

Survey For Dust-Enshrouded Supernovae with miniTAO/ANIR

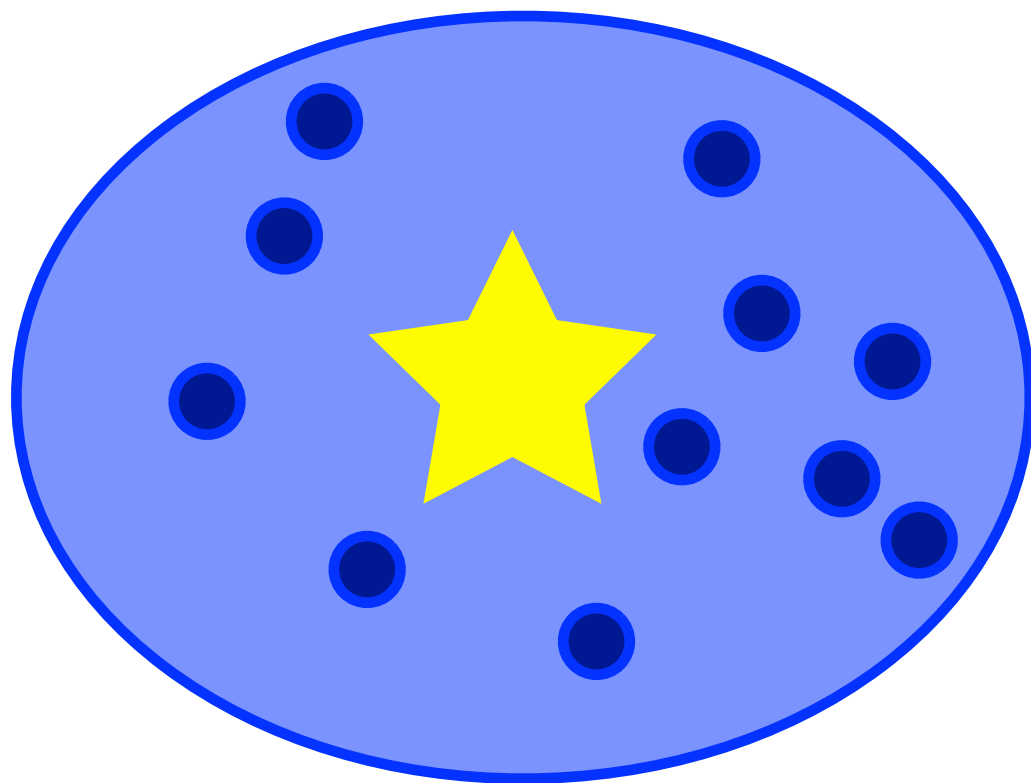
Supernova Capturing survey with ANIR
in Dusty And Luminous IR galaxies
(SCANDAL)

Tomoki Morokuma (IoA, Univ. of Tokyo)
w/ Nozomu Tominaga (Konan Univ.)
Masaomi Tanaka (NAOJ)

Dust-Enshrouded Supernovae

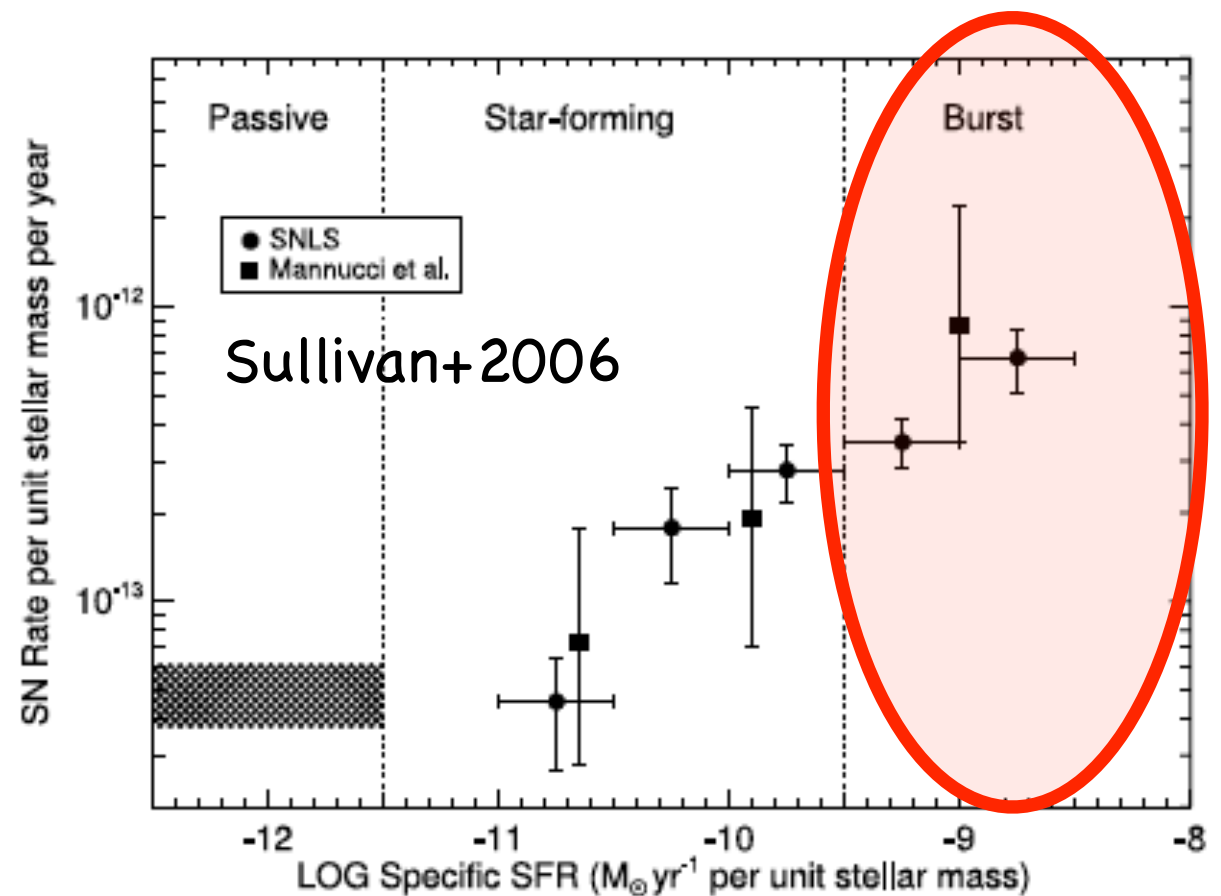
core-collapse SN (CCSN)

