(Astro)Physics 343 Lecture # 2:
Lab #1 & Radiative Processes
(+ Chilean trip report)

Lab and office hour schedules

Section	Time	Students
A	Mon 1:40	S. Galkin, B. Llamas, H. Patel
B	Tue 12:00	P. Law, J. Rodriguez
C	Tue 5:00	S. Demarest, S. Heiblim, S. Tarabichi
D	Wed 1:40	M. Brady, K. Patterson
E	Wed 3:20	B. Salmon, R. Shah, I. Spassova

Office hours (every week): Mon 6:40–8:00pm (Baker; call 732-445-5500 x2544 to get through fire doors) and Thu 10:20–11:40 (Sharon), or by appointment

"On call" hours (analysis week): regular lab times

Computer accounts

I have set up individual accounts for you on the *obsastro* PC network, which includes the computer we will use to run the telescope ("blanco" in room 403b).

Accounts (and passwords) carried over from last semester:

Demarest, Law, Patel, Patterson, Rodriguez, Salmon, Shah Spassova

New accounts:

instinct, sgalkin, sheiblim, vllamas, saeedt

Computing protocol for labs

The directory on blanco in which the telescope control software is installed is c:\srt . This directory contains a reference file srt.cat that should not be modified except by the instructor! (This includes important calibration information.)

Your should use c:\srt to store command files and output data files during your lab session, but to avoid swamping that directory, make sure to copy them to the subdirectory for your lab section (c:\srt\SectionA etc.), with files identified with your name or initials), when you are done for the day.

Your analysis can be done on your own computer at home.

Lessons from last year's observations

Make sure to end an observing session by stowing the telescope and clicking the "Exit" button (not just closing the Java window).

The azimuth and elevation that are recorded in the *.rad files correspond to the current position of the telescope (not the Sun).

For optimally efficient observing, (a) sequence similar offsets together to minimize slewing, and (b) be cognizant of whether target will be rising above or setting below a critical elevation.

Do not use the "calibrate" button!

Useful DOS commands

Taken from a more complete list at

http://en.wikipedia.org/wiki/List_of_DOS_commands...

cd = change to a different directory

copy = copy a file to a new location and/or new name

del = delete a file or directory

dir /p = list contents of current directory, one page at a time

mkdir = create a new directory

more = print a file on screen, one page at a time

move = move a file to a new location and/or rename it

Useful tips for loading data into Excel

Thanks to Alex Merced (Rutgers '08):

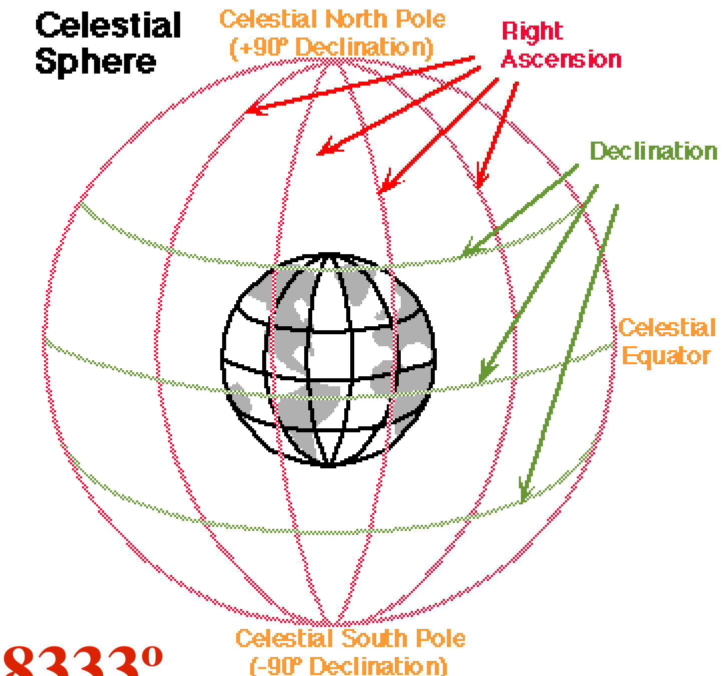
(1) Copy the original raw data file into a safe backup version, since Excel actually works directly on any input file.

(2) Click File → Open (set filter to select all files). Proceed to the "Text Import" wizard, and read in delimited input (deselect tab, select space as delimiter; treat consecutive delimiters as a single one).

(3) As a fallback, you can use the "Text Data to Columns" button to access the "Text Import" wizard.

Celestial coordinates: units of R.A.

Right ascension ("R.A.", α) & declination ("Dec.", δ) = celestial latitude and longitude that describe a source's position.



Example # 1:

A source has R.A. 14:11:45.2.

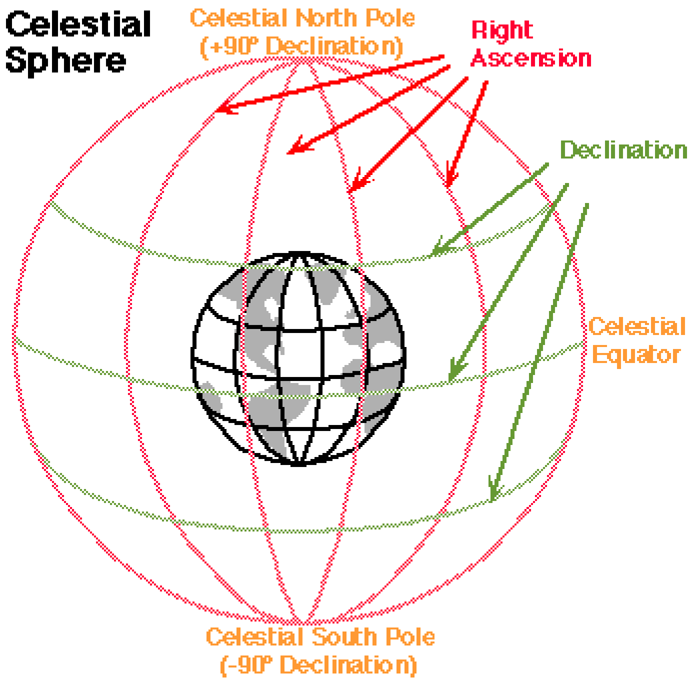
What is this in units of degrees?

Answer:

$$15 \times (14 + 11/60 + 45.2/3600) = 212.938333^{o}.$$

(Note that R.A. 23:59:59 corresponds to 359.995833^{o}.)

Celestial coordinates: source separations



Example # 2:

Source A lies at 02:33:24.5 +15:32:29.

Source B lies at 02:33:32.9 +15:24:06.

How far apart are they on the sky?

Answer:

$\Delta\delta$ is easy: $(24 \times 60 + 6) - (32 \times 60 + 29) = -503'' = -8.383'$

$\Delta\alpha$ is harder: $15 \times (32.9 - 24.5) \times \cos(15.4715) = 121'' = 2.024'$

For small angles, separation $\simeq [(\Delta\delta)^2 + (\Delta\alpha)^2]^{1/2} = 8.6'$

Celestial coordinates: directions

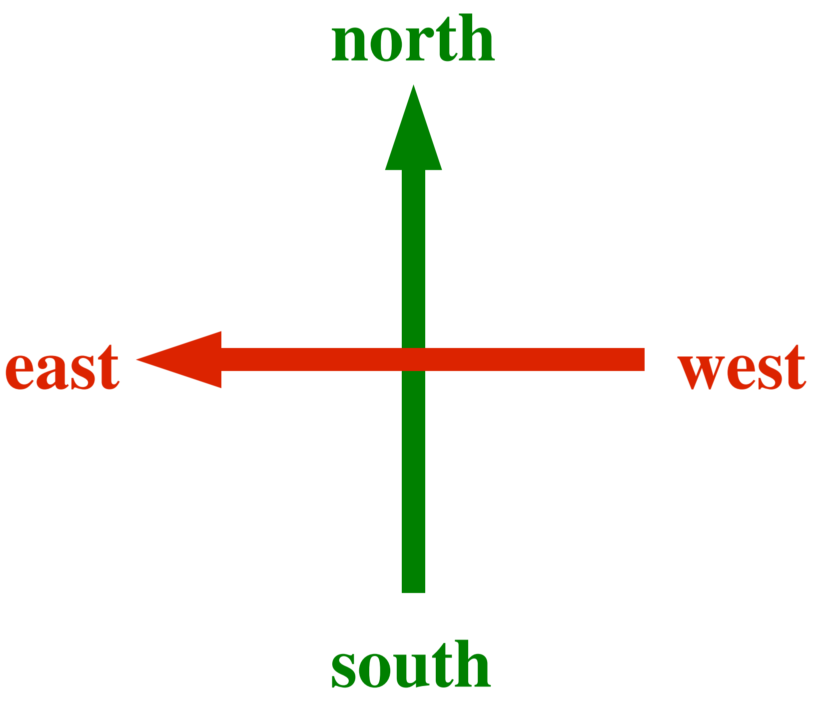
Consider again: source A lies at 02:33:24.5 +15:32:29,

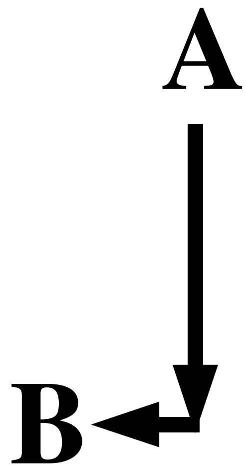
source B lies at 02:33:32.9 +15:24:06.

How do they *look* on the sky?

$\Delta\delta = -8.383'$

$\Delta\alpha = 2.024'$





Celestial coordinates: precession

When can a source's right ascension and declination change?

(1) It's a solar system object (Sun, moon, planet, asteroid, etc.).

(2) It's a nearby star with a high “proper motion” (e.g., α Cen).

(3) We wait long enough that the earth's rotation axis wobbles a little (i.e., it precesses).

To deal with (3), every right ascension and declination must be specified with an epoch (“B1950” and “J2000” are common).

Celestial timekeeping

Astronomers use two principal time conventions:

(1) UT = Universal Time

This is a solar time that corresponds (apart from daylight savings) to the local time in Greenwich, England.

At a given moment, UT is the same everywhere.

(2) LST = Local Sidereal Time

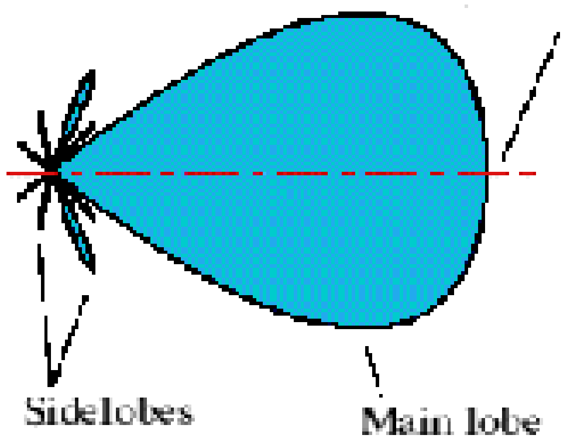
This is the R.A. that is directly overhead right now.

At a given moment, LST is different at different longitudes.

Lab # 1: measuring the telescope's beam

A radio telescope can only see a limited range in solid angle (relative to its own axis) at any given time.

The normalized beam pattern describes a telescope's response to a given sky direction (defined to be 1 on-axis).

