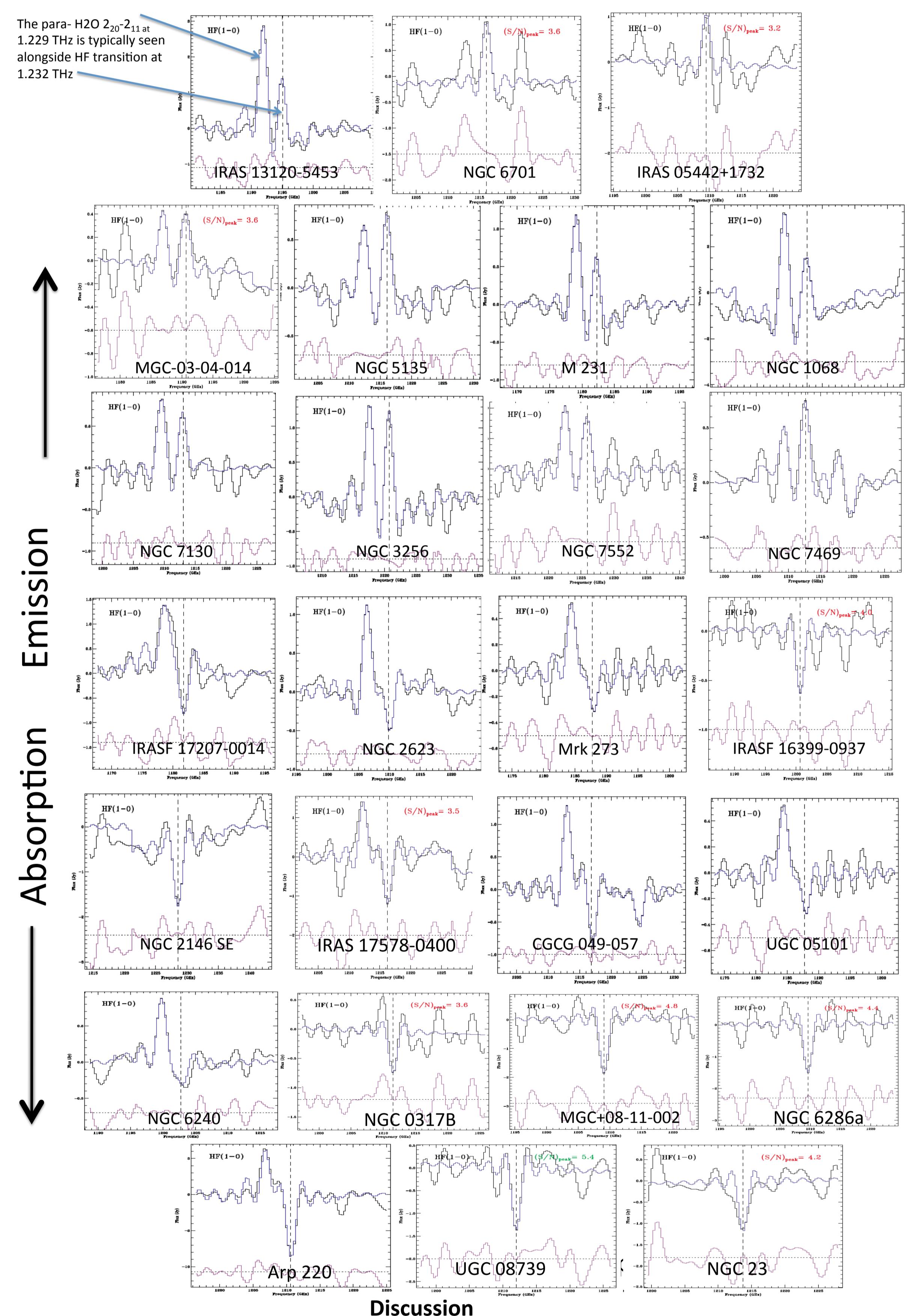


# Extragalactic HF Molecular Line Observations from Herschel SPIRE and HIFI Spectroscopy

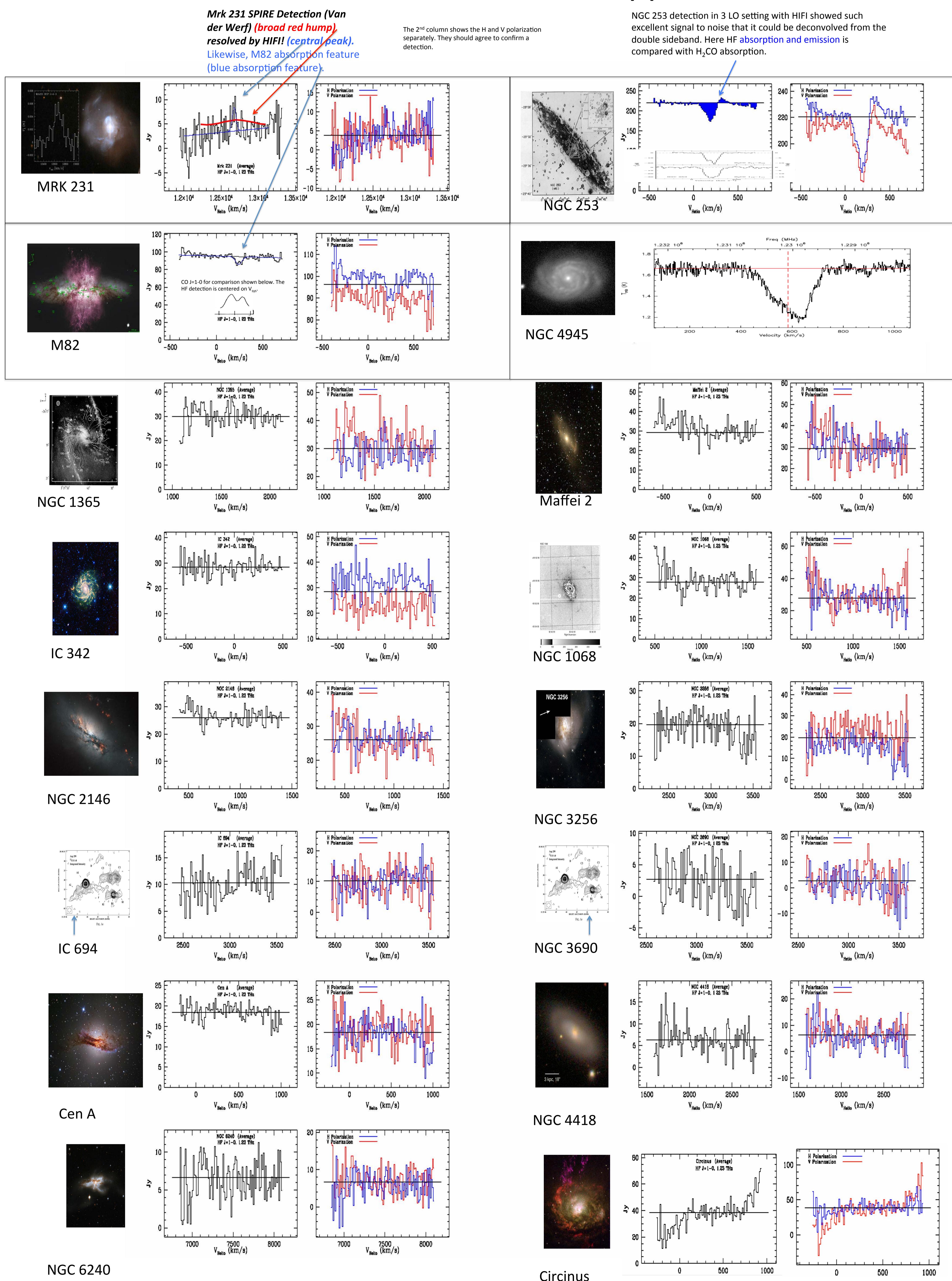
Steve Lord, Raquel Monje, Nanyao Lu, Yinghe Zhao, Darek Lis, Tom Phillips, David Neufeld, Edith Falgarone

The HF ( $J=1-0$ ) transition at 1.23 THz (243  $\mu\text{m}$ ) is providing a new diagnostic probe of the molecular gas abundance, excitation, and column density toward infrared bright galaxy nuclei. During the Herschel mission, this transition was detected and resolved in four galaxies with HIFI and gave 12 upper limits (below right). SPIRE gave strong detections of HF emission in 15 sources and absorption in 11 sources. (Data were taken from the Key program of Lu et al, the OT program of Lord et al., and the Herschel Archive).

