ALMA-ELTs Conference Summary

James Di Francesco
(National Research Council of Canada)

Outline

- General Observations
- ALMA-ELT Synergies
- Discussion Sessions
- Learnin’

(This is how I felt when Leonardo asked me to do this)

ALMA & the ELTs

2011-12

2019
?

2019
?

Total cost:
~$5,000,000,000!

QuickTime™ and a
decompressor
are needed to see this picture.

2019
?

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Bailout Plan: $2.5 Trillion and a Strong U.S. Hand

By EDMUND L. ANDREWS and STEPHEN LABATON
Published: February 10, 2009

WASHINGTON — The White House plan to rescue the nation's financial system, announced on Tuesday by Timothy F. Geithner, the Treasury secretary, is far bigger than anyone predicted and envisions a far greater government role in markets and banks than at any time since the 1930s.

Enlarge This Image

Joshua Roberts/Bloomberg News

Administration officials committed to flood the financial system with as much as $2.5 trillion — $350 billion of that coming from the bailout fund and the rest from private investors and the Federal Reserve, making use of its ability to print money.

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General Observations

- ELTs each have very strong science cases, impressive instrument plans
- Many excellent talks, up-to-date results shown from that morning's astro-ph!
- This meeting was meant to draw out the *synergy* between ALMA & ELTs
- Discussion about *implementing* these synergies has been difficult
- Nobody interrupted any talks….?

ALMA-ELT synergies

- ☞ High spatial resolution
- ☞ High continuum sensitivity
- ☞ High spectral sensitivity

ALMA-ELT synergies: High spatial resolution

- ALMA's : 0.006" FWHM at 675 GHz (B9), 14.7 km baseline over an 8" FOV
- ELT's: ~0.008" at 1.2 μm with adaptive optics over 30" FOV (TMT; GMT is 20' FOV)
- FOV sizes demonstrate why these are not considered as "survey instruments"

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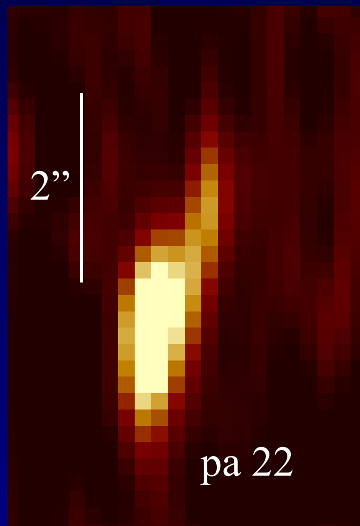
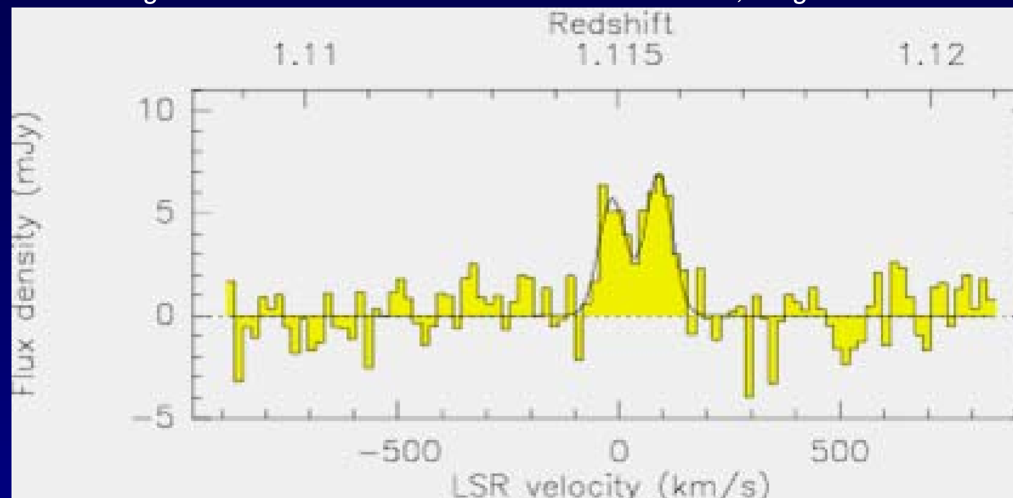
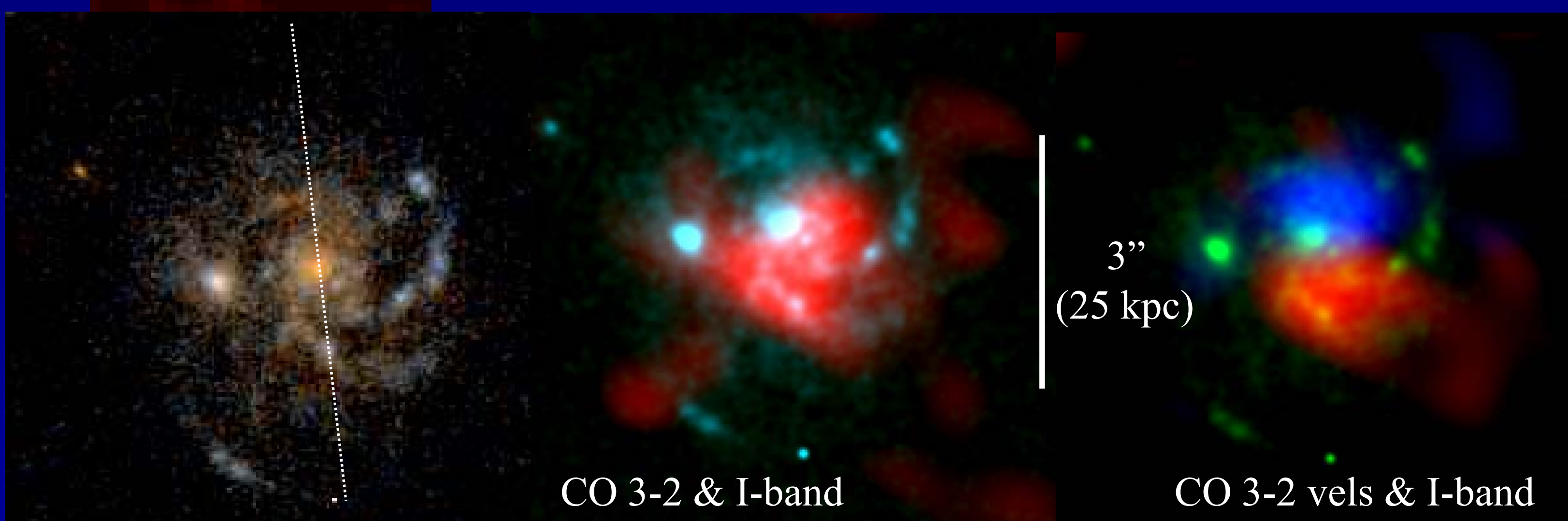
EGS13035123: Spatially Resolved CO Velocity Field in a z~1 Disk Galaxy



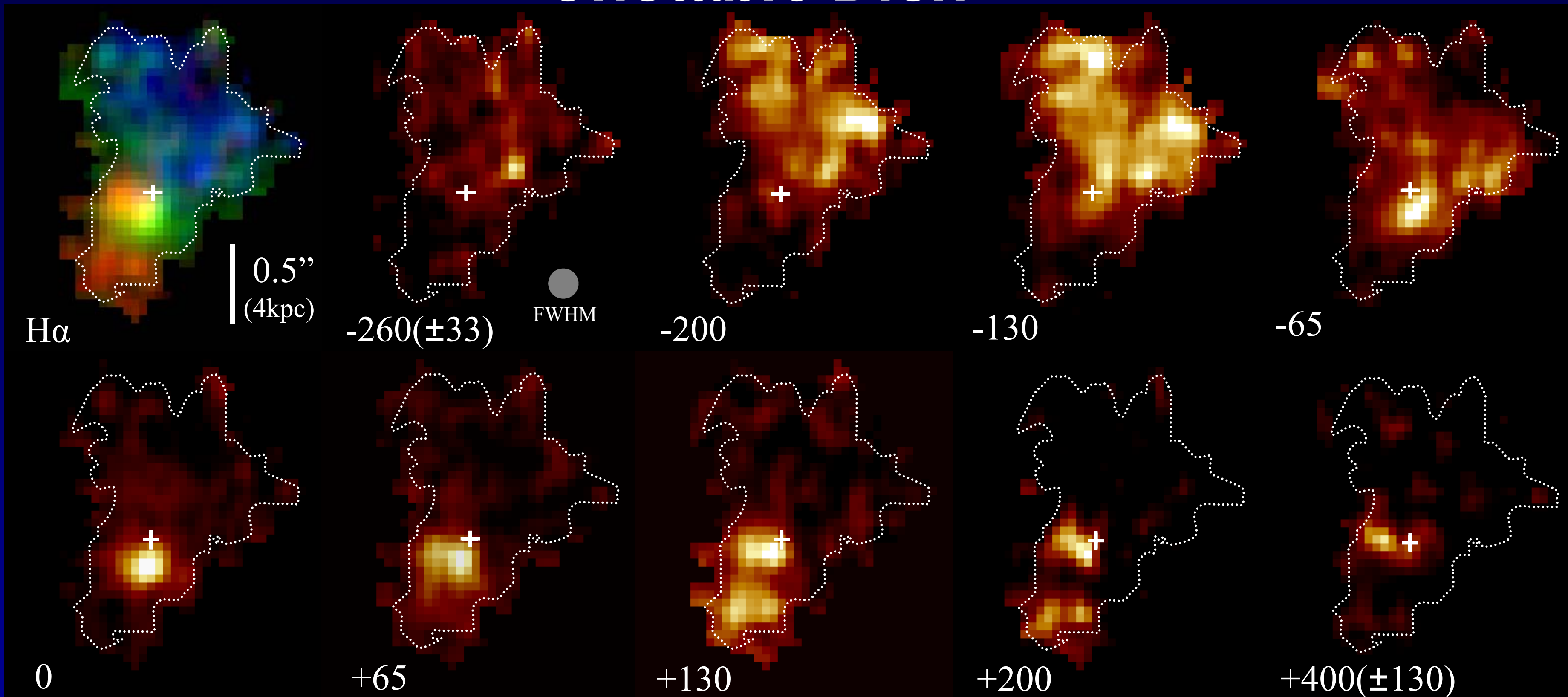
$M_{gas}\sim 4x10^{10}\ M_{\odot}$; , $M_{*}\sim 2x10^{11}\ M_{\odot}$, $f_{gas}\sim 0.2$





