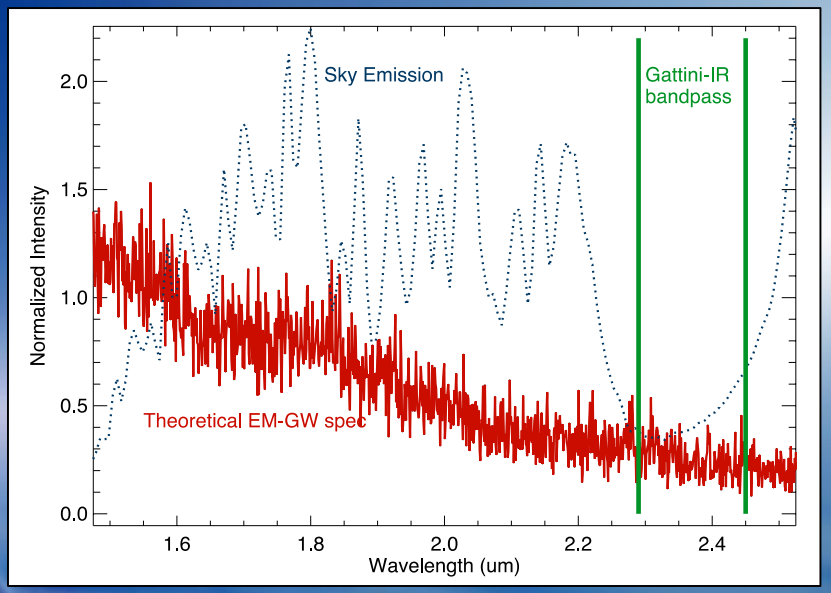
Gattini-IR

A Synoptic IR Survey from the South Pole



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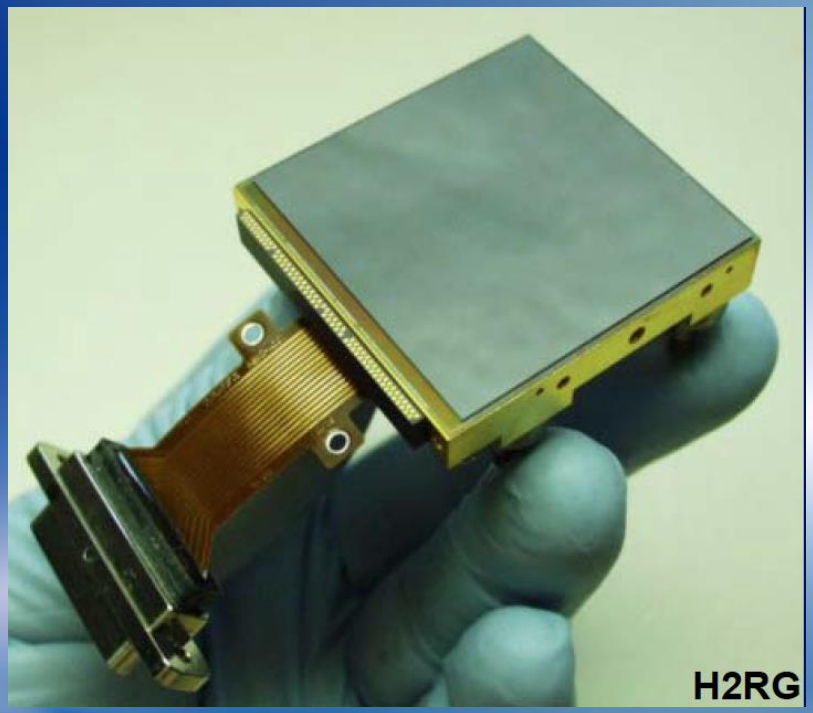
Caltech

