Sciences with ngVLA

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ngVLA: Key features

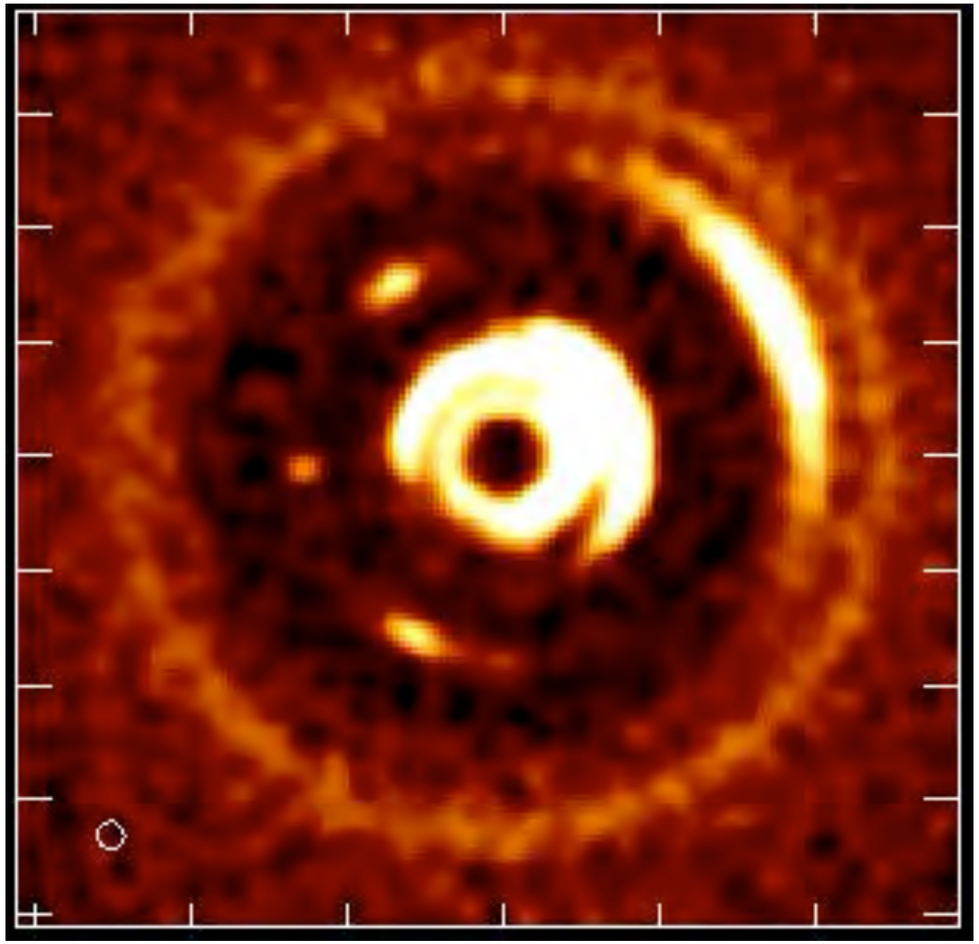
- **Goal: 10x collecting area of JVLA/ALMA** http://ngvla.nrao.edu/
  - 18m dishes x 214 (160μm surface)
- **Frequency range: 1.2 –116 GHz**
  - bridging between ALMA and SKA
- **Spatial resolution: 10x better than JVLA/ALMA**
  - Thermal imaging at “mas” resolution with baseline up to 300–1,000 km
- **Start early science operation in ~2028, full operation in ~2034**

5 Key Science Goals (ngVLA memo #19)

- Unveiling the **Formation of Solar System Analogues**
- Probing the **Initial Conditions for Planetary Systems and Life with Astrochemistry**
- Charting the Assembly, Structure, and Evolution of **Galaxies Over Cosmic Time**
- Using Pulsars in the Galactic Center as **Fundamental Tests of Gravity**
- Understanding the **Formation and Evolution of Stellar and Supermassive BH's** in the Era of Multi-Messenger Astronomy

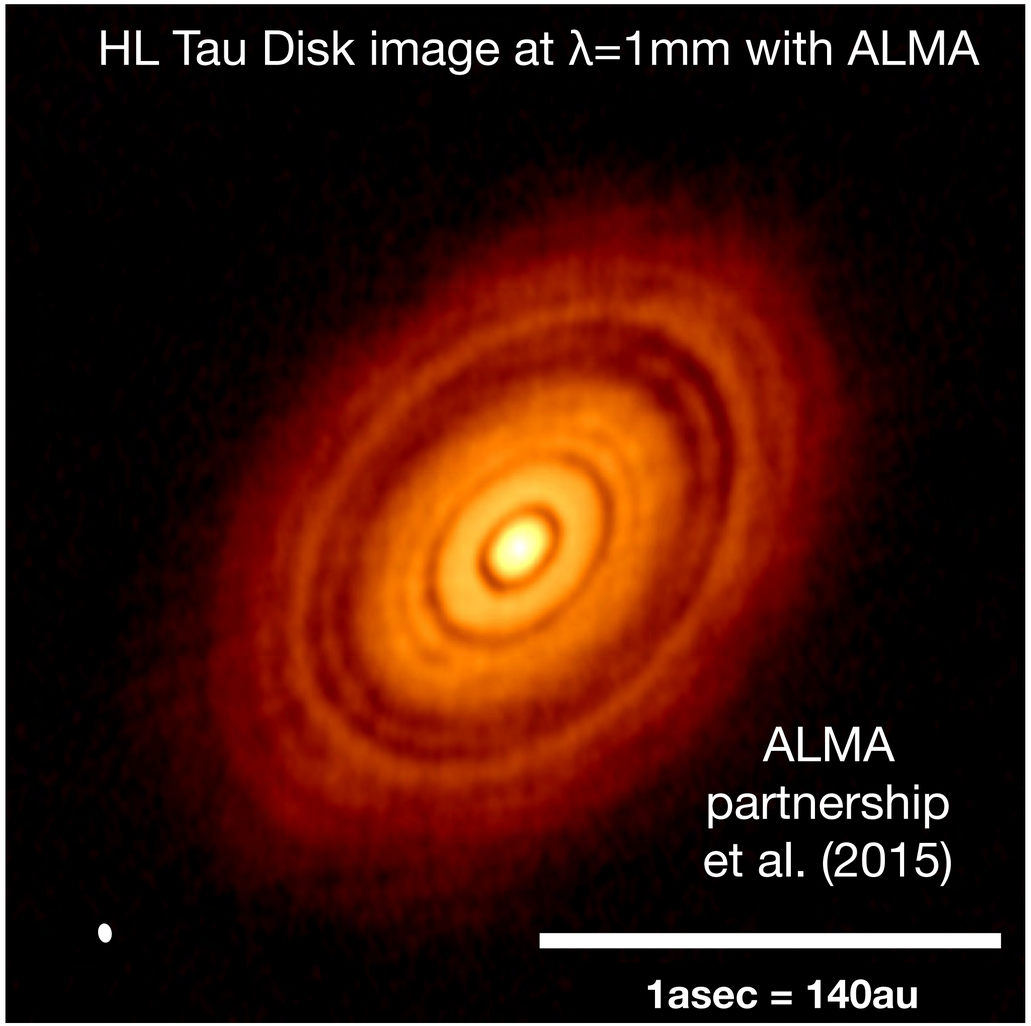
KSG1 : Unveiling the Formation of Solar System Analogues

