A. MEREDITH HUGHES 2012.1.00198.S

PROJECT TITLE:	Who Stirs the Pot? Dynamics of Edge-On Debris Disks				
PRINCIPAL INVESTIGATOR NAME:	A. Meredith Hughes	PROJECT CODE:	2012.1.00198.S		
SCIENCE CATEGORY:	Circumstellar disks, exoplanets and the solar system	ESTIMATED 12M TIME:	5.1 h	ESTIMATED ACA + TP TIME:	0.0 h
CO-PI NAME(S): (Large Proposals only)					
CO-INVESTIGATOR NAME(S):	Margaret Pan; Hilke Schlichting; David Wilner; Eugene Chiang; Bill Dent; John Carpenter; Sean Andrews				
EXECUTIVE SHARES[%]:	NA : EU : EA : CL : OTHER :	100 0 0 0 0	STUDENT PROJECT? (Yes/No)	No	
			RESUBMISSION? (Yes/No)	No	

ABSTRACT

The tenuous, dusty debris disks around main sequence stars are hallmarks of substantial reservoirs of large planetesimals. The dynamical state of debris disks is central to our understanding of their masses, grain size distribution, and collisional evolution -- as well as the presence or absence of large bodies "stirring" the planetesimal belts. Edge-on debris disks present a unique opportunity to access dynamics, since the vertical scale height encodes the velocity dispersion and the total mass of any perturbing bodies. Millimeter wavelengths are uniquely suited for revealing the dynamical state of debris disks, since the large grains are not subject to the excitatory effects of stellar radiation that puff up the vertical scale height at optical and infrared wavelengths. Here we propose to measure the vertical scale height of the debris belts around the two brightest, most prominent nearby edge-on systems: beta Pic and AU Mic. The observations will reveal whether the collision velocities are destructive or erosive, and will be sensitive to perturbing masses as low as 2 and 5 earth masses in AU Mic and beta Pic, respectively -- potentially revealing the presence of Neptune-mass planets at large distances from these young stars.

REPRESENTATIVE SCIENCE GOALS (UP TO FIRST 5)

SCIENCE GOAL	POSITION	FREQUENCY	BAND	ANG.RES.(")	ACA?
beta Pic - high resolution	J2000: 05:47:17.0877, -51:03:59.441	230.52262 GHz	6	0.3	N
AU Mic - high resolution	J2000: 20:45:09.5315, -31:20:27.243	230.53708 GHz	6	0.3	N
AU Mic - low resolution	J2000: 20:45:09.5315, -31:20:27.243	230.53708 GHz	6	2.0	N
beta Pic - low resolution	J2000: 05:47:17.0877, -51:03:59.441	230.52262 GHz	6	2.0	N
Total # Science Goals : 4					

SCHEDULING TIME CONSTRAINTS (e.g. Co-ordinated observations already scheduled)	NONE	Extra Time Requested?	No

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Who Stirs the Pot?
Resolving the Vertical Thickness of Debris Disks

PI: A. M. Hughes

1 Scientific Justification

1.1 Scientific Rationale: The Importance of Vertical Structure

The tenuous, dusty debris disks around main sequence stars indicate substantial reservoirs of large planetesimals. As these planetesimals grind down through collisions, they produce dust grains in a wide range of sizes observable at optical through radio wavelengths. The lifetimes of small dust grains observed in scattered light are short compared to the age of the star, indicating that they must be replenished with time (e.g., Wyatt 2008). Despite decades of successful imaging in scattered light and thermal emission, however, basic assumptions about the dynamical state of debris disks remain untested by observations. One fundamental concept in our understanding of debris disks is that of a collisional cascade, in which larger bodies collide and fragment into smaller bodies at such a rate as to replenish the loss of small particles from the system through radiation pressure. A central underlying assumption of the standard cascade and its resulting size distribution (Dohnanyi 1969) is that the collisional velocities are large and highly destructive. This assertion has never been tested outside the Solar System. The dynamical excitation of the debris disk is in turn directly related to the properties of massive bodies that perturb the orbits of nearby planetesimals (see, e.g., Pan & Schlichting 2012). In the absence of dynamical information, fundamental properties like the amount of dust locked up in planetesimals and the presence or absence of massive bodies sculpting the belts remain essentially unknown. In short, it is not yet clear whether the spectacular debris rings imaged on the sky represent a frenzy of catastrophic asteroid collisions whipped up by an ice giant, or gentle dust erosion stirred by nothing larger than a super-earth.

