID #s

Name - sn name (*06aj* = *grb060218*)

SNTEMP.ID - different from SN.ID

mosaics on disk # of J,H,K mosaics rsynced to CfA, bad images included

(excludes unreduced data on lyra)

Temp: includes both good and bad quality templates rsynced to CfA

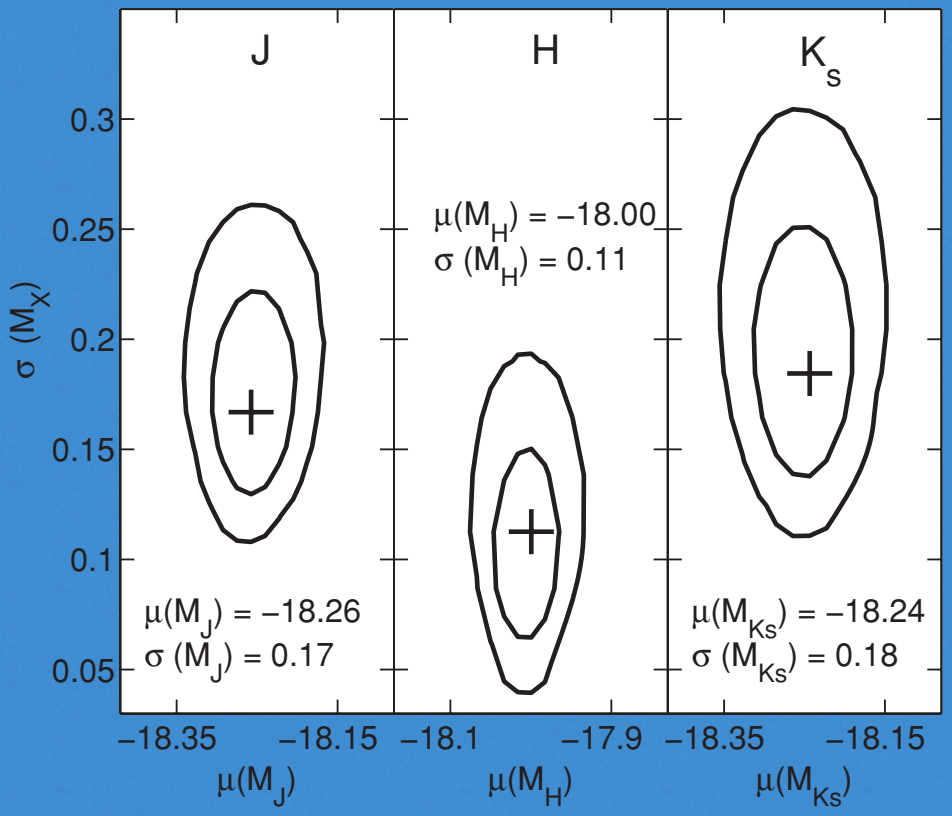
*1 = 1 hr template (the rest are 30 min)

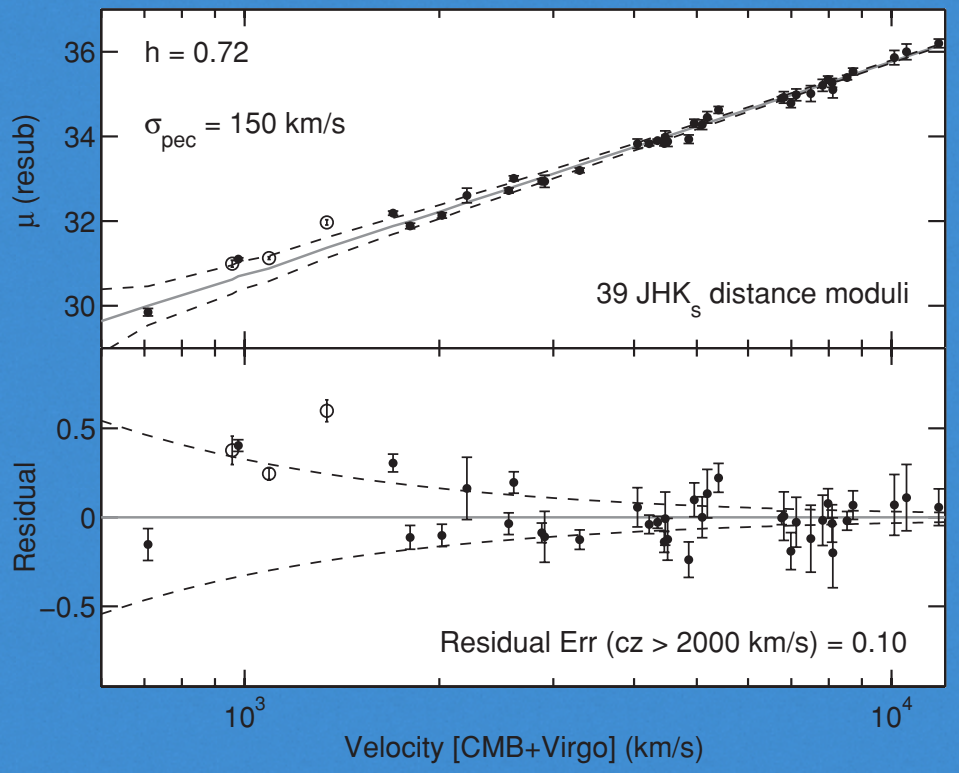
$ = late time images where the SN has faded can serve as templates

