Heterodyne Instruments

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Why heterodyne?

- **Paul Goldsmith made good case in last meeting**
- **unique tool for detailed studies of cloud kinematics, structure, chemistry**
- **CCAT particularly suited for study of warm gas in galactic and near extragalactic sources through observations of short submm lines (400-900 GHz).**

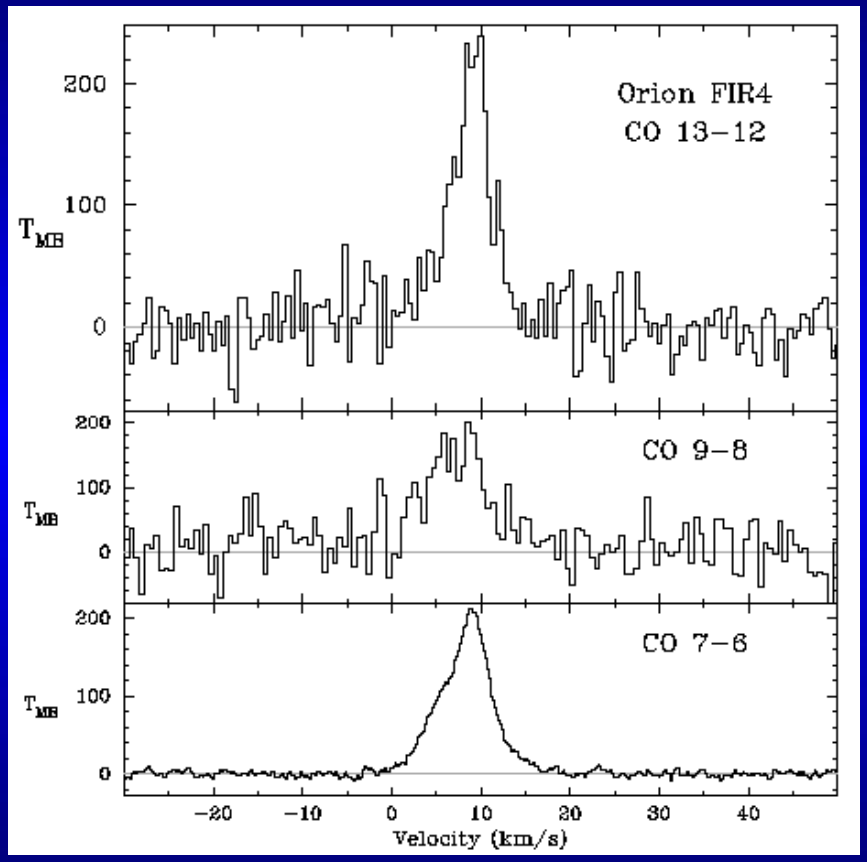
Modes of operation

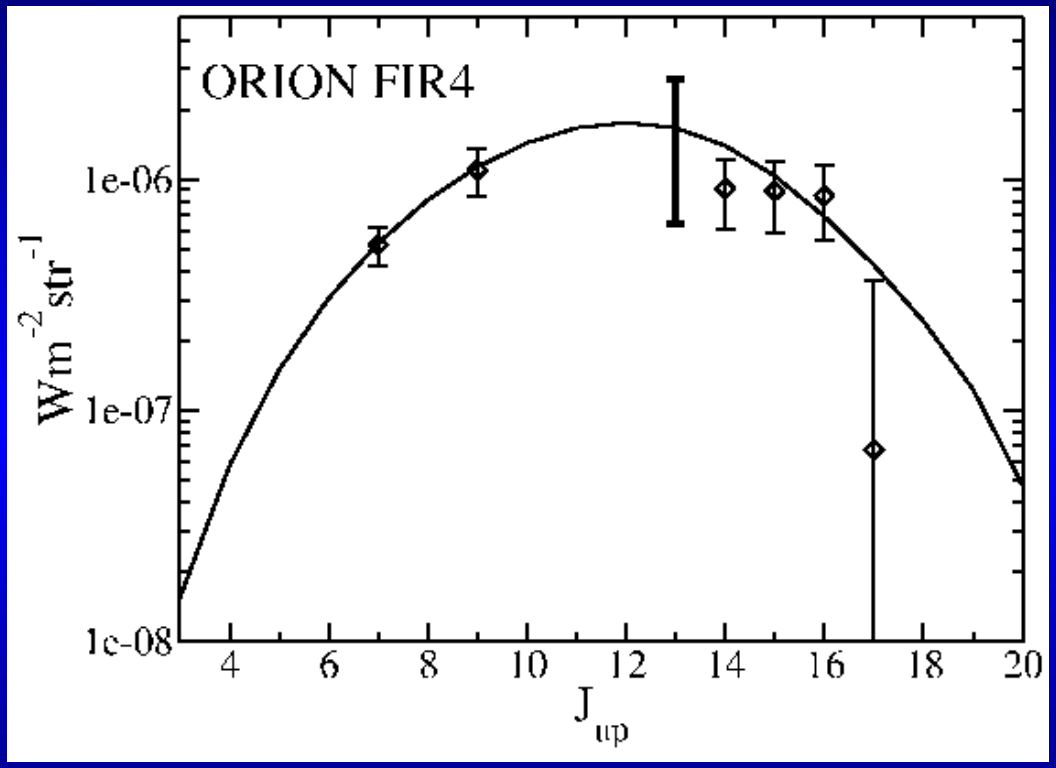
- basically two modes of operation (apart from integration into ALMA):
  - Lines of opportunity:
    - very high point source sensitivity (vs. APEX, SOFIA)
    - site (vs. APEX)
  - Large scale surveys:
    - large field of view enables fast mapping with large arrays

Which instrument(s)?

- proposed CHARM (CCAT Heterodyne ARray for Mapping) – a 650-700 GHz, ≥64 pixel array
  - covers many interesting lines
  - could be built with reasonable effort
- but:
  - need something else for lines of opportunity
  - leaves out interesting lines (e.g. CI fine structure lines)