Type-II, Type-Ib/c



death of massive stars ($>8 M_{\odot}$)

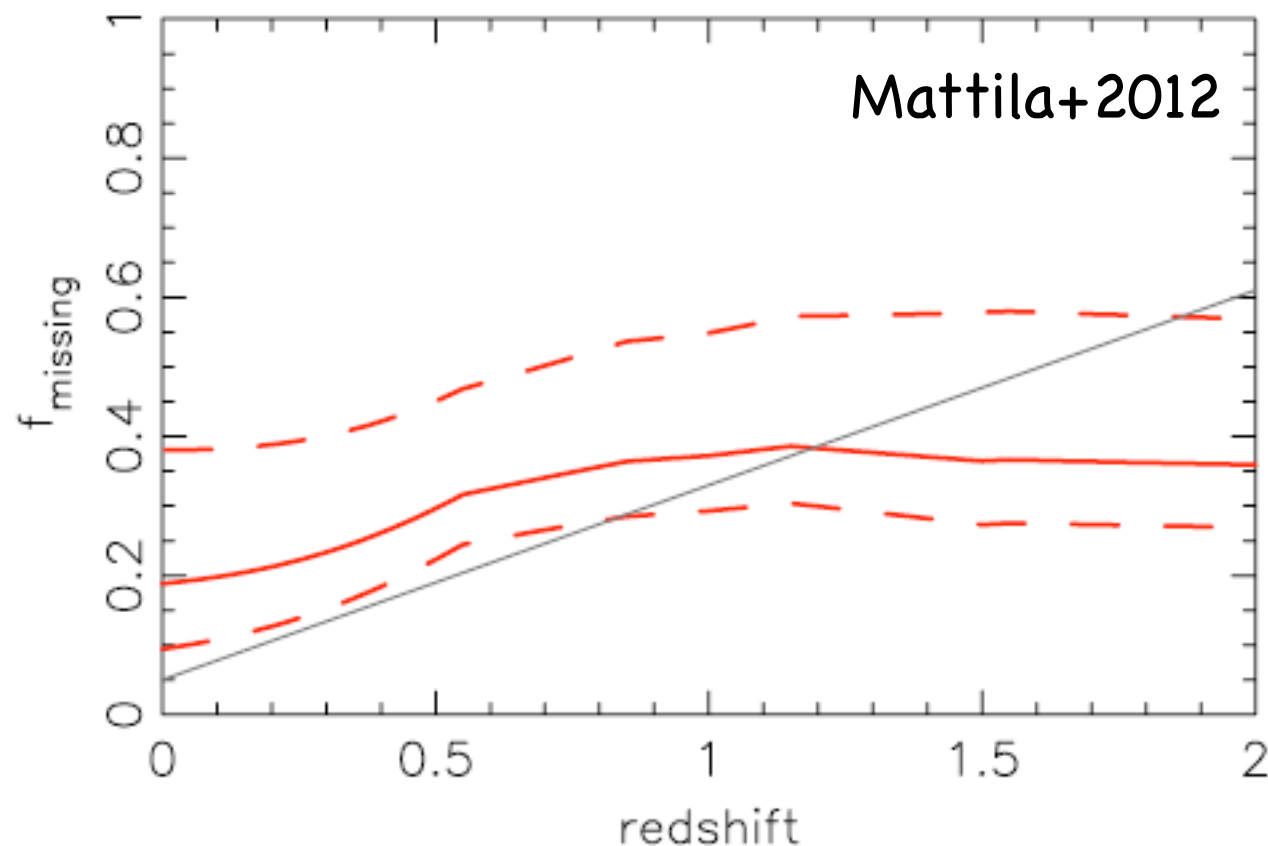