Introduction

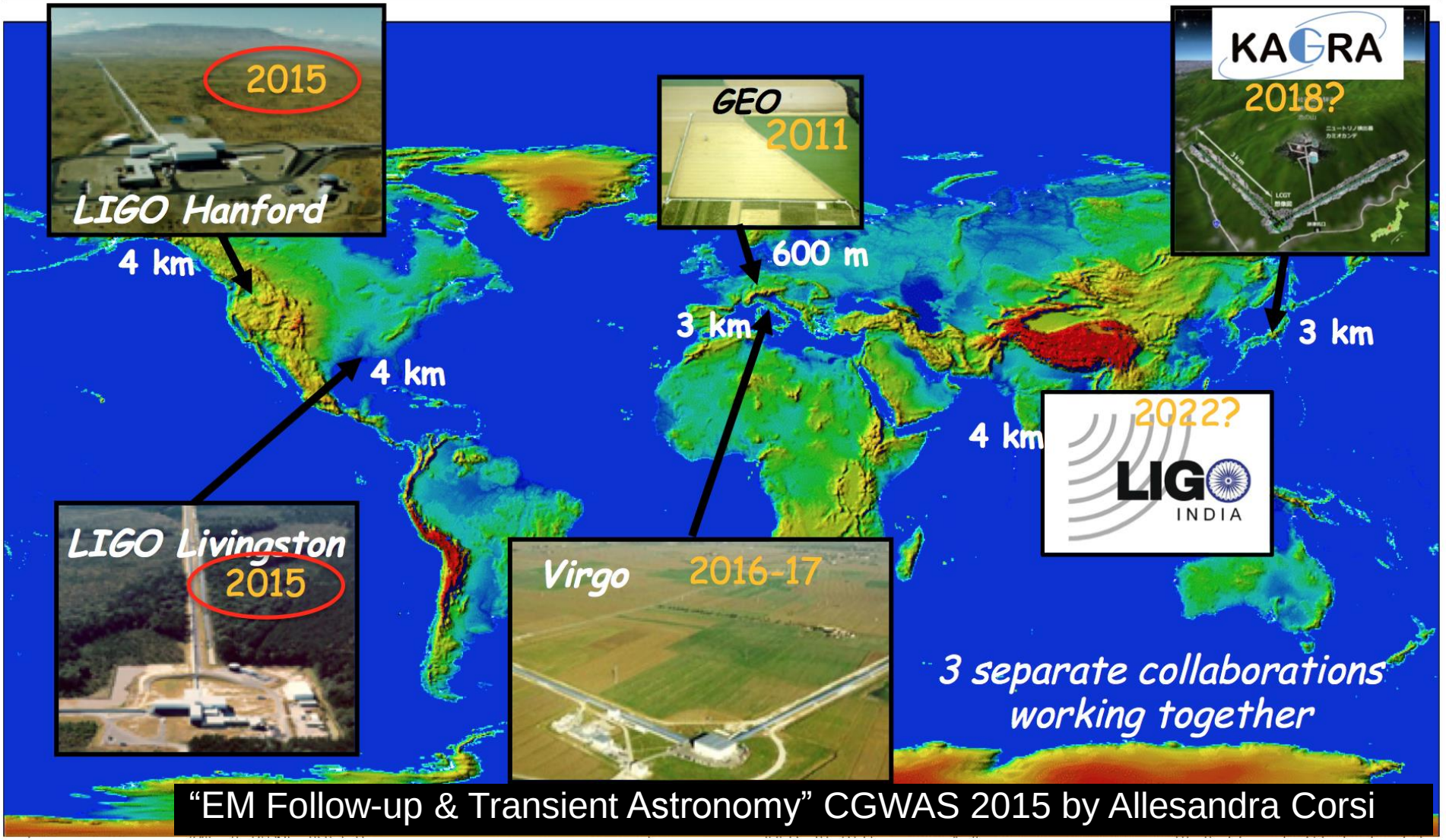
- Dedicated instrument to systematically chart the transient IR sky
- South Pole location
  - ✧Low sky background, especially “Kdark window” [2.29-2.45um x20-40 times lower than Mauna Kea]
  - ✧A unique, continuous visibility window on ≈15,000 sq deg at a reasonable airmass (<2.5)
- 100 sq deg across 1xH-2RG IR array
  - ✧17.6 arcsec/pixel
  - ✧17.9 M_{Vega} [19.7AB] with SNR=5 in t=3600s