Lines of opportunity

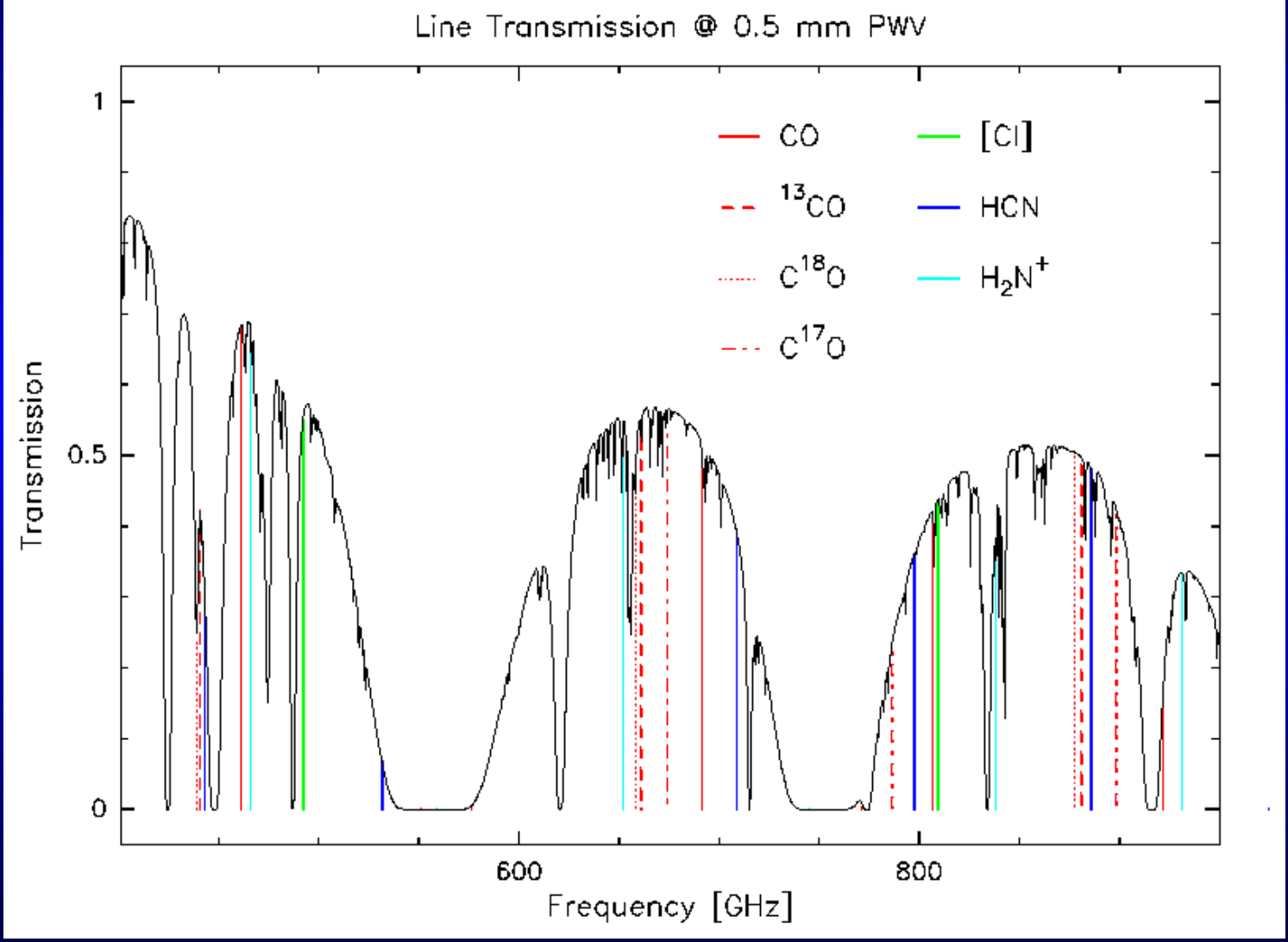




Wiedner et al. 2006

1500 GHz, measured at APEX. Difficult, but can be done.

