Physics 343 Lecture # 2:
Lab #1 & Radiative Processes

Any questions from last week?

Scheduling covered on next slide, but any questions about requirements, subject matter, course policies, field trip, etc.?

Lab and office hour schedules

Section	Time	Students
A	Mon 3:20	C. Carroll, C. Sarnicki, J. Xiao
B	Tue 10:20	J. Jedrusiak, M. Mustafa, N. Patel
C	Tue 1:40	N. Herskovitz, T. Holoien, D. Rodriguez, S. Tripathi
D	Tue 3:20	C. Handy, A. Morey, J. Nissenbaum
E	Wed 10:20	C. Apgar, S. Rowe, Z. Rzetelny
F	Wed 1:40	A. Chan, M. Harper, J. Smith
G	Wed 3:20	V. Pandya, G. Pikul, P. Rosenkrantz

Office hours (every week): Thu 5:00–6:20pm (Deshpande) and Fri 10:20–11:40 (Baker; this week Deshpande), or by appointment

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

Computing protocol for labs

There will be a single class account on the PC that controls the telescope (user =   ). The directory in which the telescope control software is installed is c:\SRTvsrt . Please do not modify the srt.cat reference file, which includes important calibration information!

Your should use c:\SRTvsrt to store command files and output data files during your lab session, but to avoid swamping that directory, make sure to copy them to a subdirectory for your lab section (c:\SRTvsrt\SectionA etc.), identifying files with your name or initials), when you are done for the day. Your analysis can be done on your own computer at home.

Simulation mode

We're still in the process of recovering from water damage, so for the first lab you will need to operate the telescope in **simulation mode** and analyze archival data I send you.

To get going in simulation mode:

+ open a command terminal

+ in that terminal window, type **cd c:\SRTvsrt**

+ then type **setup.bat**

+ then type **java srt 1 –24** (to simulate observations
   24 hours in the future, or however many hours
   are appropriate for observations of the Sun)

Lessons from previous classes

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:

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

(Note that R.A. 23:59:59 corresponds to 359.995833°.)
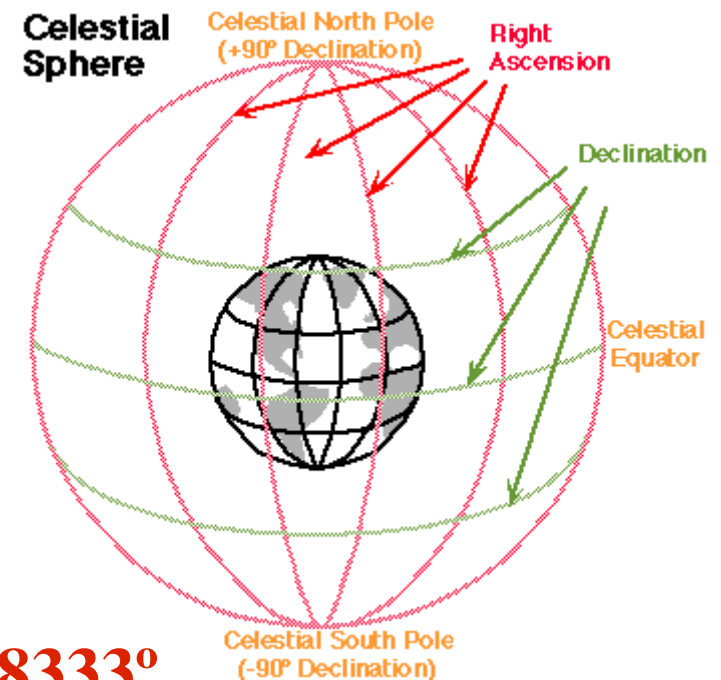
Celestial coordinates: source separations

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: $15 \times (32.9 - 24.5) \times \cos(15.4715) = 121'' = 2.024'$**

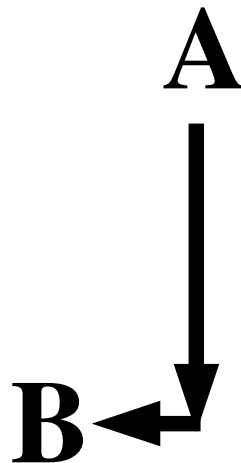**For small angles, separation $\simeq [(\Delta\delta)^2 + (\Delta\alpha)^2]^{1/2} = 8.6'$**
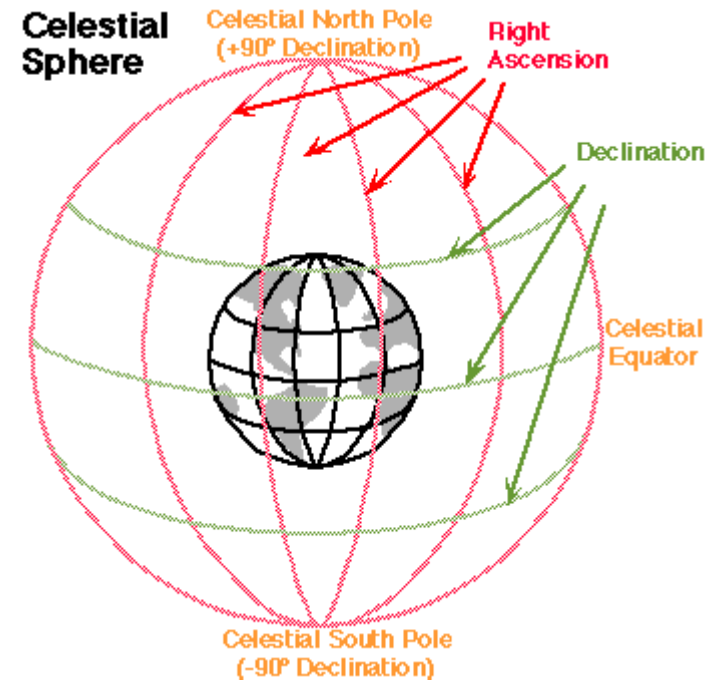
Celestial coordinates: directions

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?

$\Delta\delta = -8.383'$

$\Delta\alpha = 2.024'$

north

east ⟵ west

south

A

B
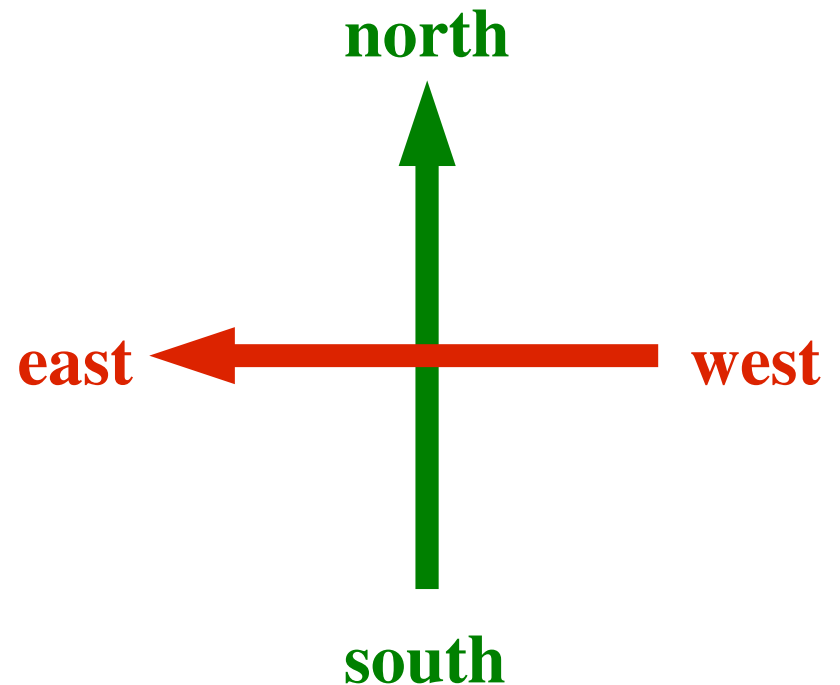
Celestial coordinates: precession

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).

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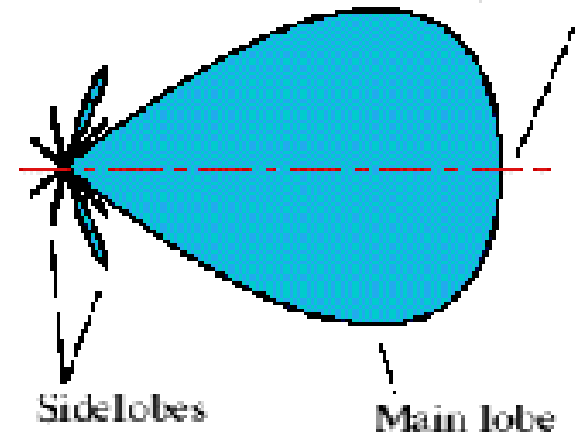
The **main lobe** has a width proportional to λ/D for λ the wavelength and D the diameter of the telescope. We will measure the width of the main lobe for the SRT by scanning across the sun.