H2RG

- H-2RG array is in-house at Caltech Optical Observatories
- Potential for a quick turnaround
- Deploy IR camera in 2017/2018 austral season

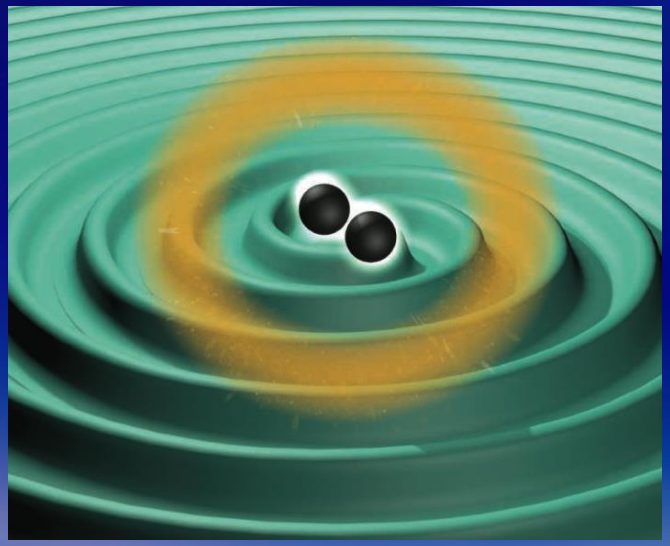


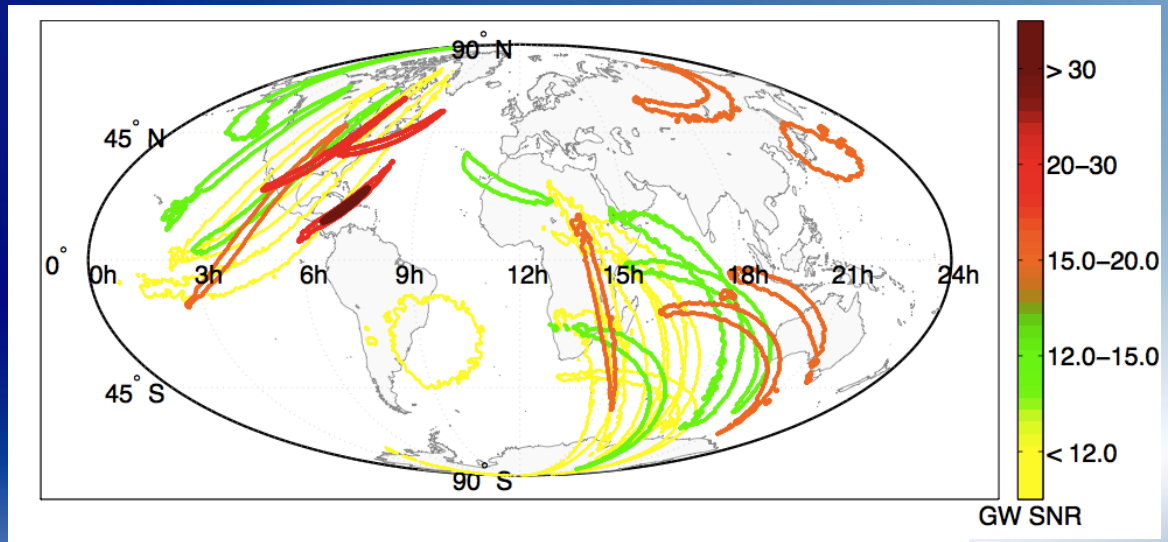
Advanced GW detector Network