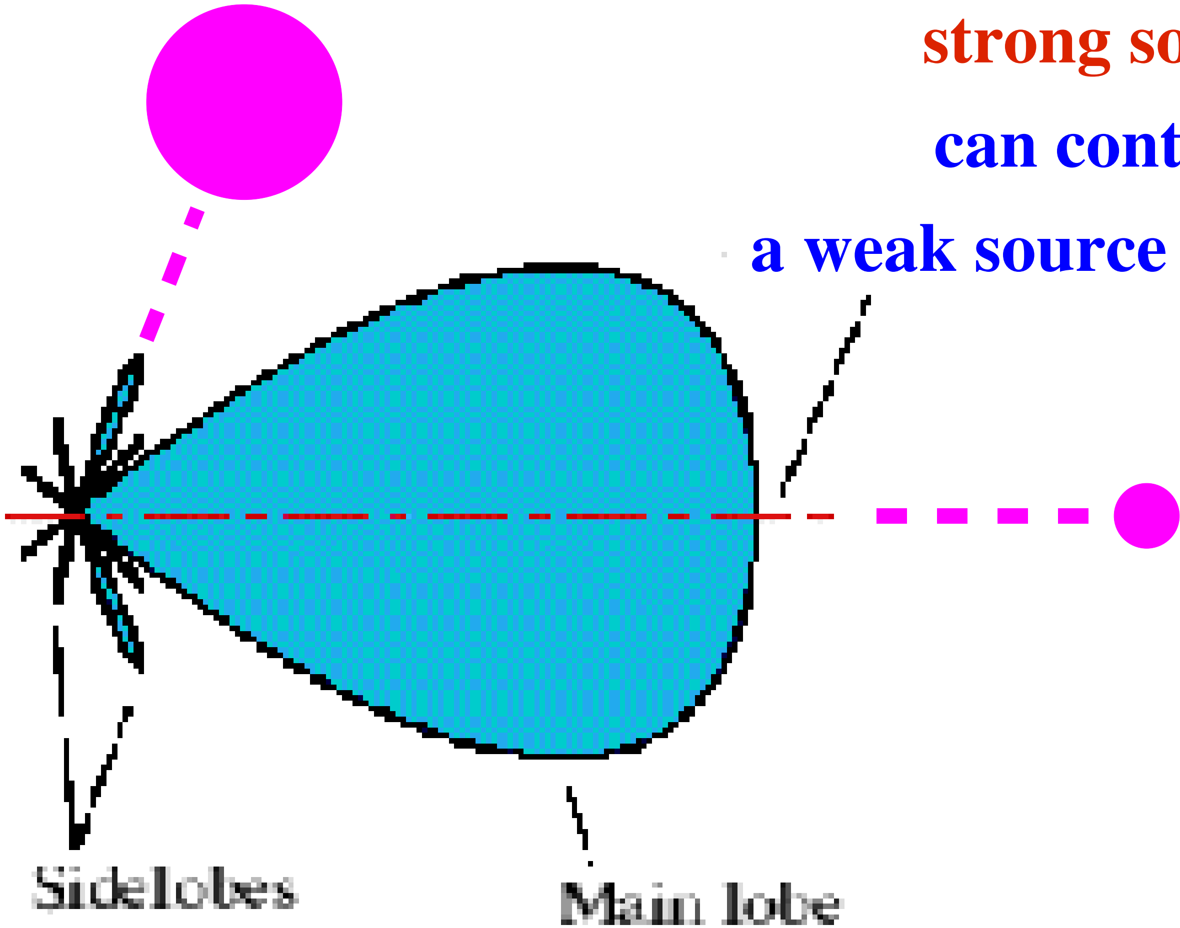


The main lobe has a width proportional to λ/D for λ the wavelength and D the diameter of the telescope. We will measure the width of the main lobe for the SRT by scanning across the sun.

Why we care about the telescope's beam

Shape of the beam corresponds to the weighting in a particular direction of the total summed response:

strong source in a sidelobe can contribute as much as a weak source in the main beam!



The SRT's receiver

The telescope on the roof of Serin is equipped with the digital receiver rather than the analog receiver (digital systems use digital signals, i.e., 1s and 0s, while analog systems use signals that are continuous in time and amplitude).

Output is one long row per time dump, containing: time stamp, azimuth, elevation, azimuth offset, elevation offset, frequency, channel spacing, 1, # of spectral bins (typically 64), and finally the contents of all of those bins.

The SRT's command language

Our observing scripts can be prepared as *.cmd (text) command files, copied to “blanco”, and executed within the SRT control software environment. Results will be recorded into *.rad files. Note that all commands except an instruction to wait must be preceded by a ': '!

Quiz

Line and continuum emission/absorption

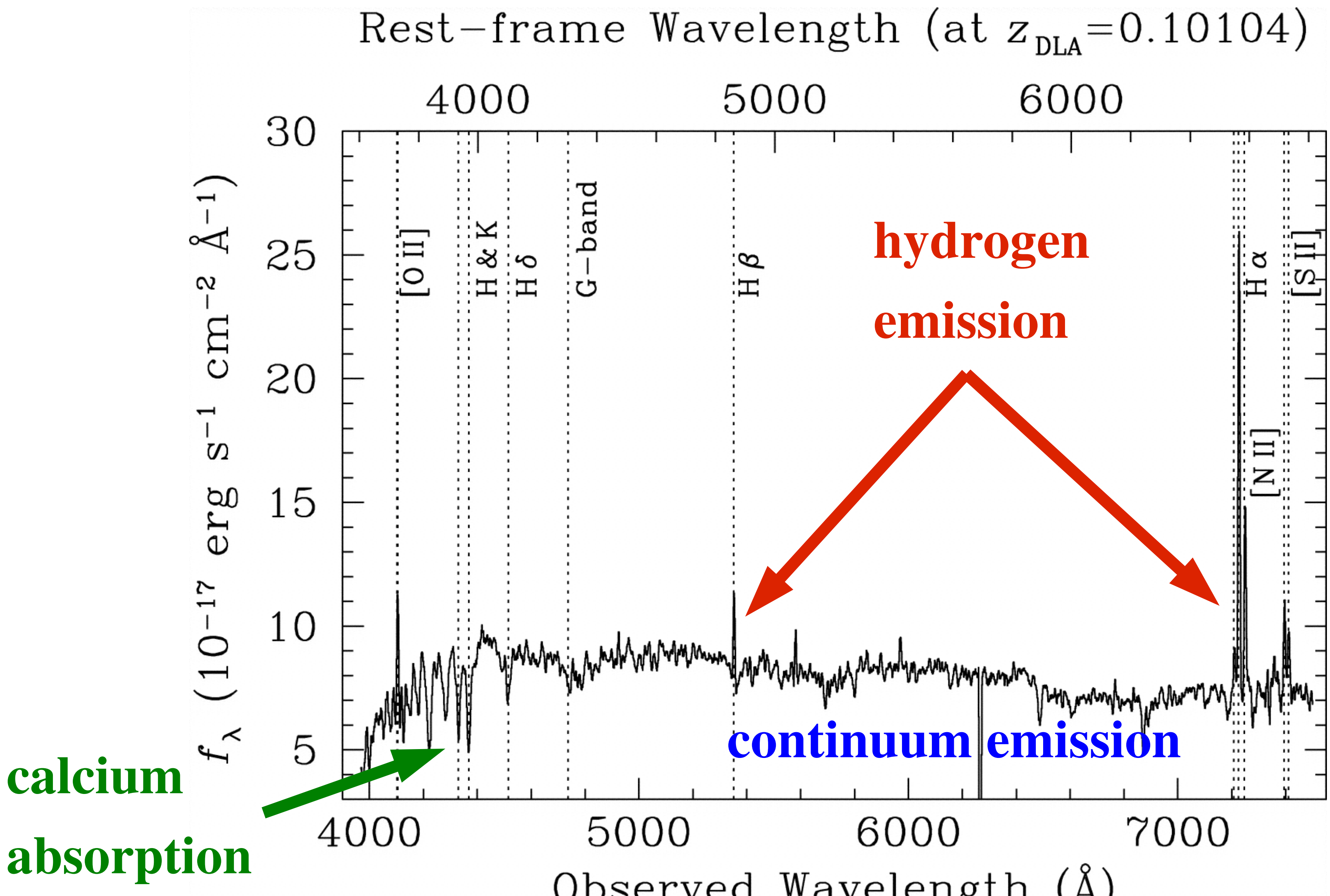
When we look at astronomical spectra (at all wavelengths), we classify features in two ways:

(1) line vs. continuum (roughly, narrow vs. broad)

(2) emission vs. absorption

Note: for an absorption line to be produced, there must be "background" continuum emission to be absorbed!

Example: optical spectrum of a galaxy



Radio continuum emission

Three principal mechanisms:

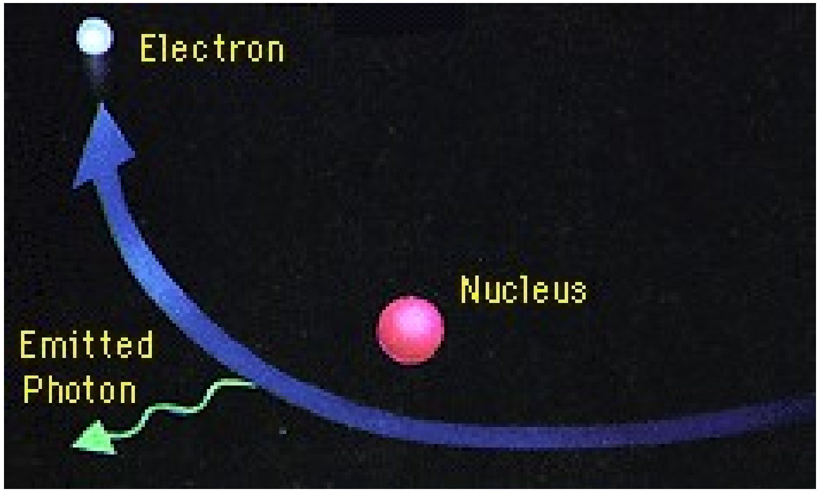
(1) **free-free emission (a.k.a. "bremsstrahlung" = "braking radiation") from ionized gas**

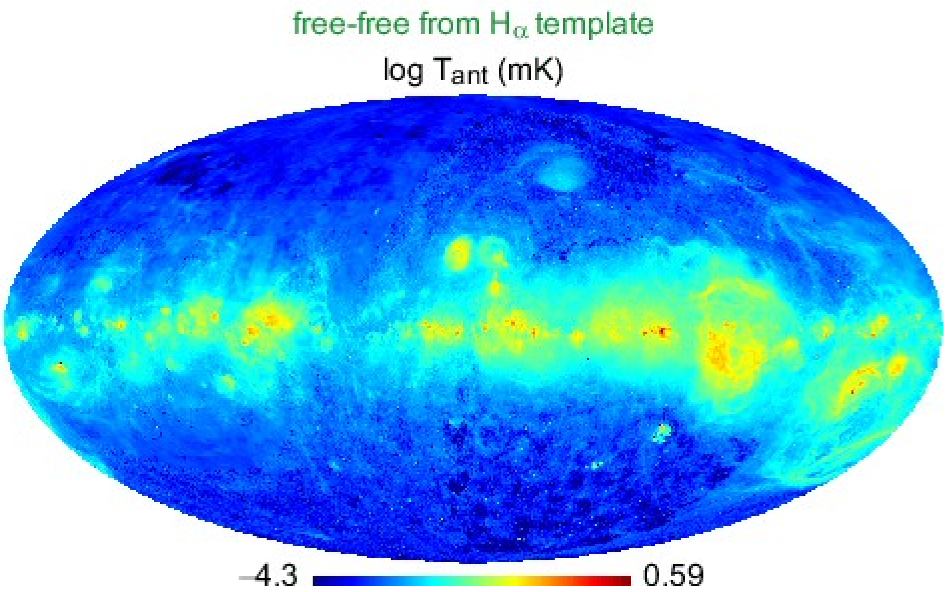
(2) **synchrotron emission from electrons being accelerated in a strong magnetic field**

(3) **thermal emission (i.e., produced due to heat) by dust grains**

Free-free emission

Mechanism: electrons are accelerated by the Coulomb potential of ions (higher temperature ⇔ faster motions ⇔ higher-energy photons).