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:
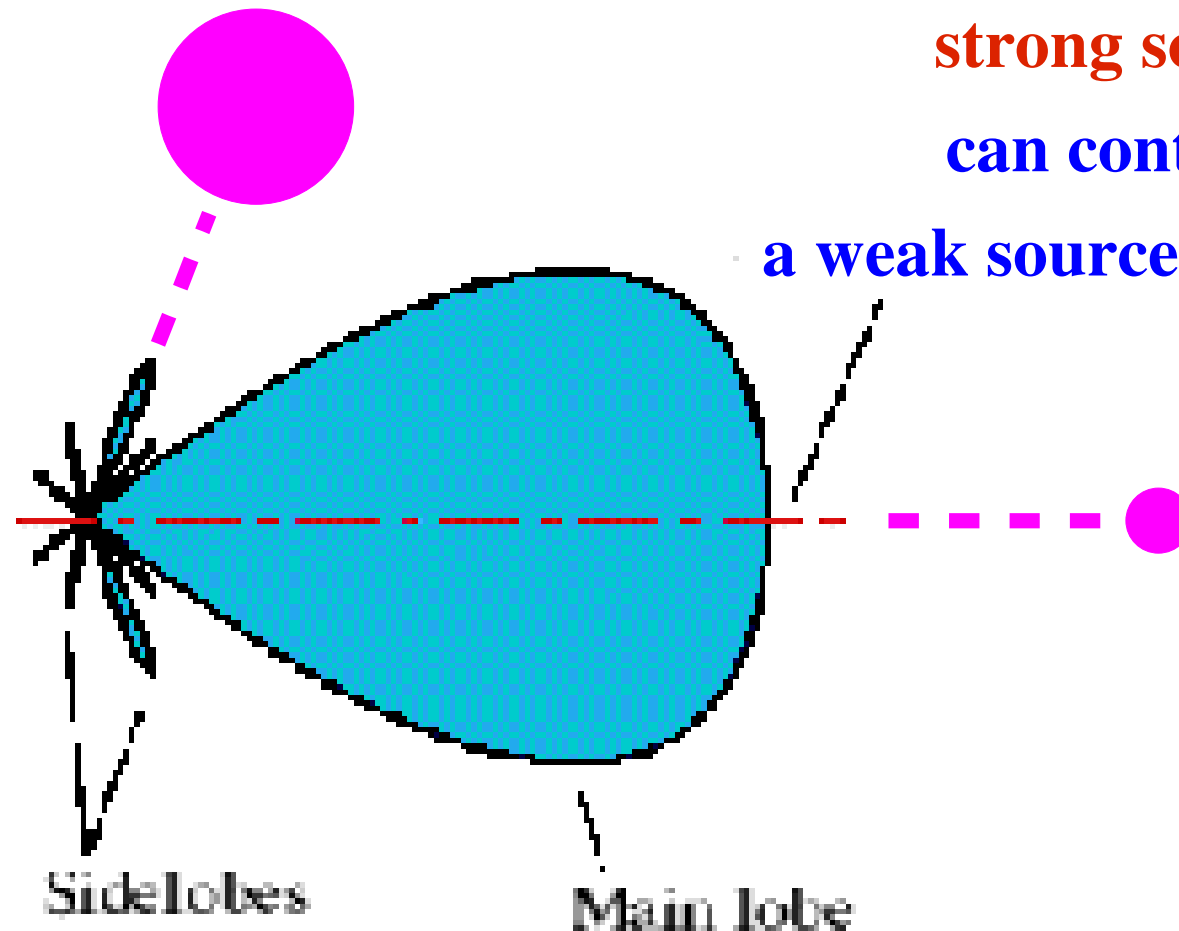
strong source in a sidelobe

can contribute as much as

a weak source in the main beam!

Sidelobes

Main lobe

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 the control computer, 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 ': '!

Many email programs dislike attachments with names ending in *.cmd, so you may need to rename files before sending them to yourself.

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
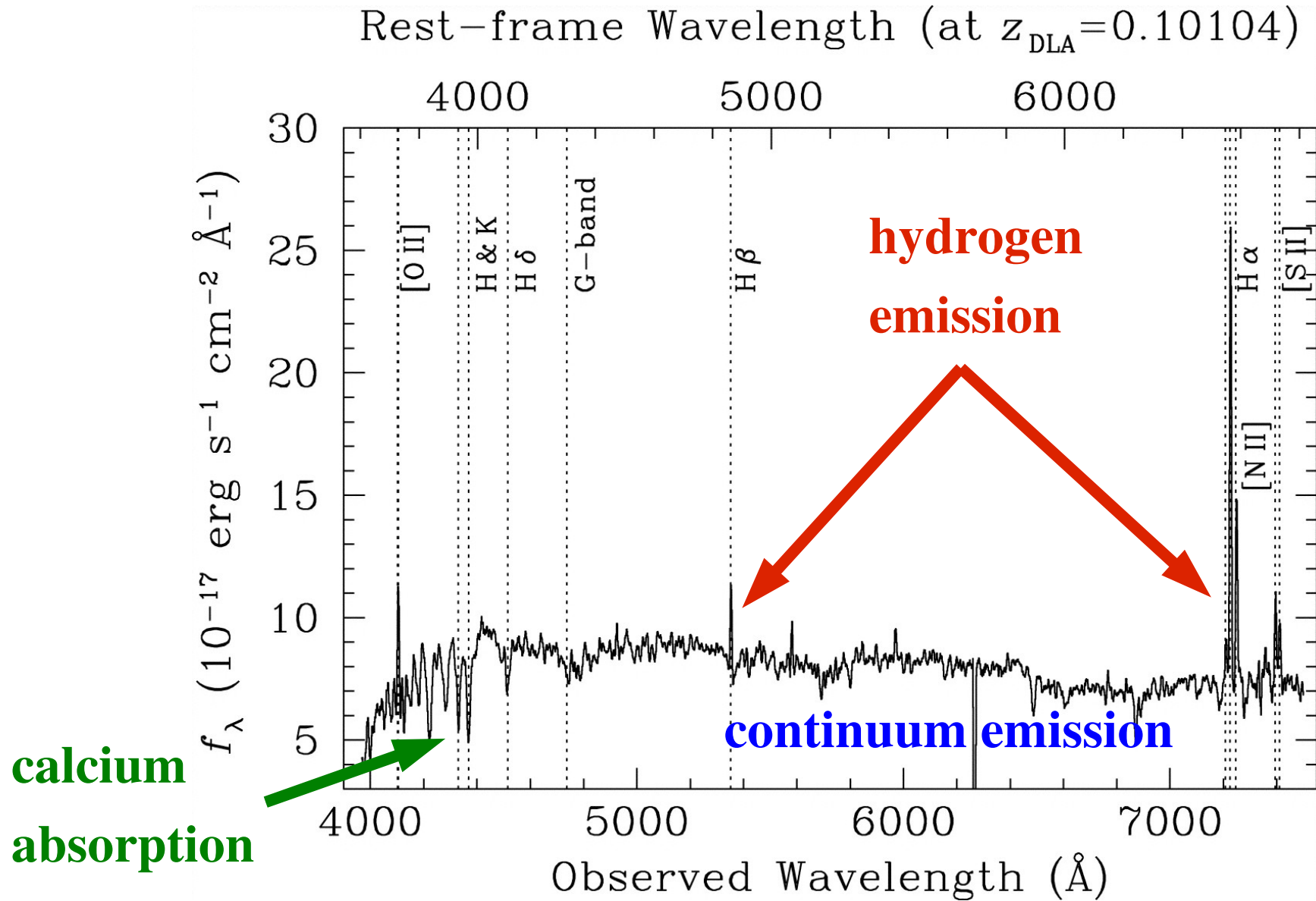
Radio continuum emission

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).

free-free from Hα template
log T_ant (mK)

−4.3 ▬▬▬ 0.59

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).
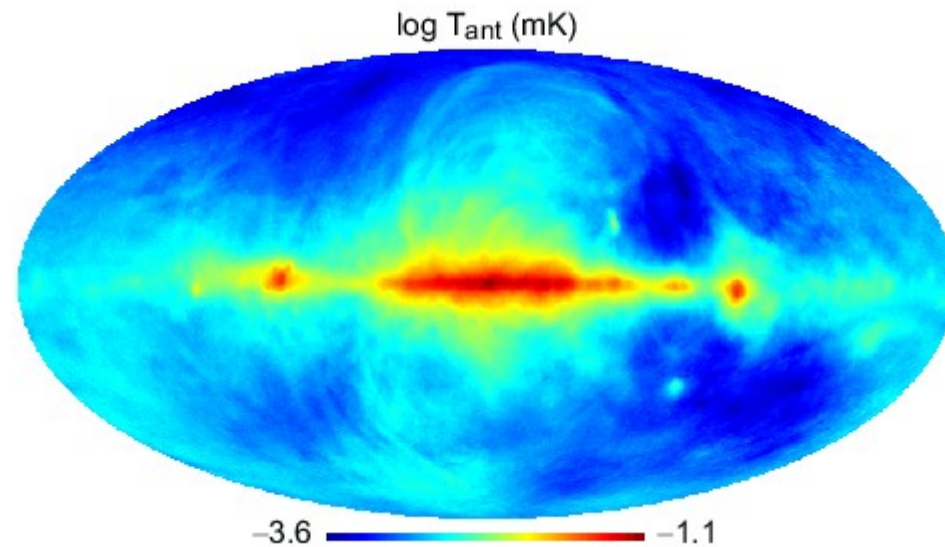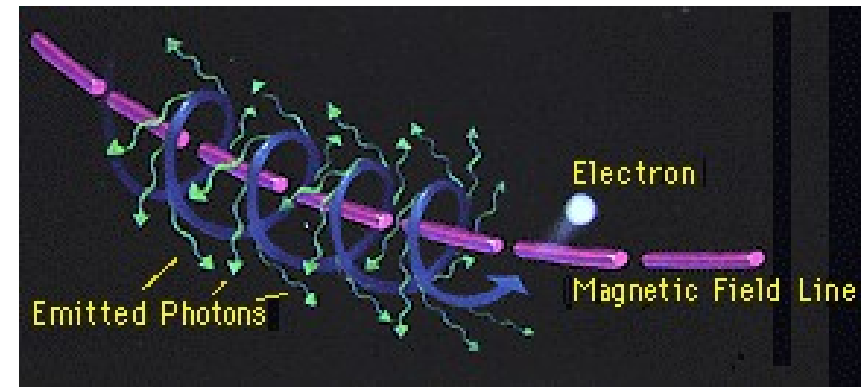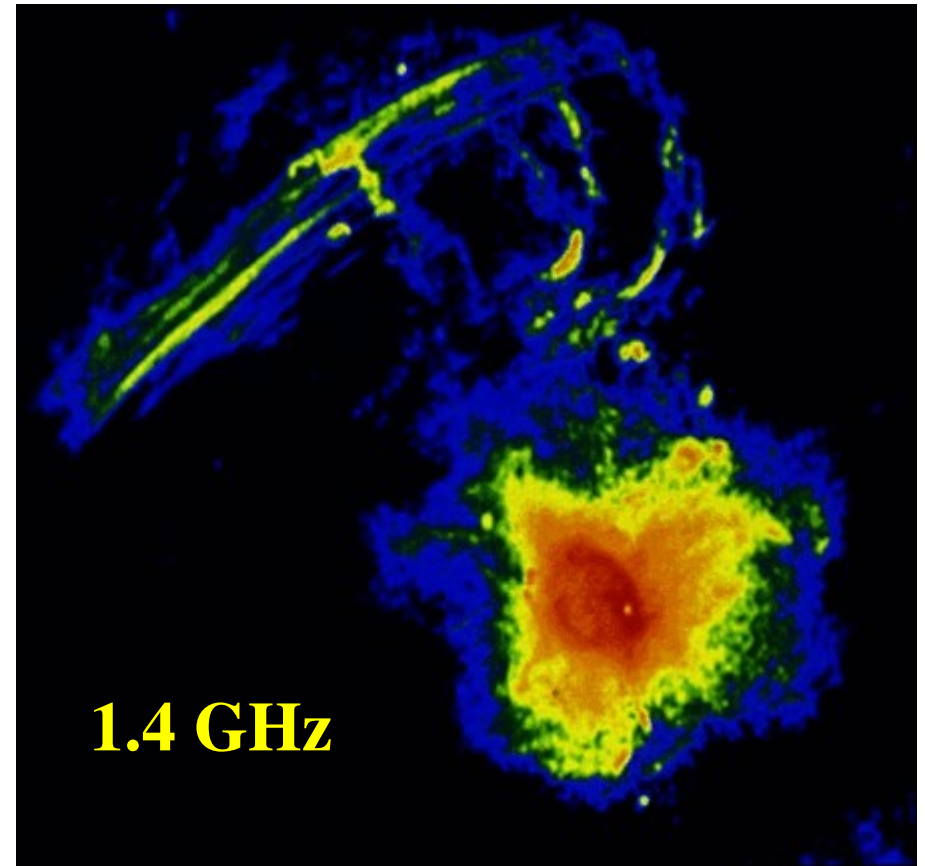