"EM Follow-up & Transient Astronomy" CGWAS 2015 by Allesandra Corsi

EM Counterparts of Gravitational Waves

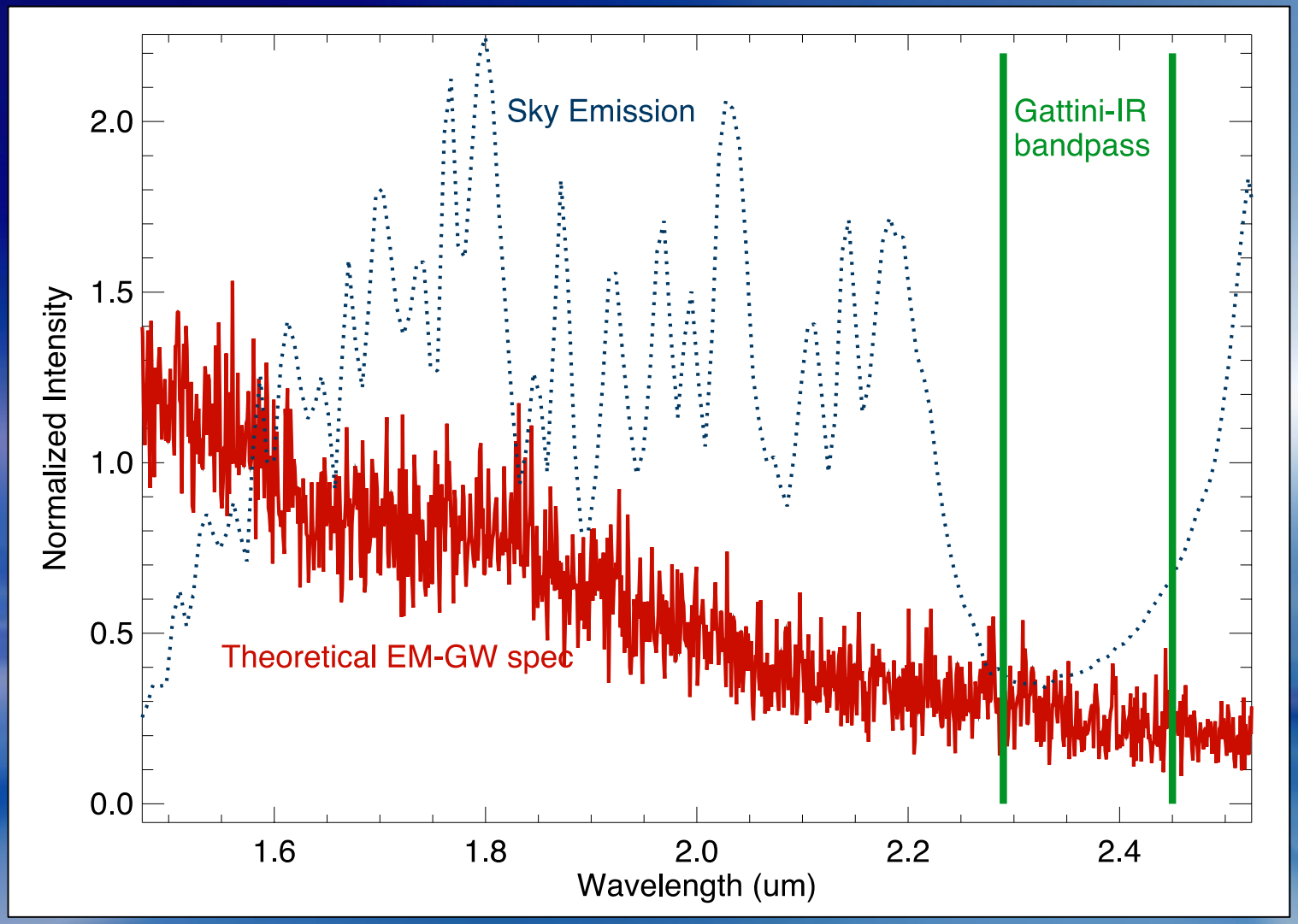




Simulation of sky localizations of arcs of mergers detected by LIGO-Hanford and LIGO-Louisiana.