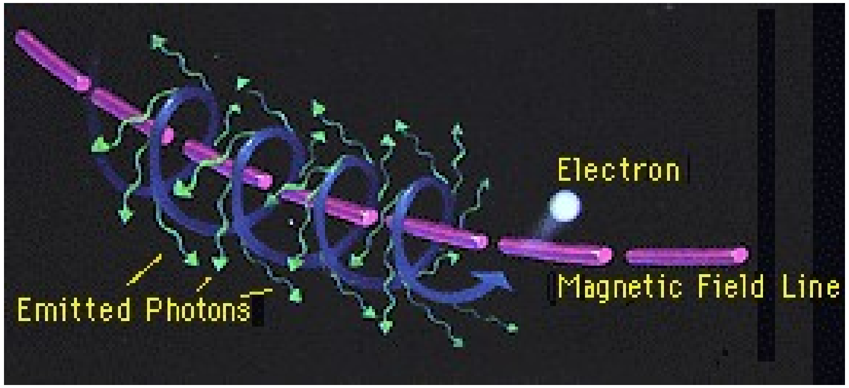


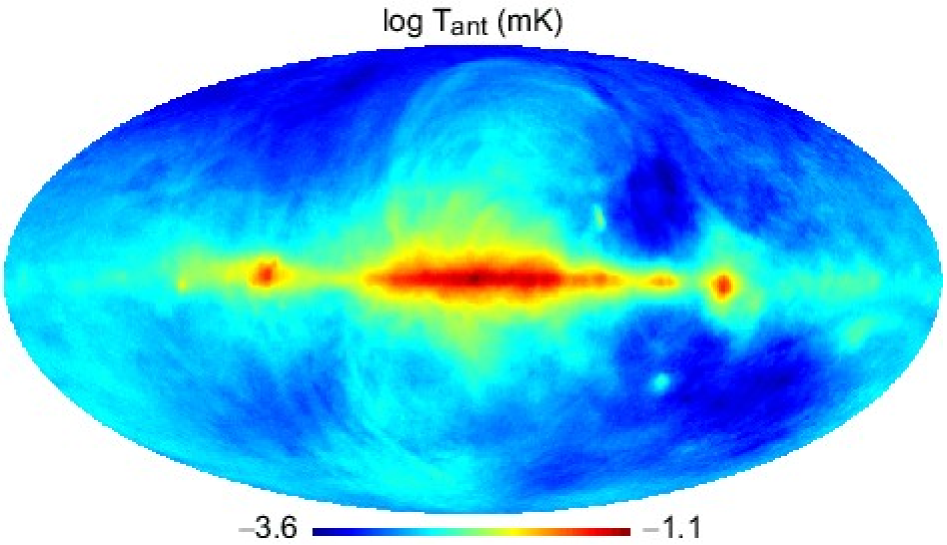


Burigana et al. (2004):
free-free emission from Milky Way at 100 GHz

Synchrotron emission

Mechanism: electrons are accelerated along helical trajectories in magnetic fields (stronger magnetic fields ⇔ higher-energy photons).

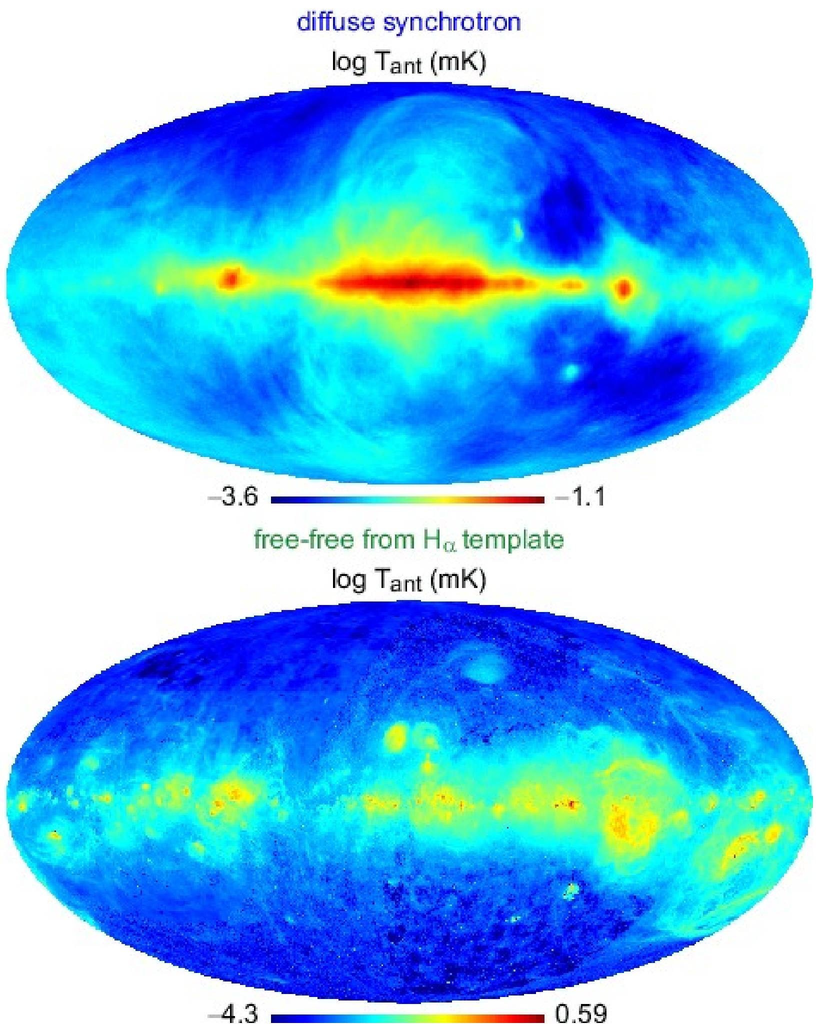




Burigana et al. (2004):

synchrotron emission from Milky Way at 100 GHz

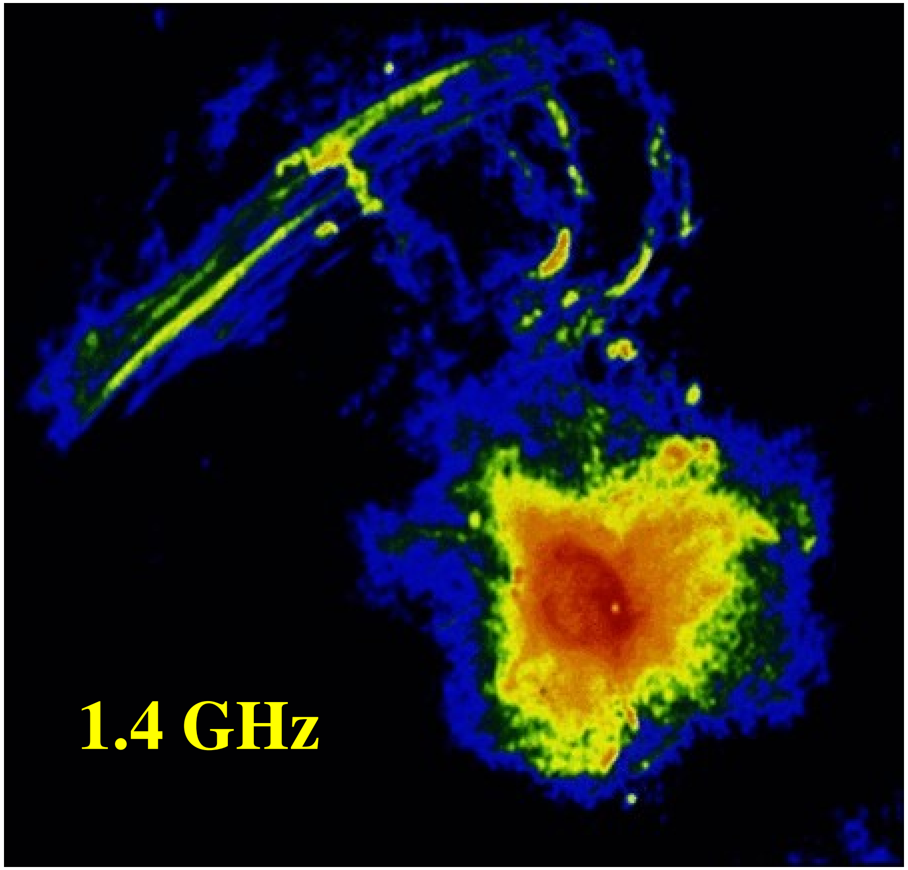
Free-free vs. synchrotron emission



Why do these look different?

Galactic Center filaments:

which mechanism is responsible?

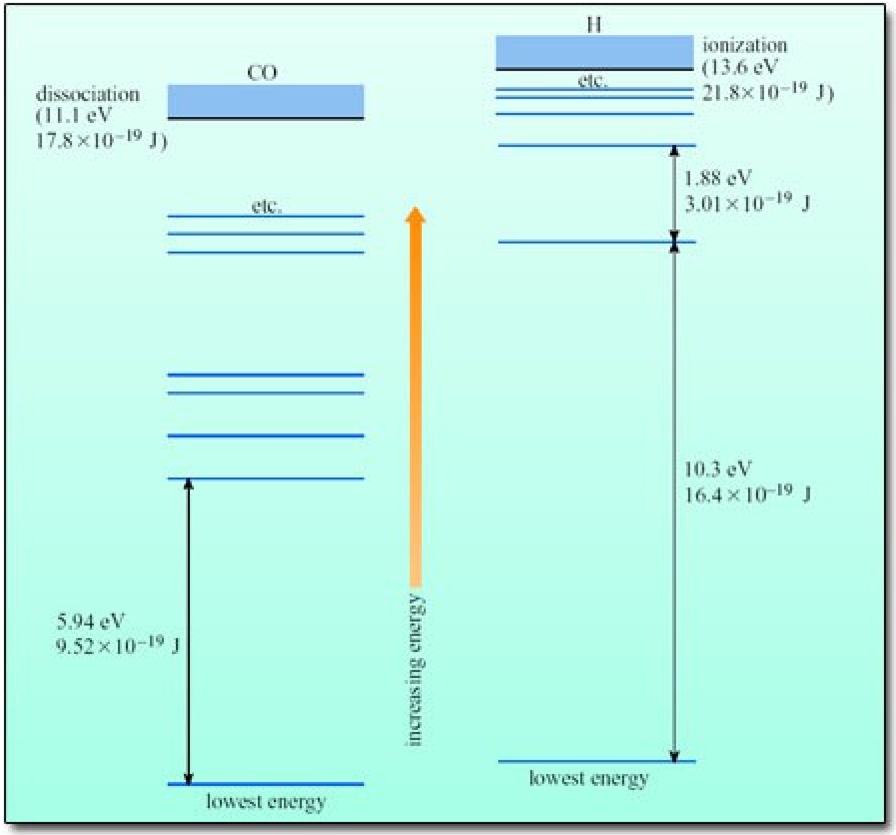


Line emission

A sharp line feature occurs when there is a transition in the electronic or spin state of an atom, or in the electronic, vibrational, or rotational state of a molecule.

This sharp feature is broadened by line-of-sight motions in the emitting/absorbing material (i.e., by the Doppler effect).