Burigana et al. (2004):
synchrotron emission from Milky Way at 100 GHz

Free-free vs. synchrotron emission

diffuse synchrotron
log T$_{ant}$ (mK)

−3.6 −1.1

free-free from H$_\alpha$ template
log T$_{ant}$ (mK)

−4.3 0.59

Why do these look different?

Galactic Center filaments:

which mechanism is responsible?

1.4 GHz

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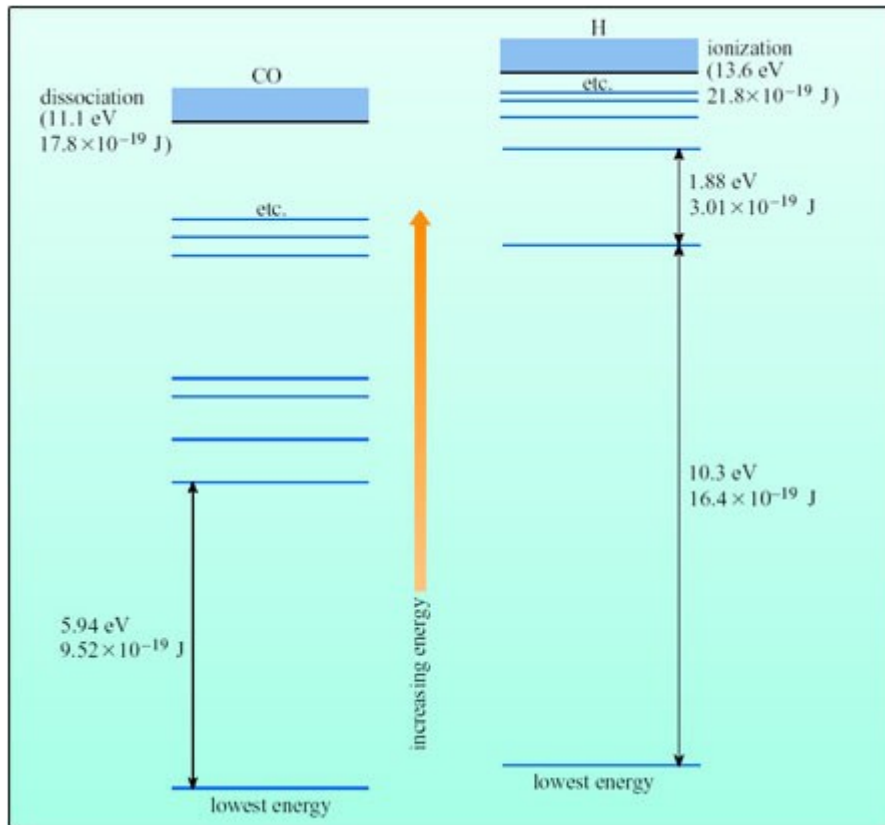
When an electron in an atom or molecule drops from a higher energy level to a lower energy level, a photon is **emitted**.

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

Courtesy of Open University.

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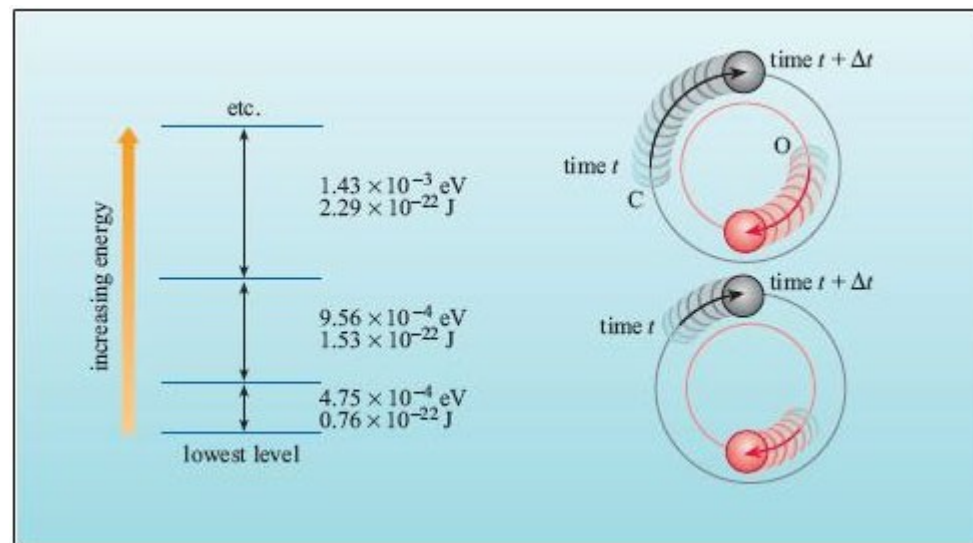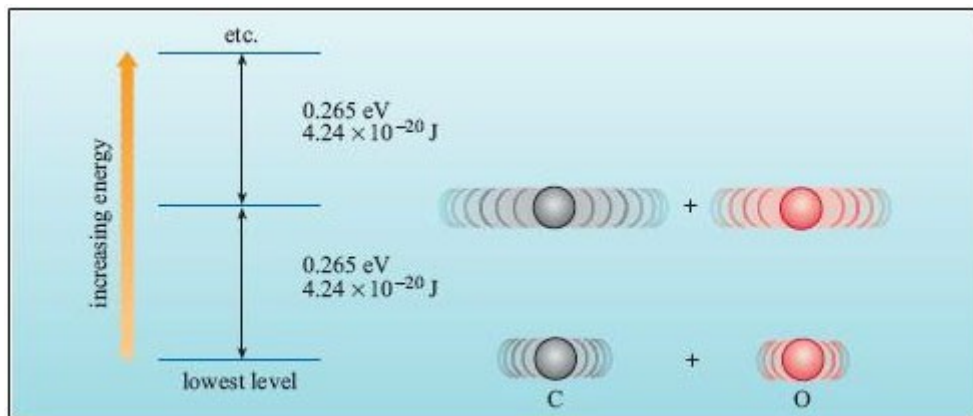
Molecules also have quantized levels of vibrational and rotational energy (spacings are higher for the former).