Vertical thickness is the most direct measure of the gravitational excitation of debris disk systems. Stirring by massive bodies can excite the eccentricities and inclinations of dust grains, increasing their out-of-plane velocity dispersion and thereby the disk thickness. Measuring the vertical scale height therefore allows the inference of two fundamental properties of the debris belt: (1) the velocity dispersion of particles and (2) the mass of the largest bodies stirring the planetesimal population (e.g., Artymowicz et al. 1997; Quillen et al. 2007). Such measurements have been achieved in the optical and near infrared (OIR) for a handful of nearby systems including the iconic edge-on disks around the nearby β Pic and AU Mic (Heap et al. 2000, Krist et al. 2005). However, theoretical work by Thebault (2009) has shown that simple radiation effects from starlight will increase the eccentricity and inclination of the small dust grains that emit the bulk of the radiation observed at OIR wavelengths, resulting in a substantial "natural" scale height consistent with the observations even in the absence of large bodies.

Millimeter-wavelength interferometry therefore has a key role to play: the macroscopic dust grains that dominate the emission in ALMA bands are large enough to be impervious to excitation by stellar radiation. Instead, they trace directly the gravitational excitation of the system. Other millimeter wavelength interferometers have sufficient spatial resolution to image structure on the relevant scales, but their sensitivity is insufficient for the low surface brightness of debris disk emission. Only the combination of sensitivity and spatial resolution achieved by ALMA Cycle 1 enables this exciting new science. Timely work by Pan & Schlichting (2012) represents the first theoretical calculation of steady-state, size-dependent velocity distributions in collisional cascades, providing a robust framework in which to interpret the observations. We are now in a position to solidify our understanding of the collisional cascades that represent a cornerstone of debris disk theory, and to confirm or refute the presence of Neptune-mass planets at large distances from two nearby young stars.

1.2 Immediate objectives:

We propose to obtain high spatial resolution observations of the debris disks around β Pic and AU Mic to measure their vertical scale heights. These closest and brightest edge-on disks (19.3 and 9.9 pc, respectively), with spectral types A and M, are ideal candidates for such a study. The scale heights measured in the OIR ($\sim$0.3" and 0.5" for AU Mic and β Pic) serve as upper limits on the millimeter scale height since the puffing effect of starlight can only increase the OIR scale height above the dynamical height. We can easily resolve scale heights up to a factor of 5$\times$ lower than the OIR scale height for β Pic and 2.5$\times$ for AU Mic. The inclination of the two systems is well constrained from the OIR observations: 87$\pm$1° and 90$\pm$1° for β Pic and AU Mic, respectively (Kalas & Jewitt 1995; Krist et al. 2005). The uncertainty in inclination translates into a scale height uncertainty of roughly $\Delta R \cos i$, or $\lesssim$ 10% for both systems given the constraints on the ring width ΔR from spatially resolved SMA data (Wilner et al. 2011, 2012). Since we have already resolved the large-scale distribution of millimeter flux in these systems, we have strong constraints on the radial flux distribution and can predict the sensitivity quite well; both systems exhibit narrow rings of millimeter flux, in contrast to the extended OIR flux distribution. Given the relatively narrow width of the millimeter rings ($\Delta R/R \lesssim 0.3$) and the concentration of flux in the ansae, disk warping should not introduce significant uncertainty into the scale height measurement (unlike at OIR wavelengths). It should also be noted that the presence of the directly imaged planet in the β Pic system, with a semimajor axis of 8-15 AU (Lagrange et al. 2010), will not significantly excite the velocity dispersion of the millimeter ring at 90 AU (Wilner et al. 2011). The proposed observations have two main objectives:

Measuring the Velocity Dispersion — Since scale heights translate quite readily into velocity dispersions, the proposed measurements would provide the first observational test of the collisional destruction paradigm and resulting size distribution derived in Dohnanyi (1969). The spatial resolution of the ALMA observations will allow velocity dispersion measurements as low as $\sim$30 m/s. Based on laboratory experiments, this is just on the edge of destructive collisions, which occur reliably at velocities above a few tens of m/s (Blum & Wurm 2008). A measurement consistent with the OIR scale height would therefore place the velocity dispersion firmly within the destructive collision regime ($\sim$200 m/s), while the narrowest measurable scale height would approach a non-destructive regime in which the dust production rate is much lower than typically assumed and the total (unseen) planetesimal mass necessary to sustain a steady-state cascade is correspondingly higher. Such a measurement will have far-reaching implications for the inferred masses, grain size distributions, and evolutionary timescales of all debris disks.