- Thought to be very bright in IR (if NS-NS and NS-BH events are sources of r-process elements "Gold and Platinum mines of the Universe")
- 100-250 sq. degree search area after initial alert from Adv-LIGO
- Search areas have elongated shapes for combined detections
- EM counterparts (kilonova) visible for week-10 days
- Gattini-IR would be able to survey any southern alert region immediately with no time delay

Kdark window



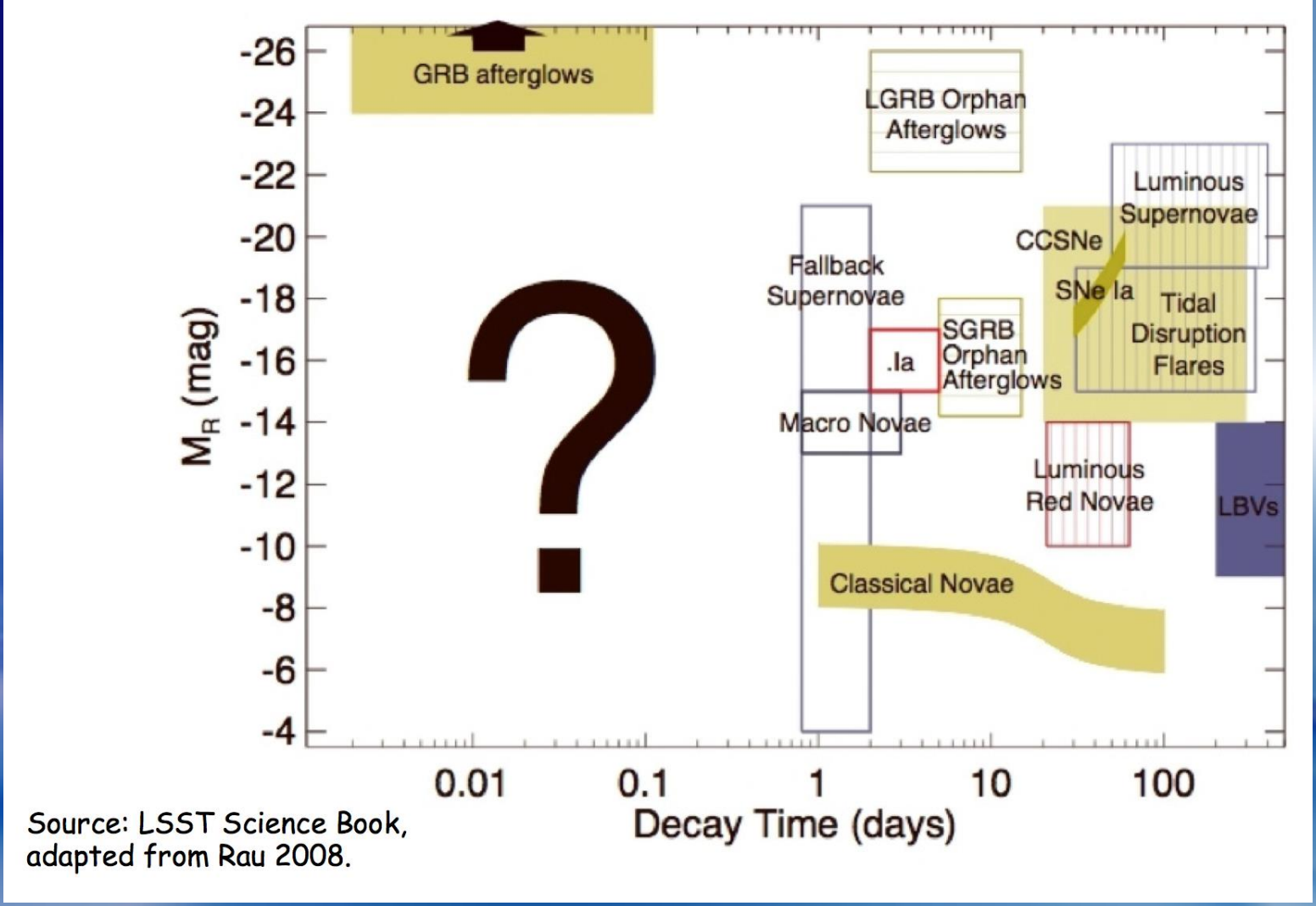
Advantages of South Pole Location

- Advantages are both scientific and technical
- It's cold (!) = low thermal emission from sky