Transitions are associated with absorption/emission of photons.
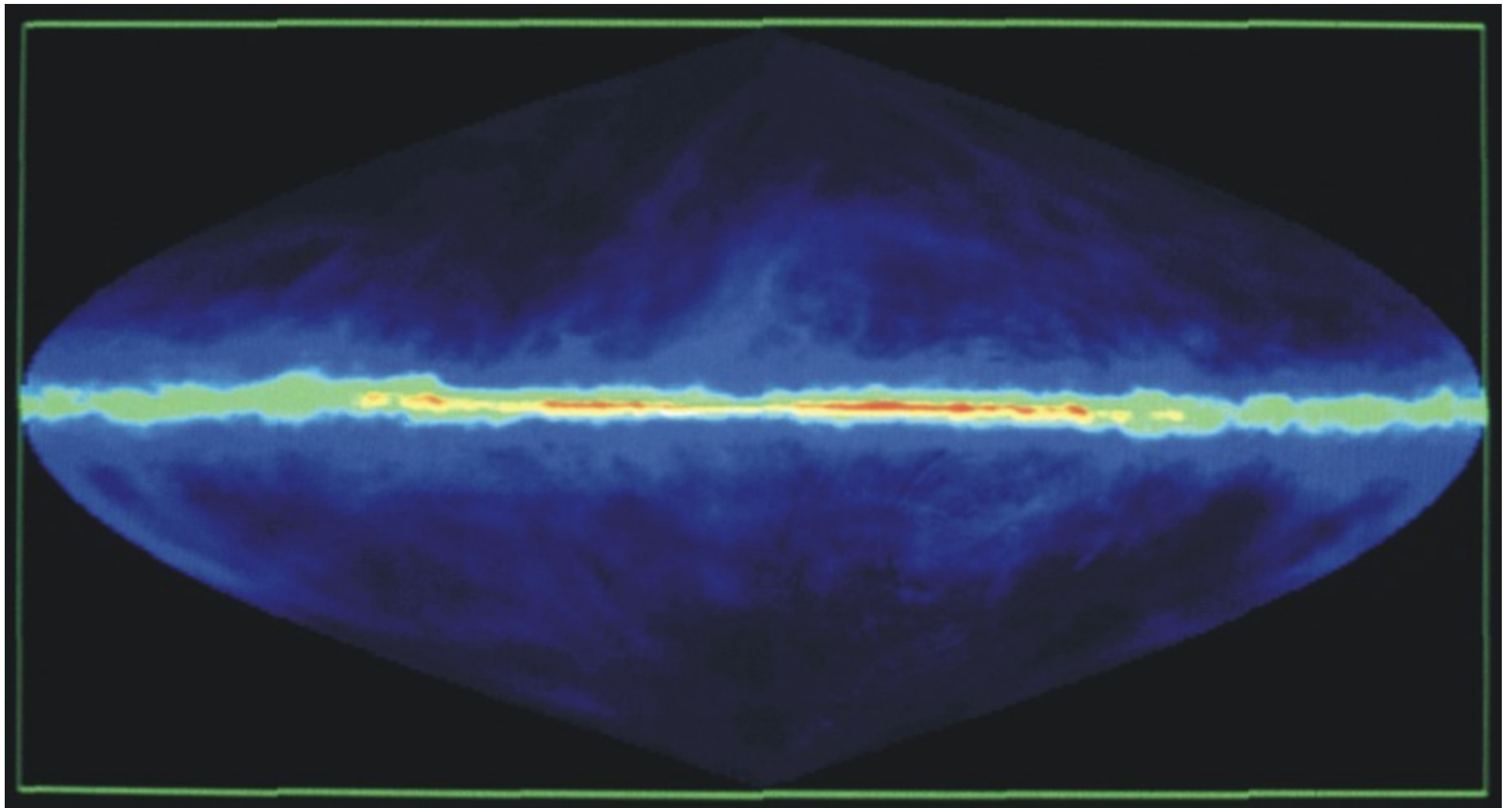
Courtesy of Open University.

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.
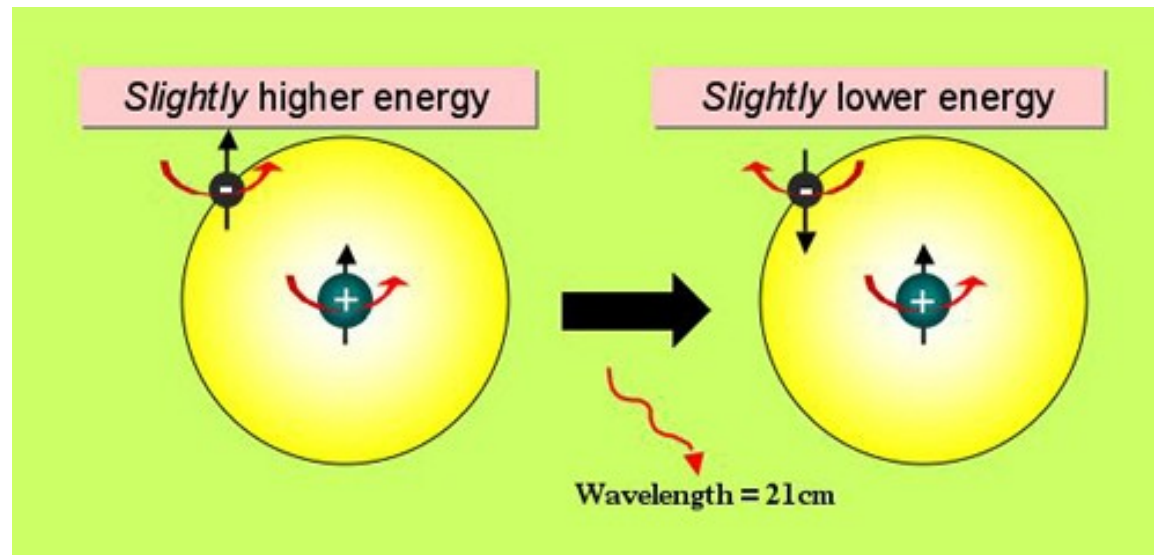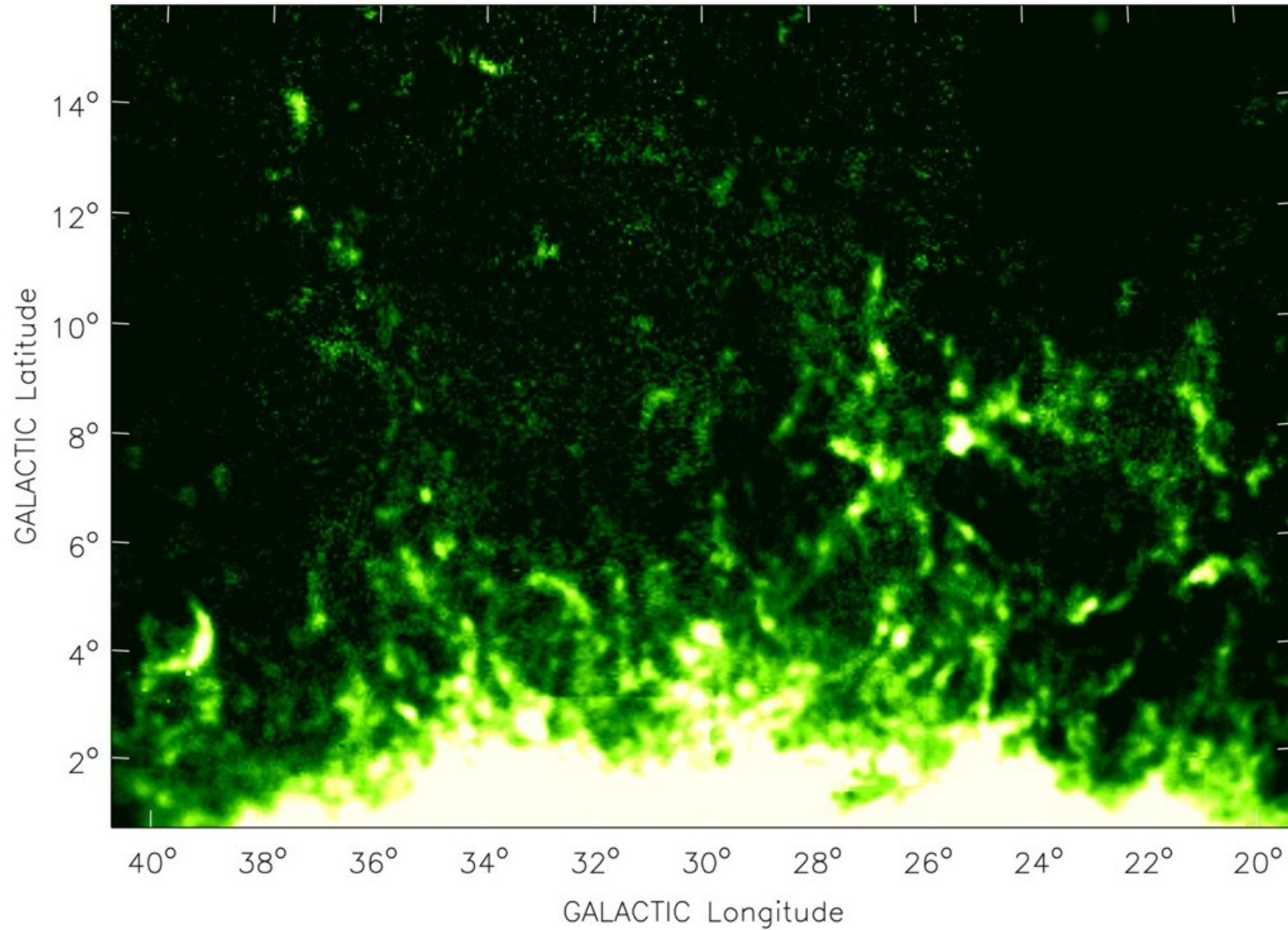