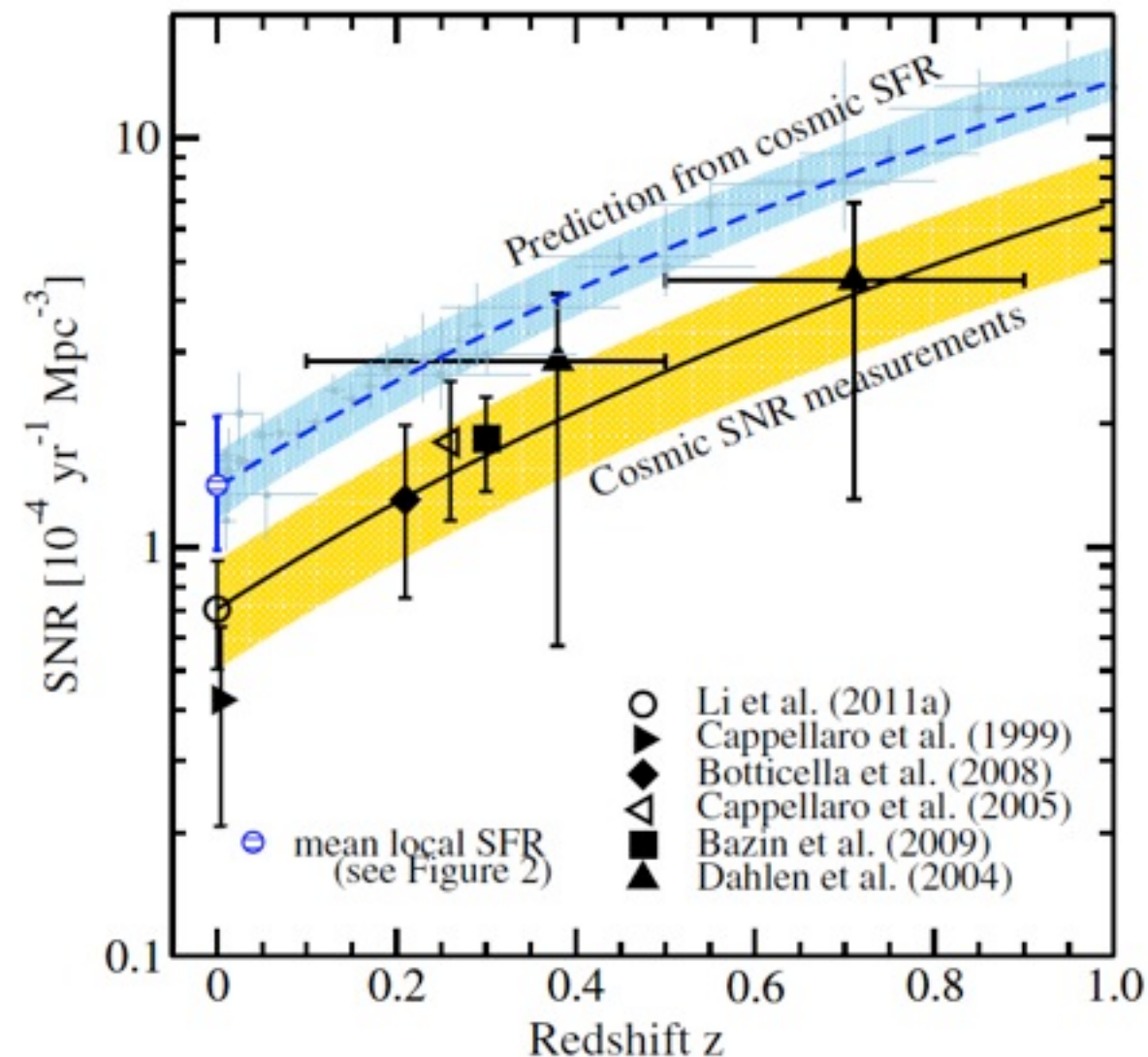
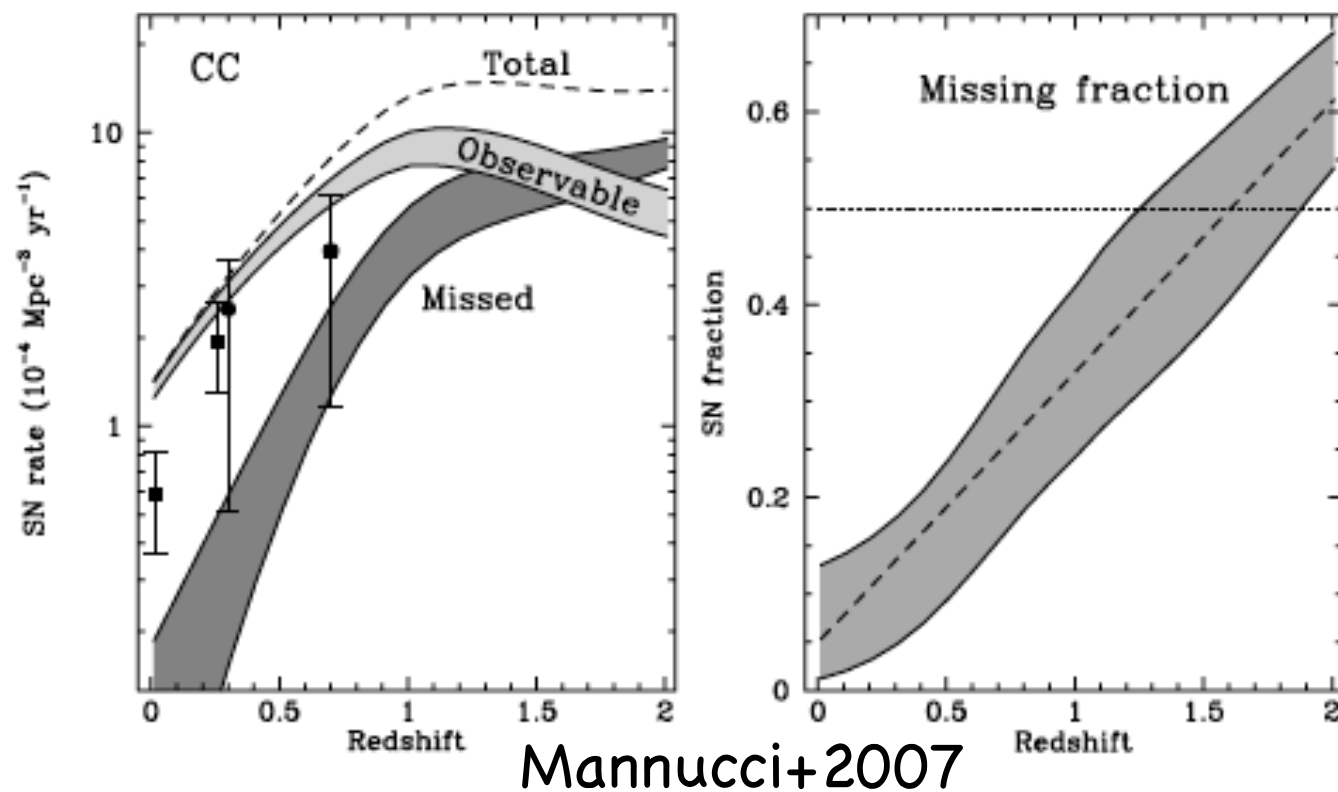
thermonuclear SN (white dwarf@binary system)
Type-Ia