some with bad K band, but at least 1 with JHK all acceptable

c. 2007

Ia SNe



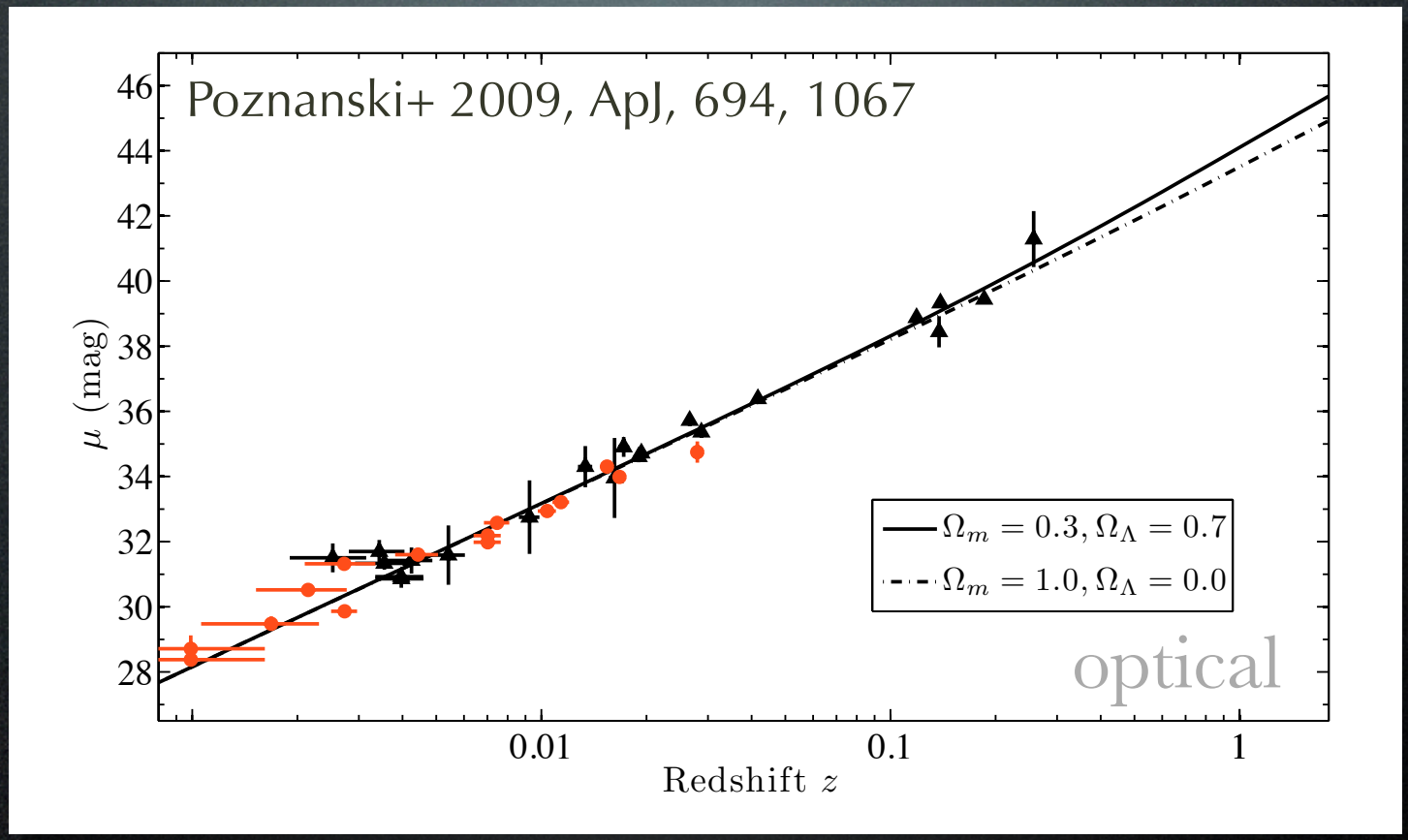


10-15% rms luminosity

5% distance errors in the Hubble diagram

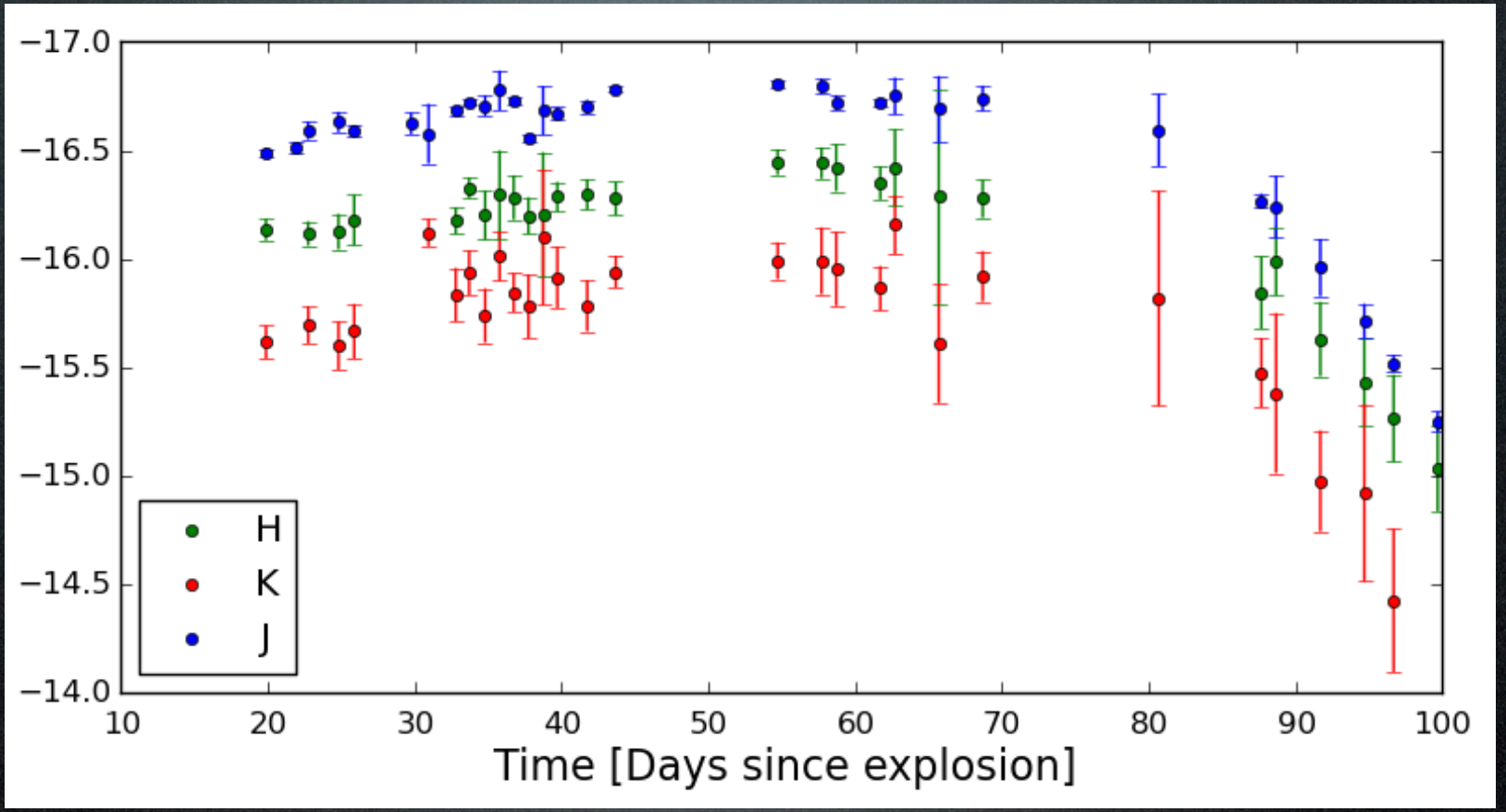
Friedman, JSB+08; Mandel+09; also Krisciunas+04

IIP SNe



- Scatter of ~ 10% in distance using optical bands.
- Mystery best $R_V \sim 2$.

IIP SNe

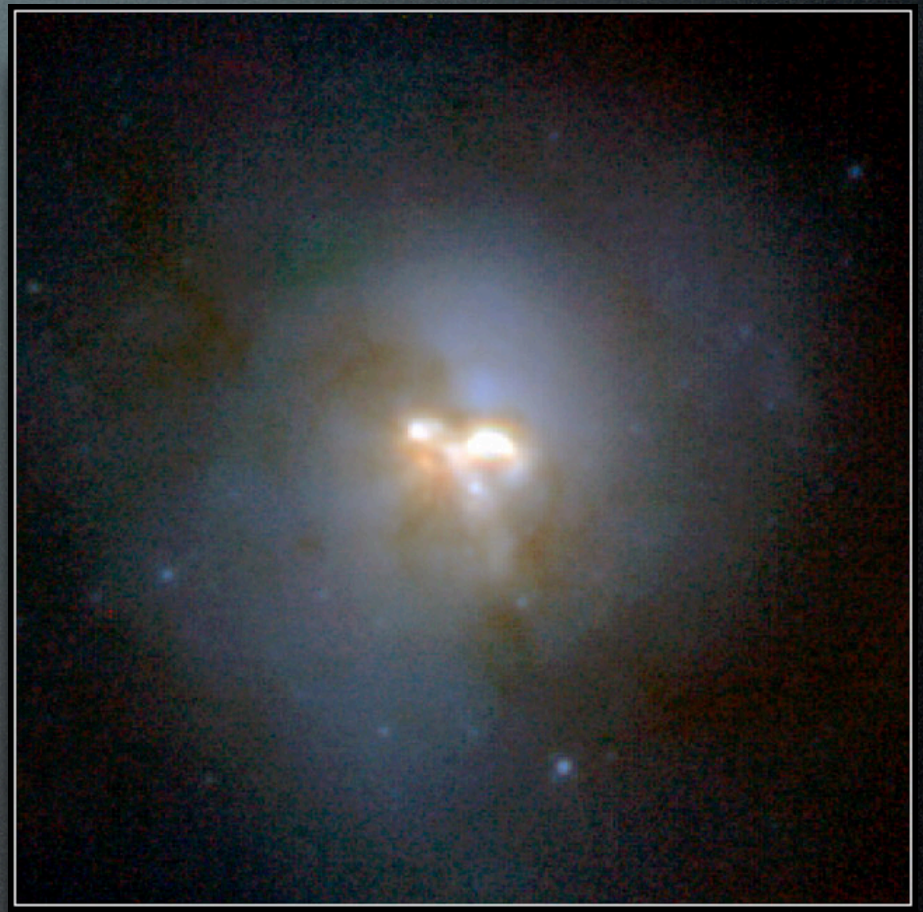


- Maguire+10 find a factor of 2 improvement in IR.
- > 15 SN II-P light curves with PAIRITEL.