IRAM PdBI CO(3-2) @2mm

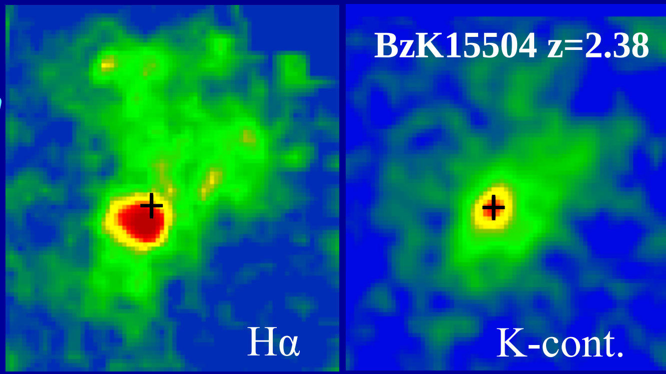
BzK 15504 z=2.38: A Thick, Clumpy & Globally Unstable Disk



M_{dyn}(<10 kpc) ~10^{11} $M_\odot$
v_c=230 km/s, σ = 50 km/s,
R_d=4 kpc, Q=0.8
SFR = 150 $M_\odot yr^{-1}$, f_{gas}~0.3

Genzel et al. 2006

SINFONI +AO (VLT):
0.2” (1.6 kpc) resolution



Protostellar jets

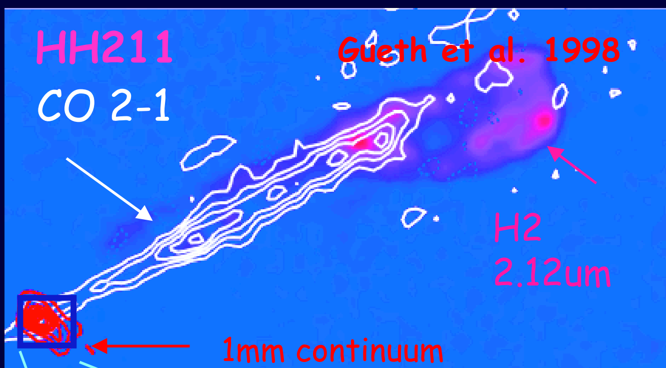
Class 0 (Av > 100 mag)

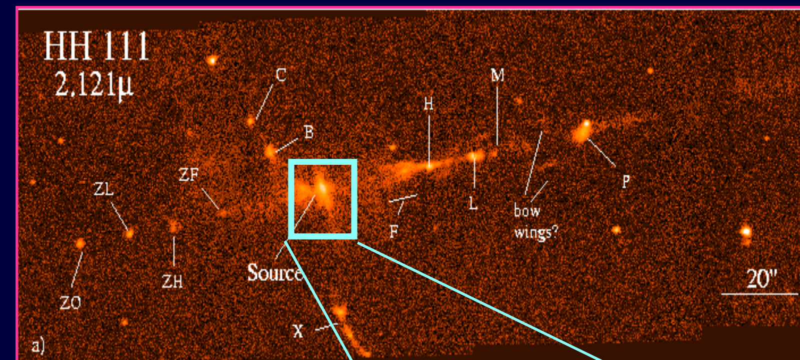
- molecular flows
- tracers:CO,SiO

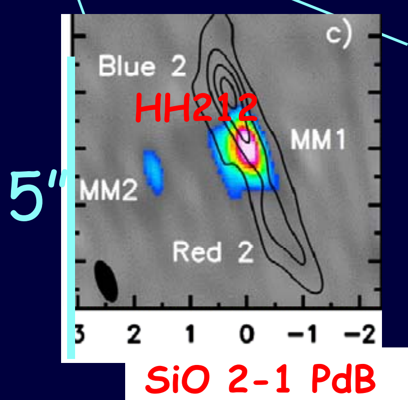
Class I (Av ~ 20-50 mag)

-molecular and atomic flows

-tracers: H_2, FeII

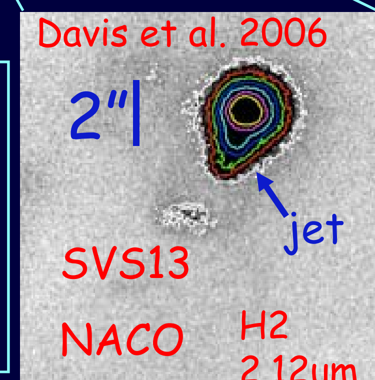






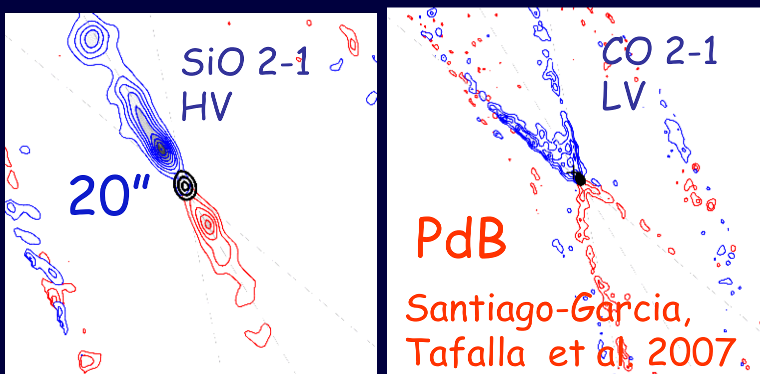
Codella et al. 2008

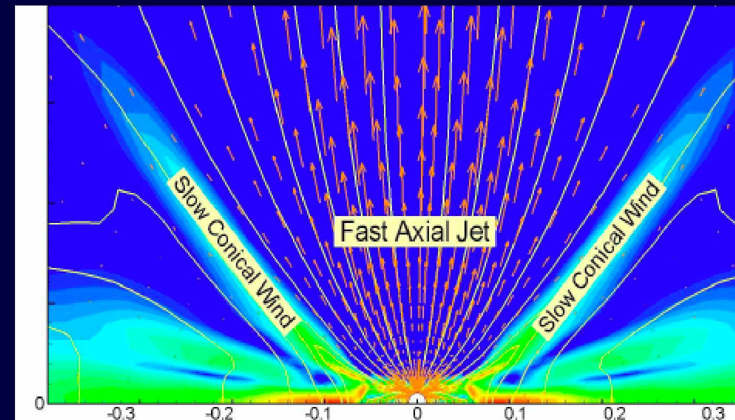
- How the jets are launched and collimated
- How angular momentum is transferred from the accretion disk to the jet
- Which is the initial heating process



Velocity structure as a test for ejection models
ALMA and ELT may provide a unified picture