many dust-enshrouded supernovae???

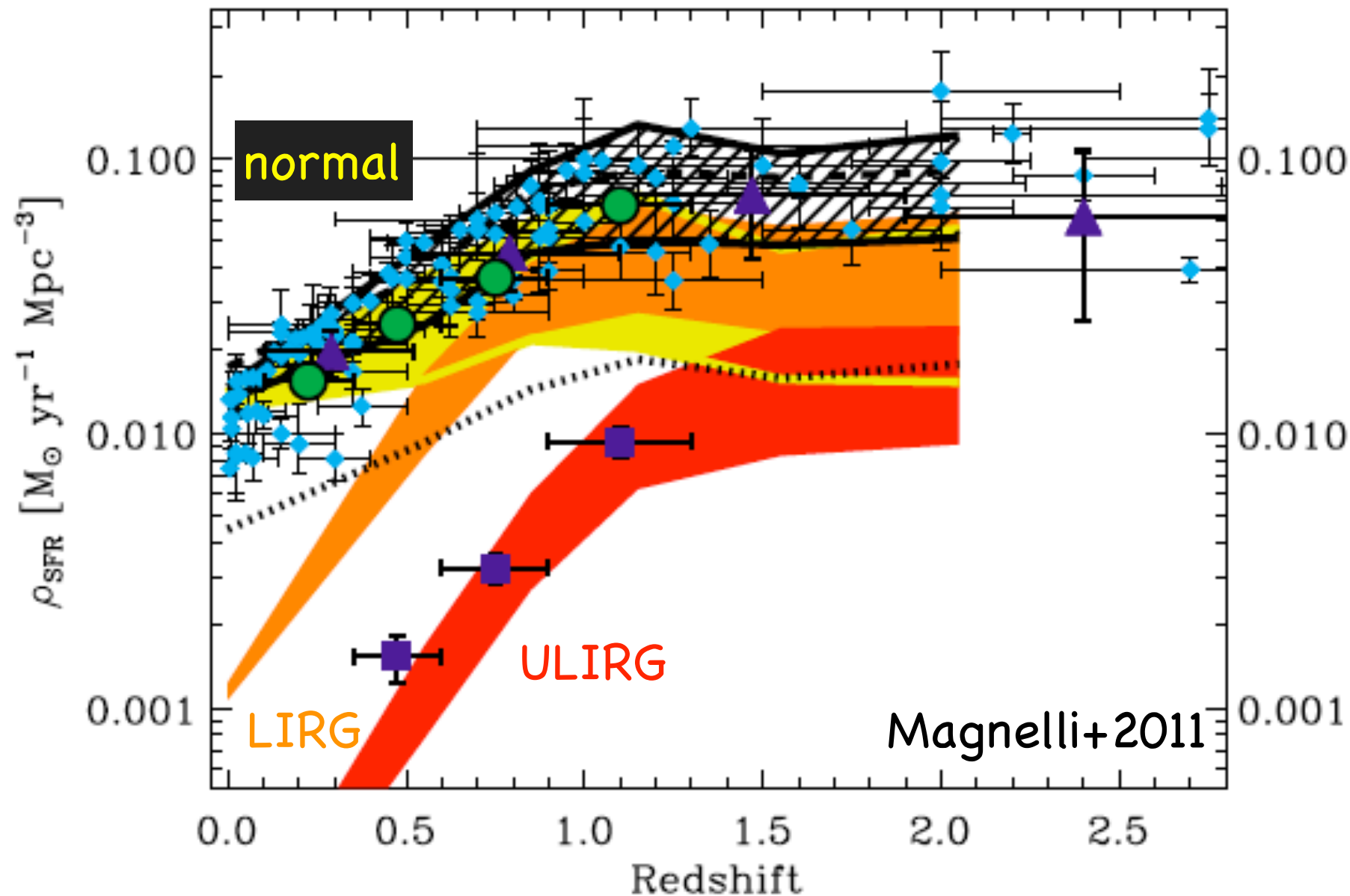
SN Missing fraction

Horiuchi+2011



- most SN surveys are in optical.
- missing (in optical) fraction: several tens %
- inconsistency between CCSN rate and SFR (a factor of ~ 2)
- 83% missed in optical in Arp 229
- > **infrared observations**
- R_v=3.1, R_k=0.35 (Cardelli+1989, Table 3)

Cosmic Star Formation History



Luminous InfraRed Galaxies (LIRGs) / Ultra-Luminous InfraRed Galaxies (ULIRGs)

- high infrared luminosity ($>10^{11} \text{ L}_{\text{sun}}$ / $10^{12} \text{ L}_{\text{sun}}$) \leftrightarrow high star formation
- large contribution to cosmic star formation rate in LIRGs/ULIRGs
- need to examine **in the local universe...**

NIR survey for Obscured SNe

only a few systematic survey results

+ Richmond+1998:

@optical(<1 μ m). 5 SNe in 142 nearby starburst galaxies. no rate excess.

+ Maiolino+2002:

@2.1 μ m. SN 1999gw, SN2001db ($A_V \sim 5.5$ mag) @LIRG.

+ Mannucci+2003:

@2.2 μ m. 4 SNe in 46 LIRGs ($>10^{11.1} L_{\text{sun}} = 0.4 \text{ SN/yr}$, $d < 20 \text{ Mpc}$)

smaller by a factor of 3-10 than expected from L(FIR)

+ Mattilla+2007:

@2.2 μ m. VLT/NAOS/CONICA w/ AO, SN2004ip, $A_V \sim 40$ mag.

+ Kankare+2008:

@2.2 μ m. Gemini-N/ALTAIR(AO)/NIRI, HST/NICMOS. 2 SNe. $A_V = 15.7$ mag.

+ Vaisanen+2010:

@2.2 μ m. local LIRGs/ULIRGs, 4 SNe.