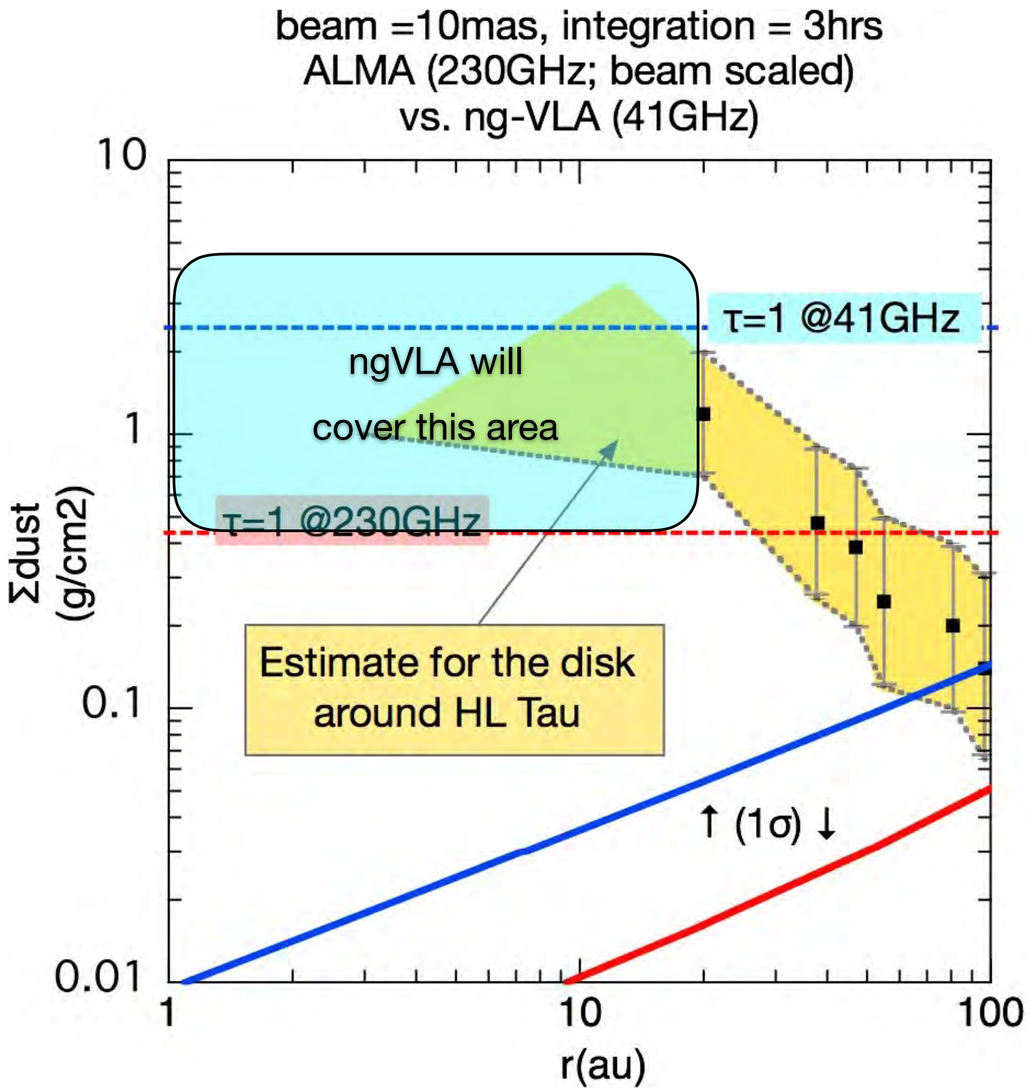
- orbital motion of planets and related features on monthly timescales
  - simulated 100 GHz ngVLA observations of a newborn planetary system comprising a Jupiter analogue orbiting at 5 au from a Solar type star



Ricci et al. (2018)

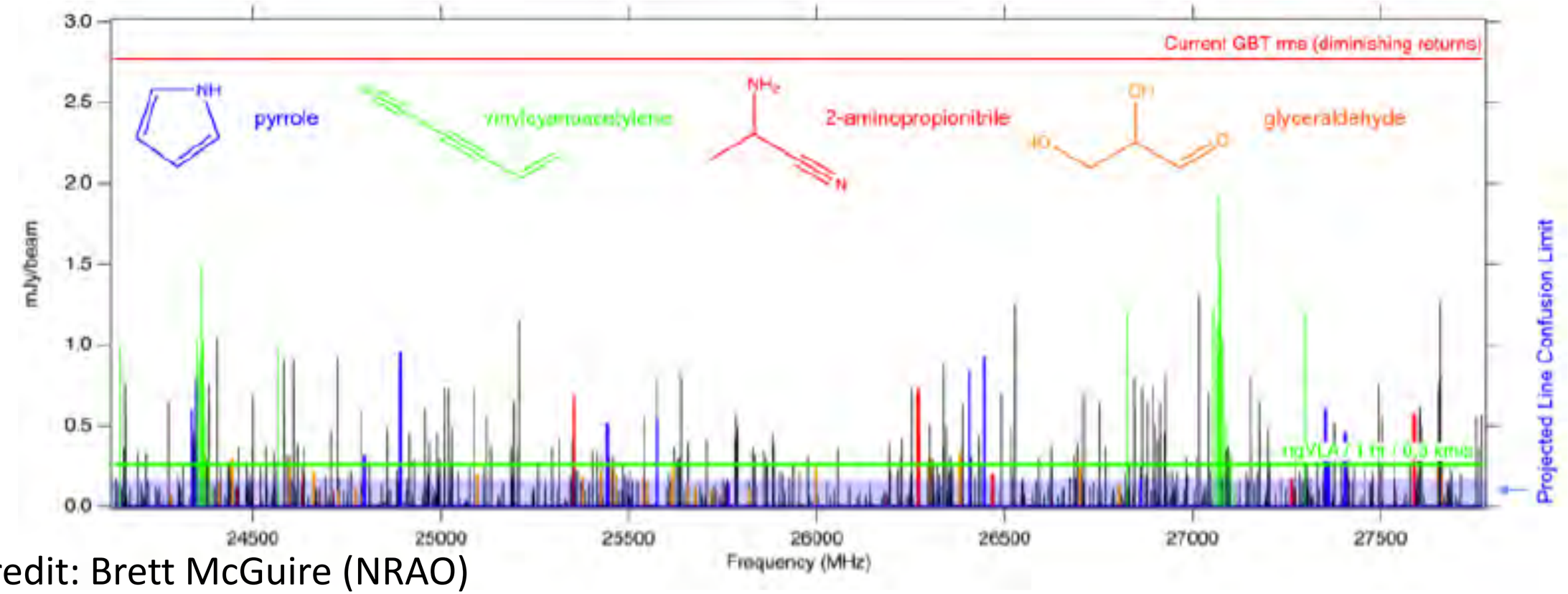
KSG1 : Inner regions are optically thick at submm wavelengths





KSG2 : Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry

- simulated line survey towards Sgr. B2
  - a line of “pre-biotic” molecules with T=200K, N=$10^{12\text{-}14}$ cm^{-2} will be detectable without confusion

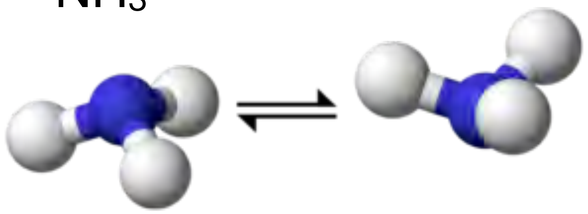


Credit: Brett McGuire (NRAO)

KSG2 : Importance of N-bearing molecules

- a building block for a larger N-bearing molecules (including NH_2CHO, glycine, etc.)
- information about the location of NH_3 snowline in a protoplanetary disk