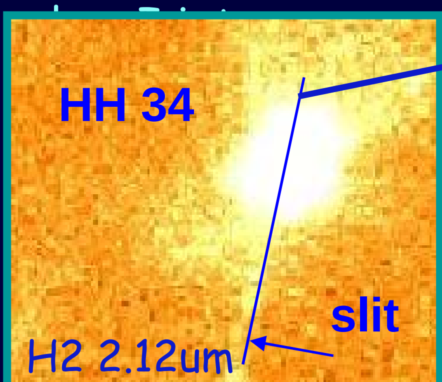
IRAS04166+2706



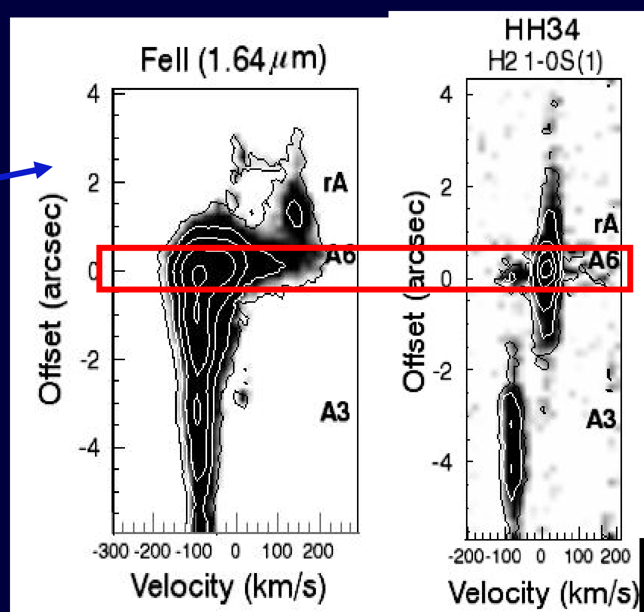


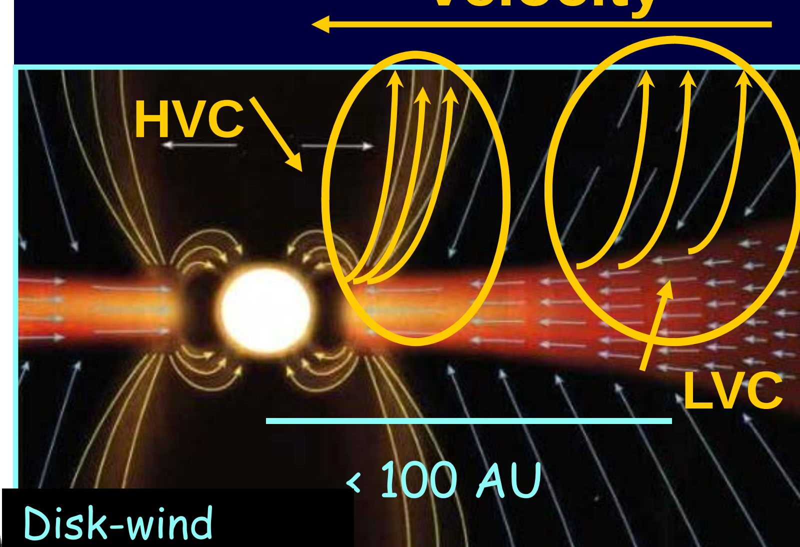
Romanova et al. 2009

ISAAC spectroscopy of



Garcia Lopez, Nisini et al. 2008



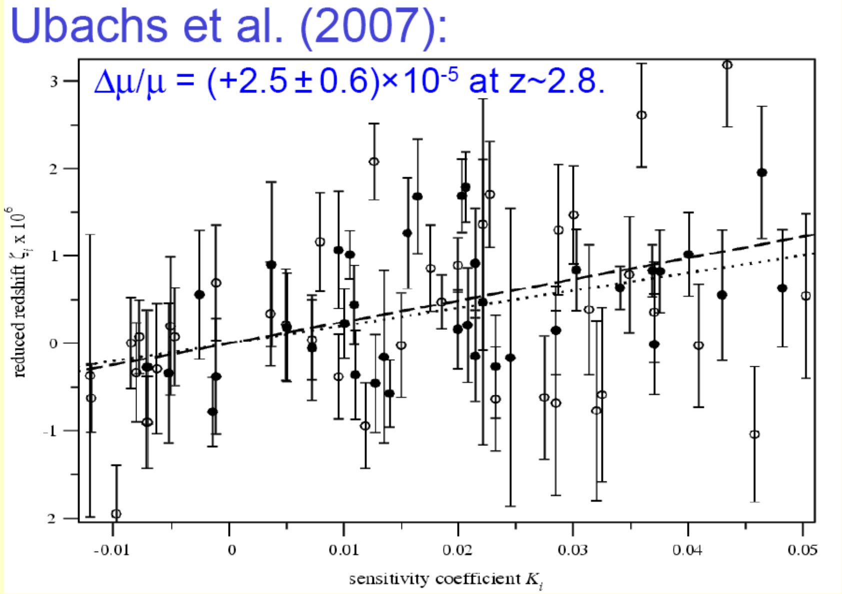


Disk-wind model

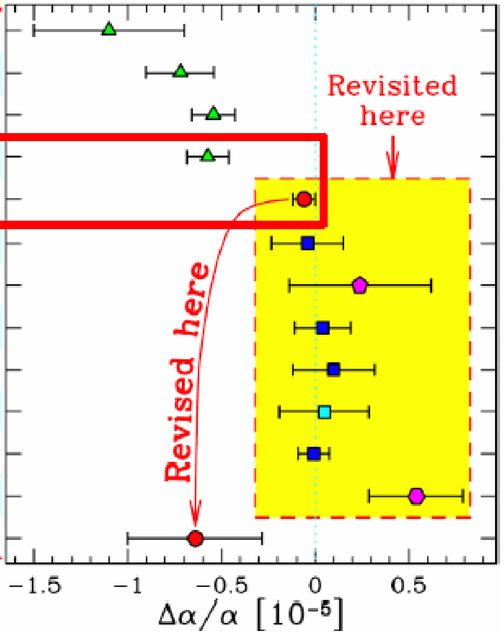
ALMA-ELT synergies: High spectral resolution

- ☞ ALMA's : 3.8 kHz, or 0.003 km/s at 345 GHz (B7), R ~ 10^8
- ☞ ELT's: HROS (TMT), CODEX (ELT) optical eschelle spec'meter, R ~ 50,000, 150,000

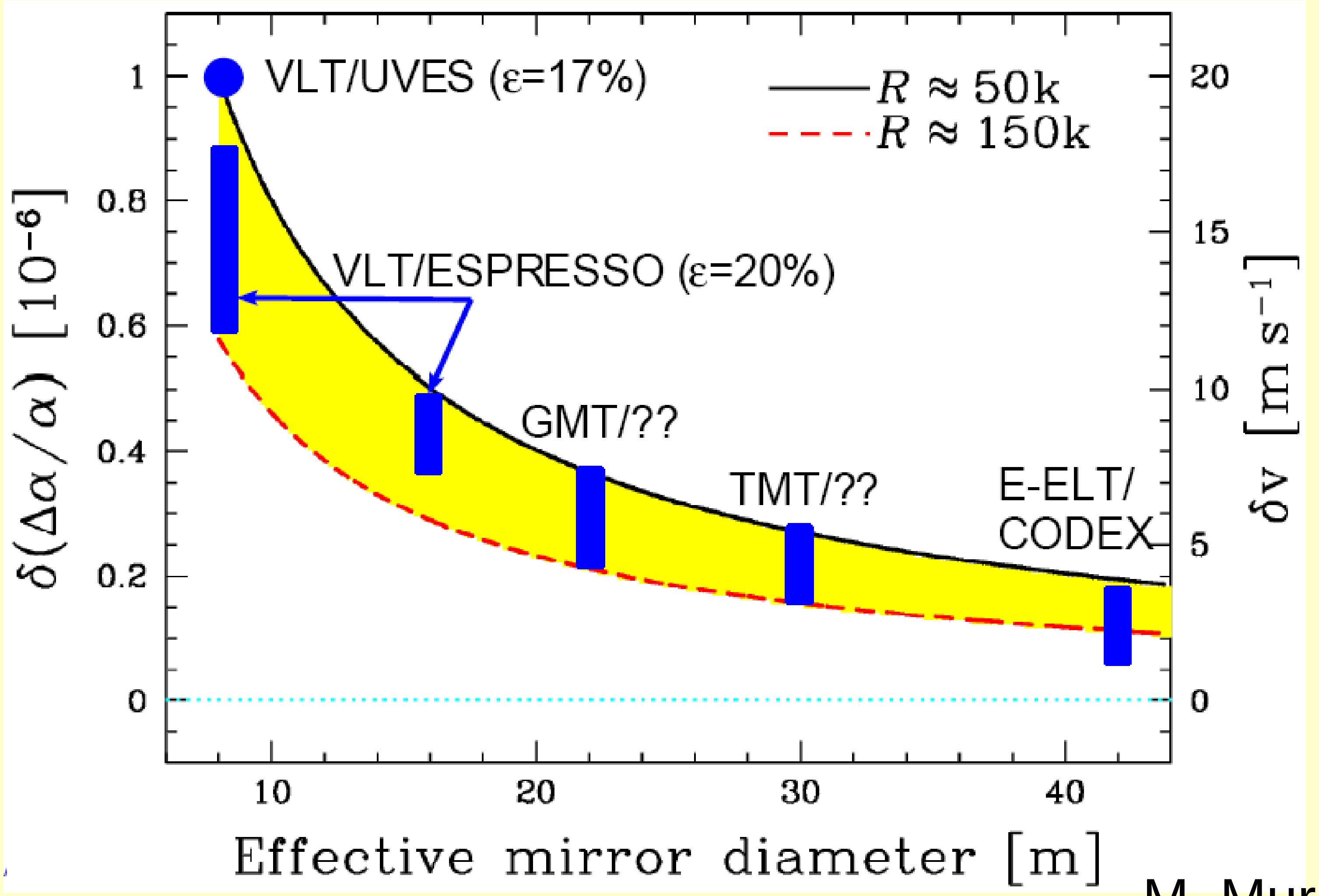
Current constraints: Intriguing but controversial



Instrument	N_{abs}	z_{abs}	$\Delta\alpha/\alpha$ [10^{-5}]	Reference
HIRES	30	0.5–1.6	−1.100 ± 0.400	Webb et al. (1999)
HIRES	49	0.5–3.5	−0.720 ± 0.180	Murphy et al. (2001a)
HIRES	128	0.2–3.7	−0.543 ± 0.116	Murphy et al. (2003)
HIRES	143	0.2–4.2	−0.573 ± 0.113	Murphy et al. (2004)
UVES	23	0.4–2.3	−0.060 ± 0.060	Chand et al. (2004)
UVES	1	1.151	−0.040 ± 0.190 ± 0.270	Quast et al. (2004)
UVES	1	1.839	+0.240 ± 0.380	Levshakov et al. (2005)
UVES	1	1.151	+0.040 ± 0.150	Levshakov et al. (2005)
UVES	1	1.151	+0.100 ± 0.220	Chand et al. (2006)
HARPS	1	1.151	+0.050 ± 0.240	Chand et al. (2006)
UVES	1	1.151	−0.007 ± 0.084 (± 0.100)	Levshakov et al. (2006)
UVES	1	1.839	+0.540 ± 0.250	Levshakov et al. (2007)
UVES	23	0.4–2.3	−0.640 ± 0.360	This work



How much will measurement improve?



M. Murphy

Absorption lines

More sensitive to cold gas along l.o.s.
with ALMA 100 times more background sources
explore:

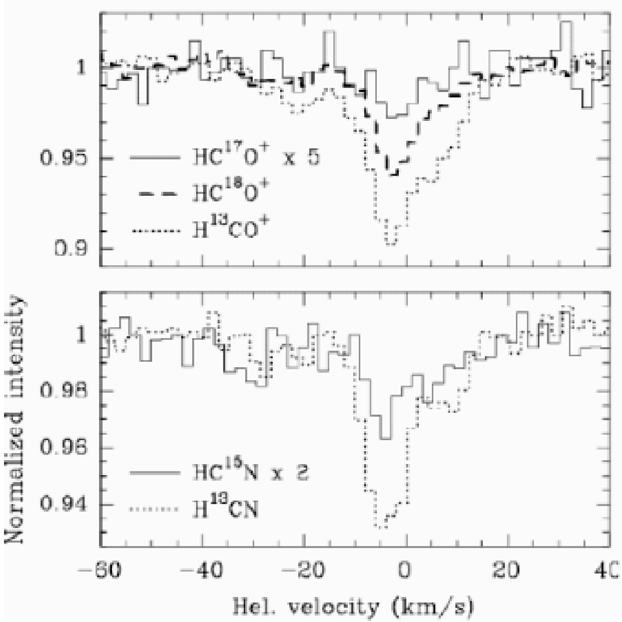
- abundances & chemistry as function of z
- $T_{CMB}(z)$
- Hubble constant through time delay btw two lensed images
- variation of fundamental constants:
  - fine structure constant
  - m_e/m_p
  - proton gyromagnetic ratio

  (Kaluza-Klein, Superstrings, compactified extra-dimensions)