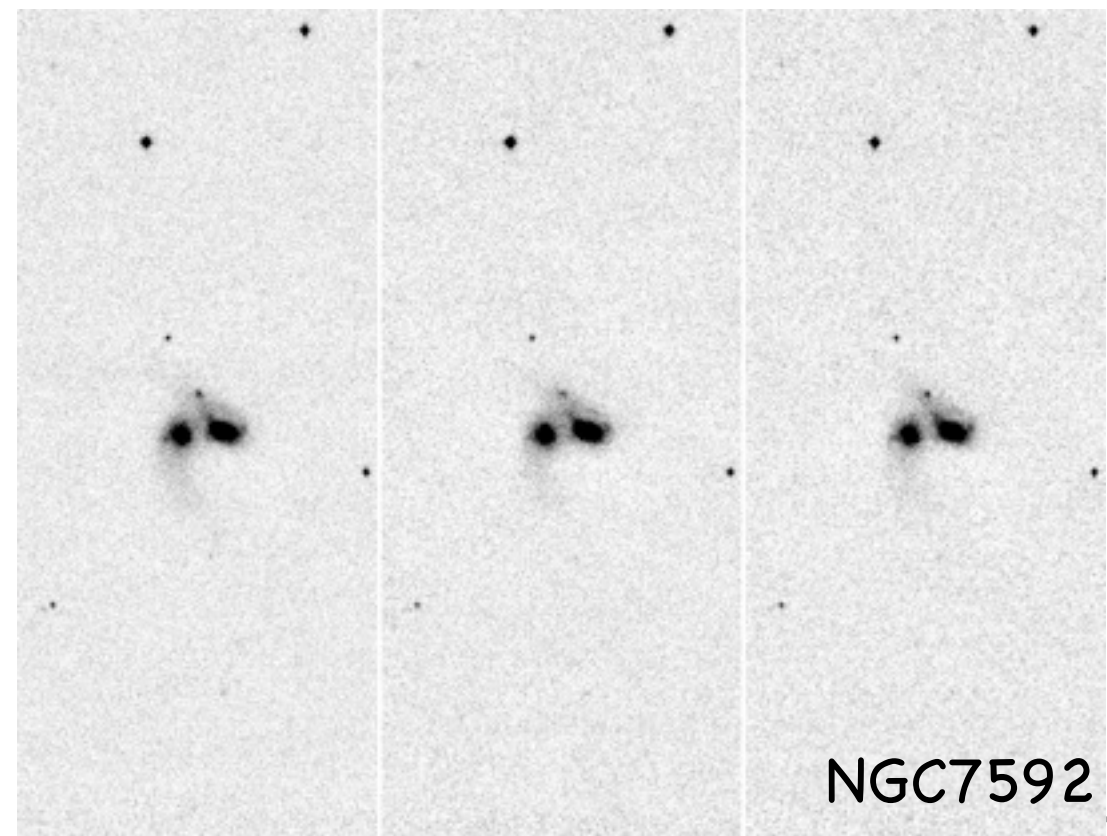
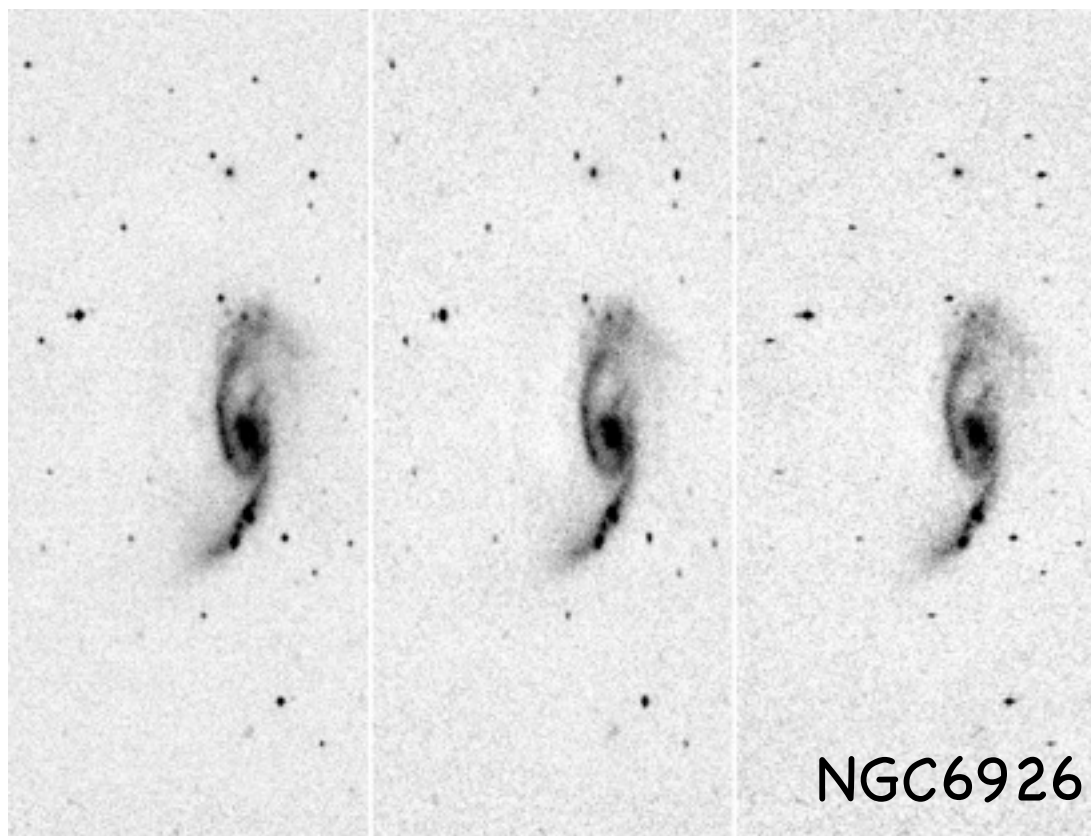
1. large dust extinction even in NIR?
2. universal Initial Mass Function?
3. Star Formation Rate?

systematic survey in NIR
w/ miniTAO/ANIR

SN survey strategy

understand unknown missing (in optical) fraction
and its reason even in the local universe

- + most SN surveys: in optical --> in NIR
- + nearby (<100Mpc) LIRGs
 - Pa-alpha imaging obtained w/ miniTAO/ANIR
 - > spatially-resolved examination of star formation (Tateuchi+, in prep.)
 - where are SN located? How much dust extinction?



miniTAO/ANIR observation for SNe in LIRGs

miniTAO/ANIR

- miniTAO 1-m telescope @ Co. Chajnantor, Chile
- optical-**NIR** simultaneous imager: ANIR
- **good seeing (spatial resolution)**: < 1 arcsec (~ 0.5 kpc@ $d=100$ Mpc)
- good weather condition

to find supernovae...