Measuring the Mass of the Perturbing Bodies — Based on the work presented in Pan & Schlichting (2012), we can robustly connect the scale height measurement to the total mass of the largest bodies in the system, which dominate the dynamical stirring of the disk. While there is some degeneracy involved in the interpretation (with a single measurement it is not simple to distinguish between, say, a single Neptune-mass perturber or two super-Earths), such a total mass measurement would nevertheless represent a fundamental characterization of the dynamical conditions in the disk. Fig. 1 plots the dependence of the measured scale height on the total mass of the perturbing bodies. The spatial resolution of the observations (note that the scale height is effectively half the disk FWHM in the vertical direction) will be sensitive to perturbers of down to roughly 5 $M_\oplus$ for β Pic and 2 $M_\oplus$ for AU Mic (note that while the AU Mic disk is thinner in scattered light, the mass constraints are better due to its proximity and stellar type). Detection of Neptune-mass perturbers at such large distances from such young stars would present a significant challenge to existing theories of planet formation. And this is only a first step: the frequency dependence of scale height is a sensitive function of the strength of the colliding dust grains (Pan & Schlichting 2012). If these observations are successful, follow-up observations measuring the scale height at a range of millimeter wavelengths will provide insight into the strengths of the bodies in the collisional cascade.

1.3 Ancillary Science

In addition to the main objectives of this project, a substantial amount of ancillary science will be enabled by the rich data sets. *These observations will represent the deepest search for molecular gas emission to date*

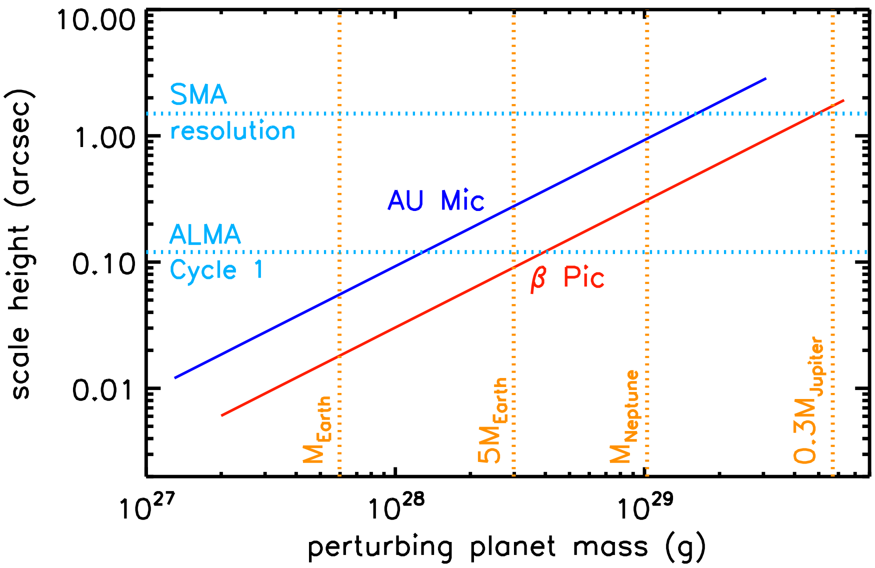

Figure 1: *Dependence of measured scale height on the total mass of the perturbing bodies in the debris disk. This figure is based on calculations of steady-state, size-dependent velocity distributions in collisional cascades from Pan & Schlichting (2012), with dust mass measurements from Liu et al. (2004) and Nilsson et al. (2010). Even though the AU Mic disk has a narrower observed scale height in scattered light, a given millimeter-wavelength spatial resolution provides a tighter constraint on perturbing body mass due to the proximity and stellar mass of the system. Note that since we resolve both the top and bottom halves of the disk, we can measure a scale height (HWHM) of roughly half the spatial resolution (FWHM) of the observations. The observations will be the first to resolve below the OIR scale height (∼0.3" and 0.5" in AU Mic and β Pic respectively), improving on existing SMA observations by an order of magnitude and providing the first measurement of perturbing planet mass in a debris disk.*