Bread and butter lines



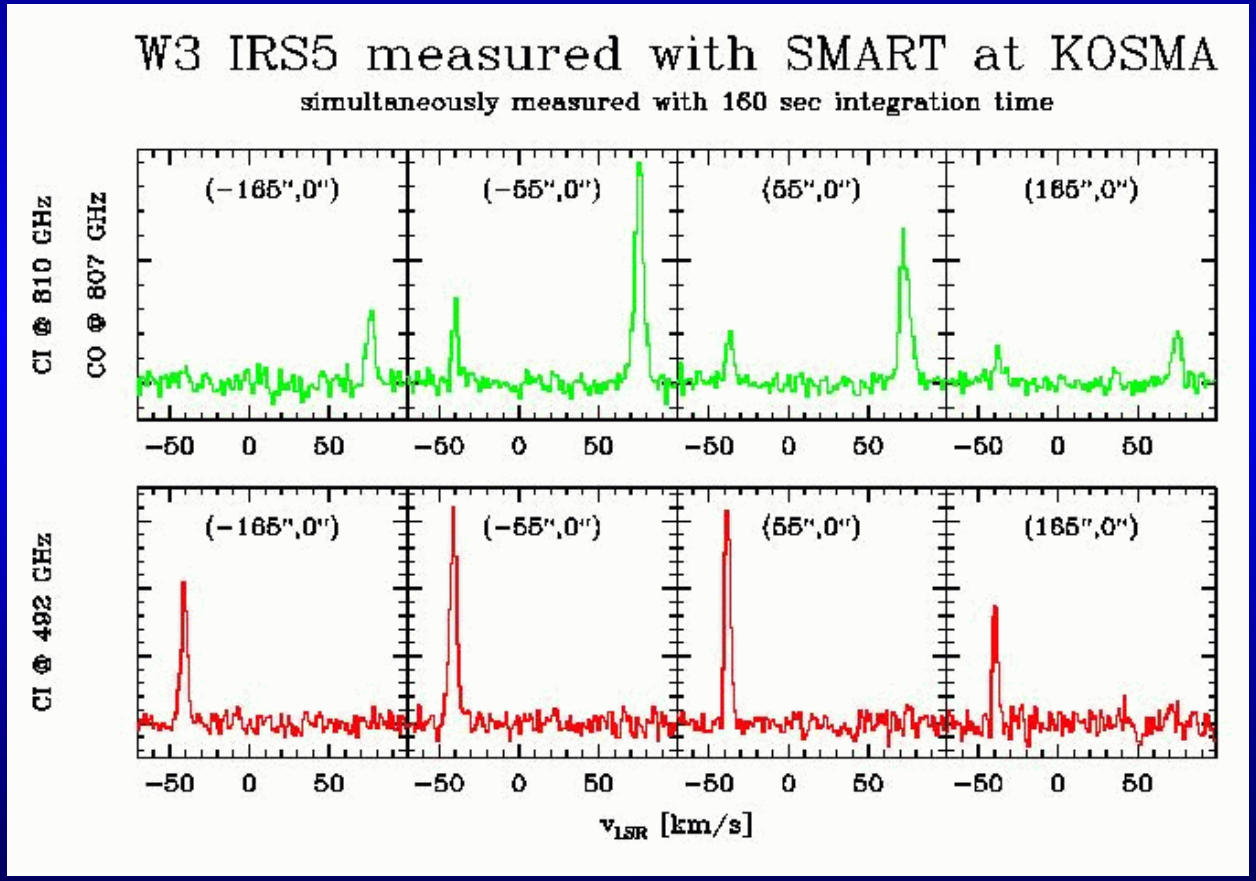
Maximize Efficiency

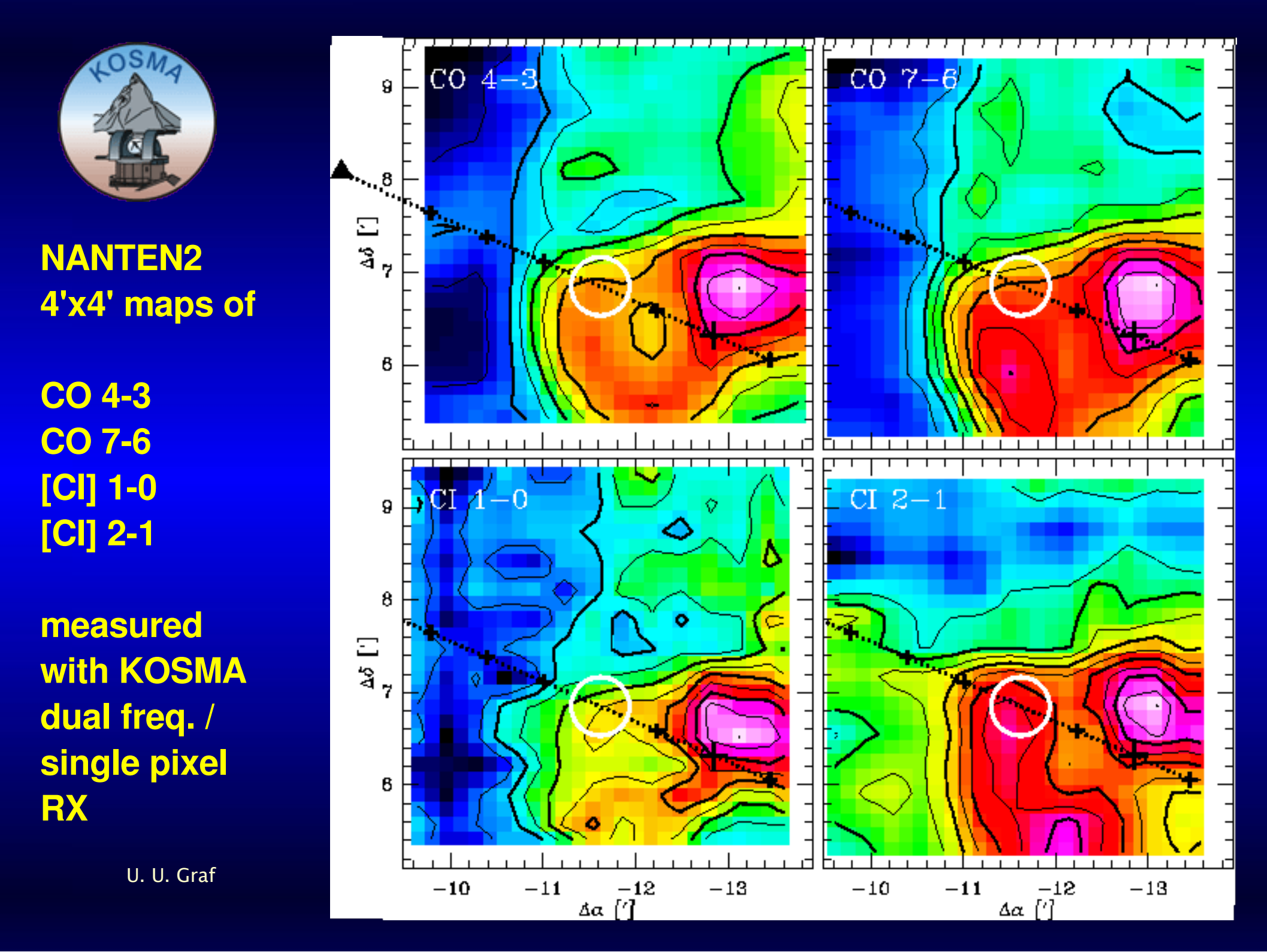
- **Large number of spatial pixels**
- **Upgradeability!**
  - **even more pixels**
  - **large IF bandwidth i.e. instantaneous frequency coverage**
  - **sideband separating receivers**