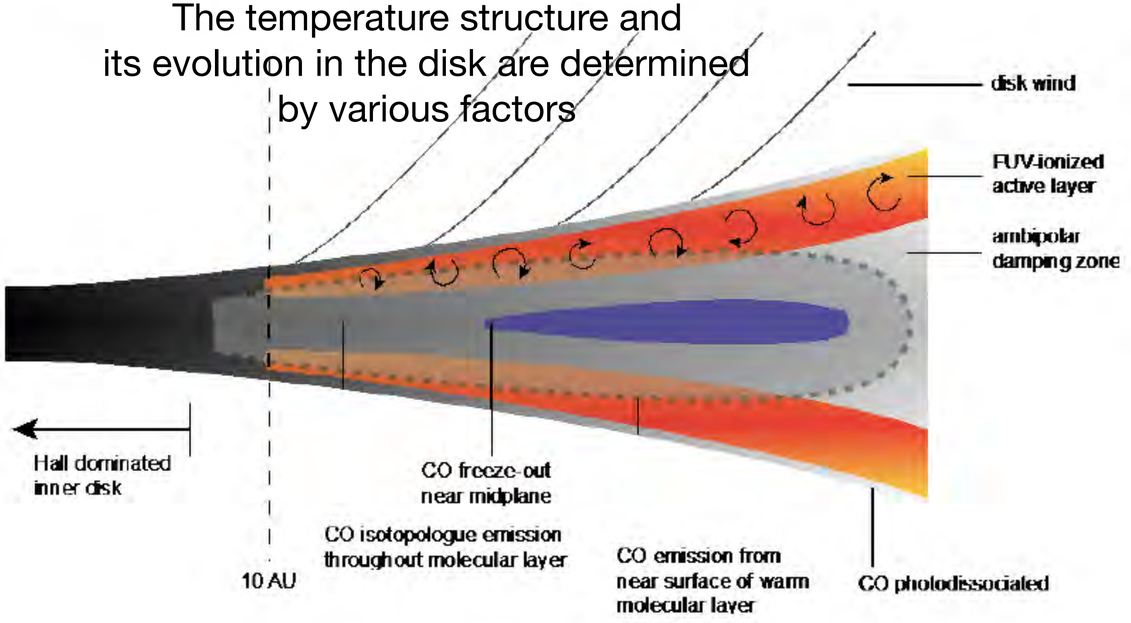
NH_3



(figure from wikipedia)

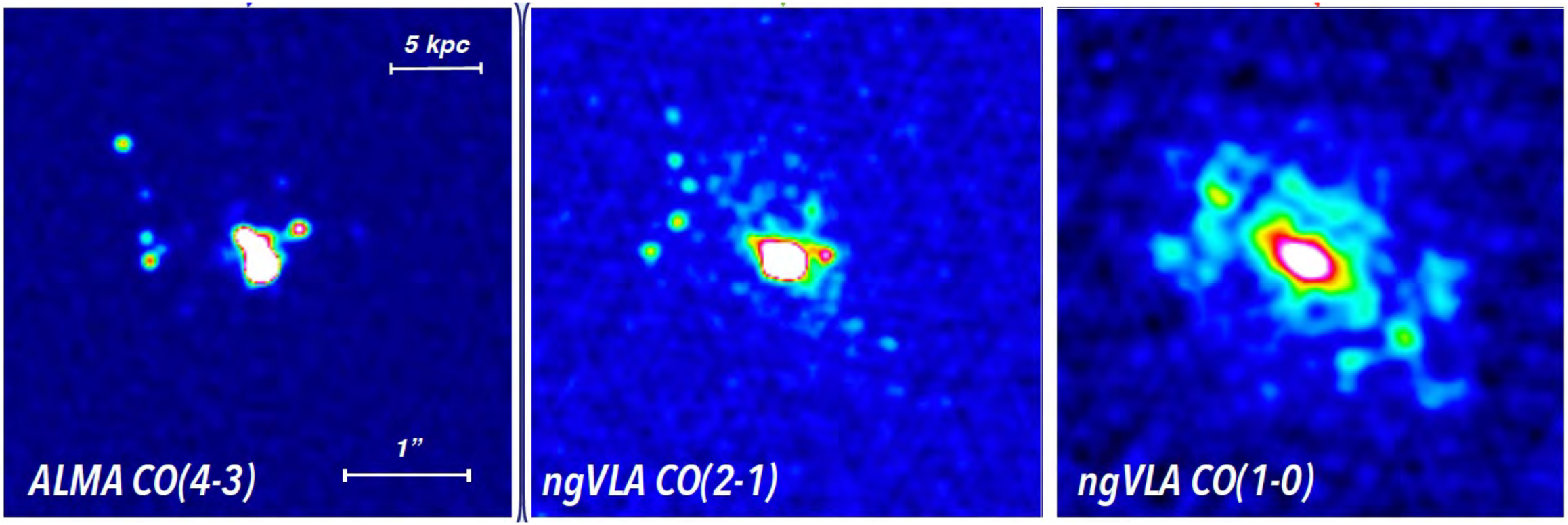
inversion transition
@ 23GHz
(λ≈1.3cm)

The temperature structure and
its evolution in the disk are determined
by various factors



KSG3 : Charting the Assembly, Structure, and Evolution of Galaxies from the First Billions Years to the Present

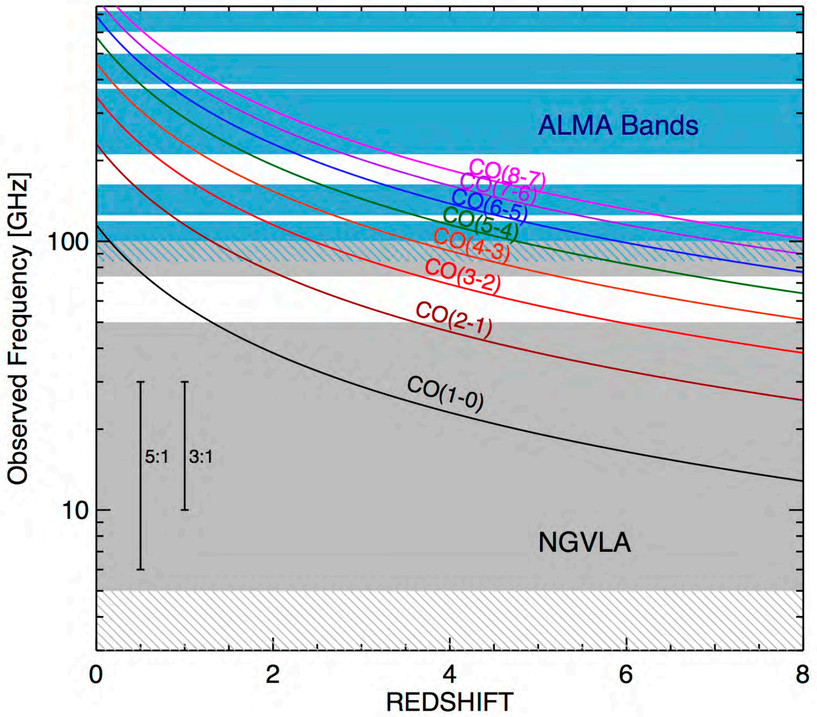
- simulated images of SMG (SFR=400M⊙/yr) at *z*=4.4
  - higher-*J* transitions of CO are not inadequate to reveal dense & cold molecular clouds forming new stars