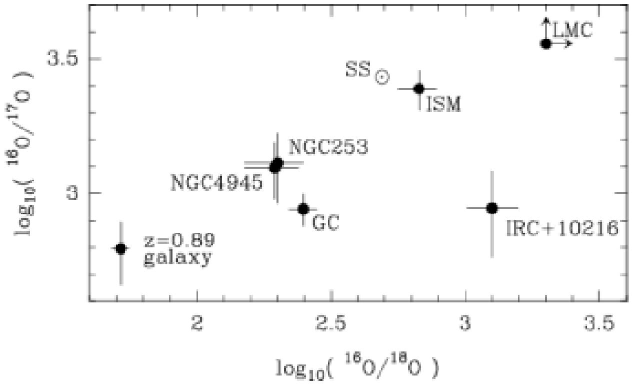
  Doublets/multiplets: $O(10^{-5})$

  Radio advantage: high spec. res., cold narrow lines

  Problem: kinematical bias



PKS 1830-211



ALMA-ELT synergies: High sensitivity

- ALMA's : ~200 μJy in 60 s (16 GHz BW) at 345 GHz (B7)
- ELT's: EPICS or PFI, imaging at high contrasts of $10^{6\text{-}9}$ for planet detection

EGPs - ALMA Direct Detection

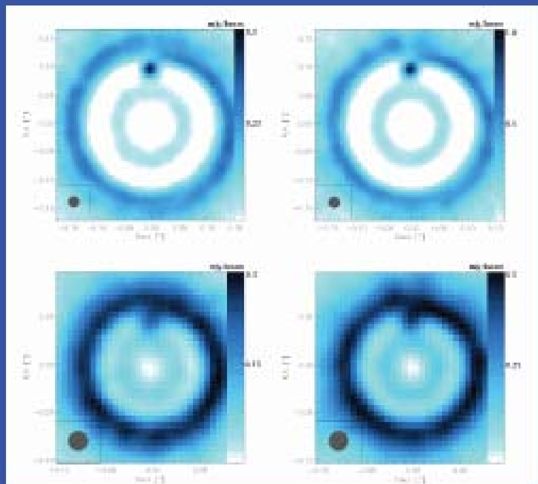
Expected flux density at 345 GHz:

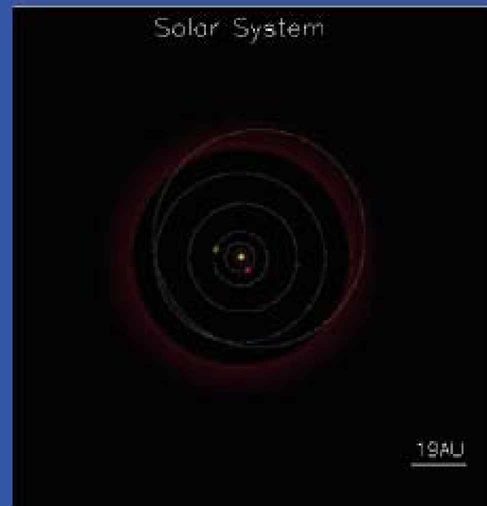
$$F_{345} = 6 \text{ X } 10^{-2} \; T \; \frac{R_J^2}{D_{pc}^2} \quad [\mu\text{Jy}]$$

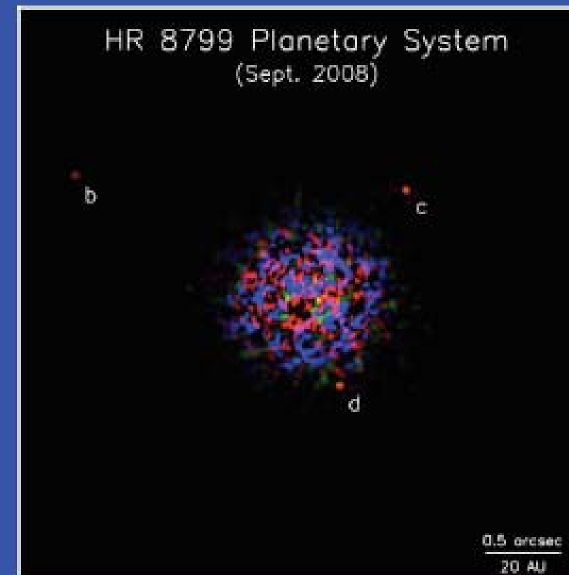
Distance (pc)	Jupiter	Gl229B	Proto-Jupiter
1	12	130	59000
5.7	.36	4.1	1820
10	.12	1.3	590
120	.0008	.009	4.1

Details in Butler, Wootten, & Brown 2003

Imaging a planet, the last frontier...



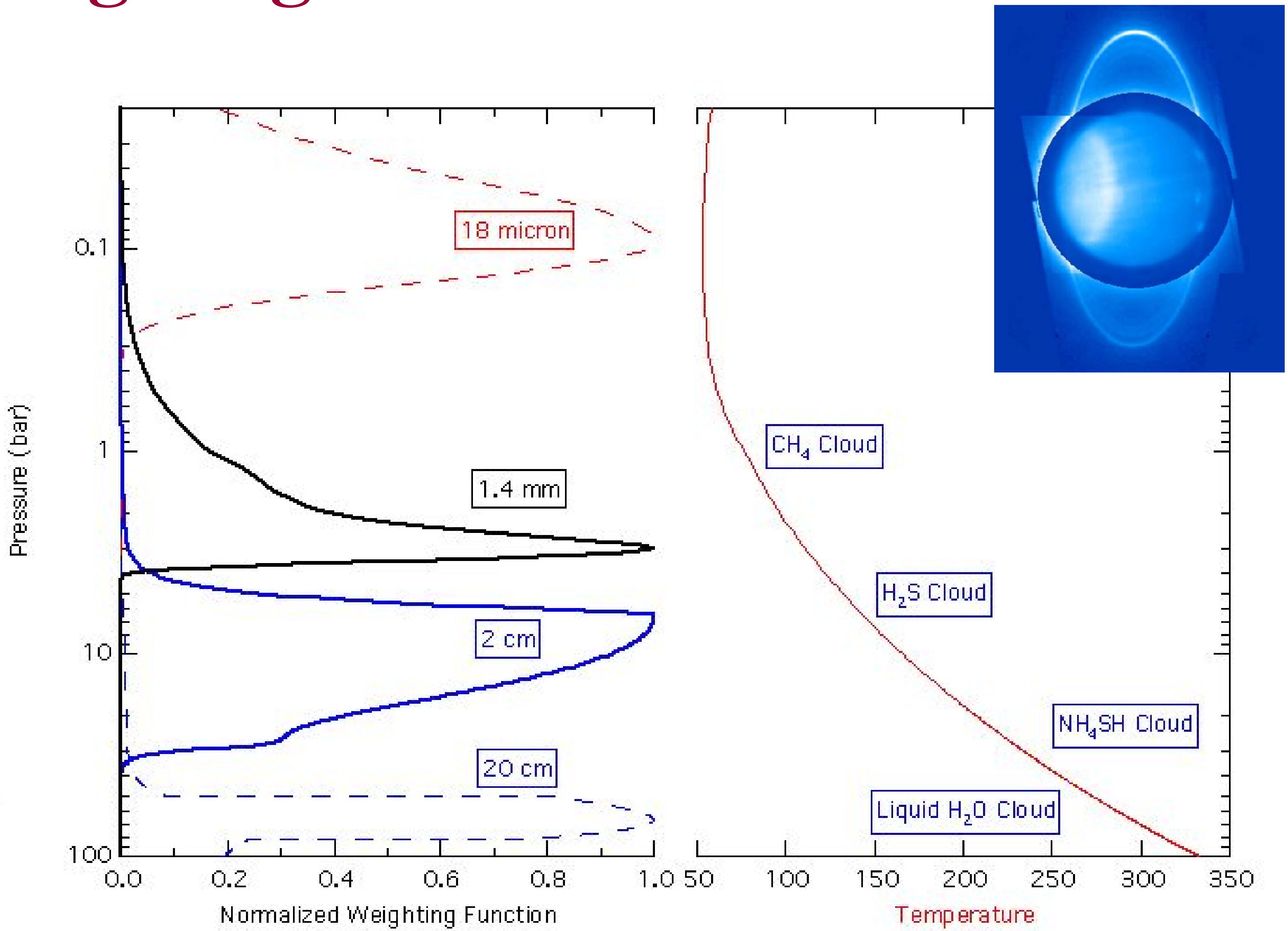




- SPHERE (VLT, 8-m telescope), 2011
  - Young self luminous exo-planets
    - Angular separation: $0.1 < \alpha < 1$ arcsec
    - Contrast (Near Infrared): 10^{-4} - 10^{-6}

- EPICS (E-ELT, 42-m telescope),
  - Mature gas giant and massive rocky exoplanets
    - Angular separation: $0.02 < \alpha < 1$ arcsec
    - Contrast (Near Infrared) H: 10^{-7} - 10^{-9}