## SPIRE 26 detections (unresolved)

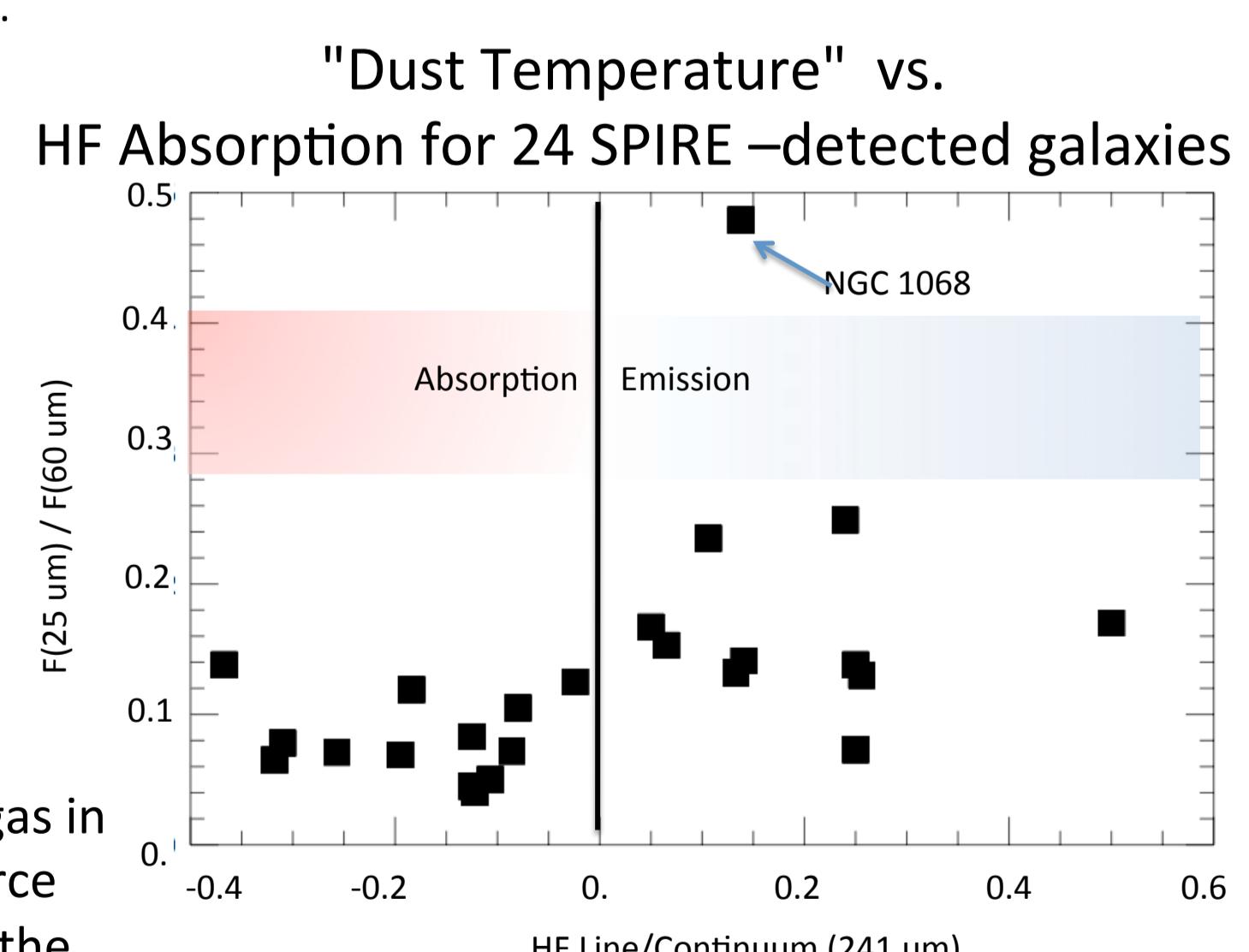


## HIFI (resolved) 4 detections, 12 upper limits



It has been recognized (Neufeld et al. 2005, 2010) via fundamental energetic considerations that HF is the dominant reservoir of fluorine in the ISM. Preliminary Herschel studies identified the transition in Milky Way objects while subsequent Herschel observations have allowed us to extend our view to IR-bright galaxy nuclei and even to their spiral arms (e.g. NGC 2146 SE). Here we show numerous examples the  $J=1-0$  HF transition occurring both absorption and emission toward IR-bright galactic nuclei. While SPIRE has yielded the strong detections shown above, there is little assurance that, within the profiles shown, we are not seeing the superposition of regions of *emission and absorption*, thus making interpretation difficult. E.g.: In NGC 253 the combination of the two effects yields a *p-Cygni* profile, which Monje et al. (2013) interpret as tracing two velocity components: in-fall and outflow toward the nucleus. From this example we see the need for high spectral resolution observations of the line. Below, we show evidence that the *emission* regions are consistent with regions of warm dust which may fill the beam, conceivably the result of AGN-heating (see talk here of M. Pereira Santaella) while the *absorption* lines may originate in a narrow line-of-sight to a background nuclear continuum source. (See figure here!) Is this line, in emission, a new AGN diagnostic? Clearly high-z ALMA studies are needed here!

Counter-examples to the simplistic assertions made above are apparent in the HF *absorption* seen toward the star-forming region of NGC 2146 SE and the HF *emission* seen toward the non-AGN NGC 3256. But the interpretation of HF spectra are just now beginning with these discoveries.



Depending on the amount of cold molecular gas in the line of sight to the central continuum source (pencil beam) vs. the amount of warm gas in the main beam (19'' in diameter) HF may be seen in emission or absorption. In NGC1068 for example, the main beam includes the inner region of the starburst ring, which may account for the strong HF emission seen.