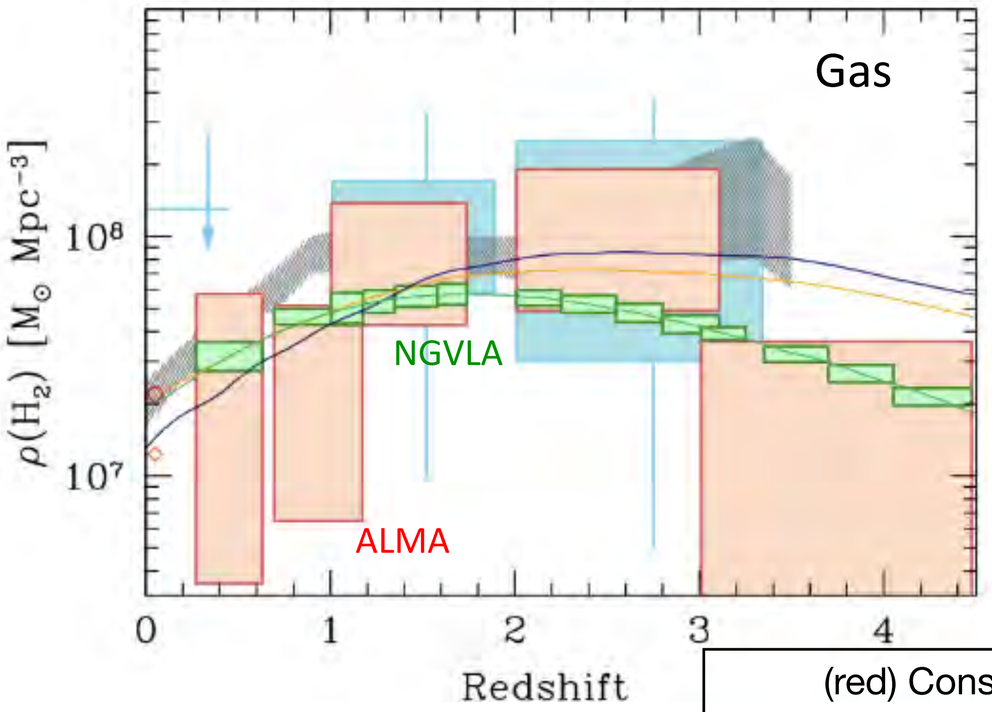
Credit: Caitlin Casey (UT Austin)

KSG3 : “Cold” molecular clouds as high as z ≈ 5

- CO, the fundamental tracer of molecular clouds
- higher-*J* transitions of CO are not inadequate to reveal dense & cold molecular clouds forming new stars



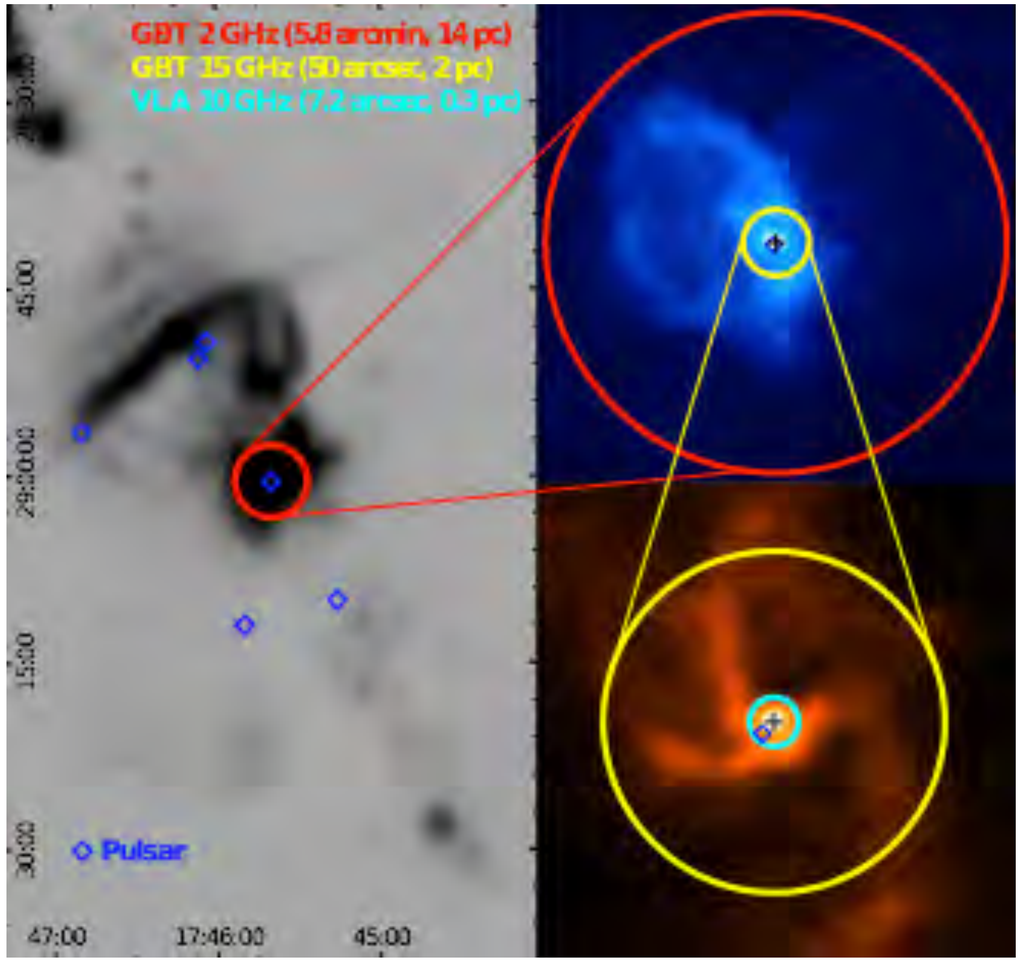
Density of MCs (as a function of z)



(red) Constraints by ALMA spectroscopic survey towards HUDF
(green) ngVLA will improve the estimate
Decarli+2016

KSG4 : Using Pulsars in the Galactic Center as Fundamental Tests of Gravity

- The ngVLA sensitivity and frequency coverage will probe deeper than currently possible into the GC area looking for pulsars, which are moving clocks in the space-time potential of Sgr A*
- New tests of theories of gravity, constraints on exotic binaries, SF history, stellar dynamics and evolution, and ISM at the GC
- Estimates are as high as 1,000 PSRs. Only known example is PSR J1745-2900 magnetar, which are extremely rare (<1%)