Weighting Functions

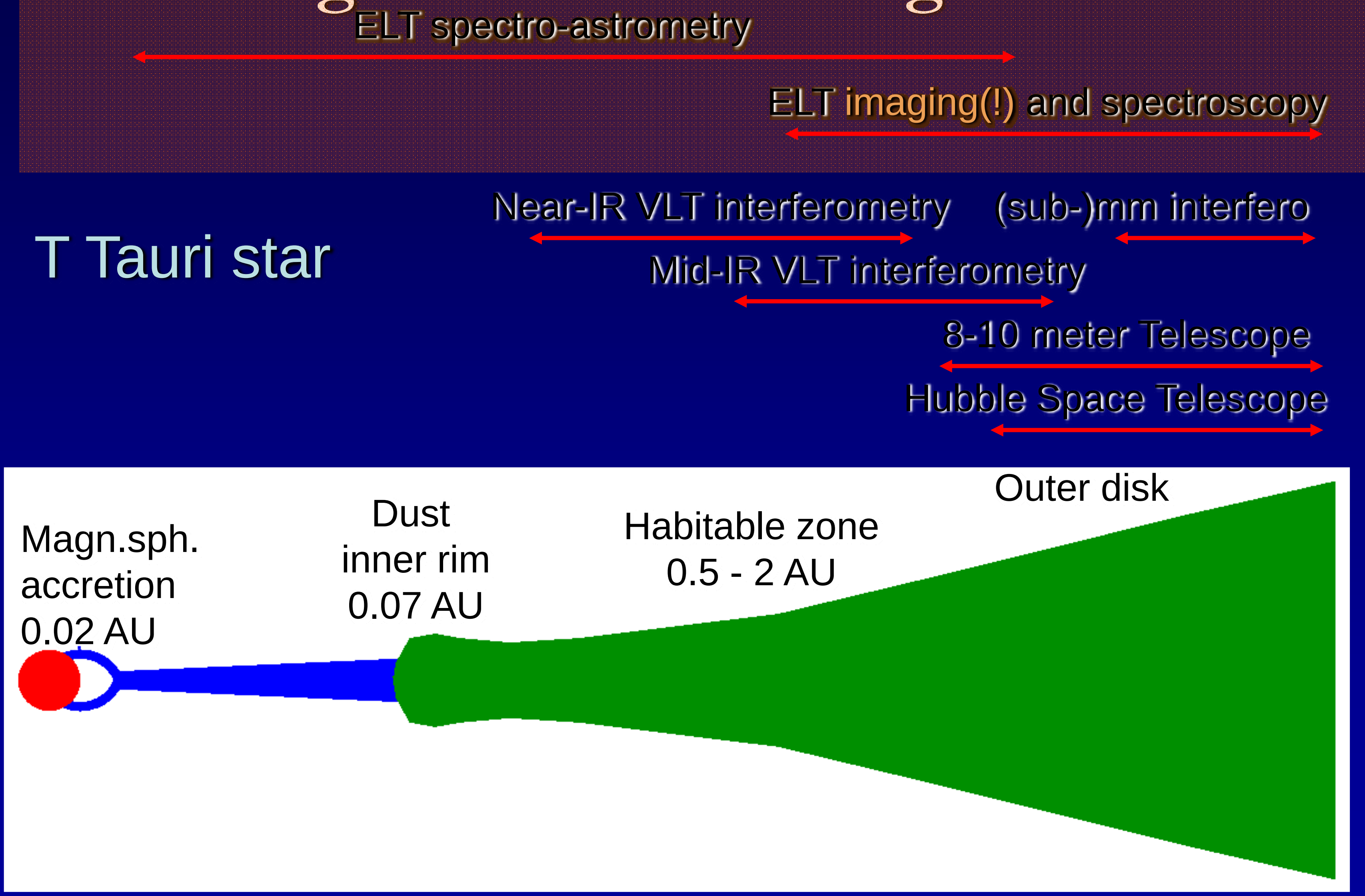


ALMA-ELT synergies:
High resolution and sensitivity!

- ☞ can utilize large apertures and instrumental sensitivities of ALMA & ELTs for breakthroughs in new areas….

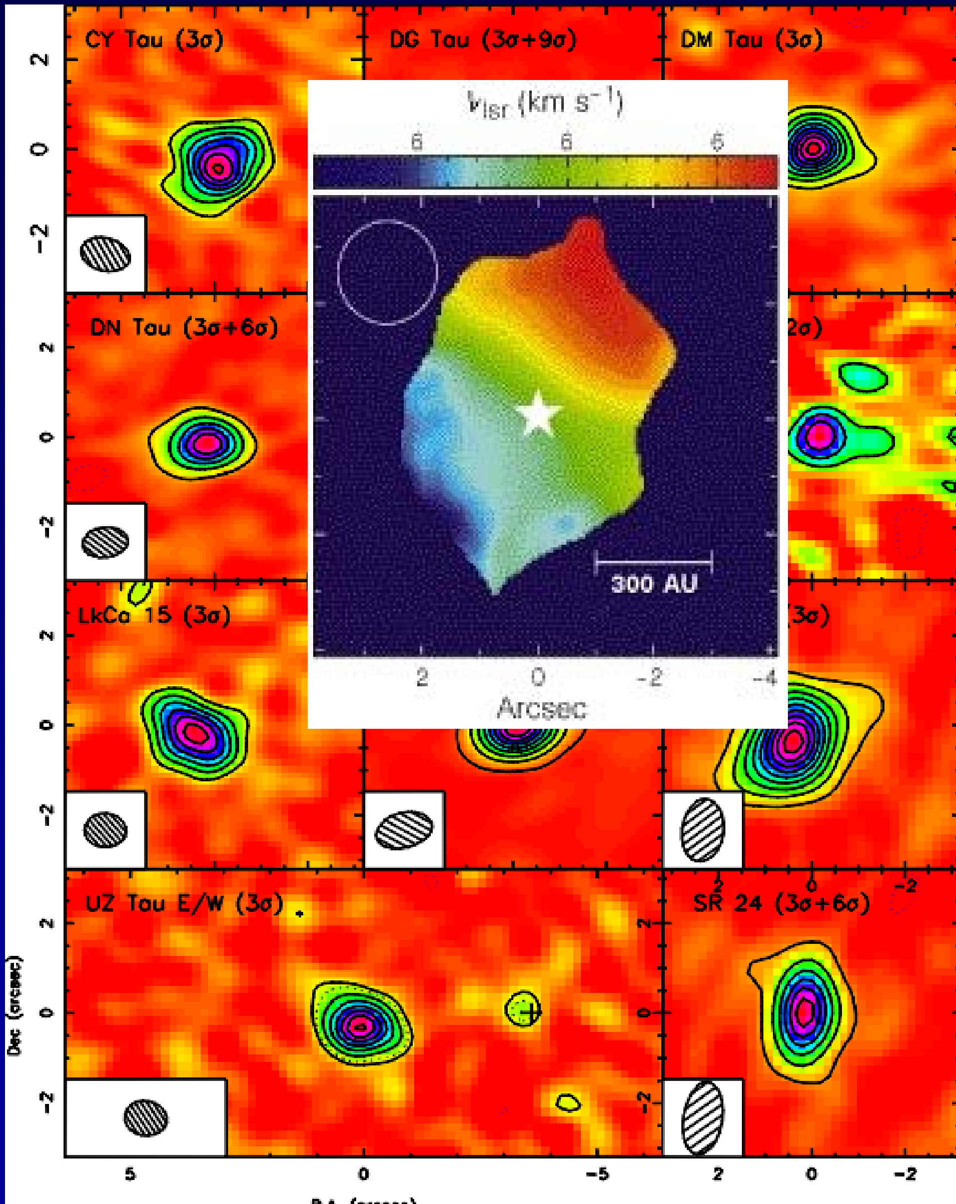
- ☞ Circumstellar disks
- ☞ High-Z universe

Probing the inner disk regions...

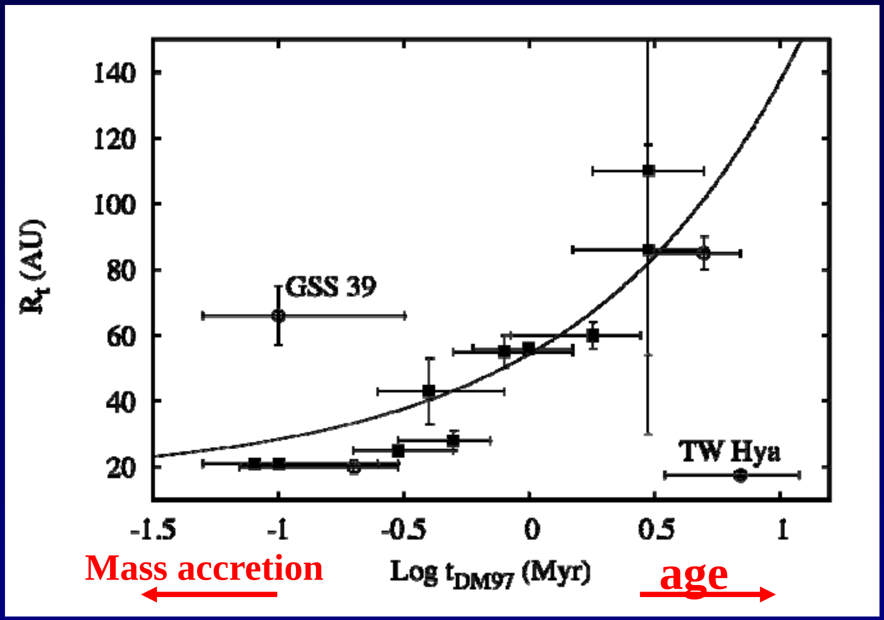


Note: ALMA can only image lines *outside* ~10 AU; ELT *inside* 10 AU

Disk around pre-main sequence stars



Isella, Carpenter & Sargent 2009 CARMA



- Constrain masses + sizes of disks, velocity patterns of *outer* disks, level of turbulence, …

Q: how do disks and stars co-evolve?