in any debris disk. In the optically thin environment of a debris disk, edge-on systems represent the best opportunity for detection, as molecular gas emission piles up along the line of sight in the ansae. It is almost certain that β Pic harbors a molecular gas reservoir, given the CO lines observed in absorption against the stellar photosphere (Roberge et al. 2000), but the amount and spatial distribution of the gas can only be determined from emission measurements. Molecular gas in debris disks is a topic of considerable interest from a dynamical, chemical, and evolutionary perspective, and a detection in these nearby systems would be extremely valuable. Given the unprecedented sensitivity and angular resolution, it may also be possible to study *non-axisymmetry and planet-disk interactions* in the inner, warped regions of the disks. While our emphasis is on the outer rings, which dominate the millimeter emission and are symmetric as far as can be determined from the SMA data, the OIR observations of both systems hint at more complex structure in the inner regions, for which we have only poor constraints on the millimeter flux. These complications would not compromise our ability to measure scale heights in the ring ansae, and they would be extremely interesting in their own right if detected.

2 Technical Justification

Requested sensitivity: The total 1.3 mm flux in the debris rings measured by the SMA is 13±1.4 and 8.5±2 mJy for β Pic and AU Mic, respectively, with both systems concentrated into rings approximately 2" in radial width. Since the primary purpose of the experiment is to determine the spatial distribution of flux, we make a conservative estimate based on the lowest surface brightness allowed by existing observational constraints. In a worst-case scenario, the millimeter flux for β Pic might be distributed over several arcseconds in radius (concentrated in the ∼2"-wide ansae) and up to ∼1" FWHM vertically across the disk midplane (equivalent to the height measured in scattered light). As a gross estimation, assuming that the 13 mJy of flux is spread uniformly into two 2"x1" squares (one at each ansa) and resolved into 0.25" beams, this implies a required flux sensitivity of ∼17 μJy/beam to achieve a signal-to-noise ratio of 10 per beam in Band 6. AU Mic is fainter, but its OIR height (∼0.5-0.7") is smaller than β Pic, making the sensitivity requirements comparable. To obtain a more realistic sensitivity estimate, we simulate observations of edge-on debris disks with properties similar to those for the β Pic and AU Mic systems (see Fig. 2) and find that, for the full range of allowed vertical scale heights, sufficient signal-to-noise is achieved with a single hour (rms 17 μJy/beam) in the extended configuration and half an hour (rms 26 μJy/beam) in a compact configuration.