Credit: R. Wharton

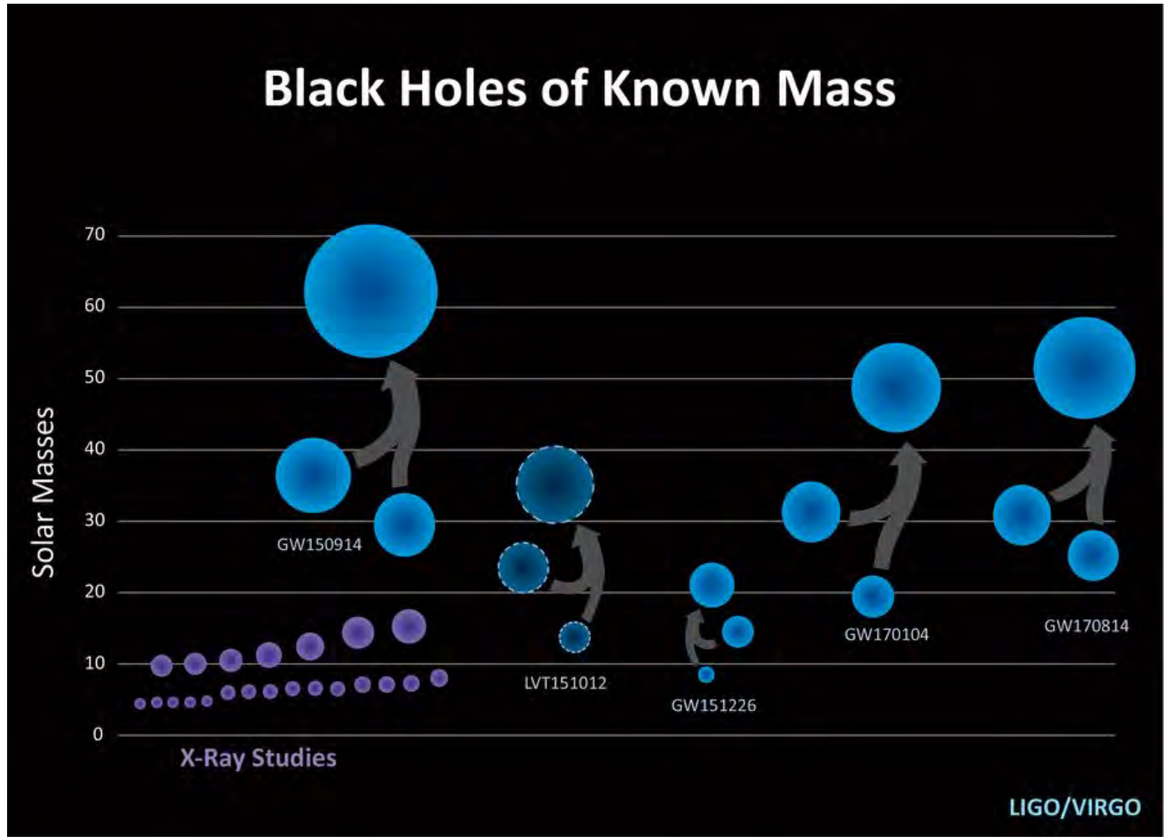
KSG5 : Understanding the Formation and Evolution of Black Holes in the Era of *Multi-Messenger Astronomy*

- Unaffected by dust obscuration and with the angular resolution to separate Galactic sources from background objects using proper motions, the ngVLA will enable a search for accreting black holes across the entire Galaxy.

- Key to understanding GW discoveries

An artist's impression of NS merger

Credit: ESO

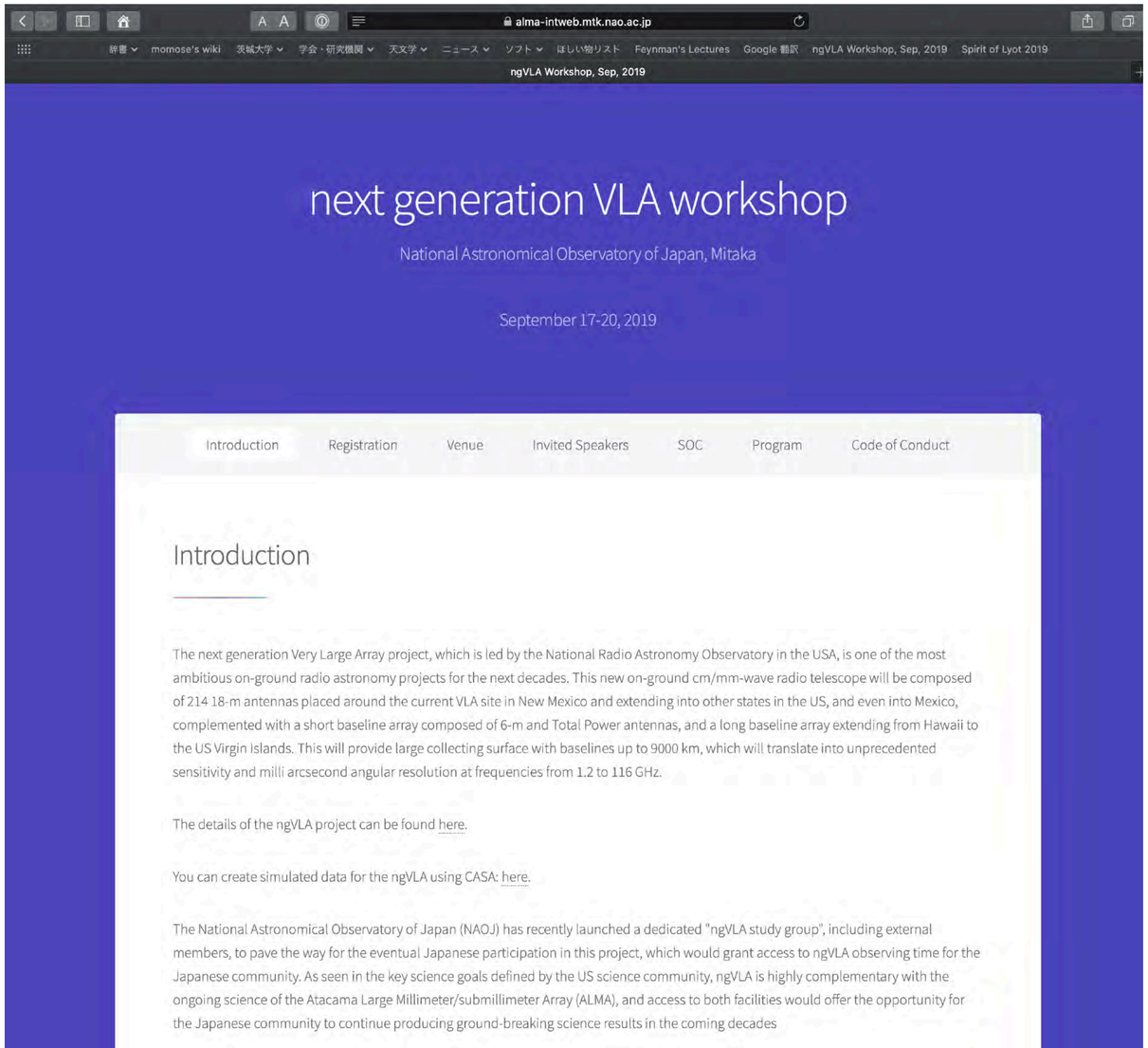


Credit: LIGO/VIRGO

Science meeting in Japan

https://alma-intweb.mtk.nao.ac.jp/~ngvla/workshops/mitaka2019/

- Sep. 17-19, 2019 at NAOJ Mitaka
- ~ 100 participants in Japan, Taiwan, Korea, with NRAO key personnel
- Many “original” ideas
  - Diversified science fields (e.g., Sun and solar system)
  - Synergies with other projects in Japan
  - Related to ALMA/SKA science cases (e.g., molecular/HI/ionized gas)



35 talks (16 invited + 19 contributed)

ngVLA Workshop (Sep 17-20)