Maximize Efficiency

- **Use second polarization**
  - **to increase effective sensitivity by √2**
    - **important for efficient mapping of small and weak sources**
  - **to increase instantaneous sampling (vs. OTF)**
  - **or to observe two different lines simultaneously**
    - **important for efficient mapping of strong sources**
    - **yields best line ratios**
    - **example: SMART**

Simultaneous multi-line observations





NANTEN2
4'x4' maps of

CO 4-3
CO 7-6
[CI] 1-0
[CI] 2-1

measured with KOSMA dual freq. / single pixel RX

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Side Remark

- **KOSMA/NANTEN2 start extended mapping of southern galaxy in CO 4→3, 7→6 and both CI lines**
- **Can serve as data base for follow-up observations with CCAT's 6-times higher spatial resolution**

How to combine all?

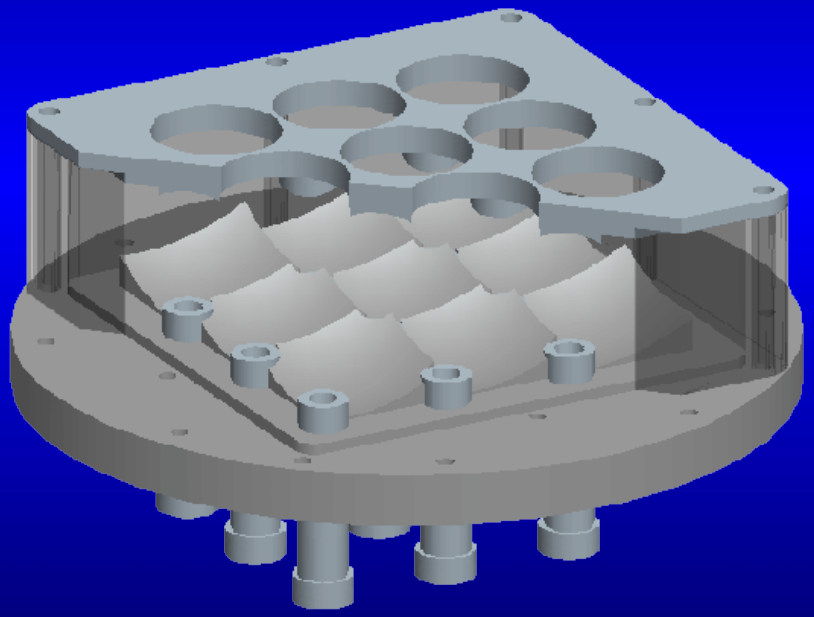
Need modular frontend:

- **Cryostat, optics and backends should be common to all arrays → saves lots of money!**
- **Two orthogonal polarization ports on cryostat**
- **Standardized, exchangeable mixer/LO units (cartridges) that can be mounted on either port**

Example: CHARM (KOSMA's)

CHARM: Compact Heterodyne Array Receiver Module

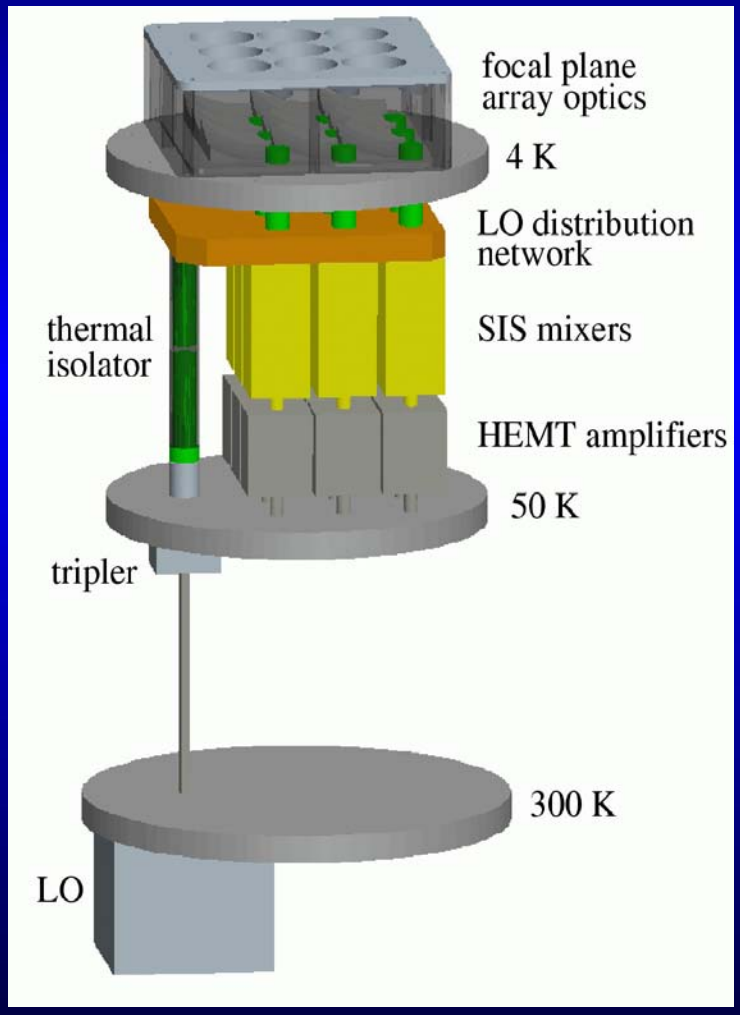
- Each pixel is collimated by a small Cassegrain telescope
- Integrated optics → simple alignment
- scalable both in frequency and pixel-#
- hexagonal array under development



Lüthi et al. 2005, 2006

CHARM Optics Unit

Array Cartridge



- **In-line design of optics, mixers, amplifiers and LO**
- **self contained unit is easily exchanged**

CHARM^2 Concept

- Build multi-purpose dual-polarization frontend (i.e. cryostat, optics – e.g. image rotator – as needed) as common heterodyne RX-frame
- Build RX-cartridges, either single pixel ("lines of opportunity") or (e.g. CHARM-type) array units
- Use common IF processing and (FPGA-based) backends
- Swap cartridges based on observing goals and weather conditions (downtime ~2 days)
- Upgrade/extend receiver as technology and funds become available

The End

Thank you

Beam Pattern @ 345 GHz