Kisklak, Miller, Poznanski...10

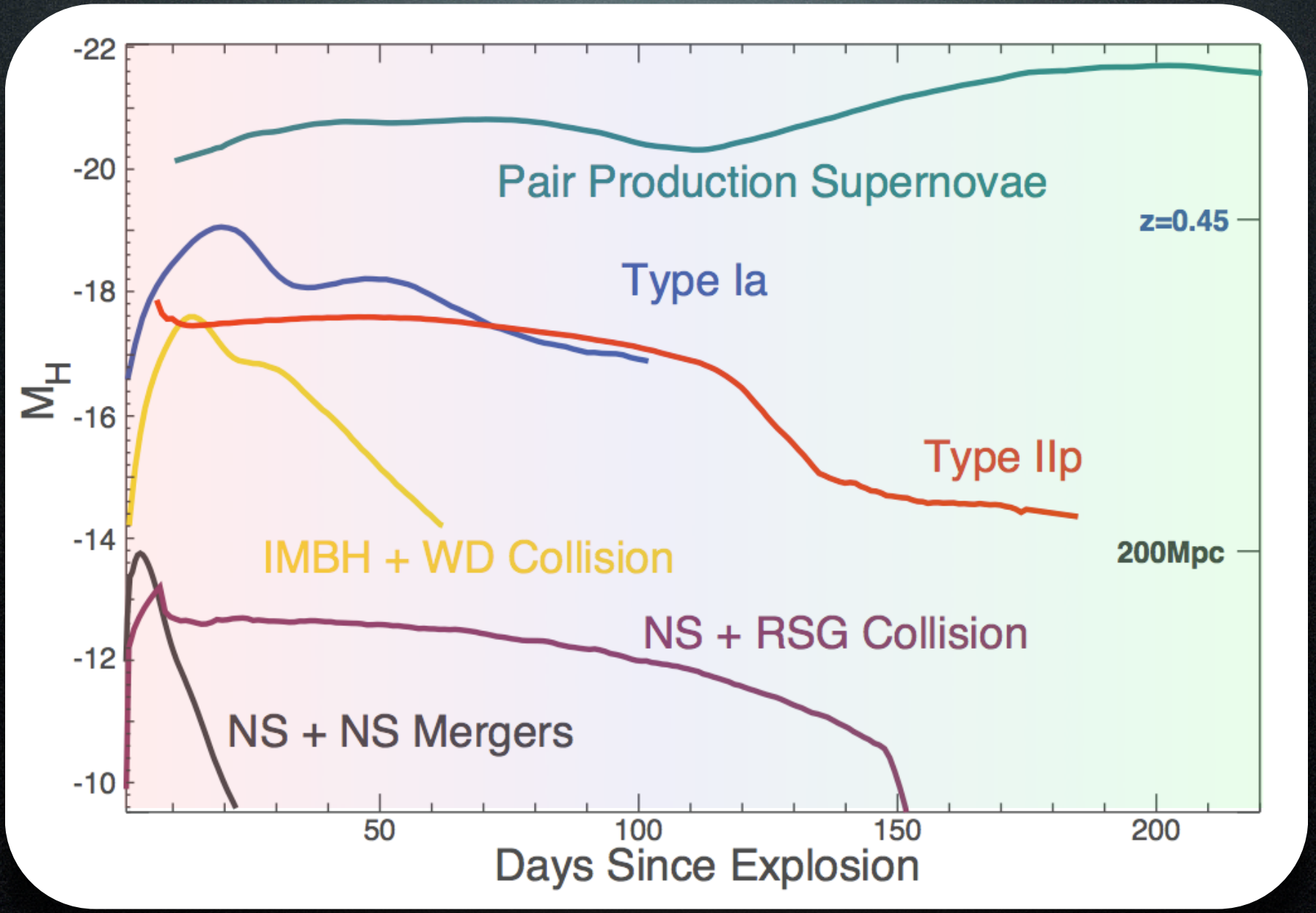
Dust Obscured SNe

- Which SNe are we missing in the optical because of dust?
- Are there intrinsically red SNe out there?
- A better mapping of progenitor star to SN type.
- Better constraining SN cosmic rates.



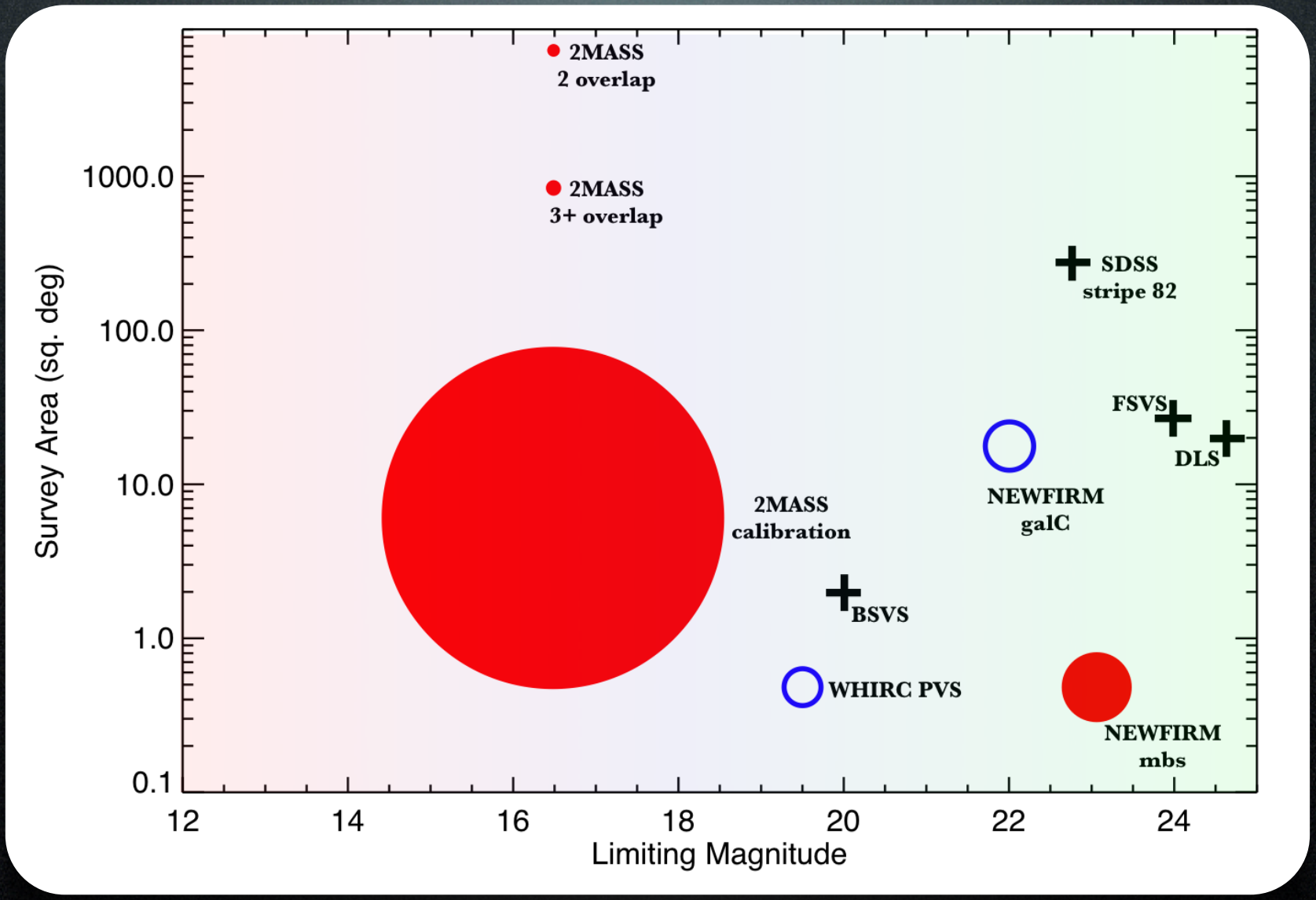
Ultraluminous Infrared Galaxy Arp 220 HST • NICMOS
PRC97-17 • ST ScI OPO • June 9, 1997
R. Thompson (University of Arizona),
N. Scoville (California Institute of Technology) and NASA

Characterizing the IR Transient Sky



Ramirez-Ruiz, Kasen; also Heger, today

Characterizing the IR Transient Sky



relative to optical: shallow & small

THE SYNOPTIC ALL-SKY INFRARED SURVEY

SASIR

UC University of California

Instituto Nacional de Astrofísica, Óptica y Electrónica

UNAM Universidad Nacional Autónoma de México

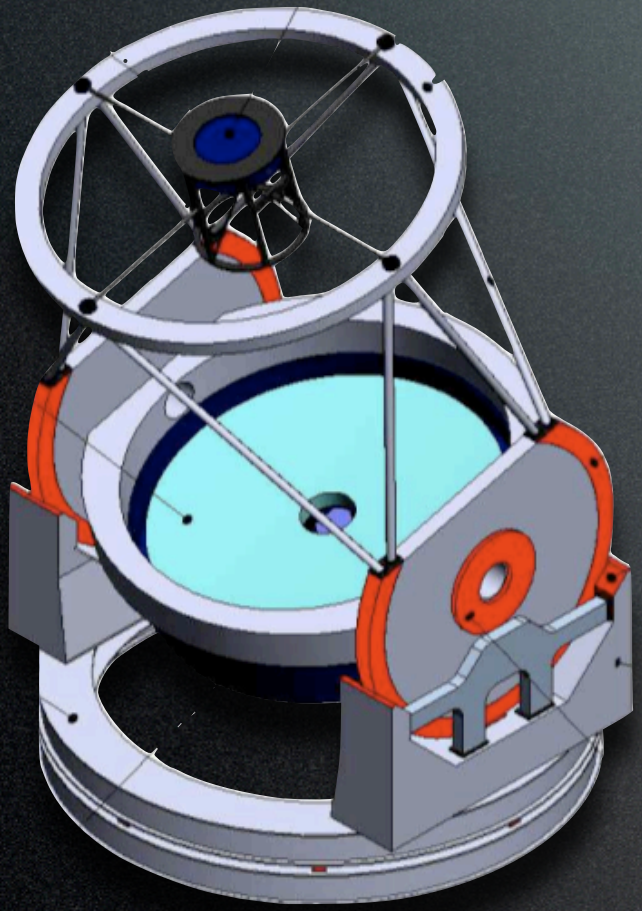
THE UNIVERSITY OF ARIZONA

SCIENTIFIC, EDUCATIONAL & TECHNOLOGICAL PARTNERSHIP ACROSS BORDERS

http://sasir.org

SASIR, in a Nutshell

The SPMT 6.5 meter telescope (Magellan inspired)