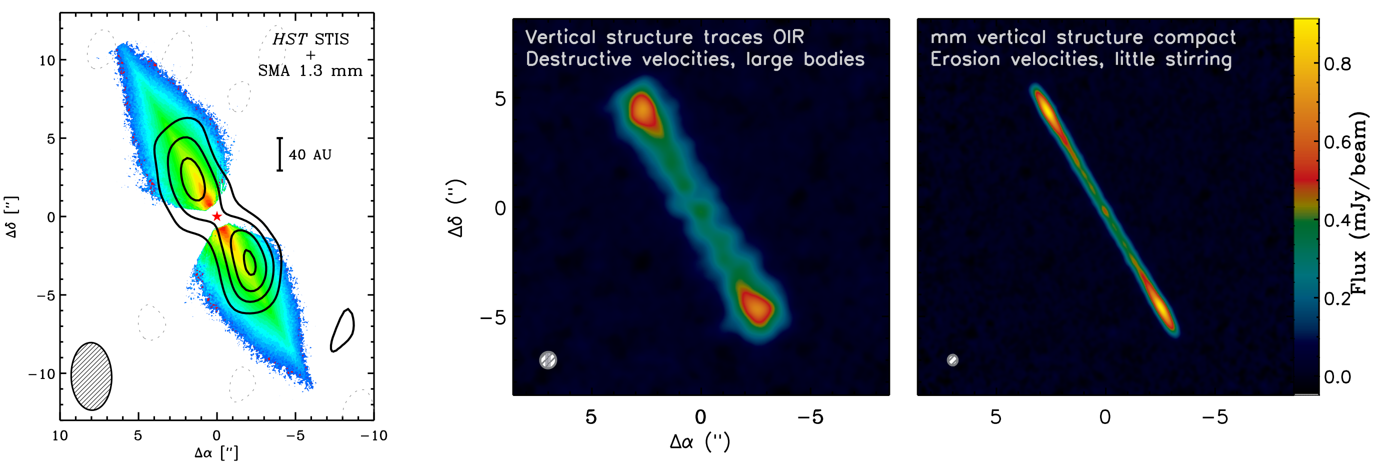

Figure 2: **Left**: *HST/STIS image of the β Pictoris scattered light disk (colors) overlaid with contours of 1.3 mm emission observed with the SMA (Wilner et al. 2011). Contour levels are [2,4,6,8]×0.6 mJy/beam (the rms noise). The SMA observations indicate that the millimeter emission, unlike the scattered light, is distributed in a radially thin ring; however, the spatial resolution is insufficient to measure the scale height of the disk.* **Right**: *Simulated Band 6 ALMA image of β Pictoris with rms noise 17 μJy/beam that resolves the vertical scale height of the disk. The beam size is indicated in the lower left of each panel. On the left, the vertical thickness of the millimeter emission is assumed to trace that observed in scattered light. (The visibilities have been imaged with a slight taper to bring out the extended emission.) Such a measurement would indicate destructive collisional velocities between particles, confirming a central paradigm in the theory of debris disk structure. It would also indicate stirring by large bodies with a total mass of at least 0.3 M_{Jup}. If instead, as on the right, the millimeter emission is substantially more compact in the vertical dimension than the scattered light, the velocity dispersion would be far smaller. This would indicate very small collision velocities, requiring more mass in planetesimals than has been previously inferred to sustain the observed small dust grain population. It would also require that the total mass of the largest bodies stirring the belt be no larger than 5 M_{Earth}.*

Imaging requirements: The diameters of the two debris rings are ∼8-9", which will fit comfortably within the primary beam at either Band 6 or 7. (Band 9 observations would require both mosaicking and ACA to capture the entire disk and the largest scale in the image; we choose to start with bands that allow for single pointings to achieve the best sensitivity and stability.) The edge-on orientation of the disks tends to concentrate flux along the midplane, which is advantageous for imaging, but to recover all of the flux it is still important that the observations be sensitive to structure on scales comparable to the major axis of the disk (8-9"). A scale of ∼2" is also crucial to the observations, since that is roughly the width of both rings estimated from the SMA data. Therefore, our simulations showed substantial improvement in image quality when a short (half-hour) observation in a compact configuration was included in the observations (Fig. 2). Short baselines are also advantageous for the ancillary science goal of searching for molecular gas. Of course, this project is fundamentally a high-resolution experiment, hence the request for the most extended configuration: the higher the resolution, the better the constraints we can place on masses and velocities in the disk. While Band 7 provides slightly higher spatial resolution (0.16" compared with 0.25"), Band 6 has a number of other advantages that make it preferable: the sensitivity requirements are less challenging due to the larger synthesized beam and the largest spatial scales are more easily attainable. Furthermore, our experiment relies heavily on resolving the flux in the bright disk ansae, which are located far from the star and hence are quite sensitive to the size of the primary beam. Finally, our experiment is limited more by phase stability than sensitivity, and the weather conditions seem to be more favorable at Band 6. We therefore request both compact (C32-1 or equivalent) and extended (C32-6 or equivalent) observations at Band 6, with emphasis on the long baselines. The spatial resolution of 0.25" will allow us to measure the total mass of the large bodies dynamically stirring the debris belt, down to masses of roughly $5\,M_\oplus$ for β Pic and $2\,M_\oplus$ for AU Mic.

Correlator setup: This is primarily a continuum project, so we request maximum bandwidth (7.5 GHz per polarization). To search for CO, we will allocate one band at the lowest spectral resolution, which will not result in any loss of continuum sensitivity. If CO were associated with the millimeter ring, the expected rotational linewidth would be 8 km/s for β Pic and 5 km/s for AU Mic, easily resolved by the 1.3 km/s channel spacing of the lowest-resolution setting.

3 Potential for Publicity

The proposed observations will produce spectacular images of two iconic nearby debris disks, achieving spatial resolution comparable to the existing *HST* images; a multiwavelength montage would present an extremely appealing image for publicity. Furthermore, the science enabled by these observations probes the dynamics of planetary systems, always a topic that engenders keen public interest.