- Sky is warmer than the ground
  - 100 sq deg IR camera (F/0.7) does not need an internal cold stop
- No diurnal cycle during winter
  - Gattini-IR can integrate continuously after GW alert received

Gattini-IR SNR

f/0.7, 300mm, Kdark, SNR=5, Sky B=17 Mvega/arcsec^2 (zenith median)	Mvega	MAB
(1 module) 3600s	17.7	19.4
(1 module) 10,000s	18.2	19.9
(1 module) 1 day	19.4	21.1
(1 module) 1 week	20.4	22.1
(1 module) 1 month	21.2	22.9
(1 module) Season	22.1	23.8

Dynamic IR sky unexplored



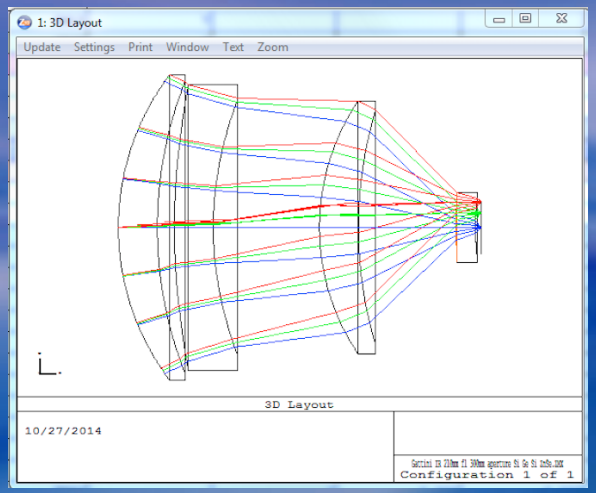
Source: LSST Science Book, adapted from Rau 2008.