- **Filters:** *Y, J, H, K* (3 dichroics)
- **Detectors:** 124 2k × 2k IR arrays
- ~1.05° diameter field of view
  - ➡ 2 sq. deg. on-sky
- autonomous/robotic surveying
- **Survey:** cover entire sky in ~2-3 months;

  4-5 year survey
  - ◉"shallow" (~2.5 π; 6-12 visits)
  - ◉"medium" (0.5 π; ~200 visits)
  - ◉ "deep" (~1000 sq deg; 10^3+ visits) surveys

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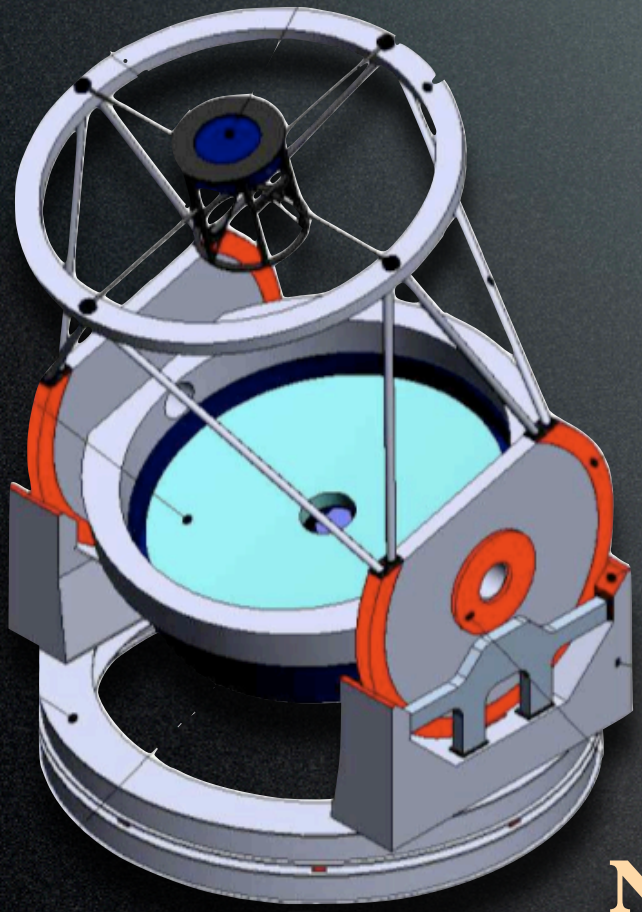

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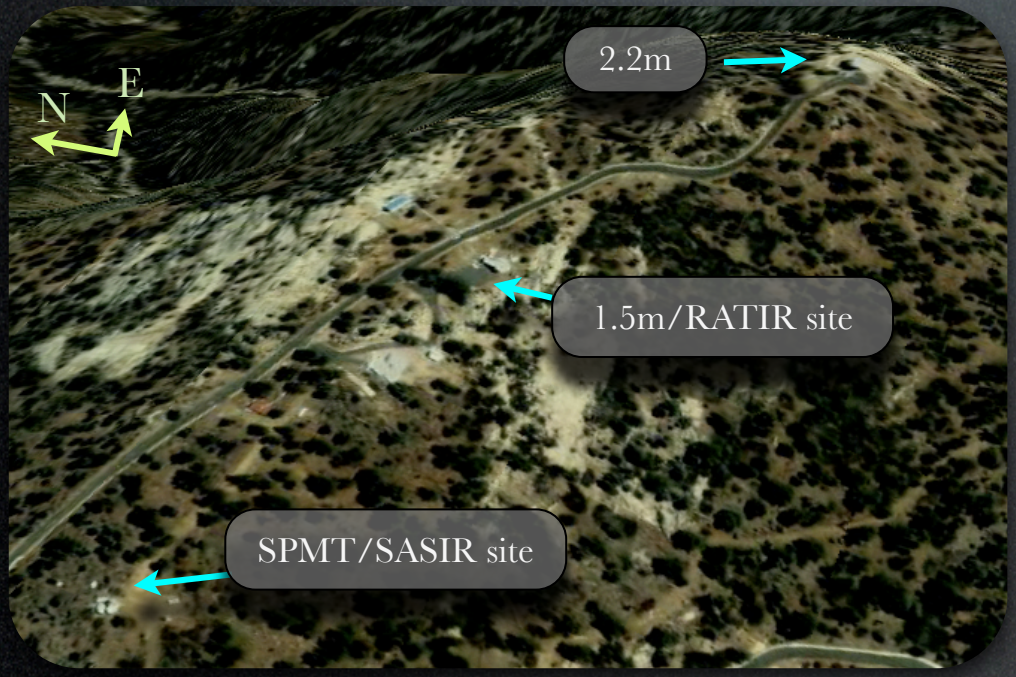
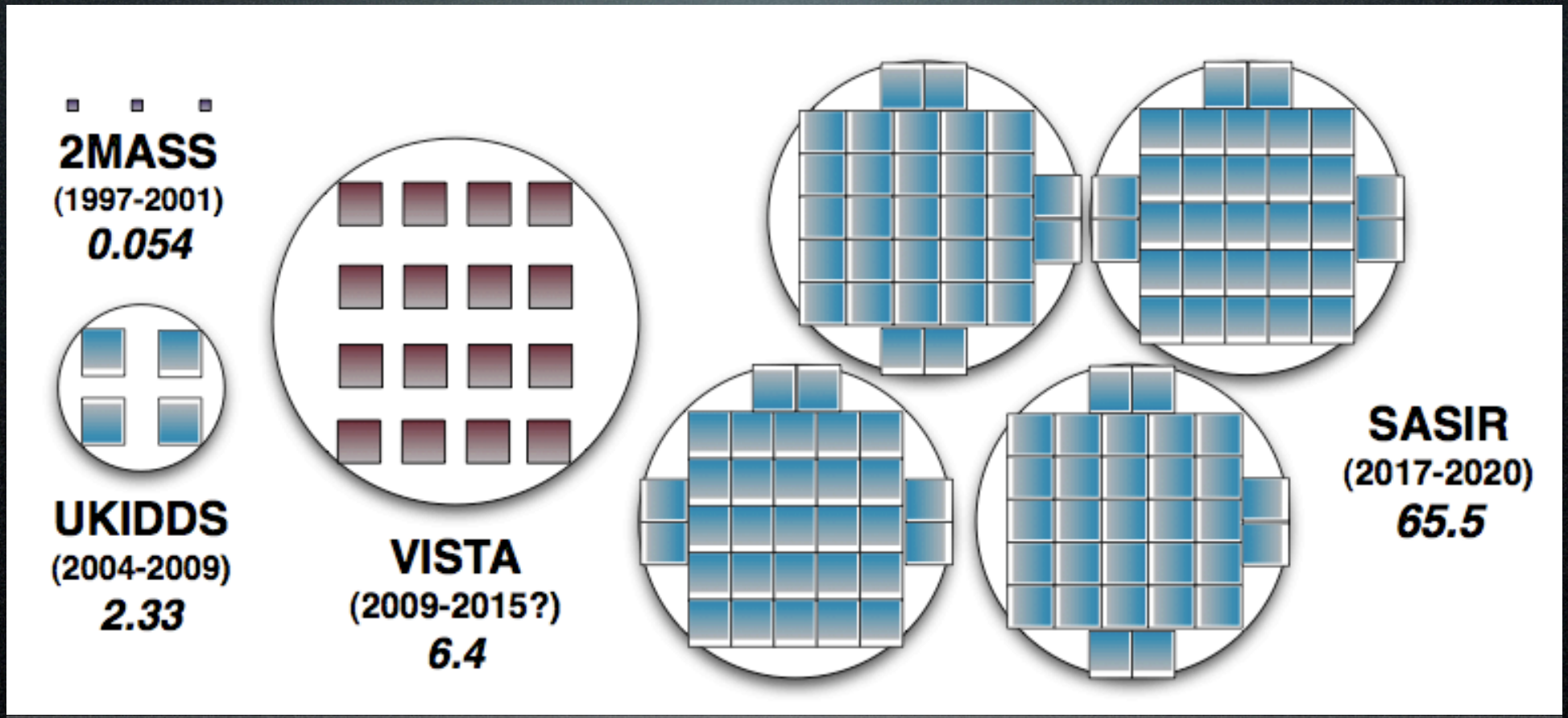
New Phase Space:

Aperture + wavebands + Field of View + Time

SASIR/SPMT: in progress

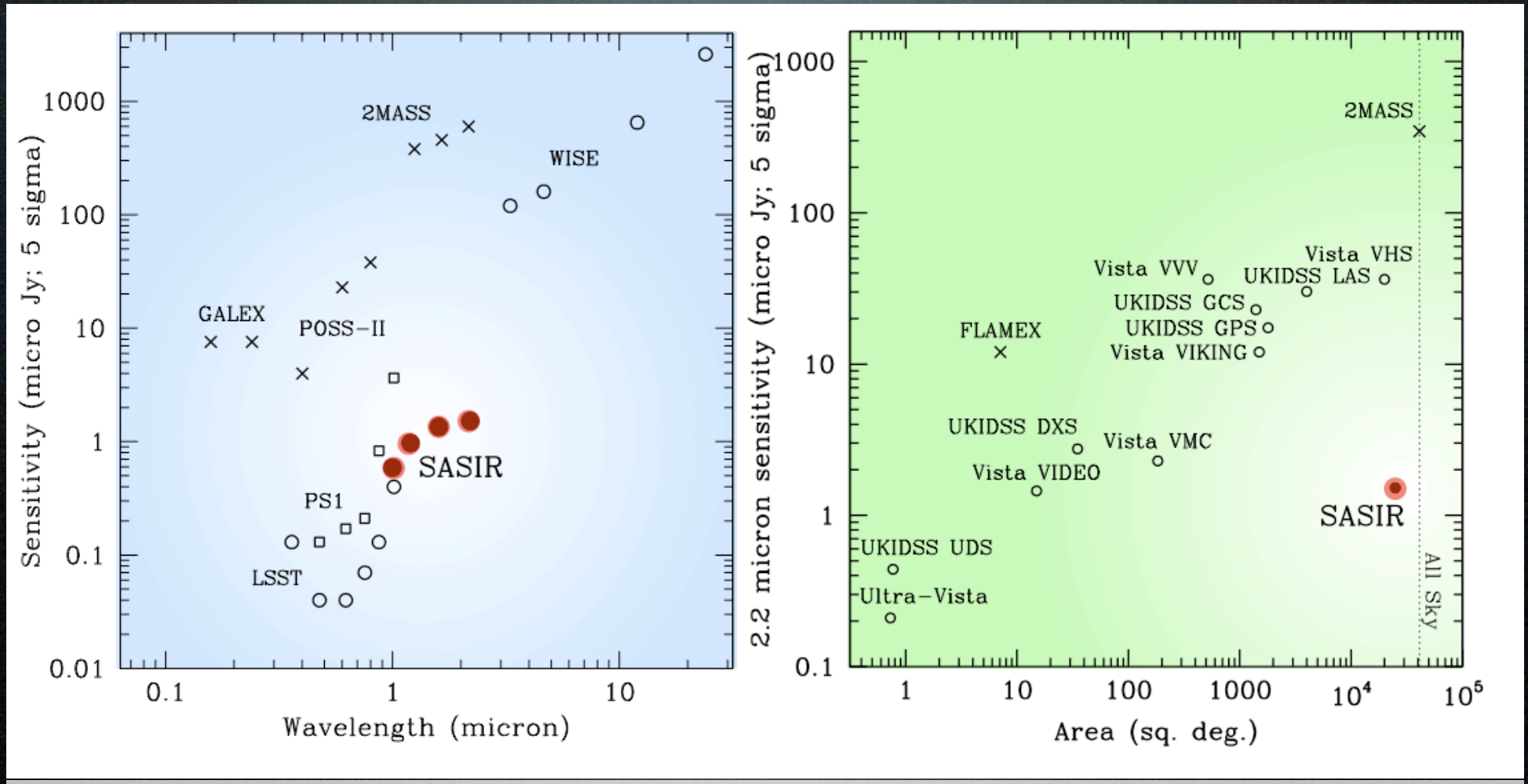


Comparison to Other Surveys



étendue-couleur© (m^2 deg^2 × number of simultaneous bands)

Comparison to Other Surveys



other survey data compiled by D. Stern (JPL)

SASIR Impact Across Astrophysics

- **Unveiling the Lowest Temperature Neighbors:**
  finding the local brown dwarf & Y dwarf population
  (candidates for exoplanet imaging)
- **Probing the Epoch of Reionization w/ Quasars**
- **Multi-messenger Probe**:
  Gravity Wave & Particle Counterparts
- **IR cosmology/distance ladder:**
  supernovae, RR Lyrae, Mira, etc.

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Synergies
- Large Millimeter Telescope (LMT)
- discovery engine for GTC, Keck, GSMTs, JDEM
- high-resolution dust maps (esp. in the Galactic Plane)
- adaptive optics grid
- photo-z improvement over optical-only (e.g. BAO)