Electronic transitions

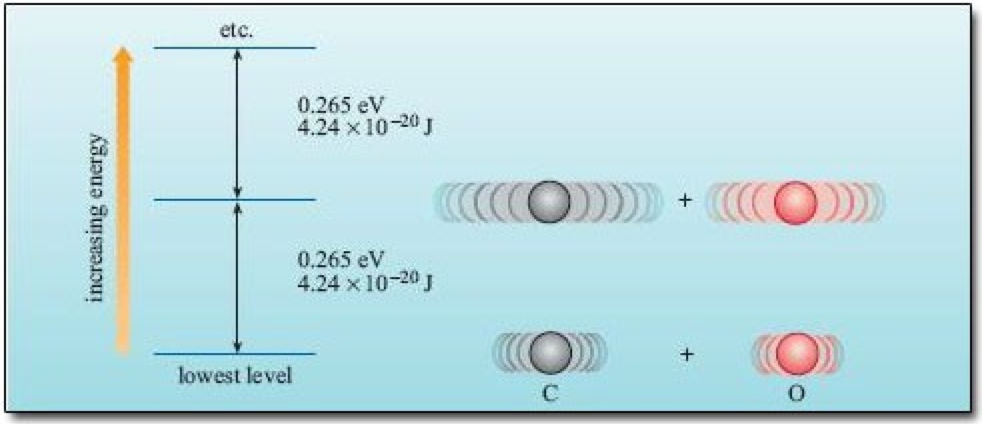


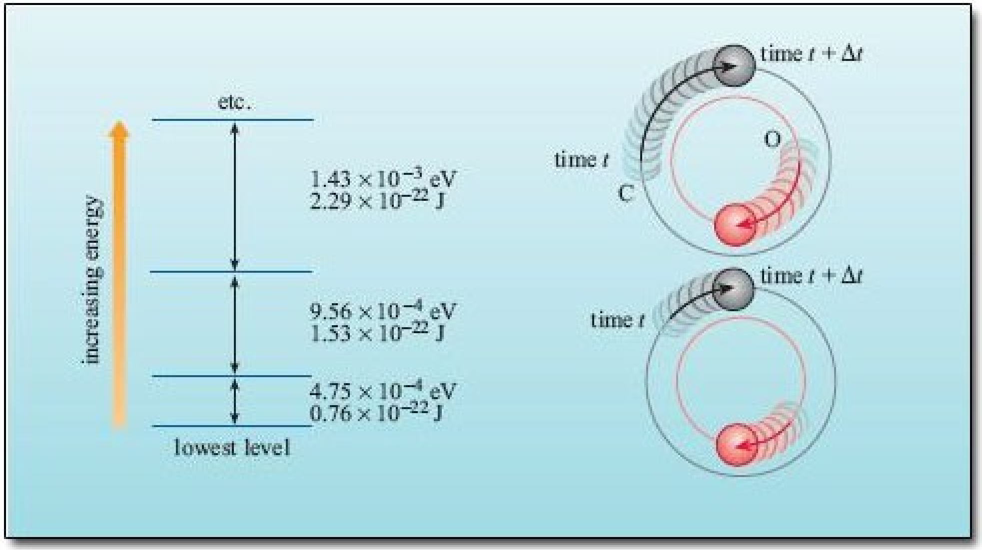
When an electron in an atom or molecule drops from a higher energy level to a lower energy level, a photon is emitted.

An incoming photon of the right wavelength/frequency can also be absorbed.

Courtesy of Open University.

Vibrational and rotational transitions





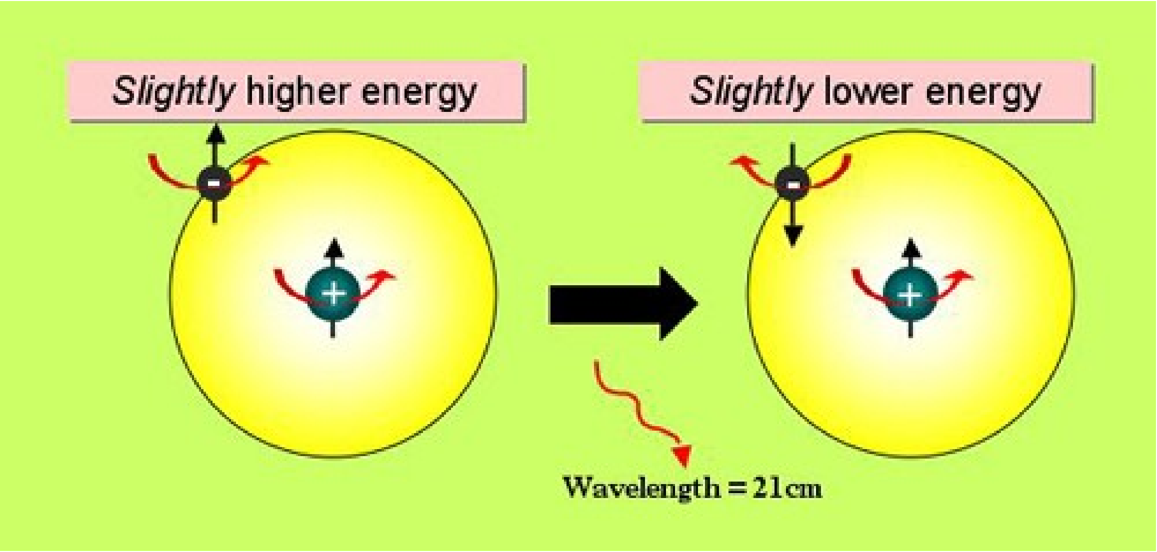
Courtesy of Open University.

Molecules also have quantized levels of vibrational and rotational energy (spacings are higher for the former).

Transitions are associated with absorption/emission of photons.

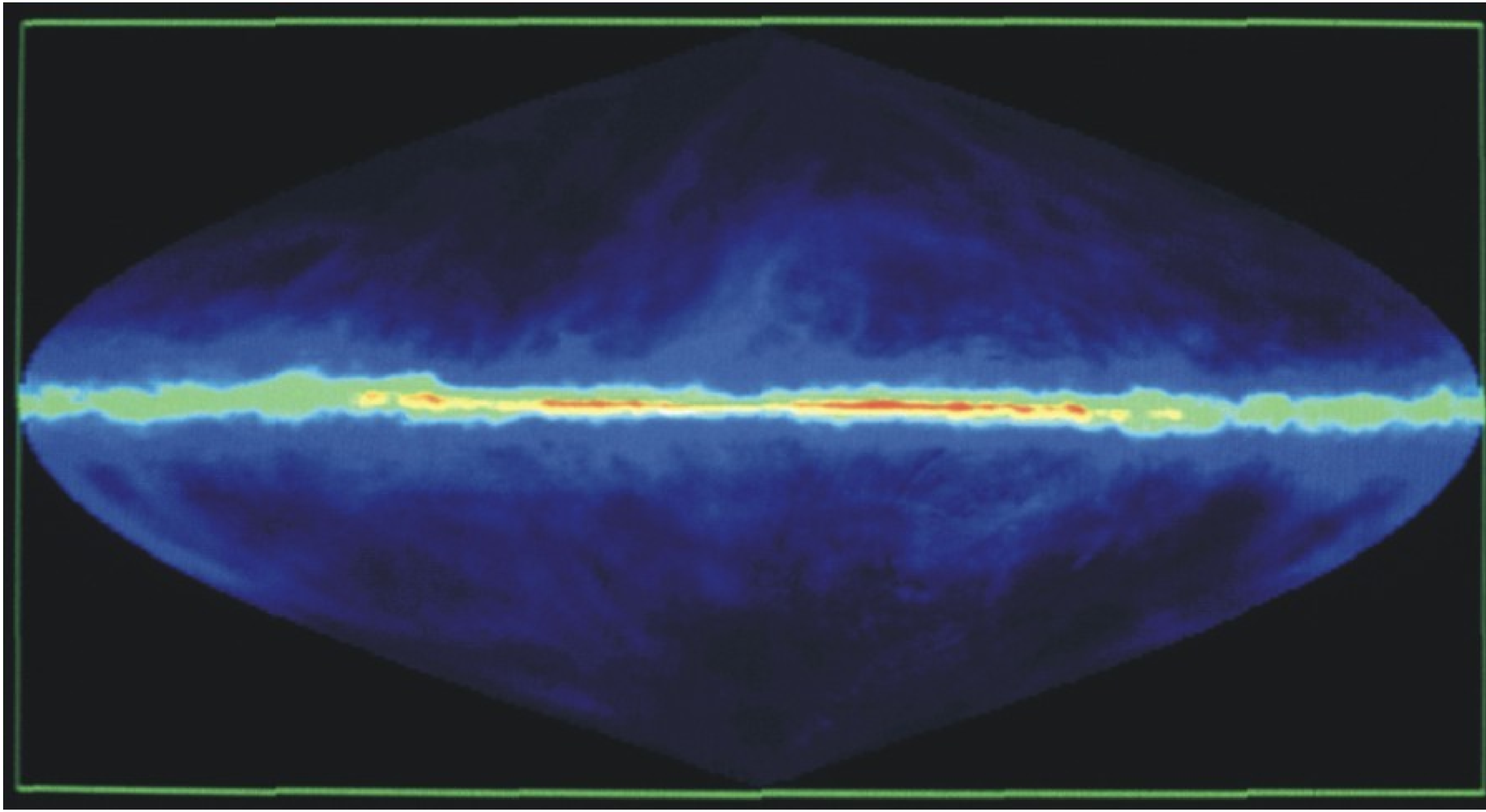
The key "spin flip" transition: 21cm H line

In a H atom, when the electron and the proton switch from having parallel spins to having antiparallel spins, a 21cm photon is emitted.



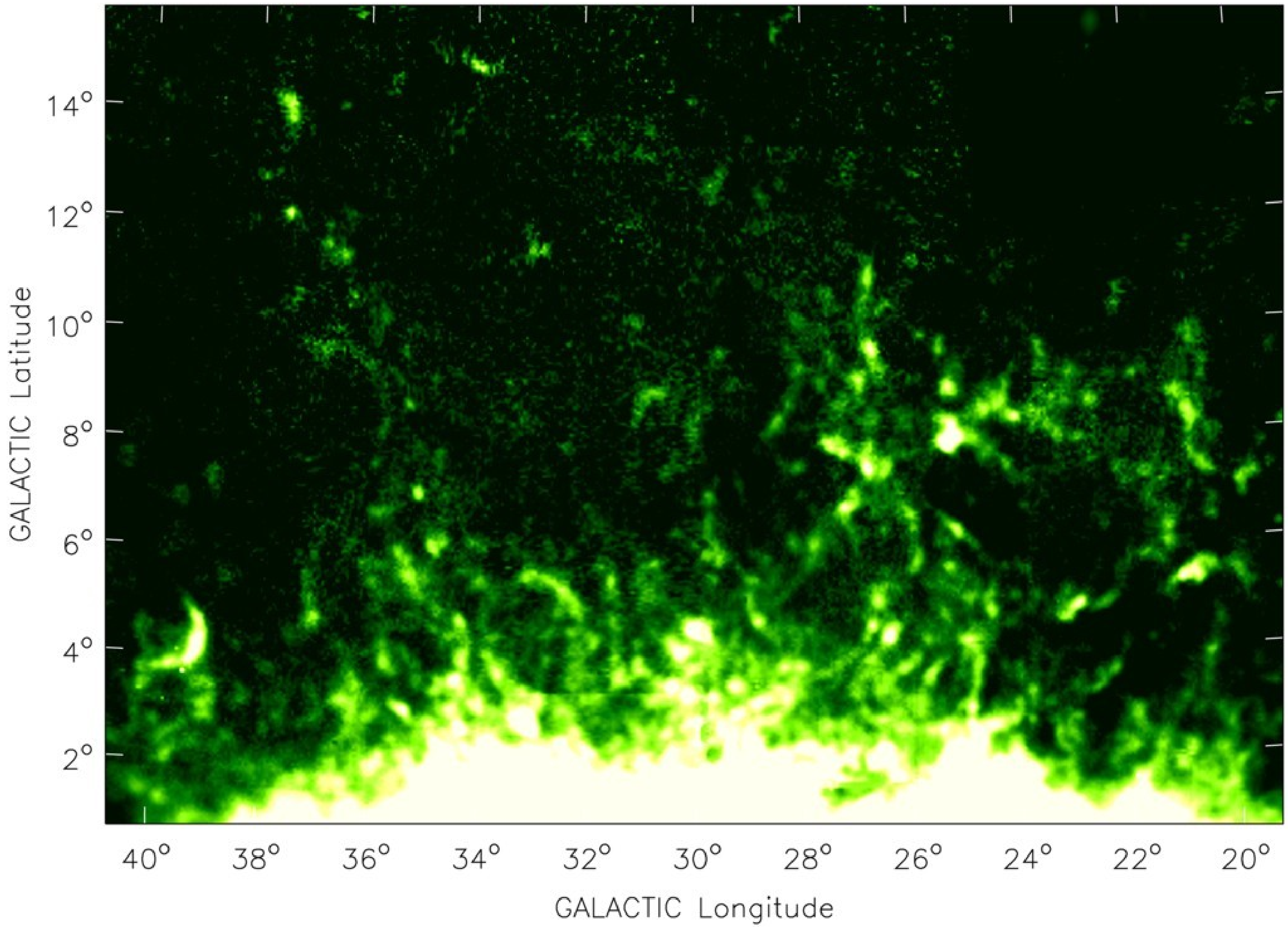
Doesn't trace ionized or molecular gas – just neutral atomic gas!