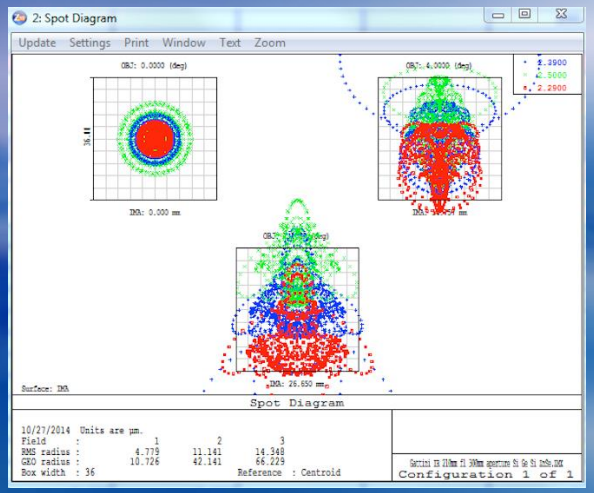
Science Flowdown

SPECIFICATION	*REQUIREMENT*	*NOTES*
FOV	100 sq deg.	Advanced LIGO alert (median 250 sq deg)
Bandpass	2.29-2.45um	Large gain at South Pole. EM counterparts are brightest in the infrared.
Sensitivity (SNR=5, t=3,600s)	17-18 mag (Vega)	Minimum point source sensitivity requested by science team.
Distortion	~few%	Equalize sky background/pixel across field
Image Quality	Spot Size PTV ≤ 2x2 pixels across entire FOV; Goal ≤ 1x1	Goal ≤ 1x1 pixel maximizes sensitivity to Advanced LIGO EM counterparts
Ghost Performance	<1%	All ghosts are static in this system, but pixel sampling on sky and sky background are large
Vignetting	0 across 80% of the field	Equalize SNR; minimize exposure time
Sky Access	Full Sky Access	Gravitational Wave Trigger locations cannot be controlled!
Acquisition/ Slew time	<1min max between any two locations	H2RG readings are fast so slewing time should be negligible compared to on-sky time
Filters	K-dark 2.29-2.45μm	Project driven to reduce costs/No filter mechanism
Focusing	2x2 pixel to 1x1 pixel a goal but not vital to success of project	Lens heating will be prototyped as an active focus tool
Communication/Alerts	24/7	Advanced LIGO

Instrument Design

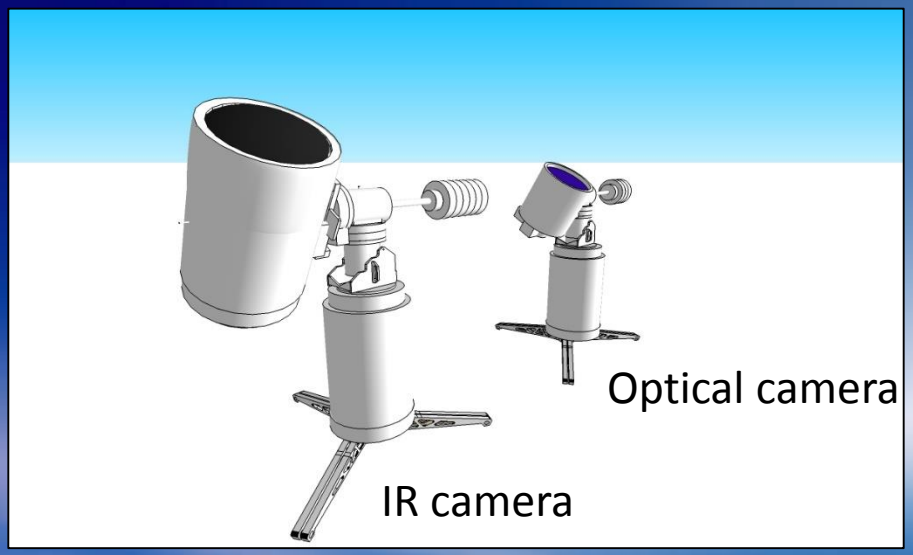
- Targeted design aided by bandpass and >2μm wavelength
  - ✧ F/0.7 300mm Germanium and Silicon lens design
- Proven winterized components adopted eg mount
- Instrument control system proven and based on previous Gattini instruments
- Sky is warmer than the ground at the South Pole making instrument design easier





Redundancy

- Two identical systems (including control) will be deployed in successive years



- Year 1: Optical camera deployed
  - ✧End to end system tested in the field
  - ✧Data reduction pipeline written and tested
  - ✧Communication/alerts/data download all thoroughly tested
- Year 2: Deploy IR camera
- Year 2 onwards: Operate IR/Optical cameras in parallel

Survey Strategy

- Build deep 15,000 sq deg reference image (1 month)
- Perform series of cadence experiments to logarithmically sample different time baselines
  - ✧ Eg 1hr, 3hr, 9hr, 27hr etc one cadence at a time
- 24/7 communication with South Pole station so alerts in/out not a problem


Amundsen Scott South Pole Station

Comparison with other facilities

Telescope	Location	Diam [m]	FoV [sq deg]	Sampling [pix]	Depth [Kd/Ks]	Exposure [sec]	**Mapping Speed [sq deg/hr]**
Gattini-IR	South Pole	0.3	100	1	17.9	3600	**100**
VISTA	C. Paranal	4.1	0.6	6	18.0	2	**72**
UKIRT	Mauna Kea	3.8	0.2	8	18.0	4	**80**
CFHT	Mauna Kea	2.6	0.1	7	17.9	4	**29**
Euclid	Space	1.2	0.92	11	17.9	8	**87**
WFIRST	Space	2.4	0.28	6	17.9	1.5	**32**