Invited: 35 min (30 + 5) 16 talks

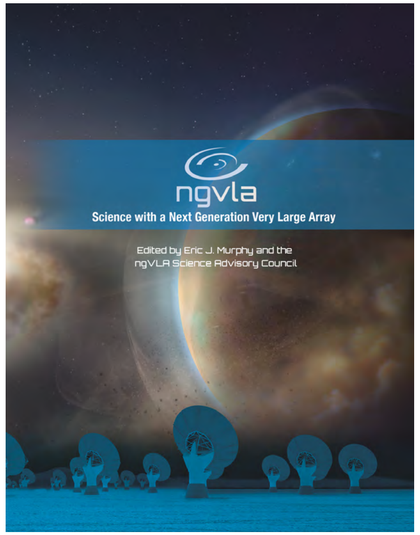
Contributed: 25 min (20+5 19 talks

https://alma-intweb.mtk.nao.ac.jp/~ngvla/workshops/mitaka2019/program_public.pdf

Start		Name	Affiliation	title
17-Sep				
		Project talks (Chair: A. Gonzalez)		
13:00		Nami Sakai	RIKEN	Intro and status of domestic activities
13:05	I	Mark McKinnon	NRAO	ngVLA Project Overview
13:40	I	Eric Murphy	NRAO	Science with ngVLA
14:15	I	Rob Selina	NRAO	ngVLA Technical Overview
14:50		break		
		Solar System and Exoplanets (Chair: T. Hasegawa)		
15:10	I	Shogo Tachibana	University of Tokyo	A New Perspective of Solar System Chemical Evolution from Radio Astronomy
15:45	I	Norio Narita	NAOJ/U Tokyo	Potential science cases of ngVLA: inputs from Astrobiology Center
16:20	I	Takaaki Yokoyama	University of Tokyo	Future science in solar physics by ngVLA
16:55	C	Masumi Shimojo	NAOJ	Synergy of the joint observations between ALMA and ngVLA in solar physics
18-Sep				
		Planetary Disks and Exoplanets (Chair: M. Momose)		
9:30	I	Satoshi Ohashi	RIKEN	Observations for protoplanetary disks: From ALMA to ngVLA
10:05	C	Takahiro Ueda	NAOJ	Effect of Scattering on the Apparent Disk Brightness: Application to the Inner Region of the TW Hya Disk
10:30	C	Akimasa Kataoka	NAOJ	Disk surveys in the ngVLA era
10:55	C	Takayuki Muto	Kogakuin University	Imaging Observations of the Planet-Forming Regions of Protoplanetary Disks with ngVLA
11:20	C	Yuki Tanaka	Tohoku University	Possibility of giant planet formation by pebble accretion in Class 0/I phases
11:45		Lunch		
13:00	I	Satoshi Okuzumi	Tokyo Institute of Technology	Testing planet formation theories with the ngVLA
		Galaxies and High Energy Phenomenon (Chair: K. Kohno)		
13:35	I	Tomoharu Oka	Keio University	Galactic Center Studies with the ngVLA
14:10	I	Fumi Egusa	University of Tokyo	Study on Nearby Spiral Galaxies with ngVLA
14:45	C	Takafumi Tsukui	Sokendai	HI gas kinematics for SMBH, Bulge and Disk, and Dark matter in the mass assembly history of galaxies.
15:10		break		
15:30	I	Nozomu Tominaga	Konan University	Fast radio bursts and pulsars with ngVLA
16:05	C	Hiroshi Nagai	NAOJ	AGN Jet Science with ngVLA and Other Instruments
16:30	C	Masatoshi Imanishi	NAOJ	Molecular gas around actively mass-accreting supermassive black holes
TBD		Banquet		

19-Sep				
		Galaxies and High Energy Phenomenon (cont) (Chair: N. Sakai)		
9:30	I	Kenta Hotokezaka	Princeton	Radio counterparts to compact binary merger with ngVLA
		Star Formation and Chemistry (Chair: N. Sakai)		
10:05	I	Satoshi Yamamoto	University of Tokyo	Astrochemistry with ngVLA
10:40	C	Kazuki Tokuda	Osaka Prefecture/NAOJ	Revealing the substructures of prestellar/protostellar cores with ALMA and the ngVLA
11:05	C	Shigehisa Takakuwa	Kagoshima University	ngVLA Survey for Kernels and First Cores in the 7-mm Molecular Lines
11:30	C	Tien-Hao Hsieh	ASIAA	Earliest stage of star formation studied with ngVLA
11:55		Lunch		
		Chair: T. Onishi		
13:00	C	Sarolta Zahorecz	Osaka Prefecture/NAOJ	Deuteration in high-mass star-forming cores from APEX to ngVLA
13:25	I	Yasuo Fukui	Nagoya University	HI with ngVLA; a new powerful tool to pursuit active star formation
14:00	C	Kei Tanaka	Osaka University/NAOJ	Free-free Outflows and Synchrotron Jets in Massive Star Formation
14:25	C	Yichen Zhang	RIKEN	Probing kinematics of ionized gas around forming massive stars
14:50	C	Hidetoshi Sano	Nagoya University	Interstellar gas associated with supernova remnants
15:15		Poster flash (3 min x 4)		
15:30		break		
		Galaxy Formation and Evolution (Chair: D. Iono)		
15:45	I	Hideki Umehata	RIKEN	ngVLA and galaxy formation in proto-clusters
16:20	C	Tao Wang	University of Tokyo	New insights into massive galaxy and cluster formation at high redshifts from ngVLA/ALMA
16:45	C	Bunyo Hatsukade	University of Tokyo	Constraining the nature of superluminous supernovae and their host galaxies
20-Sep				
		Galaxy Formation and Evolution (cont)		
9:30	C	Yuki Yoshimura	University of Tokyo	Studies of molecular absorption near and far using ALMA PI/archive data: some prospects for ngVLA
9:55	C	Kenichi Tadaki	NAOJ	A sub-kiloparsec-view of submillimeter galaxies
		Collaboration and Discussion (Chair: M. Fukagawa)		
10:20	I	Takuya Akahori	NAOJ	A status report of SKA and a progress of SKA-HIGH discussion
10:55		Panel Discussion		
11:50		Summary		

Science Working Groups in Japan



- Review the science cases listed in the “Science Book” & “White Papers”
  - http://aspbooks.org/a/volumes/table_of_contents/?book_id=592
  - https://ngvla.nrao.edu/page/scicase
- Discuss our original ideas to be reflected in the ngVLA-J’s “Project book” and memos