- w/ $A_v \sim < 10$ mag (factor $\sim 10,000$)
- in nearby LIRG@ $d < 100$ Mpc

SN rate: 1 [SN/yr]
SFR: 91.7 [Msun/yr]
L(FIR): $10^{11.72}$ [Lsun]

long-term monitoring observations for LIRGs

- no SNe found so far in our pilot observing runs
- monitor ~ 40 LIRGs
- ~ 10 SNe over 2 years (2 months \times 2)
- understand missing/obscured SN fraction, why they are missed

reference images for searching for GW EM counterparts

- **high spatial resolution images for nearby LIRGs@ ~ 100 Mpc**

ANIR Data (2011A–2012B)

○2012B (miniTAO/ANIR)

- 6 LIRGs
- 1 epoch: 11/16 (6 LIRGs)

○2011B (miniTAO/ANIR)

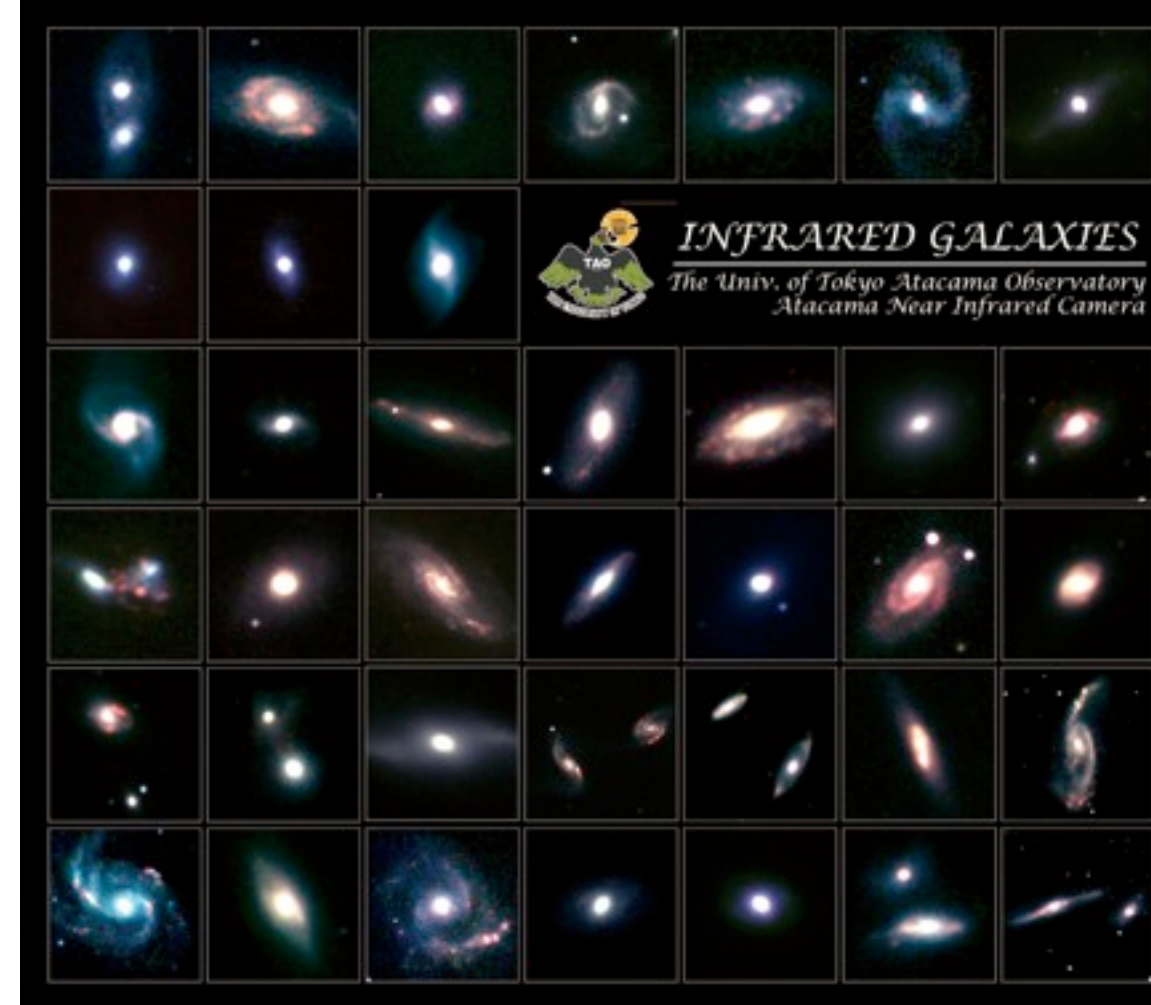
- 17 LIRGs over 17 days
- 4 epochs: 10/4 (16 LIRGs), 9 (0 LIRGs),
14 (4 LIRGs), 17 (17 LIRGs), 21 (16 LIRGs)

○2011A (miniTAO/ANIR)

- 10 LIRGs over 25 days
- 5 epochs: 4/20 (8 LIRGs), 25 (10 LIRGs), 28 (8 LIRGs), 5/9 (0 LIRGs),
5/11 (2 LIRGs), 15 (7 LIRGs)

○2011/02/17 (IRTF/SpeX)