Doesn't trace ionized or molecular gas – just neutral atomic gas!
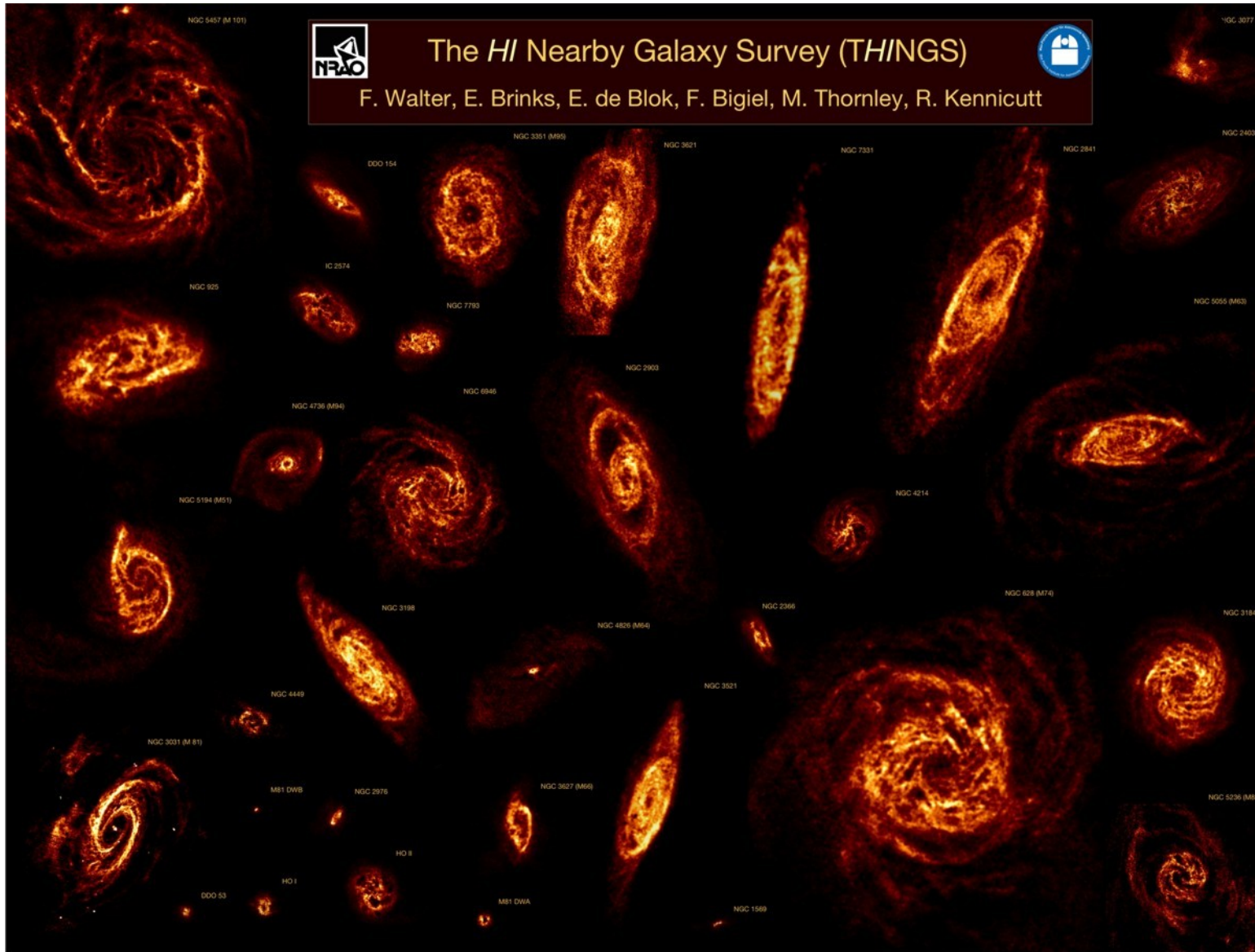
Courtesy of Swinburne University.

HI in the Milky Way, plotted in (*l,b*) coordinates
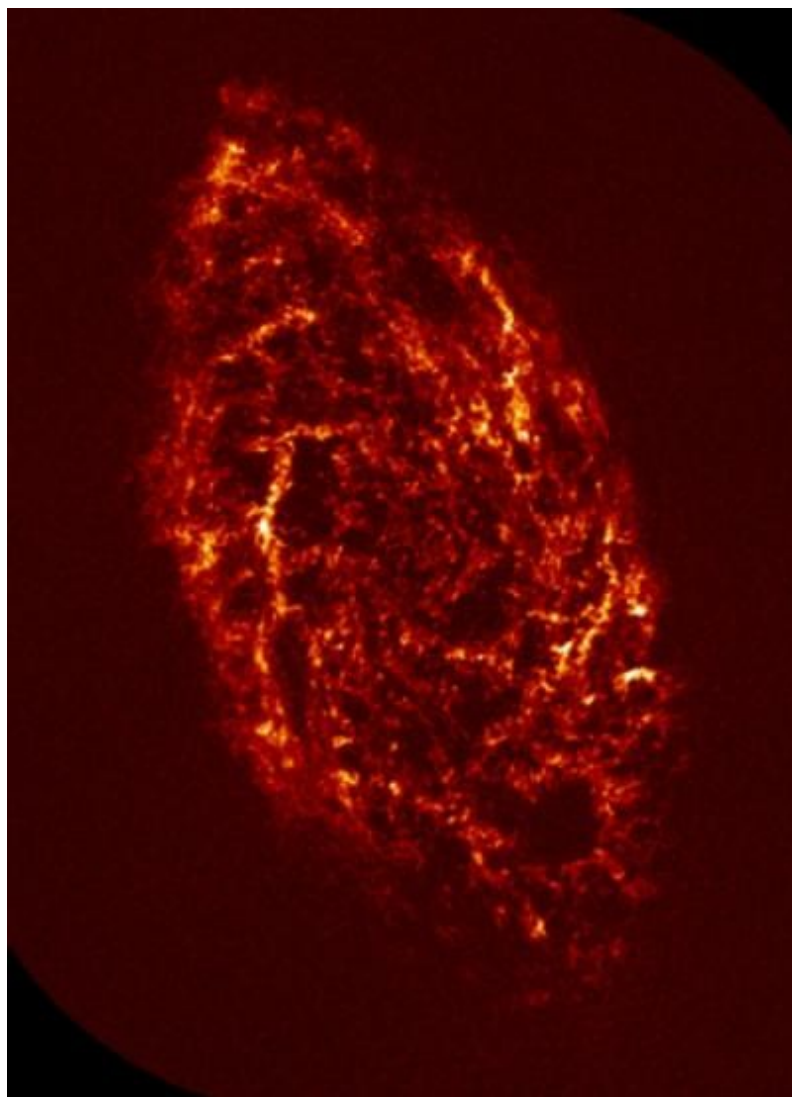
J. M. Dickey & F. J. Lockman

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

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

HI in nearby, normal galaxies
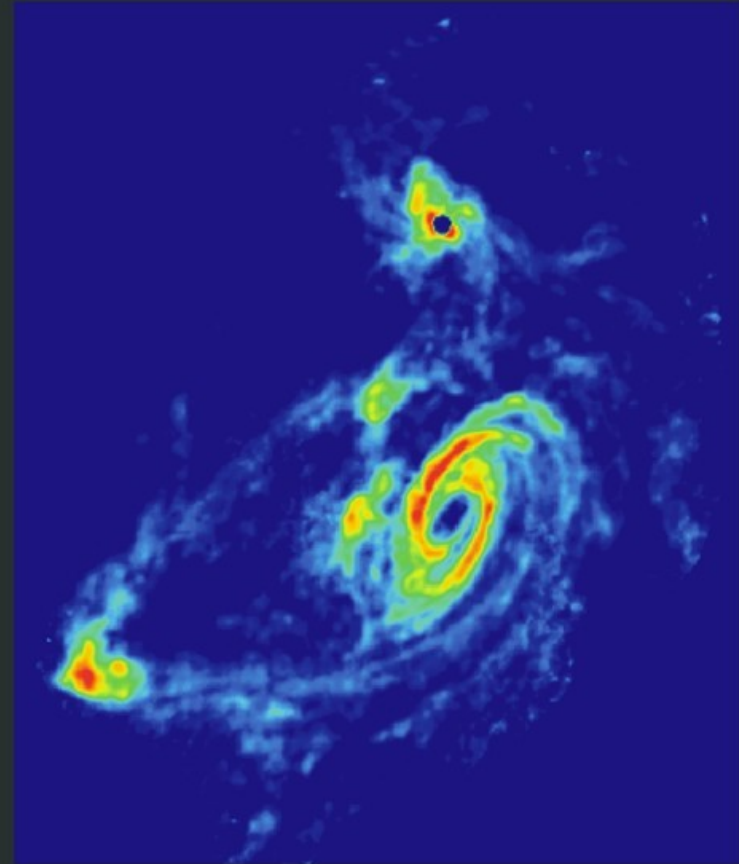
HI in M33 (very nearby spiral)