KSG programs vs. other science

ngVLA Reference Observing Program

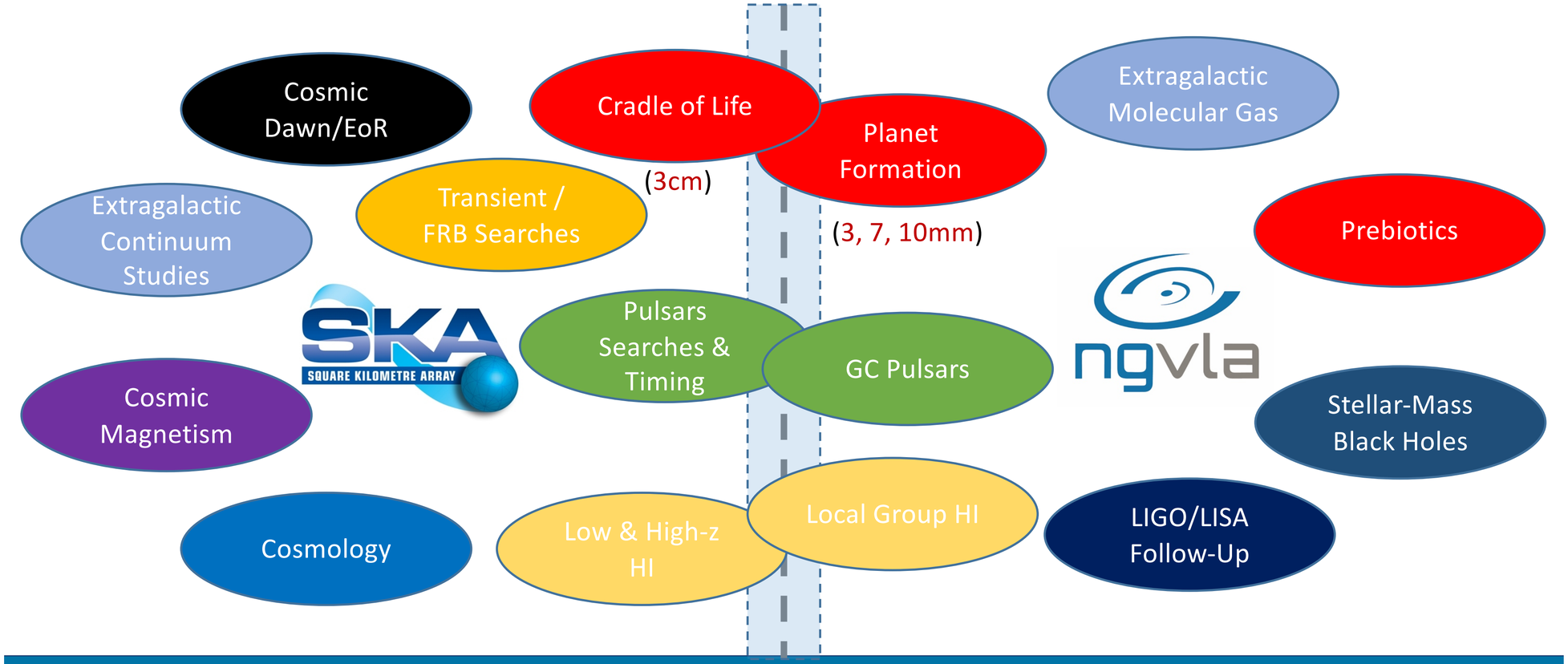
Synopsis

Driving Case & Possible Pilot	Type	Band(s)	Tsubarray (hours)			Subarray	Note
			Year 1	Year 2	Year 3		
KSG1 Taurus disks	Continuum	6, 4	176	305	305	Main	
KSG2 Sgr B2(N), IRAS 16293	Molecules	5, 4, 3	120	120	0	Main	Done
KSG3 COSMOS	CO	5, 4, 3	105	105	105	Plains + Core	
KSG3 Spiderweb galaxy	Molecules	6, 5, 4	123	0	0	Main	Half done
KSG3 Virgo cluster galaxy	Molecules	6	132	132	132	Plains + Core	Slow progress
KSG3 M81 grp, in galaxies	HI	1	213	213	213	Plains + Core	
KSG3 M81 grp, near galaxies	HI	1	264	264	264	Core	
KSG4 Galactic Center pulsars	Continuum	3	99	99	99	Main	
KSG5 LIGO events	Continuum	1	142	142	142	Main	
KSG5 LIGO proper motions	Continuum	3	470	470	470	Long Baseline	Co-observe
KSG5 LISA events	Continuum	4	0	0	400	Plains + Core	
KSG5+4 Stellar BHs, Pulsars	Continuum	2	169	169	169	Plains + Core	
KSG5 Pulsar Timing Array	Continuum	1, 2	312	312	312	Mid Baseline	Co-observe
Total Hours for Key Science Goals (KSGs)			**~1550**	**~1560**	**~1840**		Skip Mid, Long
Total Hours for Other Science = 6000 – KSG Hours			***~4450***	***~4440***	***~4160***		

courtesy: Eric Murphy (NRAO; project scientist)

Relationship with SKA

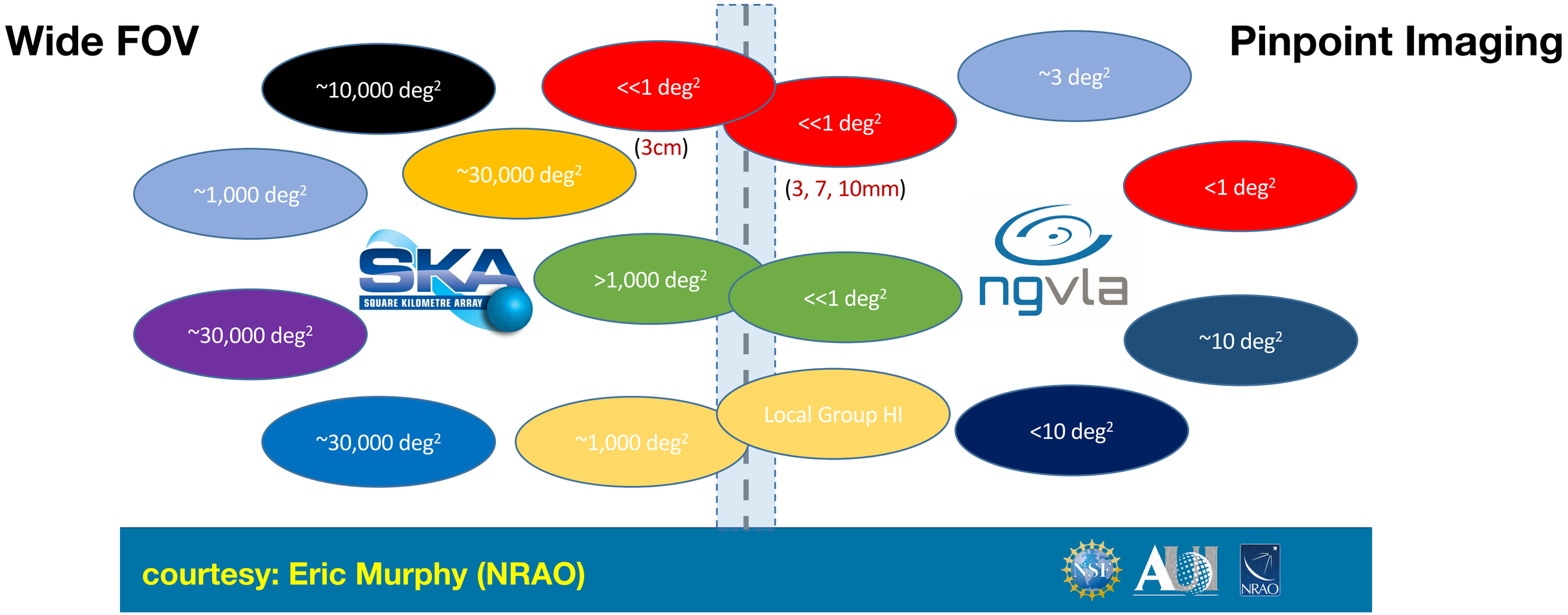
SKA and ngVLA Key Science Drivers



courtesy: Eric Murphy (NRAO)

