Focus

- Due to spectral confusion science return of Herschel, SOFIA, and ALMA will be negatively impacted without improved spectroscopic information.
- High angular resolution offers significant benefits that can be achieved at higher frequencies
  - Due to significant improvements in sensitivity and new spectral windows these facilities will be used more widely than in past - high spatial resolution will be a key draw
  - THz region has the largest frequency uncertainties
- Timeline:
  - ALMA: initial science 2007, operations 2011 - long life
  - SOFIA: initial operational capability 2010 - 20 yr life
  - Herschel: launch no earlier than May 2008 - 3 year mission with limited opportunity for follow-up
- Herschel presents the most immediate issue with the largest instantaneous wavelength coverage (spectral survey mode) It will be a pathfinder at THz frequencies for other observatories
- <u>Need immediate information within the next 2-3 years to allow for more complete analysis of Herschel data</u>
- In the longer term (5-10 yrs) we can have more ambitious goals

The Panel

- Its purpose is to lead and focus discussion of all participants
- Its final output should be succinct report describing the problem and proposed solution with funding and time requirements
- Its members are:
  - Ted Bergin
  - Frank De Lucia
  - Paul Goldsmith (chair)
  - Hashima Hasan
  - Eric Herbst
  - Gary Melnick
  - John Pearson

Steps Forward

Identify which molecules are the worst offenders for Herschel HIFI, SOFIA, and ALMA

Define what laboratory measurements need to be made to mitigate the impact of weeds

Establish a program, work out what will it take to realize it and determine how soon it can be done

Be aggressive, but realistic!

Initial Panel Recommendation #1

- Basic working definition of a weed:
  - Abundant (10[-7] w.r.t. H_2)
  - Dense rotational emission spectrum
  - Normally associated with hot cores (100-300 K) and "saturated" organics
  - Either heavy and/or associated with internal degrees of freedom such as torsion
  - Low-lying vibrational states
  - Spectra particularly difficult to predict

Initial Panel Recommendation #1

- Based on this definition - at minimum we have 5 weeds:
  - CH_3OH (methanol)
  - $HCOOCH_3$ (methyl formate)
  - CH_3OCH_3 (dimethyl ether)
  - CH_3CH_2CN (ethyl cyanide)
  - SO_2 (sulfur dioxide) - pretty much done
  - isotopologues

Discussion topic: are there more?

Initial Panel Recommendation #2

- Given compressed time frame and wide band (0.4 - 2 THz) for Herschel:
  - **There is not time to do traditional analyses with assignments**
  - **Reducing the baseline clutter limit will require even more complete spectral knowledge.**
  - **A combined bootstrap/experimental program (FASSST: F. De Lucia) has the potential to obtain needed data rapidly with reasonable accuracy.**
  - **Need for spectral atlases to be made public in a rapid manner -- frequencies and intensities needed; quantum ID not critical**
  - **How can this be organized?**

Discussion topic: comments/alternatives?

Initial Panel Recommendation #3

Flowers:

- One person's flower may be someone else's weed
- But there are clear absolute flowers from the "big" science perspective (i.e. where you can get funding from your peers)
  - H_2O, $H_2{}^{18}O$, $H_2{}^{17}O$, HDO
  - astrobiological molecules
  - etc…
- Unless there is a clear statement of something crucial that is missing the panel will not make specific recommendations for specific molecules beyond the weeds.

Discussion topic: comments?

Programmatic Specifics

- Laboratories must at a minimum be able to support Herschel & ALMA
  - Frequency knowledge must be better than 50-100 kHz
  - Coverage 700-770, 940-1060, 1220-1272, 1440-1575, 1655-1925 lacking
  - Ideally coverage should be redundant (more than one lab)
    - e.g. second source of coverage in 700-1272, 1440-1925 is desirable
- Currently SOFIA high frequency coverage Targets 2.4-2.7 THz, OI at 4.6 THz
  - These key bands will need to be covered as well
  - No easy technology for this!

International Aspects

- Herschel, ALMA, SOFIA are all international projects, and so should be the crtitical laboaratory spectroscopy support for them
- Difficult to arrange explicitly, but this is happening empirically
- Want to support all efforts to increase funding
- Focus here on US funding options for evident reasons

Programmatic Specifics

- Cost for complete coverage (not redundant)
  - $200,000-$350,000
  - In principle, sources can be procured
  - Detectors are probably needed for THz frequencies $30,000-$50,000
  - Ensures that entire frequency range is covered at least in one facility
- Cost for redundant coverage (recommended)
  - $400,000-$800,000
  - Detector needs will add to total
- Completely impossible under current NRA structure
  - $100,000/year grants
  - Equipment is 1-3 years of NASA total in Far-Infrared lab astrophysics

Programmatic Specifics

- Best current estimate: 2-3 years should be sufficient to produce bare bones weed catalog useful for Herschel
  - With 2-3 labs having appropriate funding
- Needed funding level is $200-300K/yr personnel costs per lab
  - Post-doc
  - Student
  - Minimal PI support

Work to Do

- Facilities
  - Inventory of facilities for highest priority work
  - Identify investment required
  - Develop strategy for investment/leveraging of resources
- Personnel
  - Identify training strategies to attract and retain next generation of investigators
- Need for catalogs to provide citable references for data

Discussion

Build Community Support

- Establish presence at major meetings
  - Identify meetings where data users are present (AAS, IAU, Columbus Spect. Meeting, ALMA meetings, etc..)
  - Present papers
  - Coordinate with mission booths and advertise lab astro needs for mission
- Establish relationship with advisory committees
  - Keep chairs of NASA and NSF advisory committees and working groups informed of any major development

Funding Options

- NASA/APRA
  - Identify/prioritize programs that have wider application (i.e. not a single mission)
  - Solicitation could direct investigators to the white paper
- NSF
  - Identify programs which are of higher priority to NSF (e.g. ALMA specific)
- NASA/Herschel
  - Make roadmap identifying programs of high priority to Herschel (e.g. US leading Orion/SgrB2 surveys)
  - **Develop strong case for Herschel funding**
- Cross-agency
  - Identify programs of interest to both NASA and NSF for a possible joint solicitation
- Program coordinator
  - Find program manager to coordinate programs across different institutions

Panel Recommendation #4

- Lubrication (funding) for *directed and immediate* spectroscopic work is crucial and the primary conclusion of this report will be a strong statement in this regard.
- Stress the importance of training the next generation of spectroscopists for future observatories.