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

HI in common envelope for the M81 galaxy group
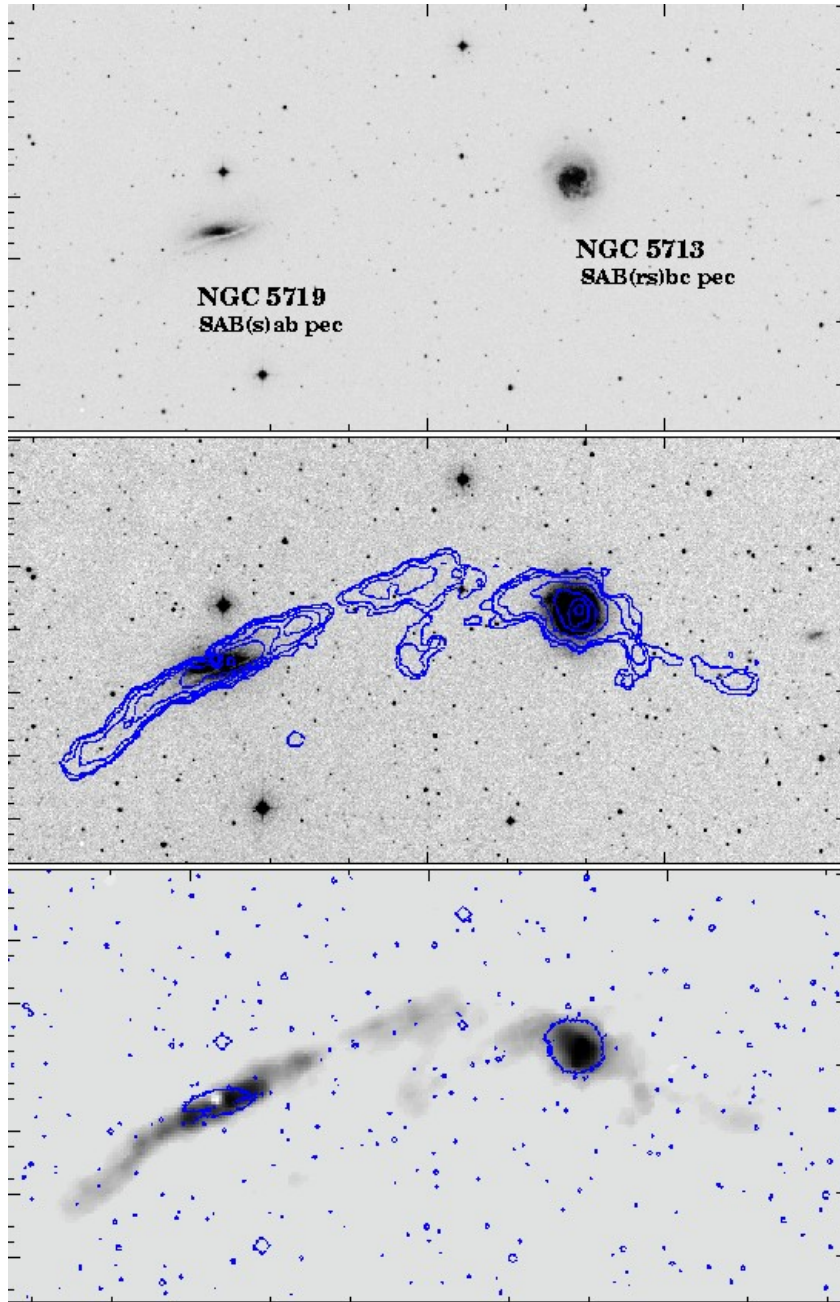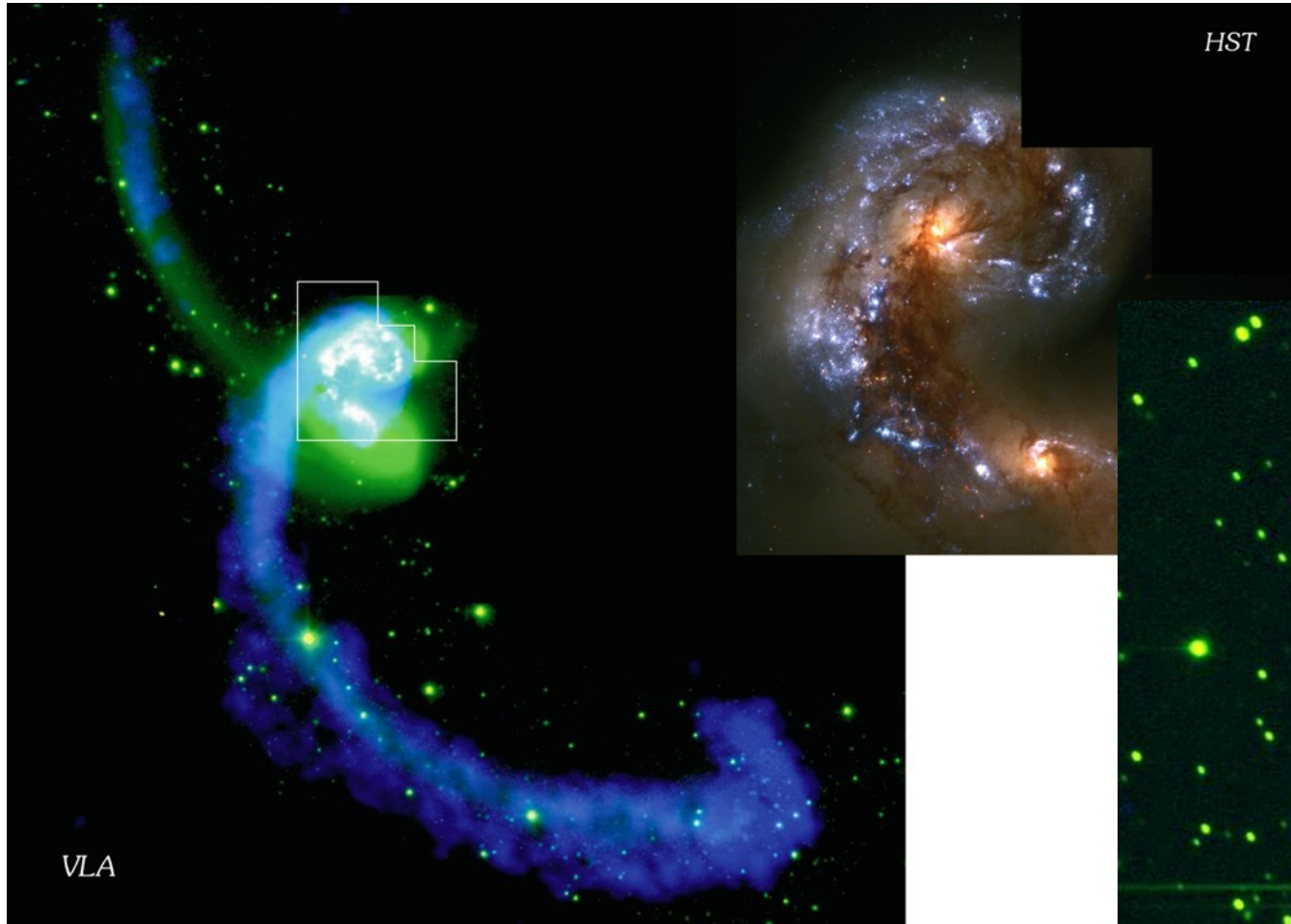
M. S. Yun, P. T. P. Ho, & K. Y. Lo

NGC 5713
SAB(rs)bc pec

NGC 5719
SAB(s)ab pec

LEDA 140150

LEDA 140148

?

MCG −03−34−013
S0?

NGC 5022
SBb pec

NGC 5018
E3:
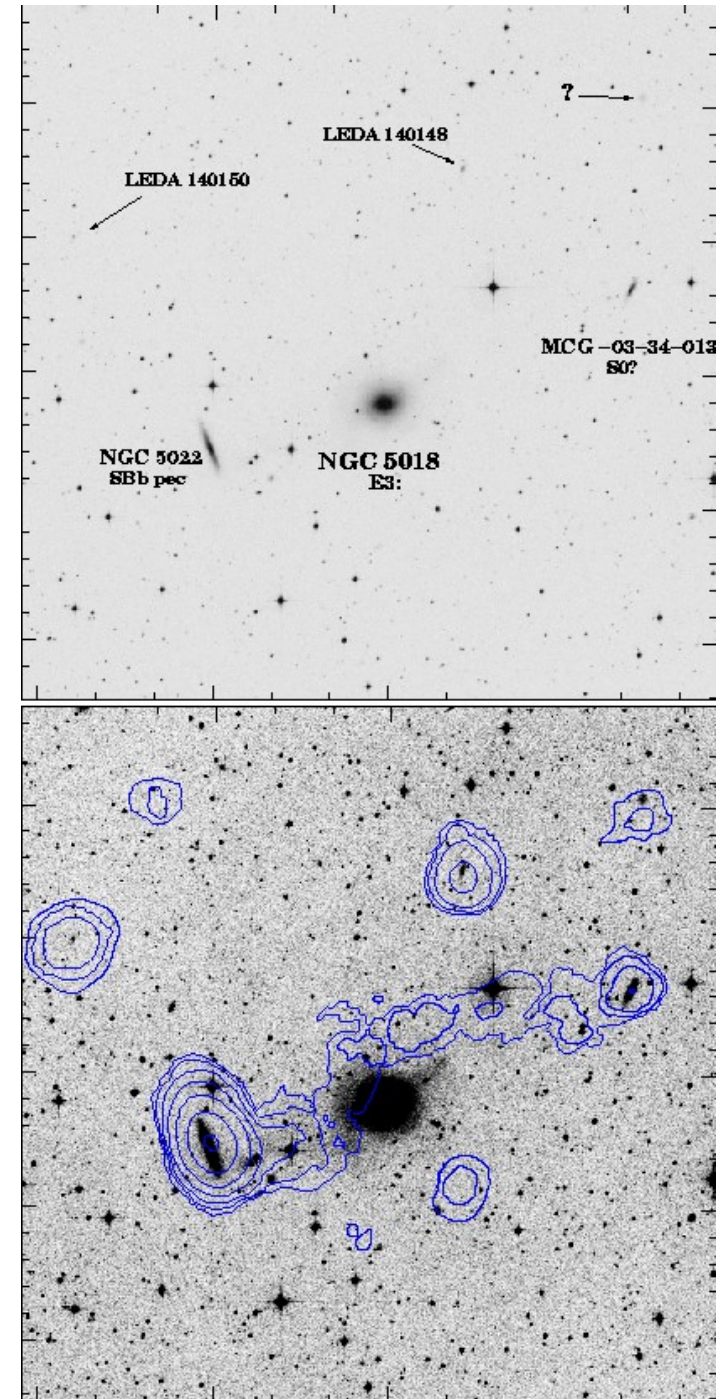
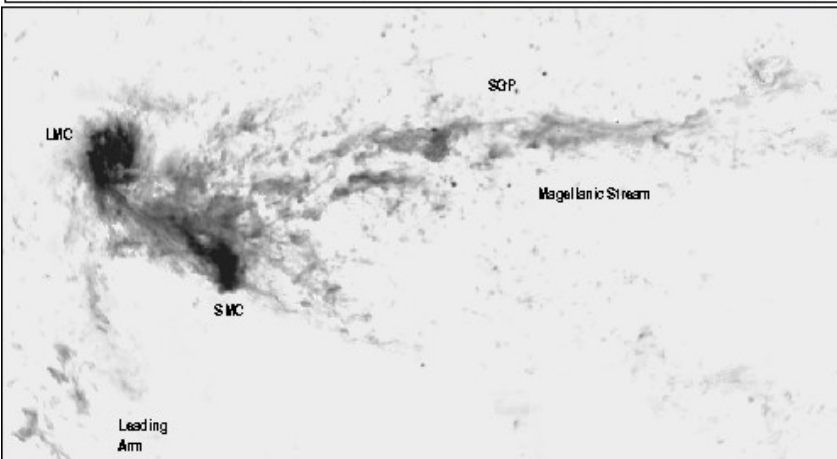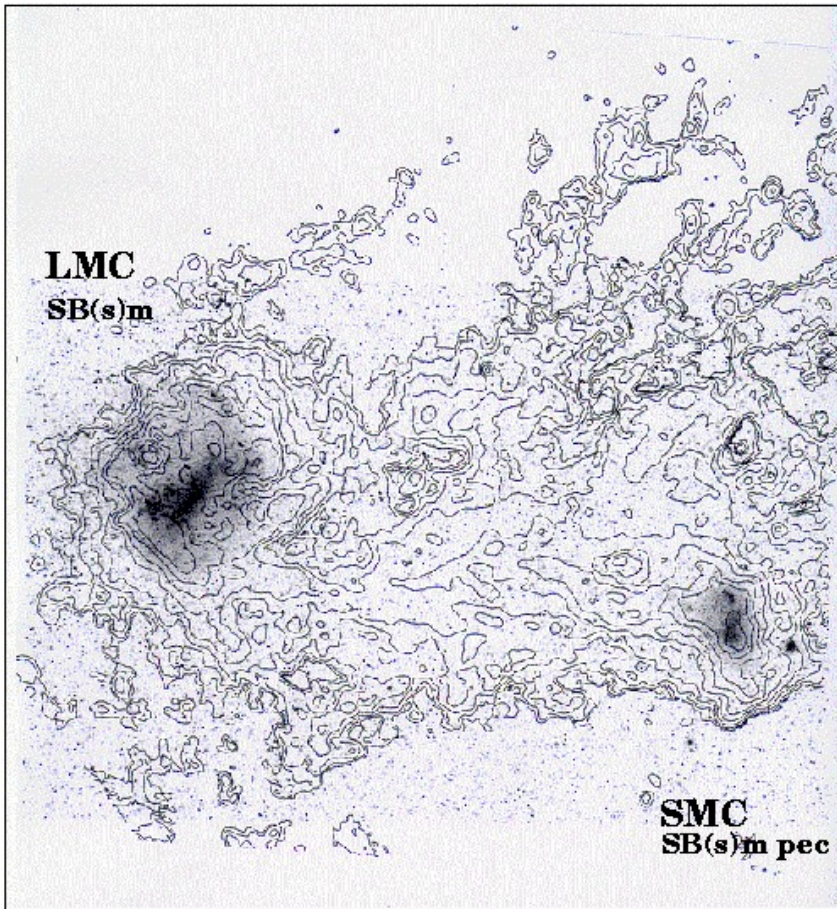**HI in current or past interacting systems**