Courtesy of Swinburne University.



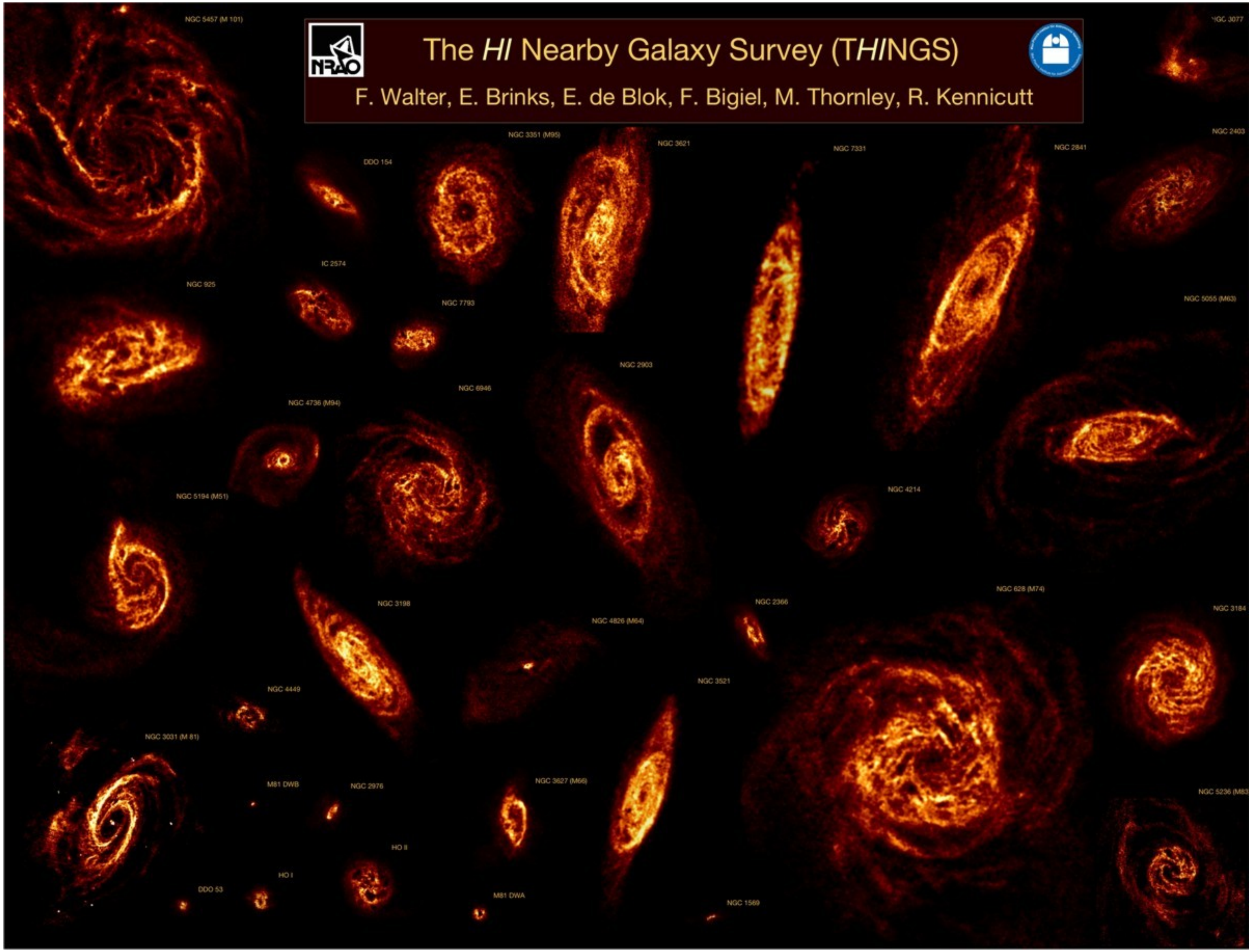
HI in the Milky Way, plotted in (*l*,*b*) coordinates