> dozen Astro2010 Science Whitepapers

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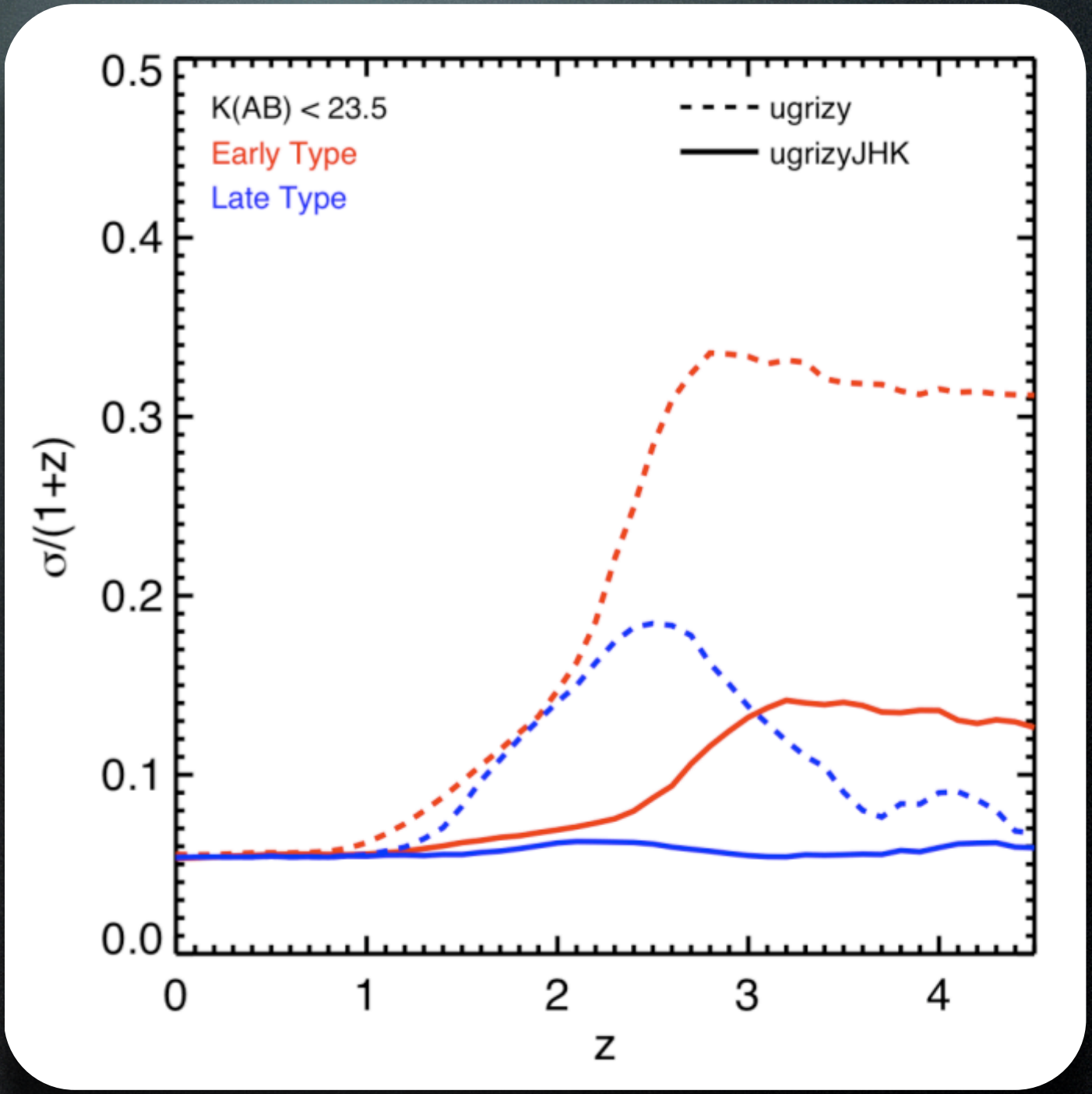
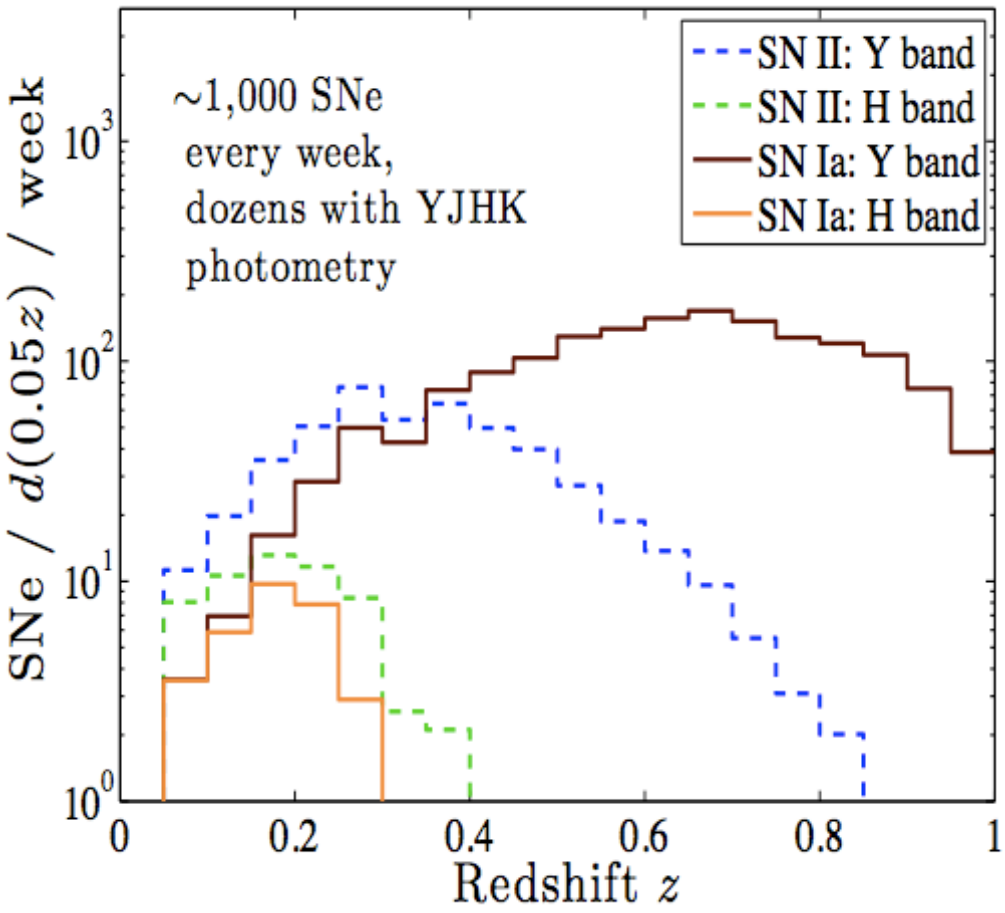
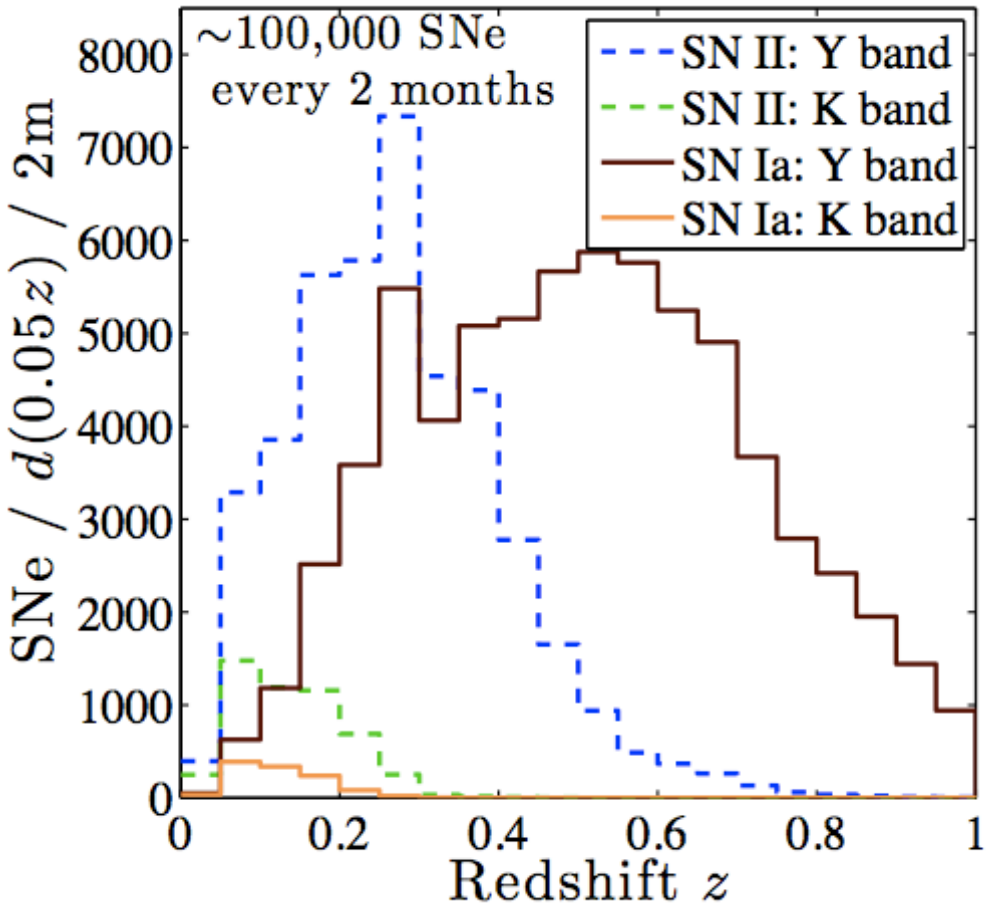
Improved photometric redshift errors