Relationship with SKA

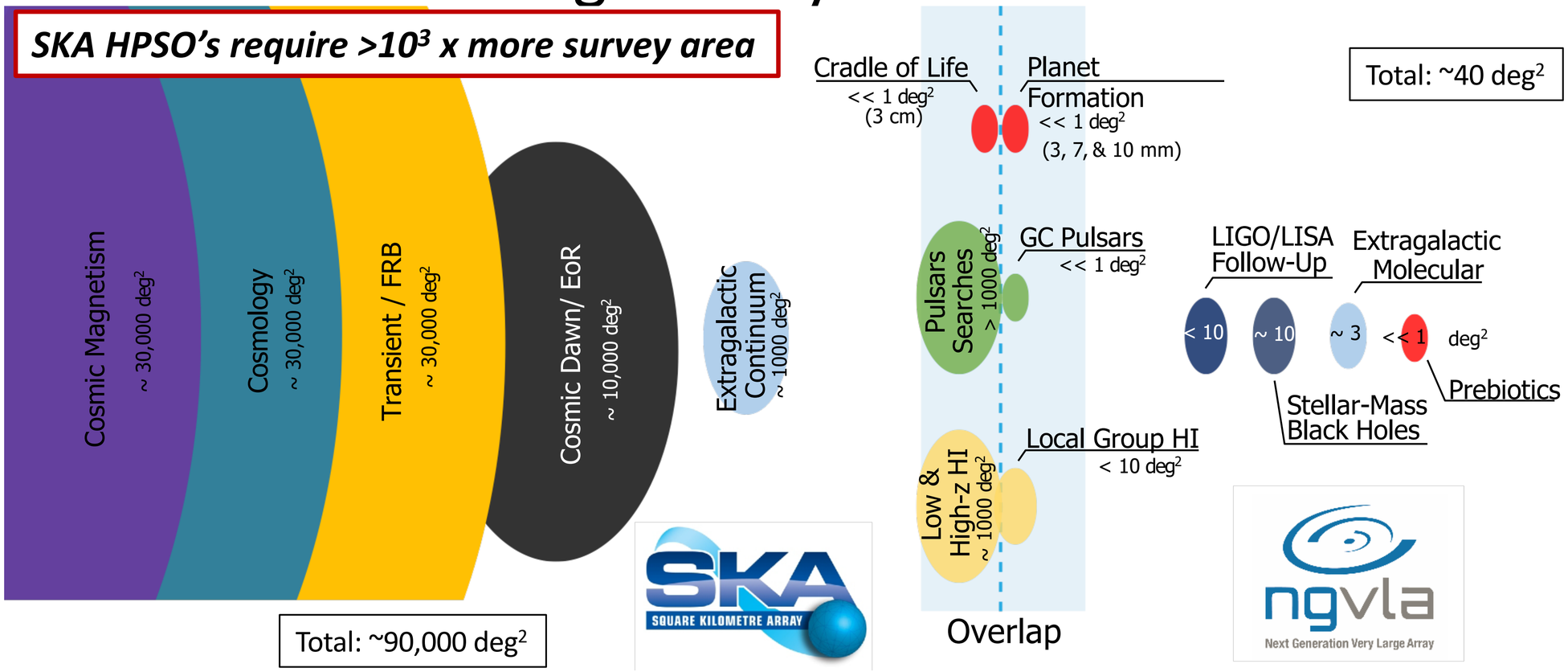
SKA and ngVLA Key Science Drivers



courtesy: Eric Murphy (NRAO)

Relationship with SKA

SKA and ngVLA Key Science Drivers



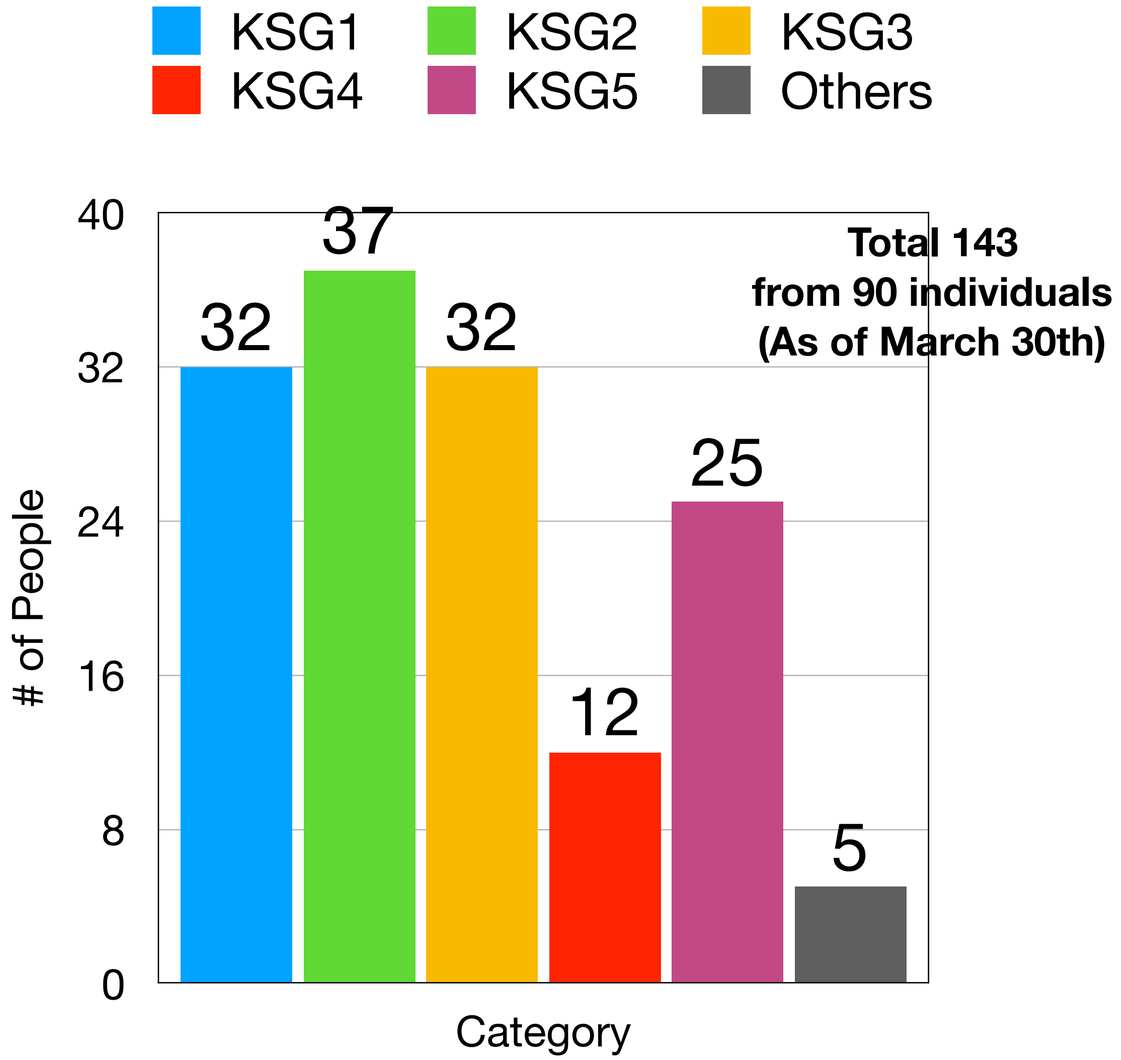
courtesy: Eric Murphy (NRAO)

Questions ?

Discussion

Initiating science working groups in JP

- Thank you for your interest !
- The community’s interests cover wide areas of potential sciences with ngVLA
- Please join science working group(s) and enjoy the discussion !
- “Others” include:
  - Molecular clouds formation (1)
  - Evolved stars (1) / Sun (1)
  - Engineering (1)/Telescope system (1)
- A new member is always welcome



How do we proceed discussion ?

- Tentative Leaders
  - SubWG 1: Momose, M. (Ibaraki)
  - SubWG 2: Tachihara, K. (Nagoya)
  - SubWG 3: Iono, D. (NAOJ)
  - SubWG 4: Niinuma, K. (Yamaguchi)
  - SubWG 5: Nagai, H. (NAOJ)
  - Others: contact individually
- Each SubWG works independently, but a joint meeting of multiple SWGs will also be possible if needed
  - The style of the meeting would be at the discretion of each leader
  - Remote connection (ZOOM) and mailing lists can be cared by NAOJ

Timeline

- 2020. 4: initiating SWGs, start discussion
  - Review the science documents in NRAO site
  - Our original ideas
- 2021. 7 or 8 : Project Book in Japanese
  - Summarize the discussions in all SWGs
  - The (tentative) leader of each SWG + the members of the study group in NAOJ will be the main authors of the project book
  - Comments by advisory members & all the working group members

Possible products from SWGs

- Any inputs to the project book (either English or Japanese)
- Original article for ngVLA(-J) memo series (English, style-file will be provided)
- Original research paper for refereed journal and arXiv (English or Japanese)

Questions ?