J. M. Dickey & F. J. Lockman

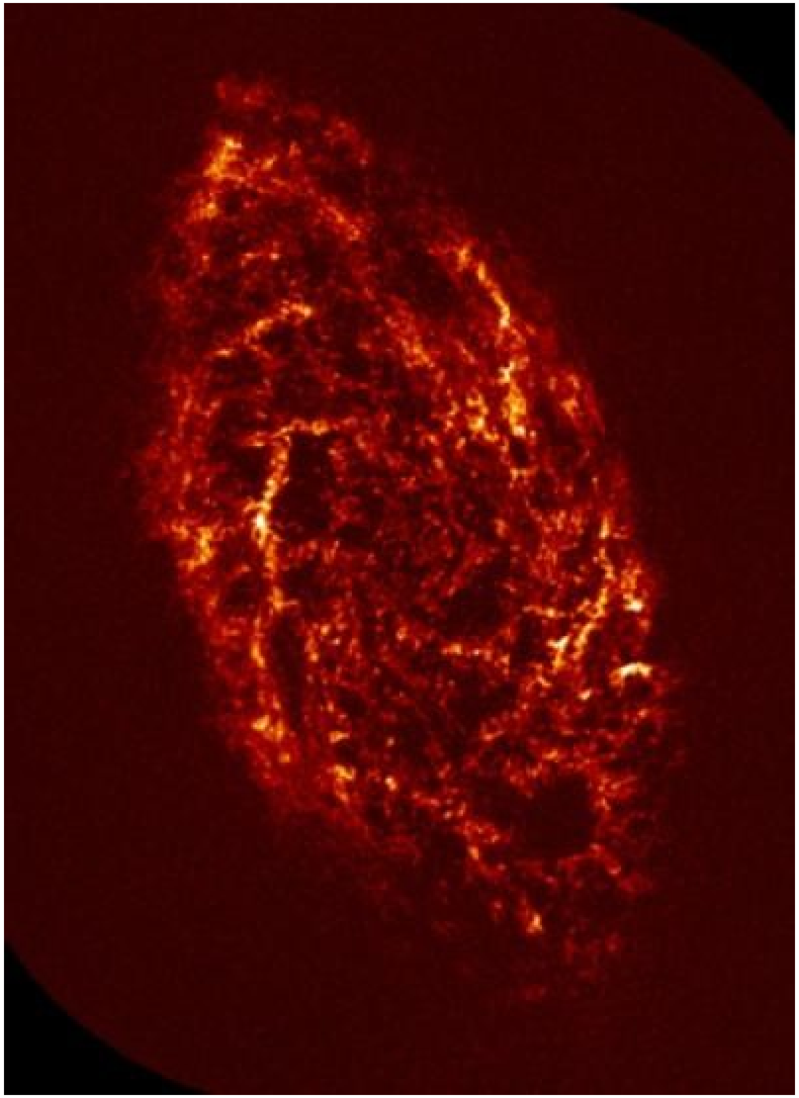


HI in the Milky Way halo (z ~ 2 kpc); field's total M_{HI} ~ 10^6 $M_{\odot}$

Y. Pidopryhora, F. J. Lockman, & J. Shields

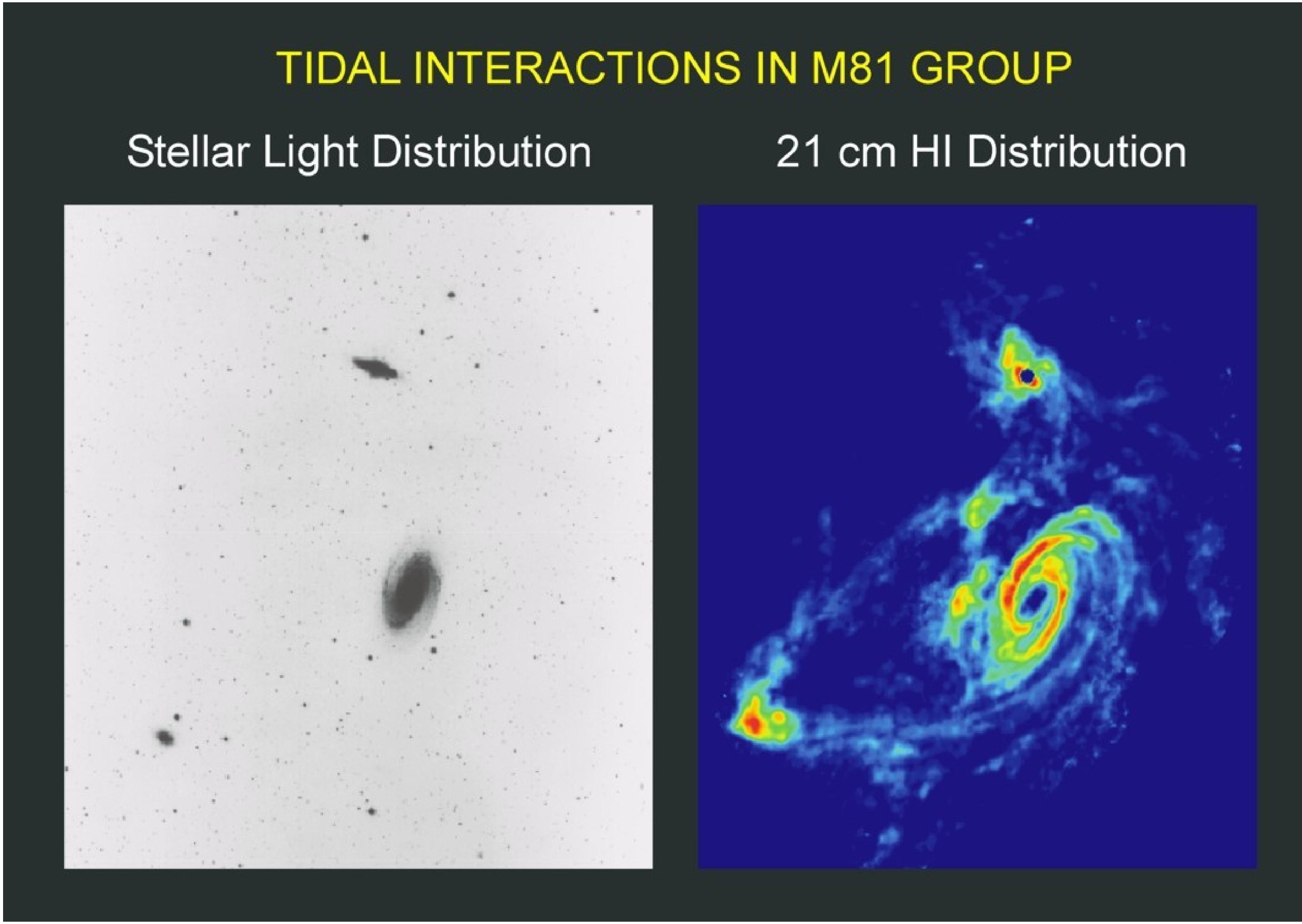


HI in nearby, normal galaxies



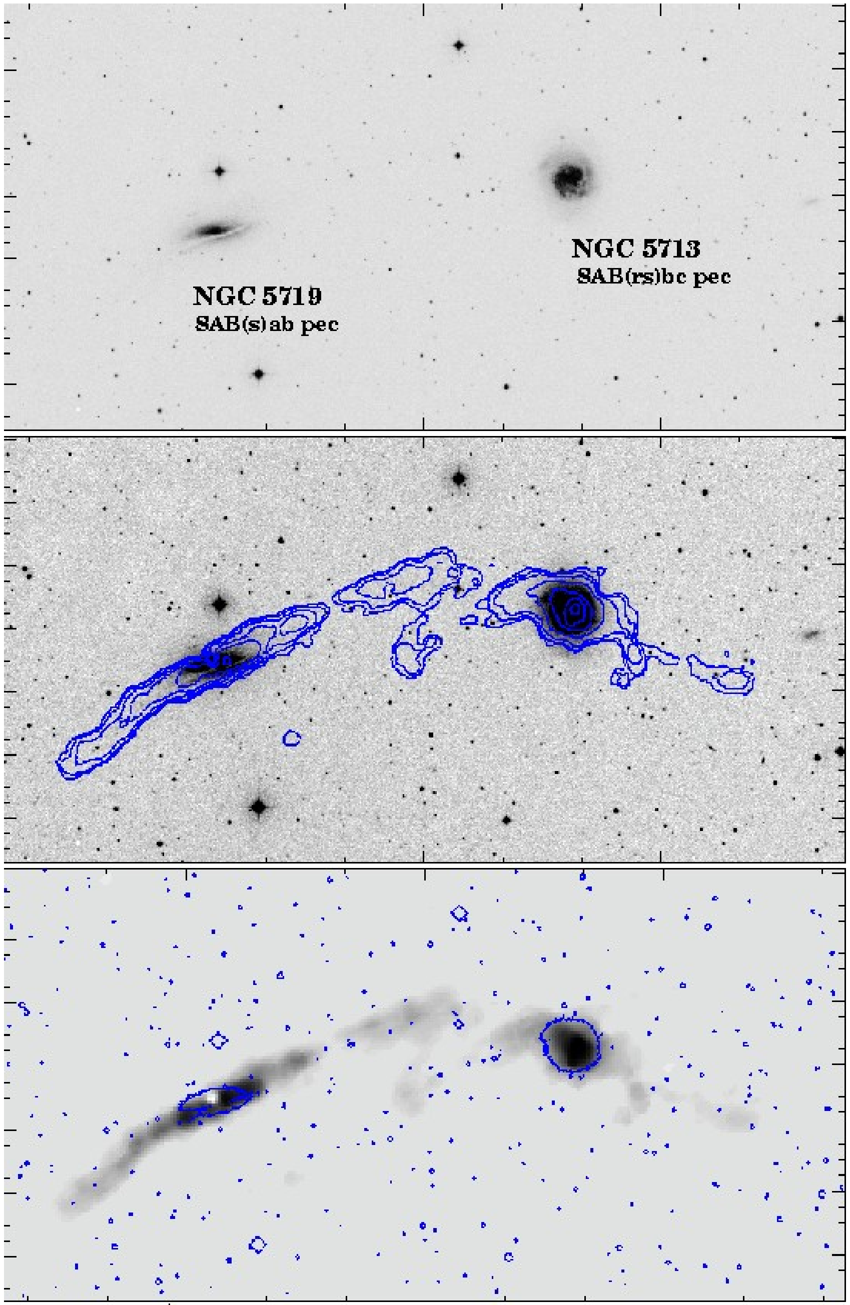
HI in M33 (very nearby spiral)

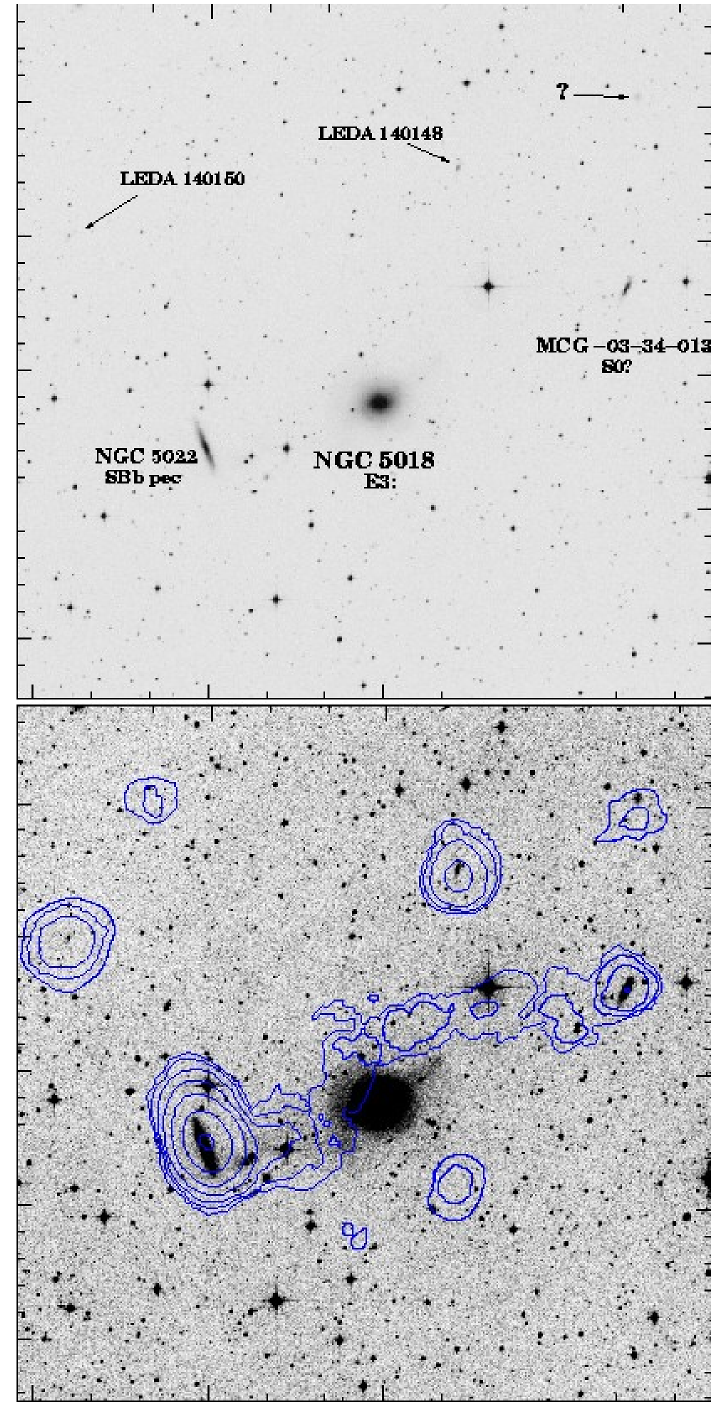
D. Thilker, R. Braun, & R. Walterbos



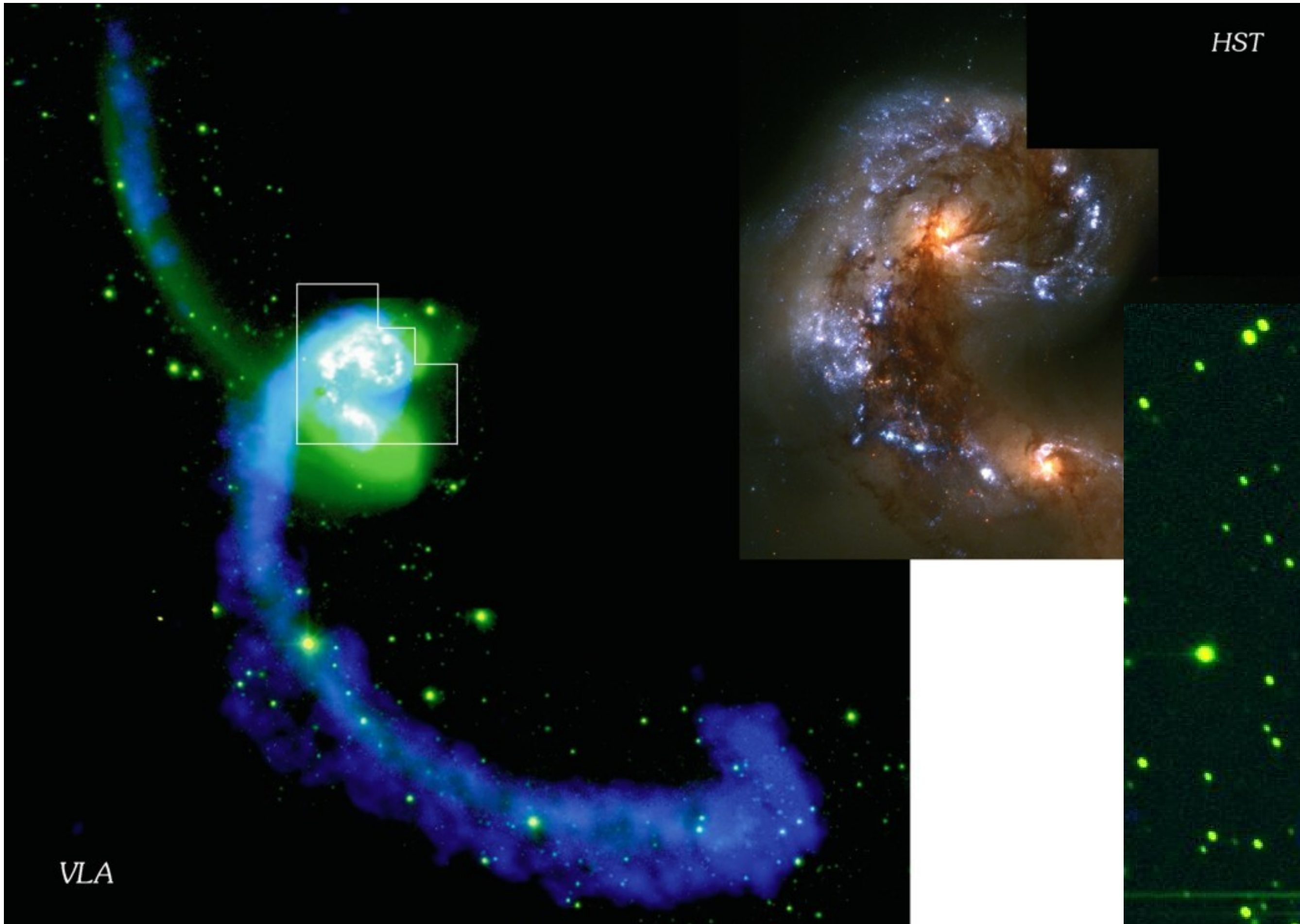
HI in common envelope for the M81 galaxy group