from A. Stanford

Supernovae





D. Poznanski

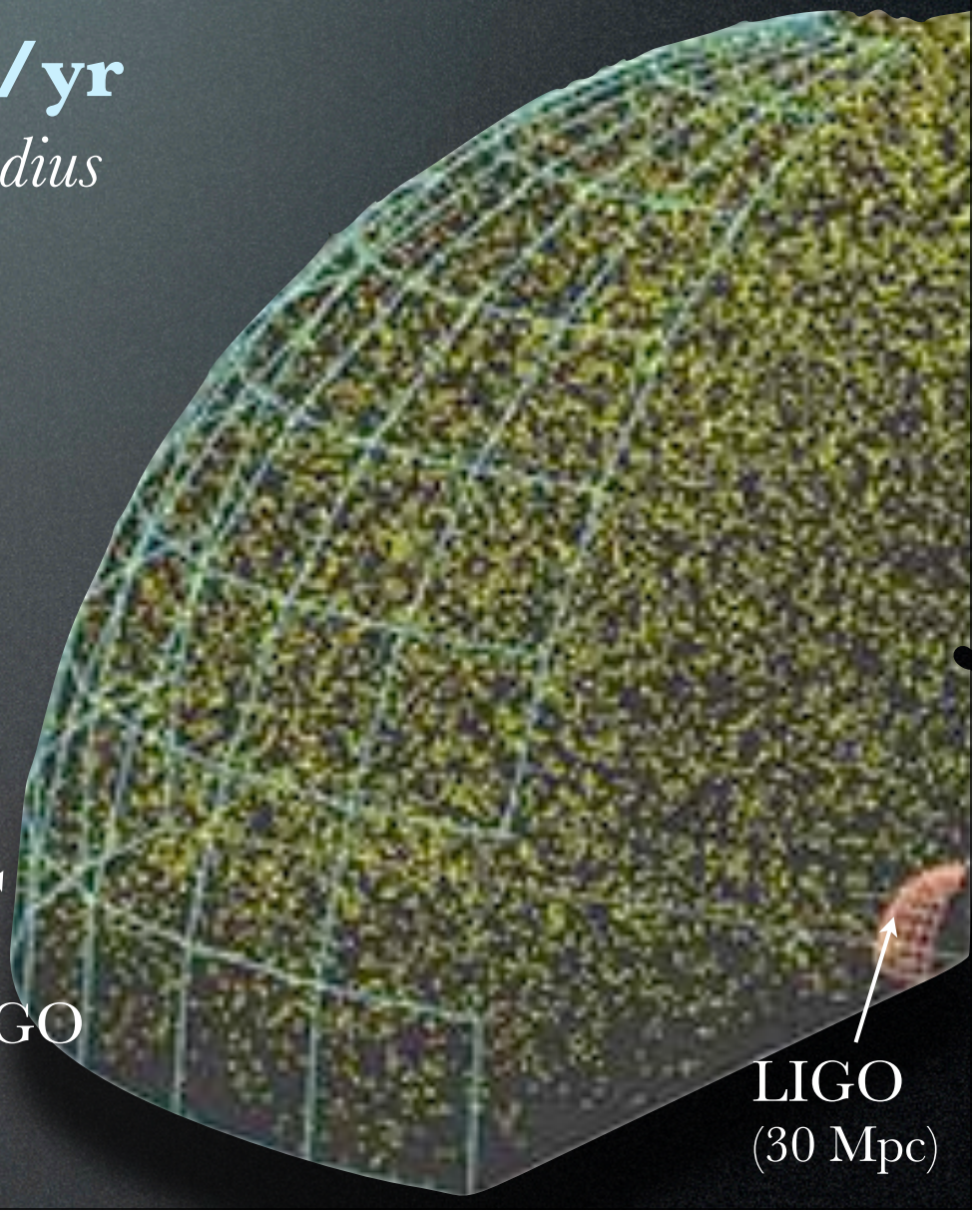
Gravitational Wave & Neutrino Follow-up

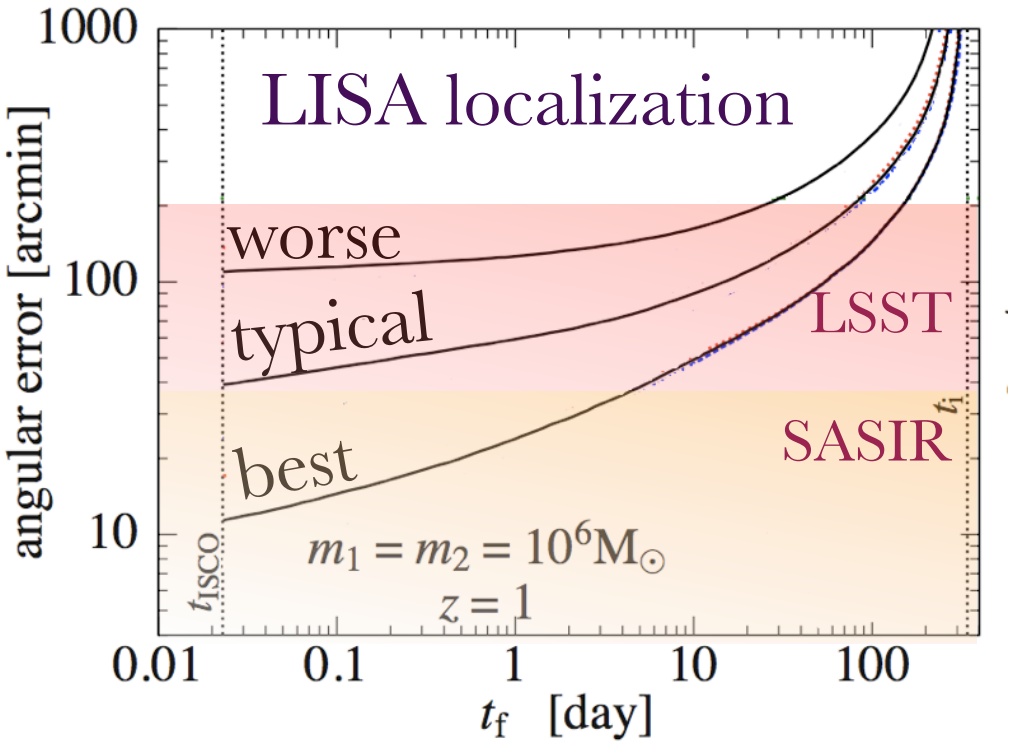
E&M connection to the next generation observatories