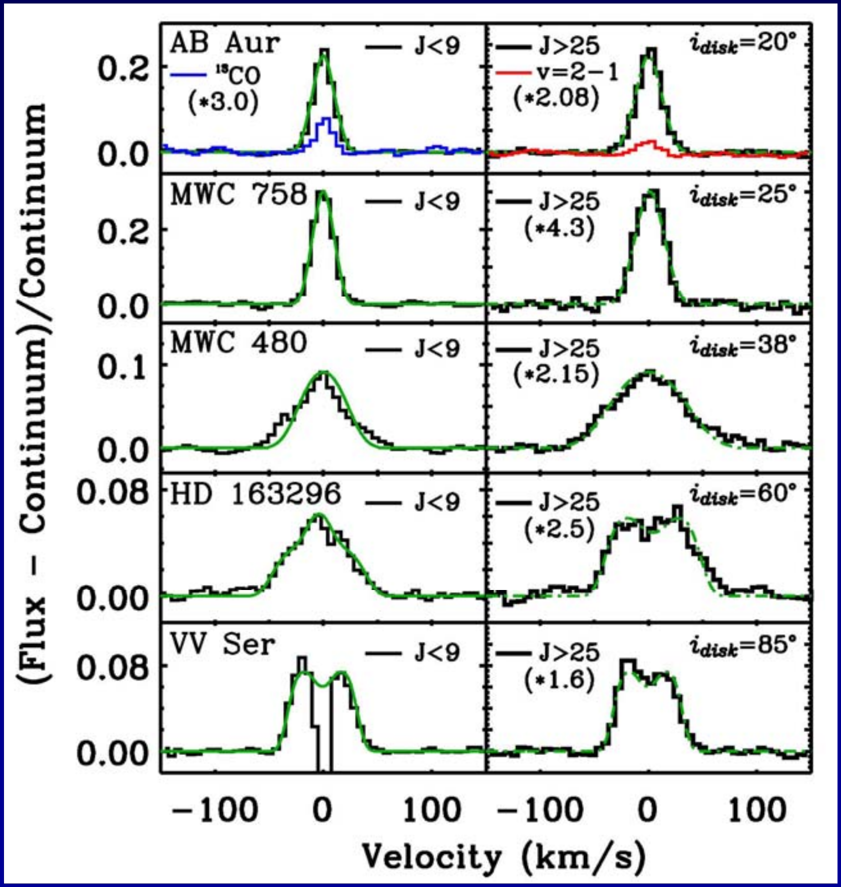
See also Dutrey, Guilloteau, & Simon, Ohashi et al, Kitamura et al , Qi et al, Andrews & Williams, ….

Hot gas in inner disks

CO v=1-0 band at 4.7 μm in disks around Herbig stars

Low-J **High-J**

inclination



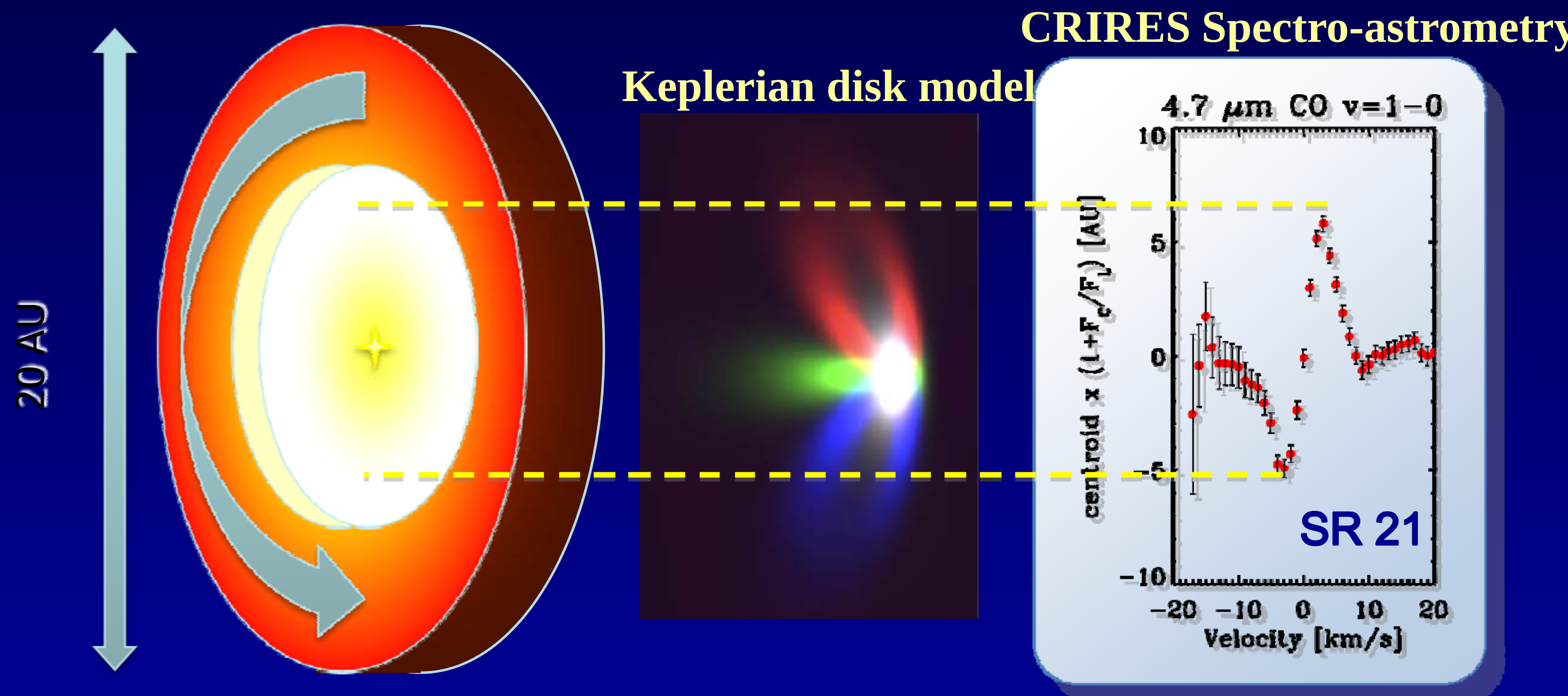
R=25000
Keck-NIRSPEC

T_{ex}**~1000 K**

Blake & Boogert 2004
Brittain et al. 2003, 2007
Najita et al.2003

Excitation by collisions (inner few AU) and resonant fluorescence (larger R)

Spectro-astrometry at milliarcsec resolution

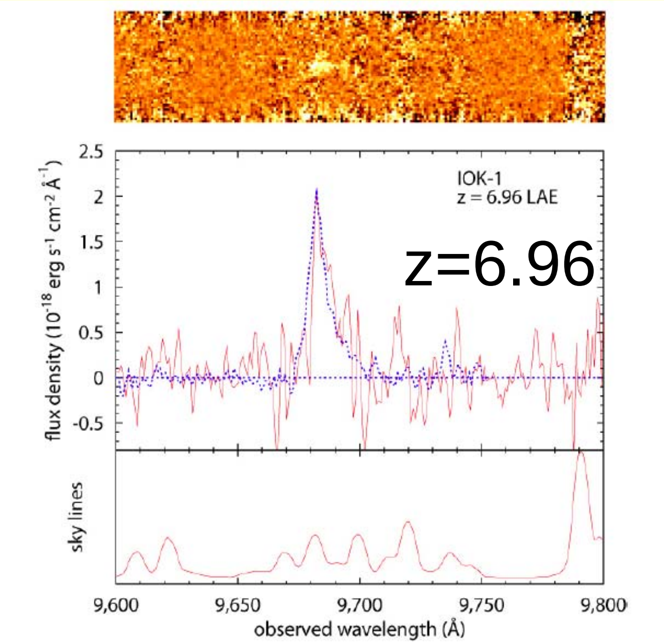


< 1 mas RMS @ λ/Δλ = 100,000

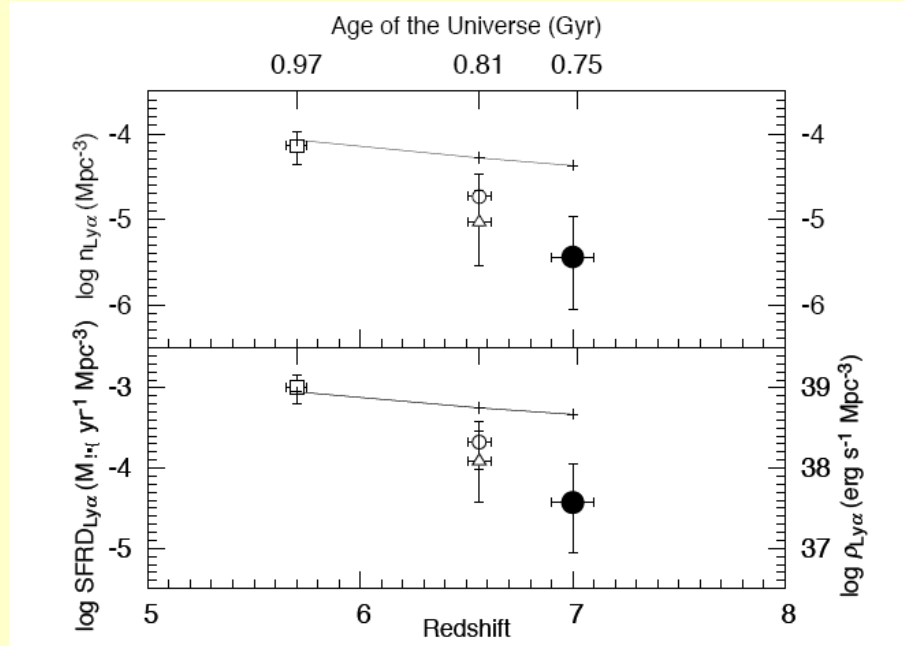
- Can locate gas down to 1 AU scale
- ELT can image kinematics directly down to few AU with IFU

Pontoppidan et al. 2008

Ly α Galaxy LF at z>6



Iye et al. 2006
Kashikawa et al. 2006
Ota et al. 2007

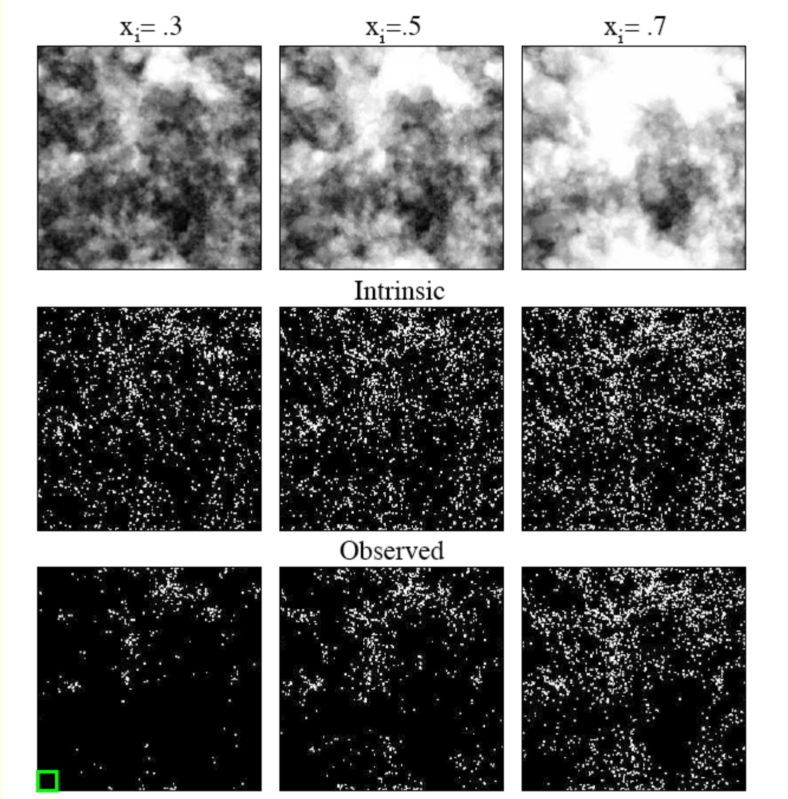


- Neutral IGM has extended GP damping wing → attenuates Ly α emission line
- Detectability of Ly α galaxies as markers of IGM optical depth
  - Reionization not completed by z~6.5
  - **f_{HI} ~ 0.3 - 0.6 at z~7**
  - **Overlapping at z=6-7?**