4 References

Artymowicz & Clampin 1997, ApJ, 490, 863
Blum & Wurm 2008, ARA&A, 46, 21
Dohnanyi 1969, JGR, 74, 2531
Heap et al. 2000, ApJ, 539, 435
Kalas & Jewitt 1995, AJ, 110, 794
Krist et al. 2005, AJ, 129, 1008
Lagrange et al. 2010, Science, 329, 57
Liu et al. 2004, ApJ, 608, 526
Nilsson et al. 2010, A&A, 518, 40
Pan & Schlichting, ApJ, 747, 113
Quillen et al. 2007, MNRAS, 380, 1642
Roberge et al. 2000, ApJ, 538, 904
Thebault 2009, A&A, 505, 1269
Wilner et al. 2011, ApJL, 727, 42
Wilner et al. 2012, ApJL, 749, 27
Wyatt 2008, ARA&A, 46, 339

TA's ID : ProposalID :

2012.1

SG : 1 of 4 beta Pic - high resolution has 1 Target

Description of This Science Goal

Sub-arcsecond continuum imaging of beta Pictoris to measure its vertical scale height, including one baseband on CO to look for molecular g emission.

ALMA Band 06 General Properties : 211 - 275 GHz (2SB)

IF GHz	Trx	Tsys	Zenith opacity	1MHz	1mJy@1"
5.0-10.0	55-55K	93-149K	0.06-0.22	1.23 km/s	0.016-0.027K

HPBW 12m	HPBW 7m	resolution 12m Array	resolution 7m Array
22-29"	39-50"	0.225-0.293"	

Science Goal Control Parameters

Resolution	Largest Structure	Rms	Representative Freq.	Ref. Freq. Width	Extra Time Asked For?	Time Constrained?	User Defined Cal?
0.25"	2.0"	17 µJy, 6.3 mK	230.522621 GHz	7.500 GHz	no	no	no

Use of 12m Array (32 antennas)

Mode	Time	Map Size	#12m ptgs or hpbw	12m Spacing	Joint?	Data Vol	Data Rate
Synthesis	1.9 h		1		no	99.4 GB	15.1 MB/s

Use of ACA 7m Array (9 antennas) and TP Array

Mode	Time	Map Size	#7m ptgs or hpbw	7m Spacing	Joint?	Data Vol	Combined Data Rate
Synthesis							

Target list for Science Goal 01

Expected Source Properties

Target	Ra,Dec(J2000)	l,b	Motion	V,def,frame --OR--z	Linewidth	Peak Flux	Pol'n	Dyn. Range
1-beta_Pictoris	05:47:17, -51:03:59		Sidereal	20.0 km/s,hel,RELATIVIS...	8 km/s	0.800 mJy	0%	47.1

Frequency/correlator/spectral Info

Baseband 0 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
230.538000	230.522621	CO v=0 2-1	XX,YY	3840	1875.0 MHz, 2438.4 km/s	976.56 kHz, 1.270 km/s

Baseband 0 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
230.538000	98.0 K	17 µJy, 6.3 mK

Baseband 1 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
228.515244	228.500000	continuum	XX,YY	128	2000.0 MHz, 2624.0 km/s	31250.00 kHz, 41.000 km/s

Baseband 1 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
228.515244	97.1 K	16.82 µJy, 6.3 mK

Baseband 2 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
213.514244	213.500000	continuum	XX,YY	128	2000.0 MHz, 2808.4 km/s	31250.00 kHz, 43.881 km/s

Baseband 2 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
213.514244	95.5 K	16.43 µJy, 7.1 mK

Baseband 3 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
216.014410	216.000000	continuum	XX,YY	128	2000.0 MHz, 2775.9 km/s	31250.00 kHz, 43.373 km/s

Baseband 3 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
216.014410	95.7 K	16.47 µJy, 6.9 mK

TA's ID : ProposalID :

2012.1

SG : 2 of 4 AU Mic - high resolution has 1 Target

Description of This Science Goal

Sub-arcsecond continuum imaging of AU Mic to measure its vertical scale height, including one baseband on CO to look for molecular gas emission.