HST

VLA

J. E. Hibbard et al.
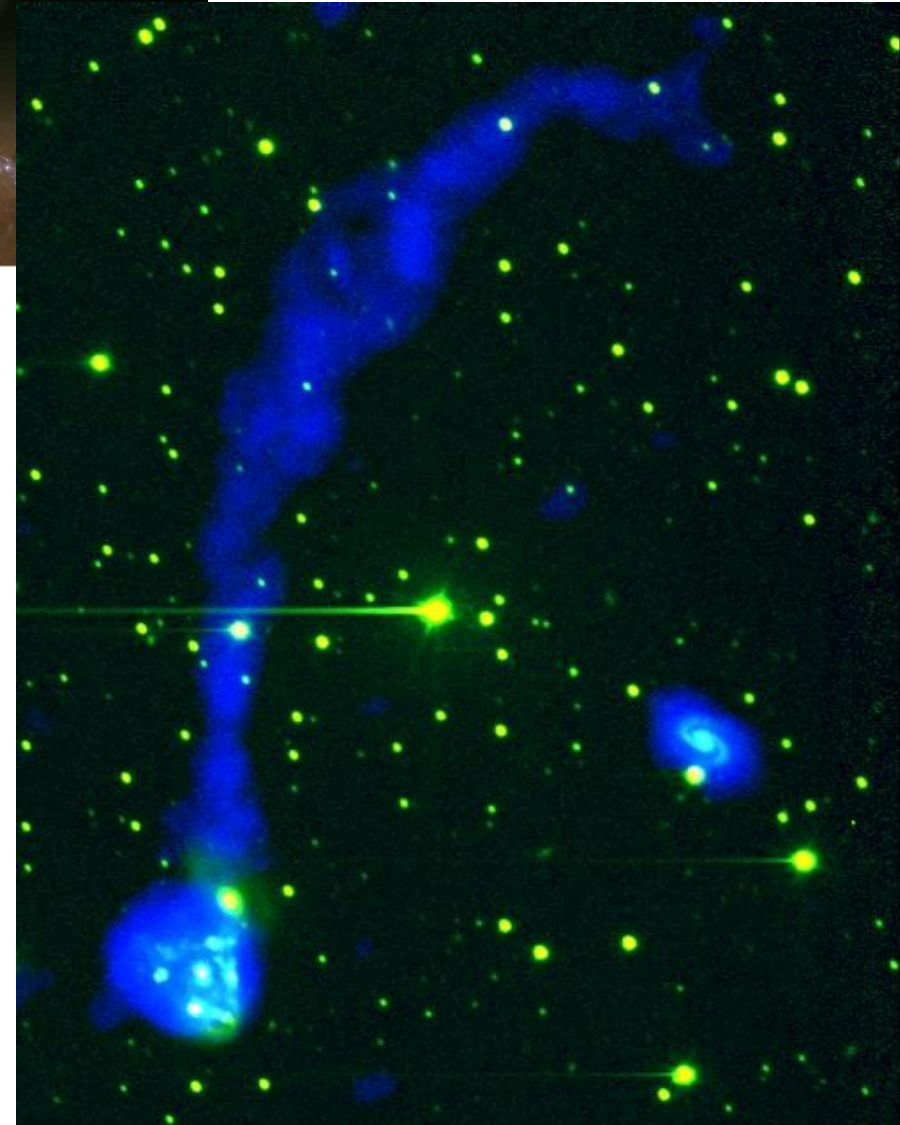
gas+stellar tails imply tidal (gravity)
gas-only tails imply ram-pressure
stripping

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

A MeerKAT HI deep field survey

The MeerKAT time allocation committee has approved 5000 hours of observations of a single field at top priority.

Survey will be carried out starting in 2015 by a team of 65 astronomers from around the world led by:

Dr. Sarah Blyth

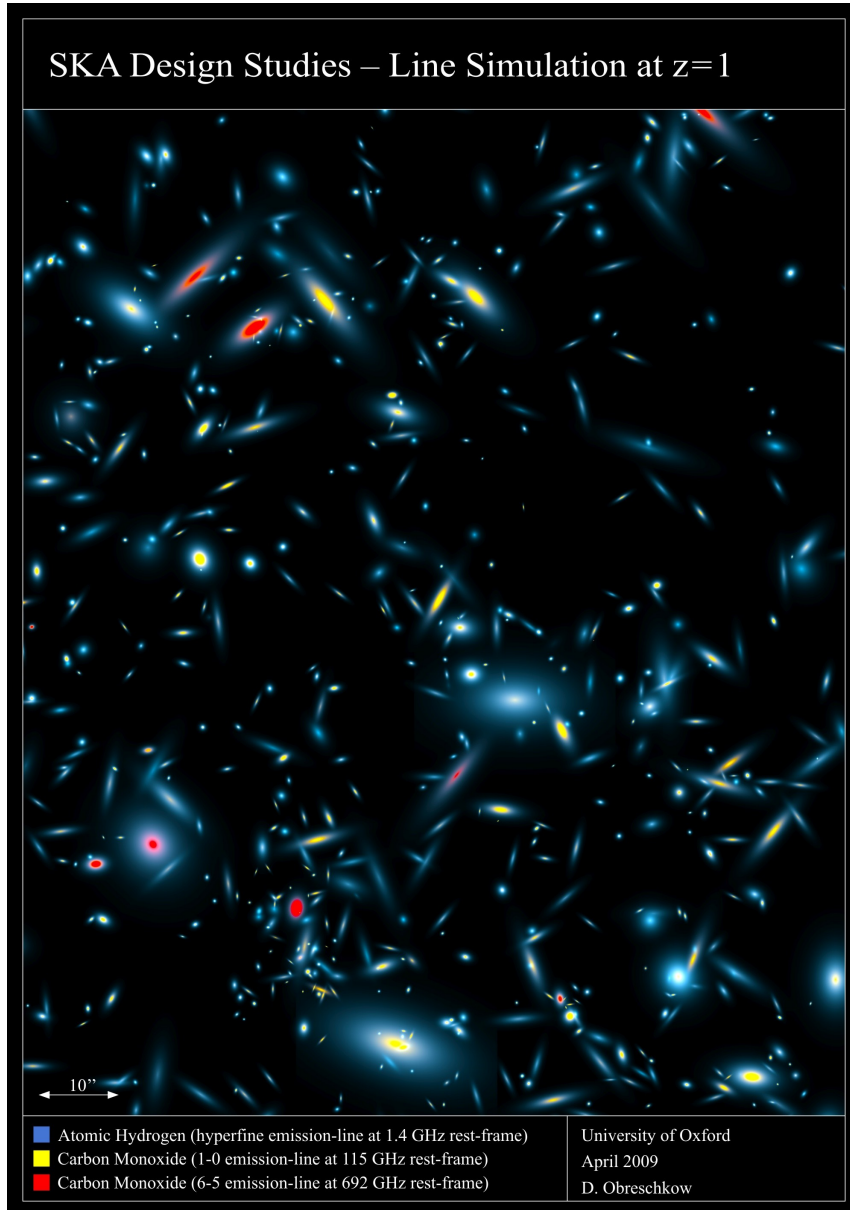**University of Cape Town (South Africa)**

Dr. Benne Holwerda

European Space Agency (Netherlands)

Dr. Andrew Baker

Rutgers University (United States)

Atomic hydrogen: the 21cm line

SKA Design Studies – Line Simulation at z=1

10"

Atomic Hydrogen (hyperfine emission-line at 1.4 GHz rest-frame)
Carbon Monoxide (1-0 emission-line at 115 GHz rest-frame)
Carbon Monoxide (6-5 emission-line at 692 GHz rest-frame)