- 4 LIRGs
- 1 epoch



2 SNe expected, but no SNe found so far
but consistent with previous studies...



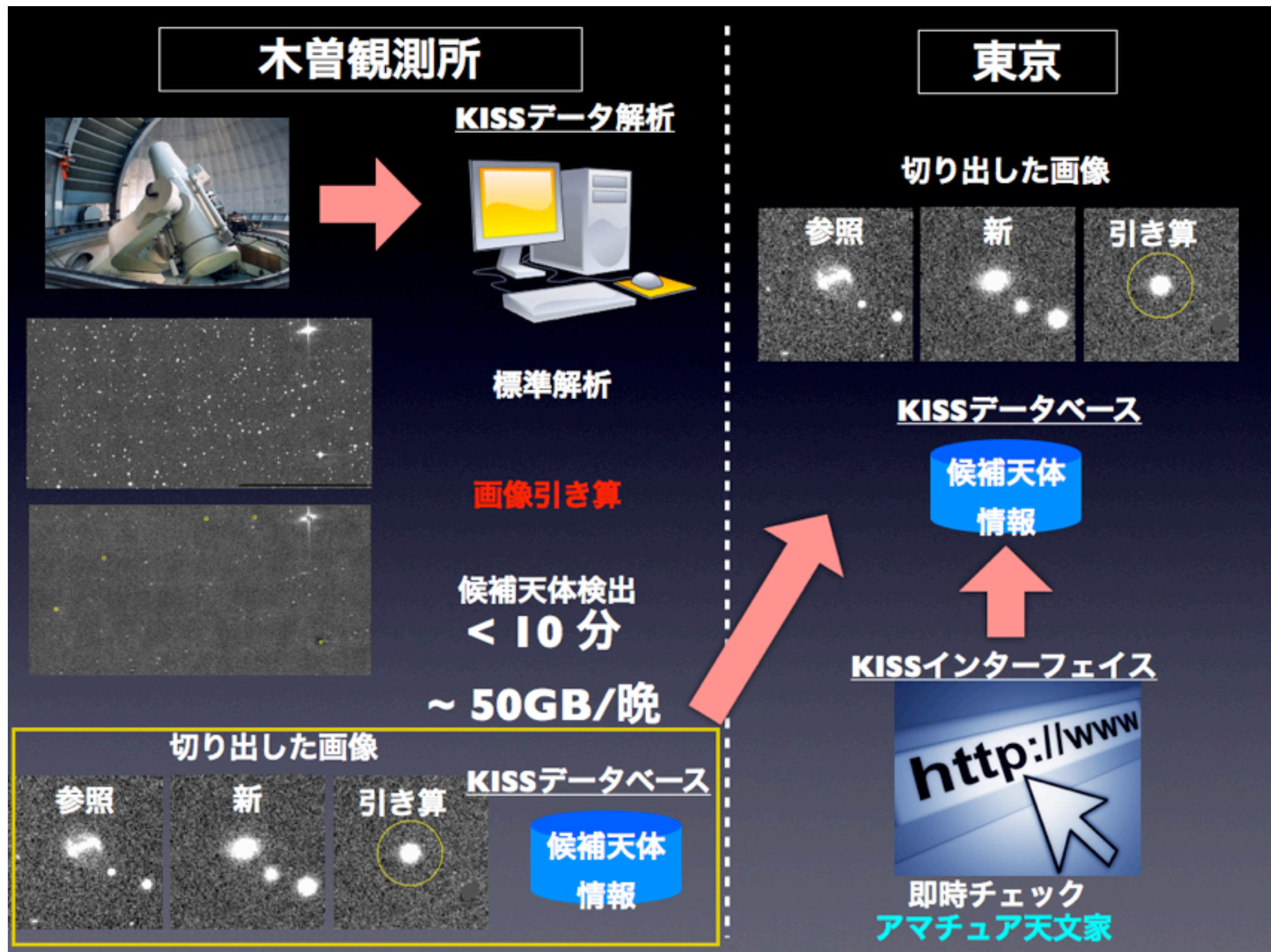
implementation of KISS software

Kiso Supernova Survey (KISS)

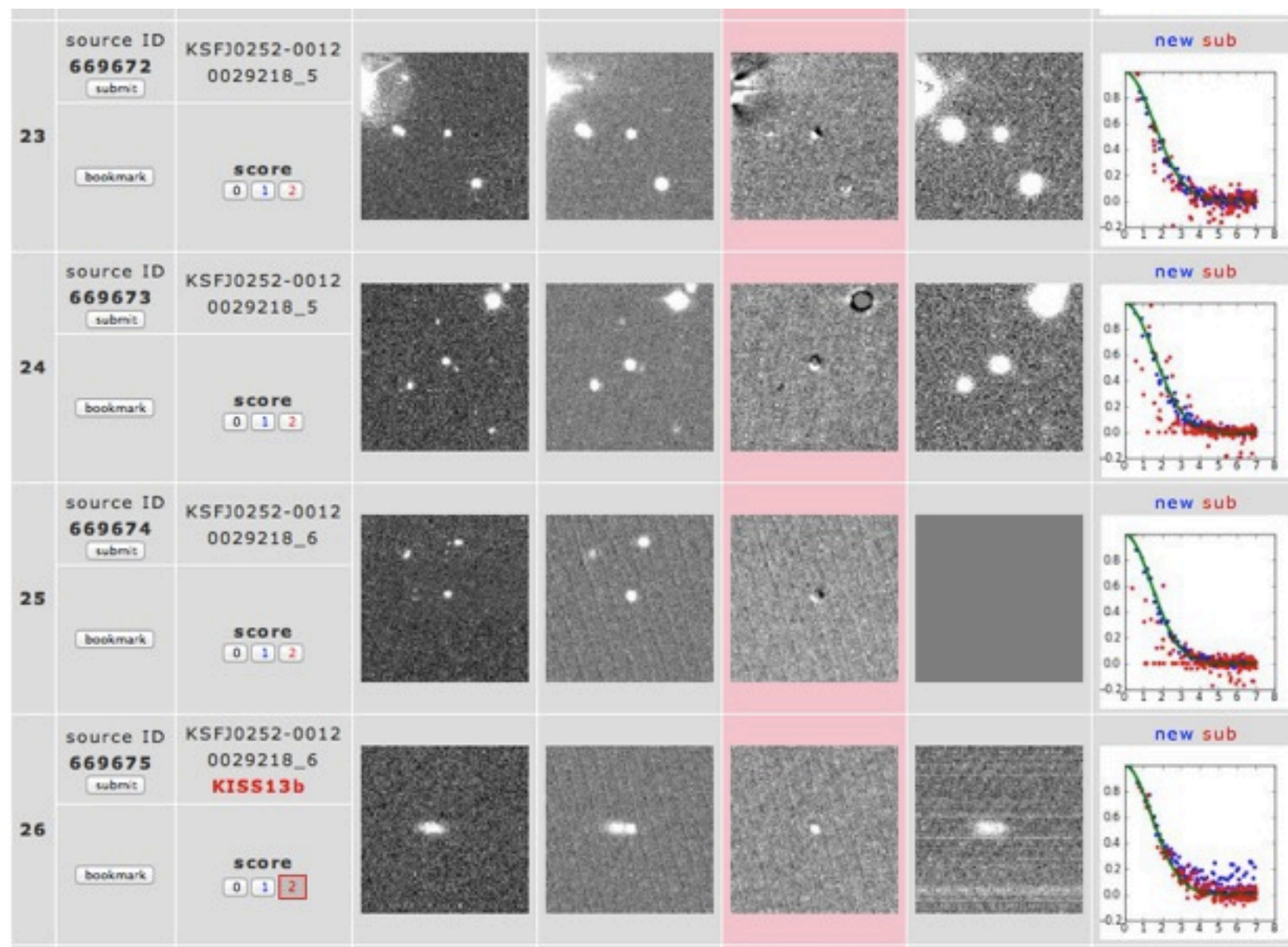
- detect supernova shock breakout (the moment of supernova explosion)
 - $z < 0.03$
 - ~ 100 SNe over 3 years
- very high cadence (~ 1 hour interval) supernova survey
 - $50\text{--}100 \text{ deg}^2 / \text{night}$
 - ~ 100 nights / year
- verify theoretical model with high S/N observations
 - cosmic star formation history up to $z \sim 3$ w/ Subaru/Hyper-Suprime-Cam