ALMA Band 06 General Properties : 211 - 275 GHz (2SB)

IF GHz	Trx	Tsys	Zenith opacity	1MHz	1mJy@1"
5.0-10.0	55-55K	93-149K	0.06-0.22	1.23 km/s	0.016-0.027K

HPBW 12m	HPBW 7m	resolution 12m Array	resolution 7m Array
22-29"	39-50"	0.225-0.293"	

Science Goal Control Parameters

Resolution	Largest Structure	Rms	Representative Freq.	Ref. Freq. Width	Extra Time Asked For?	Time Constrained?	User Defined Cal?
0.25"	2.0"	17 µJy, 6.3 mK	230.537077 GHz	7.500 GHz	no	no	no

Use of 12m Array (32 antennas)

Mode	Time	Map Size	#12m ptgs or hpbw	12m Spacing	Joint?	Data Vol	Data Rate
Synthesis	1.8 h		1		no	95.2 GB	15.1 MB/s

Use of ACA 7m Array (9 antennas) and TP Array

Mode	Time	Map Size	#7m ptgs or hpbw	7m Spacing	Joint?	Data Vol	Combined Data Rate
Synthesis							

Target list for Science Goal 02

Target	Ra,Dec(J2000)	l,b	Motion	V,def,frame --OR--z	Linewidth	Peak Flux	Pol'n	Dyn. Range
					Expected Source Properties			
1-AU_Mic	20:45:09, -31:20:27		Sidereal	1.2 km/s,hel,RELATIVISTIC	5 km/s	1.500 mJy	0%	88.2

Frequency/correlator/spectral Info

Baseband 0 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
230.538000	230.537077	CO v=0 2-1	XX,YY	3840	1875.0 MHz, 2438.3 km/s	976.56 kHz, 1.270 km/s

Baseband 0 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
230.538000	95.1 K	17 µJy, 6.3 mK

Baseband 1 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
228.500915	228.500000	continuum	XX,YY	128	2000.0 MHz, 2624.0 km/s	31250.00 kHz, 41.000 km/s

Baseband 1 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
228.500915	94.3 K	16.83 µJy, 6.3 mK

Baseband 2 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
213.500855	213.500000	continuum	XX,YY	128	2000.0 MHz, 2808.4 km/s	31250.00 kHz, 43.881 km/s

Baseband 2 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
213.500855	92.9 K	16.46 µJy, 7.1 mK

Baseband 3 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
216.000865	216.000000	continuum	XX,YY	128	2000.0 MHz, 2775.9 km/s	31250.00 kHz, 43.373 km/s

Baseband 3 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
216.000865	93.0 K	16.51 µJy, 6.9 mK

TA's ID : ProposalID :

2012.1

SG : 3 of 4 AU Mic - low resolution has 1 Target

Description of This Science Goal

A low-resolution observation of AU Mic to fill in short spacings for sensitivity to the largest (~8") structures in the disk. Will also provide the best prospects for spectral line observations.

ALMA Band 06 General Properties : 211 - 275 GHz (2SB)

IF GHz	Trx	Tsys	Zenith opacity	1MHz	1mJy@1"
5.0-10.0	55-55K	93-149K	0.06-0.22	1.23 km/s	0.016-0.027K

HPBW 12m	HPBW 7m	resolution 12m Array	resolution 7m Array
22-29"	39-50"	0.225-0.293"	

Science Goal Control Parameters

Resolution	Largest Structure	Rms	Representative Freq.	Ref. Freq. Width	Extra Time Asked For?	Time Constrained?	User Defined Cal?
2.00"	8.0"	26 µJy, 149....	230.537077 GHz	7.500 GHz	no	no	no

Use of 12m Array (32 antennas)

Mode	Time	Map Size	#12m ptgs or hpbw	12m Spacing	Joint?	Data Vol	Data Rate
Synthesis	0.7 h		1		no	38.6 GB	15.1 MB/s

Use of ACA 7m Array (9 antennas) and TP Array

Mode	Time	Map Size	#7m ptgs or hpbw	7m Spacing	Joint?	Data Vol	Combined Data Rate
Synthesis							

Target list for Science Goal 03

Target	Ra,Dec(J2000)	l,b	Motion	V,def,frame --OR--z
1-AU_Mic	20:45:09, -31:20:27		Sidereal	1.2 km/s,hel,RELATIVISTIC