M. S. Yun, P. T. P. Ho, & K. Y. Lo

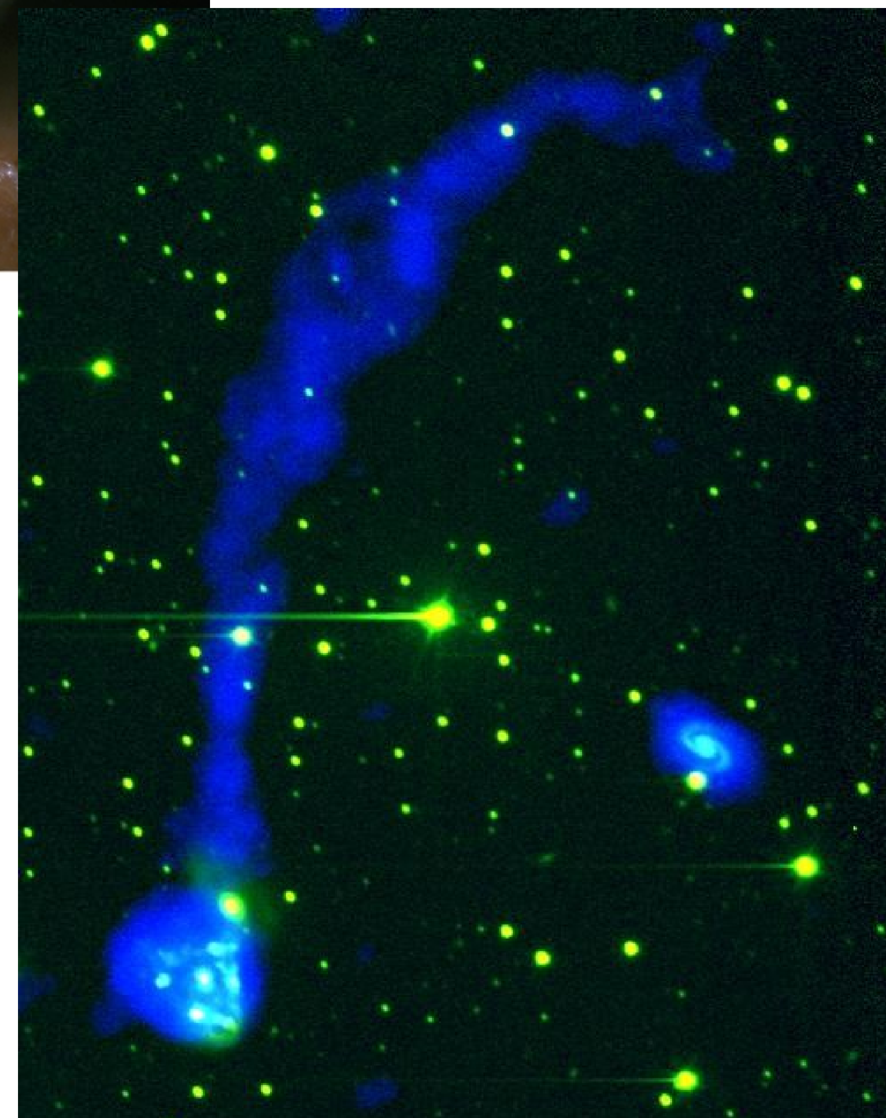




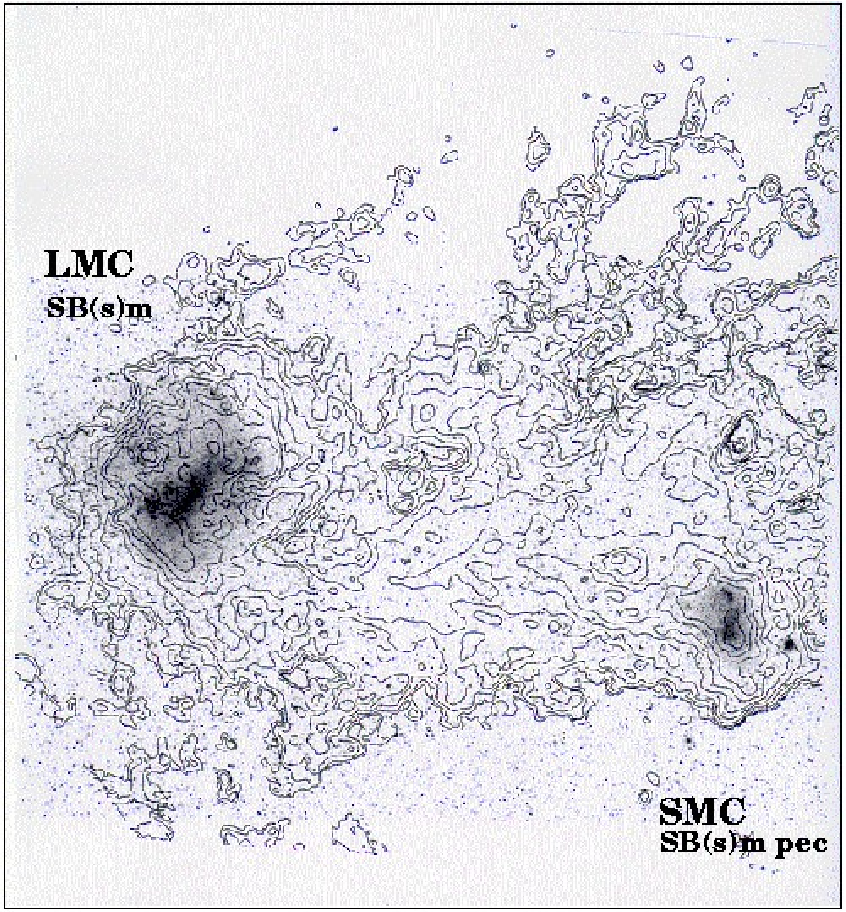
HI in current or past interacting systems

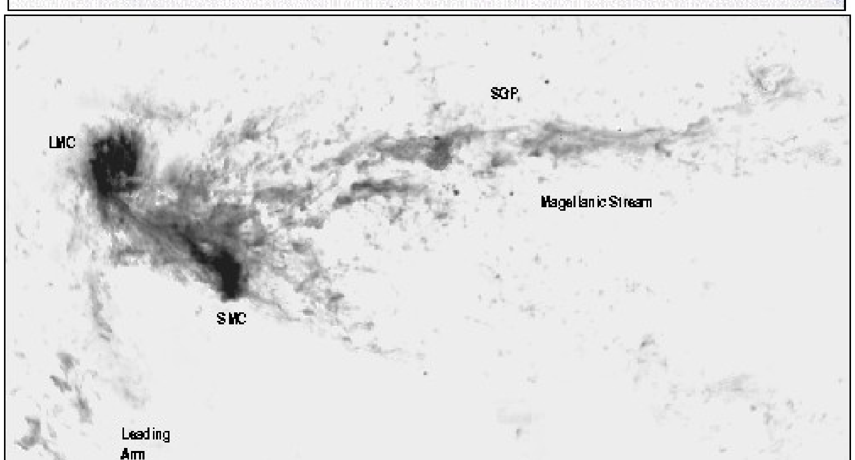


J. E. Hibbard et al.



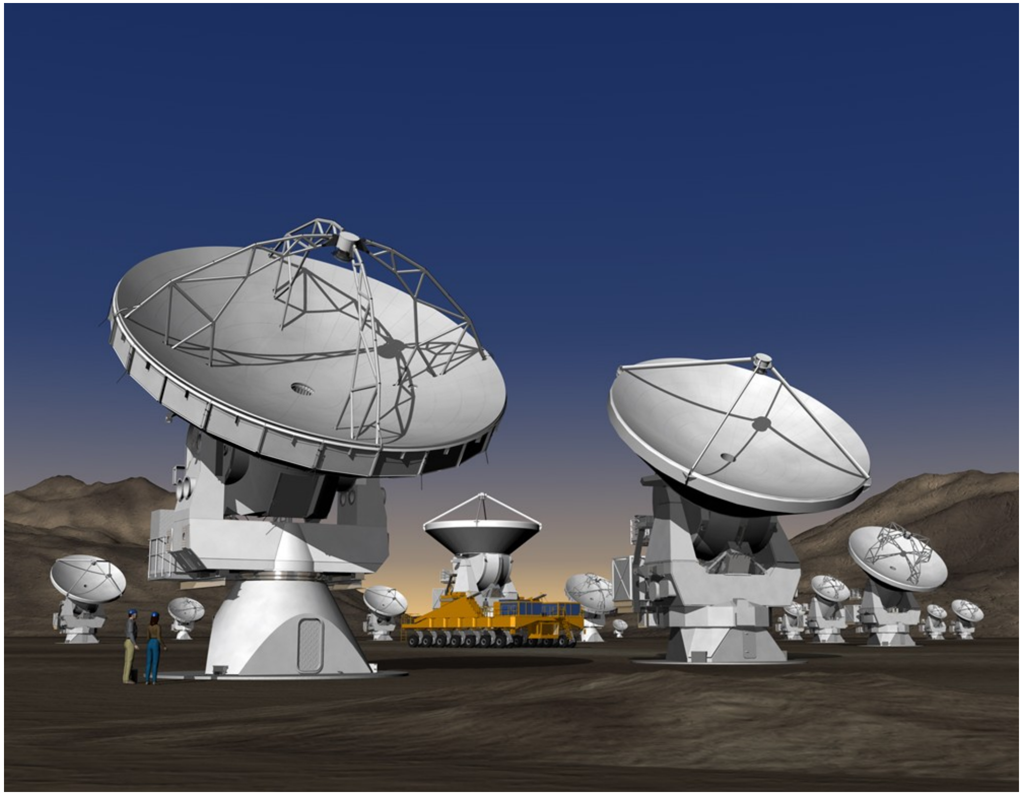
gas+stellar tails imply tidal (gravity)
gas-only tails imply ram-pressure stripping





Magellanic Stream is being ripped out of Large & Small Magellanic Clouds by hot gas in halo of Milky Way.

ALMA: the Atacama Large Millimeter Array



Early science in 2011, full operations in 2013.

Key gains:

- **+ frequency coverage from 100-700 GHz (more lines!)**
- **+ sensitivity to map the Milky Way at $z \sim 3$ in 24 hours**

ALMA: why a science advisory committee?

An international partnership...

32.5% North America (US + Canada + Taiwan)

32.5% Europe

25% East Asia (Japan + Taiwan)

10% Chile

Lots of questions relevant to scientific productivity of ALMA are still under discussion. For example:

- When should people first be allowed to propose for time?

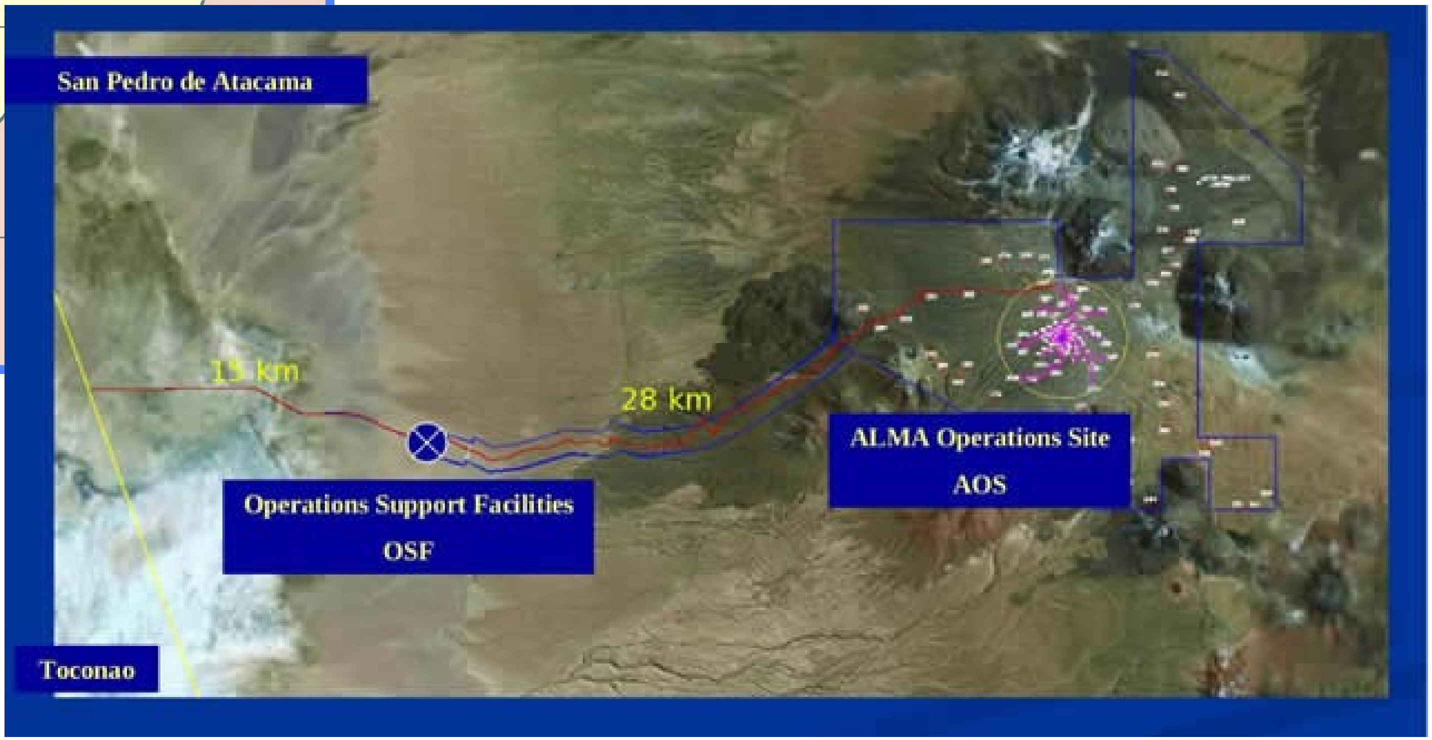
- How will observing time be awarded to proposers?

- Which sort of support will be provided to users?

- Is the data analysis software up to snuff?

Where in Chile?

Northeast corner, close to Bolivian border.