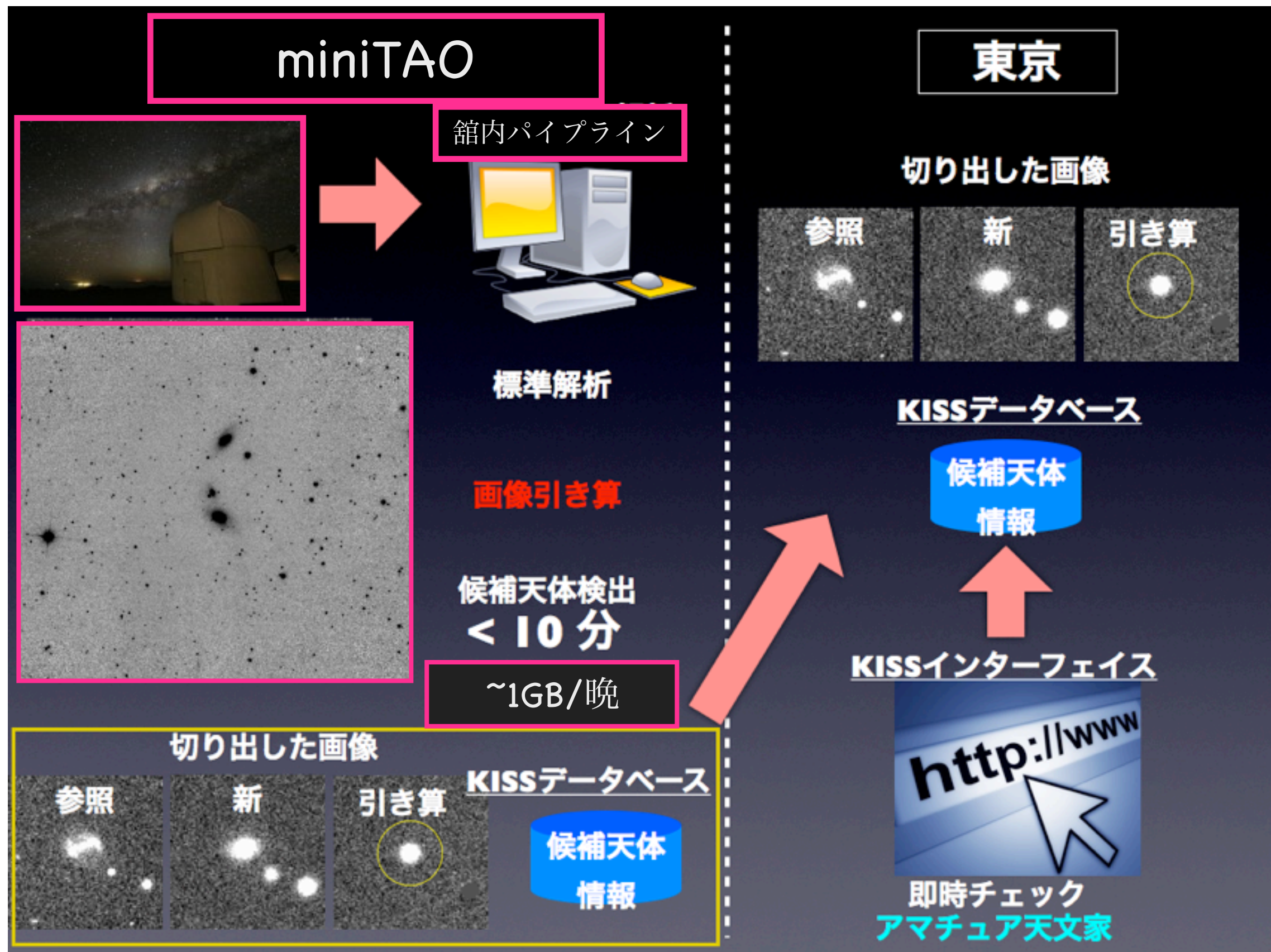
implementation of KISS software



implementation of KISS software



implementation of KISS software



Summary

- + A significant fraction of (core-collapse) SNe are missed in optical surveys.
- + SN missing (in optical) fraction as well as its reason have not been understood well.
- + only a few systematic SN survey in NIR even in the local universe.
- + find SNe w/ $A_V \sim < 10 \text{ mag}$ in nearby LIRGs at $d \sim < 100 \text{ Mpc}$ w/ miniTAO/ANIR.
 - good spatial resolution, dusty star formation examination w/ Pa-alpha emission lines
 - reference images for future GW detections
- + need long-term observations
 - > ~ 10 SNe / 2 years (~ 4 months)
- + implementation of KISS software for easy/quick search
- + change observing strategy...?