Reionization Topology with Lyα Emitters

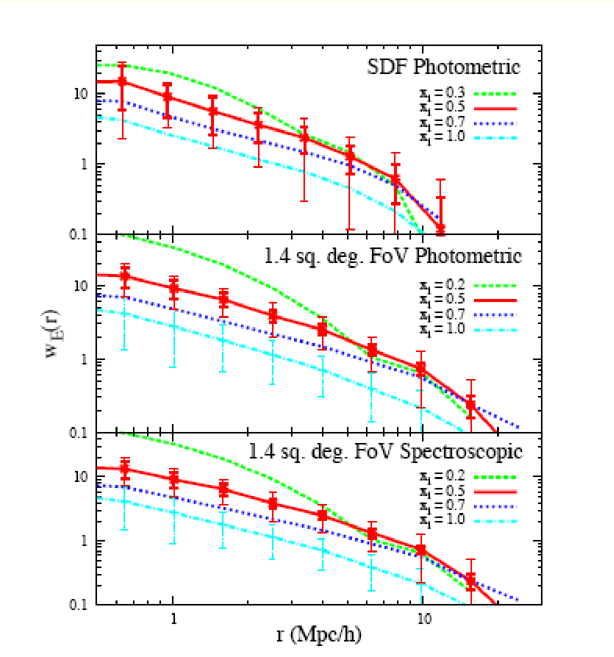
- Ly α emitter could provide sensitive probe to reionization history, especially during overlapping
  - Evolution of LF (constrain f_{HI})
  - Clustering

Distribution of Lyα emitters over 3' FOV



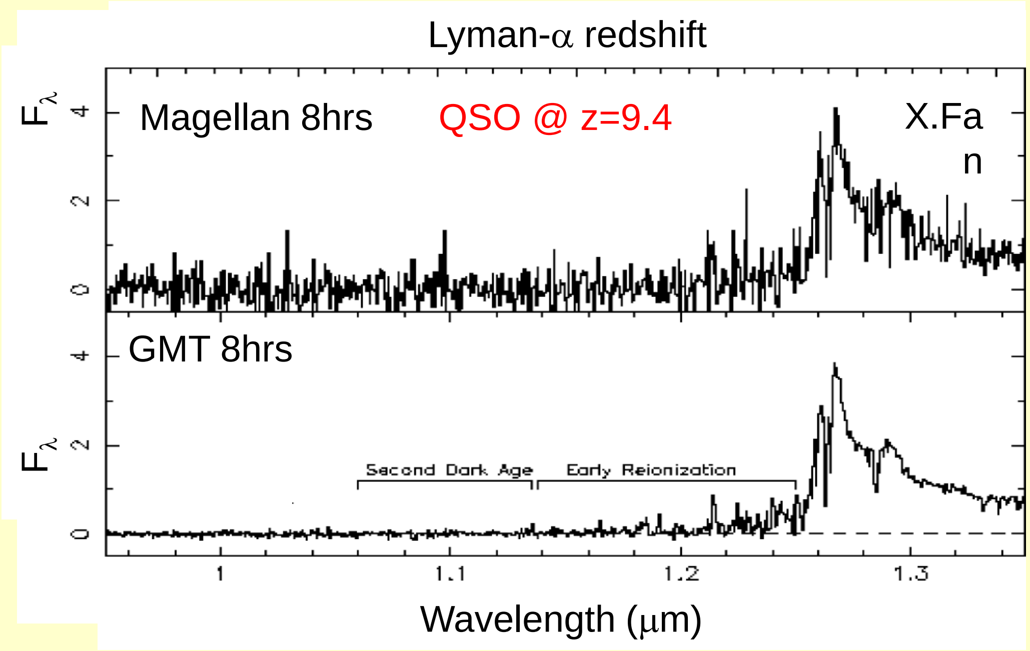
Neutral → Ionized

McQuinn et al.



Angular correlation of Lyα emitters

Probing the Neutral Era with ELT Quasar/GRB Spectroscopy

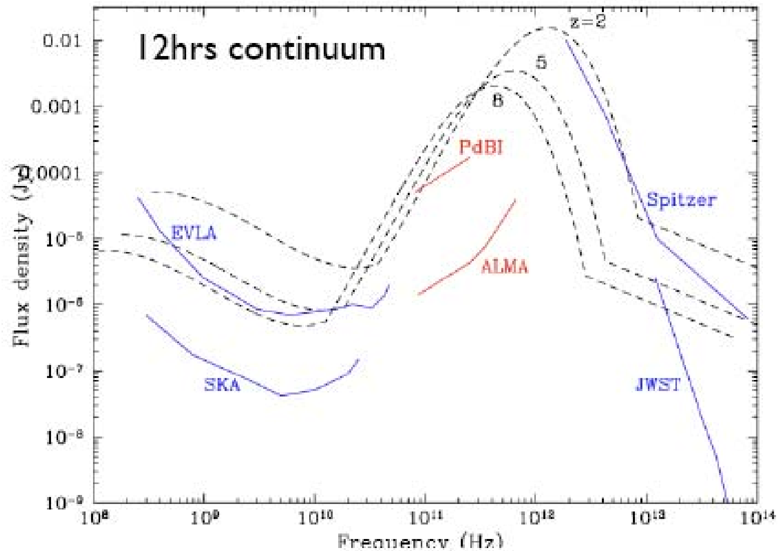


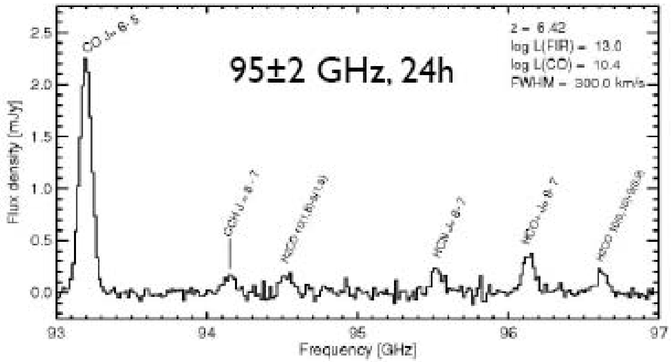
- High resolution, moderate (R~5000) resolution spectroscopy of bright quasars/GRBs will allow determination of reionization, using
  - optical depth measurements
  - distribution of dark absorption troughs
  - sizes of quasar HII regions

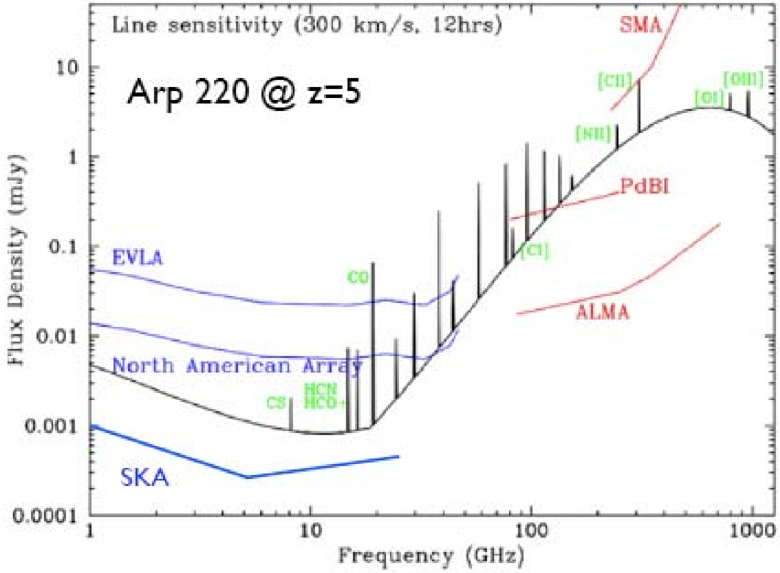
ALMA will detect J1148 in 1 sec
normal SF galaxies in hours:
20 μJy , 10 M_{sun}/yr