- Assumes no overhead on telescope slewing, image mosaicking is equivalent between systems etc.
- AST3-NIR ("KISS") is a highly complimentary facility (eg follow-up of Gattini-IR)

Cloud Cover/Aurora

- Gattini-SPUV deployed to South Pole 2011-2013 to quantify (blue) optical properties of winter sky
- Usable hours per season=2,586hrs
- Compare to PTF (2,100hrs/year)
- No aurora of any measure in Kdark window (Phillips et al, 1999)
- There are better Antarctic sites (the Domes) but SP is good enough for this science and the logistics are superb

	Mauna Kea (Gemini)	South Pole
Any other usable (extinction >3)	10%	13%
Cloudy (extinction 2 – 3)	20%	6%
Patchy cloud (extinction 0.3 – 2)	20%	34%
Photometric (extinction <0.3)	50%	47%

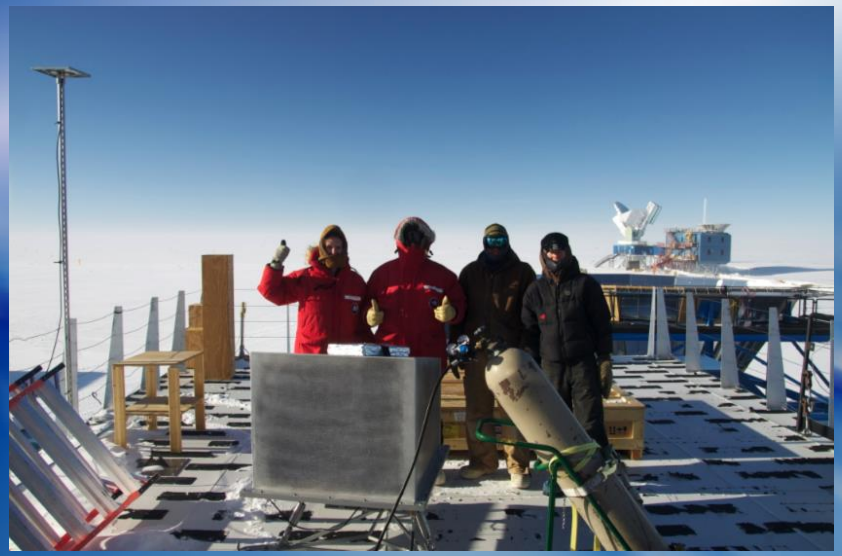
Cloud cover comparison of the South Pole and Mauna Kea. The Mauna Kea results come from Gemini Observatory [18]. South Pole statistics were measured by Gattini-SPUV [15] for 2011 & 2012 Antarctic winter seasons.

Timeline

- Award start June 2016
- Order components for Optical camera system
- Design, assemble, test IR camera
- Deploy optical camera to South Pole in Dec/Jan 2016
- Optical camera on-sky April-September 2017
- IR camera deployed to South Pole in Dec/Jan 2017
- IR and Optical cameras on-sky April-October 2018
- Minimum 3 year campaign

Summary

- IR dynamic sky is ripe for exploration
- Dedicated Kdark 100 sq deg imager with a South Pole location monopolizes on unique sky conditions and design simplifications
- Searching for EM counterparts of GW events is a potentially ideal science case



How can SCAR AAA help Gattini-IR?

- Synergies/collaboration
  - Workshop provides medium for inter-project discussion
  - AST-NIR, IceCube, Evryscope, AST3 etc.

- Provide guidance for future relocation to higher altitude site (Ridge A or other)
  - If background is 25uJ/arcsec^2 this is very exciting!