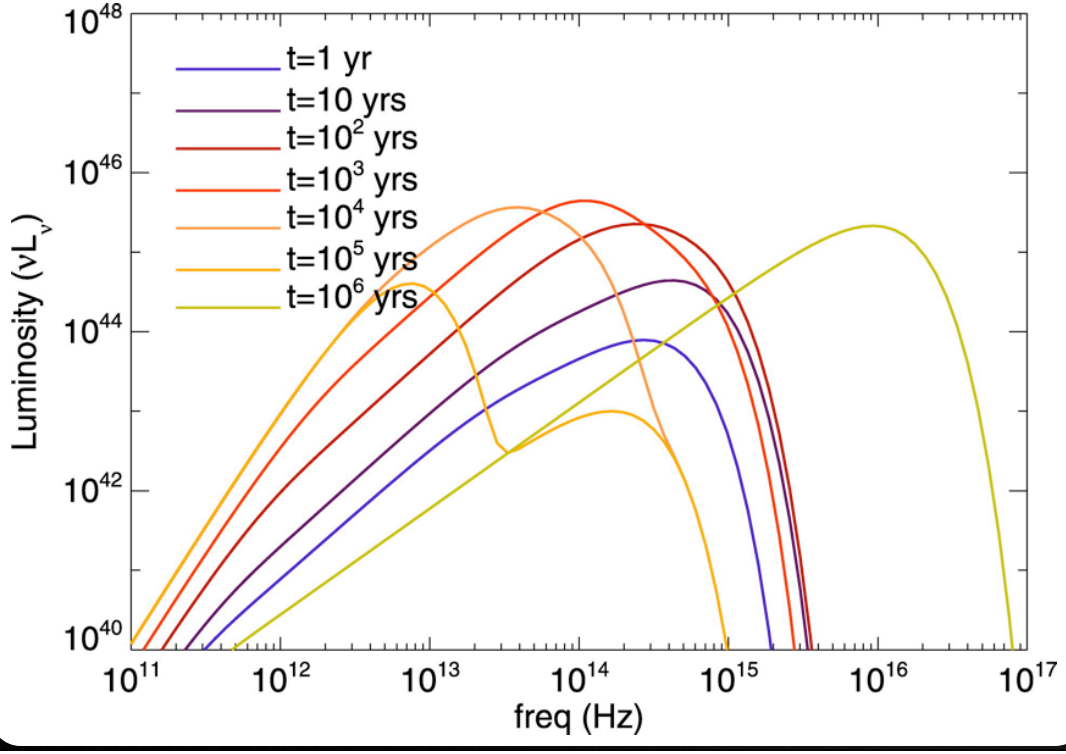
Advanced LIGO Rate: 40/yr

but localization accuracy ~10 deg^2 radius

SASIR: unique FOV + aperture, well-suited to rapid follow-up



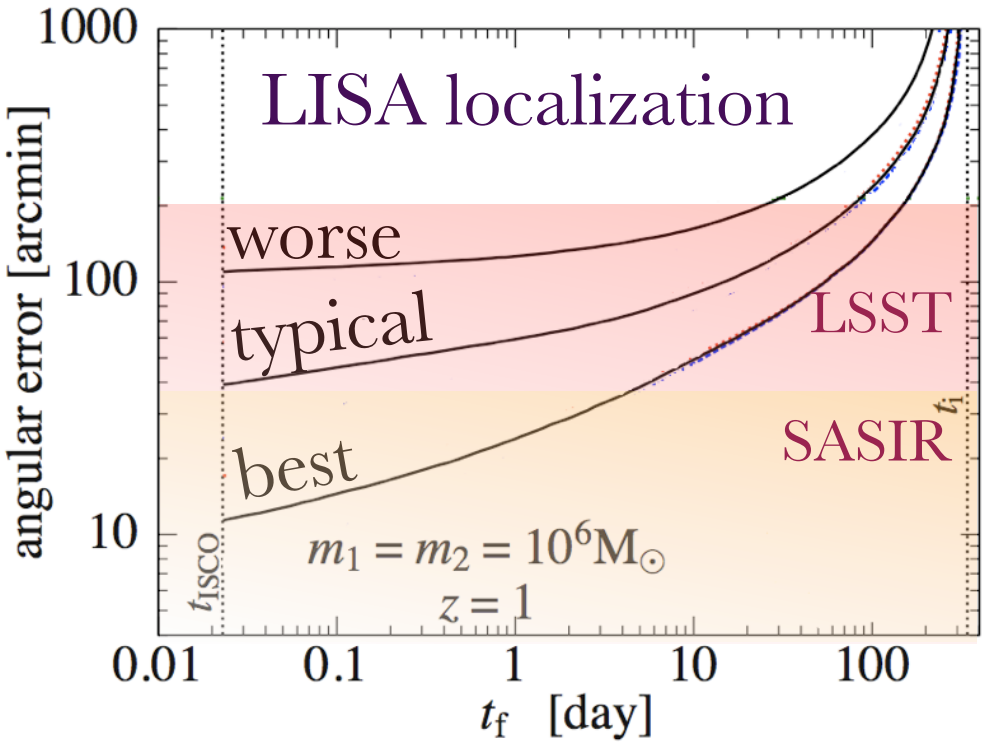


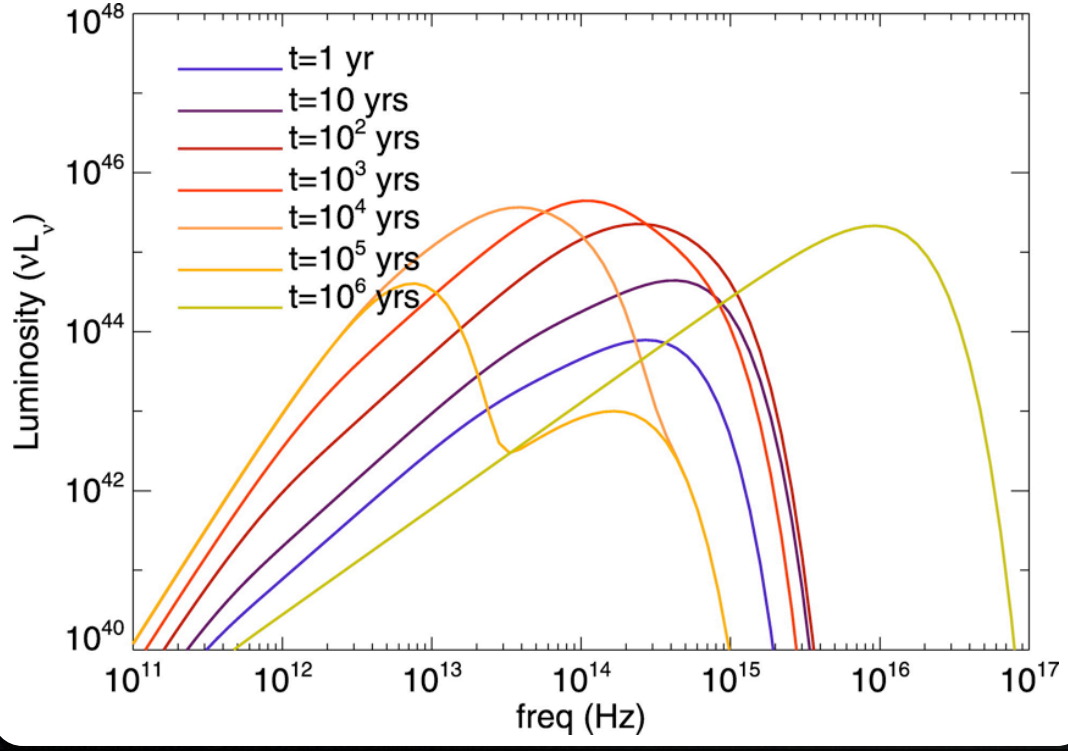


MBH-MBH mergers: Periodic transients prior to coalescence, infrared afterglows afterwards

EM event discovery (via time variability) breaks the ~deg^2 GW localization problem

Schnittman & Krolik 08
Haiman+08





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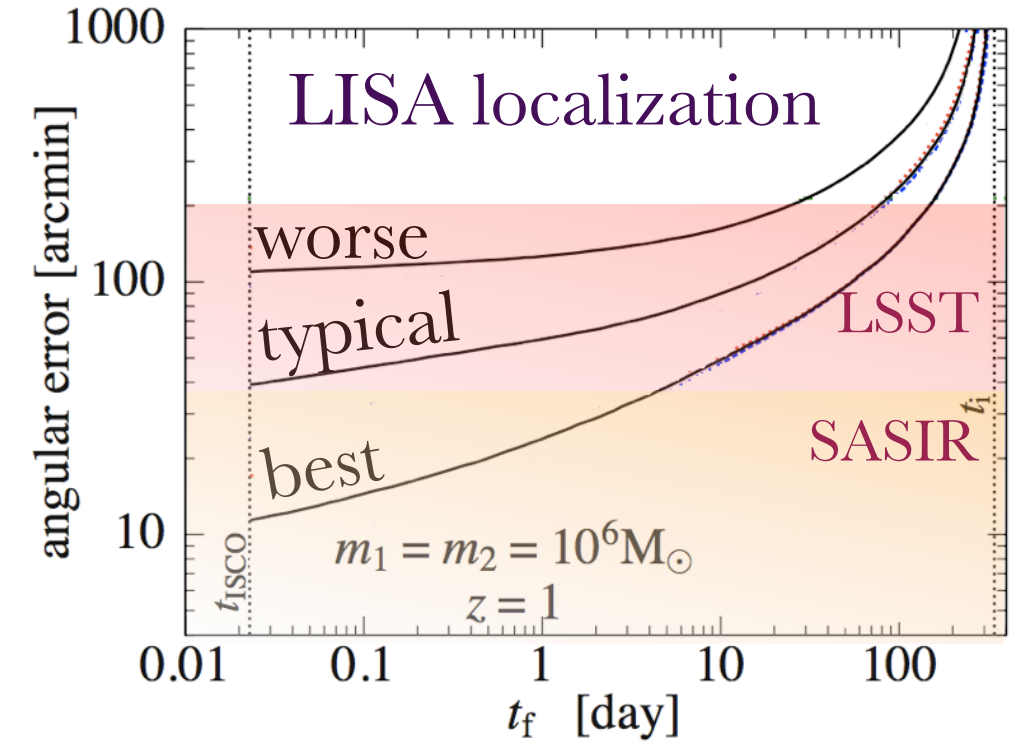

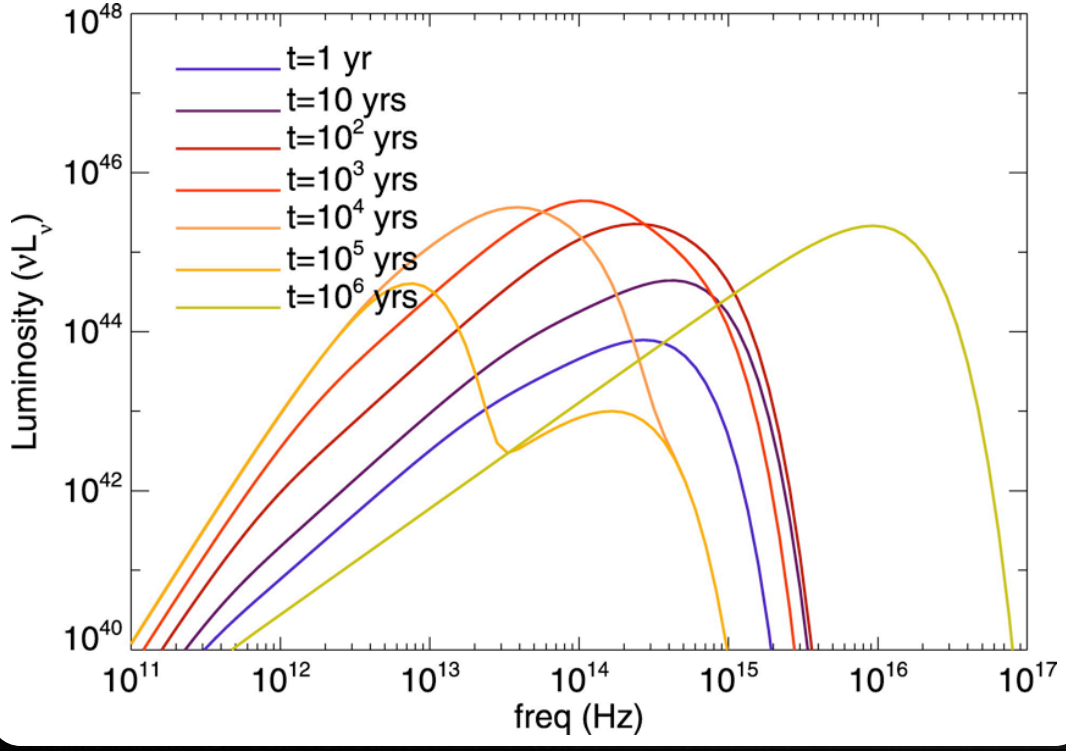

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GW chirp gives d_L to 1% (@ z=1) + host redshift:
new precision cosmology tool

Schnittman & Krolik 08
Haiman+08

Summary

New progenitor populations that are IR rich

Very promising utility for IR SNe as cosmographic tool

(IR only glimpe to SNe from first stars...)

Heger, Fryer, ... today

Important role of theory in motivating science of new IR Surveys (e.g. SASIR)

Funding

As Proposed:

Design phases:

50/50 US/Mexico Federal Funding (90%)
Institutional & Private (10%)

Construction phases:

Significant private funding (~70%), Institutional (5%),
Mexican Federal (25%), **US Federal (0%)**
US partners responsible for camera ($50M)
Mexico responsible for telescope & observatory

Survey phase:

50/50 US/Mexico Federal Funding (90%)
Institutional & Private (10%)