Lines:
CO, HCN, HCO+, H2O, ...
CII 158
CI 370, 609
OI 63, 145
OIII 52, 88
NII 205
NIII 57

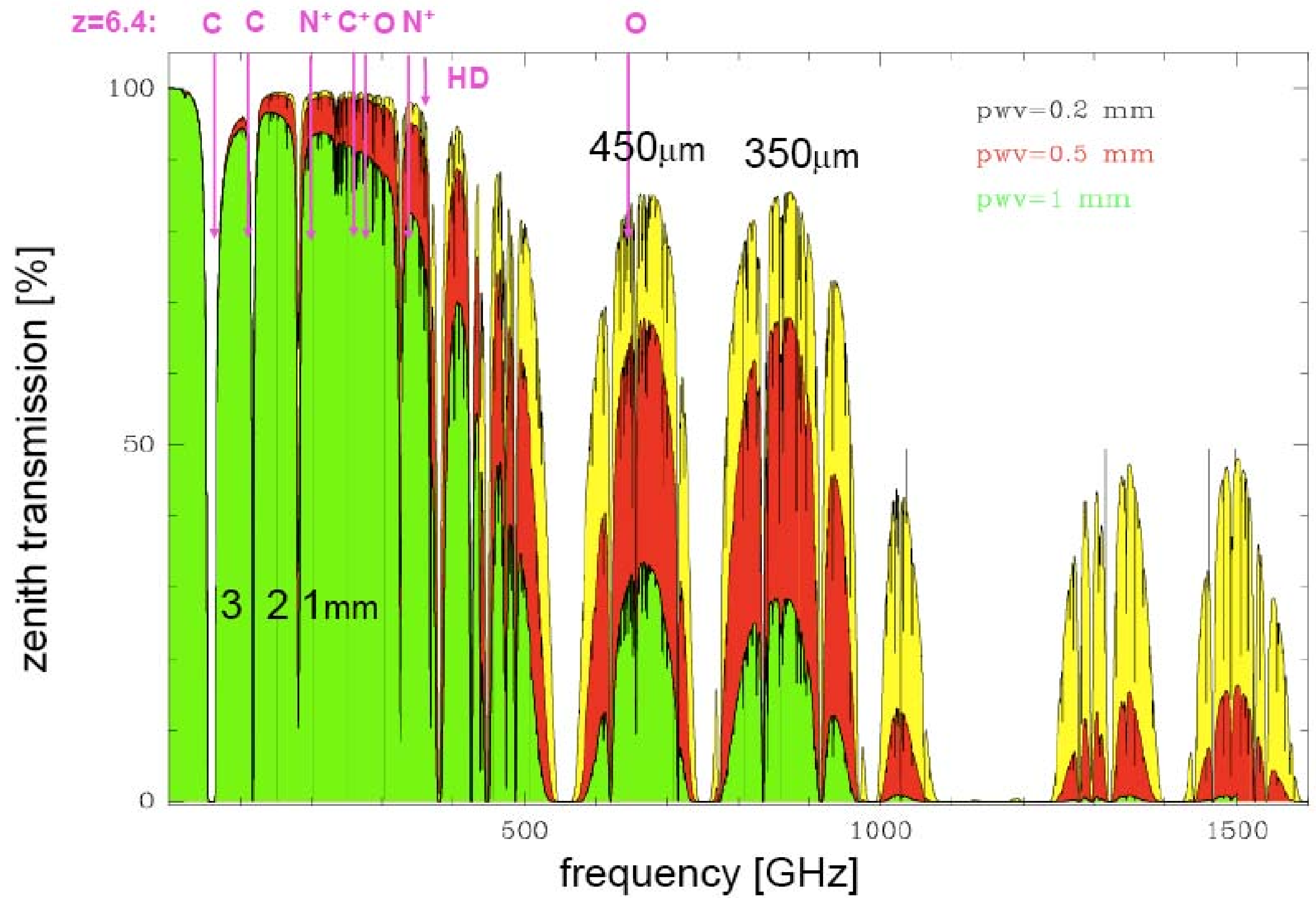
Note: C^+ line obs. not sensitivity-limited!



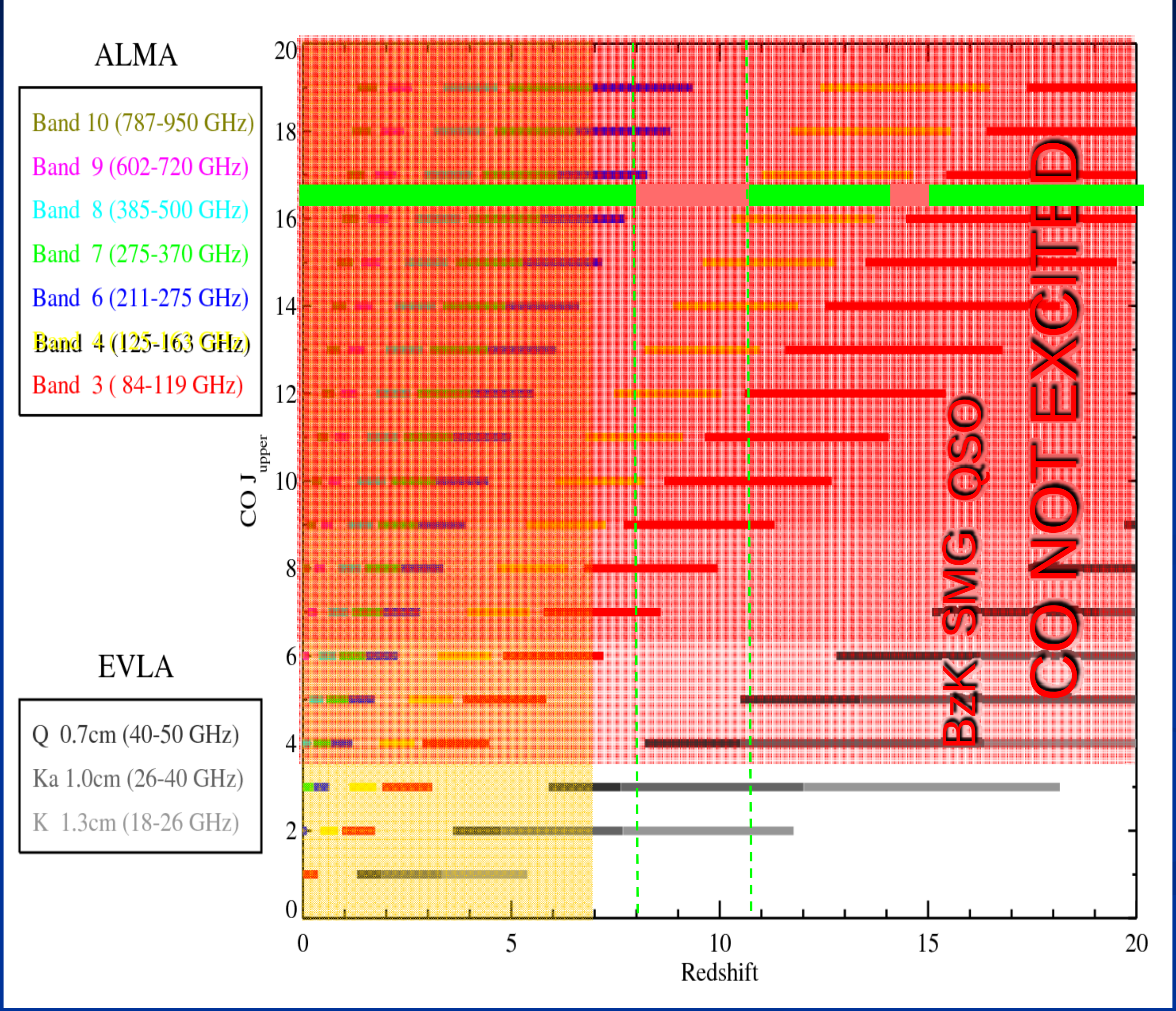




Far-IR Cooling lines at high z shifted into observable windows



[CII] will (almost) make our day at z>7



[CII] line

Need Band 5!

Discussion Sessions

Q1: Which ELT instruments and/or ALMA upgrades would be needed to produce a major impact in disks and at high-Z?

A1: for disks, ELTs need high R opt/IR eschelle spectrometers; for high-Z, need MOS (GMACS): AO is *critical*

for disks, ALMA needs longer baselines; for high-Z, need Bands 1 and 5.

Discussion Sessions

Q2: What are the main scientific synergies in 4 defined areas of research?

A2: I) Fundamental physics, cosmology:

- constants, high-Z galaxies

ii) Galaxy and ISM Evolution:

- galaxy mergers at Z ~ 2-3+

iii) SF from EoR to present:

- disk charcterization

iv) Solar Systems near and far:

- planet detection (direct, indirect)

Discussion Sessions

Q3: Do the communities overlap enough?

A3: Some, but not enough! Tendency to get stuck with the familiar, especially without incentives ($$$) to branch out

- workshops certainly help, especially ones targeted to specific science drivers that demonstrate the utility of other community instruments
- cross-fertilzation of committees can help
- why not hire some people from the other community on your faculty???

Discussion Sessions

Q4: What instrumentation will reinforce the synergies?

A4: Didn’t I answer that for Q1? >:-(ELT needs high-contrast imagers for planets, and IFUs for galaxy mergers; ALMA needs more antennas

Discussion Sessions

Q5: Formal connections made to allow simultaneous proposals?

A5: Not sure…probably good to have staggered deadlines so that results of one competition could be folded into the next one, probably up to community input

- perhaps incentives needed for large, “boring” projects since they are important?

Discussion Sessions

Q7: Which survey programs should be planned WRT location of ELTs to enable synergies?

A7: duh…an ELT should be in the south for maximal synergy with ALMA. Putting 3 ELTs in the south is probably a bad idea.

Having ELTs with the same instruments (at first) also probably a bad idea… (TMT has selected its already…)

Large programs are probably worthwhile at a small level during the early days of each facility. Doesn't lock up time for a small cadre of people, and allows usage to grow. Also, instrument will only improve with time!

Discussion Sessions

Q8: Should ALMA systematically prepare follow-up targets for the ELTs?

A8: not really addressed but loads of targets will probably be discovered in the ~6-8 years between ALMA early science and ELTs first lights. I suspect “systematic” observations will come more from dedicated wide-field surveys though…remember “ALMA not a survey instrument”

Discussion Sessions

Q9: What ALMA upgrades will most fully exploit synergy with the ELTs?

A9: God, this again? Haven’t I already answered this in Qs 1, 2 and 4? Man, I wonder what time it is back home…holy christ I’m tired.

Discussion Sessions

Q10: Are there possible synergies in terms of data standards, VO tools and post-pipeline analysis?

A10: YES. A VO-standard format will make using data between facilities much easier, helping communities grow. Also good to have “common interfaces for models”. Useful tools written by the community should be made available to the project.

Optical community can learn from 3D visualization and analysis tools being developed in radio wavelengths:

- Karma, 3D slicer for visualization
- “dendrograms” for analysis

Learnin' From Each Other

Can the projects learn from each other and if so in what area?

- International cooperation leads to better instruments
- Level 1 science case to guide development
- Enforcing ease-of-use for planning tools AND data products
- Software that is easy to understand and that are continuously improved
- Accessible archives that are continually re-developed

Fin