Expected Source Properties

Linewidth	Peak Flux	Pol'n	Dyn. Range
5 km/s	1.500 mJy	0%	57.7

Frequency/correlator/spectral Info

Baseband 0 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
230.538000	230.537077	CO v=0 2-1	XX,YY	3840	1875.0 MHz, 2438.3 km/s	976.56 kHz, 1.270 km/s

Baseband 0 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
230.538000	95.1 K	26 µJy, 149.5 µK

Baseband 1 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
228.500915	228.500000	continuum	XX,YY	128	2000.0 MHz, 2624.0 km/s	31250.00 kHz, 41.000 km/s

Baseband 1 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
228.500915	94.3 K	25.75 µJy, 150.7 µK

Baseband 2 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
213.500855	213.500000	continuum	XX,YY	128	2000.0 MHz, 2808.4 km/s	31250.00 kHz, 43.881 km/s

Baseband 2 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
213.500855	92.9 K	25.18 µJy, 168.9 µK

Baseband 3 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
216.000865	216.000000	continuum	XX,YY	128	2000.0 MHz, 2775.9 km/s	31250.00 kHz, 43.373 km/s

Baseband 3 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
216.000865	93.0 K	25.24 µJy, 165.4 µK

TA's ID : ProposalID :

2012.1

SG : 4 of 4 beta Pic - low resolution has 1 Target

Description of This Science Goal

A low-resolution observation of beta Pic to fill in short spacings for sensitivity to the largest (~8") structures in the disk. Will also provide the best prospects for spectral line observations.

ALMA Band 06 General Properties : 211 - 275 GHz (2SB)

IF GHz	Trx	Tsys	Zenith opacity	1MHz	1mJy@1"
5.0-10.0	55-55K	93-149K	0.06-0.22	1.23 km/s	0.016-0.027K

HPBW 12m	HPBW 7m	resolution 12m Array	resolution 7m Array
22-29"	39-50"	0.225-0.293"	

Science Goal Control Parameters

Resolution	Largest Structure	Rms	Representative Freq.	Ref. Freq. Width	Extra Time Asked For?	Time Constrained?	User Defined Cal?
2.00"	8.0"	26 µJy, 149....	230.522621 GHz	7.500 GHz	no	no	no

Use of 12m Array (32 antennas)

Mode	Time	Map Size	#12m ptgs or hpbw	12m Spacing	Joint?	Data Vol	Data Rate
Synthesis	0.8 h		1		no	40.7 GB	15.1 MB/s

Use of ACA 7m Array (9 antennas) and TP Array

Mode	Time	Map Size	#7m ptgs or hpbw	7m Spacing	Joint?	Data Vol	Combined Data Rate
Synthesis							

Target list for Science Goal 04

Target	Ra,Dec(J2000)	l,b	Motion	V,def,frame --OR--z	Linewidth	Peak Flux	Pol'n	Dyn. Range
					Expected Source Properties			
1-beta_pictoris	05:47:17, -51:03:59		Sidereal	20.0 km/s,hel,RELATIVIS...	8 km/s	0.800 mJy	0%	30.8

Frequency/correlator/spectral Info

Baseband 0 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
230.538000	230.522621	CO v=0 2-1	XX,YY	3840	1875.0 MHz, 2438.4 km/s	976.56 kHz, 1.270 km/s

Baseband 0 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
230.538000	98.0 K	26 µJy, 149.6 µK

Baseband 1 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
228.515244	228.500000	continuum	XX,YY	128	2000.0 MHz, 2624.0 km/s	31250.00 kHz, 41.000 km/s

Baseband 1 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
228.515244	97.1 K	25.73 µJy, 150.6 µK

Baseband 2 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
213.514244	213.500000	continuum	XX,YY	128	2000.0 MHz, 2808.4 km/s	31250.00 kHz, 43.881 km/s

Baseband 2 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
213.514244	95.5 K	25.13 µJy, 168.5 µK

Baseband 3 - setup

Center Freq Rest GHz	Center Freq Sky GHz	Line ID	Pol Products	Eff # Channels per product	Bandwidth	Resolution
216.014410	216.000000	continuum	XX,YY	128	2000.0 MHz, 2775.9 km/s	31250.00 kHz, 43.373 km/s

Baseband 3 - rms

Frequency (GHz)	Tsys	12m Array Synthesis
216.014410	95.7 K	25.19 µJy, 165.1 µK