University of Oxford
April 2009
D. Obreschkow

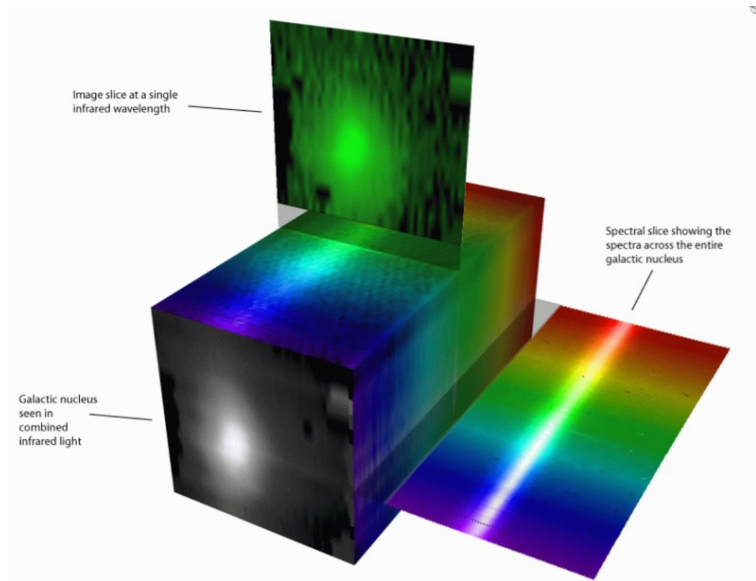**The λ = 21cm line of neutral atomic hydrogen traces gas in the outer parts of galaxies. MeerKAT will use this line to study the growth of galaxies back in time to when the universe was only one third its present age!**

**Obreschkow et al. (2009): simulation of all large galaxies at $1 < z < 1.1$ in a 2' x 2.4' field.**

"Stacking" the MeerKAT data cube

MeerKAT observations will yield a data "cube" with two spatial dimensions and one frequency/redshift dimension.

Image slice at a single infrared wavelength

Spectral slice showing the spectra across the entire galactic nucleus

Galactic nucleus seen in combined infrared light

**S. Todd & D. Pierce-Price**

Holwerda & Blyth (2010)

To see very faint HI emission, we can average the signal in the data cube at the positions and redshifts of known galaxies – even if they are too weak to detect individually!

z = 1.0
4000 hours
500 coadded spectra
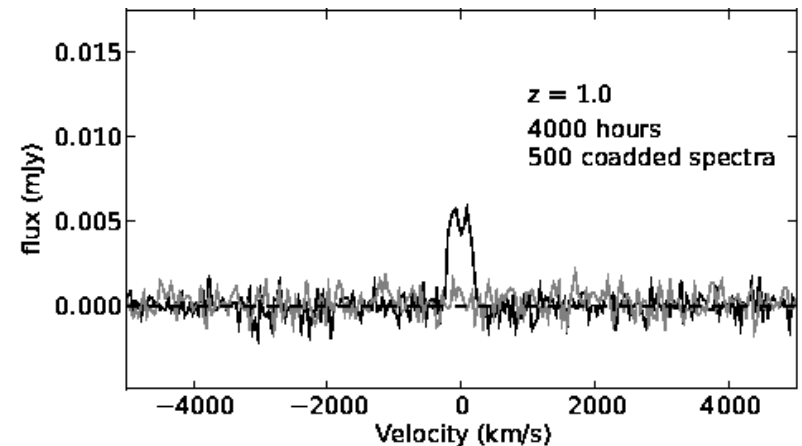
Observing the "ECDFS"

To facilitate stacking, the survey will target a field encompassing the "Extended Chandra Deep Field South," in which thousands of galaxies are already known and can be studied further with the Southern African Large Telescope.
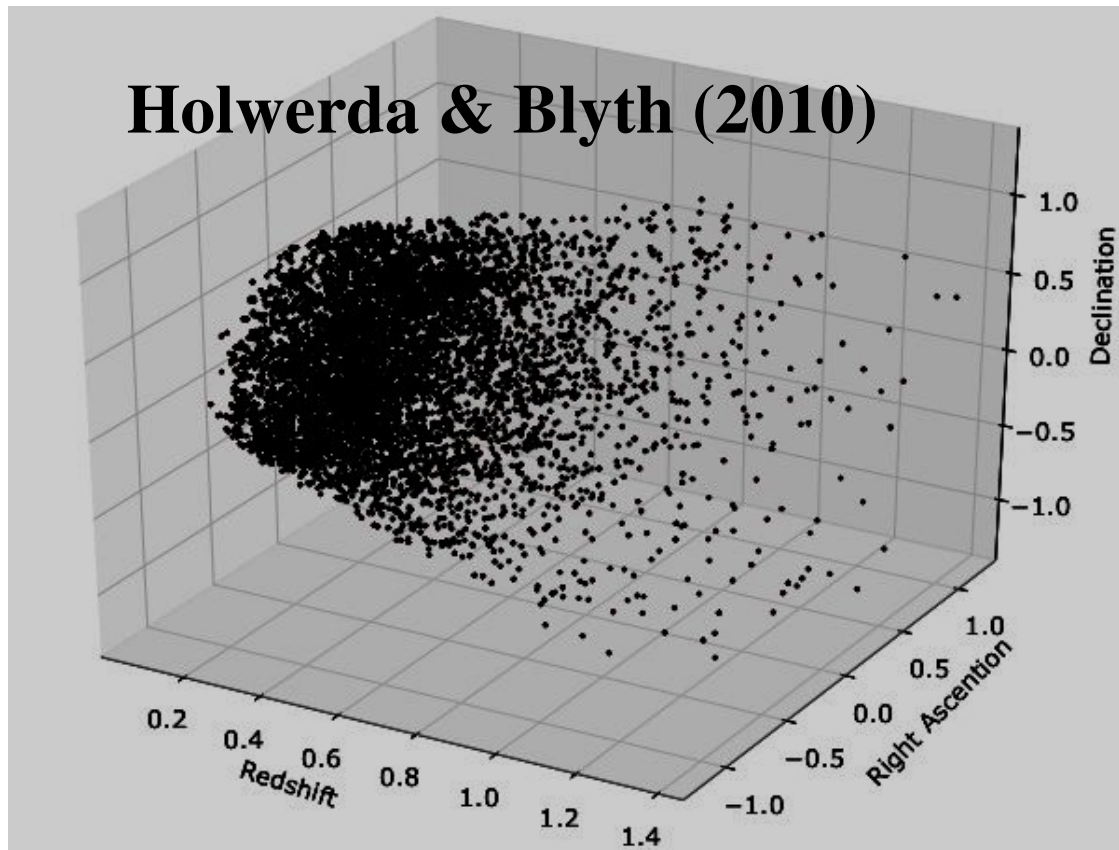
30' x 30' field

Cardamone et al. (2010)
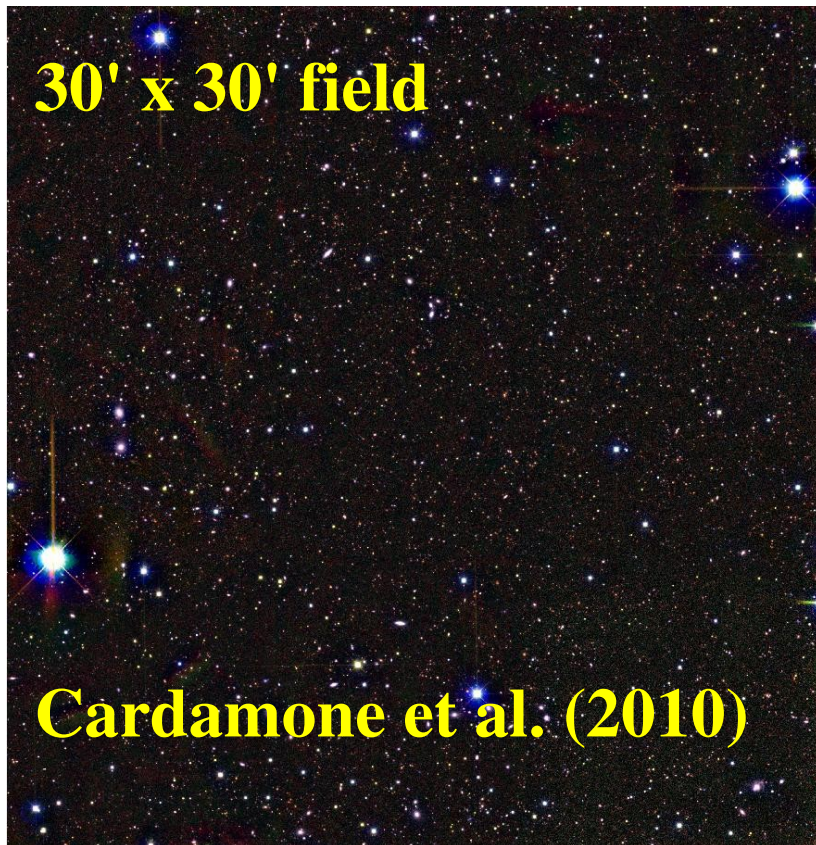
SALT/ SAAO

The "cosmic vuvuzela"

Because MeerKAT's field of view is proportional to the ratio λ/D, and therefore increases with redshift, the survey volume will be shaped like a "cosmic vuvuzela." This makes the survey's name even more appropriate:

LADUMA = Looking At the Distant Universe with the MeerKAT Array.

Holwerda & Blyth (2010)

Er, but the telescope doesn't exist yet!

Standard practice is to award time after a telescope has been built and "commissioned" (i.e., thoroughly tested).

MeerKAT has awarded time first, to induce successful science teams to participate in construction and commissioning (starting with current KAT-7).

A possible complication?

MeerKAT and the Australian SKA Pathfinder (ASKAP) are two precursors for the Square Kilometre Array (SKA), which is to be built by an international consortium (AU, CA, CN, DE, IT, NL, NZ, SE, UK, ZA, more soon?).

May 2012: SKA Board announced that SKA will be hosted by both South Africa and Australia, and that MeerKAT and ASKAP dishes will be incorporated into Phase 1 of the SKA.