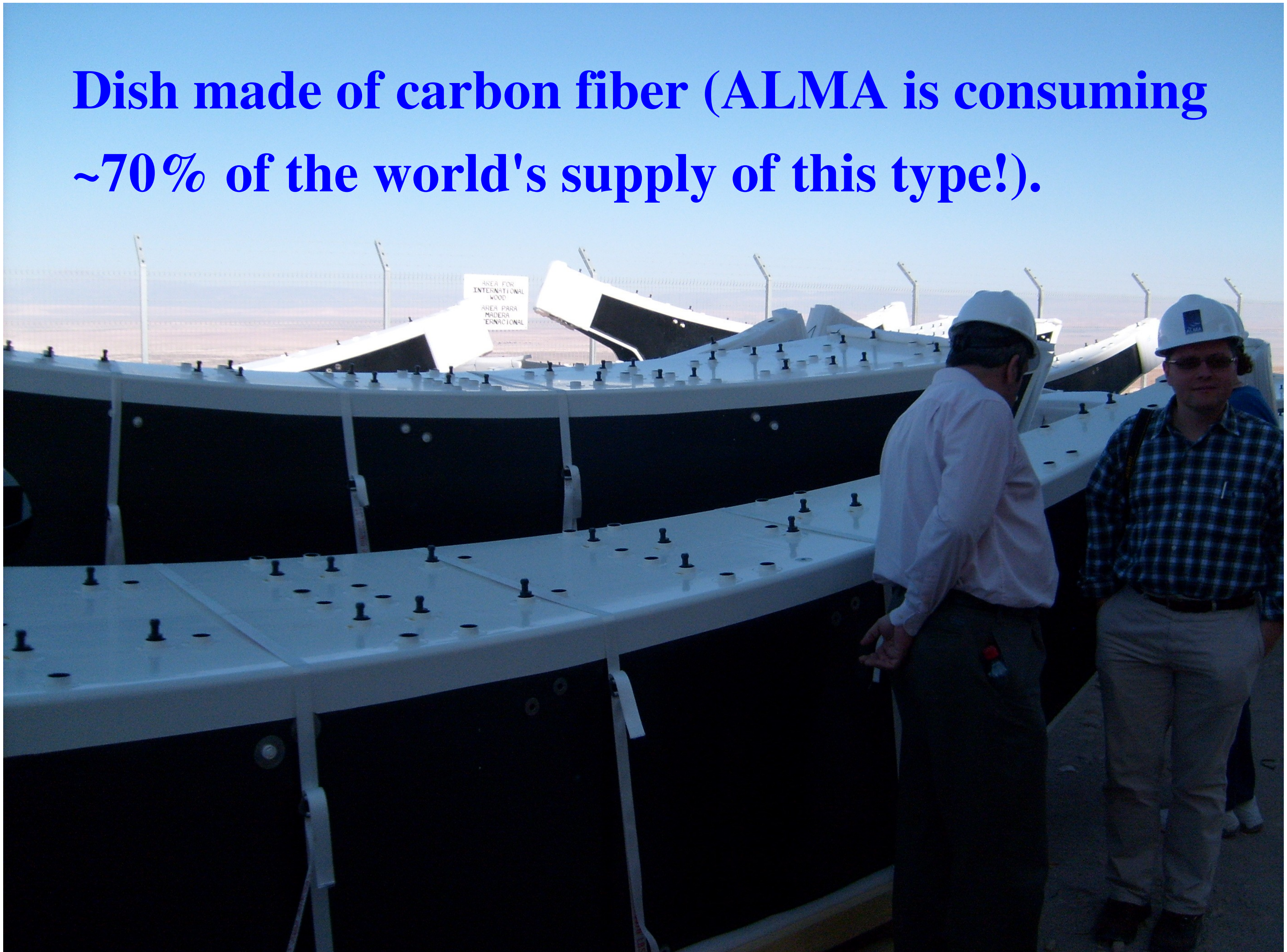
Looking west from the OSF at 9500 feet

Looking north from the OSF

Testing receiver package

Testing North American 12m antennas

Pieces of a North American 12m antenna



First 12m antenna “accepted” in December

Transporter for 12m antennas (one of two)

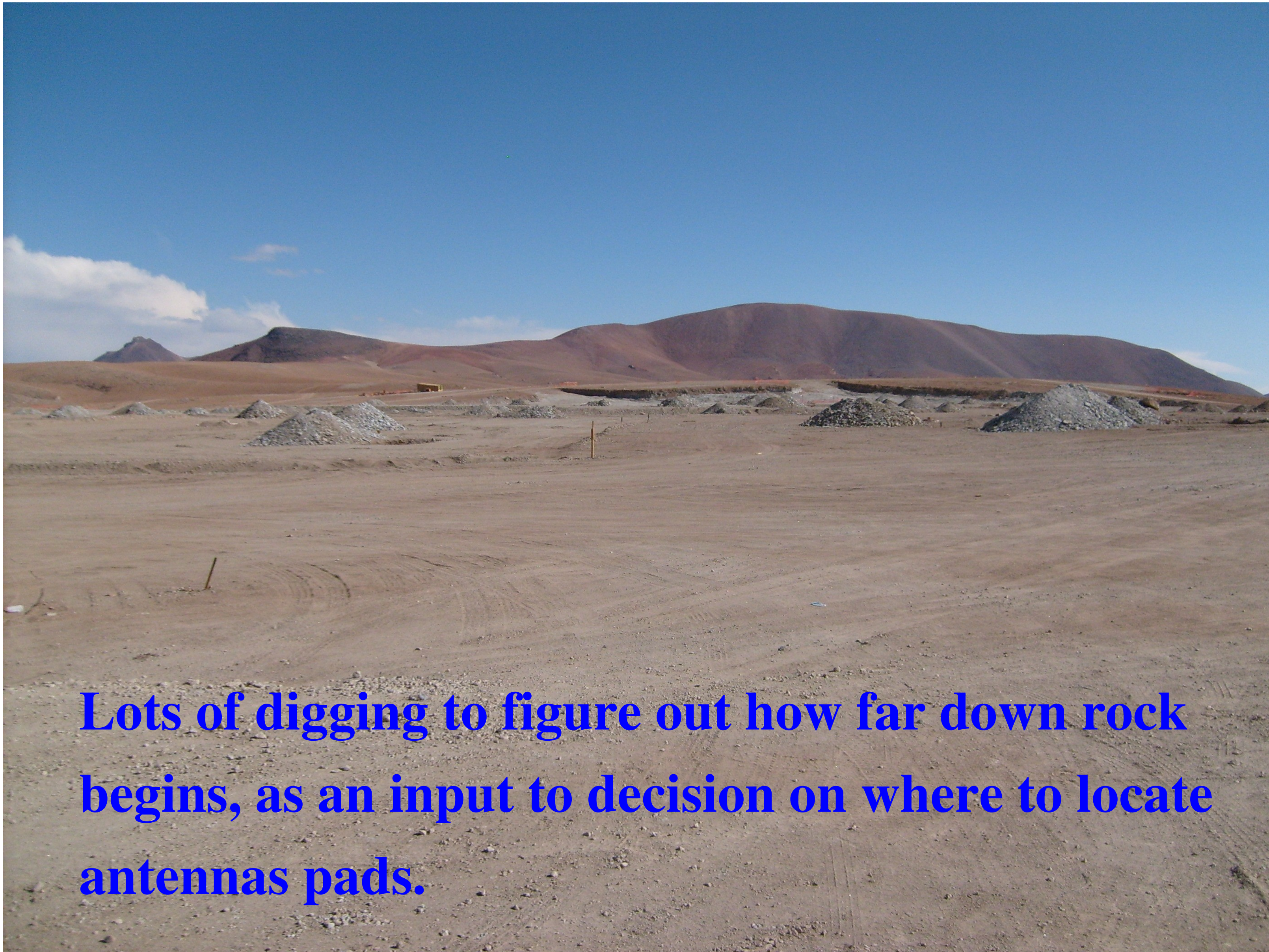
Heading up to the AOS at 16,400 feet

Array Operations Site at 5000m: better for telescopes than for people. Requires a quick medical check and supplies...

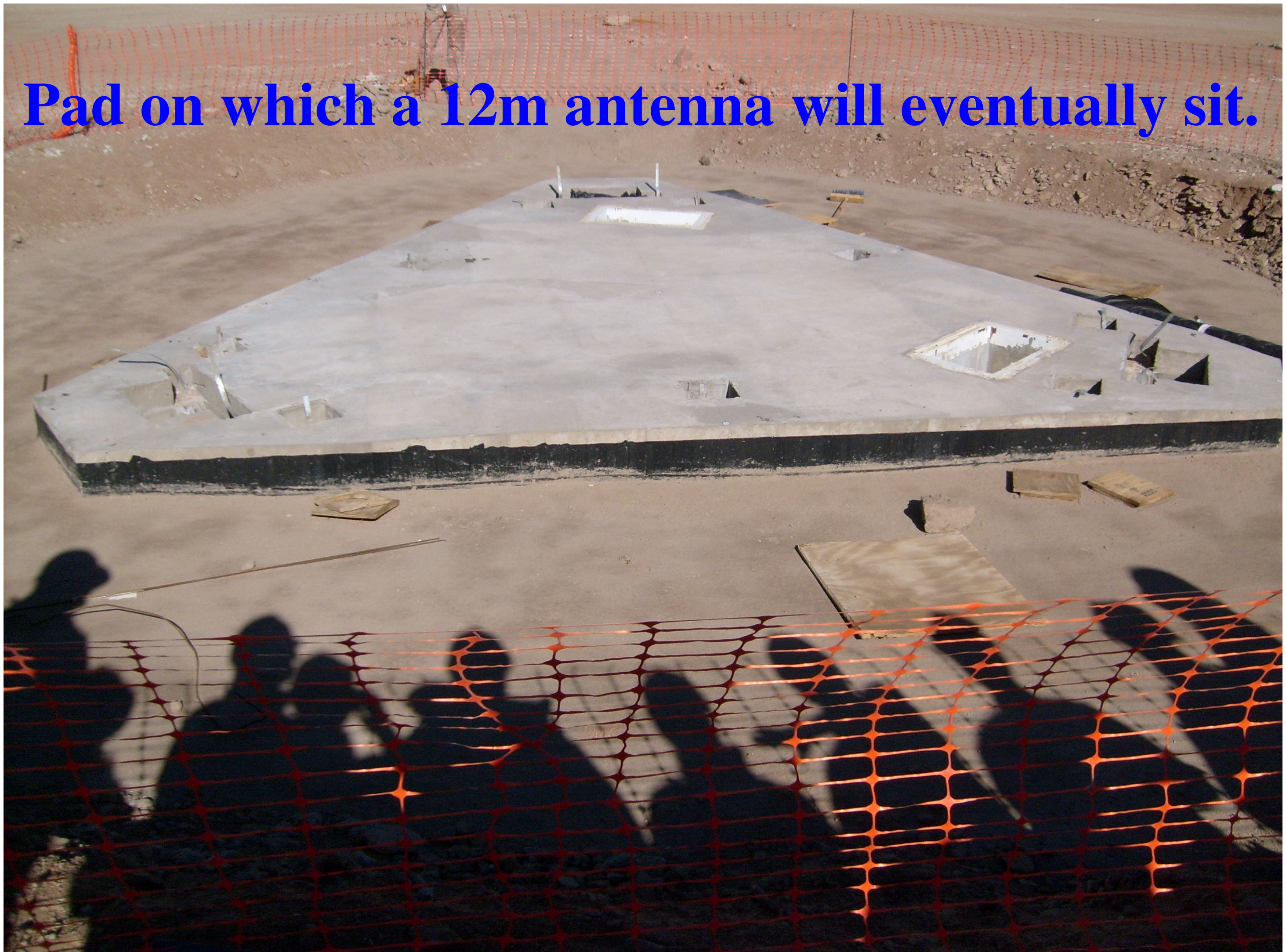
In case of problems: pick up the phone

AOS: high + flat + dry = perfect!

Gopher problems at 5000m?



Astronomers fascinated by concrete



Bad weather from Bolivia

At intermediate elevations: plants!